WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

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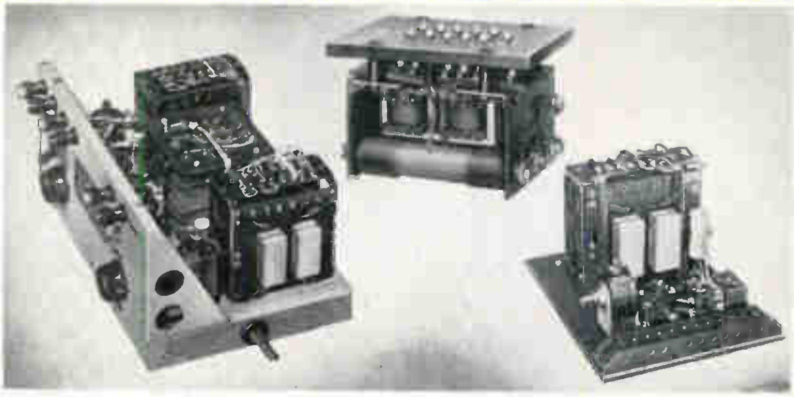

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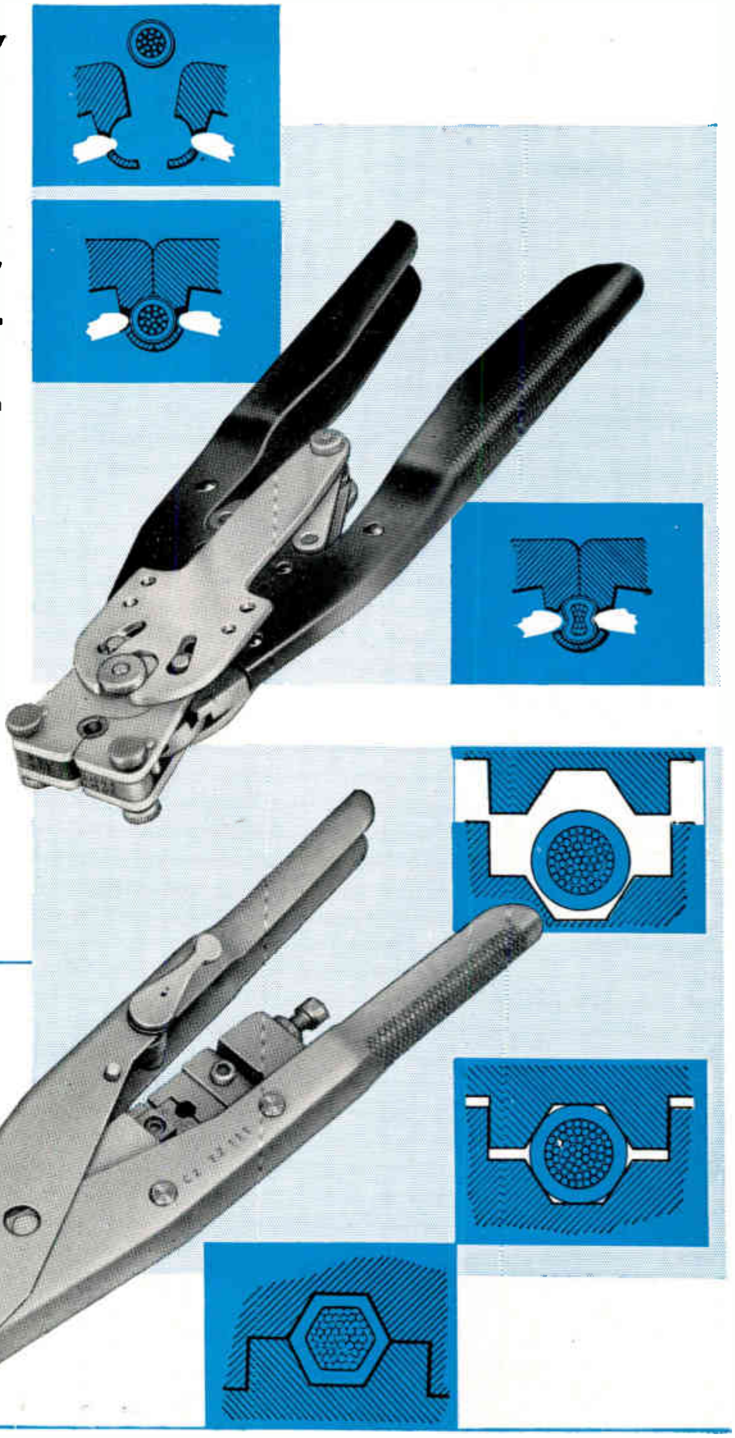

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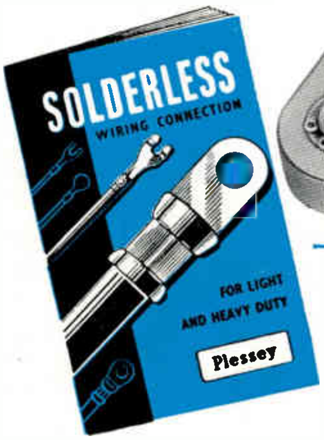

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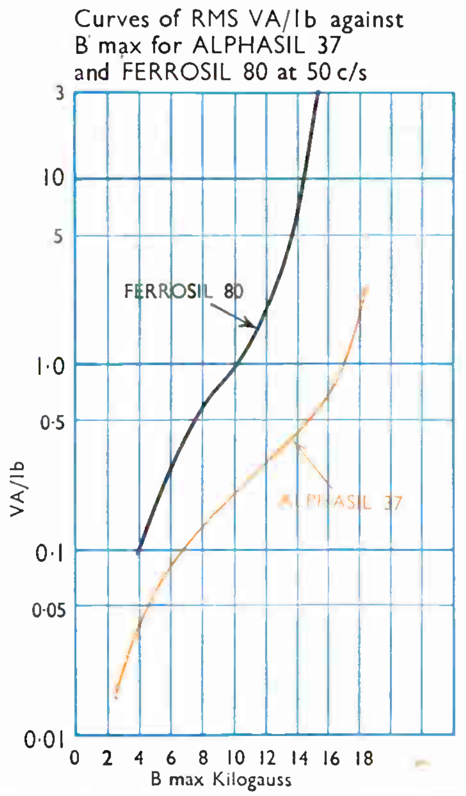

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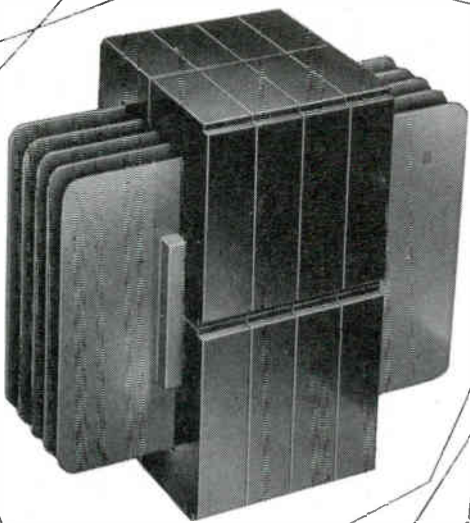

WIRELESS ENGINEER

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The Bifilar-T Trap

IN last month's Editorial, we discussed a new rejector circuit which is known as the bifilar-T trap Fig. 1(a) and we derived an equivalent circuit for it Fig. 1(b). The equivalence requires $L' = 2L_1$, $C' = C_1/2$, $R' = 2R$, $L_c = 4LL_1/(L - L_1)$, $C_c = C_1/4$ when R is equal to the dynamic resistance of L_1C_1.

When used as a coupling element between valves, the input and output terminals of Fig. 1(a) will inevitably be shunted by resistance and capacitance and, if desired, they can be shunted by inductance also. The equivalent circuit of Fig. 1(b) still applies, but the values of L', C' and R' become changed to take into account these external elements.

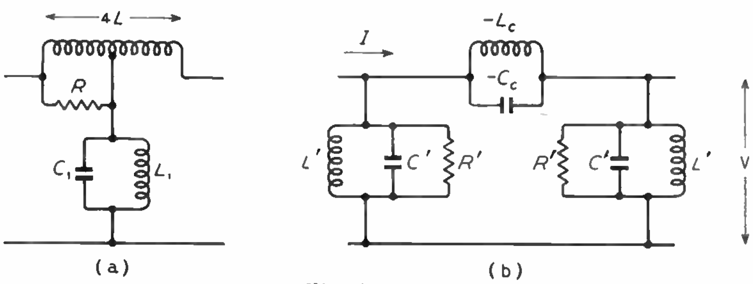

Fig. 1.

For simplicity, we shall assume that the two shunt arms are alike, which means that the same values of external elements must be added at each end. The transfer admittance is then

$$Y_T = I/V = Y'\ (2 + Y'Z_c)$$

where Y' is the admittance of a shunt arm and Z_c the impedance of the series arm.

It is a straightforward matter to expand this to the form

$$|Y_T R'|^2 = [1 + (QF - QH)^2] \left[\left\{2 - \frac{L_c}{L'} + \frac{L_c}{L'} \cdot \frac{QH}{QF}\right\}^2 + \left(\frac{L_c}{L'} \cdot \frac{1}{QF}\right)^2\right]$$

where $Q = R'/\omega_c L'$; $F = 2\Delta f/f_c$; $H = 2\delta f/f_c$;
and $f_c = \omega_c/2\pi$ = resonance frequency of the L_cC_c arm

Δf = frequency difference from f_c

δf = difference of resonance frequency of an $L'C'$ arm from f_c.

In deriving this equation, the common assumptions that $\Delta f/f_c$ and $\delta f/f_c$ can be neglected in comparison with unity have been made. The error due to this probably does not exceed 10%.

Taking QF as the frequency variable, the performance depends upon two factors, the relative detuning of the series and shunt arms QH and the effective coupling between the shunt arms L_c/L'. By taking a series of values of each, the performance can be expressed in the form of families of curves relating $Y_T R'$ to QF. It is easy but tedious to compute such families. We have not attempted this, but we have calculated one curve for arbitrarily selected values (QH = —1 and $L_c/L' = 2{\cdot}5$) and this is shown in Fig. 2. As will appear later, we made a lucky choice with these values, for they are of the right order for a television i.f. amplifier.

It is worth noting that there is a minimum possible value of 2 for L_c/L'. The ratio tends to this when $L \gg L_1$ and there is no external shunt inductance.

When the response is zero dB in Fig. 2, the value of $Y_T R'$ is 2, which means that the maximum transfer impedance is $R'/2$. This is, of course, the normal value for a pair of circuits with optimum coupling.

As an intervalve coupling in a television i.f. amplifier, we might want f_c = 38 Mc/s and a response of -2 dB at 34·5 Mc/s and 37·5 Mc/s. For the latter, $\Delta f = -0{\cdot}5$ Mc/s and from Fig. 2 $QF = -1{\cdot}33$ so

$$Q = \frac{-1{\cdot}33 \times 38}{-0{\cdot}5 \times 2} = 50{\cdot}7$$

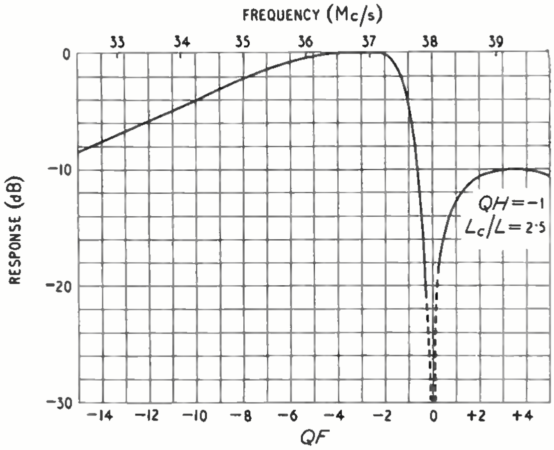

Fig. 2.

At 34·5 Mc/s, $\Delta f = -3{\cdot}5$ Mc/s and so

$$QF = -3{\cdot}5 \times 50{\cdot}7 \times 2/38 = -9{\cdot}5$$

and the curve shows the response to be $-3{\cdot}65$ dB. The required conditions are thus not met but the difference is not very great; we judge that a slightly smaller value of L_c/L' would enable the specification to be met.

Since $QH = -1$ we have

$$\delta f = \frac{-1 \times 38}{2 \times 50{\cdot}7} = -0{\cdot}375 \text{ Mc/s.}$$

The shunt arms are thus tuned between the upper limit of the pass-band and the rejection frequency.

A frequency scale has been added in Fig. 2 for the particular conditions just discussed, so that the characteristics can more readily be seen.

It is important to determine the values of the elements in the real circuit of Fig. 1(a). A typical modern valve will have an input resistance of the order of 20 kΩ and a capacitance of some 10 pF while the output capacitance may be 5 pF.

Let us assume, therefore, that the circuit of Fig. 1 (a) is to be terminated at each end by 10 pF shunted by 20 kΩ. These values are to be absorbed in C' and R' of Fig. 1 (b). From the relations given earlier $L/L_1 = 5$, since $L_c/L' = 2{\cdot}5$.

Also $L_cC_c = 1/\omega_c^2$ and $L'C' = 1/\omega_c^2(1 - \delta f/f_c)^2$, so $L_cC_c/L'C' = 0{\cdot}98$ and $C'/C_c = 2{\cdot}55$.

Now $C_c = C_1/4$ and $C' = C_s + C_1/2$ where C_s is the external capacitance, hence

$$\frac{C_1}{C_s} = \frac{4}{C'/C_c - 2} = \frac{4}{0{\cdot}55} = 7{\cdot}3$$

with C_s = 10 pF, C_1 = 73 pF; and C' = 46·5 pF, C_c = 18·25 pF.

From the frequency relation, $L_c = 0{\cdot}97\ \mu$H, where $L' = 0{\cdot}388\ \mu$H, $L_1 = 0{\cdot}194\ \mu$H and $L = 0{\cdot}97\ \mu$H. With $Q = 50{\cdot}7$

$$R' = \omega_c L'Q = 4{\cdot}65 \text{ k}\Omega$$

This includes the effect of the 20-kΩ shunt. Without it, the resistance becomes 6·04 kΩ and so R and R_1 must be 3·025 kΩ. This is the value of the dynamic resistance of L_1C_1 and so the required Q for this circuit is $3{\cdot}025 \times 10^3/\omega_cL_1 = 66$. This is readily possible.

The final circuit with values thus takes the form shown in Fig. 3. The L_1/C_1 ratio is actually rather low but, although we have not considered this, it can obviously be changed at will by connecting the bifilar coil to a tap on the coil L_1. In practice, one would use about one-third of the capacitance and three times the inductance and tap down the circuit to keep the impedance unchanged.

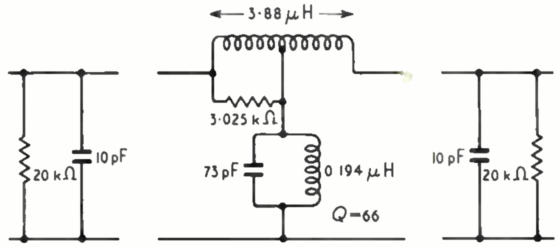

Fig. 3.

The transfer resistance at mid-band is 4·65/2 = 2·325 kΩ so that, with suitable valves, stage gains of the order of 20 times are possible.

The values which we have deduced here cannot be considered as precise ones, for in all this work we have assumed negligible losses, self-capacitance and leakage inductance in the bifilar coil. In practice, they may not be negligible and they may well require changes in the values of other components. Nevertheless, the values should afford a good starting point for experimental work.

Reference to Fig. 4(a) of the April Editorial shows that, apart from the external capacitance, the frequency of $L'C'$ depends only on L_1C_1, whereas the rejection frequency depends on L, L_1 and C_1. Plainly then, L_1C_1 should be tuned to $f_c - \delta f$, for the required shape of pass-band, and L should be adjustable afterwards for maximum attenuation at f_c.

Inspection of the figures obtained during the calculation of the curve of Fig. 2 shows that the falling off in response at large negative values of QF is due to the first bracket of the equation, which actually represents the response of a single tuned circuit. The second bracket by itself gives an increasing response.

It is plain, therefore, that tuning the shunt arms to a lower frequency would improve the low-frequency response. This would, however, be at the expense of the high-frequency end. Increasing L_c/L' tends to narrow the bandwidth.

Apart from varying QH and L_c/L', there is the possibility of staggering the tuning of the shunt arms by using unequal capacitance and/or inductance shunts external to the basic network. Theoretical investigation of this becomes difficult, but it is a very practical way of modifying the performance. W.T.C.

GROUP-DELAY MEASUREMENTS

Use of Wobbulator and C.R. Display

By C. J. Heuvelman and A. van Weel

(Philips Research Laboratories, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland)

SUMMARY.—A description is given of a simple group-delay meter which, in combination with any conventional wobbulator generator, gives the group-delay characteristic directly on an oscilloscope. An automatic-gain-control circuit, necessary to maintain a constant level at the output of the network under test, enables the tracing of the amplitude characteristic on a second oscilloscope at the same time. Calibration of amplitude and group-delay scales is possible for any oscilloscope used. A sensitivity of 1 milli-microsecond can be achieved. The frequency range is 20–45 Mc/s.

Introduction

IN recent years, the measurement of group-delay characteristics of electric networks has been the subject of many investigations and a number of different measuring devices has been described in the literature[1–8]. In general, these group-delay measuring equipments are rather intricate and often not too easy to handle. As a consequence, their use has mainly been restricted to research laboratories or to the development of professional transmitting equipments for coaxial cables, radio-relay systems, etc.

However, the problems posed by the non-linear phase characteristics in modern domestic television receivers have given rise to an increased interest in the measurement of the group-delay characteristics of these receivers[9–11]. Consequently, the need for a simple measuring device has become urgent. In this article such a device is described. It is especially intended for use with intermediate-frequency amplifiers of television receivers; the equipment is expected to become commercially available this year.

Principle

The underlying principle of the instrument is well known; it was given by Brand and Nyquist in 1930. The high-frequency output voltage of a standard-signal generator (angular frequency ω) is amplitude modulated by a low-frequency sinusoidal voltage (angular frequency p) generated by an oscillator (see Fig. 1). The modulated signal passes the network under test and is subsequently detected. The phase shift between the detected signal and the modulating signal depends directly on the group-delay time of the network at the frequency ω. This follows from Fig. 2 in which the phase–frequency characteristic of the network under test has been depicted. For a small value of the low frequency p, the phase shift of each sideband component of the modulated signal equals $p\ d\phi/d\omega$. The phase of the amplitude modulation is shifted over this same angle; therefore, the phase difference indicated by the phase meter Ph.M. in Fig. 1 is

$$\Delta\phi = p\frac{d\phi}{d\omega} = p\ \tau_{gr},$$

in which equation the group-delay at the frequency ω is indicated by τ_{gr}.

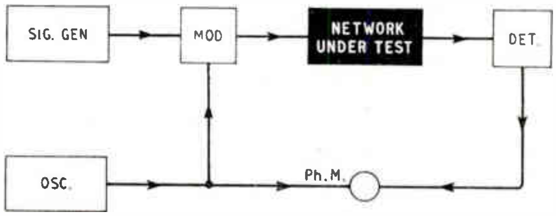

Fig. 1. *Principle of group-delay measurement. Sig. Gen. = standard signal generator; Mod. = modulator; Det. = detector: Osc. = oscillator; Ph.M. = phase meter.*

If the carrier frequency is varied, the change in the phase shift $\Delta\phi$ is proportional to the change in group delay. Consequently, the scale of the phase meter can be calibrated directly in group-delay time units, usually milli-microseconds (nano-seconds).

One of the main problems in designing such a measuring equipment is the necessary sensitivity

MS accepted by the Editor, March 1956

for the phase meter. The group delay measured according to this principle is the average value of the actual group delay between $\omega - p$ and $\omega + p$. Obviously it is advantageous to choose the p-frequency as low as possible; the p-frequency should in any case be small compared to the frequency band in which the delay curve has to be measured. However, the ultimate phase shift $\Delta\phi$ is directly proportional to p; therefore a smaller value of the frequency p necessitates a high sensitivity of the phase meter. For instance with a frequency $f_p = 30$ kc/s, a group-delay variation of one milli-microsecond corresponds to a phase variation of 2×10^{-4} radian = 0·01 degree.

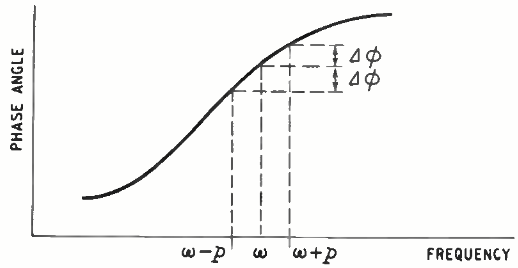

Fig. 2. *The phase of the sideband components is shifted over a phase angle $\Delta\phi = pd\phi/d\omega$ as compared with the phase of the carrier.*

Wobbulator Measurement

The group-delay measuring device to be described in this article traces the group-delay characteristic on the screen of an oscilloscope. This can be achieved by using a wobbulator generator as high-frequency voltage source and a phase meter, which gives a voltage or current output proportional to the phase shift to be measured. This method is in one aspect fundamentally simpler than the point-by-point method, but has also one fundamental drawback.

The advantage is that with a wobbulator measurement the sensitivity of the phase meter is no longer a problem, because the output signal of the phase meter is an a.c. signal. It can, therefore, be simply amplified to achieve the necessary sensitivity.

The disadvantage lies in the fact that with a wobbulator system the bandwidth of the output signal of the phase meter is substantially larger than with a point-by-point method. With a wobbulator having a repetition frequency of 50 c/s this bandwidth may be several thousand cycles, whereas with a point-by-point method the bandwidth can be reduced to one cycle or even less. As a consequence, the noise level will be much larger with a wobbulator system.

The signal at the detector output consists of a p-frequency voltage, the phase of which is modulated according to the magnitude of the group-delay at the instantaneous frequency. The magnitude of this phase modulation is directly proportional to the value of the p-frequency. Thus a high noise level can be counteracted by choosing a high p-frequency.

As a matter of fact, the p-frequency, for which a value of 30 kc/s was chosen in the preliminary experiments, had to be increased to 100 kc/s to achieve a satisfactory signal-to-noise ratio.

The phase modulation, which contains the information on the group-delay characteristic, can be derived from the phase-modulated p-frequency voltage by applying the latter to any conventional phase or frequency-detector circuit. Because, in this case, a reference p-frequency signal with constant phase is available, a phase detector of the type EQ80 was chosen. It was found that a preceding limiter stage was necessary to reduce the noise level to a minimum.

Necessity for a Constant Detector Level

From experiments with other delay meters it was known that the carrier-frequency level on the detector diode should be kept rigorously constant during the measurement of a group-delay characteristic. This necessity is due to the fact that, with most wideband amplifiers, the detector does not work fully linearly because the voltage on the detector is rather small. In a detector stage, the detector diode gives a certain amount of coupling between i.f. and video-frequency circuits. With a non-linear detector this coupling depends on the magnitude of the i.f. carrier voltage. As a consequence, the properties of the i.f. circuit depend to a certain extent on the signal level on the diode.

The effect on the measured group-delay characteristic is such that, with different signal levels on the diode, different phase shifts are introduced in the p-frequency signal. However, as a first approximation and at a given level, this phase shift does not vary throughout the frequency band considered. If, therefore, group-delay characteristics are measured at different, but constant, diode levels, the characteristics have the same shape but are only shifted in the vertical direction over different distances. As the absolute value of the group delay is of no importance for most purposes, this constant group-delay shift need not be considered.

It is obviously necessary to maintain a constant level on the diode during the measurement of a group-delay curve, because a varying level would cause a varying phase shift in the p-frequency signal during the measurement of a delay curve, which varying phase shift would be interpreted by the equipment as a change in group-delay time. Erroneous measurements would be the result.

The constant signal level on the diode can, with point-by-point measurements, easily be achieved by varying the output of the standard-signal generator. This can be done manually using the diode direct voltage as an indication.

With a wobbulator measurement, this amplitude control has obviously to be done by an automatic-gain-control device. For this purpose the p-frequency output signal of the detector is rectified to give a direct voltage which controls the gain of a radio-frequency amplifier stage inserted between the wobbulator and the modulator. The rectifier diode has a large bias voltage on its cathode so as to achieve a rigorous constant voltage on the i.f. detector.

An additional advantage of this automatic-gain-control system follows from the fact that the control voltage is a measure of the amplification of the network under test. By using a valve with suitable g_m–V_g curve in the controlled stage, the control voltage can be made roughly proportional to the logarithm of the gain of the network under test. By applying the control voltage to a second oscilloscope, the amplitude characteristic of the network under test will then be traced on a logarithmic scale. Thus both amplitude and delay characteristic are measured at the same time, which is a great convenience in the adjustment of filters.

The amplitude scale can be calibrated if the wobbulator generator is fitted with a calibrated attenuator. A certain decrease of the wobbulator output, for instance 10 dB, causes the amplitude curve to shift as a whole over a corresponding distance in the vertical direction.

The delay meter can be used in combination with a conventional wobbulator generator. In most wobbulators a frequency-marker device enables the frequency axis to be calibrated. However, these markers are often so-called 'active' markers, consisting of a variable oscillator the frequency scale of which is accurately calibrated. Such an active marker is less suitable for a frequency marker with the delay meter for the following reason.

The signal of the wobbulator as well as the signal of the marker oscillator will both be amplitude modulated in the modulator stage with the p-frequency voltage (see Fig. 1); therefore, the input voltage of the network under test will consist of two carrier frequencies, each with two sidebands. One carrier with its sidebands is wobbulated through the frequency band considered; when it passes the constant frequencies of the marker signal with its sidebands, a beat frequency equal to the p-frequency will be formed at a number of discrete frequencies of the wobbulator signal.

At each of these frequencies, this extra p-frequency component causes a sudden phase shift in the output of the detector, which gives a deviation in the delay characteristic on the oscilloscope. As a consequence, an active marker does not give one indication on the delay curve, but a discrete number spaced at mutual frequency differences equal to the p-frequency (see Fig. 3). Sharp frequency calibration is therefore impossible.

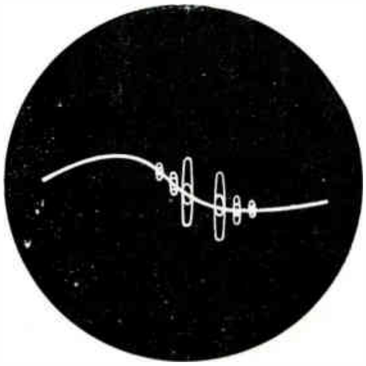

Fig. 3 (left). *An active frequency marker causes a complicated interference pattern in the group-delay curve on the oscilloscope.*

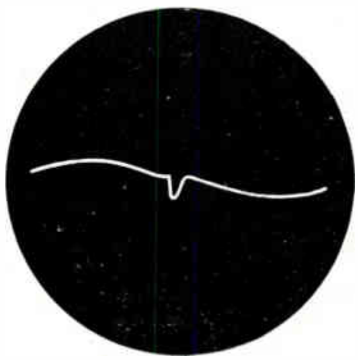

Fig. 4 (right). *The influence of an absorption frequency marker on the group-delay curve on the oscilloscope.*

To enable a better frequency calibration, a passive absorption marker circuit has to be provided; such a marker consists of a tuned circuit of high quality which is loosely coupled to the radio-frequency circuit. It causes a dip in the delay curve of the shape depicted in Fig.

Scale Calibration

The output of the phase meter (EQ80) is fed to the input terminals of the oscilloscope. In general, the sensitivity of an oscilloscope is not very accurately known; therefore a device enabling the calibration of the delay scale in terms of milli-microseconds per cm is necessary.

This calibration can be performed by introducing a known phase shift $\Delta\phi$ in the path of the p-frequency signal. This phase shift causes a vertical movement of the delay curve as a whole over a distance corresponding to a delay equal to $\Delta\phi/p$. This provides a direct calibration of the vertical scale on the oscilloscope.

The amplitude scale can be calibrated if the

4 and, at the same time, a dip in the amplitude curve; however this dip is much smaller than the dip in the delay characteristic. Increased coupling with the absorption circuit obviously increases both dips to the same extent, so a compromise has to be made, between a somewhat too small dip in the amplitude characteristic and a too large dip in the delay curve.

Description of the Complete Instrument

The circuit diagram is given in Fig. 5. The oscillator triode, which generates the *p*-frequency (100 kc/s in this instrument) is the triode of a valve ECH81 (V_8). Part of the generated voltage is directly fed to one of the control grids of the EQ80 (V_{10}). Another part of the oscillator voltage is amplified in the heptode part of

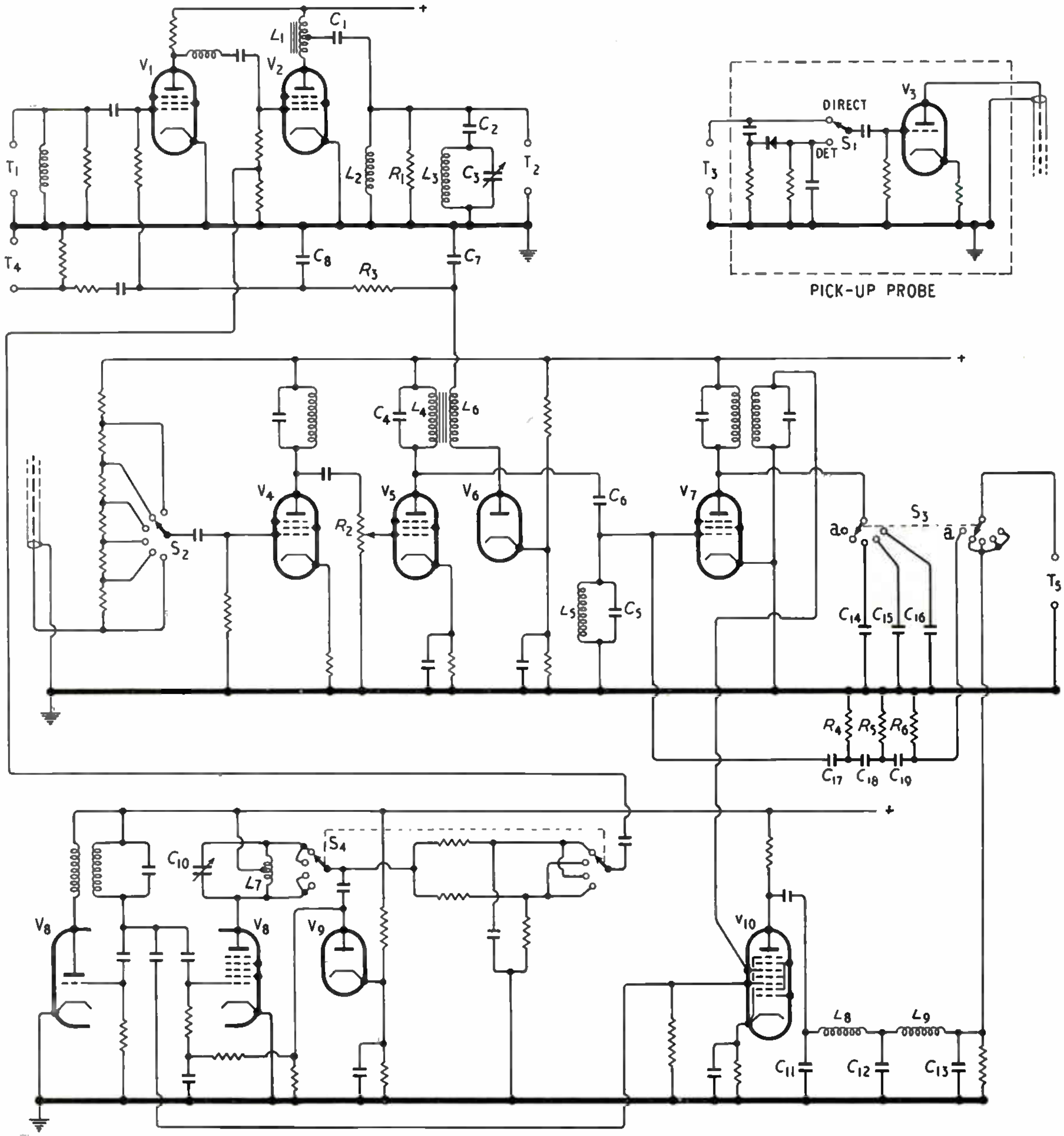

Fig. 5. *Simplified circuit diagram of the group-delay meter. Upper left, radio-frequency amplifier and modulator: upper right, pick-up probe; centre, p-frequency amplifier; lower left, p-frequency oscillator and phase-shifter; lower right, phasemeter EQ80; terminals, T_1—radio-frequency input from wobbulator; T_2—radio-frequency output to network under test; T_3—radio-frequency or p-frequency input from network under test: T_4—low-frequency output to amplitude-characteristic oscilloscope; T_5—low-frequency output to delay-characteristic oscilloscope. Valves: V_1, V_2, EF95; V_3, EC70; V_4, V_5, V_7, EF83; V_6, V_9, EA50; V_8, ECH81; V_{10}, EQ80.*

valve V_8 and passes subsequently a phase-shifting device which allows the introduction of 4×90 degrees phase shift in discrete steps (S_7), as well as continuous phase shift over about 100 degress (C_{10}).

The necessity for this phase-shifting device is given by the fact that the EQ80 has only a limited range of phase angles in which the anode current is linearly proportional to the phase difference between the two input voltages.

As the network under test may introduce any amount of constant phase shift in the 100-kc/s signal, it is essential to have a phase shifter in the delay meter which can counteract a possible large phase shift.

In this apparatus, the continuous phase shift is brought about by detuning the anode circuit L_7C_{10} of the heptode V_8. The 4×90 degrees phase shift is achieved with simple resistance-capacitance sections in combination with a $\pm$ 180 degree switch connected to the anode circuit L_7C_{10}. Obviously, the output voltage of such a simple phase-shifting device is not constant. An automatic-gain-control circuit, comprising the diode V_9, stabilizes the output voltage of the phase shifter. This output voltage is fed to the modulator valve V_2.

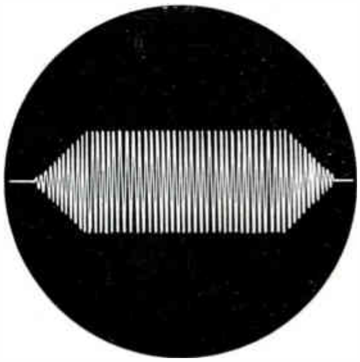

Fig. 6. *Image on the oscilloscope in monitoring position of switch S_3.*

The radio-frequency signal from the wobbulator generator enters the apparatus at the terminal T_1 (input impedance 75 Ω) and is subsequently amplified in the gain-controlled valve V_1 and amplitude-modulated by the p-frequency signal in valve V_2. The anode impedance of this modulator stage consists of the inductance L_1, which is in parallel resonance with the anode capacitance at the centre frequency of the pass-band. The output terminal T_2 is connected to a tap on L_1; the resistance R_1 serves as terminating resistance for the output cable as well as damping resistance for the anode circuit of the modulator stage. The control-grid impedance of valve V_1, the coupling network between the valves V_1 and V_2 and the transformer L_1 have been designed so as to give a flat amplitude characteristic as well as a flat group-delay curve in the frequency range from 20–45 Mc/s. The capacitance C_1 and the inductance L_2 act as a high-pass filter, thus suppressing the 100-kc/s signal. The absorption frequency marker L_3C_3 is coupled to the output lead by way of a small capacitance C_2.

In many cases the network, of which the input is connected to the output-terminal T_2, will contain a detector stage at the output of which the 100-kc/s signal will be directly available.

