WIRELESS ENGINEER

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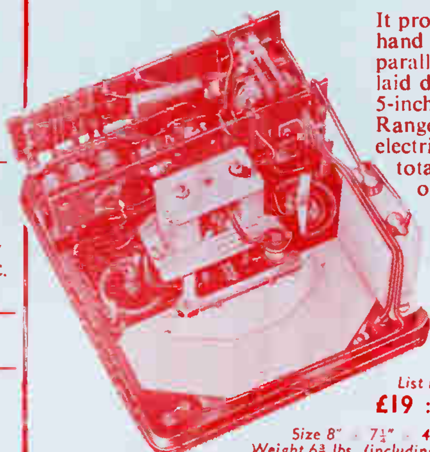

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5 ,, A.C. & D.C.	500 ,, ,, ,,
10 ,, ,, ,,	1V ,, ,,
50 ,, ,, ,,	5 ,, A.C. & D.C.
100 ,, ,, ,,	10 ,, ,, ,,
500 ,, ,, ,,	50 ,, ,, ,,
1 A ,, ,,	100 ,, ,, ,,
5 ,, ,, ,,	200 ,, ,, ,,
10 ,, ,, ,,	400 ,, ,, ,,
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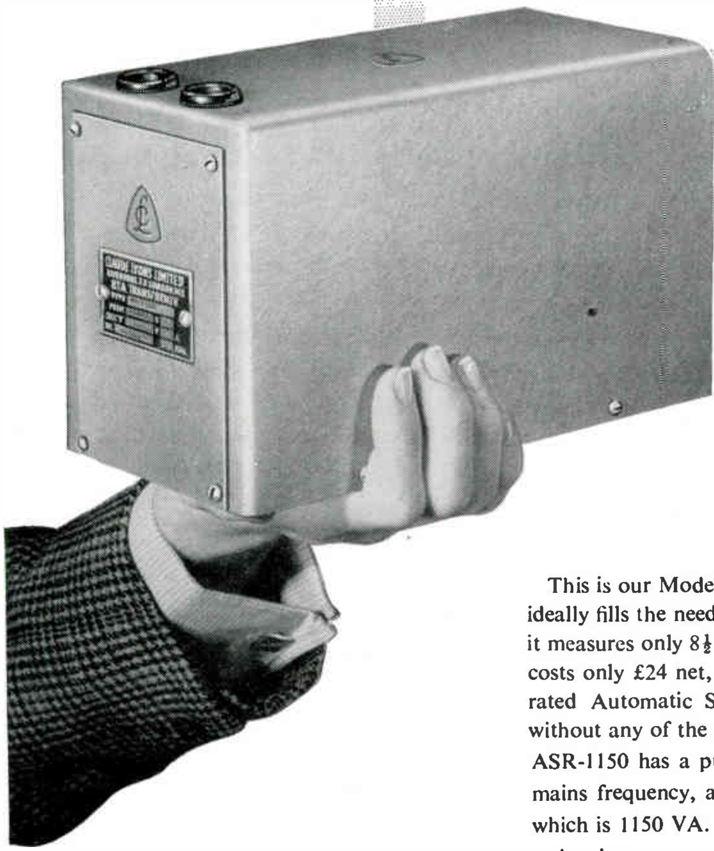

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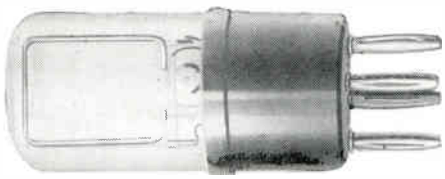

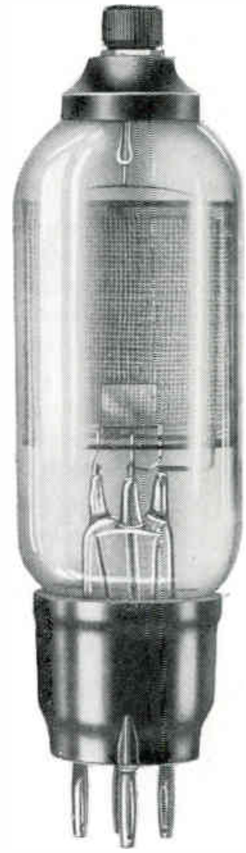

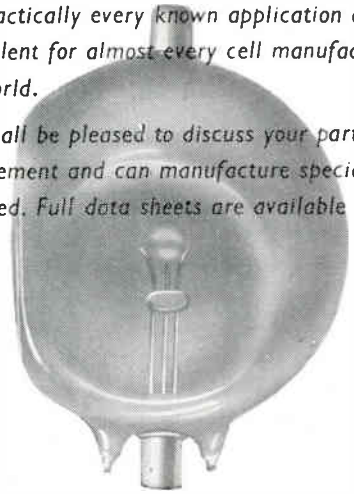

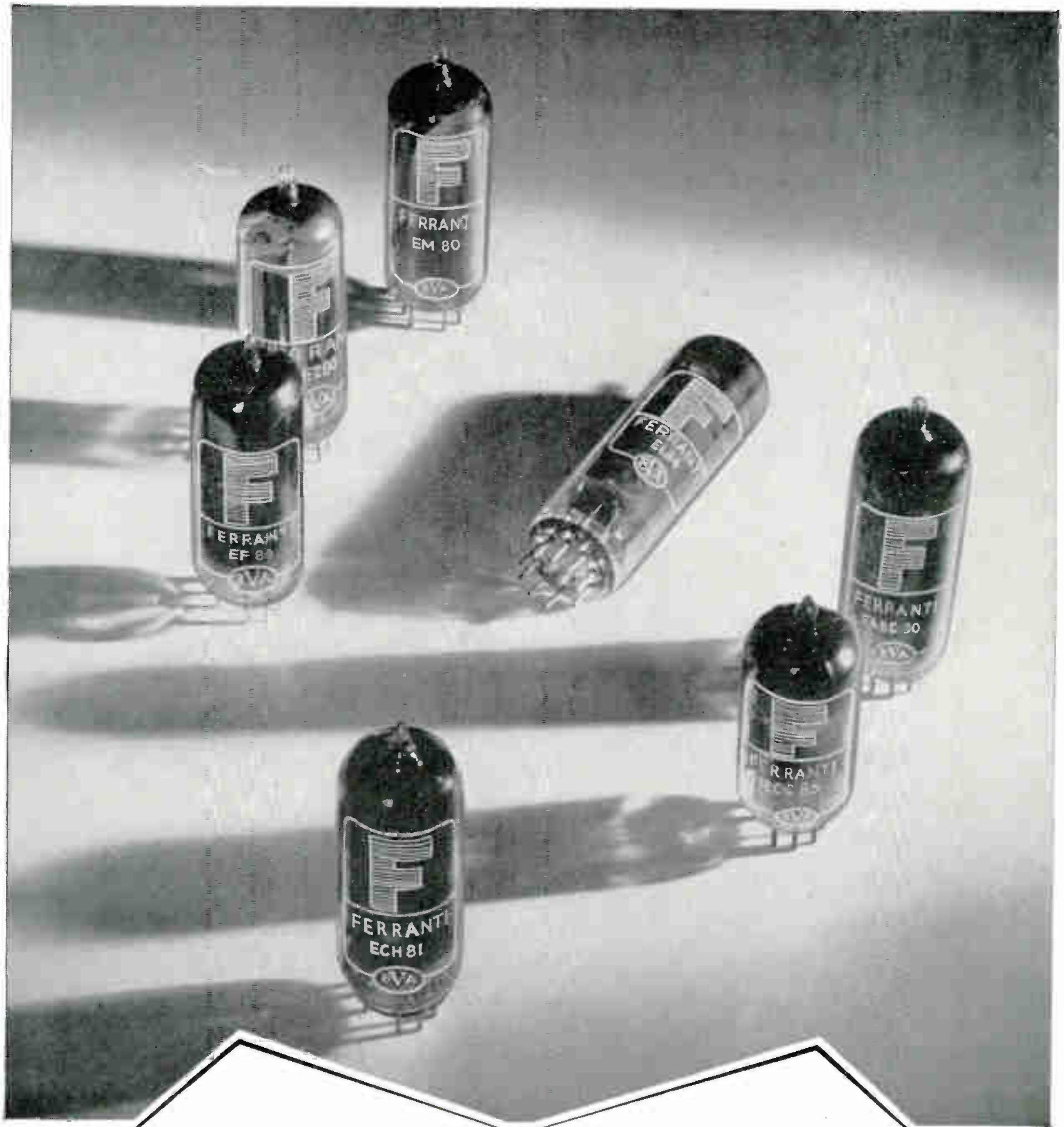
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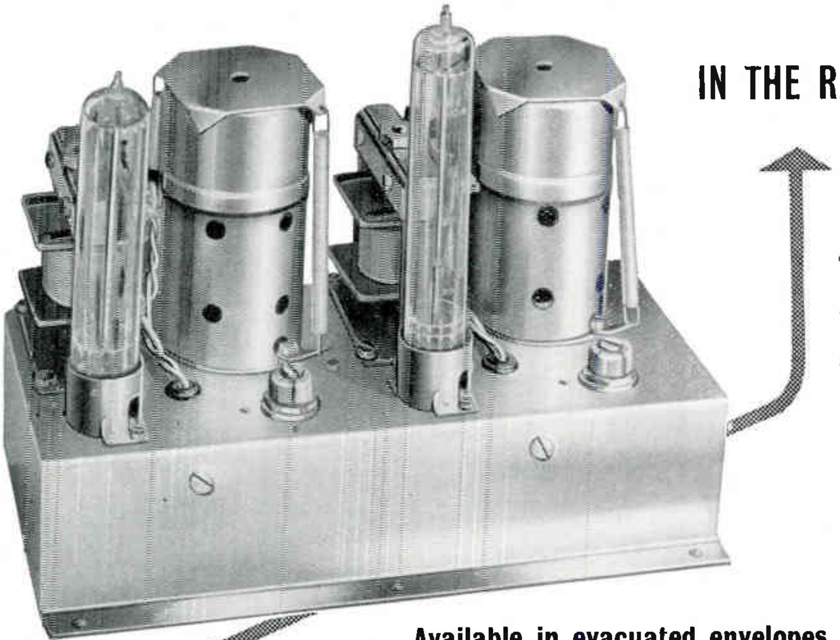