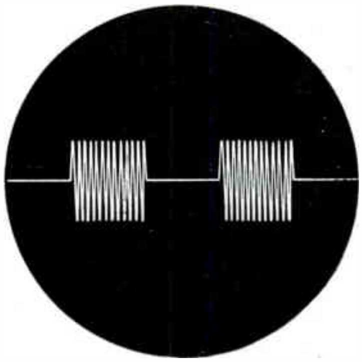

Fig. 7. *Output voltage of the wobbulator generator* G.M.2889.

However, it also often occurs that no such detector is present, for instance if measurements are made on a single stage or a part of an i.f. amplifier. In these cases a separate detector is necessary. Therefore, the pick-up probe (see upper right-hand corner of Fig. 5) contains a switch S_1 with two positions. In position 'direct' a 100-kc/s input signal is directly fed to the grid of the valve V_3. In the position 'det.' an i.f. input signal is first demodulated by a crystal diode, the detected 100-kc/s signal being subsequently fed to the same valve V_3.

After passing V_3 in the probe, the signal is amplified by V_4 and V_5 in the delay-meter itself. The switch S_2 permits a discontinuous control of the total gain in steps of roughly 10 dB, while potentiometer R_2 provides a continuous adjustment of the gain.

The anode impedance of valve V_5 consists of a capacitively-coupled bandfilter L_4C_4, C_6, L_5C_5. The voltage for the p-frequency amplitude detector (the diode V_6) is taken from an inductance L_6, which is tightly magnetically-coupled to the inductance L_4 of the bandfilter. The detector diode V_6 has a large d.c. bias voltage on its cathode so as to achieve a very rigorous gain control. The rectified voltage is fed through the inductance L_6 and the low-pass filter $C_7R_3C_8$ to the control grid of the gain-controlled stage V_1. A part of this voltage can be taken from the terminal T_4 to feed the amplitude-characteristic oscilloscope.

The secondary circuit of the bandfilter L_4C_4, C_6, L_5L_5 is connected to the control grid of limiter valve V_7. The anode of this valve is coupled through a bandfilter to the second control-grid of the phase-detector valve V_{10}.

The low-frequency output signal of this phase detector is taken through a low-pass filter $C_{11}L_8C_{12}L_9C_{13}$ to the output terminal T_5. The voltage at this terminal is such that it can be fed directly to an oscilloscope with conventional sensitivity (20 mV_{eff}/cm).

Calibration of the delay axis can be done with switch S_3, which switch connects different capacitances in parallel to the input terminals of the bandfilter between valves V_7 and V_{10}. The detuning of this bandfilter causes a certain phase shift, which corresponds in the three positions of switch S_3 to delay variations of 25, 100 and 250 milli-microseconds, respectively.

In the extra position (a) of switch S_3, the input of the oscilloscope is connected by wav of a high-pass filter $C_{17}R_4C_{18}R_5C_{19}R_6$ to the grid of the limiter valve V_7 so as to make the 100 kc/s-signal visible on the oscilloscope. The high-pass filter is necessary to reject low-frequency voltages due to level variations of the 100-kc/s signal. The level of the 100-kc/s signal is constant as long as the a.g.c. system works effectively. Outside the pass-band of the network under test, however, the total amplification can decrease to such an extent that the a.g.c. system can no longer counteract this decrease. At these carrier frequencies, the level on the i.f. detector may therefore vary considerably, which might cause substantial errors in the group-delay curve as indicated on the oscilloscope.

For an accurate measurement the i.f. carrier level at the detector should therefore be constant, in which case the 100-kc/s level on the grid of the limiter valve will also be constant. This can be monitored in the extra position of switch S_3. The image on the oscilloscope should resemble the picture of Fig. 6. The group-delay curve can be trusted over the frequency range where the 100-kc/s signal has a constant amplitude.

Performance of the Equipment

The delay meter can be used with any wobbulator generator; we combined it with the Philips wobbulator GM 2889 and used it extensively in the design of i.f. amplifiers for television receivers[11]. The output voltage of the wobbulator GM 2889, the sweep-repetition frequency of which is 50 c/s, is in one half of the sweep period a wobbulated signal, whereas in the other half of the period the output is nil (see Fig. 7). As a consequence a horizontal zero axis is drawn on both oscilloscopes, which is of great help in the estimation of the non-flatness of the measured characteristics as well as the calibration process.

A measuring set-up is shown in Fig. 8; the amplitude and group-delay characteristics of the

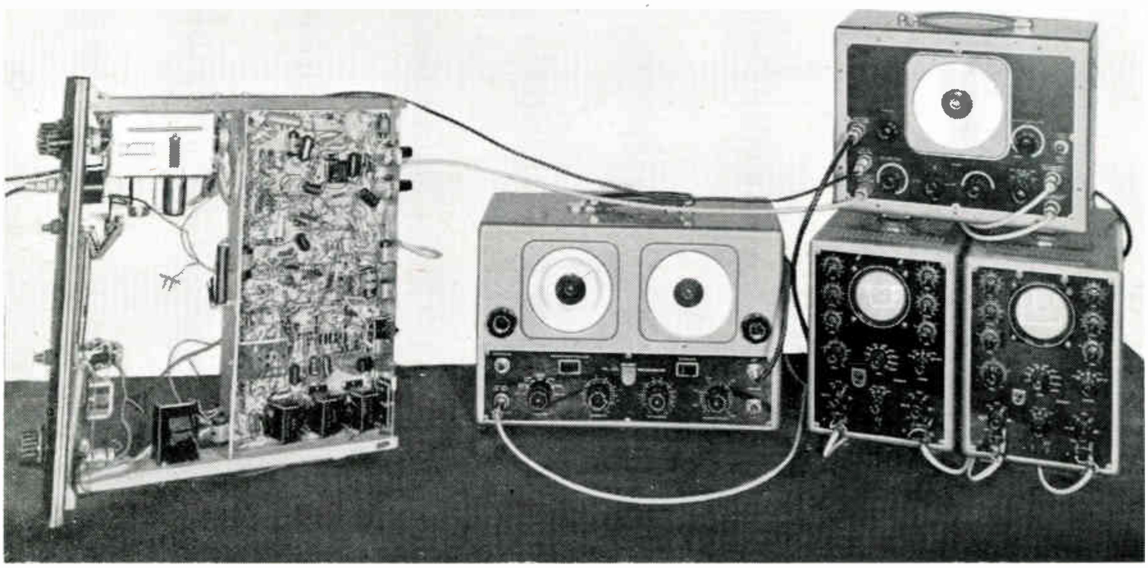

Fig. 8. *Set-up for measuring the steady-state characteristics of an i.f. amplifier of a television receiver (left). Wobbulator generator type GM 2889 in the centre. Delay-measuring equipment type GM 2894 on top of the oscilloscopes. Left-hand oscilloscope gives amplitude curve, right-hand oscilloscope gives group delay curve. Sensitivities for the curves on the oscilloscopes: 6 dB/cm for amplitude, 50 × 10^{-9} sec/cm for delay.*

receivers under test appear on the screens of the left- and right-hand oscilloscopes, respectively.

In general, the technique of measuring a group-delay curve is somewhat more difficult than the classical measurement of an amplitude curve in that it is easier disturbed by interfering signals, more vulnerable to the overloading of valves, etc. This can well be understood, because a group-delay measurement is a very sensitive measurement. Some possible error sources have been described elsewhere[12]; measures have been taken in the design of this equipment to eliminate these error sources as much as possible (for instance the a.g.c. system). The user of the instrument on the other hand should be well aware of the possible consequences of the disturbing external influences mentioned above.

The apparatus is primary designed for measurements on i.f. amplifiers of television receivers; therefore the frequency band has been fixed at 20–45 Mc/s. The sensitivity depends ultimately on the noise level, because the amplification in the oscilloscope can be arbitrarily increased. The inherent noise level of the delay meter is such that group-delay variations of below one milli-microsecond can be distinguished. A much smaller sensitivity is sufficient for measurements with television receivers; our practice is to adjust the vertical amplification of the oscilloscopes to a sensitivity of 50 milli-microseconds per cm for the delay oscilloscope and of 6 dB/cm for the amplitude oscilloscope. With measurements on high-gain amplifiers, the noise introduced in such an amplifier may disturb the measurements even at this reduced sensitivity. It is then necessary to decrease the gain of the amplifier to make the measurement possible at all.

It may be mentioned that an additional unit has been developed, which enables the tracing of video-frequency delay and amplitude characteristics on oscilloscopes (frequency range 300 kc/s–10·0 Mc/s). We hope to describe this equipment in a later publication.

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PHASE-ANGLE MEASUREMENT

C.R. Tube Methods

By C. H. Vincent, M.Sc., A.Inst.P., A.M.I.E.E.

SUMMARY.—The paper discusses the method of phase-angle measurement due to Fleming, in which X and Y deflections are adjusted for equality, and the phase difference is deduced from the proportions of the resulting ellipse. A thorough analysis is made of the geometrical factors which might lead to error in this method, and it is found that, provided the method is modified slightly to take certain reasonable precautions, it is an accurate and practical one at all phases, in spite of certain criticisms which have been made.

Introduction

It is well known that the phase difference between two sinusoidal voltages of the same frequency may be determined in several ways[1,2,3] from measurements of the ellipse that appears when the two voltages are applied to the deflection plates of a cathode-ray tube. One such method[1,4] is to adjust the relative amplitudes of the voltages so that the peak X and Y deflections are equal, and to measure the major and minor diameters of the ellipse. The phase difference is then 2α, where

$$\alpha = \pm \tan^{-1} \frac{D_2}{D_1} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where D_1 is the major or minor diameter that lies within the 1st and 3rd quadrants, and D_2 that which lies within the 2nd and 4th (see Fig. 1). This method has the practical advantages that it is simple and direct, and that the measurements are made with the trace crossing the scale at right angles, permitting greater accuracy. Since

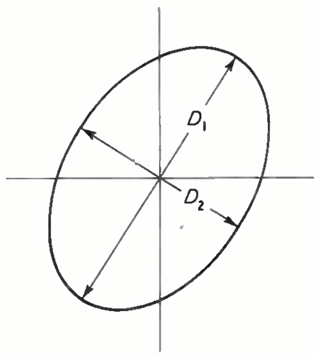

Fig. 1. Measurement of D_1 and D_2. The scale is orientated for maximum and minimum measurement on a line through the origin.

$$\frac{d}{d\alpha} \tan \alpha = \sec^2 \alpha \geqslant 1$$

an accurate determination of tan α gives an

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accurate value of α at all phases. [See also Equ. (10)]. The sign of the phase difference is not indicated by the ellipse, and must be determined from some other consideration, whatever measurements are made.

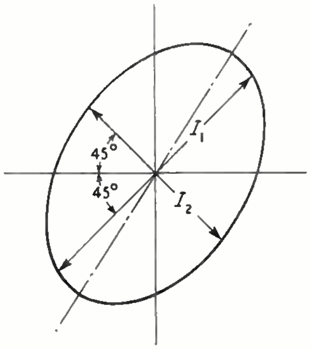

Fig. 2. *Measurement of I_1 and I_2. The scale is orientated at 45° to the axes on a line through the origin and the intercepts are measured.*

Discussion

This method of measurement has been criticized by Benson[5] on the grounds that appreciable error might be caused by the residual inequality of the deflection amplitudes or by incorrect positioning of the scale used. However, if a detailed analysis is made, taking account of any such residual inequality, it is found that the

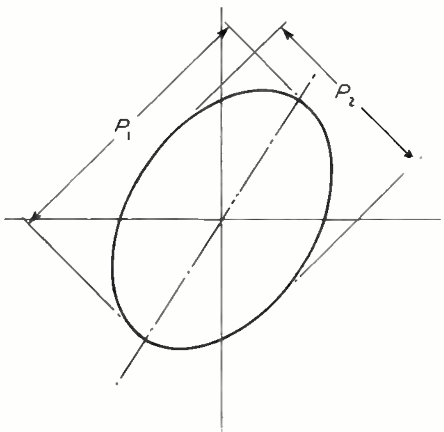

Fig. 3. *Measurement of P_1 and P_2. The scale is orientated at 45° and the distances between the tangents to the ellipse at 45° to the axes are measured.*

error due to this inequality is, in general, a second-order effect [see Equ. (4)], and can therefore be kept very small with reasonable care in the amplitude adjustment. Moreover, when this adjustment has been made, the axes of the ellipse coincide closely in general with the radials from the origin at 45° to the deflection axes. Further analysis shows that either the intercepts I_1, I_2 of the ellipse on these 45° radials (see Fig. 2) or the perpendicular distances P_1, P_2 between the tangents to the ellipse which are parallel to these radials (see Fig. 3) may be substituted for D_1 and D_2 in the ratio giving $\tan \alpha$. The error due to any difference between the deflection amplitudes is again normally of the second order [see Equs. (5a), (5b), (6a), (6b)], and may therefore be kept very small. Hence scales fixed at 45° to the deflection axes may be used, if necessary, to avoid error due to incorrect scale orientation, the scales being used appropriately to measure I_1, I_2 or P_1, P_2 as desired.

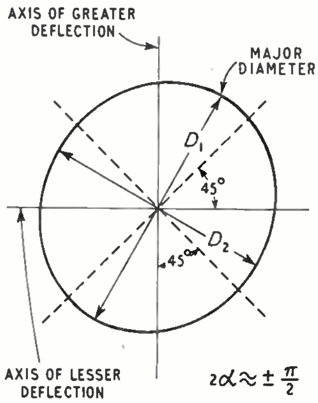

Fig. 4. *When D_1 and D_2 become inaccurate, I_1, I_2, P_1 and P_2 are accurate. The ellipse approaches circular form and the major and minor axes may shift towards the deflection axes.*

Although either D, I, or P may be used, in general, with only second-order errors, the equations referred to above show that there is one phase angle where each of these measurements becomes relatively inaccurate, and it is therefore desirable to use one of the other two in this vicinity, although the error will still be small, unless the equality adjustment is very poor. These conditions are illustrated with an exaggerated amplitude difference in Figs. 4, 5 and 6. It is clear from these figures that where the errors occur they can be anticipated intuitively, apart from the analysis. The procedure for this method is summarized below, and should give an accurate and practical measurement.

Furthermore, provided that the conditions

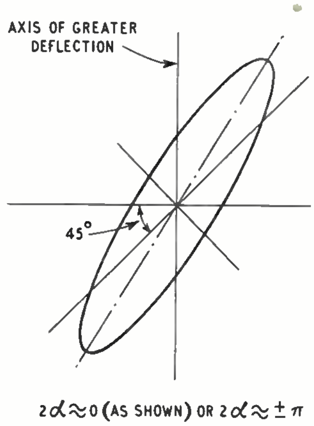

Fig. 5. *When I_{major} becomes inaccurate, D_1, D_2, I_{minor} and P_{major} are accurate. The ellipse becomes long and narrow and the major axis may shift off the 45° radial.*

described as leading to inaccuracy are avoided, errors in the measurement of D, I, or P, due to slight displacement or misorientation of the measuring scale, are in all cases second-order, and can therefore be kept very small, with reasonable care. This is because the measurements D and I are made at or near values which are stationary with respect to small changes in the position or orientation of the scale. Measurements P are also made at or near stationary values with respect to changes in orientation, and are independent of position.

A first-order effect on the ratio determining $\tan\alpha$ will be caused by any error in the relative orientation of the deflection axes of the cathode-ray tube itself [see Equs. (7a), (7b)], but this error is normally small. It could, if necessary, be compensated for by reversing the phase of one of the voltages thereby, in effect, interchanging the 1st and 3rd quadrants with the 2nd and 4th, and taking the geometrical mean of the ratios thus obtained [see Equs. (8a), (8b), (9)]. Further sources of possible error, against which the usual precautions should be taken, are parallax, non-linear deflection to voltage relationships, unwanted phase shifts of the voltages applied to the deflector plates, and the presence of harmonics in these voltages.

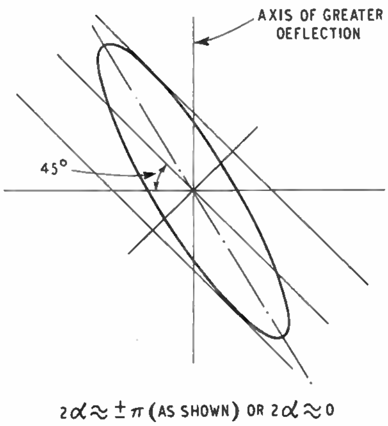

Fig. 6. *When P_{minor} becomes inaccurate, D_1, D_2, I_{minor} and P_{major} are accurate. The ellipse becomes long and narrow and the corresponding 45° tangents may become separated by more than the minor diameter.*

Summary of Procedure

(1) Adjust the deflection amplitudes to equality.

(2) If the ellipse is approximately circular, calculate the phase difference as

$$2\alpha = \pm\, 2 \tan^{-1}\frac{Q_2}{Q_1} \quad \ldots \quad \ldots \quad (2)$$

where $Q_1 = I_1$ or P_1 and $Q_2 = I_2$ or P_2 respectively.

(3) If the ellipse is markedly elongated, calculate the phase difference as above but with

$Q_1 = D_1$, or I_1 (if minor), or P_1 (if major), and with

$Q_2 = D_2$, or I_2 (if minor), or P_2 (if major), according to the positions of the major and minor axes.

(4) In other cases, use either D, I, or P.

(5) If desired, compensate for faulty relative orientation of the c.r. tube deflection axes by reversing the phase of one voltage (interchanging suffixes 1 and 2 above), and taking the geometrical mean of the ratios as $\tan\alpha$.

Acknowledgment

I am most grateful to my colleagues Dr. W. Fishwick, Dr. H. M. Melvin, and Mr. T. S. M. Maclean for helpful comment and criticism.

APPENDIX 1

Summary of the Mathematical Results

Consider deflections given by

$$x = (A + \delta)\cos(\omega t + \alpha) \quad \ldots \quad \ldots \quad \ldots \quad (3a)$$

$$y = (A - \delta)\cos(\omega t - \alpha) \quad \ldots \quad \ldots \quad \ldots \quad (3b)$$

where 2δ is the residual difference in amplitude, and the other symbols have their usual significance. Then it is found that

$$D^2_{maj},\ D^2_{min} = 4(A^2 + \delta^2) \pm 2[2A^4 + 12A^2\delta^2 + 2\delta^4 + 2(A^2 - \delta^2)^2 \cos 4\alpha]^{\frac{1}{2}} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

giving

$$D_1^2 \approx 8A^2 \cos^2\alpha \quad \text{for small } \delta$$

and

$$D_2^2 \approx 8A^2 \sin^2\alpha \quad \text{for small } \delta$$

D_1 being the major axis for $-\pi/2 < 2\alpha < \pi/2$ and D_2 for $-\pi < 2\alpha < -\pi/2$ or $\pi/2 < 2\alpha < \pi$. The error is of order δ^2 in both cases, except when $\cos 4\alpha = -1$ so that the term in A^4 disappears from within the square-root sign. This occurs when $2\alpha = \pm\,\pi/2$, and the ellipse approximates to a circle.

Also

$$I_1^2 = \frac{4(A^2 - \delta^2)^2 \sin^2 2\alpha}{A^2 + \delta^2 - (A^2 - \delta^2)\cos 2\alpha} \quad \ldots \quad \ldots \quad (5a)$$

$$\approx 8A^2 \cos^2\alpha \quad \text{for small } \delta$$

and

$$I_2^2 = \frac{4(A^2 - \delta^2)^2 \sin^2 2\alpha}{A^2 + \delta^2 + (A^2 - \delta^2)\cos 2\alpha} \quad \ldots \quad \ldots \quad (5b)$$

$$\approx 8A^2 \sin^2\alpha \quad \text{for small } \delta$$

the error being of order δ^2 in each case, except when the term in A^2 in the denominator vanishes. This occurs when the intercept concerned is the major one and when $\cos 2\alpha = 1$ (i.e., $2\alpha = 0$) for I_1, and when $\cos 2\alpha = -1$ (i.e. $2\alpha = \pm\,\pi$) for I_2. At all of these phases the ellipse degenerates into a segment of a straight line.

Also

$$P_1^2 = 4(A^2 + \delta^2) + 4(A^2 - \delta^2)\cos 2\alpha \quad \ldots \quad (6a)$$

$$\approx 8A^2 \cos^2\alpha \quad \text{for small } \delta$$

and

$$P_2^2 = 4(A^2 + \delta^2) - 4(A^2 - \delta^2)\cos 2\alpha \quad \ldots \quad (6b)$$

$$\approx 8A^2 \sin^2\alpha \quad \text{for small } \delta$$

the error being of order δ^2 and negligible in each case except when the term in A^2 vanishes. This occurs when the perpendicular distance P concerned is the minor one and when $\cos 2\alpha = -1$ (i.e., $2\alpha = \pm\pi$) for P_1, and when $\cos 2\alpha = 1$ (i.e., $2\alpha = 0$) for P_2. These are again the phases at which the ellipse degenerates into a segment of a line.

If the angle in the 1st quadrant between the X and Y axes of the cathode-ray tube is $(90 - 2\theta)$ degrees, then

$$Q_1' \approx Q_1\,(\cos\theta^\circ + \sin\theta^\circ) \quad \ldots \quad \ldots \quad \ldots \quad (7a)$$

and

$$Q_2' \approx Q_2\,(\cos\theta^\circ - \sin\theta^\circ) \quad \ldots \quad \ldots \quad \ldots \quad (7b)$$

where Q_1' and Q_2' refer to the actual values of D, I, or P as measured, and Q_1 and Q_2 refer to the corresponding values which they would have if the axes were perpendicular.

Also

$$Q_1'' \approx Q_1 (\cos \theta° - \sin \theta°) \quad \ldots \quad \ldots \quad \ldots \quad (8a)$$

and

$$Q_2'' \approx Q_2 (\cos \theta° + \sin \theta°) \quad \ldots \quad \ldots \quad \ldots \quad (8b)$$

where Q_1'' and Q_2'' refer to the corresponding measurements with the phase of one voltage reversed and with the suffixes transferred accordingly.

Hence

$$\sqrt{\frac{Q_2'}{Q_1'} \cdot \frac{Q_2''}{Q_1''}} \approx \frac{Q_2}{Q_1} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

It is of interest to note that if the measurements of Q_1 and Q_2 are subject to independent random errors δQ_1 and δQ_2 such that $\overline{(\delta Q_1)^2} = \overline{(\delta Q_2)^2} = \sigma^2$, as is reasonable to assume, σ being a constant, and if these errors cause an error $\delta\alpha$ in α, then

$$\overline{(\delta\alpha)^2} = \frac{\sigma^2}{8A^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

which is independent of the phase being measured. In practice, therefore, the error in phase from this cause is likely to be of the same order at all phases.

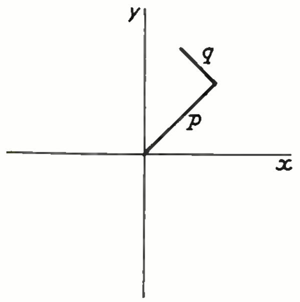

Fig. 7. *Definition of co-ordinates p and q.*

APPENDIX 2

Proofs

If $A + \delta = B$ and $A - \delta = C$, then from equations (3a), (3b)

$$x^2 + y^2 = B^2 \cos^2 (\omega t + \alpha) + C^2 \cos^2 (\omega t - \alpha)$$

$$= \frac{B^2}{2} \left[1 + \cos 2(\omega t + \alpha)\right] + \frac{C^2}{2} \left[1 + \cos 2(\omega t - \alpha)\right]$$

$$= \frac{B^2 + C^2}{2} + \frac{B^2 + C^2}{2} \cos 2\omega t \cos 2\alpha - \frac{B^2 - C^2}{2} \sin 2\omega t \sin 2\alpha$$

$$= \frac{B^2 + C^2}{2} + \left[\left(\frac{B^2 + C^2}{2}\right)^2 \cos^2 2\alpha + \left(\frac{B^2 - C^2}{2}\right)^2 \sin^2 2\alpha\right]^{\frac{1}{2}} \times \cos\left[2\omega t + \tan^{-1} \frac{B^2 - C^2}{B^2 + C^2} \tan 2\alpha\right]$$

Hence

$$D^2_{maj}, D^2_{min} = 4(x^2 + y^2)_{max}, 4(x^2 + y^2)_{min}$$

$$= 2(B^2 + C^2) \pm 4\left[\left(\frac{B^2 + C^2}{2}\right)^2 \cos^2 2\alpha + \left(\frac{B^2 - C^2}{2}\right)^2 \sin^2 2\alpha\right]^{\frac{1}{2}}$$

$$= 2(B^2 + C^2) \pm 2[B^4 + 2B^2C^2 \cos 4\alpha + C^4]^{\frac{1}{2}}$$

$$= 4(A^2 + \delta^2) \pm 2[2A^4 + 12A^2\delta^2 + 2\delta^4 + 2(A^2 - \delta^2)^2 \cos 4\alpha]^{\frac{1}{2}}$$

as stated above [Equ. (4)].

From the original deflection equations (3a) and (3b),

$$\frac{x}{B} + \frac{y}{C} = \cos (\omega t + \alpha) + \cos (\omega t - \alpha)$$

$$= 2 \cos \omega t \cos \alpha$$

and similarly

$$\frac{x}{B} - \frac{y}{C} = -2 \sin \omega t \sin \alpha$$

Eliminating ωt, we get

$$\frac{\left(\frac{x}{B} + \frac{y}{C}\right)^2}{4 \cos^2 \alpha} + \frac{\left(\frac{x}{B} - \frac{y}{C}\right)^2}{4 \sin^2 \alpha} = 1$$

giving

$$\frac{x^2}{B^2} + \frac{y^2}{C^2} - \frac{2xy}{BC} \cos 2\alpha = \sin^2 2\alpha \quad \ldots \quad \ldots \quad (11)$$

For the intercept on the 45° radial in the 1st quadrant, $x_1 = y_1 = \frac{I_1}{2\sqrt{2}}$. Hence

$$x_1^2 \left(\frac{1}{B^2} + \frac{1}{C^2} - \frac{2}{BC} \cos 2\alpha\right) = \sin^2 2\alpha$$

$$\therefore I_1^2 = 8x_1^2$$

$$= \frac{8B^2 C^2 \sin^2 2\alpha}{B^2 + C^2 - 2BC \cos 2\alpha}$$

$$= \frac{4(A^2 - \delta^2)^2 \sin^2 2\alpha}{A^2 + \delta^2 - (A^2 - \delta^2) \cos 2\alpha}$$

as stated above [Equ. (5a)]. I_2 may be derived similarly [Equ. (5b)].

If equation (11) above is transformed to co-ordinates p, q, at 45° to the original ones (see Fig. 7) we have

$$x = \frac{p - q}{\sqrt{2}}$$

and $$y = \frac{p + q}{\sqrt{2}}$$

giving

$$\frac{p^2 - 2pq + q^2}{2B^2} + \frac{p^2 + 2pq + q^2}{2C^2} - \frac{(p^2 - q^2) \cos 2\alpha}{BC} = \sin^2 2\alpha$$

i.e.,

$$p^2\left(\frac{1}{B^2} + \frac{1}{C^2} - \frac{2 \cos 2\alpha}{BC}\right) + q^2\left(\frac{1}{B^2} + \frac{1}{C^2} + \frac{2 \cos 2\alpha}{BC}\right) + 2pq\left(\frac{1}{C^2} - \frac{1}{B^2}\right) = 2 \sin^2 2\alpha$$

Differentiating with respect to q and putting $\frac{dp}{dq} = 0$ for maximum or minimum p, we get

$$\frac{q}{p} = -\frac{\left(\frac{1}{C^2} - \frac{1}{B^2}\right)}{\left(\frac{1}{B^2} + \frac{1}{C^2} + \frac{2 \cos 2\alpha}{BC}\right)}$$

and substituting for q,

$$p^2 \left[\frac{1}{B^2} + \frac{1}{C^2} - \frac{2 \cos 2\alpha}{BC} + \frac{\left(\frac{1}{C^2} - \frac{1}{B^2}\right)^2}{\left(\frac{1}{B^2} + \frac{1}{C^2} + \frac{2 \cos 2\alpha}{BC}\right)} - \frac{2\left(\frac{1}{C^2} - \frac{1}{B^2}\right)^2}{\left(\frac{1}{B^2} + \frac{1}{C^2} + \frac{2 \cos 2\alpha}{BC}\right)}\right] = 2 \sin^2 2\alpha$$

i.e.,

$$p^2 \left[\frac{1}{B^2} + \frac{1}{C^2} - \frac{2 \cos 2\alpha}{BC} - \frac{\left(\frac{1}{C^2} - \frac{1}{B^2}\right)^2}{\left(\frac{1}{B^2} + \frac{1}{C^2} + \frac{2 \cos 2\alpha}{BC}\right)}\right]$$

$$= 2 \sin^2 2\alpha$$

i.e.,

$$p^2 \frac{\dfrac{4}{B^2C^2}(1-\cos^2 2\alpha)}{\dfrac{1}{B^2}+\dfrac{1}{C^2}+\dfrac{2\cos 2\alpha}{BC}} = 2\sin^2 2\alpha$$

$$\therefore p^2 = \frac{B^2+C^2+2BC\cos 2\alpha}{2}$$

and since this is for maximum or minimum p

$$P_1^2 = 4p^2$$
$$= 4(A^2+\delta^2)+4(A^2-\delta^2)\cos 2\alpha$$

as stated above [Equ. (6a)]. P_2 may be derived similarly [Equ. (6b)].

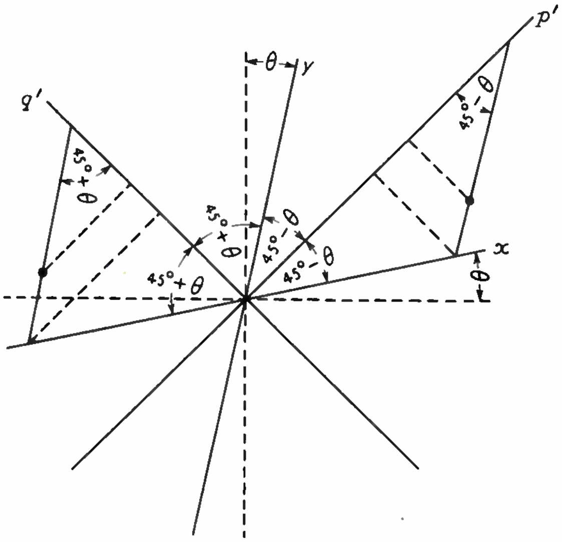

Fig. 8. *Effect of non-perpendicular deflection axes.*

If the X and Y deflection axes of the c.r. tube are not necessarily exactly at right angles, consider the transformation to co-ordinates p' and q' with axes bisecting the deflection axes (see Fig. 8). The p' and q' axes are then at right angles to each other. If the angle between the X and Y axes in the 1st quadrant is $(90-2\theta)$ degrees,

$$p' = x\cos(45-\theta)^\circ + y\cos(45-\theta)^\circ$$

and $$q' = -x\cos(45+\theta)^\circ + y\cos(45+\theta)^\circ$$

Hence, if p and q respectively denote the values which p' and q' would have if the axes were at right angles, for any given x and y, then

$$p' = p\frac{\cos(45-\theta)^\circ}{\cos 45^\circ}$$

and $$q' = q\frac{\cos(45+\theta)^\circ}{\cos 45^\circ}$$

For any measurement Q_1' which is made near the p axis, the corresponding co-ordinate q_1' is small compared with the corresponding co-ordinate p_1', and hence

$$Q_1'^2 = 4(p_1'^2+q_1'^2)$$
$$= 4p_1^2\frac{\cos^2(45-\theta)^\circ}{\cos^2 45^\circ} + 4q_1^2\frac{\cos^2(45+\theta)^\circ}{\cos^2 45^\circ}$$
$$\approx 4(p_1^2+q_1^2)\frac{\cos^2(45-\theta)^\circ}{\cos^2 45^\circ}$$
$$\approx Q_1^2\frac{\cos^2(45-\theta)^\circ}{\cos^2 45^\circ}$$

i.e., $$Q_1' \approx Q_1\frac{\cos(45-\theta)^\circ}{\cos 45^\circ}$$
$$\approx Q_1\frac{\cos 45^\circ\cos\theta^\circ+\sin 45^\circ\sin\theta^\circ}{\cos 45^\circ}$$
$$\approx Q_1(\cos\theta^\circ+\sin\theta^\circ)$$

as stated above [Equ. (7a)]. Equations (7b), (8a), and (8b) can be derived similarly.

Regarding equation (10), if $\alpha = \tan^{-1}\dfrac{Q_2}{Q_1}$, then we have for any small δQ_1 and δQ_2

$$\tan^{-1}\frac{Q_2+\delta Q_2}{Q_1+\delta Q_1} \approx \alpha + \frac{1}{\sec^2\alpha}\left(\frac{\delta Q_2}{Q_1} - \frac{Q_2\cdot\delta Q_1}{Q_1^2}\right)$$

$$\therefore \delta\alpha \approx \frac{1}{\sqrt{8}\sec^2\alpha}\left(\frac{\delta Q_2}{A\cos\alpha} - \frac{A\,.\,\delta Q_1\sin\alpha}{A^2\cos^2\alpha}\right)$$
$$\approx \frac{\delta Q_2}{A}\cdot\frac{\cos\alpha}{\sqrt{8}} - \frac{\delta Q_1}{A}\frac{\sin\alpha}{\sqrt{8}}$$

$$\therefore (\delta\alpha)^2 = \left(\frac{\delta Q_2}{A}\right)^2\frac{\cos^2\alpha}{8} + \left(\frac{\delta Q_1}{A}\right)^2\frac{\sin^2\alpha}{8}$$
$$= \frac{1}{8}\left(\frac{\sigma}{A}\right)^2$$

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VISUAL DETECTABILITY OF SIGNALS IN NOISE

The Effect of "Contrast"

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SUMMARY.—The effect of 'contrast' (in the form of a bias) on the detectability of signals displayed for visual observation in a noise background is very controversial, as many different considerations arise in different applications. This paper is concerned with the effect of such contrast on a particular derived signal-to-noise-ratio criterion (R_{B2}), and it is shown that the results obtained agree, at least qualitatively, with experimental results on probability of detection in very simple systems.

1. Introduction

SUBJECTIVE experiments[1] in the laboratory have shown reasonable amounts of contrast* to have little, or no, effect on the probability of detection. A theoretical treatment[4], which assumed simplified probability distributions, has shown that this result was not unexpected and that contrast would only have a significant effect when the number of Just Noticeable Differences of intensity available on the display was small, or the contrast very large. The calculation of the effect of contrast on detectability criteria†, using actual probability distributions has not hitherto been achieved, since long numerical calculations were involved. However, a recent internal report by Mr. F. A. J. Ford drew the author's attention to the fact that one of the integrals requiring solution occurred in other fields and had been important enough to employ a computing staff for numerical evaluation. With this inspiration an associated integral has been computed over a very small range and has enabled a few results to be obtained—sufficient to be indicative of the trend.

2. Theory

The criterion of output signal/noise ratio used most widely in theoretical assessments of various circuits is R_{B2} (see reference 2), which is defined as $\dfrac{\text{change in mean level on application of signal}}{\text{r.m.s. fluctuation with signal absent}}$.

The evaluation of this for any particular case, involves the calculation of the mean level and r.m.s. fluctuation in the absence of the signal and the mean level when the signal is present. The former presents little difficulty and it is only in the latter problem that the integration involves laborious computation.

*Contrast: Throughout this paper the term contrast is used in the sense of a bias; i.e., the input has to reach a predetermined level before its effect is registered. This is similar to the photographer's use of the term, in that the difference between the high and low amplitudes is exaggerated.