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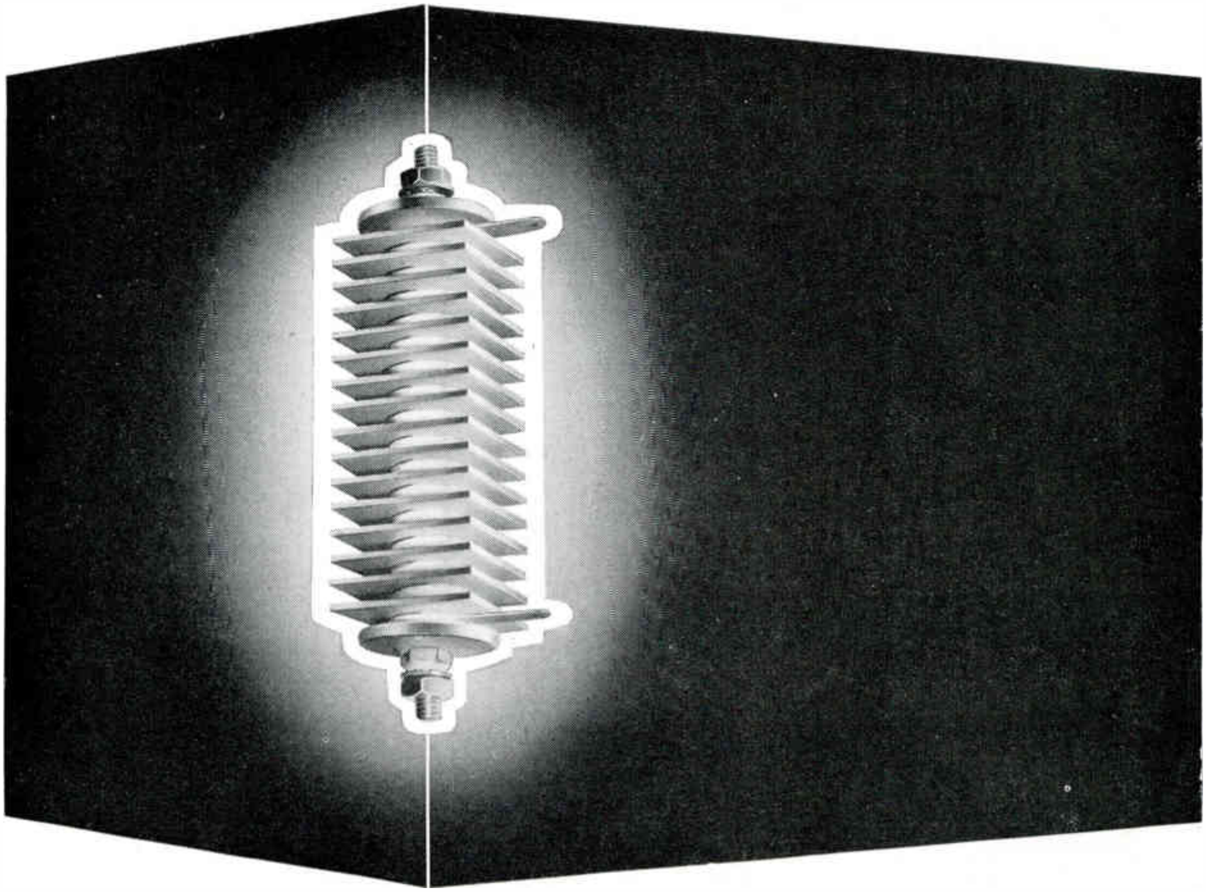