†A full discussion of detectability criteria can be found in reference 2.

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Rice[3] shows that the probability density of the envelope of the combination of a pure sine wave and Gaussian random noise is given by

$$p(R) = \frac{R}{\psi_0} \exp.\left[-\frac{R^2 + Q^2}{2\,\psi_0}\right] I_0\left(\frac{RQ}{\psi_0}\right)$$

where R = amplitude
ψ_0 = mean square of the noise
Q = peak amplitude of signal
I_0 = is a modified Bessel function

This equation can be normalized for simplicity by letting $x = \dfrac{R}{\sqrt{2\psi_0}}$ and $\dfrac{Q}{\sqrt{2\psi_0}} = y$ = signal/noise ratio. We wish to express a probability distribution in terms of another variable related by a constant to the original; i.e., express $p(R)$ as $p(aR)$ where a is a constant. Since the probability at any point is independent of the variable we have

$$p(R)dR = p(aR)d(aR)$$

Hence $p(aR) = \dfrac{1}{a} p(R)$

i.e.,
$$p(x) = \sqrt{2\psi_0}\, p(R) = 2x \exp.[-(x^2 + y^2)]\, I_0(2xy)$$

Since $p(x)$ is dependent on y we can define any particular distribution as

$$p(x, y) = 2x \exp.[-(x^2 + y^2)]\, I_0(2xy)$$

thus when no signal is present, $y = 0$ and we have

$$p(x, 0) = 2x \exp.[-x^2]$$

i.e., the well-known Rayleigh distribution.

Fig. 1 shows the form of $p(x, y)$ for various values of y. [These curves have been abstracted from Rice's paper.] The mean is given by

$$\frac{\int_0^\infty x p(x, y) dx}{\int_0^\infty p(x, y)\, dx}$$

and the mean square by $\dfrac{\int_0^\infty x^2 p(x, y) dx}{\int_0^\infty p(x, y) dx}$

All these integrals may be evaluated. But when the limits are not zero and infinity the integration can be carried out only by numerical methods so long as $y > 0$.

When contrast in the form of a bias voltage or current is applied, all amplitudes below a given

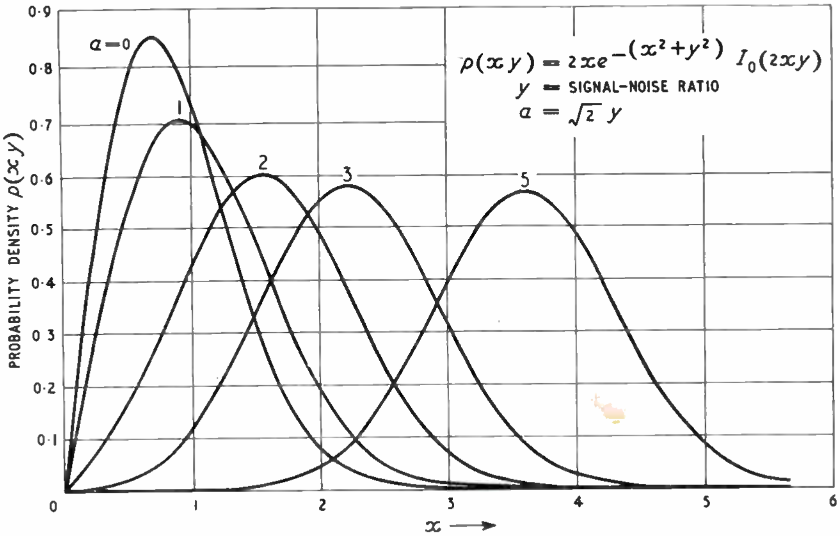

Fig. 1. *Probability density of the envelope (from Ref. 3).*

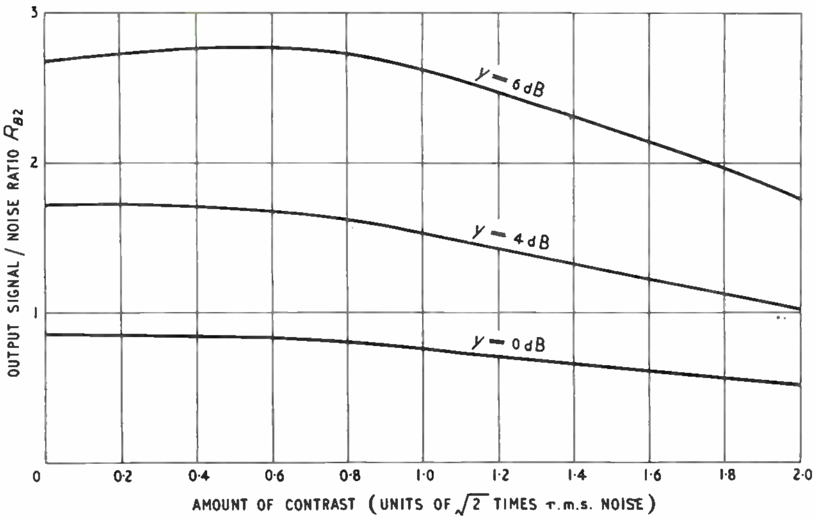

Fig. 2. *Effect of contrast on* R_{B2}.

value A are not displayed. This of course alters the mean and standard deviation of the remaining distribution and the limits of integration are now from A to infinity. In the Appendix the new mean and standard deviations for the Rayleigh distribution are derived, but the mean of the distribution including signal requires numerical calculation. Fortunately the integral $\int_A^\infty p(x,y)dx$ has been tabulated over quite a wide range and a small approximation enables the integral $\int_A^\infty xp(x,y)dx$ to be calculated, viz.

$$\int_A^\infty xp(x,y)dx$$

$$= \sum_{n=0}^{n=\infty} \left\{A + (2n+1)\frac{\Delta}{2}\right\} \int_{A+n\Delta}^{A+(n+1)\Delta} p(x,y)dx$$

$$= \sum_{n=0}^{n=\infty} \left\{A + \frac{(2n+1)\Delta}{2}\right\}$$

$$\left\{\int_0^{A+(n+1)\Delta} p(x,y)dx - \int_0^{A+n\Delta} p(x,y)dx\right\}$$

The accuracy of this method obviously depends on the interval Δ which is of course limited by the original tabulation of $\int_0^A p(x,y)dx$. (The interval of the table available was 0·1 over most of the range.) A check was obtained by using this method to evaluate the integral from zero to infinity since the answer to this can be obtained analytically, and the resulting accuracy was found to be about 0·1%.

3. Results

It was not thought worth while to work out more than one or two examples to determine the trend of the result and these are shown graphically in Fig. 2 for signal/noise ratios of 0, 4, and 6 dB ($y = 0$, 1·5 and 2). The scale of the abscissa is in units of x; i.e., the point 1 is where $x = \dfrac{R}{\sqrt{2\psi_0}} = 1$. This means that at $x = 1$ the amplitude R has to exceed $\sqrt{2\psi_0}$ before it is displayed; i.e., R must exceed $\sqrt{2}$ times the r.m.s. of the noise. Since less than 2% of the noise peaks exceed $2\sqrt{2}$ times the r.m.s. then the normal range of contrast is below $x = 2$.

4. Discussion and Conclusions

The dependence of the numerical value of the criterion R_{B2} on contrast is a function of the signal/noise ratio. Increase of contrast causes a reduction of the standard deviation when no signal is present, and an increase in the mean both with and without signal present. Consequently, unless this increase in means has a significant effect on the difference between them, the decrease in standard deviation would cause an increase in the value of R_{B2}. Hence for large signal/noise ratios, where the mean when signal is present is relatively high, the value of R_{B2} increases at first with contrast. Further increase in contrast, however, causes a reduction in the difference of means at a greater rate than the fall of the standard deviation, thus causing a reduction in the values of R_{B2}. For small signal/noise ratios the difference in means decreases sufficiently to counterbalance the fall in standard deviation even with small amounts of contrast.

The general tendency, for the signal/noise ratios considered (0–6 dB), is that reasonable amounts of contrast have little effect on R_{B2} but large amounts cause a considerable reduction of its value. This would have been the predicted result of the effect of contrast on the probability of detection using the simplified distributions assumed in reference 4. Although this agreement must be regarded as only qualitative (since probabilities of detection for real distributions have not yet been calculated), yet it adds support for the use of the criterion R_{B2} as a measure of the relative efficiency of detector circuits for any given display medium. This is of importance, since criteria like R_{B2} are usually much more easily calculated than probabilities of detection. Reference 5 has already indicated that R_{B2} may well be a reliable criterion for the relative effectiveness of detection using linear and square-law detector circuits with A-scan display; square-law response is, of course, another kind of contrast, since the larger amplitudes are accentuated relative to the smaller ones.

Acknowledgments

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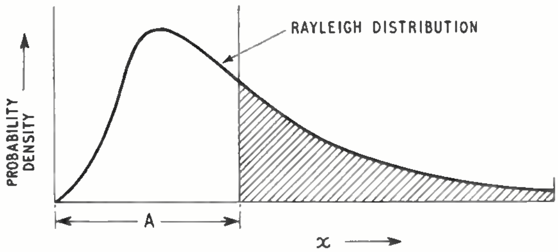
APPENDIX

To obtain the mean and standard deviation of a contrasted Rayleigh Distribution



$$\text{Shaded area} = \int_A^\infty 2x\, e^{-x^2}\, dx = e^{-A^2}$$

$$\text{1st moment} = \int_A^\infty 2x^2\, e^{-x^2}\, dx = -\int_A^\infty x d(e^{-x^2})$$

$$= -\Big[xe^{-x^2}\Big]_A^\infty + \int_A^\infty e^{-x^2}\, dx$$

$$= Ae^{-A^2} + \frac{\sqrt{\pi}}{2}[1 - \text{erf.}(A)]$$

$$\therefore \text{Mean} = A + \frac{\sqrt{\pi}}{2} e^{A^2} [1 - \text{erf.}(A)]$$

$$\text{2nd moment} = \int_A^\infty 2x^3\, e^{-x^2}\, dx = -\int_A^\infty x^2\, d(e^{-x^2})$$

$$= -\Big[x^2\, e^{-x^2}\Big]_A^\infty + \int_A^\infty x\, e^{-x^2}\, dx$$

$$= A^2 e^{-A^2} + e^{-A^2}$$

$$\therefore \text{Mean Square} = 1 + A^2$$

$$\text{Standard Deviation} = \{\text{Mean Square} - (\text{Mean})^2\}^{\frac{1}{2}}.$$

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THE IMPEDANCE CONCEPT

Part 2—Quartic and Quintic Characteristic Equations: Maximum Feedback

By C. G. Mayo and J. W. Head

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SUMMARY.—In Part 1, the fundamental properties of impedances, and of the 'p-world' to which these impedances belong, were discussed. A general condition for an algebraic equation to be free from roots with positive real parts was obtained; a network whose characteristic equation has this property is stable. Here we consider in more detail the effect on stability and damping of adding terms in p^4 and p^5 to a given cubic in p. The addition of extra 'step-circuit' elements to a three-stage *RC* amplifier, in order to improve feedback, is then discussed. Only the parameters associated with the additional elements are under our control, and a graphical method of finding, roughly, values of these parameters suitable for obtaining a given amount of feedback is explained. Only elementary algebra is involved, including the condition for a quadratic equation to have real roots, provided that the characteristic equation of the amplifier, with the additional elements is, at worst, quintic. The procedure can be extended to characteristic equations of higher degree, in the manner indicated by a numerical example where the degree is 7.

LIST OF PRINCIPAL SYMBOLS

$a_0, a_1, a_2 \ldots a_n$	Coefficients of the polynomial P_n.
A	Transfer function of amplifier without step-circuit [equation (3)].
A'	Transfer function of amplifier with step-circuit [equation (7)].
b	Parameter associated with the step-circuit [equation (7)].
b_1, b_2, b_3, b_4	Parameters defined by equations (9) associated with the characteristic equation of a feedback amplifier with three *RC* stages and a step-circuit.
B	Parameter associated with the step-circuit [equation (7)].
E_n	Real part of the polynomial P_n when p is replaced by $j\omega$.
k	Parameter associated with the step-circuit [see equation (7)].
n	Degree of the polynomial P_n.
O_n	Imaginary part of the polynomial P_n when p is replaced by $j\omega$.
p	Heaviside operator, in terms of which impedances are expressed. In this article p can often be replaced by $j\omega$.
P_n	A polynomial of degree n in p.
T_1, T_2, T_3	Time constants of three *RC* amplifier stages [equation (3)].
β	Transfer function of the feedback path [equation (4)].
λ	Feedback [defined precisely just before equation (4)].
Λ_0	Value of λ which makes E_7 have minimum value zero [Section 6].
Λ_1	Value of λ which makes O_7 have minimum value zero [Section 6].
ω	See definition of p.
$\omega_1, \omega_2 \ldots$	Zeros of E_n (in ascending order).
$\omega_{m1}, \omega_{m2} \ldots$	Turning values of E_n (in ascending order).
Ω_1, Ω_2	Zeros of O_n (in ascending order).

1. Introduction

IN Part 1 we showed how useful information on circuit behaviour could be obtained within the 'p-world', p being a variable closely associated with time differentiation which can be manipulated algebraically. A general condition for a polynomial P_n of degree n in p to be free from zeros with positive real parts was obtained, and applied to the case of a three-stage *RC* feedback amplifier. Here our main objective is to determine the effect of adding extra 'step-circuit' elements on the gain and the maximum feedback obtainable. So we first derive the characteristic equation as modified by the presence of the extra elements. The parameters associated with the extra elements are in fact involved in all the coefficients of the characteristic equation, but for the purposes of discussion and understanding it will be easier initially to consider how the roots of a given cubic equation in p, namely

$$P_3 \equiv a_0 + a_1 p + a_2 p^2 + a_3 p^3 = 0 \quad \ldots \quad (1)$$

are affected by the addition of terms $a_4 p^4$ and $a_5 p^5$, so that we compare the roots of (1) with those of

$$P_5 \equiv a_0 + a_1 p + a_2 p^2 + a_3 p^3 + a_4 p^4 + a_5 p^5 = 0 \quad (2)$$

when a_0, a_1, a_2, and a_3 are regarded as fixed and out of our control but a_4 and a_5 are regarded as variable and under our control.

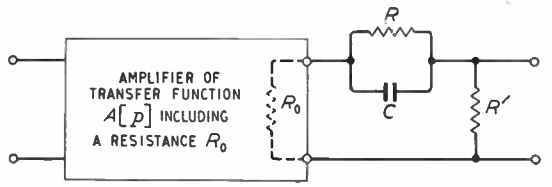


Fig. 8. *Three-stage amplifier with added step circuit elements to improve feedback. (This is repeated from Part 1 for easy reference.)*

2. Characteristic Equation of a Three-Stage *RC* Amplifier with Added Elements to improve Feedback

We shall suppose that, before the additional 'step-circuit' elements indicated in Fig. 8 are introduced, our three-stage *RC* amplifier has the transfer function

$$A = A_0/[(1 + T_1 p)(1 + T_2 p)(1 + T_3 p)] \quad (3)$$

C

where A_0 is a constant, and the time constants T_1, T_2 and T_3 are determined by the parameters of the three valves and are not under our control except in so far as some trading of bandwidth for gain is possible. R_0 is taken into account in the determination of T_1, T_2 and T_3. We shall also suppose that negative feedback is introduced, so that the transfer function $\beta[p]$ of the feedback path is a mere negative constant $-\lambda/A_0$. The characteristic equation before the additional elements are introduced is then

$$1 - A\beta = 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

which reduces to

$$(1 + \lambda) + (T_1 + T_2 + T_3)p + (T_2T_3 + T_3T_1 + T_1T_2)p^2 + T_1T_2T_3p^3 = 0 \quad (5)$$

and in Part 1 we found that the condition for stability was

$$\lambda < (T_2/T_3) + (T_3/T_2) + (T_3/T_1) + (T_1/T_3) + (T_1/T_2) + (T_2/T_1) + 2 \quad \ldots \quad (6)$$

The effect of the additional elements is to replace the original forward gain A by A' where

$$A' = kA\,\frac{1 + bp}{1 + Bp} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

k being a constant less than unity and b, B being positive constants such that $b > B$ and $k \leqslant B/b$, since the additional elements are passive, so that their presence cannot increase the gain at low or high frequencies. k, b and B are determined in terms of the valve constants of the original amplifier, the position at which the additional elements are attached, and the magnitudes of these additional elements. The gain is thus reduced in the ratio k:1 (which we can control by adjusting the point of attachment of the additional elements) at low frequencies, but is reduced in the higher ratio kb/B at high frequencies. In the characteristic equation (4) we have to replace A by A', so that (4) reduces to

$$(1 + \lambda k) + (b_1 + \lambda kb)p + b_2p^2 + b_3p^3 + b_4p^4 = 0 \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

where

$$\left.\begin{aligned} b_1 &= (T_1 + T_2 + T_3) + B \\ b_2 &= (T_2T_3 + T_3T_1 + T_1T_2) \\ &\qquad + B(T_1 + T_2 + T_3) \\ b_3 &= T_1T_2T_3 + B(T_2T_3 + T_3T_1 + T_1T_2) \\ b_4 &= T_1T_2T_3B \end{aligned}\right\} \quad (9)$$

(8) is thus a quartic in p, and the coefficients of the terms in 1, p, p^2 and p^3, though not identical with the corresponding coefficients of (5), are closely related to them, especially when b, B and λ are small and k is near 1. It will be easier to understand the significance of (9) if we first compare the roots of (1) and (2).

3. The Effect of Adding Quartic and Quintic Terms to a Given Cubic in p

At first, suppose that, in (2), a_5 is zero while a_4 is gradually increased from zero. It is shown in Part 1 that (2) must have roots with positive real parts if

$$a_5 = 0,\ a_4 > a_2^2/4a_0 \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

since then the real part E_4 of P_4 when p is replaced by $j\omega$, namely

$$E_4 = a_0 - a_2\omega^2 + a_4\omega^4, \quad \ldots \quad \ldots \quad (11)$$

would have complex zeros. We are thus not at liberty to increase a_4 indefinitely. Again, the zeros of the imaginary part of O_4 of P_4 when p is replaced by $j\omega$, namely

$$O_4 = \omega(a_1 - a_3\omega^2) \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

occur when $\omega = 0$ and $\omega^2 = (a_1/a_3)$. If P_5 (with $a_5 = 0$) is free from zeros with positive real parts, it is shown in Part 1 that this last value of ω^2 must separate the two values of ω^2 which make E_4 zero when a_4 is small enough for these values of ω^2 to be real. An alternative way of expressing this is to say that E_4 in (11) must be negative when $\omega^2 = (a_1/a_3)$.

Now if

$$a_1/a_3 < a_0/a_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

the value of E_4 is necessarily positive when $\omega^2 = a_1/a_3$ since $(a_0 - a_2\omega^2)$ is then positive. But (13) happens also to be the condition that (1) shall have a root with a positive real part. It follows that if the characteristic equation (1) is associated with instability, the addition of a quartic term cannot correct the instability.

When (13) is not true, (2) with $a_4 = a_5 = 0$ can be regarded as the characteristic equation of a stable system; if $a_5 = 0$ but a_4 is varied, the zero Ω_1 of O_4 remains constant at $(a_1/a_3)^{\frac{1}{2}}$ while the zeros ω_1, ω_2 ($\omega_1 < \omega_2$) of E_4 are given by

$$1/\omega_1^2 = \left[a_2 + \left\{a_2^2 - 4a_0a_4\right\}^{\frac{1}{2}}\right]/2a_0;$$

$$1/\omega_2^2 = \left[a_2 - \left\{a_2^2 - 4a_0a_4\right\}^{\frac{1}{2}}\right]/2a_0 \quad \ldots \quad (14)$$

When a_4 is zero, $\omega_1^2 = a_0/a_2$, ω_1 is less than Ω_1, and ω_2 is infinite. As a_4 increases, ω_1 increases and ω_2 decreases until, just before (10) is violated, ω_1^2 and ω_2^2 are both near $2a_0/a_2$ but $\omega_1^2 < 2a_0/a_2 < \omega_2^2$. If therefore

$$2a_0/a_2 > a_1/a_3 > a_0/a_2 \quad \ldots \quad \ldots \quad \ldots \quad (15a)$$

the effect of increasing a_4 is to make ω_1 approach Ω_1 from below, whereas if

$$a_1/a_3 > 2a_0/a_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (15b)$$

the effect of increasing a_4 is to make ω_2 approach Ω_1 from above. The important point is that, in either case, increasing the quartic term tends to reduce the difference between Ω_1 and one or other of the zeros ω_1, ω_2 of E_4, and this is associated with a reduction in the effective damping rate of the system whose characteristic equation is (2) with $a_5 = 0$.

Now let us consider what happens when a_5 is not zero. There is no possibility of avoiding roots with positive real parts unless

$$a_2^2 > 4a_0a_4\ ;\ a_3^2 > 4a_1a_5 \quad \ldots \quad \ldots \quad (16)$$

(so that we are not at liberty to increase a_5 indefinitely) because for stability we now have (as shown in Part 1) that the zeros of

$$E_5 = a_0 - a_2\omega^2 + a_4\omega^4 \quad \ldots \quad \ldots \quad (17)$$

must be real and separate those of

$$O_5 = \omega[a_1 - a_3\omega^2 + a_5\omega^4] \quad \ldots \quad \ldots \quad (18)$$

Since E_5 is the same as E_4 in (11), its zeros ω_1, ω_2 are given by (14), while the zeros Ω_1, Ω_2 of O_5 are given by

$$1/\Omega_1^2 = \left[a_3 + \left\{a_3^2 - 4a_1a_5\right\}^{\frac{1}{2}}\right]/2a_1;$$

$$1/\Omega_2^2 = \left[a_3 - \left\{a_3^2 - 4a_1a_5\right\}^{\frac{1}{2}}\right]/2a_1 \quad (19)$$

For stability we require

$$\omega_1 < \Omega_1 < \omega_2 < \Omega_2 \quad \ldots \quad \ldots \quad \ldots \quad (20)$$

and we note that

ω_1 increases with a_4 but is independent of a_5
Ω_1 increases with a_5 but is independent of a_4
ω_2 decreases as a_4 increases but is independent of a_5
Ω_2 decreases as a_5 increases but is independent of a_4

By careful consideration of the behaviour of (14) and (19) when a_4 and a_5 vary, it can be shown that if (13) is true, it is not possible to find a_4 and a_5 so that (2) is free from roots with positive real parts. If, however, (13) is untrue, so that (1) is free from roots with positive real parts, then given any value of a_4 less than $a_2^2/4a_0$ [so that (17) has real roots] it is always possible to find a range of values of a_5 such that (2) is free from roots with positive real parts, and given any value of a_5 less than $a_3^2/4a_1$ [so that (18) has real roots] it is always possible to find a range of values of a_4 such that (2) is free from roots with positive real parts. This can be best illustrated by means of two examples, in the first of which (1) has a root with positive real part while in the second (1) has no such root. For these examples, we shall require the well-known condition for the equation (2) to have a purely imaginary root, which is

$$(a_0a_5 - a_1a_4)^2 = (a_2a_5 - a_3a_4)\,(a_0a_3 - a_1a_2) \ldots \quad \ldots \quad (21)$$

Consider then the equation

$$1 + p + 4p^2 + 5p^3 + a_4p^4 + a_5p^5 = 0 \quad (22)$$

Here the cubic obtained by equating a_4 and a_5 to zero has a root with positive real part.

(21) reduces to

$$(a_5 - a_4)^2 = 4a_5 - 5a_4 \quad \ldots \quad \ldots \quad (23)$$

and if a_4 is plotted against a_5 to satisfy (23), we obtain the parabola in Fig. 9. The number of roots of (22) with positive real parts in (22) cannot change when we vary (a_4, a_5) unless this variation causes the parabola (23) to be crossed. If $a_5 = 0$ while a_4 is very small, (22) will have roots very similar to those of the cubic obtained by equating a_4 and a_5 to zero, together with a large negative root near $-5/a_4$. Hence the exterior of the parabola is all a region in which (22) has one pair of complex roots with positive real parts. If (a_4, a_5) is inside the parabola it will be found that (22) has two pairs of complex roots with positive real parts.

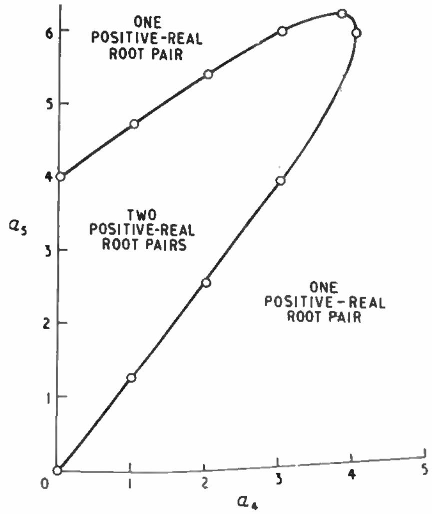


Fig. 9. *a_5 plotted against a_4 to satisfy* (23). *Nature of roots of* (22).

Now suppose that the coefficients of p^2 and p^3 are exchanged in (22) so that the equation being considered is

$$1 + p + 5p^2 + 4p^3 + a_4p^4 + a_5p^5 = 0 \quad (24)$$

If $a_4 = a_5 = 0$ we now have a cubic free from roots with positive real parts. (21) becomes

$$(a_5 - a_4)^2 = 4a_4 - 5a_5 \quad \ldots \quad \ldots \quad (25)$$

so that the locus of points for which (24) has purely imaginary roots is obtained from Fig. 9 by exchanging a_4 and a_5, and is as in Fig. 10. In this case we find that if (a_4, a_5) is within the part of the parabola (25) which is in the first quadrant, (24) is free from roots with positive real parts, but if (a_4, a_5) is outside the parabola and in the first quadrant, there is one pair of roots with positive real parts. In Fig. 10, we notice

(i) As a_5 increases, the range of permissible values of a_4 decreases; this range never includes zero.

(ii) If $4 < a_4 < 6{\cdot}25$, the range of permissible values of a_5 does not include zero. This means that the quartic characteristic equation associated with an unstable system obtained from (24) by putting $a_5 = 0$ and giving a_4 a value between 4 and 6·25 can be 'corrected' by the addition of a quintic term whose coefficient is between certain limits which approach each other as the coefficient a_4 approaches the maximum permissible value $a_2^2/4a_0 = 6{\cdot}25$.

(iii) No 'correction' is possible if either a_4 exceeds $a_2^2/4a_0$ or a_5 exceeds $a_3^2/4a_1$.

The peculiar result (ii) does not always occur. The general condition for it to occur is derived from (21) by putting $a_5 = 0$. If the non-zero value $C = a_3(a_1a_2 - a_0a_3)/a_1^2$ of a_4 thus obtained is such that the slope of the tangent at $(C, 0)$ to the parabola (21) is positive, we shall have a similar situation to that of Fig. 10, but not in the contrary case. It thus appears that the situation of Fig. 10 will occur when

$$a_0a_3 < a_1a_2 < 2a_0a_3$$

since Fig. 10 is not applicable at all unless (13) is untrue.

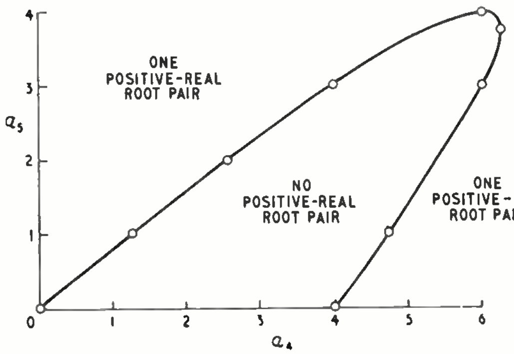


Fig. 10. *a_5 plotted against a_4 to satisfy* (25). *Nature of roots of* (24).

4. Nature of the Roots of the Characteristic Equation of the Three-Stage *RC* Amplifier with Added Elements

We now have to apply the above considerations to (8). The zero Ω_1 of (12) is given by

$$\Omega_1^2 = (b_1 + \lambda kb)/b_3 \quad \ldots \quad \ldots \quad \ldots \quad (26)$$

while those of (11) are given by

$$(1 + \lambda k) - b_2\omega^2 + b_4\omega^4 = 0 \quad \ldots \quad (27)$$

The condition that (26) shall separate (27), so that (8) has no roots with positive real parts can in this case be written down; it reduces to

$$b^2b_4\lambda^2k^2 - \lambda k\{b_1b_2b_3 - 2bb_1b_4 - b_3^2\} < \{b_1b_2b_3 - b_3^2 - b_4b_1^2\} \quad \ldots \quad (28)$$

The term independent of λ in (28) is positive since when $\lambda = 0$ (8) has four real negative roots, $-T_1$, $-T_2$, $-T_3$ and $-B$, in p. For very large λ the first term of (28) prevails, so that there is a limit to the feedback obtainable. But although in any particular case (28) can be solved to obtain the maximum feedback, it is not easy to deduce from (28) how to adjust k, b and B so as to increase the feedback. If however we apply (13) to (8) we see that there cannot possibly be stability unless the cubic equation formed from (8) by omitting the last term is free from roots with positive real parts, so that

$$b_1b_2 - b_3 > \lambda k\{b_3 - bb_2\} \quad \ldots \quad \ldots \quad (29)$$

Similarly, if we put $p = 1/q$ in (8), we should obtain a quartic equation for q which must be free from roots with positive real parts (the real parts of p and q have the same sign). Applying (13) to this q-equation, we find that there cannot be stability unless

$$(b_1 + \lambda kb)q^3 + b_2q^2 + b_3q + b_4 = 0 \ldots \quad (30)$$

is free from roots with positive real parts; this requires

$$b_2b_3 - b_1b_4 > \lambda kbb_4 \quad \ldots \quad \ldots \quad \ldots \quad (31)$$

(29) may be true for all positive λk, but (31) will always set an upper limit to λk. If (29) and (31) are both satisfied, (8) may be associated with a stable system if B is sufficiently small. Thus (29) and (31) indicate the order of magnitude of the maximum feedback obtainable. It is useless to proceed further, whether by examining (28) or by examining the behaviour of (26) and (27) as functions of λ, unless B, b and k can be adjusted so that the required value of λ can be substantially exceeded without violating (29) or (31).

5. Choice of the Parameters under our Control to obtain Improved Feedback

Let us now consider a specific problem: if $T_1 = 100$, $T_2 = 10$ and $T_3 = 1$, the maximum feedback obtainable from the circuit without additional elements is deducible from (6) and is 122·21. From the nature and arrangement of the added elements, there must inevitably be some loss of gain (i.e., k must be less than 1) but we do not want the loss of gain to be excessive, so we can perhaps take a reasonable value of k to be 0·2; what values of b, B, if any, are then suitable if we wish to increase the maximum feedback obtainable to 1,500 with $k = 0{\cdot}2$? In this case (8) reduces to

$$(1 + \lambda k) + (111 + B + \lambda kb)p + (1110 + 111B)p^2 + (1000 + 1110B)p^3 + 1000Bp^4 = 0 \quad \ldots \quad \ldots \quad \ldots \quad (32)$$

(29) and (31) become respectively

$$\lambda k < \frac{122{\cdot}21 + 12{\cdot}321B - 0{\cdot}111B^2}{1 - 1{\cdot}11\,(b - B) - 0{\cdot}111bB} \quad \ldots \quad (33)$$

and

$$\lambda k < \frac{999 + 1342{\cdot}1B + 123{\cdot}21B^2}{b} \quad \ldots \quad (34)$$

Now we saw at the end of Section 4 that (29) and (31) should be satisfied for a value of λ considerably in excess of the required value. In (33) and (34), therefore, we put 1800 instead of 1500 for λ; k is 0·2. We thus obtain from (33)

$$b > \frac{0{\cdot}5951 + 0{\cdot}9692B + 0{\cdot}000278B^2}{1 + 0{\cdot}1B} \quad (35)$$

and from (34)

$$b < 2{\cdot}775 + 3{\cdot}7281B + 0{\cdot}34225B^2 \quad \ldots \quad (36)$$

We also know that

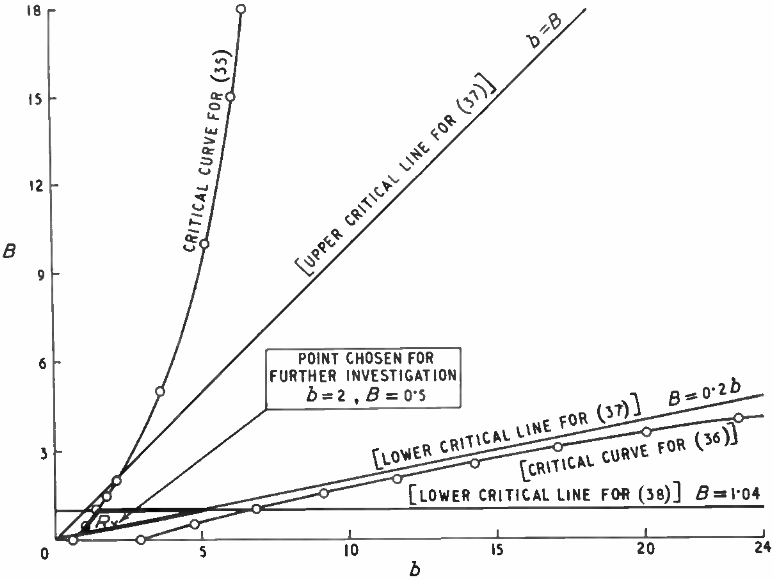
$b > B > kb$ ... ... (37)

and that the roots of (27) must be real. The latter fact in our case gives

$(1110 + 111B)^2 > 4000B\ (1 + \lambda k)$ ... (38)

(38), like (33) and (34), should be satisfied for a value of λ considerably greater than the required value of 1,500, since satisfying (38) for $\lambda = 1{,}500$ only ensures that the roots of (27) are real. If these roots are close together it may be very difficult to ensure that they are separated by (26). In (38) therefore, we put $\lambda = 1{,}800$ and $k = 0{\cdot}2$; we deduce that B is not between 1·04 and 96·16.

Fig. 11. *Regions of the* (b, B) *plane in relation to* (35), (36), (37) *and* (38).



In Fig. 11, the positive quadrant of the (b, B) plane is divided into regions according to whether (i) $(b - B)$ is positive or negative, (ii) (35) is true or false, (iii) (36) is true or false, and (iv) the roots of (27) are real or complex ; i.e., (38) is true or false. It is thus clear that a possible region in which suitable points (b, B) are likely to be found is the region labelled R in Fig. 11, bounded by $B = 0{\cdot}2b$ below, by $b = (0{\cdot}5951 + 0{\cdot}9692B + 0{\cdot}000278B^2)/(1 + 0{\cdot}1B)$ on the left, and by $B = 1{\cdot}04$ above. A suitable point within this region would appear to be $b = 2$, $B = 0{\cdot}5$, and we shall arbitrarily choose this for further examination. Practical considerations might easily cause us to be particularly interested in some other part of the region R, but the point we wish to emphasize here is that it is useless to attempt to look outside the region R, or possibly the region S described next.

The region S (which cannot be included in Fig. 11 because a scale which allowed us to include it would make the region R too small) is bounded on the left by the line $b = B$, and bounded below by $B = 96{\cdot}16$ for $96{\cdot}16 < b < 480{\cdot}8$ and by the line $B = 0{\cdot}2b$ for $B > 480{\cdot}8$, this line being always above the parabola along which the two sides of (36) are equal. A typical point well within this region is $b = 150$, $B = 120$.

For $b = 2$, $B = 0{\cdot}5$, $k = 0{\cdot}2$, (32) reduces to

$$(1 + 0{\cdot}2\lambda) + (111{\cdot}5 + 0{\cdot}4\lambda)p + 1165{\cdot}5p^2 + 1555p^3 + 500p^4 = 0 \quad \ldots \quad \ldots \quad (39)$$

In this case, (26) becomes

$$\Omega_1^2 = (111{\cdot}5 + 0{\cdot}4\lambda)/1555 = 0{\cdot}0717 + 2{\cdot}57235 \times 10^{-4}\lambda \quad \ldots \quad (40)$$

while (27) can be written

$$\lambda = -5 + 5827{\cdot}5\omega^2 - 2500\omega^4 \quad \ldots \quad (41)$$

From (41), it is clear that the sum of the values of ω^2 for a given λ is $5827{\cdot}5/2500 = 2{\cdot}331$. We now choose any value ω_1^2 of ω^2, and deduce λ from (41). The other root of (41) for the same λ is $\omega_2^2 = 2{\cdot}331 - \omega_1^2$. The root Ω_1^2 of (40) for the same λ is then deduced. In this way we obtain the corresponding sets of values of ω_1^2, ω_2^2, ω_3^2 and λ shown in Table 1

TABLE 1

ω_1^2	0·01	0·1	0·3	0·6	0·9	1
Ω_1^2	0·0853	0·2139	0·4622	0·7383	0·8986	0·9264
ω_2^2	2·321	2·231	2·031	1·731	1·431	1·331
λ	53·025	552·75	1518·24	2591·5	3214·7	3322·5

It is thus clear that stability breaks down because ω_1 approaches Ω_1 when λ is about 3,214, which is well in excess of the value 1,500 sought.

For $b = 150$, $B = 120$, $k = 0{\cdot}2$, (32) reduces to

$$(1 + 0{\cdot}2\lambda) + (231 + 30\lambda)p + 14{,}430p^2 + 134{,}200p^3 + 120{,}000p^4 = 0 \quad \ldots \quad (42)$$

so that (26) becomes

$$\Omega_1^2 = (231 + 30\lambda)/134{,}200 = (1{\cdot}72131 \times 10^{-3}) + (2{\cdot}23547 \times 10^{-4}\lambda) \quad \ldots \quad (43)$$

while (27) can be written

$$\lambda = -5 + 72150\omega^2 - 600{,}000\omega^4 \quad \ldots \quad (44)$$

Proceeding as before $\omega_1^2 + \omega_2^2$ is now $72150/600{,}000 = 0{\cdot}12025$, while Ω_1^2 is obtained from (43). We thus obtain the values ω_1, ω_2, Ω_1 and

λ shown in Table 2.

TABLE 2

ω_1^2	0·005	0·01	0·008	0·0078	0·0074
Ω_1^2	0·0779	0·1485	0·1210	0·1182	0·11261
ω_2^2	0·11525	0·11025	0·11225	0·11245	0·11285
λ	340·74	656·49	533·79	521·265	496·05

We thus have the disappointing result that stability is broken because Ω_1 becomes equal to ω_2 when λ is about 496 instead of the 1,500 sought. We now show that there are in fact no points (b, B) in the region S which give the required value of λ. ω_2^2 is necessarily less than the ratio of the coefficient of p^2 in (32) to the coefficient of p^4, and Ω_1^2 must be appreciably less than this ratio if there is to be any hope of stability for the required value of λ. We thus require, in addition to the conditions we have already obtained,

$$\frac{111 + B + \lambda kb}{1000 + 1110B} > \frac{1110 + 111B}{1000B} \quad \ldots \quad (45)$$

and since we also require $b > B$, it follows that

$$B < b < \left\{\frac{1110}{B} + 1232{\cdot}1 + 122{\cdot}21B\right\}/\lambda k \quad \ldots \quad (46)$$

If $\lambda = 1{,}500$ and $k = 0{\cdot}2$, the first and last members of (46) give, when B is positive

$$B^2 - 10{\cdot}08181B - 9{\cdot}08272 < 0 \quad \ldots \quad (47)$$

so that B must not exceed 10·914, whereas B must exceed 76·42 to satisfy (38) even with $\lambda = 1{,}500$ and $k = 0{\cdot}2$. This difficulty did not arise when b was 2 and B 0·5, because when stability was broken, ω_1 and not ω_2 became equal to Ω_1; (46) is easily satisfied by $B = 0{\cdot}5$, $b = 2$, $\lambda = 1{,}500$ and $k = 0{\cdot}2$.

In the foregoing discussion we admittedly gave particular values to T_1, T_2 and T_3 ab initio, but it is clear that the procedure discussed in no way depended on these particular values. The various curves involved in Fig. 11 might have different relative positions for other values of the T terms, and this might greatly affect the position and extent of the region R in which suitable points (b, B) were to be found. For certain values of the T terms and the required λ we might find that the inequalities corresponding to (38) and (46) were such that suitable points (b, B) could be found in the region corresponding to what we have called S as well as (or instead of) the region corresponding to what we have called R, but in any case the diagram corresponding to Fig. 11 shows us where to look for values of b and B such that high values of feedback can be obtained. We notice in (32) that when λ appears it is always associated with k; this means that any required value of λ can be obtained by sufficiently reducing k, but the procedure under discussion shows us the region(s) in which the appropriate values of b and B lie so that k can be reduced as little as possible. In the procedure discussed, only elementary algebra is involved, including the condition for a quadratic equation to have real roots. If the amplifier had had four stages instead of three, so that the equation corresponding to (8) was a quintic, we should have had an extra condition to consider, namely that the quadratic formed from the terms of odd degree in p would have to have real roots as well as the quadratic formed from the terms of even degree.

6. Extension to Characteristic Equations of Higher Degree

The procedure just discussed for finding b, B so that a given degree λ_0 of feedback is obtainable without instability for given k can be adapted to cases where the characteristic equation is of higher degree. We shall confine ourselves to the consideration of a particular case where the characteristic equation is of degree 7 when the additional elements are included. Thus the characteristic equation, corresponding to (4) cleared of fractions, will be taken as

$$(1 + 100p)\,(1 + 50p)\,(1 + 20p)\,(1 + 10p) \times (1 + 5p)\,(1 + 2p)\,(1 + Bp) + k\lambda(1 + bp) = 0 \quad \ldots \quad (48)$$

and we require to know in roughly what region of the (b, B) plane to look for the highest values of λ consistent with stability for a given k. Without the additional elements we should have $b = B = 0$ and $k = 1$. (48) reduces to

$$P_7 \equiv (1 + k\lambda) + (187 + B + bk\lambda)p + (10{,}970 + 187B)p^2 + (249{,}700 + 10{,}970B)p^3 + (2{,}357{,}000 + 249{,}700B)p^4 + (8{\cdot}8 + 2{\cdot}357B)10^6{\cdot}p^5 + (10 + 8{\cdot}8B)10^6{\cdot}p^6 + B{\cdot}10^7p^7 = 0 \quad \ldots \quad (49)$$

We have no hope of stability unless the equations

$$E_7 \equiv (1 + k\lambda) - (10{,}970 + 187B)\omega^2 + (2{,}357{,}000 + 249{,}700B)\omega^4 - (10 + 8{\cdot}8B)10^6\omega^6 = 0 \quad \ldots \quad (50)$$

and

$$O_7 \equiv (bk\lambda + 187 + B) - (249{,}700 + 10{,}970B)\omega^2 + (8{\cdot}8 + 2{\cdot}357B)10^6\omega^4 - 10^7B\omega^6 = 0 \quad \ldots \quad (51)$$

have all their roots real for the appropriate value of λ. Now consider E_7 in (50) as a function of ω^2. If for any given value λ_0 of λ, (50) has three real roots in ω^2, E_7 has the same value 0 for three different values ω_1^2, ω_2^2 and ω_3^2, of ω^2, and therefore E_7 has a negative minimum value for some value ω_{m1}^2 of ω^2 between ω_1^2 and ω_2^2, and a positive maximum value for some value ω_{m2}^2 of ω^2 between ω_2^2 and ω_3^2. It follows that $k\lambda_0$ cannot exceed the value $k\Lambda_0$ which makes the minimum of E_7 zero. If λ_0 is slightly less than Λ_0, ω_1 and ω_2 will be close together and it will be necessary to adjust b in (51) so that O_7 has a root Ω_1^2 sufficiently near ω_{m1}^2 to ensure that $\omega_1^2 < \Omega_1^2 < \omega_2^2$ if there is to be any hope of stability with $\lambda = \lambda_0$. Similarly, $bk\lambda_0$ cannot exceed the value $bk\Lambda_1$ which makes the minimum value of O_7 zero.

First, let us consider the situation when $b = B = 0$ and $k = 1$; i.e., when the additional elements are not present. In this case O_7 is independent of λ, and the locus of points in the $(k\lambda, \omega^2)$ plane such that O_7 is zero consists of two vertical straight lines

$$\omega^2 = \omega_1^2 = 9{\cdot}26 \times 10^{-4} ; \quad \omega^2 = \omega_2^2 = 2{\cdot}295 \times 10^{-2} \quad \ldots \quad \ldots \quad (52)$$

[strictly speaking there is a third straight line which has gone to infinity because the ω^6-term in (51) is missing when $B = 0$]. The corresponding pairs of values of $k\lambda$ and ω^2 in Table 3 are sufficient to indicate the general nature of the locus of points in the $(k\lambda, \omega^2)$ plane, for $\omega^2 \leqslant 0{\cdot}005$, such that E_7 is zero:—

TABLE 3

$10^4\omega^2$	0	4	6	8	9·26	10
$k\lambda$	−1	3·01	4·74	6·27	7·17	7·62

$10^4\omega^2$	15	20	23·627	30	50
$k\lambda$	10·19	11·59	11·893 $=k\Lambda_0$	10·97	−3·83

For greater values of ω^2, $k\lambda$ remains negative until ω^2 reaches about 0·235. The other roots of E_7 when $k\lambda = 7{\cdot}15$ are thus approximately $\omega^2 = 33 \times 10^{-4}$ and $\omega^2 = 0{\cdot}24$ which are well separated by (52). Thus stability is broken when $b = B = 0$ because the least root of E_7 becomes equal to the least root of O_7, and this happens for a small value of ω^2 such that the ω^6 term in E_7 is of little importance. If we could keep B equal to zero and increase b, we might be able to raise the value of $k\lambda$ at which stability is broken from 7·15 to somewhat less than $k\Lambda_0 = 11{\cdot}89$, the value at which E_7 has a minimum value zero and $\omega_1^2 = \omega_2^2 = \omega_{m1}^2 = 23{\cdot}63 \times 10^{-4}$, but no adjustment of b can enable $k\lambda$ to exceed 11·89 without instability when $B = 0$.

The important question to consider next, therefore, is how $k\Lambda_0$ varies with B.

As the relevant values of ω are small when B is small, we can obtain $k\Lambda_0$ approximately by neglecting the ω^6 term in (50), in which case we have

$$k\Lambda_0 \approx \frac{(10{,}970 + 187B)^2}{4(2{,}357{,}000 + 249{,}700B)} - 1 = 0{\cdot}035011B + 2{\cdot}77723 + 8{\cdot}98698/\{1 + 0{\cdot}10594B\} \quad (53)$$

This expression is 11·764 when $B = 0$, which is very near the tabulated $k\Lambda_0$ of 11·893. It decreases as B increases to a minimum value 6·129 when $B = 61{\cdot}633$ and thereafter increases indefinitely, but does not regain the value 11·764 till $B = 247{\cdot}25$. This at first suggests that B should be large. Now b has to be greater than B, and if b and B are appreciable there are two dangers we have not previously had to consider, namely (i) the largest root of O_7, which is large when B is small, might become less than the largest root of E_7, and (ii) the value $k\Lambda_1$ of $k\lambda$ which makes O_7 have a minimum value zero may severely limit the permissible value of $k\lambda$. Now the highest roots of (50) and (51) are respectively approximately

$$\omega_3^2 = \frac{2{\cdot}357 + 0{\cdot}2497B}{10 + 8{\cdot}8B} \text{ and}$$

$$\Omega_3^2 = 0{\cdot}88 + \frac{0{\cdot}2357}{B} \quad \ldots \quad \ldots \quad (54)$$

but it is easily shown that these never became equal for positive B, so (i) need not be further considered. For (ii) we know that the minimum value of O_7 occurs for a relatively small value of ω^2, so that the ω^6 term contributes little, and we thus have, corresponding to (53),

$$k\Lambda_1 \approx \tfrac{1}{4}\frac{(249{,}700 + 10970B)^2}{(8{\cdot}8 + 2{\cdot}357B)10^6} - (187 + B)$$

$$= 11{\cdot}7642B + 462{\cdot}782 + \frac{1237{\cdot}89}{1 + 0{\cdot}26784B} \quad \ldots \quad \ldots \quad (55)$$

Now if $b = B = 247{\cdot}25$, so that $k\Lambda_0$ has regained its initial value 11·764, $k\Lambda_1$ derived from (55) is 13·710. An increase in B or b/B would reduce the value of $k\Lambda_1$ derived from (55), but would increase the value of $k\Lambda_0$ derived from (53). If we equate the value of $k\Lambda_1$ obtained from (55) for $b = B$ to the value of $k\Lambda_0$ obtained from (53), we find $b = B = 295$ approximately, while the corresponding common value of $k\Lambda_0$ and $k\Lambda_1$ is 13.38. This suggests that if $B = 295$ and $(b - B)$ is small, it should be possible to obtain values of $k\lambda$ in the region of 13·3. Unfortunately this possibility is not realized for we have to choose b so that the value of ω^2 which makes the right-hand side of (50) a maximum is approximately a root of (51). As $k\lambda$ is in the region of 13·3, this gives

$$\frac{13{\cdot}3b + B + 187}{249{,}700 + 10{,}970B} = \frac{10970 + 187B}{2(2{\cdot}357 + 0{\cdot}2497B)\cdot 10^6}$$

When $B = 295$, this requires $b = 77{\cdot}77$ which is hopelessly inconsistent with the condition $b > B$. We have, however, already seen that values of $k\lambda$ up to about 11·7 can be obtained by making B as small as possible (so that kA_0, which decreases as B increases for small B, is little less than its value for B zero) and then choosing b so that the smallest zero $\Omega_1{}^2$ of O_7 is equal to the value $\omega_{m1}{}^2$ of ω^2 which makes E_7 a minimum. This gives us approximately

$$\frac{11{\cdot}7b + B + 187}{249{,}700 + 10{,}970B} = \frac{10{,}970 + 187B}{2(2{\cdot}357 + 0{\cdot}2497B){\cdot}10^6}$$

or

$$b = 0{\cdot}26562B + 9{\cdot}2903 + 230{\cdot}2418/\{B + 9{\cdot}4393\} \quad \ldots \quad \ldots \quad (56)$$

so that if $B = 0$, $b = 33{\cdot}68$. If $B = 10$, (56) gives $b = 23{\cdot}79$, but this is not quite correct since increasing B reduces kA_0 in (53), and therefore also reduces slightly the appropriate coefficient of b in (56). Thus in this case we can adjust the additional elements so that the maximum value of λk is increased by 60%, relative to the maximum value possible in the absence of additional elements. As before, we have to remember that k must not exceed B/b.

7. Conclusions

In Section 6 we have indicated approximately, but in a reasonably straightforward manner, optimum values of the parameters b and B associated with the additional 'step-circuit' elements which might be used for increasing the maximum feedback of a 6-stage RC amplifier, and the procedure could be carried out for any number of stages with quite sufficient accuracy for practical purposes.

If the particular example studied in Section 6 is typical, it appears to be very difficult to obtain, by means of the additional elements, a practically important increase in feedback without serious loss of gain for an amplifier with six stages, and presumably therefore for any larger number of stages. For a three-stage amplifier, however, the maximum feedback obtainable is readily calculated in the absence of the additional 'step-circuit' elements [equation (6)] and the presence of these additional elements appears to make very high values of feedback possible.

Given a quartic or quintic characteristic equation in which we are required to adjust the coefficients within given limits dictated by practical considerations, so that the equation shall be free from roots with positive real parts, the considerations which are most helpful in indicating the general range of values of the coefficients worth investigating are

(*a*) the equations formed from the terms of odd degree and terms of even degree respectively must have all their roots real.

(*b*) the cubic equation formed by the first four or the last four terms of the given quartic or quintic must be free from roots with positive real parts. For equations of higher degree (*a*) is still helpful, but consideration of the behaviour of the even-degree and odd-degree terms as functions of $\omega^2 (p = j\omega)$ is a preferable alternative way of obtaining the same information.

Dr. J. THOMSON

A. J. Philpot is retiring in June from the directorship of the British Scientific Instrument Research Association. He will be succeeded by Dr. J. Thomson who has for some years been deputy director of physical research at the Admiralty. Previously he was professor of physics and electrical engineering at the Royal Naval College, Greenwich.

OBITUARY

Stanley Whitehead, M.A. (Oxon) D.Sc., M.I.E.E., F.Inst.P., died suddenly on 5th May. He was director of the British Electrical & Allied Industries Research Association to which post he was appointed in 1946 having been since 1939, first, assistant director and, later, deputy director.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for March 1956

Date 1956 March	Frequency deviation from nominal: parts in 10^8	
	MSF 60 kc/s 1429–1530 G.M.T.	Droitwich 200 kc/s 1030 G.M.T.
1	+0·3	−2
2	+0·3	−1
3	+0·3	−1
4	N.M.	−1
5	+0·3	−1
6	+0·3	0
7	+0·4	0
8	+0·4	0
9	+0·4	−1
10	+0·4	0
11	+0·4	−1
12	+0·4	0
13	+0·4	0
14	+0·4	+1
15	+0·4	0
16	+0·5	+1
17	N.M.	0
18	N.M.	N.M.
19	+0·4	−3
20	+0·5	+1
21	+0·5	+2
22	+0·5	+1
23	+0·5	+1
24	+0·5	+1
25	N.M.	N.M.
26	+0·4	−4
27	+0·4	−4
28	+0·5	−4
29	+0·5	−3
30	+0·5	−4
31	+0·5	−4

The values are based on astronomical data available on 1st April 1956

N.M. = Not Measured.

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.

RC Cathode-Follower Oscillators

SIR,—The appearance of a recent paper[1] has led us to look again at two papers[2,3] on the same subject which appeared in *Wireless Engineer*. In each of these papers an oscillator is described which is regarded as a combination of a passive *RC* network having a gain greater than unity, and a cathode follower. While it is not incorrect to regard such circuits in this way, there is the danger that so doing will lead to the following ideas, which, we submit, are fallacious:

(*a*) That the circuits are quite different from well-known and long established *RC* oscillator circuits.

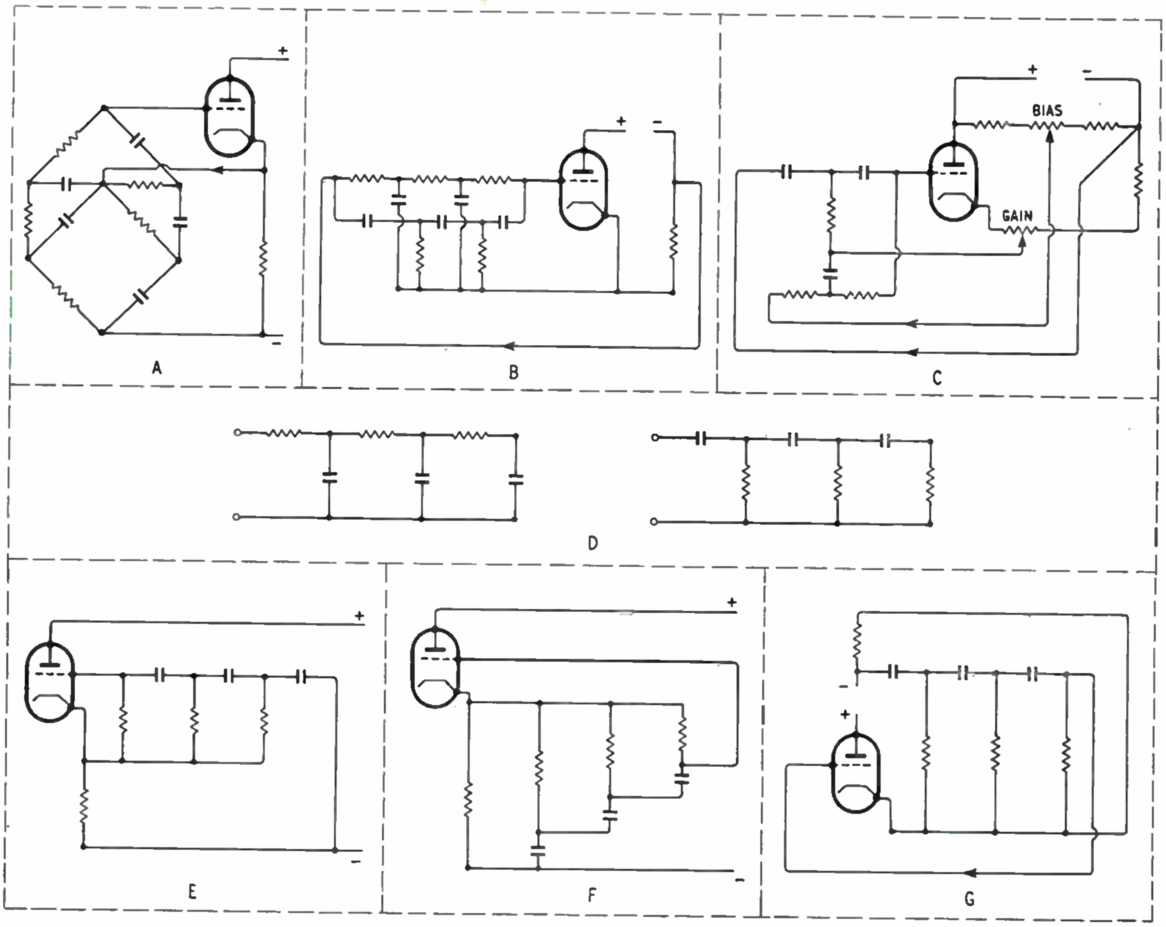
(*b*) That due to the use of the valve as a cathode follower marked advantages are obtained, in particular that there will be a reduction in the influence of valve characteristics on waveform and frequency.

That these ideas are wrong may be shown simply by redrawing the circuits. In Fig. A we reproduce the circuit given in Fig. 8 of reference 3. Precisely the same circuit redrawn is shown in Fig. B, and a similar redrawing of the circuit given in Fig. 17 of reference 2 is shown in Fig. C. Apart from the position of the high-tension battery, which is of no theoretical significance, these redrawings show the valve as a conventional amplifier. It is now easier to regard the circuits as phase-shift oscillators, the *RC* networks providing the usual 180° of phase shift between anode and grid; and if the oscillators have any particular merits, it is, we suppose, because negative feedback is provided at frequencies both above and below the oscillation frequency, thus combining the properties of the two well-known networks shown in Fig. D.

The oscillator circuit given in reference 1 is of interest because by redrawing it is shown to be a well-known phase-shift oscillator. It is drawn by the author as shown in Fig. E and, if the cathode follower with a more than unity-gain network between cathode and grid aspect is to be stressed, the rearrangement shown in Fig. F is perhaps preferable. The identity of the circuit is revealed, however, by the redrawing shown in Fig. G, which shows the oscillator to be a single-valve Van der Pol.

P. J. BAXANDALL, E. F. GOOD,
F. E. J. GIRLING, S. W. NOBLE.

R.R.E.,
Malvern, Worcs.
10th April 1956.



REFERENCES

[1] J. C. Samuels, "Cathode Follower Phase Shift Oscillator", *Electrical Communications*, Sept. 1955.

[2] S. C. Dunn, "RC Cathode-Follower Feedback Circuits", *Wireless Engineer*, Jan. 1953, Vol. 30, No. 1, p. 10.

[3] W. Bacon and D. P. Salmon, "Resistance-Capacitance Networks with Over-Unity Gain", the same, p. 20.

NEW BOOKS

Electronic and Radio Engineering (4th Edition)

By F. E. TERMAN. Pp. 1078 + vii. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 71s. 6d.

The addition of "electronic" to the title of this well-known book is, perhaps, advantageous in affording a better indication of its contents. Normally, one would feel a change of title in such a book to be a bad thing but, in this case, the book has achieved the rare distinction of being better known by its author's name than by its title. Doubtless, this edition will still be called just 'Terman'!

In this edition, Professor Terman has been assisted by R. A. Helliwell, J. M. Pettit, D. A. Watkins and W. R. Rambo, all of Stanford University. There are 26 chapters and, after an initial chapter covering the elements of a system of radio communication, the book is divided into three sections. The first has four chapters covering circuit elements and circuit theory. A major part of this deals with transmission lines and waveguides, and the treatment of lumped circuits is rather brief.

The second section is on electronic engineering fundamentals and, with 16 chapters, forms the main part of the book. The aim here has been to deal with radio-like matters more generally than is normal in a radio book so that they can be applied to communication or non-communication apparatus more readily. Valves and electron optics are treated as well as amplifiers, feedback, oscillators, modulation, detection, wave-shaping, pulse techniques, microwave valves, power supplies and transistors.

The third section is the radio one, and has five chapters on propagation, aerials, transmitters and receivers, television and radar.

In its general style, this book closely follows the early editions and anyone used to these will feel at home with it. The treatment is not detailed and is rarely analytic. It is largely descriptive and formulae are usually quoted, not derived.

W. T. C.

Principles of Radio

Wall charts, size 19 in. + 24 in. Educational Productions Ltd., East Ardsley, Wakefield, Yorks. Price 3s. per set of three.

These charts have been produced in collaboration with the E.M.I. Institute. They cover amplification, the tuned amplifier and the superheterodyne principle with a combination of diagram and very simple explanation.

Noise

By A. VAN DER ZIEL. Pp. 450 + xi. (Prentice-Hall Inc.) Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 60s.

This book covers most aspects of noise as it affects radio and electronic apparatus. The early chapters deal with thermal noise, Nyquist's and Schottky's theorems and the measurement of noise. There are individual chapters on noise in valves at low and at high frequencies, in mixing valves, in detectors and in feedback circuits.

Excess noise in semiconductors and valves is treated and there are chapters on statistical methods, Fourier analysis of fluctuating quantities and space-charge waves in electron beams.

W. T. C.

Nomograms of Complex Hyperbolic Functions (2nd Edition)

By JØRGEN RYBNER. Published by Jul. Gjellerups Forlag, Copenhagen, Denmark. Price Kr. 44.00.

The first edition was reviewed in *Wireless Engineer* for April 1948, p. 129. In this new edition which, like the first, is in English and Danish, the notation for the complex argument of the hyperbolic functions has been changed from $g = b + ja$ to $\Gamma = A + jB$ in accordance with the recommendations of the International Telephone Consultative Committee. Four new nomograms have been added to extend the range of A to 3 instead of 2 nepers.

There are two other new nomograms for interaction loss and phase-shift.

W. T. C.

International Scientific Radio Union

Proceedings of the XIth General Assembly:—

Vol. X, Part 5, Commission V. Radio Astronomy. Price 18s.

Vol. X, Part 6, Commission VI. Radio Waves and Circuits. Price 21s. 6d.

General Secretariat of the U.R.S.I., 42 Rue des Minimes, Brussels, Belgium.

Scattering and Diffraction of Radio Waves

By J. R. MENTZER. Pp. 134 + viii. Pergamon Press Ltd., 4–5 Fitzroy Square, London, S.W.1. Price 30s.

The author is Associate Professor of Electrical Engineering in the Pennsylvania State University. The book is a mathematical one and the analysis is concerned primarily with the solution of radar problems, not with scatter propagation.

Electrical Interference

By A. P. HALE, Graduate I.E.E. Pp. 122 + vii. Heywood & Co. Ltd. Tower House, Southampton Street, London, W.C.2. Price 15s.

Radio Amateurs' Handbook (33rd Edn.)

Pp. 620. American Radio Relay League Inc., West Hartford 7, Connecticut, U.S.A. Price $4.

Practical Radio Servicing

By WILLIAM MARCUS and ALEX LEVY. Pp. 565 + viii. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 49s.

Commercial Broadcasting in the British West Indies

Produced by Central Rediffusion Services Ltd. Pp. 91 + xii. Butterworths Publications Ltd., 88 Kingsway, London, W.C.2. Price 5s. (Postage 10d.).

BRITISH STANDARDS

Terms Relating to the Performance of Measuring Instruments

B.S. 2643:1955. Price 3s.

Glossary of Terms Relating to Automatic Digital Computers

B.S. 2641:1955. Pp. 15. Price 3s.

Colour Codes for Connections in Radio and Allied Electronic Equipment (excluding telephone exchange and associated transmission equipment)

B.S. 2311:1955. Price 2s. 6d.

Performance of Power Transformers (not exceeding 2 kVA rating) for Radio and Allied Electronic Equipment

B.S. 2214:1955. Price 3s.

British Standards Institution, Sales Branch, 2 Park Street, London, W.1.

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 journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses.

ACOUSTICS AND AUDIO FREQUENCIES

534.014.5 + 538.56.029.1 **1269**

Subharmonic Oscillations in a Nonlinear System with Positive Damping.—S. Lundquist. (*Quart. appl. Math.*, Oct. 1955, Vol. 13, No. 3, pp. 305–310.)

534.121.2 **1270**

Study of the Thin Layer of Air between a Circular Diaphragm and a Plane Electrode.—C. Colin. (*J. Phys. Radium*, Nov. 1955, Vol. 16, No. 11, pp. 863–873.) An experimental investigation was made using an electromechanical system with the diaphragm arranged between two symmetrically placed electrodes. The frequency variation of the transfer function of the equivalent quadripole network is analysed; a complex frequency is introduced.

534.13 **1271**

On Axi-symmetrical Vibrations of Shallow Spherical Shells.—E. Reissner. (*Quart. appl. Math.*, Oct. 1955, Vol. 13, No. 3, pp. 279–290.)

534.2 **1272**

Do Sound Waves possess Momentum?—W. Brenig. (*Z. Phys.*, 18th Nov. 1955, Vol. 143, No. 2, pp. 168–172.) Theory based on interaction with material indicates that sound waves have a momentum $p = \epsilon/c$, where ϵ is the energy and c the velocity of sound.

534.2 **1273**

Reflection and Transmission of Sound by a Moving Medium.—J. B. Keller. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1044–1047.) Analysis shows that the reflection and transmission coefficients depend only on that component of the velocity of the medium which lies in the plane of incidence. Total reflection occurs over a range of values of this velocity.

534.2 **1274**

Propagation of Sound in Thin Elastic Shells.—J. E. Young. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1061–1064.) Analysis leads to an expression for the axial propagation constant for a steel shell surrounding a column of air; only the lowest symmetric mode is discussed.

534.2 **1275**

Phase Velocities and Displacement Characteristics of Free Waves in a Thin Cylindrical Shell.—P. W. Smith, Jr. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1065–1072.) Analysis is presented covering all possible modes of propagation of elastic waves in the shell. Standing, axially progressive, and helically progressive waves are identified.

534.2-14 **1276**

Notes on the Exact Equations governing the Propagation of Sound in Fluids.—F. V. Hunt. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1019–1039.)

534.2-14 **1277**

Fluctuations in Intensity of Short Pulses of 14·5-kc/s Sound received from a Source in the Sea.—F. H. Sagar. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1092–1106.) Report of an extensive experimental investigation carried out off the coast of New Zealand, in which resolution of pulses arriving by direct and indirect paths was achieved. The pulse duration was 1·3 ms and the transmission range was 70–500 yd. The observed fluctuation, expressed as a 'variation coefficient' was 6·8%–10·6% for sea state 0 and 10·1%–12·5% for sea state 3.

534.2-8-14 **1278**

Swelling of a Liquid Surface under the Influence of Ultrasonic Radiation.—M. Kornfel'd & N. Molokhova. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1955, Vol. 105, No. 3, pp. 476–477. In Russian.) The experimentally determined relation between the ultrasonic energy density E, surface tension σ, the rise h of the liquid level, and the radius r of the swelling (equal to the radius of the quartz transducer) is given by $E = 2\sigma\, h/r^2$.

534.213.4 **1279**

Heat Conduction Losses in the Acoustic Boundary Layer.—J. E. Young. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1039–1043.) "The attenuation resulting from heat conduction of the quasi-plane mode in a cylindrical conduit is discussed in the high-frequency (narrow boundary layer) limit. The heat conduction part of the Kirchhoff losses is derived by means of a volume integral whose physical interpretation can be given."

534.232 1280

On the Efficiency of an Acoustic Line Source with Progressive Phase Shift.—G. J. Thiessen. (*Canad. J. Phys.*, Nov. 1955, Vol. 33, No. 11, pp. 618–621.) Analysis indicates that the radiated energy is not reduced in consequence of a phase variation along a line source unless the rate of the variation is comparable to that in the propagated wave.

534.232 1281

Directional Properties of Continuous Plane Radiators with Bizonal Amplitude Shading.—G. E. Martin & J. S. Hickman. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1120–1127.) The problem of reducing the levels of the minor lobes of linear, rectangular, and circular radiators is considered theoretically. The shading is accomplished by using equiphase normal-velocity distributions limited to two discrete amplitudes. Linear and rectangular radiators with such amplitude distributions can be designed so that minor-lobe levels are at least 21 dB below the major-lobe level; the corresponding figure for the circular radiator is 25 dB. The results are useful for the design of transducers.

534.232-8 : 549.514.51 1282

The Resonance Enhancement of Ultrasonic Quartz Crystals.—G. Bolz. (*Z. angew. Phys.*, Nov. 1955, Vol. 7, No. 11, pp. 514–516.) The investigations described previously (2115 of 1950) are supplemented by measurements of the current generated by crystals of different thickness excited by an ultrasonic field of frequency constant at 2·04 Mc/s. Values of radiation resistance deduced from these measurements are in good agreement with values derived from the approximate formula presented previously.

534.3 + 621.395.623.7 1283

Fundamental Acoustics of Electronic Organ Tone Radiation.—D. W. Martin. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1113–1119.) The design of tone chambers and loudspeaker systems for electronic-organ installations in various types of auditorium are discussed.

534.6 1284

Measurement of Correlation Coefficients in Reverberant Sound Fields.—R. K. Cook, R. V. Waterhouse, R. D. Berendt, S. Edelman & M. C. Thompson, Jr. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1072–1077.) A cross-correlation coefficient R is used as a criterion of randomness in the sound field; in a completely random field, $R = (\sin kr)/kr$, where $k = 2\pi/\lambda$ and r is the distance between two points. An instrument for recording time variations of R is described and some measurements made in the 15 000-ft^3 reverberation chamber at the National Bureau of Standards are reported.

534.614-14 1285

Fixed Path, Variable Frequency Acoustic Interferometer.—H. I. Leon. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1107–1112.) Equivalent-network analysis is presented for an interferometer comprising two crystals arranged parallel to one another, one serving as ultrasonic source and the other as fixed reflector. Measurements of the velocity of propagation in water over the frequency range 600–800 kc/s yield a value 1 496·8 ± 0·3 m/s at 25°C, with a temperature coefficient + 2·7 m/s per °C.

534.64 : 621.3.012.11 1286

Circle Diagram for Acoustics.—B. Klimeš. (*Slab. Obz., Prague*, Oct. 1955, Vol. 16, No. 10, pp. P37–P42.) An acoustic-impedance calculator based on a modified Smith chart is described in detail. Examples are given illustrating the applications and the method of using the calculator which comprises a specially graduated ruler and a Smith chart plotted partly on a base sheet and partly on a superposed transparent sheet. Six parameters are used.

534.75 1287

Improvements in Message Reception resulting from 'sequencing' Competing Messages.—J. C. Webster & L. Sharpe. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1194–1198.)