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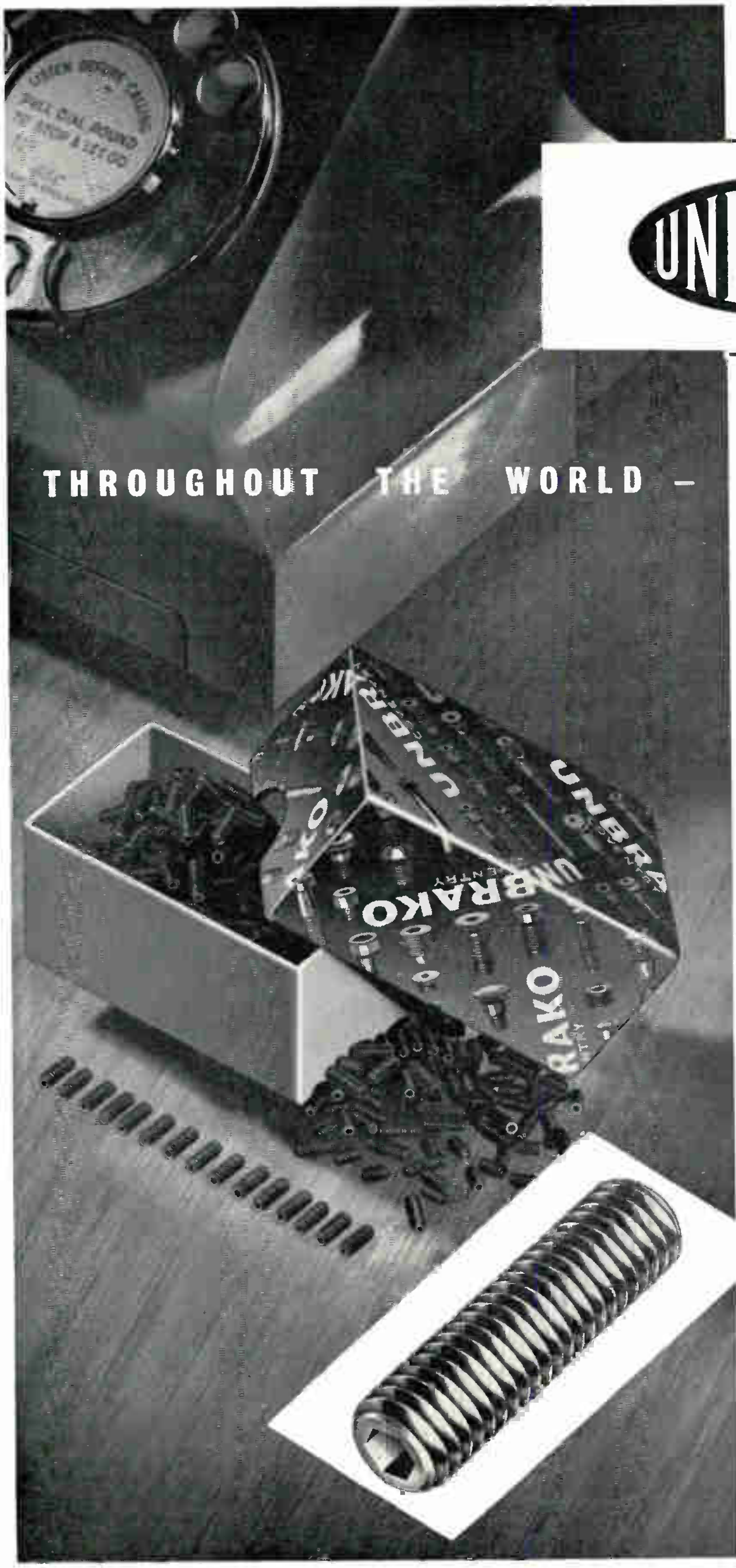

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GXU4	4.OV	7.OA	I3kV	I.25 A		CVI629, RG3—I250

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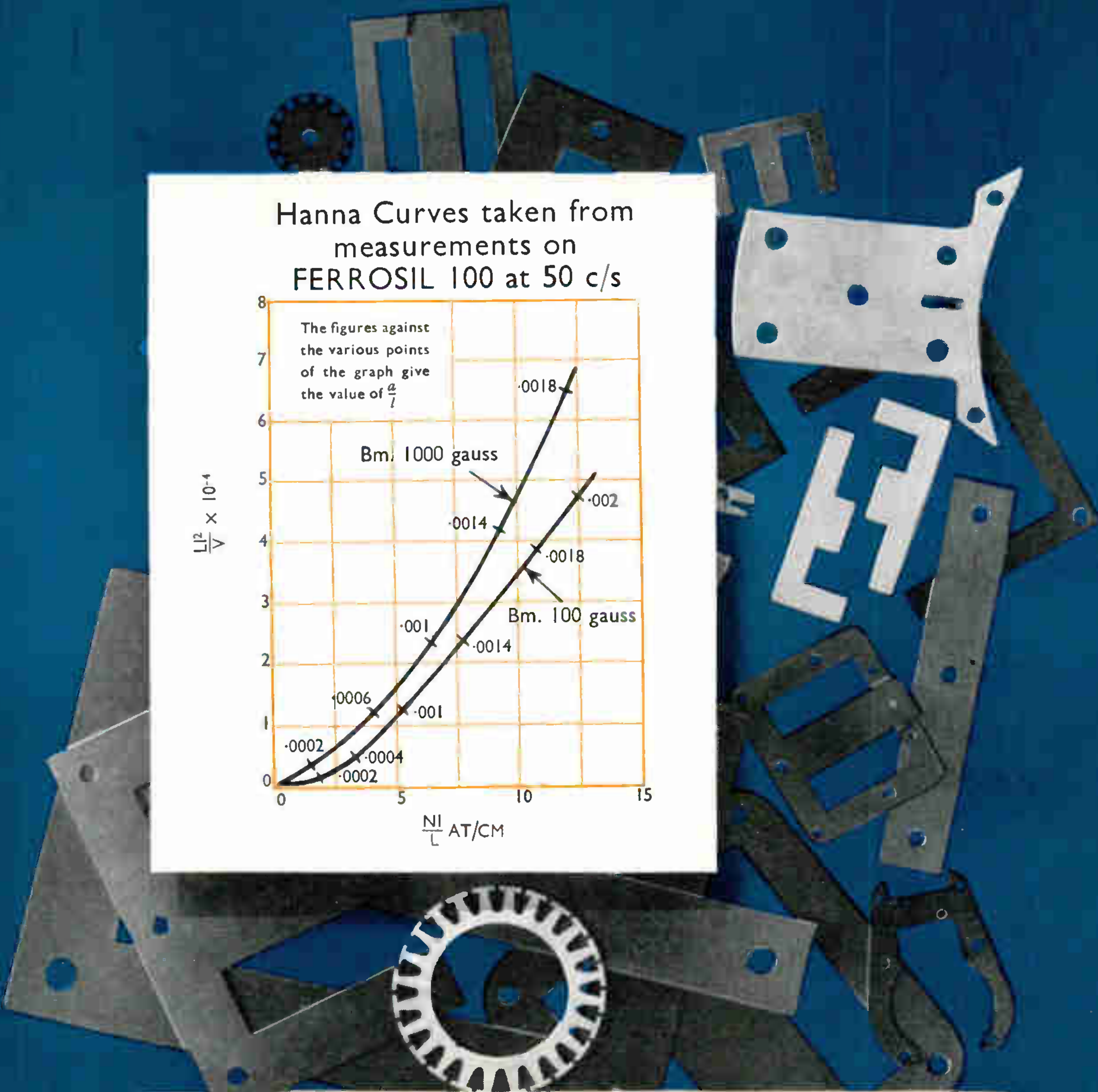