534.75 1288

Effects of Response Complexity upon Listening to Competing Messages.—J. C. Webster & L. N. Solomon. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1199–1203.)

534.75 : 534.78 1289

Relative Intelligibility of Speech Recorded Simultaneously at the Ear and Mouth.—H. J. Oyer. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1207–1212.) "Monosyllabic words recorded at the lips and left ears of six speakers were fed to the headsets of 24 trained listeners at − 12, − 15, and − 18 S/N ratios. Although the trend for intelligibility scores throughout the test is in the same direction for signals of both origins, decreasing S/N ratio is more destructive to the speech picked up at the lips."

534.75 : 534.78 1290

Effects of Training on Listeners in Intelligibility Studies.—H. M. Moser & J. J. Dreher. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1213–1219.) Experimental evidence indicates that listener training has a great effect on the results in intelligibility studies.

534.781 : 621.376.5 1291

Laboratory Equipment for Quantizing Speech.—Allen. (See 1540.)

534.79 1292

Rating Scale Method for Comparative Loudness Measurements.—W. C. Michels & B. T. Doser. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1173–1180.)

534.84 1293

Study of Acoustical Requirements for Teaching Studios and Practice Rooms in Music School Buildings.—R. N. Lane & E. E. Mikeska. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1087–1091.)

534.845 : 677.64 1294

Acoustical Properties of Carpet.—C. M. Harris. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1077–1082.) Absorption measurements by the tube method were made on several hundred samples of different types of carpet; flow-resistance was also measured. Absorption measurements on some of the samples were also made by the reverberation-chamber method; no simple relation is found between the results by the two different methods.

534.861 : 621.396.712 **1295**

Design of Studios for Small Broadcasting Stations.—R. F. Goodsman. (*J. Brit. Instn Radio Engrs*, Jan. 1956, Vol. 16, No. 1, pp. 5–28.) "Practical considerations in the siting, design and construction of studio buildings are given and methods of making studios and associated control rooms acoustically suitable are discussed. Reference is made to the studio building of the Trinidad Broadcasting Company, which incorporates one large, two medium, and two small studios. The equipment and circuit facilities provided in these studios and in the central control room are described."

621.395.616 : 534.61 : 621.3.089.6 **1296**

Probe Microphone Analysis and Testing at High Temperatures and High Intensities.—K. W. Goff & D. M. A. Mercer. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1133–1141.) Description of methods for testing a microphone system for measuring sound fields inside wind tunnels, etç.

621.395.623.64 + 534.833 **1297**

Design and Testing of Earmuffs.—J. Zwislocki. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1154–1163.) An estimate is made of the greatest attenuation that can be obtained without sacrificing comfort. The desirability of incorporating Helmholtz resonators in the design is discussed. Some subjective experiments of the sound attenuation produced by two different designs are described and the results analysed statistically.

621.395.623.743 **1298**

Design and Performance of a High-Frequency Electrostatic Speaker.—L. Bobb, R. B. Goldman & R. W. Roop. (*J. acoust. Soc. Amer.*, Nov. 1955, Vol. 27, No. 6, pp. 1128–1133.) The loudspeaker described has a diaphragm consisting of a thin polyester film covered with an evaporated gold layer, stretched around a semicylindrical ridged perforated electrode. The response varies $< \pm 2$ dB over the frequency range 8–16 kc/s.

AERIALS AND TRANSMISSION LINES

621.372.5.029.6 : 535.5 **1299**

Polarization Filters and Polarization Correctors.—G. Valensi. (*Ann. Télécommun.*, Nov. 1955, Vol. 10, No. 11, pp. 230–236.) Technique involving use of pleochroic crystals, familiar at optical frequencies, is adapted to the microwave region of the spectrum by using 'artificial crystals' comprising metal bodies regularly spaced in low-loss dielectrics. Results are reported of experiments with wire dipoles embedded in polystyrol plates arranged in a stack between radiating and receiving horns; reflection/frequency characteristics are plotted for different dipole orientations. Applications are briefly indicated.

621.372.8 **1300**

On Transients in Waveguides.—R. Gajewski. (*Bull. Acad. polon. Sci., Classe* 4, 1955, Vol. 3, No. 1, pp. 29–34. In English.) An analysis is made of the field variation during the interval between the arrival at a point in the waveguide of the forerunner and the main wave. The results are plotted as field-strength/time curves for a point 30 cm from the input of a waveguide with cut-off wavelength 6·28 cm and an applied signal of free-space wavelength 5 cm. During the interval examined, the 'frequency' changes rapidly, and a small but not negligible amount of energy is transferred.

621.372.8 **1301**

Diaphragms in Waveguides.—L. A. Vainshtein. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 841–846.) A rigorous mathematical analysis is presented of the conditions in a rectangular waveguide, half of the cross-section of which is occupied by an asymmetrical diaphragm (inductive or capacitive). The exact results so obtained are compared with previously published approximate data.

621.372.8 **1302**

On the Resonance Frequencies and the Field Configurations in Terminated Corrugated Waveguides.—V. J. Vanhuyse. (*Physica*, Oct. 1955, Vol. 21, No. 10, pp. 829–838.) Generalization of analysis presented previously (2836 of 1955).

621.372.8 : 621.372.54 **1303**

The Polarguide—a Constant-Resistance Waveguide Filter.—Klopfenstein & Epstein. (See 1330.)

621.396.67.029.53 **1304**

Standardised Transmitting Aerials for Medium-Frequency Broadcasting.—S. F. Brownless. (*Proc. Instn Radio Engrs, Aust.*, Nov. 1955, Vol. 16, No. 11, pp. 383–396.) "The [Australian] Postmaster-General's Department has developed a range of aerial systems suitable for National Broadcasting Service transmitting stations of powers from 200 watts to 50 kilowatts in the frequency range 540–1 600 kc/s. The aerial systems fall into two classes: 'high' aerials having special anti-fading properties, usually near half-a-wavelength in height, and 'low' aerials less than a quarter-wavelength in height. This paper traces the development of the designs, with special emphasis on low aerial systems suitable for construction by Departmental staff. Here the application of practices well-established at v.h.f. leads to structures believed to be novel for m.f. broadcasting. Charts and diagrams are given from which aerial structures suitable for any particular application may be readily selected."

621.396.674.33 **1305**

Broadband Antenna for Field-Intensity Meters.—E. N. Singer & H. R. Caler. (*Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 130–131.) Brief details are given of a skeleton biconical closed-end aerial which can be used without readjustment over a 1 : 4·5 frequency range, e.g. 88–400 Mc/s. The design of the associated balun is also described.

621.396.677 **1306**

Endfire Slot Antennas.—B. T. Stephenson & C. H. Walter. (*Trans. Inst. Radio Engrs*, April 1955, Vol. AP-3, No. 2, pp. 81–86.) Design theory is discussed. Discontinuities in the waveguide system are minimized by use of tapering sections and dielectric fillings; wide-band characteristics are obtained by means of wide-aperture slots. A flared slot aerial tested over the 3–6-cm band gave side lobes at least 20 dB down, with a radiation efficiency ranging from 65% at 3-cm λ

to 55% at 6-cm λ, the discontinuity minimizing device causing a 25% drop in efficiency; the voltage s.w.r. was < 1·4.

621.396.677.3.029.62 **1307**

Multiple Tuning in TV Antenna Design.—J. F. Guernsey. (*Radio and Telev. News*, Oct. 1955, Vol. 54, No. 4, pp. 91–92..94.) Use of the 'wing' dipole in a Yagi array gives good performance over bands I and III. A typical array using three wing dipoles has ten parasitic and nine active elements stagger-tuned to give flat response throughout the ranges.

621.396.677.32 **1308**

A Nonresonant Endfire Array for V.H.F. and U.H.F.—W. A. Cumming. (*Trans. Inst. Ràdio Engrs*, April 1955, Vol. AP-3, No. 2, pp. 52–58.) A development of the helical aerial [1860 of 1949 (Kraus)] using rectilinear elements and giving linear polarization is described. A balanced array has been constructed which provides a gain of 6–10 dB above a simple dipole over a 50% frequency range and gives a voltage s.w.r. ≯ 2·5 : 1 on a 300-Ω unscreened twin feeder.

621.396.677.71 **1309**

An Investigation of Slot Radiators in Rectangular Metal Plates.—D. G. Frood & J. R. Wait. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 103–109.) Measurements of the equatorial-plane radiation pattern of an axial λ/2 slot are compared with values calculated on the assumption that the plate can be represented by a thin elliptic cylinder or ribbon of infinite length. For a plate whose length is equal to or greater than its width the measured and calculated values agree to within a few per cent.

621.396.677.8 **1310**

Aerials with Reflectors and Conducting Disks for Decimetre Wavelengths.—G. von Trentini. (*Nachrichtentech. Z.*, Nov. 1955, Vol. 8, No. 11, pp. 569–577.) Dipole aerials combined with various arrangements of metal plates and strips are discussed. An arrangement relying on diffraction effects comprises a horizontal support carrying nine equally spaced parallel disks. Radiation patterns are calculated. The parallel-disk aerial has a higher gain than the reflector aerial of comparable dimensions, but the side-lobes are stronger; methods for overcoming this disadvantage are indicated.

AUTOMATIC COMPUTERS

681.142 **1311**

The Program-Controlled Electronic Computer at Munich (PERM).—H. Piloty, R. Piloty, H. O. Leilich & W. E. Proebster. (*Nachrichtentech. Z.*, Nov. & Dec. 1955, Vol. 8, Nos. 11 & 12, pp. 603–609 & 650–658.) Detailed illustrated description of a machine designed for calculations on scientific problems. A binary internal system is combined with a decimal external system. The word length is 50 binary digits. The magnetic-drum store rotates at 250 rev/sec; mean access time is 2 ms and capacity is 8 192 words. Teleprinter tape is used for input and output, with photoelectric scanning also for the input. 2 400 valves and 3 000 Ge diodes are used; the power consumption is < 11 kW.

681.142 **1312**

An Accurate Electronic Multiplier.—S. Sternberg. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 618–634.) An account of developments of the time-division multiplier described by Goldberg (151 of 1953). A design giving long-term stability and increased speed of operation is described.

681.142 : 538.221 **1313**

Magnetic Core Circuits for Digital Data-Processing Systems.—D. Loev, W. Miehle, J. Paivinen & J. Wylen. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 154–162.) Circuits for interconnecting toroidal cores used to perform various functions in digital computers are discussed. A single-diode loop permits unconditional transfer of information from one or more transmitting cores to one or more receiving cores. A split-winding loop permits conditional transfer and hence logical operations. An inhibit loop is also described. The operation of shift registers, cycle distributors, counters, etc. is explained.

681.142 : 621.317.727 **1314**

A Digital Potentiometer.—S. K. Dean & D. F. Nettell. (*Electronic Engng*, Feb. 1956, Vol. 28, No. 336, pp. 66–69.) Description of an instrument developed for use with a teleprinter perforator for feeding measured voltage readings into an electronic computer. By comparing the input signal voltage with a series of reference voltages the former is represented in integers on a binary or decimal scale. Tests on a 10-stage instrument described indicate that a reliable 7-stage unit with a reading time under 3 sec can be constructed with readily available components.

681.142 : 621.37 **1315**

The Isograph—an Electronic Root Finder.—A. K. Choudhury. (*Indian J. Phys.*, Oct. 1955, Vol. 29, No. 10, pp. 468–473.) The instrument described is designed on the principle of harmonic synthesis, short-circuited and open-circuited delay lines fed from a matched frequency-sweep generator being used to produce the sine and cosine terms respectively. By controlling the amount of frequency sweep, any desired interval of the argument can be expanded and the accuracy of measurement thus increased.

681.142 : 621.383 **1316**

Character Recognition for Business Machines.—M. H. Glauberman. (*Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 132–136.) Arabic numerals are scanned by a column of photocells whose outputs modulate a pulse-generator system to give signals usable in computers. Characters are read at a maximum rate of 1 600/sec; operation is not critically dependent on style or size of type.

681.142 : 413.164 **1317**

Glossary of Terms relating to Automatic Digital Computers, B.S.2641 : 1955. [Book Notice]—Publishers: British Standards Institution, London, 1955, 3s. (*Brit. Stand. Instn Inform. Sheet*, Nov. 1955, p. 2.)

CIRCUITS AND CIRCUIT ELEMENTS

621.3.011.3/.4 **1318**

Formulas for computing Capacitance and Inductance.—C. Snow. (*Nat. Bur. Stand. Circulars*, 10th Sept. 1954, No. 544, 69 pp.) A collection of explicit formulae in terms of elementary functions, Legendre polynomials and functions, and elliptic functions. Formulae for mutual inductance and for the forces acting between current-carrying coils are also given.

621.318.57 : 621.373.1 : 537.312.8 **1319**

New Active Circuit Element using the Magneto-resistive Effect.—A. Aharoni, E. H. Frei & G. Horowitz. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1411–1415.) A basic circuit is considered comprising a bridge with resistance arms lying in the uniform field produced by current through a coil in the bridge diagonal. Analysis indicates that bistable operation is possible with reasonably short resolving time; it may be necessary to operate at low temperature. A design is described using Bi layers in the gaps of U-shaped electromagnets. Tristable operation is possible but not practical.

621.319.4 : 621.315.615 **1320**

Chlorinated Diphenyl Capacitors: a Survey of Production Technique.—P. D. Wilmot. (*Elect. Rev., Lond.*, 28th Oct. 1955, Vol. 157, No. 18, pp. 838–840.) Advantages of chlorinated diphenyls over mineral oil as impregnants for paper include (*a*) higher dielectric strength, and (*b*) higher permittivity. Applications include use in power-factor-correction capacitors.

621.372.011.1 **1321**

Generalization of Variation and Compensation Theorems for *n* Parameters of an Electrical Circuit.—N. A. Brazma. (*C. R. Acad. Sci. U.R.S.S.*, 11th Nov. 1955, Vol. 105, No. 2, pp. 271–274. In Russian.) The effect of impedance variations in one or more branches of a network on the current in one of the branches is calculated using matrices.

621.372.412 **1322**

Thickness-Shear and Flexural Vibrations of Rectangular Crystal Plates.—R. D. Mindlin & H. Deresiewicz. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1435–1442.) Analysis is given for the infinite plate, the simply supported rectangular plate and the rectangular plate with one pair of parallel edges free and the other pair simply supported. For previous work see 1861 of 1951 and 2156 of 1952 (Mindlin).

621.372.412 : 549.514.51 **1323**

The Temperature Variation of the Frequency of AT- and BT-Cut Quartz Resonators.—R. Bechmann. (*Arch. elekt. Übertragung*, Nov. 1955, Vol. 9, No. 11, pp. 513–518.) Measured frequency/temperature characteristics can be represented analytically as power series, three terms being sufficient to deal with the temperature range − 60° to + 100°C. The influence of the order of overtone on the temperature coefficient is discussed. See also 346 of February.

621.372.413.011.2 **1324**

Calculation of Shunt Resistances of Rhumbatron-Type Cavities.—W. Chahid. (*C. R. Acad. Sci., Paris*, 14th Dec. 1955, Vol. 241, No. 24, pp. 1733–1736.) The calculation is facilitated by deriving the expression for the shunt resistance in a form in which the axial electric field strength is the only independent variable.

621.372.414 : 621.372.8 **1325**

Traveling-Wave Resonator.—P. J. Sferrazza. (*Tele-Tech & Electronic Ind.*, Nov. 1955, Vol. 14, No. 11, Section 1, pp. 84–85..143.) A circuit comprising a directional coupler with the secondary arm ports connected to form a continuous loop is used for storing energy extracted from the primary in a wave which circulates around the loop. An X-band version used in testing for high-power breakdown is briefly described. Presented at the 1955 National Electronics Conference.

621.372.5 : 512.831 **1326**

An Expression for the Powers of a Matrix and its Application to Iterated Networks.—A. Fekhikher. (*Ann. Télécommun.*, Nov. 1955, Vol. 10, No. 11, pp. 237–241.)

621.372.5 : 621.3.018.75 **1327**

Optimum Characteristics of Linear Pulse Systems.—R. Kulikowski & J. Plebański. (*Bull. Acad. polon. Sci., Classe* 4, 1955, Vol. 3, No. 1, pp. 23–28. In English.) General analysis is presented establishing the conditions for minimum distortion of pulses in linear systems. The analysis is applied to particular filter circuits. The results are embodied in three theorems.

621.372.54 **1328**

A General Theory of Reactive Non-dissipative L-Sections.—A. Mogensen. (*Kungl. tek. Högsk. Handl., Stockholm*, 1955, No. 95, 60 pp. In English.) Elementary theory is developed based on Foster's reactance theorem.

621.372.54 **1329**

The Design of Filters using only *RC* Sections and Gain Stages.—A. N. Thiele. (*Electronic Engng*, Jan. & Feb. 1956, Vol. 28, Nos. 335 & 336, pp. 31–36 & 80–82.) "A method is described of synthesizing filters, using *RC* sections within a feedback loop. Design information is given for high- and low-pass filters of 12, 18 and 24 dB per octave slope and fixed cut-off frequency, and others of approximately 12 and 18 dB per octave slope, whose cut-off frequency is variable continuously by the adjustment of a single element."

621.372.54 : 621.372.8 **1330**

The Polarguide—a Constant-Resistance Wave-guide Filter.—R. W. Klopfenstein & J. Epstein. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 210–218.) The filter described comprises a circular waveguide with spaced radial-line cavities by means of which a linearly polarized input wave is converted to a circularly polarized wave [see 25 of 1955 (Klopfenstein)] and subsequently re-converted. The device can handle high powers; a design for a television vestigial-sideband filter is described.

621.372.54 : 621.39.001.11 **1331**

Statistical Design and Evaluation of Filters for the Restoration of Sampled Data.—R. M. Stewart. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 253–257.)

621.372.54.029.62 : 621.372.2 **1332**

'T'-Stub Calculation for V.H.F. Transmission Line Filters.—M. Telford. (*Marconi Rev.*, 4th Quarter 1955, Vol. 18, No. 119, pp. 121–131.) A method is presented which has advantages over earlier methods in respect of flexibility and ease of calculation. It is applicable whether the stubs in a filter are true reciprocals or not and also in cases where another element, such as an isolating stub, is combined with a 'T' stub to give a required frequency response.

621.373.42.029.42 **1333**

An Oscillator for Very Low Frequencies.—(*Radio elect. Rev., Wellington, N.Z.*, 1st Oct. 1955, Vol. 10, No. 8, pp. 31–32.) A circuit giving sinusoidal oscillations with periods of 35 sec or more uses cathode-follower connected triodes as phase-shift elements.

621.373.52 : 621.314.7 1334

Frequency Stability of Point-Contact Transistor Oscillators.—C. C. Cheng. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 219–223.) The duality relation between circuits using the voltage-controlled negative-impedance base-input characteristic and those using the current-controlled negative-impedance emitter-input or collector-input characteristic is demonstrated. Stabilization criteria for both cases are derived analytically and are confirmed experimentally.

621.373.52.029.3 1335

A Frequency-Stable Transistor Audio Oscillator of Very Simple Design.—W. D. Edwards. (*Canad. J. Technol.*, Nov. 1955, Vol. 33, No. 6, pp. 413–420.) A circuit is described in which a point-contact transistor maintains oscillations by supplying current pulses to a series *LC* circuit during half-cycle periods when the emitter is conducting. Frequency stability is improved by including a diode in the emitter circuit.

621.374.3 : 621.318.57 1336

High Sensitivity and Accuracy Pulse Trigger Circuit.—S. Barabaschi, C. Cottini & E. Gatti. (*Nuovo Cim.*, 1st Nov. 1955, Vol. 2, No. 5, pp. 1042–1051. In English.) A pulse-height discriminator is described which incorporates a highly stable differential negative resistance provided by a Type-6CS6 multi-electrode valve, by virtue of current division between screen grid and anode. This circuit is compared with that of Kandiah (3486 of 1954), in which the negative resistance is provided by a cathode-coupled pair of valves. The discriminator threshold can be set in the range 1–30 mV with stability within 1%.

621.374.32 : 621.318.57 : 621.387.032.212 1337

Subtracting Counter using Dekatron Tubes.—A. Coche. (*J. Phys. Radium*, Nov. 1955, Vol. 16, No. 11, pp. 861–863.)

621.375 : 621.372.57 1338

Active Quadripoles with Intermediate-Point Earthing.—H. Beneking. (*Arch. elekt. Übertragung*, Nov. 1955, Vol. 9, No. 11, pp. 519–527.) The discussion is based on a valve circuit described by Cantz (*Telefunken Röhre*, 1953, No. 30, p. 52) in which a point on a coil in the grid-cathode circuit is earthed. Generalized analysis is presented, using matrices. The treatment is suitable for any valve or transistor circuits that can be considered as series-parallel or parallel-series networks, and facilitates the development of some useful new circuits.

621.375.13 1339

Effect of Component Tolerances in Low-Frequency Selective Amplifiers—an Analysis.—N. S. Nagaraja. (*J. Indian Inst. Sci.*, Section B, Oct. 1955, Vol. 37, No. 4, pp. 324–337.) Amplifiers with Wien-bridge or twin-T selective feedback networks are considered. When the networks are designed for maximum selectivity, the *Q* factor of the amplifier is relatively sensitive to variation of network component values; this sensitivity can be reduced by suitable choice of component relative values, but a higher gain is then required to obtain the same selectivity.

621.375.2 1340

Amplifier Stage with Monotonically Rising Response to a Step Signal.—J. Roorda. (*Tijdschr. ned. Radiogenoot.*, Nov. 1955, Vol. 20, No. 6, pp. 353–377.) The problem is to combine the monotonic response with the shortest possible rise time. Starting from consideration of a simple *RC* coupling, and using analysis based on Laplace transforms, the coupling circuit giving the required response is found in the form of a Π network with parallel-*RC* vertical and series-*LR* horizontal arms.

621.375.2.024 1341

Valve Amplifiers for Very Low Frequencies.—W. Ruppel. (*Nachrichtentech. Z.*, Nov. 1955, Vol. 8, No. 11, pp. 595–602.) D.c. amplifier circuits are briefly reviewed and descriptions are given of a high-gain voltage amplifier using two triodes and a low-output-impedance current amplifier using four triodes in a push-pull arrangement.

621.375.221.2 : 621.385.15 1342

Distributed Amplifier using Tubes with Secondary Emission.—D. T. Jovanović & V. N. Kostić. (*Bull. Inst. Nuclear Sci. 'Boris Kidrich'*, March 1955, Vol. 5, pp. 23–27. In English.) Description of a two-stage amplifier with three Type-EFP60 valves in each stage, having a gain of 35 and a bandwidth of 160 Mc/s.

621.375.3 1343

Magnetic-Amplifier Design—a Practical Approach.—M. Lilienstein. (*Elect. Mfg*, March 1955, Vol. 55, No. 3, pp. 90–98.)

621.375.4 : 621.314.7 1344

Transistor Operating Conditions.—W. T. Cocking. (*Wireless World*, March 1956, Vol. 62, No. 3, pp. 109–111.) The use of the collector current/voltage characteristic curves in the design of earthed-base transistor amplifiers is discussed and numerical examples are given.

621.375.4 : 621.314.7 1345

Raising the Cut-Off Frequency of Transistors.—H. Rühl. (*Nachrichtentech. Z.*, Nov. 1955, Vol. 8, No. 11, pp. 593–594.) Results of experiments with *n-p-n* and *p-n-p* transistors support Herzog's calculations (42 of 1955) of the rise of cut-off frequency attainable by connecting a neutralizing inductance in parallel with the capacitance between collector and emitter.

621.375.4.029.3 : 621.314.7 1346

High-Gain Transistor Amplifier.—J. J. Davidson. (*Audio*, Oct. 1955, Vol. 39, No. 10, pp. 66..70.) The advantages of transistors over valves as low-level, high-gain, amplifiers with low noise properties are discussed and illustrated by a commercial application in a gramophone pre-amplifier, in which a single transistor stage takes the place of two or more valve stages.

621.375.43 1347

Broadband Transistor Feedback Amplifiers.—J. Almond & A. R. Boothroyd. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 93–101.) Negative-feedback amplifiers involving three cascaded common-emitter junction-transistor stages are discussed. With large feedback, stability conditions can be determined with sufficient accuracy by considering the forward and return paths of the feedback loop separately. The maximum feedback possible without instability depends on the frequency characteristic of the transistor current gain; this characteristic can be represented with adequate accuracy by a minimum-phase *RC* approximation. Amplifiers with overall gain of 33 dB and negative feedback of 30 dB are described in which stability is secured by means of phase-advancing networks in the return path.

621.372 **1348**

Théorie des Réseaux de Kirchhoff. Régime Sinusoïdal et Synthèse. [Book Review]—M. Bayard. Publishers: Éditions de la Revue d'Optique, Paris, 1954, 408 pp., Swiss Fr. 42.65. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st Nov. 1955, Vol. 33, No. 11, p. 476.) A comprehensive work on the analysis and synthesis of linear networks, forming one of a series presented by the Centre National d'Études des Télécommunications.

GENERAL PHYSICS

530.1 **1349**

The General Statistical Problem in Physics and the Theory of Probability.—D. Bohm & W. Schützer. (*Nuovo Cim.*, 1955, Supplement to Vol. 2, No. 4, pp. 1004–1047. In English.) An extended discussion leads to the conclusion that the problems of statistical physics in which the theory of probability does not apply may be more important than those in which it does.

530.145 : 621.396.822 **1350**

Quantum Theory of Fluctuations.—H. Ekstein & N. Rostoker. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1023–1029.) On the basis of an analysis of method of measurement, an operator is constructed for the spectral density of a fluctuating variable; the classical dynamic variables are replaced by time-dependent Heisenberg operators. The theory is used to deduce Nyquist's law for a particular case, and to calculate the shot effect for free uncorrelated electrons.

530.152.15 **1351**

A General Approach to Hysteresis: Part 4—An Alternative Formulation of the Domain Model.—D. H. Everett. (*Trans. Faraday Soc.*, Nov. 1955, Vol. 51, No. 395, pp. 1551–1557.) A comparison is made of various methods of formal representation of hysteresis phenomena in terms of a domain model. A symmetrical treatment is developed permitting the equations to scanning curves within a hysteresis loop to be written in a simple form. Part 3: *ibid.*, 1954, Vol. 50, pp. 1077–1096.

535.22 **1352**

Improved Value of the Velocity of Light derived from a Band-Spectrum Method.—D. H. Rank, H. E. Bennett & J. M. Bennett. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, p. 993.) A more accurate result than that reported previously [2619 of 1954 (Rank et al.)] has been obtained by using a new interferometric technique. The new value is 299 791·9 ± 2·2 km/s.

535.43 **1353**

Theory of Scattering [of light] by an Inhomogeneous Solid possessing Fluctuations in Density and Anisotropy.—M. Goldstein & E. R. Michalik. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1450–1457.)

537/538].081 **1354**

Memorandum on Electrical and Magnetic Units.—O. Löbl. (*Bull. Soc. franç. Élect.*, Nov. 1955, Vol. 5, No. 59, pp. 804–808.) Digest of a paper presented to the Society. The various units systems in use are examined; disadvantages of the m.k.s. and c.g.s. systems are indicated. A new system is proposed, called the 'système paritaire de coefficients'; this is based on four fundamental units and retains the practical units such as the volt etc. together with unity values for the dielectric constant and permeability of vacuum.

537.311 **1355**

The Electron-Phonon Interaction, according to the Adiabatic Approximation.—J. M. Ziman. (*Proc. Camb. phil. Soc.*, Oct. 1955, Vol. 51, Part 4, pp. 707–712.)

537.312.62 **1356**

Superconductivity at Millimeter Wave Frequencies.—G. S. Blevins, W. Gordy & W. M. Fairbank. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1215–1216.) Preliminary results of experiments on Sn at frequencies between 77 and 150 kMc/s are reported; residual resistivity is observed at these frequencies.

537.5 : 621.387 **1357**

The Electron Affinity of Hydrogen in a Microwave Gas Discharge.—D. Walsh. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 444–448.) Experiments show that hydrogen in a microwave gas discharge is a much better electron captor than its calculated capture cross-section would indicate, giving de-ionization times in T-R switches comparable with those obtained with water vapour.

537.52 **1358**

Disappearance of Adsorbed Gases from Dielectric Surfaces under Electrodeless Discharge.—S. R. Mohanti (Mohanty). (*Nuovo Cim.*, 1st Nov. 1955, Vol. 2, No. 5, pp. 1107–1109. Addendum, *ibid.*, 1st Jan. 1956, Vol. 3, No. 1, pp. 219–220. In English.)

537.525.5 : 621.385.132 **1359**

Studies of Externally Heated Hot-Cathode Arcs: Part 4—The Low-Voltage Form of the Ball-of-Fire Mode (the Low-Voltage Arc).—E. O. Johnson. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 498–532.) Discussion in terms of a model based on the observation that the stream of electrons entering the ball plasma from the cathode plasma is scattered so completely that the electrons within the ball have a Maxwellian energy distribution. Theoretical predictions are compared with probe measurements. Part 3: 2591 of 1955 (Johnson & Webster).

537.533/.534 **1360**

Ionization and Desorption due to Strong Electric Fields.—F. Kirchner & H. Kirchner. (*Z. Naturf.*, May 1955, Vol. 10a, No. 5, pp. 394–400.) Experimental investigations of the intensity distribution of field-type electron emission from single-crystal W points covered with thin films of other material are reported. Where surface compounds of W with O or C are present, a characteristic change of the emission distribution is observed after application of an opposing field. The change is attributed to local ionization, an electron being released into the interior of the metal and a positive ion being emitted into the vacuum if the field is strong enough to overcome the image force. The field ionization of physically adsorbed molecules or atoms requires relatively strong fields. Quantitative estimates are made of the 'pull-off' field strength and its temperature variation.

537.533 **1361**

A Method for the Systematic Calculation of an Electron-Optically Effective Field Distribution with Specified Imaging Properties.—J. Picht. (*Optik, Stuttgart*, 1955, Vol. 12, No. 10, pp. 433–440.) Analysis is given for a purely magnetic field.

537.533 : 537.29 **1362**

High Field Electron Emission from Irregular Cathode Surfaces.—T. J. Lewis. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1405–1410.) The enhancement of the field in front of an emitter due to surface irregularities (2631 of 1954) is studied in detail, with reference to mechanisms proposed by Schottky and by Fowler & Nordheim. The enhancement factor varies with distance from the surface and is also field dependent. The results afford an explanation of anomalous conduction variations in liquids and gases.

537.533 : 621.385 **1363**

Space-Charge Effects in Electron Optical Systems.—K. T. Dolder & O. Klemperer. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1461–1471.) A discussion of spherical aberration in beams exhibiting a waist. Conditions for transition from waist to cross-over are examined. Experimental results support the theory.

537.533.7 **1364**

Mean Free Path for Discrete Electron Energy Losses in Metallic Foils.—A. W. Blackstock, R. H. Ritchie & R. D. Birkhoff. (*Phys. Rev.*, 15th Nov. 1955, Vol. 10, No. 4, pp. 1078–1083.)

537.533.7 : 546.623-31 : 539.23 **1365**

Transmission of Electrons of Energies below 16 keV by Aluminium Oxide Films of Thickness 1 000 to 3 000 Å.—O. Hoffmann. (*Z. Phys.*, 18th Nov. 1955, Vol. 143, No. 2, pp. 147–152.)

537.56 : 537.311.37 **1366**

Critical Examination of the Theory of Plasmas based on Mean Free Path, in the Light of the Method based on the Distribution Function derived by solving Boltzmann's Equation.—R. Jancel & T. Kahan. (*J. Phys. Radium*, Nov. 1955, Vol. 16, No. 11, pp. 824–828.) Discussion indicates that the distribution-function method is more suitable than the mean-free-path method for calculating the conductivity of anisotropic plasmas (e.g. plasmas subjected to electric and magnetic fields).

537.581 : 548.0 : 546.78 **1367**

Velocity Analysis of Thermionic Emission from Single-Crystal Tungsten.—G. F. Smith. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1115–1116.) It is suggested that the departure from a Maxwellian distribution observed by Hutson (3228 of 1955) is due to the finite resolution of the analyser.

538.114 **1368**

Spin-Deviation Theory of Ferromagnetism: Part 1—General Theory.—J. Van Kranendonk. (*Physica*, Oct. 1955, Vol. 21, No. 10, pp. 749–766.)

538.114 **1369**

The Origin of Ferromagnetism in Transition Metals.—J. Friedel. (*J. Phys. Radium*, Nov. 1955, Vol. 16, No. 11, pp. 829–838.) Analysis of experimental evidence indicates that the energy-band concept constitutes a more satisfactory basis for the theory of ferromagnetism than the hypothesis that the magnetic carriers are bound to individual atoms. The occurrence of fractional numbers of carriers is explained on the basis of close-range interactions between carriers associated with the same atom. The absence of ferromagnetism in heavy elements such as Pd and Pt is a consequence of strong spin-orbit coupling.

538.114 **1370**

Influence of Crystalline Electric Fields on Antiferromagnetic Transitions.—L. D. Roberts, R. B. Murray & J. W. T. Dabbs. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1100–1103.)

538.3 **1371**

On the Ampère Force.—P. Moon & D. E. Spencer. (*J. Franklin Inst.*, Oct. 1955, Vol. 260, No. 4, pp. 295–311.) A re-examination of the expressions for the Ampère force (2923 of 1954) taking account of Warburton's comments (1321 of 1955).

538.312 **1372**

Source Representations for Debye's Electromagnetic Potentials.—A. Nisbet. (*Physica*, Oct. 1955, Vol. 21, No. 10, pp. 799–802.) Theory of e.m. radiation presented by Bouwkamp & Casimir (413 of 1955) is discussed; Debye potentials can be used for all points, even within the source distribution. This leads to an alternative method for the direct determination of multipole expansions.

538.56 : 537.56 **1373**

Electrodynamics of Turbulent Ionized Media.—T. Kahan. (*C. R. Acad. Sci., Paris*, 14th Dec. 1955, Vol. 241, No. 24, pp. 1726–1727.) The scattering of e.m. power in a turbulent ionized medium is discussed. To be applicable for arbitrary values of electron density, analysis should take account of multiple scattering. Suitably modified forms of Navier's equations are indicated.

538.56.029.1 + 534.014.5 **1374**

Subharmonic Oscillations in a Nonlinear System with Positive Damping.—S. Lundquist. (*Quart. appl. Math.*, Oct. 1955, Vol. 13, No. 3, pp. 305–310.)

538.566 **1375**

Theory of Total Reflection.—F. I. Fedorov. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1955, Vol. 105, No. 3, pp. 465–468. In Russian.) The theory of total reflection of an elliptically polarized plane wave is developed from expressions for the energy density and the Poynting vector, using the notation of the earlier paper (3239 of 1955). Results indicate that at total reflection the mean flow of energy in the refracted wave contains a component normal to the plane of incidence; this component is zero in non-total reflection and in two special cases; its magnitude is proportional to the wavelength in the first medium.

538.566 **1376**

Maximum Transmission of Electromagnetic Waves by a Pair of Wire Gratings.—G. von Trentini. (*J. opt. Soc. Amer.*, Oct. 1955, Vol. 45, No. 10, pp. 883–885.) An experimental investigation was made of the transmission of 3·2-cm-λ waves through a pair of parallel wire gratings with various wire and grating spacings for various angles of incidence. Results are compared with values derived from theory.

538.566 : 535.42] + 534.26 **1377**

Semi-asymptotic Series for the Diffraction of a Plane Wave by a Cylinder.—W. Franz & R. Galle. (*Z. Naturf.*, May 1955, Vol. 10a, No. 5, pp. 374–378.)