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Maximum output current (mean)	30mA	15mA	60mA	30mA	100mA	60mA	120mA	90mA	250mA	125mA	300mA	150mA
Maximum input voltage (r.m.s.)	125V		125V		125V		125V		250V		250V	
Maximum peak inverse voltage	350V		350V		350V		350V		700V		700V	
Max. instantaneous peak current	Unlimited		Unlimited		Unlimited		Unlimited		Unlimited		Unlimited	
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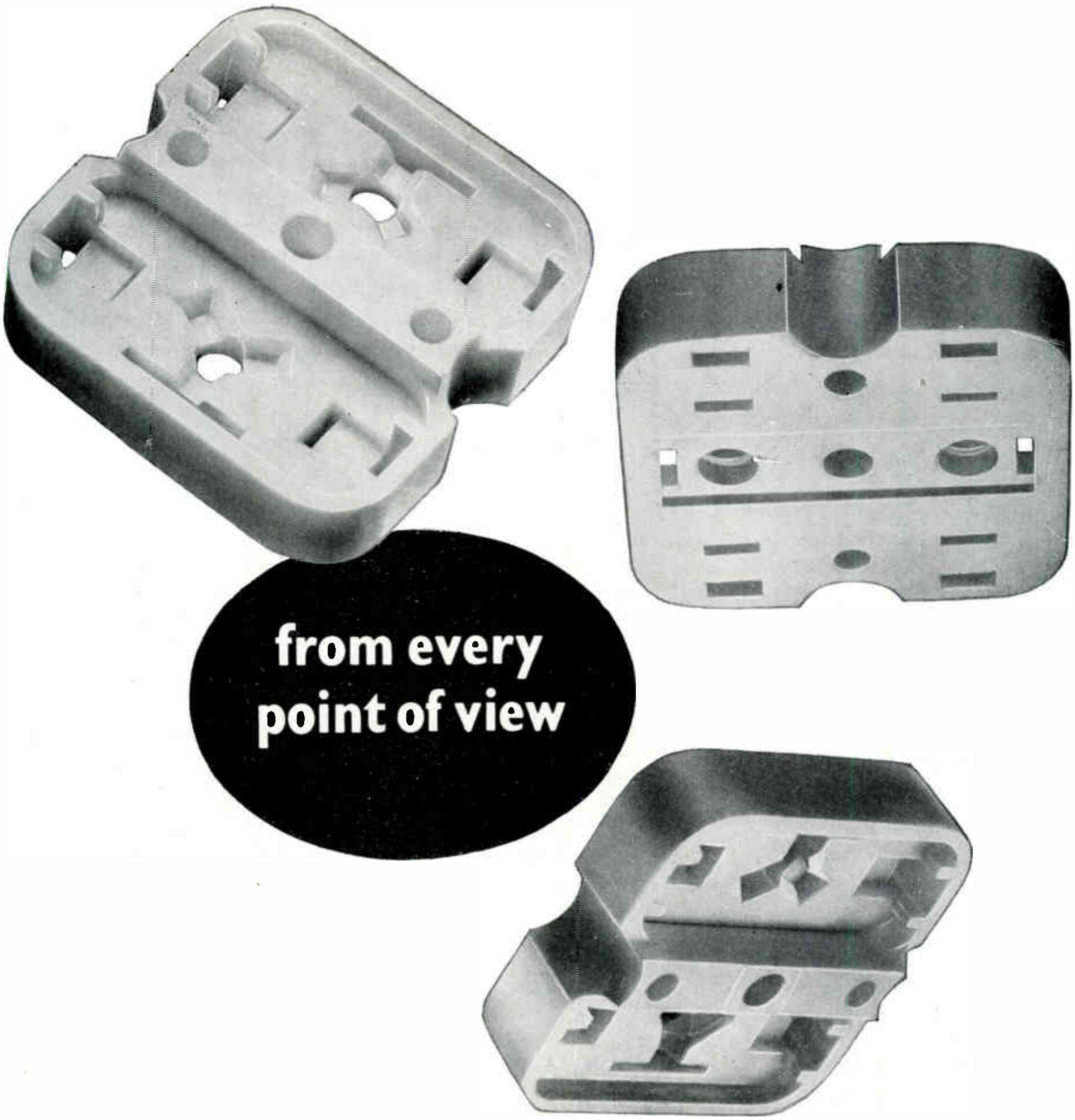
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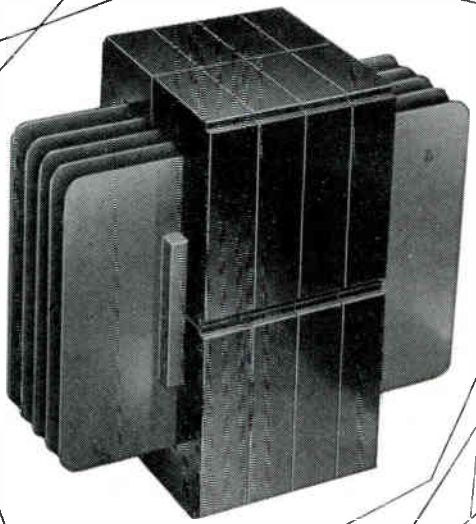

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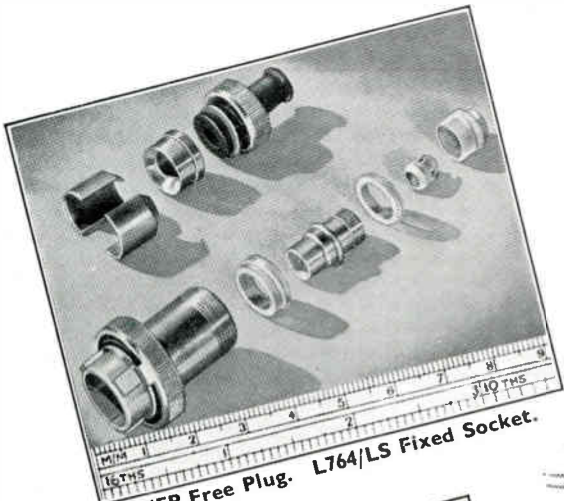
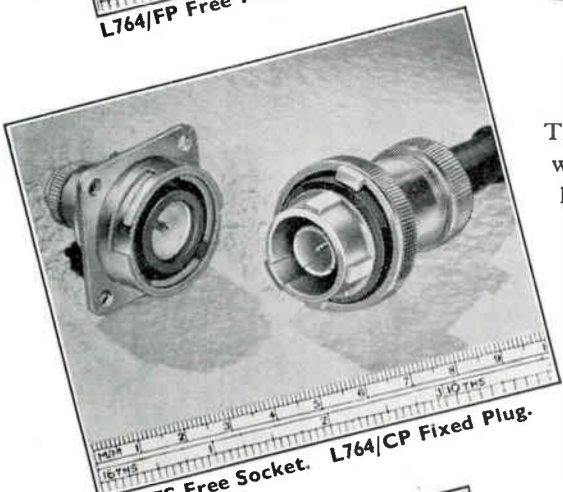
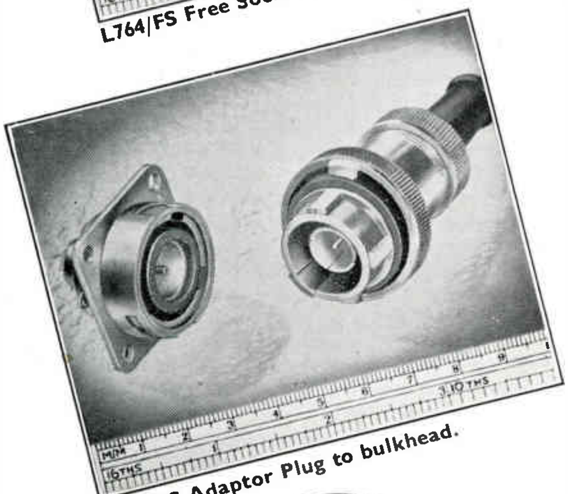