The technique described previously, involving Watson transforms [1955 of 1955 (Franz)] is used to develop series up to $(ka)^{-2}$, where $k = 2\pi/\lambda$ and a is the radius of the cylinder.

538.566 : 535.42 **1378**

Variational Formulation of Two-Dimensional Diffraction Problems with Application to Diffraction by a Slit.—A. T. de Hoop. (*Proc. kon. ned. Akad. Wetensch. B*, 1955, Vol. 58, No. 5, pp. 401–411. In English.) Diffraction particularly of e.m. waves is discussed. Analysis shows that for an incident plane wave the complex amplitude of the far-zone diffracted field can be expressed in a stationary form of the type indicated by Levine & Schwinger (83 of 1950). The case of a diffracting slit of infinite length and finite width is treated in detail. For normal incidence the results agree with those of Bouwkamp (2909 of 1954) and Müller & Westpfahl (1971 of 1953).

538.566 : 535.42 **1379**

On Integrals occurring in the Variational Formulation of Diffraction Problems.—A. T. de Hoop. (*Proc. kon. ned. Akad. Wetensch. B*, 1955, Vol. 58, No. 4, pp. 325–330. In English.)

538.566 : 535.42 **1380**

The Diffraction of Electromagnetic Waves at a Grating consisting of Parallel Conducting Strips.—L. A. Vainshtein. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 847–852.) A rigorous solution is given for diffraction of a normally incident plane e.m. wave, the width of the strips being equal to the spaces between them. Graphs show the reflection and transmission of the wave for various ratios of strip width to wavelength, and the amplitudes of the diffraction spectra.

538.566 : 535.42 : 621.372.8 **1381**

Diffraction of Centimetre Waves by a Conducting Sphere in a Waveguide.—W. Chambron. (*J. Phys. Radium*, Nov. 1955, Vol. 16, No. 11, pp. 891–892.) Measurements were made at a frequency of 9·1 kMc/s using a hybrid-T arrangement. Results indicate that reflection coefficient is proportional to sphere volume; dispersion of results is attributed to small geometrical irregularities. The work is preliminary to a study of the diffraction of e.m. waves by clouds.

538.566 : 535.43 **1382**

Scattering of Electromagnetic Waves from a Random Surface.—W. C. Hoffman. (*Quart. appl. Math.*, Oct. 1955, Vol. 13, No. 3, pp. 291–304.) The medium below the surface is assumed to be perfectly conducting, so that the far-zone form of the Stratton-Chu solution can be used. The mean and covariance of the approximate expression for the scattered radiation are determined for both vertical and horizontal polarization.

538.566 : 537.562 **1383**

Interaction of Electromagnetic Waves of Radio-Frequency in Isothermal Plasmas: Collision Cross-Section of Helium Atoms and Ions for Electrons.—J. M. Anderson & L. Goldstein. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1037–1046.) Theoretical and practical aspects of the laboratory experiments described previously [2637 and 2970 of 1953 (Goldstein et al.)] are discussed and results of measurements using He gas are presented. The ratio of the effective cross-sections of ions and atoms for electron collisions is about 3×10^5 at an ion density of $10^{11}/cm^3$ at room temperature.

538.566 : 538.221 : 621.318.134 **1384**

Nonlinearity of Propagation in Ferrite Media.—A. Clavin. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol 44, No. 2, p. 259.) Measurements are briefly reported. Both losses and phase shift varied with temperature at constant power level. The results are compared with those of Sakiotis et al. (3240 of 1955).

538.566.2.029.6 : 537.226 **1385**

Investigations on Artificial Dielectrics at Microwave Frequencies: Part 1.—S. K. Chatterjee & B. V. Rao. (*J. Indian Inst. Sci.*, Section B, Oct. 1955, Vol. 37, No. 4, pp. 304–323.) The transmission of a H_{01} wave through a parallel-plate array was studied experimentally. The observed variation of phase change with angle of incidence is in fair agreement with that calculated from the formula given by Carlson & Heins (2756 and 3504 of 1947); the difference between them is attributed to diffraction effects and the presence of higher-order modes inside the array. Values are deduced for the minimum dimensions required to avoid diffraction effects.

538.569.4 **1386**

Resonance Transitions induced by Perturbations at Two or More Different Frequencies.—N. F. Ramsey. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1191–1194.) Expressions are derived for the alteration of magnetic resonance frequency due to the presence of a second oscillation at a nonresonance frequency. Applications of the formulae to nuclear-resonance and molecular-beam experiments are discussed.

538.569.4 : 535.33/.34 : 621.385.029.6 **1387**

Improvement in a Paramagnetic-Electron-Resonance Spectrograph. Application to the Study of Diphenylpicrylhydrazyl.—G. Berthet. (*C. R. Acad. Sci., Paris*, 14th Dec. 1955, Vol. 241, No. 24, pp. 1730–1733.) The sensitivity of apparatus operating in the 3-cm band (*Onde élect.*, May 1955, Vol. 35, No. 338, pp. 489–490) is greatly increased when the klystron source of nominal power 30–40 mW is replaced by one of much higher power, e.g. 3 W.

538.569.4 : 535.34 **1388**

Relaxation Times in Magnetic Resonance.—D. Pines & C. P. Slichter. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1014–1020.) The effect of motion of the absorption centres on the width of resonance lines is discussed on the basis of a random-walk model, and a simple picture is presented of the electron relaxation processes.

538.569.4 : 535.34 **1389**

Some Devices for the Stark Modulation Millimeter-Wave Spectrograph.—A. Okaya. (*Rev. sci. Instrum.*, Nov. 1955, Vol. 26, No. 11, pp. 1024–1028.) An overall sensitivity of about $5 \times 10^{-8} cm^{-1}$ in the 6-mm wave range is attained as a result of appropriate design of Stark cell, frequency multiplier, lock-in detector and square-wave generator.

538.6 : 536.7 **1390**

Thermodynamical Theory of Galvanomagnetic and Thermomagnetic Phenomena.—R. Fieschi. (*Nuovo Cim.*, 1955, Supplement to Vol. 2, No. 4, pp. 1168–1170. In English.) Addendum to paper noted previously (1961 of 1955).

539.378.3 **1391**

The Optical Investigation of the Interdiffusion of Metals.—H. Schopper. (*Z. Phys.*, 8th Nov. 1955, Vol. 143, No. 1, pp. 93–117.) The technique used involves the preparation of very thin films of known thickness.

53.023 1392

Fundamental Formulas of Physics. [Book Review]—D. H. Menzel (Ed.). Publishers: Prentice-Hall, New York, 1955, 765 pp., $13.50. (*Science*, 18th Nov. 1955, Vol. 122, No. 3177, p. 976.) ". . . a valuable reference book for every physicist . . ."

538.569.4 : 535.33/.34 1393

Spectroscopy at Radio and Microwave Frequencies. [Book Review]—D. J. E. Ingram. Publishers: Butterworths Scientific Publications, London, 332 pp., 45s. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 457–458.)

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 1394

The Identification of Radio Stars.—A. M. Naqvi & J. N. Tandon. (*Proc. nat. Inst. Sci. India*, Part A, 26th July 1955, Vol. 21, No. 4, pp. 244–251.) An examination is made of the possibility that the fainter radio stars, classified by Mills (333 of 1954) as Class II, are within our galaxy. The observed coincidences in position of radio stars and *M* dwarfs appear to be significant.

523.16 1395

Absorption of 3·5-m Radiation in the Optical Emission Nebula, NGC 6357.—B. Y. Mills, A. G. Little & K. V. Sheridan. (*Nature, Lond.*, 28th Jan. 1956, Vol. 177, No. 4500, p. 178.) This is the first reported case of absorption of radio waves by an emission nebula; it leads to an estimated electron temperature of 6 500°K for the nebula.

523.7 1396

East/West Asymmetry in the Formation of New Sunspots.—M. d'Azambuja. (*C. R. Acad. Sci., Paris*, 14th Dec. 1955, Vol. 241, No. 24, pp. 1712–1714.) Analysis of records covering many years indicates that about twice as many centres of activity are observed on the eastern half of the solar disk as on the western half.

523.74 : 551.510.535 1397

A New Index of Solar Activity based on Ionospheric Measurements.—C. M. Minnis. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 310–321.) The monthly mean relative sunspot number R_M is assumed to contain a component constituting a direct index of solar activity R_v, together with an error component R_x having a standard deviation of about 20%. A new index I_{F_2}, based on an analysis of the critical frequency of the F_2 layer over the period 1938–1954, has been constructed whose residual error component is only one tenth that of R_x. The magnitude of I_{F_2} for a given month is computed from the mean noon F_2-layer critical frequencies at Slough, Huancayo and Watheroo and is based, in effect, on a calibration of the F_2-layer critical frequencies in terms of R_v.

523.75 1398

Accuracy of Solar-Flare Observations.—L. W. Ross. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 344–345.) The division of observed solar flares into more than three classes is not statistically justifiable; more uniform and detailed reporting is required.

523.75 : 550.385 1399

Solar H_α Filaments and Geomagnetic Disturbances.—H. I. Leighton & D. E. Billings. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 349–350.) Experiments to test Kiepenheuer's suggestion (3877 of 1947), identifying the solar *M*-regions causing geomagnetic disturbances with dark filaments on the solar disk, gave negative results.

523.78: 551.594.6 : 621.396.11 1400

The Influence of the Solar Eclipse on the Propagation of Atmospherics in the Frequency Range 5–30 kc/s.—G. Skeib. (*Veröff. met. hydrol. Dienst., Potsdam*, 1955, No. 16, pp. 24–27.) A map shows the position of sources of atmospherics in Europe at the time of the eclipse; records of measurements over a two-hour period show a marked eclipse effect on 30 kc/s with a 15-min delay, but little effect on 10 kc/s. An anomalous increase of field strength on 5 kc/s is related to the reduction of the ionosphere/earth-duct cut-off frequency resulting from the eclipse.

550.38 + 523.746 : 538.65 1401

The Stability of a Homopolar Dynamo.—E. Bullard. (*Proc. Camb. phil. Soc.*, Oct. 1955, Vol. 51, Part 4, pp. 744–760.) The stability of the self-exciting disk dynamo is considered, taking into account the friction at the axle and the effect of an external electrical load in parallel with the field coils. Possible analogies between the results obtained and the motion of an electrically conducting fluid in a magnetic field are discussed; the theory may be useful in explaining the magnetic field of the earth and of sunspots.

550.380.87 : 550.385 1402

A Method for the Elimination of Slow Variations in the Recording of Pulsations of the Geomagnetic Field.—P. A. Blum & A. Lebeau. (*C. R. Acad. Sci., Paris*, 14th Dec. 1955, Vol. 241, No. 24, pp. 1807–1809.)

550.385 : 551.510.535 1403

The Diurnal Variation of Irregular Geomagnetic Fluctuations.—S. B. Nicholson & O. R. Wulf. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 389–394.) The diurnal variation of the fluctuations, showing a maximum in late evening for middle latitudes, is correlated with atmospheric turbulence in the ionosphere, which is assumed to be hindered in daytime by electromagnetic damping. There is also a pronounced seasonal effect; this may be connected with the large-scale circulation of the atmosphere.

551.51 1404

Thermal and Gravitational Excitation of Atmospheric Oscillations.—H. K. Sen & M. L. White. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 483–495.) Previous work is extended to include a unified treatment for both gravitational and thermal forcing functions. From consideration of various atmospheric models it appears that thermal effects are far more important than gravitational ones in producing the solar semi-diurnal pressure variation; this is not confirmed by observation, but the disagreement may be eliminated by assuming the possibility of heating other than by ground eddy currents.

551.510.53 1405

Nitrogen Oxides and the Airglow.—M. Nicolet. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 297–309.) Possible chemical and photochemical reactions which would account for the formation of nitrogen oxides in the upper atmosphere are discussed and are shown to provide a possible explanation of the airglow.

551.510.535 1406

On the Cooling of the Upper Atmosphere after Sunset.—A. N. Lowan. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 421–429.) Cooling in the E and F regions of the ionosphere is investigated theoretically, assuming that heat transfer takes place only by conduction. At a time $2\frac{1}{2}$ h after sunset the temperature is unchanged at altitudes below 160 km; at a height of 380 km the maximum drop is 440°K. There should be an appreciable increase of ion density in the F layer, but this will be offset, except in equatorial regions, by downward diffusion.

551.510.535 **1407**

Formation of the Lower Ionosphere.—K. Watanabe, F. F. Marmo & J. Pressman. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 513–519.) The available evidence suggests that ions in the D layer are mainly produced by photo-ionization of NO; photo-ionization of O_2, at its first ionization potential, should occur in the E layer and further data are required to decide whether this layer is caused by such a process or by ionization by soft X rays.

551.510.535 **1408**

The Measurement of Normal E-Layer Critical Frequencies at Night.—W. R. Piggott. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 341–342.) The normal E-layer critical frequency at night is best determined from absorption/frequency curves, plotted as $-\log\rho/\log f$. Results of typical measurements taken with standard D.S.I.R. absorption measuring equipment (2301 of 1955) are shown. From the trend of f_0E variation it was possible to identify the associated absorption band on a few of the routine night-time $h'f$ curves obtained at Slough, in spite of the presence of E_s and other irregularities. From the variation of f_0E with time a recombination coefficient of about 10^{-8} was deduced, but, owing to the low transmitter power, measurements of $f_0E < 0{\cdot}7$ Mc/s could not be made; further work with higher power is needed.

551.510.535 **1409**

Night-Time Measurement of Positive and Negative Ion Composition to 120 km by Rocket-Borne Spectrometer.—C. Y. Johnson & J. P. Heppner. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, p. 533.) During a flight on 8th July 1955, only positive ions of mass number 28 were detected in the E region. These are identified as N_2^+. Ionospheric records for the same period and region show the existence of E_s clouds.

551.510.535 **1410**

Viscosity in the F Region.—J. W. Dungey & A. J. Willson. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 521–523.) It is shown that viscosity is of primary importance for disturbances whose scale is smaller than the mean free path λ, and cannot be described by an effective coefficient; any initial disturbance on such a small scale will disappear very rapidly. Assuming normally accepted values for λ at 400 km altitude, it follows that patches of ionization causing the twinkling of radio stars cannot be due to turbulence in the neutral gas as suggested by Maxwell (1649 of 1955).

551.510.535 **1411**

Changes in the Absorption of Cosmic Noise observed during Two Ionospheric Disturbances.—C. A. Shain. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 347–348.) Curves are given showing the observed time variation of total absorption at Hornsby (34° S, 151° E) and of f_0F_2 at Canberra (35° S, 149° E) and Brisbane (28° S, 153° E), at the period of ionospheric disturbances on 25th November 1950 and 20th August 1950. Following the suggestions of Mitra & Shain (1426 of 1954), increased absorption is shown to be correlated with increased f_0F_2 and is presumably due to F-region attenuation. Deductions are made as to the path and speed of the disturbances.

551.510.535 : 523.78 **1412**

Interpretation of Ionospheric Results during Eclipses.—J. Hunaerts & M. Nicolet. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 537–538.) Accounts published by various workers of the solar eclipse of 25th February 1952 have been analysed using the scale-height variation concept introduced by Nicolet (1644 of 1951). The vertical distribution of terrestrial atmospheric temperature varies with latitude, and the recombination coefficient in the E layer is $\nless 4 \times 10^{-8}$ cm³/sec.

551.510.535 : 551.594.5 **1413**

The Recombination Coefficient in the E-layer during Aurorae.—A. Omholt. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 345–346.) In an earlier paper (710 of 1955) a mechanism involving variations in positive-ion concentration was suggested to explain the abnormally high values of recombination coefficient during aurorae. An alternative explanation assuming a high value of the negative-ion/electron ratio (in the range 0·5–3) is shown to be in accordance with observed data.

551.510.535 : 621.317.799 **1414**

Variable-Frequency Echo Sounding of the Ionosphere at Oblique Incidence.—W. Dieminger, K. H. Geisweid & H. G. Möller. (*Nachrichtentech. Z.*, Nov. 1955, Vol. 8, No. 11, pp. 578–586.) The development of the technique described by Dieminger (674 of 1952) is discussed with particular attention to synchronizing arrangements. Records obtained over two paths are compared with records of vertical-incidence soundings at points on the paths.

551.510.535 : 621.396.11 **1415**

Heights of Irregularities giving Rise to the Fading of 150-kc/s Waves.—R. B. Banerji. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 431–439.) A calculation is made of the relation between phase and amplitude for a wave propagated through a region of random absorption below the reflection level; results agree with those obtained experimentally. A method for estimating particle collision frequency in the absorbing region is presented, based on that of Jones et al. (2311 of 1953), from which data regarding the region may be deduced.

551.510.535 : 621.396.11 **1416**

Polarization of Electromagnetic Waves for Vertical Propagation in the Ionosphere.—Roy & Verma. (See 1526.)

551.510.535 : 621.396.11 **1417**

Some Remarks concerning Ionospheric Absorption Work.—K. Rawer. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 534–535.) Irregularities in the frequency dependence of observed aborption decrements are attributed to focusing effects due to curvature of the layers involved. In the F layer these effects occur particularly with third-order echoes. Account should be taken of the effect in the analysis of absorption observations made during conditions of rapid fading.

551.510.535 : 621.396.812.3 **1418**

Ionospheric Wind Determination from Spaced Radio Receiver Fading Records.—G. W. G. Court. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp.

333–340.) Direct analysis of the fading patterns of reflected signals at three spaced receivers [96 of 1950 (Mitra)] can indicate the true ionospheric wind and changes in orientation of the patterns without assuming any particular distribution of orientation. A new method of analysis of the fading records is proposed, together with an alternative method of observation in which a single fixed receiver is used in conjunction with a second one which is moved in a circle round the first.

551.510.535"1955" : 621.396.11 **1419**

Ionosphere Review 1955.—T. W. Bennington. (*Wireless World*, March 1956, Vol. 62, No. 3, pp. 145–146.) Consideration of the records of sunspot numbers and ionosphere data indicates that solar activity may increase rapidly to reach a maximum in the middle of 1957, with the monthly mean daytime m.u.f. reaching 34 Mc/s for east-west transmissions and 38 Mc/s for southerly paths by November 1956.

551.594.5 **1420**

Vertical Extent of Auroral Arcs and Bands.—B. W. Currie & J. T. Weaver. (*Canad. J. Phys.*, Nov. 1955, Vol. 33, No. 11, pp. 611–617.) Measurements on 181 photographs taken from three stations indicate that quiet arcs and bands are confined to a narrow layer just about the 100-km level. The thickness of this layer is most often between 20 and 40 km, and rarely $>$ 50 km. From the ratio of the number of arcs and bands to the total number of observed forms it is inferred that the percentage of auroral time during which the luminosity is restricted to this layer is 60%.

551.594.6 : 621.396.821 **1421**

The Effect of Atmospherics on Tuned Circuits.—Edwards. (See 1538.)

LOCATION AND AIDS TO NAVIGATION

621.396.93 **1422**

The Theoretical Design of Direction-Finding Systems for High Frequencies.—W. C. Bain. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 113–119.) "The problem of finding the bearing of a distant h.f. transmitter in conditions of wave interference is examined for the simplified case of non-interacting aerials on a plane earth and with no pick-up of horizontally polarized radiation. Two methods of approach are considered—solution of the field equations for a number of incident plane waves from a knowledge of the field at the aerials, and the fitting of rectilinear constant-phase lines to observed values by a 'least squares' process. It is shown that the cyclical system of Earp & Godfrey [1059 of 1949] is a 'least squares' system of the latter type. Systems of the Wullenwever kind bear a close resemblance to a least-squares system with weighting according to the signal amplitude at each aerial; the difference lies in the fact that they operate with sinusoidal functions of phase instead of linear functions."

621.396.93 **1423**

Spacing-Error Analysis of the Eight-Element Two-Phase Adcock Direction Finder.—D. N. Travers. (*Trans. Inst. Radio Engrs*, April 1955, Vol. AP-3, No. 2, pp. 63–65.) In the array described the elements are arranged on a circle, with alternate angular separations of 54° and 36°; the operating frequency range is 20 : 1. Element-spacing values $> \lambda$ may be used; bandwidth is limited by other factors, such as aerial impedance or vertical pattern, rather than spacing error.

621.396.933 **1424**

Air Safety Service at the Zürich Intercontinental Airport.—A. Fischer. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Nov. 1955, Vol. 33, No. 11, pp. 449–470. In German and French.) An account of the navigation aids, air traffic control and communication systems used, and of the interrelation between these services.

621.396.96 **1425**

Radar Polarization Power Scattering Matrix.—C. D. Graves. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 248–252.) An improved method is described for calculating the amount and polarization of the energy reflected from the target for arbitrary polarization of the incident wave from measurements with any one polarization.

621.396.96 : 551.578 **1426**

Airborne Weather Radar uses Isoecho Circuit.—F. W. Ruppert & J. M. Smith. (*Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 147–149.) A light-weight equipment suitable for use in commercial aircraft is described. Return signals stronger than a pre-set level cause blacking out on the p.p.i. display, so that storm centres appear as dark areas surrounded by illumination.

621.396.962.3 **1427**

Prediction of Pulse Radar Performance.—W. M. Hall. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 224–231.) Improved range-calculation procedure is described, based on detailed reconsideration of all the terms entering into the radar equation. The procedure is particularly useful for comparisons of performance.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.583 : 546.82 **1428**

Gettering of Gas by Titanium.—V. L. Stout & M. D. Gibbons. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1488–1492.) Experiments are described which indicate that Ti can be used as a getter for O_2, N_2 and CO_2 at temperatures above 700°C, for H_2 in the temperature range 25°–400°C, and for water vapour and methane at high or low temperature. Only H_2 is released by Ti on heating subsequent to sorption.

535.215 + 537.533.8 **1429**

Effect of Electron Bombardment on Secondary and Photoelectric Emission of Cesium Antimonide.—K. Miyake. (*J. phys. Soc. Japan*, Oct. 1955, Vol. 10, No. 10, pp. 912–913.) Continuation of experiments described previously (2968 of 1955). Photoelectric fatigue effects are also discussed in a separate paper (*ibid.*, pp. 913–915).

535.215 : 546.24 : 537.311.33 **1430**

Recombination Processes in Tellurium.—D. Redfield. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1094–1100.) Studies were made on single crystals with acceptor densities of about $10^{16}/cm^3$, using photoconductivity techniques with pulsed illumination. The results indicate that at 100°K direct recombination dominates over recombination through localized traps at all illumination levels. It is deduced that small-energy-gap materials should have long lifetimes and should be sensitive photoconductors, and that there should be an optimum value of energy gap, probably near 0·5 eV, giving maximum lifetime.

535.37 : 546.472.21 **1431**

On the Spectral Distribution of Infrared-Stimulated Phosphorescence of Pb-Activated ZnS-Type Phosphors.—S. Asano. (*J. phys. Soc. Japan*, Oct. 1955, Vol. 10, No. 10, pp. 903–905.)

535.376 : 546.472.21 **1432**

Electroluminescence of Zinc Sulfide Single Crystals.—D. R. Frankl. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1105–1111.) Measurements made using half-wave 60-c/s excitation are reported and the results are compared with those of other workers, the intensity and phase of the electroluminescence peaks being examined in detail. It is deduced that excitation occurs by impact of conduction electrons accelerated through internal barriers, that the two electroluminescence peaks in each cycle result respectively from immediate recombination and from recombination delayed by electron trapping, and that the applied field tends to hold the electron in the trap.

535.376 : 546.681.18 **1433**

Electroluminescence of GaP.—G. A. Wolff, R. A. Herbert & J. D. Broder. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1144–1145.) Experimental observations are reported; the phenomena are consistent with the impact-excitation mechanism suggested by Piper & Williams (3439 of 1952).

537.226/.228.1 : 546.431.824-31 **1434**

Effect of Firing Cycle on Structure and some Dielectric and Piezoelectric Properties of Barium Titanate Ceramics.—L. Egerton & S. E. Koonce. (*J. Amer. ceram. Soc.*, 1st Nov. 1955, Vol. 38, No. 11, pp. 412–418.) Experimental results indicate the existence of particular conditions for firing time and temperature leading to optimum grain size, as evidenced by the corresponding values of dielectric constant, piezoelectric constants and coupling coefficients. Firing cycles should be modified to suit the particular purpose for which the material is to be used. By using a special technique involving rapid heating and cooling, it is possible to prepare specimens with dielectric constants as high as 3 000 accompanied by low piezoelectric constants.

537.226/.227 : 546.431.824-31 **1435**

Phase Equilibria in the System $BaTiO_3$-SiO_2.—D. E. Rase & R. Roy. (*J. Amer. ceram. Soc.*, 1st Nov. 1955, Vol. 28, No. 11, pp. 389–395.) A comprehensive experimental investigation is reported. The existence of three intermediate compounds was established and three simple eutectics were determined. Glasses with high refractive indices were obtained over a limited range of compositions. The dependence of the cubic-hexagonal transition temperature on the SiO_2 content is discussed.

537.226 : 621.315.612.4 **1436**

X-Ray Investigation of Solid Solutions of $BaTiO_3$-$PbZrO_3$.—E. A. Porai-Koshits, N. Ya. Karasik & G. O. Gomon. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 945–946.)

537.226:621.315.616 **1437**

Artificial Dielectrics utilizing Cylindrical and Spherical Voids.—H. T. Ward, W. O. Puro & D. M. Bowie. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 171–174.) Artificial dielectrics are investigated comprising three-dimensional arrays of holes in polystyrene, teflon and other materials with relatively high mechanical strength. A theoretical expression is derived for the overall dielectric constant when the holes are spherical or cylindrical with nearly equal length and diameter; for cylindrical holes with large length/diameter ratios the dielectric constant depends on the orientation with respect to the electric field. Values of 1·1–2·6 are obtained by measurements at 5 kMc/s.

537.227 : 546.431.824-31 **1438**

Ferroelectric Hysteresis in Barium Titanate Single Crystals.—H. H. Wieder. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1479–1482.) An experimental and theoretical investigation has been made of the hysteresis loop of crystals with antiparallel domains only. Measurements were made over the temperature range −100° to +100°C. Coercivity and losses decrease sharply as the crystal passes through the phase transitions from tetragonal to orthorhombic at −10°C and from orthorhombic to trigonal at −90°C, but the loop remains rectangular. It may be possible by controlling the crystal growth to shift the orthorhombic phase to room temperature.

537.311.33 **1439**

The Transport of Injected Electrons and Holes in a Semiconductor.—R. Gevers. (*Physica*, Nov. 1955, Vol. 21, No. 11, pp. 888–896.) Laplace-transformation technique is used to solve differential equations describing the transport of added current carriers in a homogeneous semiconductor. For time intervals much greater than the relaxation time, the result agrees with that derived by Keilson (753 of 1954) using a different method. An effective diffusion coefficient and a mobility value applicable to the establishment of charge neutrality during the relaxation time are introduced. The value of the small local space charge occurring during the transport period is calculated. The polarizability of the injected pairs when the applied field is alternating is discussed.

537.311.33 : 546.23/.24 : 539.26 **1440**

Soft X-Ray Absorption of Tellurium and Vitreous and Metallic Selenium.—M. P. Givens, C. J. Koester & W. L. Goffe. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1112–1115.) Measurements are reported and the results are discussed in relation to the density of states in the conduction band.

537.311,33 : [546.28 + 546.289 **1441**

Crystal Cutting.—T. H. Kinman & C. Hayward. (*B. T.-H. Activ.*, Sept./Oct. 1955, Vol. 26, No. 5, pp. 137–139.) A method of slicing and dicing Ge and Si crystals is described, using a multiple tungsten-wire cutter.

537.311.33 : 546.28 **1442**

Electrical Properties of Near-Degenerate Boron-Doped Silicon.—R. O. Carlson. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1075–1078.) Measurements have been made of resistivity and Hall effect in single-crystal Si specimens with B content in the range 10^{18}–10^{19} atoms/cm³. The anomalous Hall mobility effect previously observed by Morin & Maita (750 of 1955) was studied over the temperature range 25°–300°K. For degenerate samples the Hall mobility is about 46 cm/s per V/cm at 300°K.

537.311.33 : 546.289 **1443**

Minority Carrier Extraction in Germanium.—R. Bray. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1047–1055.) A method of carrier extraction is discussed in which special contacts are used to limit the entry of minority carriers into the specimen while offering no barrier to majority carriers. Almost complete depletion of minority carriers was obtained with electric fields of strength well under 50 V/cm using samples 1–2 cm long with minority-carrier lifetime of the order of 100 μs. Resistance at 65°C was increased as much as

13-fold, corresponding to extraction of about 90% of all the carriers, for a specimen with room-temperature resistivity of 32 Ω.cm. This method of extraction has been termed 'exclusion' by Low (3296 of 1955).

537.311.33 : 546.289 **1444**

Removal of Copper from Germanium.—K. B. Blodgett. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1520–1521.) Samples of *n*-type Ge were first coated with Cu which was allowed to diffuse into the interior. Experiments were then made on removing the Cu by heating the samples at 700°C (*a*) in O_2 atmosphere, (*b*) in H_2 atmosphere, or (*c*) in H_2, the samples being coated with an iron salt. The results indicate that the coating in method (*c*) serves as a 'sink' for the Cu; by cleaning off the surface and applying a fresh coating the Cu content can be reduced repeatedly.

537.311.33 : 546.289 **1445**

A Study of the Etching Rate of Single-Crystal Germanium.—P. R. Camp. (*J. electrochem. Soc.*, Oct. 1955, Vol. 102, No. 10, pp. 586–593.) Experiments were made using etchants composed mainly of H_2O_2, HF and water. The temperature variation of the etching rate is consistent with the assumption that two surface reactions take place in sequence. Crystal orientation is significant. From the etching data, the thickness of the surface layer disturbed by abrasive grinding was estimated to be 2–10 μ.

537.311.33 : 546.289 **1446**

Electrolytic Etching at Small-Angle Grain Boundaries in Germanium.—S. G. Ellis. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1140–1141.) "There is a difference of appearance between *n*-type and *p*-type germanium crystals which have been anodically etched. This can be explained if only the hole current contributes to the etching. An *n*-type crystal can be made to etch in the same way as a *p*-type crystal if injected holes reach the crystal-electrolyte interface. Hole-electron recombination within the crystal can then reduce the rate of etching. Such recombination at small-angle grain boundaries has been demonstrated."

537.311.33 : 546.289 **1447**

Electron Microscopy of Etched Germanium Surfaces.—J. W. Allen & K. C. A. Smith. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 439–443.) Examination of Ge surfaces, etched by a reagent whose activity depends on the presence of free carriers, reveals raised areas which may mark the emergence of edge dislocations.

537.311.33 : 546.289 **1448**

Variation of the Conductivity of Germanium by an External Electric Field.—S. G. Kalashnikov & A. E. Yunovich. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 952–954.) Negative charges were induced on thin plates of Ge, and the conductivity of the plates was measured. Considerable variation was observed, depending on the type of Ge used and on the previous surface treatment (polishing or etching). These experiments show that surface treatment considerably alters the surface states, and also that the normally observed hole conductivity of the surface layer is changed into electronic conductivity when paraffin wax is present at the surface.

537.311.33 : 546.289 : 535.215 **1449**

Longitudinal Photomagnetoelectric Effect in Germanium.—J. Aron & G. Groetzinger. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1128–1129.) "The e.m.f. developed parallel to the gradient of light absorption (Dember e.m.f.) in a germanium crystal is reduced by the application of a transverse magnetic field, the diminution being about 10% for a field of 5 000 gauss. The size of the effect is approximately quadratic in the field up to about 2 000 gauss, is then linear to 4 000 gauss, and subsequently saturates."

537.311.33 : 546.289 : 537.228 **1450**

Temperature Dependence of the Elastoresistance in *n*-Type Germanium.—R. W. Keyes. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1104–1105.) A more extensive study of the temperature dependence of the elastoresistance of *n*-type Ge than that reported by Smith (2418 of 1954) indicates that the elastoresistance is inversely proportional to absolute temperature, in agreement with theory developed e.g. by Herring (2642 of 1955).

537.311.33 : 546.289 : 538.214 **1451**

Magnetic Susceptibility of Germanium.—D. K. Stevens, J. W. Cleland, J. H. Crawford, Jr, & H. C. Schweinler. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1084–1093.) An experimental investigation covering the frequency range 70°–300°K is reported. High-purity specimens exhibit decreasing diamagnetism with increasing temperature. The charge-carrier susceptibility for *n*- and *p*-type specimens is found by comparing the observations with those for the pure Ge at the same temperature. Deductions are made regarding the charge-carrier masses and the nature of the energy surfaces. The specimens examined included one of *n* type which had been bombarded by fast neutrons.

537.311.33 : 546.289 : 539.89 **1452**

Conductivity, Hall Effect, and Magnetoresistance in *n*-Type Germanium, and their Dependence on Pressure.—G. B. Benedek, W. Paul & H. Brooks. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1129–1139.) Measurements have been made over the pressure range 1–10 000 kg/cm². The results are interpreted in terms of a low-field theory based on a shape parameter of the energy ellipsoids and on the dependence of collision time on energy. Effects due to impurities are considered.

537.311.33 : 546.289 : 621.314.7 **1453**

Transistor Fabrication by the Melt-Quench Process.—J. I. Pankove. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 185–188.) A method is described for forming *p-n* junctions close to one another in a bar of impurity-doped Ge by partly melting the material and re-solidifying it. The method is distinguished from that described by Pfann (2125 of 1954) by the high speed of the solidifying process, which may be > 0·85 cm/s.

537.311.33 : 546.289 : 621.396.822 **1454**

Noise in Germanium.—S. Okazaki & H. Oki. (*J. phys. Soc. Japan*, Oct. 1955, Vol. 10, No. 10, pp. 910–912.) Observations were made on thin single-crystal specimens over the frequency range 100 kc/s–100 Mc/s, using a heterodyne circuit with square-law detector and c.r.o. The excess current noise varies with frequency according to a $1/f^{\beta}$ law, where β is always > 1 and most often about 2. The noise figure at 100 kc/s is 10–20 dB when the current passed is 5 mA.

537.311.33 : 546.3-1-28-289 **1455**

Magnetoresistance of Germanium-Silicon Alloys.—M. Glicksman. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1146–1147.) Measurements have been made on n-type crystals with various compositions. The results are consistent with the energy-band structure suggested by Herman (460 of 1955).

537.311.33 : 546-3-1-28-289 : 538.569.4 **1456**

Cyclotron Resonance in Ge-Si Alloys.—G. Dresselhaus, A. F. Kip, Han-Ying Ku, G. Wagoner & S. M. Christian. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1218–1219.)

537.311.33 : 547 **1457**

The Semiconductivity of Organic Substances: Part 2.—D. D. Eley & G. D. Parfitt. (*Trans. Faraday Soc.*, Nov. 1955, Vol. 51, No. 395, pp. 1529–1539.) The resistance of crystalline organic substances in vacuo has been determined by an a.c. method. The results are used to determine the energy gaps for intrinsic semiconductivity in *iso*dibenzanthrone (0·96 eV), α:α-diphenyl β-picryl hydrazyl (0·26 eV) and metal-free phthalocyanine (1·49 eV). An impurity conductivity has been detected in phthalocyanine at temperatures up to about 150°C. Possible conduction mechanisms are discussed. Part 1: *ibid.*, 1953, Vol. 49, pp. 79–86 (Eley et al.).

537.311.33 : 621.314.7 **1458**

Transistor Physics.—W. Shockley. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 23–41.) Text of the 46th Kelvin lecture. Crystal imperfections basic to transistor operation are indicated and the technology of controlling these imperfections to produce desired properties is discussed.

538.221 **1459**

On the Origin of Magnetic Anisotropy induced by Magnetic Annealing.—S. Chikazumi & T. Oomura. (*J. phys. Soc. Japan*, Oct. 1955, Vol. 10, No. 10, pp. 842–849.) The anisotropy induced by annealing was measured as a function of the composition of Fe-Ni alloys for various cooling rates. The results are not compatible with theories of 'strain in directional order' or of 'elongated order phase', but are consistent with a theory of dipole-dipole interaction differing with different sorts of atomic pairs.

538.221 **1460**

Effect of Shape Anisotropy on the Coercive Force of Elongated Single-Magnetic-Domain Iron Particles.—T. O. Paine, L. I. Mendelsohn & F. E. Luborsky. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1055–1059.) Experiments have been made on elongated particles with diameters around 150 Å, produced by an electro-deposition method. Direct correlation was observed between the coercive force and the length/diameter ratio of the particles.

538.221 **1461**

An Approach to Elongated Fine-Particle Magnets.—I. S. Jacobs & C. P. Bean. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1060–1067.) The relation between the coercive force and the shape of elongated single-domain particles is examined in the light of experimental results obtained by Paine et al. (1460 above). A 'chain-of-spheres' model is presented by means of which the processes involved can be explained.

538.221 **1462**

The Fluctuating Field Model of Ferromagnetism with Particular Reference to Nickel.—F. D. Stacey. (*Canad. J. Phys.*, Nov. 1955, Vol. 33, No. 11, pp. 661–667.)

538.221 **1463**

Influence of Carbon in Solution on the Magnetic Properties of Soft Iron and 3·5% Si Iron Alloys.—A. Ferro & G. Montalenti. (*Ricerca sci.*, Oct. 1955, Vol. 25, No. 10, pp. 2828–2833.) Armco and other alloys were investigated. The percentage of free carbon is deduced from magnetic relaxation measurements. The differences in behaviour are related to the different mobility of free carbon in the Si-Fe matrix.

538.221 **1464**

Investigation of Nucleation Centres of Reverse Magnetization in Silicon Iron Crystals.—Ya. S. Shur & V. R. Abel's. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1955, Vol. 105, No. 3, pp. 469–471. In Russian.) An experimental study, by the powder-pattern method, of domain formation on reverse magnetization. Specimens of 4%-Si iron 0·1–0·2 mm thick were used. See also 470 of 1955 (Goodenough) and *Proc. phys. Soc.*, 1st Feb. 1953, Vol. 66, No. 398A, pp. 162–166 (Bates & Martin).

538.221 : 538.632 **1465**

The Spontaneous Hall Effect in Ferromagnetics: Part 1.—J. Smit. (*Physica*, Nov. 1955, Vol. 21, No. 11, pp. 877–887.) The effect is investigated analytically and experimentally; measurements at different temperatures suggest that it is closely related to the resistivity of the material. An explanation of the effect is advanced based on an isotropic scattering of conduction electrons by lattice imperfections.

538.221 : 546.74 **1466**

Influence of the Internal State on the Position of the Poles in Magnetized Nickel Wires.—C. Schwink. (*Z. Phys.*, 18th Nov. 1955, Vol. 143, No. 2, pp. 205–218.) The influence of stresses and texture on the position of magnetic poles was investigated using an electron-optical method [2465 of 1954 (Marton et al.)]. The results in the region of plastic deformation can be explained on present-day theories of the behaviour of polycrystalline metals; in the region of mixed plastic-elastic deformations results are explained by assuming an easily deformable surface layer of thickness about 0·03 mm.

538.221 : 621.318.134 **1467**

Origin of the Uniaxial Anisotropy in Iron-Cobalt Ferrites.—S. Iida, H. Sekizawa & Y. Aiyama. (*J. phys. Soc. Japan*, Oct. 1955, Vol. 10, No. 10, p. 907.)

538.221 : 621.318.134 **1468**

Note on an Investigation of the Anomalous Time-Constant of certain Iron-Deficient Magnesium Manganese Ferrites.—L. C. F. Blackman & N. P. R. Sherry. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 385–388.) Experiments on MgMn ferrites having Fe deficiencies of 10%–40% show that the dielectric constant, and possibly also the resistivity, of the material is critically dependent on firing temperature, showing a pronounced peak corresponding to temperatures between 1 330° and 1 380°C. The effect diminishes as the Fe content is increased and is not present in the stoichiometric material.

538.221 : 621.376.32 **1469**

Measurements of Reversible Permeability and their Theoretical Interpretation.—H. Wilde. (*Z. angew. Phys.*, Nov. 1955, Vol. 7, No. 11, pp. 509–513.) A variometer having a ferrite core and a magnetizing coil with high-μ core was used as an oscillator at a mean frequency of 75 Mc/s in experiments to determine how useful such an arrangement would be as an u.s.w. frequency modulator. The frequency/excitation-current characteristic is of 'butterfly' form, the splitting being due to hysteresis. The relation between the main curve and the modulation loops obtained at different values of bias current is investigated. The field-strength variation of the overall reversible permeability determined by calculating the contributions from the elementary domains before and after wall movements is in good agreement with measured values.

538.569.3.029.63/.64 **1470**

Broadband Absorbing Materials.—W. H. Emerson, A. G. Sands & M. V. McDowell. (*Tele-Tech & Electronic Ind.*, Nov. 1955, Vol. 14, No. 11, Section 1, pp. 74–75 . . 137.) An experimental investigation of microwave absorption by spun mats of animal hair impregnated with a special rubber solution is reported. A typical value of the reflection factor for an 8-in.-thick mat on a metal base is < 2% at 500 Mc/s. Percentage-reflection curves are given for two specimens at frequencies up to 10 kMc/s and above.

538.569.4 : 546.87 **1471**

Cyclotron Absorption in Bismuth.—R. N. Dexter & B. Lax. (*Phys. Rev.*, 15th Nov. 1955, Vol. 100, No. 4, pp. 1216–1218.)

538.639 : 546.87 : 537.311.31 **1472**

Effect of Small Admixtures on Galvanomagnetic Properties of Bismuth.—N. E. Alekseevski, N. B. Brandt & T. I. Kostina. (*C. R. Acad. Sci. U.R.S.S.*, 1st Nov. 1955, Vol. 105, No. 1, pp. 46–49. In Russian.) The magnetoresistance effect in Bi with traces of Sn and Te impurities was investigated experimentally at normal and at 1 750 atm pressure, at low temperatures. Results are presented graphically. See also 3632 of 1955 (Alekseevski & Brandt).

549.514.51 **1473**

Investigation of Piezoelectric Oscillations of Quartz by X-Ray Diffraction.—R. Mermod. (*Helv. phys. Acta*, 15th Nov. 1955, Vol. 28, Nos. 5/6, pp. 543–562. In French.)

549.514.51 : 537.226 **1474**

Dielectric Constant of Quartz as a Function of Frequency and Temperature.—M. R. Stuart. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1399–1404.) Measurements were made over the temperature range 20°–400°C, at frequencies from 1 to 90 kc/s, with the electric field directed along the optic axis. Results are presented graphically and discussed in relation to the hypothesis that ions are displaced in 'tunnels' parallel to the optic axis.

621.315.61 **1475**

Dielectric Absorption due to Water of Crystallization in Pinacol Hydrate.—J. S. Cook & R. J. Meakins. (*Trans. Faraday Soc.*, Nov. 1955, Vol. 51, No. 395, pp. 1483–1488.) Results are reported of dielectric measurements made at frequencies between 5 c/s and 50 Mc/s, at various temperatures. The dielectric absorption and dispersion decrease rapidly with decreasing water content.

621.315.61 : 546.287 **1476**

Silicone Insulants.—J. D. Hayden. (*Electronic Engng*, Feb. & March 1956, Vol. 28, Nos. 336 & 337, pp. 58–63 & 115–119.) An illustrated review of properties and applications.

621.315.616 **1477**

An Investigation into the Relaxation Processes in Polyvinyl Acetate at Temperatures below the Softening Temperature.—P. F. Veselovski & A. I. Slutsker. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 939–942.) Measurements of the dielectric properties of the material were carried out over a temperature range from − 150° to + 20°C and a frequency range from 50 to 10^{10} c/s. Experimental curves are shown.

621.318.22 : 538.221 **1478**

A Method of preparing Iron Powder for Permanent Magnets.—E. H. Carman. (*Metallurgia, Manchr*, Oct. 1955, Vol. 52, No. 312, pp. 165–168.)

621.791.3 **1479**

The Significance of Contact-Angle Measurements in Soldering.—N. R. Srinivasan & H. S. Aswath. (*J. Indian Inst. Sci.*, Section B, Oct. 1955, Vol. 37, No. 4, pp. 293–303.)

MATHEMATICS

517.93 **1480**

Uniformly Almost Periodic Solutions of Nonlinear Differential Equations of the Second Order: Part 1—General Exposition.—C. Obi. (*Proc. Camb. phil. Soc.*, Oct. 1955, Vol. 51, Part 4, pp. 604–613.)

MEASUREMENTS AND TEST GEAR

621.3.018.41(083.74) + 529.786 **1481**

The Unit for Frequency.—J. Hers. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 260–261.) Bullard's suggestion to adopt a new definition of the second (3686 of 1955) is deprecated. It is suggested that the unit of frequency, to be termed the hertz, should be defined independently of the second as the 9 192 632th part of Cs frequency. A more precise value could be adopted later by international agreement; the value should be such that one hertz would equal one cycle per second at some convenient date.

621.3.018.41(083.74) : 621.396.9 **1482**

Frequency Variations in New Zealand of 16-kc/s Transmissions from GBR Rugby.—A. H. Allan, D. D. Crombie & W. A. Penton. (*Nature, Lond.*, 28th Jan. 1956, Vol. 177, No. 4500, pp. 178–179.) The frequency of the received signal has been compared with that of a local standard crystal oscillator adjusted to be about 3 parts in 10^7 fast; the beats were recorded continuously. Specimen records illustrate the diurnal distribution of the apparent frequency variation of the transmitted signals. The frequency of WWVH as measured at the same site [*J. Instn elect. Engrs*, Oct. 1955, Vol. 1, No. 10, pp. 650–651 (Allan)] shows variations at least one order greater than those of GBR.

621.317.3 : 621.314.7 **1483**

Measuring R.F. Parameters of Junction Transistors.—W. N. Coffey. (*Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 152–155.) "Equipment and techniques for measuring small-signal *h* parameters of triode and tetrode junction transistors in the range from 1 to 24 Mc/s are described."

621.317.3 : 621.396.822 **1484**

Measurement of Electrical Fluctuations with the Aid of Thermoelectric Devices.—V. I. Tikhonov. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 817–822.) It is suggested that thermocouples and thermistors may be used as standard noise sources for measurement of noise spectra. The theory of the method is discussed and a formula (16) is derived expressing the accuracy of the measurements. A brief report is also given on an experiment.

621.317.312 **1485**

The Exact Measurement of Alternating Currents.—G. Trautner. (*Arch. Elektrotech.*, 30th Aug. 1955, Vol. 42, No. 2, pp. 94–99.) An arrangement is described using a Wheatstone bridge with one load-dependent resistance and an ordinary vibration galvanometer as null indicator. After initial calibration with d.c., an a.c. of e.g. 170 mA can be determined to within 0·04%.

621.317.32 **1486**

Time-Voltage Pulse Discriminator.—C. E. Lowe. (*Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 178..186.) A circuit is described whose sensitivity is not affected by the absolute magnitude of the compared voltages. The difference component is detected as a series of pulses by the use of an alternating reference voltage in a bridge network.

621.317.32 : 621.385.032.216 **1487**

Arrangement for the Measurement of Low Alternating Voltages by the Compensation Method.—A. Vanavermaete. (*Helv. phys. Acta*, 15th Nov. 1955, Vol. 28, Nos. 5/6, pp. 522–524. In French.) A description is given of a circuit designed primarily for measuring the conduction properties of oxide cathode coatings.

621.317.382.029.6 : 538.632 **1488**

The Hall Effect and its Application to Power Measurement at Microwave Frequencies.—H. E. M. Barlow & L. M. Stephenson. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 110–112.) Experiments were made on a crystal of *n*-type Ge mounted in a cavity resonator magnetically coupled to a rectangular waveguide, so that the crystal was immersed in a microwave field; a current proportional to the microwave electric field was passed through the crystal at right angles to the microwave magnetic field. The time average of the Hall e.m.f. observed under these conditions was approximately proportional to the power in the waveguide. The method can be used under any conditions of load without absorbing more than a small fraction of the power being transmitted.

621.317.7 : 621.397.6 **1489**

A Test-Signal Generator for Measurements on Television Transmission Systems.—O. Macek. (*Frequenz*, Nov. 1955, Vol. 9, No. 11, pp. 380–386.) The signals provided by the equipment discussed are those recommended by the German Funk-Betriebs-Kommission; these are compared with those recommended by the C.C.I.F.

621.317.7.089.6 : 621.311.6 **1490**

An Electronic Supply for Use in the Calibration of Instruments.—Wilkins & Harkness. (See 1554.)

621.317.727 : 681.142 **1491**

A Digital Potentiometer.—Dean & Nettell. (See 1314.)

621.317.729 **1492**

The Rubber Membrane and Resistance Paper Analogies.—J. H. O. Harries. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 236–248.) Methods of investigating fields by means of rubber-membrane and resistance-paper models are reviewed; precautions necessary to avoid errors are indicated.

621.317.742 **1493**

Standing-Wave Detector with a Helix-Line Element.—F. J. Tischer. (*Tele-Tech & Electronic Ind.*, Nov. 1955, Vol. 14, No. 11, Section 1, pp. 70–71..134.) The detector comprises an insulated helix wound on a metal cylinder. This reduces the wave velocity by a factor of 10, resulting in an extension of the useful range to below 500 Mc/s.

621.317.755 **1494**

The Recording of High-Speed Single-Stroke Electrical Transients.—D. R. Hardy, B. Jackson & R. Feinberg. (*Electronic Engng*, Jan. & Feb. 1956, Vol. 28, Nos. 335 & 336, pp. 8–12 & 75–79.) A review of developments during the last 20 years, covering c.r. tubes, auxiliary circuits and photographic techniques. 81 references.

621.317.755 : 621.385.832 **1495**

A Precision Cathode-Ray Oscillograph with a Spot Diameter of a few μ.—M. von Ardenne. (*Nachr-Tech.*, Nov. 1955, Vol. 5, No. 11, pp. 481–489.) Detailed description of an instrument in which the oscillograms are photographed at normal size; the area of the spot is about 10^{-9} times that of the screen. A reduced image of the first cross-over is produced by an auxiliary magnetic lens, and a slightly magnified image of this second cross-over is produced by the main magnetic lens. Reproduced oscillograms of various phenomena indicate the degree of detail attainable.

621.317.761 : 538.569.4 **1496**

Broadband Microwave Frequency Meter.—P. H. Vartanian & J. L. Melchor. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 175–178.) An arrangement is described depending on paramagnetic resonance in α,α-diphenyl β-picryl hydrazyl; its operating range is from 600 Mc/s upwards through the X band. The hydrazyl is contained in a 2-in. section of coaxial line placed in a longitudinal magnetic field. A c.r.o. indication of resonance is obtained as the magnetic field is swept up to 4 kG. Frequencies 8 Mc/s apart in the S band can be resolved, and single frequencies can be determined to within ± 1 Mc/s.

621.317.761.029.51/.63 **1497**

Wide-Range Heterodyne Frequency Meter.—W. C. Reichard. (*Tele-Tech & Electronic Ind.*, Nov. 1955, Vol. 14, No. 11, Section 1, pp. 86–87..149.) A description is given of a meter for the range 10 kc/s–1·040 kMc/s developed for the U.S. Signal Corps. The range is covered by using the harmonic output of a modified Hartley oscillator with fundamental ranges 125–250 kc/s and 2·5–5 Mc/s and of a particular version of the Colpitts circuit with fundamental range 65–130 Mc/s. Schematic and block diagrams are given.

621.317.79 : 621.396.822 **1498**

Automatic Noise-Factor Meter.—H. Wallman. (*Chalmers tek. Högsk. Handl.*, 1955, No. 161, 17 pp.) A null method is described based on the principle of balancing amplifier noise against ½ (amplifier noise + noise-diode noise); the advantage over other standard methods is that the only source of systematic error lies in the calibration of the 3-dB attenuator used.

621.317.794 1499

Metal-Resistance Bolometers at Low Temperatures.—K. Bischoff, E. Justi, M. Kohler & G. Lautz. (*Z. Naturf.*, May 1955, Vol. 10a, No. 5, pp. 401–412.) Sensitivity can be improved by operating at an appropriate low temperature; using a Ni-foil element, the sensitivity at 90°K is ten times as great as at room temperature. The problem is discussed in relation to measurements of long-wave infrared radiation, and the effect of interrupting the radiation is considered.

621.319.4(083.74) 1500

An Adjustable Absolute Capacitance Standard.—G. Zickner. (*Arch. Elektrotech.*, 30th Aug. 1955, Vol. 42, No. 2, pp. 71–93.) Description of the cylindrical capacitance standard of the Physikalisch-Technische Bundesanstalt. The capacitance is about 100 pF and the setting accuracy about 0·001 pF per scale division. The absolute value can be estimated to within 0·15‰ in the least favourable circumstances.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

550.8 : 534.2-8 1501

The Scientific Bases for the Use of Ultrasonics in Mining and Geology.—I. Malecki. (*Acta tech. Acad. Sci., hungaricae*, 1955, Vol. 13, Nos. 3/4, pp. 397–407. In German.)

621.3-52 : 621.9 1502

Electronic Controls for Machine Tools.—D. A. Findlay. (*Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 122–129.)

621.3.012.8 : 621-52 : 628.8 1503

Electrical Analogues for Heat Exchangers.—R. L. Ford. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 65–82.) Equivalent circuits for heat exchangers are discussed in relation to problems of automatic control. Circuits composed entirely of passive elements and circuits including amplifiers are considered.

621.317.39 : 538.221 1504

A High-Frequency Method for Metallurgical Investigations of Magnetic Alloys.—F. Fraunberger. (*Z. Metallkde*, Oct. 1955, Vol. 46, No. 10, pp. 749–751.) The method described is based on the marked dependence of the alloy resistivity on its crystal structure at frequencies above those at which irreversible processes play a part.

621.317.39 : 620.1.08 1505

The Phase Comparator.—J. C. Anderson. (*Electronic Engng*, Feb. 1956, Vol. 28, No. 336, pp. 63–65.) Description of a nondestructive method of testing steel springs by measuring the L/R ratio for a coil within which the spring is compressed.

621.384.6 1506

Cascade Generators for Particle Acceleration up to 4 MeV.—W. Heilpern. (*Helv. phys. Acta*, 15th Nov. 1955, Vol. 28, Nos. 5/6, pp. 485–491. In German.) Circuit modifications leading to reduced ripple and internal resistance are described.

621.384.6 + 621.387.4] : 539.1(44) 1507

Nuclear Energy and its Industrial Applications: Part 2—Particle Accelerators and Nuclear-Physics Apparatus.—(*Onde élect.*, Nov. 1955, Vol. 35, No. 344, pp. 955–1115.) This issue comprises a further group of papers on subjects including particle counters and other electronic apparatus and techniques involved in nuclear physics. Part 1: 958 of March.

621.384.611/.612 1508

Nonlinear Regenerative Extraction of Synchrocyclotron Beams.—K. J. Le Couteur & S. Lipton. (*Phil. Mag.*, Dec. 1955, Vol. 46, No. 383, pp. 1265–1280.) Analysis indicates that a nonlinear deflector can extract the beam with higher energy and perhaps greater theoretical efficiency than the linear one used hitherto in the Liverpool machine. See also 873 of March.

621.384.612 1509

The Influence of Magnetic-Field Errors on Betatron Oscillators in the Strong-Focusing Synchrotron.—G. Lüders. (*Nuovo Cim.*, 1955, Supplement to Vol. 2, No. 4, pp. 1075–1146. In German.) Summarized report of research carried out for the European Organization for Nuclear Research up to the autumn of 1953.

621.385.833 1510

Investigation of Focusing Properties of Cylindrical Magnetic Lenses and Systems comprising such Lenses.—S. Ya. Yavor. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 779–790.)

621.385.833 1511

Determination of the Magnetic Field for focusing Electron Beams of a Given Type.—I. I. Tsukkerman. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 853–860.) The limitations are established which are imposed on the magnetic field of a curvilinear electron-optical system when the axial trajectory of the beam and the electric field adjacent to this trajectory are given, and also when it is required to obtain a real similar image in a given normal plane. Examples are given of the design of some purely magnetic electron-optical systems (systems with spiral, circular and straight-line axes).

621.385.833 1512

Variable - Magnification Magnetic Electron-Optical Systems free from Image Rotation.—Tsukkerman. (See 1598.)

621.385.833 1513

Numerical Calculation of the Induction in a Magnetic Electron Lens causing No Image Rotation.—M. Laudet. (*C. R. Acad. Sci., Paris*, 14th Dec. 1955, Vol. 241, No. 24, pp. 1728–1730.)

621.385.833 1514

100-keV Electrons in the Electrostatic Electron Microscope (Intermediate Accelerator).—G. Möllenstedt. (*Optik, Stuttgart*, 1955, Vol. 12, No. 10, pp. 441–466.) Description of an instrument in which the cathode potential is − 50 kV and the object potential is + 50 kV, so that the electrons are incident on the object with an energy of 100 keV, while the energy of electrons striking the viewing screen is arranged to be only 50 keV.

621.385.833 1515

New Quantitative Methods in Electron-Optical Shadow Technique.—C. Schwink. (*Optik, Stuttgart*, 1955, Vol. 12, No. 11, pp. 481–496.) Continuation of previous work [1536 of 1954 (Rollwagen & Schwink)].

The finite divergence of the illuminating beam is taken into account. Possible methods of improving the sensitivity are discussed.

621.387.464 **1516**

Characteristics of the Optical Arrangement of a Scintillation Counter.—Y. Koechlin. (*J. Phys. Radium*, Nov. 1955, Vol. 16, No. 11, pp. 849–853.) An investigation is made of the possibility of increasing the fraction of the scintillation light reaching the cathode of the photomultiplier cell by providing the scintillator with a diffusing coating; the influence of geometric factors is also studied.

621.398 : 631.3 **1517**

Radio-Controlled Tractor.—(*Engineer, Lond.*, 7th Oct. 1955, Vol. 200, No. 5202, pp. 518–519.) A system demonstrated near London used a battery-operated 27·12-Mc/s transmitter with six non-simultaneous channels, provided by tone modulation, respectively controlling the steering left and right, clutch release, implement raising and lowering, and engine stop. The receiver has tuned-reed relays.

621.398 : 681.142 **1518**

A Transducer for Digital Data-Transmission Systems.—R. H. Barker. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 42–51.) Transducers for target-coordinate representation, for weapon control systems, have been constructed to represent the angular position of a shaft as a 14-digit binary number, i.e. to an accuracy of rather better than one minute of arc. Photoelectric scanning is used. Possible errors are discussed.

537.228.1 : 621.317.39 **1519**

Einführung in die piezoelektrische Messtechnik. [Book Review]—W. Gohlke. Publishers: Akademische Verlagsgesellschaft Geest & Portig, Leipzig, 1954, 241 pp., DM 21. (*Z. angew. Phys.*, Nov. 1955, Vol. 7, No. 11, p. 555.) This introduction to piezoelectric measurements constitutes the eighth volume of a series of monographs, and provides a detailed treatment of the fundamentals and applications of the subject.

PROPAGATION OF WAVES

621.396.11 **1520**

The Shielding of Radio Waves by Conductive Coatings.—E. L. Hill. (*Trans. Inst. Radio Engrs*, April 1955, Vol. AP-3, No. 2, pp. 72–76.) The subject is discussed with particular reference to shielding effects experienced in aircraft where conducting coatings are provided on external surfaces to prevent charge accumulation; wavelengths considered are long compared with openings in the aircraft skin.

621.396.11 : 551.510.535 **1521**

The Interaction of Pulsed Radio Waves in the Ionosphere.—J. A. Fejer. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 322–332.) Preliminary daytime measurements using low-power transmitters and a receiver on a common site are discussed. The electron density and collision frequency and the energy-loss coefficient are deduced from the theory of Bailey & Martyn (2168 of 1935 and back references). The resulting collision-frequency values agree with laboratory determinations by Crompton et al. (106 of 1954) and with a value obtained from work on partial reflections by Gardner & Pawsey (132 of 1954). The electron densities are near those obtained by Gardner & Pawsey. The energy-loss coefficient, obtained in the present case for electrons of low excess energy, is much higher than the values found by Crompton et al. working with electrons having high excess energies. The results appear to agree better with the original Bailey-Martyn theory than with the alternative form suggested by Huxley (231 of 1954).

621.396.11 : 551.510.535 **1522**

On the Level at which Fading is imposed on Waves Reflected Vertically from the Ionosphere.—H. G. Booker. (*J. atmos. terr. Phys.*, Dec. 1955, Vol. 7, No. 6, pp. 343–344.) By comparing theoretical with experimental autocorrelation functions for plane waves incident normally upon a diffracting screen, it is shown that fading is imposed upon the wave within, or near, the reflecting stratum; scattering by irregularities in this region plays an important part in the propagation of the wave.

621.396.11 : 551.510.535 **1523**

Some Results of a Sweep-Frequency Propagation Experiment over an 1150-km East-West Path.—B. Wieder. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 395–409.) Experiments using a pulsed frequency-sweep ionosphere recorder at each of the end points and another at the mid-point of the great-circle path show that the transmission-curve-derived F_2-layer m.u.f. is up to 5% too low, depending on time of day and season.

621.396.11 : 551.510.535 **1524**

Sweep-Frequency Pulse-Transmission Measurements over a 2 400-km Path.—P. G. Sulzer. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 411–420.) Analysis of results of experiments similar to those detailed by Wieder (1523 above) shows propagation on numerous occasions during the winter of 1953–1954 at frequencies considerably above the m.u.f. calculated from vertical-incidence observations at the mid-point of the path.

621.396.11 : 551.510.535 **1525**

Heights of Irregularities giving Rise to the Fading of 150-kc/s Waves.—Banerji. (See 1415.)

621.396.11 : 551.510.535 **1526**

Polarization of Electromagnetic Waves for Vertical Propagation in the Ionosphere.—R. Roy & J. K. D. Verma. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 457–482.) A solution is given of the wave equations obtained e.g. by Saha et al. (1442 of 1948), and the orientation of the polarization ellipses is deduced. Electron density and collision frequency in the ionized layers are deduced from the value of the tilt angle and the ratio of the ellipse axes. Applied to experimentally obtained patterns, the theory gives a value of $1{\cdot}7 \times 10^6$/sec for the collision frequency in the E layer.

621.396.11 : 551.510.535 **1527**

Regularly-Observable Aspect-Sensitive Radio Reflections from Ionization aligned with the Earth's Magnetic Field and located within the Ionospheric Layers at Middle Latitudes.—A. M. Peterson, O. G. Villard, Jr, R. L. Leadabrand & P. B. Gallagher. (*J. geophys. Res.*, Dec. 1955, Vol. 60, No. 4, pp. 497–512.) The reflection geometry and the characteristics of echoes received at frequencies between 6 and 30 Mc/s suggest that the phenomenon is caused by a type of particle bombardment generally similar to that which is believed to cause the aurora.

621.396.11 : 551.594.6 : 523.78 **1528**

The Influence of the Solar Eclipse on the Propagation of Atmospherics in the Frequency Range 5–30 kc/s.—Skeib. (See 1400.)

621.396.11.029.51 : 551.510.535 **1529**

Long-Range Propagation of Low-Frequency Radio Waves between the Earth and the Ionosphere.—J. Shmoys. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 163–170.) "The problem of modes of propagation of electromagnetic waves between a perfectly conducting earth and a gradually varying ionosphere is considered. The case of exponentially varying ionospheric parameters is solved in terms of Bessel functions. The propagation constant, the angle of arrival and the group velocity are calculated for the first few modes of propagation."

621.396.11.029.6 **1530**

Synthesis of Radio Signals on Overwater Paths.—A. H. LaGrone, A. W. Straiton & H. W. Smith. (*Trans. Inst. Radio Engrs*, April 1955, Vol. AP-3, No. 2, pp. 48–52.) The fluctuations of microwave radio signals on overwater paths are correlated with variations in water level. The signal-strength variations will contain the first, second and third harmonics of the water-level cycles. An expression is derived relating the cross-correlation function of signal-strength variations at two vertically spaced aerials with variations of spacing.

621.396.11.029.62 **1531**

Radio Transmission Loss vs Distance and Antenna Height at 100 Mc/s.—P. L. Rice & F. T. Daniel. (*Trans. Inst. Radio Engrs*, April 1955, Vol. AP-3, No. 2, pp. 59–62.) Curves based on extensive observations are given which are considered to be more precise than those published in 1949 by the F.C.C. Ad Hoc Committee [see 3524 of 1949 (Lewis)].

621.396.11.029.62 **1532**

Coverage Conditions for TV and F.M. Stations elucidated by Field-Strength Charts.—K. Steen-Andersen. (*Teleteknik, Copenhagen*, Nov. 1955, Vol. 6, No. 4, pp. 205–221.) The preparation and method of use of field-strength charts is described. Statistical information gathered by the Danish Post Office is used as basis for a discussion of field-strength distribution inside and outside buildings. Interference of various types is considered. The field-strength values and interference protection conditions laid down at the 1952 Stockholm conference are given for comparison.

621.396.11.029.62 : 551.594.5 **1533**

V.H.F. Auroral and Sporadic-E Propagation from Cedar Rapids, Iowa, to Ithaca, New York.—R. Dyce. (*Trans. Inst. Radio Engrs*, April 1955, Vol. AP-3, No. 2, pp. 76–80.) Analysis of continuous records, taken over the period April 1952–May 1954, of reception of a 50-Mc/s transmission show that auroral propagation occurred during 4·77% of the time and propagation by E_s during 0·82% of the time.

RECEPTION

621.396.621 : 621.376.33 **1534**

A Locked-Oscillator Quadrature-Grid F.M. Sound Detector.—J. Avins & T. Brady. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 648–655.) The circuit described uses a pentode valve with sharp-cut-off suppressor characteristic. A.m. rejection and static limiting are provided at high signal level by grid damping and degeneration, and at low signal level by operation of the circuit as a locked oscillator.

621.396.621 : 621.376.5 : 621.396.41 **1535**

Electrical Pulse Communication Systems: Part 3—Transmission and Reception Problems in Pulse Systems.—Filipowsky. (See 1546.)

621.396.722 **1536**

Extendible Long-Distance Receiver Installations for Telegraph Services.—W. Hasselbeck. (*Telefunken Ztg*, Sept. 1955, Vol. 28, No. 109, pp. 162–171. English summary, p. 196.) A series of rack-mounted units is described including the s.w. receivers Type E127, Type E104 and Type E305, receiver Type E108 (10 kc/s–1·8 Mc/s), a teleprinter keying unit, dual-diversity combining unit, double-current power supply unit, etc. Racks are cabled for the maximum number of units, switches in the rack cabling being actuated automatically on inserting a unit. The build-up of installations for reception of various types of transmission is illustrated.

621.396.82.029.51 : 621.317.729 : 621.314.7 **1537**

A Radio Interference Measuring Set using Point-Contact Transistors.—J. N. Barry & G. W. Secker. (*Electronic Engng*, Feb. 1956, Vol. 28, No. 336, pp. 53–57.) Circuit and detailed description of a portable battery-operated unit designed to measure interference in the long-wave band due to harmonic radiation from television line timebase circuits. The instrument is essentially a superheterodyne receiver with i.f. 90 kc/s. The minimum input signal for reliable readings is one giving an output signal/noise ratio of 10 dB, viz. 1 μV in 75 Ω or 15 μV in 15 kΩ.

621.396.821 : 551.594.6 **1538**

The Effect of Atmospherics on Tuned Circuits.—A. G. Edwards. (*J. Brit. Instn Radio Engrs*, Jan. 1956, Vol. 16, No. 1, pp. 31–39.) From a general analysis of the effect of an aperiodic signal on a tuned system the Fourier component at the resonance frequency is determined. Available information on the lightning discharge is summarized, and an estimate is made of the spectrum of the waveform radiated from the main return stroke and its variation at different distances from the source. Experiments are described in which atmospherics received from distant and close sources were recorded simultaneously in tuned and untuned channels. The results are consistent with predictions from earlier work when allowance is made for scatter in source distance.

621.396.828 **1539**

Radio Interference Control in Aircraft.—A. L. Albin & J. McManus. (*Tele-Tech & Electronic Ind.*, Nov. 1955, Vol. 14, No. 11, Section 1, pp. 76–77..124.) Methods of interference control at frequencies up to several kMc/s are discussed. The importance of proper bonding and screening of openings by copper mesh is stressed. The use is suggested of waveguide attenuators for holes for control shafts and other openings up to 1 in. diameter. 11 references to U.S. military standards and special reports.

STATIONS AND COMMUNICATION SYSTEMS

621.376.5 : 534.781 **1540**

Laboratory Equipment for Quantizing Speech.—V. H. Allen. (*Electronic Engng*, Feb. 1956, Vol. 28, No. 336, pp. 48–52.) Details are given of a trigger unit and quantizing unit used in investigating the fine structure of speech waveforms and the effect of distortion on intelligibility. The operation of the units in a delta modulation system is described; with this system, good intelligibility was preserved with quantizing frequencies down to 5 kc/s.

621.39 **1541**

A Review of Line and Radio-Relay Communication Systems.—H. Stanesby. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 11–17.) The evolution of long-distance communication systems is outlined and the work on international standardization carried out by the C.C.I.F. and the C.C.I.R. is mentioned.

621.39.001.11 **1542**

Methods of sampling Band-Limited Functions.—R. S. Berkowitz. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 231–235.) "A family of signals is considered which lie within a bandwidth of *W* c/s. Methods are discussed of experimentally obtaining suitable discrete numbers at the rate of 2 *W* per second to describe completely any given member of the family. An 'Educated Direct' sampling method is presented and compared with previously known sampling methods."

621.391.1 : 621.376.23 : 621.397.2 **1543**

Transient Response of Detectors in Symmetric and Asymmetric Sideband Systems.—Murakami & Sonnenfeldt. (See 1566.)

621.394.14 **1544**

Investigation of a Special Transformation of the Teleprinter Alphabet as a Transformation of Vectors.—E. Henze. (*Arch. elekt. Übertragung*, Nov. 1955, Vol. 9, No. 11, pp. 528–532.) A simple method of privacy coding is discussed.

621.396.41 **1545**

A New Low-Power Single-Sideband Communication System.—E. A. Laport & K. L. Neumann. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 635–647.) Description of a simple system, Type SSB-1, for simplex or duplex operation on telephony or telegraphy over short or medium distances.

621.396.41 : 621.376.5 : 621.396.621 **1546**

Electrical Pulse Communication Systems: Part 3—Transmission and Reception Problems in Pulse Systems.—R. Filipowsky. (*J. Brit. Instn Radio Engrs*, Jan. 1956, Vol. 16, No. 1, pp. 40–58.) Various time-division multiplex systems are discussed, synchronous and asynchronous systems being compared. The use of functional multiplexing (CODEP) to reduce redundancy is described. When choosing a system for a particular purpose, limitations in power radiation must be considered. Effects due to various types of noise are discussed; regenerative repeating is the most important method for overcoming these effects in long-range systems. Special detection methods and frequency- and time-selection methods for separating the signal from the noise are reviewed. 56 references. Part 2: 562 of February.

621.396.41.029.6 : 621.3.018.78 **1547**

R.F. Bandwidth of Frequency-Division Multiplex Systems using Frequency Modulation.—R. G. Medhurst. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 189–199.) The frequency distribution of energy in f.m. microwave multiplex systems is analysed and an examination is made of the extent of intermodulation distortion caused by limiting the bandwidths of the r.f. networks in the system. The results are used to determine the minimum filter bandwidths for given permissible distortion.

621.396.65.029.6 + 621.397.26 **1548**

The Austrian Radio-Link Network for Television and U.S.W. Broadcasting.—(*Radio Tech., Vienna*, Oct./Nov. 1955, Vol. 31, Nos. 10/11, pp. 335–340.) The special planning problems encountered in Austria are discussed and a brief account is given of the equipment so far installed. The system operates mainly in the 2-kMc/s band.

621.396.712 : 534.861 **1549**

Design of Studios for Small Broadcasting Stations.—Goodsman. (See 1295.)

621.396.73 : 621.396.61/.62 **1550**

Portable Radiotelephone Sets.—H. Muth & G. Ulbricht. (*Telefunken Ztg*, Sept. 1955, Vol. 28, No. 109, pp. 143–149. English summary, p. 194.) Sets are generally designed for eight hours continuous service (transmission time 20%), using ph.m. in the 80-Mc/s or 160-Mc/s band, with up to 12 switch-selected channels. Operating costs are lowest using a vibrator power pack with lead-acid accumulators. Details are given of two recently developed sets. Applications are described in the following papers:—

"Teleport" Portable F.M. U.S.W. Radiotelephone Sets in Industry.—W. Leisner (pp. 150–153. English summary, pp. 194–195).

Portable Radiotelephone Sets in the Operation of Railways.—A. Schepp & F. Pepping (pp. 154–159. English summary, p. 195).

Use of Portable Radiotelephone Sets on Airfields (pp. 159–161. English summary, pp. 195–196).

621.396.931 **1551**

Multichannel Networks in the Public Mobile Radiotelephone Service.—K. H. Deutsch. (*Funk-Technik, Berlin*, Oct. 1955, Vol. 10, No. 19, pp. 556–557.) A discussion of the maximum number of mobile stations which can conveniently share one or two channels. The number, which varies between 45 and 70 per channel in the U.S.A., is likely to be smaller in Germany; limited experience on one network indicates a maximum of about 35. Use of two channels and suitable switching nearly trebles this maximum for the same average delay time.

SUBSIDIARY APPARATUS

621-52 : 621.375.3 **1552**

Magnetic-Amplifier Two-Speed Servo System.—J. J. Suozzi. (*Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 140–143.) A system is described in which two half-wave bridge-type magnetic-amplifier stages drive a full-wave slave-type output stage. Design data are presented for a number of systems.

621-526 **1553**

A Servo System for Digital Data Transmission.—R. H. Barker. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 52–64.) The stability of the servo system is affected by the quantized nature of the digital data and by time delays inherent in the transmission and digital systems. A method of synthesis is discussed enabling a degree of prediction to be incorporated which ensures that the regenerated data do not lag on the original data under steady-state conditions.

621.311.6 : 621.317.7.089.6 **1554**

An Electronic Supply for Use in the Calibration of Instruments.—F. J. Wilkins & S. Harkness. (*Proc. Instn elect. Engrs*, Part B, Jan. 1956, Vol. 103, No. 7, pp. 83–92.) Description of a high-power oscillator/amplifier set, with phase-shift unit, giving an output of at least 700 VA at unity power factor within the range 30 c/s–5 kc/s from each of two amplifiers. The output voltage does not vary by more than 0·01% during the time taken to calibrate a point on an instrument scale.

621.311.6 : 621.373.52 **1555**

Transistor Power Converter Capable of 250 Watts D.C. Output.—G. C. Uchrin. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 261–262.) A unit based on the circuit described previously [974 of 1955 (Uchrin & Taylor)] has been developed giving 250 W output from a 24-V input. Experimental performance figures are given.

621.314.5 : 621.387 1556

Thyratron Inverter uses Controlled Firing Time.—F. Lawn. (*Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 164–167.) The circuit described permits control of a.c. output voltage without saturable reactor, with improved regulation, efficiency and response speed. One thyratron serves as control tube for extinguishing the conducting power tube at any desired phase.

TELEVISION AND PHOTOTELEGRAPHY

621.397.26 + 621.396.65.029.6 1557

The Austrian Radio-Link Network for Television and U.S.W. Broadcasting.—(See 1548.)

621.397.5 : 535.623 1558

A New Look at Colorimetry.—D. L. MacAdam. (*J. Soc. Mot. Pict. Telev. Engrs*, Nov. 1955, Vol. 64, No. 11, pp. 629–630. Discussion, pp. 630–631.) An account of the proceedings at the meeting of the International Commission on Illumination (C.I.E.) in June 1955, at which the revision of colorimetry standards was discussed. The relevance of the problem to colour television is briefly indicated.

621.397.5 : 535.623 1559

Survey of the Various Colour-Television Systems.—E. Schwartz. (*Arch. elekt. Übertragung*, Nov. 1955, Vol. 9, No. 11, pp. 487–504.) The systems discussed include the N.T.S.C., the two-colour-subcarrier, and the coding method [1815 of 1953 (Valensi)]. 185 references.

621.397.5 : 535.623 1560

The Moscow Colour-Television Experiments.—A. M. Warbanski (Varbanski). (*NachrTech.*, Nov. 1955, Vol. 5, No. 11, pp. 490–492.) German adaptation of paper noted previously (582 of February). The standards used are 525 lines, 25 complete pictures per sec, corresponding to 150 frames of each colour per sec. The picture-carrier frequency is 78 Mc/s and the width of the video channel 8·4 Mc/s.

621.397.5 : 778.5 1561

Television Signal Recording.—W. Woods-Hill. (*Wireless World*, March 1956, Vol. 62, No. 3, pp. 127–130.) A recording system using 35-mm microfilm moving at normal or twice-normal film speed is outlined. The recording is made via a c.r. tube in which the timebase applied to the X plates is synchronized with the line pulses, and a 15-Mc/s voltage applied to the Y plates is modulated by the picture signal. The image is projected with its height optically reduced so as to occupy $< 1/200$ of the height of the film frame, and the sweep is adjusted to occupy the total usable width. Reproduction is effected by means of a photoelectric pick-up system.

621.397.6 : 621.317.7 1562

A Test-Signal Generator for Measurements on Television Transmission Systems.—Macek. (See 1489.)

621.397.62 1563

Television Receiver with Continuously Variable Tuning.—A. V. J. Martin. (*Télévision*, Nov. 1955, No. 58, pp. 271–272.) A Belgian version of the Boncourt all-standards receiver is described. The layout follows normal practice except for the timebase system, in which two thyratron relaxation oscillators are used which can be tuned to synchronization according to the relevant standards, and the continuous-tuning feature. The television bands I (40–70 Mc/s) and III (164–220 Mc/s) are covered, alternative receiver bandwidths of about 4 and 8 Mc/s being provided.

621.397.62 : 621.314.26.029.62 1564

Simplified Band-III Converter.—O. E. Dzierzynski. (*Wireless World*, March 1956, Vol. 62, No. 3, pp. 134–139.) A single-stage converter using a triode-pentode frequency changer, designed for use in areas of high signal-strength, is described in detail.

621.397.62 : 621.314.7 1565

Transistorized Sync Separator Circuits for Television Receivers.—H. C. Goodrich. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 533–550.) Double clipping of synchronizing signals can be achieved in a circuit using only one junction transistor as a result of the low-voltage knee in the characteristic. The immunity of the circuit to impulse noise can be improved by including a diode to control the circuit time constant. The performance is satisfactory for ordinary commercial receivers.

621.397.62 : 621.391.1 : 621.376.23 1566

Transient Response of Detectors in Symmetric and Asymmetric Sideband Systems.—T. Murakami & R. W. Sonnenfeldt. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 580–611.) Analysis is presented indicating the advantages of the synchronous detector over the envelope detector, with special reference to asymmetric-sideband systems for television. General formulae are particularized for the triple-stagger-tuned band-pass filter for different modulation levels. Observations of the transient performance of synchronous detectors are described.

621.397.621.2 : 535.623 : 621.385.832 1567

Improvement in Color Kinescopes through Optical Analogy.—D. W. Epstein, P. Kaus & D. D. VanOrmer. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 491–497.) "In color kinescopes wherein the phosphor dots are deposited by the conventional optical exposure, the movement of the deflection center with deflection angle causes a radial misregister between the phosphor dots and electron spots. This misregister has been eliminated by interposing a thin aspheric lens between the light source and the aperture mask during exposure of the phosphor screen in the manufacture of the tube."

621.397.7 1568

Low-Power Telecasting.—M. E. Williamson & S. E. Rodby. (*J. Soc. Mot. Pict. Telev. Engrs*, Nov. 1955, Vol. 64, No. 11, pp. 618–621.) Short account of the development of inexpensive television stations for the U.S. armed forces. An area of radius about 5 miles can be served using equipment with about 30 W effective radiated power.

621.397.7 1569

Copenhagen Television Station.—J. Hansen & I. L. Nielsen. (*Teleteknik, Copenhagen*, Nov. 1955, Vol. 6, No. 4, pp. 197–204.) A description is given of the station arrangement; some details are included on the transmitters and aerial.

621.397.8 1570

Image Gradation, Graininess and Sharpness in Television and Motion-Picture Systems: Part 4 A & B—Image Analysis in Photographic and Television Systems (Definition and Sharpness).—

O. H. Schade. (*J. Soc. Mot. Pict. Telev. Engrs*, Nov. 1955, Vol. 64, No. 11, pp. 593–617.) 'Aperture theory' is developed. The properties and combination of 'apertures' (point images) can be described in the space domain by transmittance functions and in the frequency domain by their Fourier spectra (sine-wave response). The basic operation of image formation and analysis is the convolution of two functions. The 'equivalent pass-band' is a significant parameter. Part 3: 1233 of 1954.

TRANSMISSION

621.376.222 **1571**

Why Fight Grid Current in Class B Modulators?—J. L. Hollis. (*Proc. Instn Radio Engrs, Aust.*, Nov. 1955, Vol. 16, No. 11, pp. 397–401.) Reprint. See 3249 of 1953.

621.376.32 : 538.221 **1572**

Measurements of Reversible Permeability and their Theoretical Interpretation.—Wilde. (See 1469.)

621.396.61.004 **1573**

Unattended Broadcasting Transmitters.—W. J. Baker. (*Brit. Commun. Electronics*, Nov. 1955, Vol. 2, No. 11, pp. 64–68.) Techniques developed for unattended operation are briefly reviewed. Important aspects are use of air-cooled valves, automatic monitoring, and devices for protection against failure.

VALVES AND THERMIONICS

621.314.63 **1574**

A Note on the Small-Amplitude Transient Response of *P-N* Junctions.—B. R. Gossick. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, p. 259.) Analysis indicates that when the forward bias is sufficient to make the barrier *RC* time constant small compared with the average recombination time, the response is very fast.

621.314.63 : 546.289 **1575**

Capacitance Measurements on Alloyed Indium-Germanium Junction Diodes.—D. R. Muss. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1514–1517.) "Donor densities in the base material of fused junction diodes, inferred from capacitance data, are used to calculate majority carrier mobilities. The dependence of capacitance on reverse bias at very low biases is found to be given by the sum of two terms, a space charge capacitance and a capacitance due to the flow of holes as given by Shockley's low level *p-n* junction theory."

621.314.63 : 621.396.822 **1576**

Spectral Analysis of Flicker Noise of Ge Diodes at Low Frequencies.—J. P. Borel, C. Manus & R. Mercier. (*Helv. phys. Acta*, 15th Nov. 1955, Vol. 28, Nos. 5/6, pp. 454–458. In French.) Noise measurements were made at 10 kc/s, 1·7 kc/s, 167 c/s and 16·6 c/s; calibration was performed using a resistor noise source. The apparatus gave a direct reading of the mean-square value of noise current. Results indicate that this mean-square value varies with the diode reverse current according to a power law which depends on the frequency; consequently the spectral distribution of the noise depends on the diode current.

621.314.7 **1577**

The Frequency Response of Bipolar Transistors with Drift Fields.—L. B. Valdes. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 178–184.) Details of charge-carrier transport in point-contact transistors are discussed. The frequency variation of current multiplication is calculated taking account of the distribution of transit time of minority carriers between emitter and collector. The absolute transit time depends on both drift and diffusion effects, but the distribution depends only on diffusion. Calculated results are compared with measurements.

621.314.7 : 537.311.33 **1578**

Transistor Physics.—Shockley. (See 1458.)

621.314.7 : 621.317.3 **1579**

Measuring R.F. Parameters of Junction Transistors.—Coffey. (See 1483.)

621.383.27 **1580**

Feedback in Photoelectron Multipliers.—L. G. Leiteizen & N. S. Khlebnikov. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 943–944.) It was found that a photoelectron multiplier with a semi-transparent Sb-Cs cathode had a low noise level and an amplification factor of the order of 10^6–10^7 at a voltage of 1–1·2 kV. Attempts to increase secondary emission by raising the voltage were ineffective owing to optical feedback. By making certain constructional improvements the amplification factor was raised to 10^8.

621.385 : 621.396.822 **1581**

Theory of Shot Effect.—M. E. Gertsenshtein. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 827–833.) Mean values of noise current in a valve are evaluated from the local fluctuations of the convection current.

621.385 : 621.396.822 **1582**

Correlation of Fluctuations in an Electron Gas.—M. E. Gertsenshtein. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 834–840.) Continuation of analysis (1581 above). Methods are indicated for calculating the correlation tensor (1) for an electron gas with arbitrary electron-velocity distribution; this is required for determining the shot-noise intensity.

621.385.029.6 **1583**

Space-Charge Waves in Accelerated and Decelerated Unidimensional Electron Streams.—R. Müller. (*Arch. elekt. Übertragung*, Nov. 1955, Vol. 9, No. 11, pp. 505–512.) Analysis is given for a system in which the potential distribution along the electron stream can be represented by a simple power law. For practical conditions the space-charge waves can be considered as distorted sine waves.

621.385.029.6 **1584**

Space-Charge Distribution in a Static Magnetron.—H. C. Nedderman. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1420–1430.) A method of investigation is described based on photoelectric measurement of the radiation intensity from gas atoms in the interaction space excited by electron collisions. The results indicate that space charge extends to the anode under all conditions. A considerable fraction of the space charge consists of electrons trapped for long times.

621.385.029.6 **1585**

Space-Charge Waves in Crossed Electric and Magnetic Fields.—S. S. Solomon. (*J. appl. Phys.*, Dec. 1955, Vol. 26, No. 12, pp. 1443–1449.) Analysis shows that growing waves can be propagated along a neutralized beam in crossed fields by converting either the kinetic or the potential energy of the electrons into wave energy. In the former case the TE and TM modes are coupled in general, but the coupling coefficient is negligible for electron velocities much smaller than the velocity of light. In the latter case, which is that of the travelling-wave magnetron, the TE and TM modes are uncoupled even when the electron velocity is comparable with the velocity of light.

621.385.029.6 1586

Magnetron Theory.—D. Gabor & G. D. Sims: R. Q. Twiss. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 449–452 & 454–456.) Buneman's criticisms (939 of March) of previous papers by the authors (3787 and 3785 of 1955) are answered.

621.385.029.6 1587

Self-Sustained Electronic Spokes in Magnetrons.—A. Raev, I. Uzunov & A. Angelov. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 452–454.) Conditions are described in which oscillations occurring in two- and four-segment magnetrons appear to be due to a rotating electronic 'spoke' which is self-sustained without a tuned circuit. Similar oscillations have also been found with a single-anode magnetron.

621.385.029.6 1588

X-Band Klystrons for High-Power C.W. Operation.—H. S. Cockroft & J. R. Pickin. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 359–372.) Description of the construction and performance of amplifiers with up to 2 kW output and oscillators with 500 W output.

621.385.029.6 1589

Design Information on Large-Signal Traveling-Wave Amplifiers.—J. E. Rowe. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, pp. 200–210.) Formulae are derived for high-power operation of travelling-wave valves taking account of space charge. The parameters considered are the relative injection velocity, the gain parameter, the input level, the space-charge parameter and the space-charge-range parameter. Results are presented graphically.

621.385.029.6 1590

E- and C-Type Traveling-Wave Devices.—P. Guénard & O. Doehler. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, p. 261.) Comment on 3436 of 1955 (Heffner & Watkins).

621.385.029.6 : 621.373.4 1591

Generation of Electromagnetic Oscillations by means of a Travelling-Wave Valve with an External Helix.—V. S. Mikhalevski & D. N. Venerovski. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 812–816.) An experimental investigation was conducted to establish the conditions for excitation of oscillations as determined by the pitch of the helix, the mean velocity of electrons and the intensity of the magnetic focusing field, for an assumed electron-velocity distribution. The experimental results are in agreement with the theoretical conclusions.

621.385.029.6 : 621.376 1592

Klystron Modulation and Schlömilch Series.—J. R. M. Vaughan. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 430–438.) Amplitude modulation of the output of a klystron oscillator, whose frequency is varied by modulation of the reflector voltage, is investigated theoretically by use of the Schlömilch series of Bessel functions; the conclusions are verified by experiment.

621.385.029.6 : 621.396.822 1593

Analysis of Noise in Electron Beams.—F. N. H. Robinson & H. A. Haus. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 373–384.) Extension of analysis presented previously [3442 of 1955 (Haus & Robinson)]. Linear systems, including amplifiers with lossy circuits and those with beams involving more than two modes of propagation, are discussed. The minimum noise figure of any beam-type amplifier can be calculated from a knowledge of the propagation modes and associated power flow.

621.385.029.6 : 621.396.822 1594

Interception Noise in Electron Beams at Microwave Frequencies.—W. R. Beam. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 551–579.) Theory is developed particularly for pencil beams and intercepting elements with round apertures, on the basis of an assumed transverse distribution of probability of electron interception. Results of experiments support the assumptions made. Partial interception of the beam gives rise to two noise components, due respectively to velocity and current fluctuations.

621.385.029.6.032.213 1595

A High-Temperature Cantilever-Cathode for Noise Investigations of 8-mm C.W. Magnetron.—A. E. Barrington. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 421–429.) A tantalum cathode operating at 1 900°C and heated by hydrogen ion bombardment (see 2798 of 1955) is described. Experiments show that noise is critically dependent on the value of the magnetic field, on mismatch and on cathode position.

621.385.2 : 621.316.722.1 1596

Saturated Diodes.—D. L. Hall: D. M. Sutherland: F. A. Benson & M. S. Seaman. (*Electronic Engng*, Feb. 1956, Vol. 28, No. 336, pp. 84–85.) Comments on 3447 of 1955 and authors' reply.

621.385.832.032.2 1597

Experimental High-Transconductance Gun for Kinescopes.—F. H. Nicoll. (*RCA Rev.*, Dec. 1955, Vol. 16, No. 4, pp. 612–617.) "Use of electroformed fine mesh on the control grid aperture of an experimental electron gun gives an order of magnitude reduction in required video drive. Focus and current characteristics are acceptable for many applications."

621.385.833 1598

Variable-Magnification Magnetic Electron-Optical Systems free from Image Rotation.—I. I. Tsukkerman. (*Zh. tekh. Fiz.*, May 1955, Vol. 25, No. 5, pp. 950–952.) Design theory is presented. One of the simplest systems satisfying the requirements is the so-called solenoid lens giving unity magnification. The results obtained could be applied to television cameras for altering the scale of the image.

621.387 : 621.37 1599

Some New Microwave Control Valves employing the Negative Glow Discharge.—D. H. Pringle & E. M. Bradley. (*J. Electronics*, Jan. 1956, Vol. 1, No. 4, pp. 389–404.) See also 2579 of 1955 (Pringle) and back reference.

MISCELLANEOUS

061.3 : 621.3 1600

Some Thoughts on Technical Meetings.—R. M. Fano. (*Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, p. 260.) A short discussion on the best methods of organizing meetings and literature within the I.R.E. to serve (*a*) researchers in a particular field, (*b*) those engaged on detailed practical developments, and (*c*) those interested in the broad lines of progress in the field.

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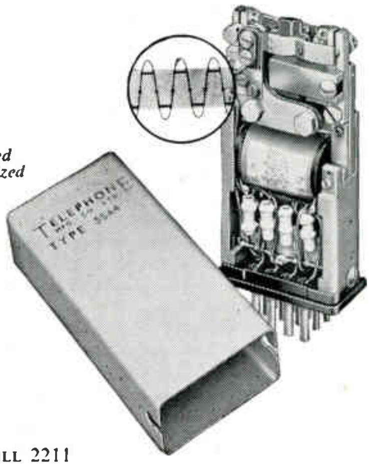

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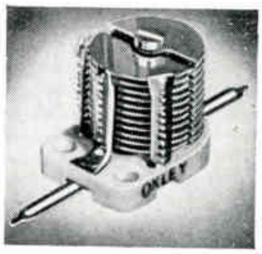

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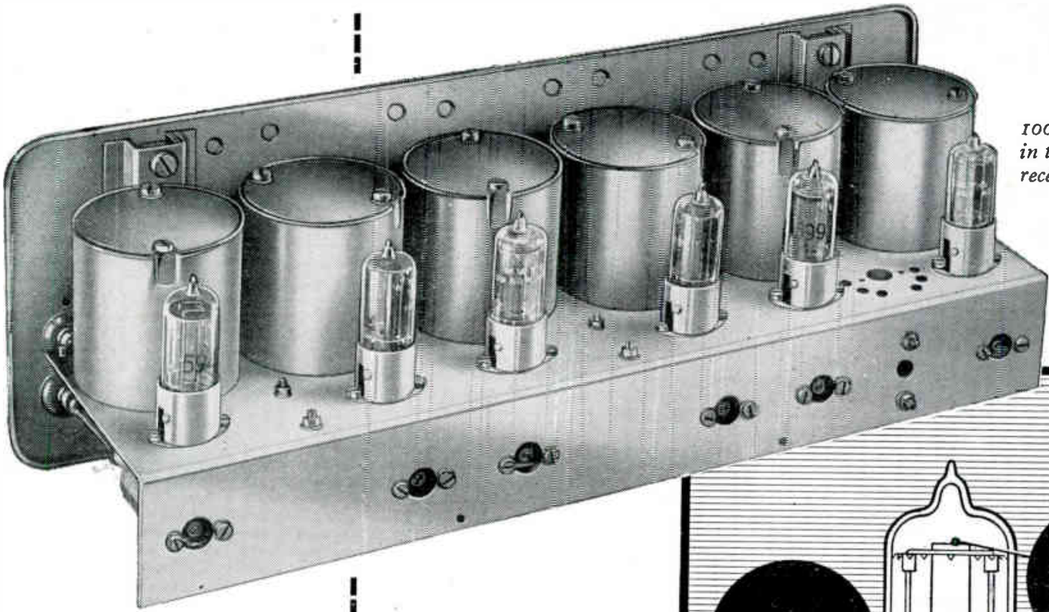

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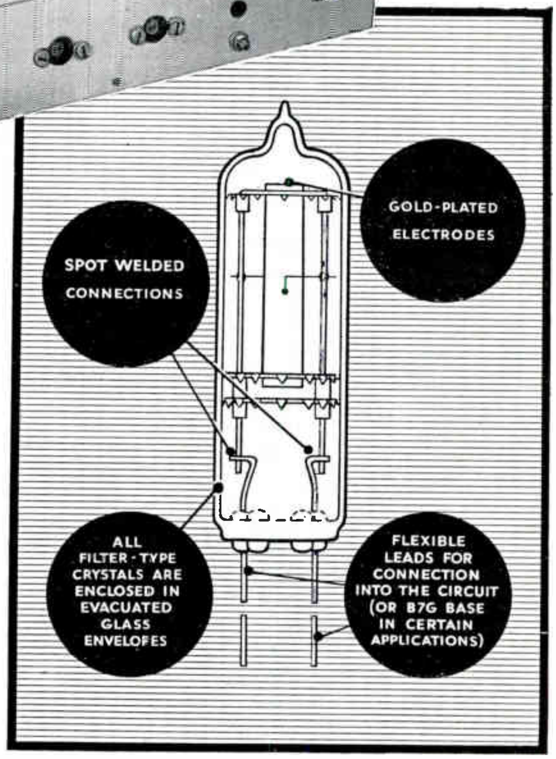

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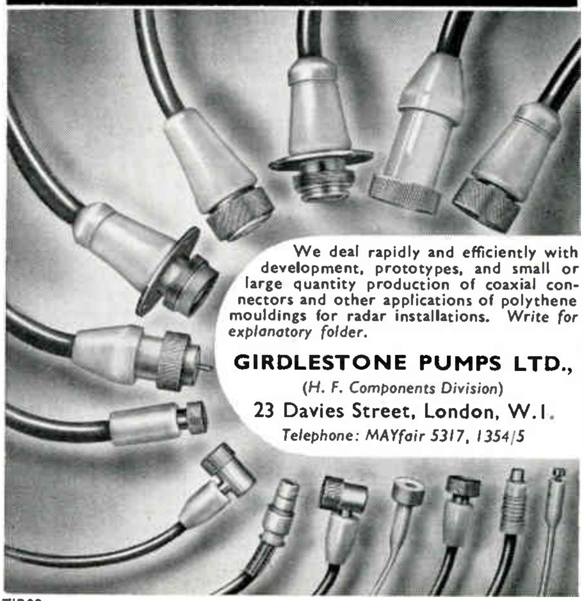

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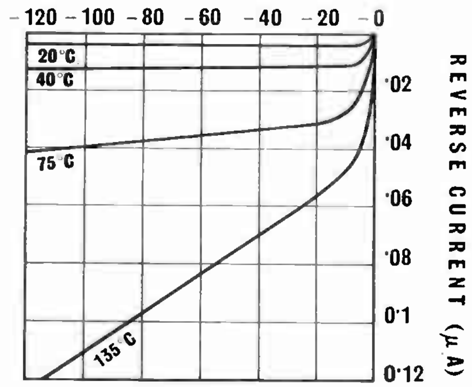

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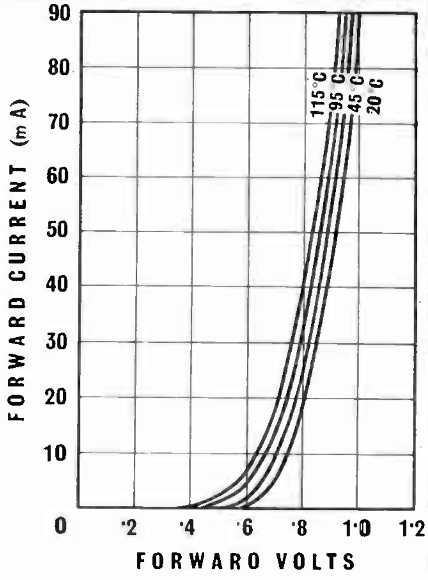

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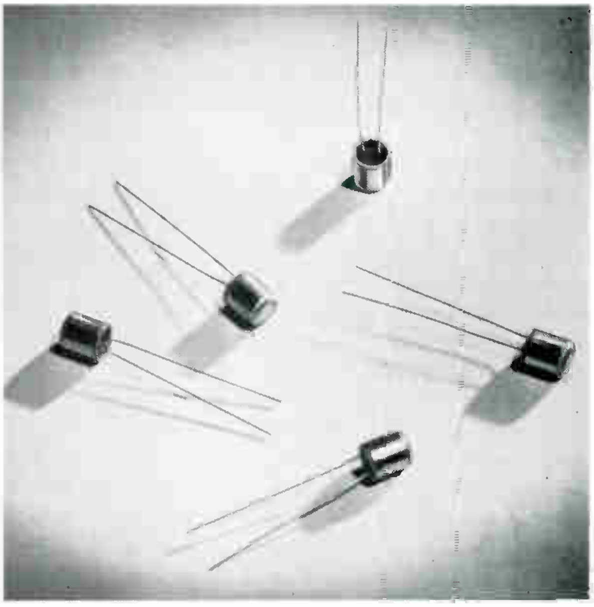

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Apply immediately with full particulars in strictest confidence to Box No. 1834, c/o *Wireless Engineer*.

PHILIPS RADIO AND TELEVISION LABORATORIES

require Mechanical Designers for the expanding activities at their Mitcham, Surrey establishment.

There are excellent opportunities for interesting work with scope for personal initiative. The minimum starting salary would be £800 per annum, plus bonus. Candidates should apply in confidence to the Personnel Officer, THE MITCHAM WORKS LIMITED, New Road, Mitcham Junction, Surrey, quoting reference—D.D.R/1.

SENIOR ELECTRONIC ENGINEER

Bruce Peebles & Co. Ltd., East Pilton, Edinburgh 5, are forming an Electronic Development Group, and have a vacancy for a Senior Electronic Engineer to take charge of the Group. Applicants should have considerable experience in research and development in electronics and light current engineering. Some service in H.M. Forces or at a research establishment on radar will be advantageous. Qualifications should include an Honours Degree in Electrical Engineering or Physics and preferably corporate membership of the Institute of Electrical Engineers. In general applicants should be in their middle thirties, though a younger man with outstanding capabilities will be considered. The position requires a high degree of responsibility and carries a salary commensurate with this. Applications with full details to Mr. O. L. Robson, Manager, Rectifier Department, at above address.

Ministry of Supply require Physicists and Electrical Engineers in Radio Division of Royal Aircraft Establishment, Farnborough, Hants, for experimental work on aeronautical radio communications and navigation and electronic equipment, including field investigations and observations in flight. *Qualifications:* Higher School Certificate (Science) or equivalent, but possession of a pass degree, H.N.C. or final C. & G. Certificate in Telecommunications may be an advantage. Appointments as Experimental Officer (min. age 26) or Assistant E.O. Salary within ranges, E.O. £781–£968; A.E.O. £328 (age 18)–£706. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D.178/6A. Closing date 20th June 1956.

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FOCUS ON LEADERSHIP

'VISCONOL' CATHODRAY

The increasingly high voltages encountered in television receivers and allied equipment demand outstanding features in condenser design to ensure dependability and long service life.

The 'Visconol' process — exclusive to T.C.C.—gives maximum stability to the dielectric and enables it to withstand sharp-front, short-time surges. The leakage-path between high and low potential terminals is the maximum possible and flash-over is virtually eliminated.

The fact that T.C.C. 'Visconol' Cathodray condensers are consistently used in leading equipments is indisputable proof that in every respect they are completely reliable under the most stringent conditions.

Max. Work'g Voltages (at 60 C.)	Cap. in μF.	T.C.C. Type No.	Max. Height above Chassis	Max. Diam.	Mounting Stud Diameter	List Price Each
2000	0.1	CP56X	2 5/8″	1 3/16″	O.B.A.	10/-
2500	0.1	CP59GO	6″	2 7/8″	3/8″ Whit.	35/-
3000	0.025	CP56HO	2 5/8″	1 3/16″	O.B.A.	10/-
5000	0.1	CP57MO	5 3/8″	1 3/4″	3/8″ Whit.	18/-
6000	0.001	CP55QO	2 3/8″	13/16″	2 B.A.	6/-
6000	0.01	CP56QO	2 5/8″	1 3/16″	O.B.A.	10/-
7000	0.1	CP58QO	5 3/8″	2″	3/8″ Whit.	20/-
12500	0.0005	CP56VO	2 5/8″	1 3/16″	O.B.A.	10/-
12500	0.001	CP56VO	2 5/8″	1 3/16″	O.B.A.	10/-
15000	0.0005	CP56WO	2 5/8″	1 3/16″	O.B.A.	10/-
15000	0.001	CP56WO	2 5/8″	1 3/16″	O.B.A.	10/-
18000	0.002	CP57XO	5 3/8″	1 3/4″	3/8″ Whit.	18/-
20000	0.001	CP56GOO	2 5/8″	1 3/16″	O.B.A.	10/-
25000	0.001	CP57HOO	5 3/8″	1 3/4″	3/8″ Whit.	18/-
75000	0.0005	CP59ROO	6″	2 7/8″	3/8″ Whit.	35/-

Details of complete range available on request.

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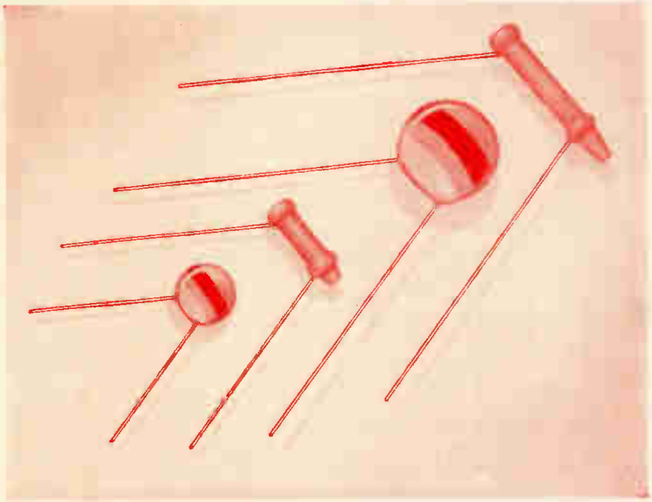

Hunts announce their new ranges of Tubular and Disc Ceramics. Precise in their characteristics and robust in design, these capacitors are available in High-K, High-Q and Special Purpose Tubulars and in High-K Discs. Full technical specifications on request.

HIGH-Q TUBULAR

STANDARD CAPACITANCE RANGES

Capacitance Range Picofarads	Length of Insulated Tube Millimetres
*Type P100. Temperature Coefficient $(+100 \pm 100) \times 10^{-6}$ pF/pF/°C	
1.5 to 7	11
7.1 to 11	13
11.1 to 16	16
16.1 to 26	21
26.1 to 33	26
33.1 to 40	31
40.1 to 50	36
50.1 to 60	41
*Type N33. Temperature Coefficient $(-33 \pm 60) \times 10^{-6}$ pF/pF/°C	
5.0 to 27	11
27.1 to 45	13
45.1 to 69	16
69.1 to 100	21
100.1 to 140	26
140.1 to 180	31
180.1 to 220	36
220.1 to 250	41
*Type N750. Temperature Coefficient $(-750 \pm 250) \times 10^{-6}$ pF/pF/°C	
10.0 to 80	11
80.1 to 110	13
110.1 to 180	16
180.1 to 240	21
240.1 to 350	26
350.1 to 450	31
450.1 to 550	36
550.1 to 650	41

*Capacitors with closer limits of Temperature Coefficient can be supplied by special arrangement.

HIGH-K TUBULAR

STANDARD CAPACITANCE RANGE

Capacitance Picofarads	Length of Insulated Tube Millimetres TB1000	TB3000
470	11	—
680	11	—
800	11	11
1000	13	11
1500	16	11
2000	19	11
2200	19	11
3000	—	16
3300	—	16
4000	—	19
4700	—	19
5000	—	21

POWER CERAMICS

Ranges of Power Ceramics and Temperature Compensating types are also available.
Details on application.

HIGH-K DISC

STANDARD CAPACITANCE RANGE

Capacitance Picofarads	Type Number	Diameter (over insulation) Millimetres
470	CD8K/2	9
680	CD8K/2	9
1000	CD9K/2	10.5
1500	CD9K/2	10.5
2200	CD11K/2	12
3300	CD12K/2	13
4700	CD14K/2	14.5

MATERIAL EMPLOYED

The temperature coefficient graph of the material is such that the capacitance increases with temperature from 20°C until it reaches a peak at approximately 50°C. With a further increase of temperature the capacitance falls, reaching its 20°C value again at approximately 80°C.
Maintenance of capacitance is thus ensured from 20°C to 80°C.

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