L764/FP Free Plug. L764/LS Fixed Socket.



L764/FS Free Socket. L764/CP Fixed Plug.



L764/BS Adaptor Plug to bulkhead.

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Centre contacts are hard gold plated and the complete internal assemblies are interchangeable in their housings. Cable clamping nuts are incorporated in both fixed and free members. In addition the free members have a rubber gland entry. The adaptor bulkhead has two sockets ; one for L.764/FP; the other, through chassis, to take a standard coaxial plug (L.734/P or L.781/P).

Working voltage—pin/screen, and screen/housing: 500 volts peak. *Insulation resistance (500 volts d.c.) :* 50,000 megohm min. *current rating (continuous) :* 3 amp. max. *Contact resistance, all poles after sizing :* Less than 5 milliohm. *Characteristic impedance :* 70 ohms. *Engagement force :* 12 lb. max. Withstands Specification R.I.C. 322 vibration tests.

The housings are supplied also with 2, 3, 4, 6 and 12-pole assemblies, and are then known as 'Multipole' plugs and sockets.

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WIRELESS ENGINEER

Vol. 33 AUGUST 1956 No. 8

DISC-SEAL TRIODE AMPLIFIERS

By G. Craven

(Standard Telecommunication Laboratories, Enfield)

SUMMARY.—The design of a resonant π-type coupling network for disc-seal triodes operating in the earthed-grid connection at frequencies in the range 300–3,000 Mc/s is considered. A coaxial form of line is adopted. Tuning for a small range can be by a "screw" or, for a larger range, by a built-in capacitance.

Complete amplifiers can give 100-W output and 30-dB gain using three stages.

Introduction

DISC-SEAL, or planar-element, triodes are commonly used as amplifiers in the frequency range 300–3,000 Mc/s and may be regarded as intermediate between conventional valves, employed at lower frequencies, and the velocity-modulation types found necessary at still higher frequencies. As is appropriate to this frequency range, the associated circuitry is provided by rigid coaxial lines, the valve being so constructed that, electrically, it can be made an integral part of the line. The common-grid (earthed-grid) type of circuit is generally employed, the input and output circuits being tuned to resonance by adjusting the length of the line so that, electrically, it is some odd multiple of a quarter wave. Radio-frequency power is introduced and abstracted by probes or loops that are connected to flexible coaxial lines. By providing feedback the amplifier may be readily converted to an oscillator. Examples of the circuitry and general construction are to be found in the literature[1,2].

Though capable of good performance, amplifiers of this type have a number of disadvantages, particularly where a multistage amplifier is contemplated. The number of adjustments per stage is excessive, the plunger contacts are troublesome and the complete amplifier is unnecessarily large. This is difficult to avoid if a large tuning range is needed. However, if only limited frequency coverage is required radical improvement is possible. The plunger tuning may be eliminated and replaced by some type of

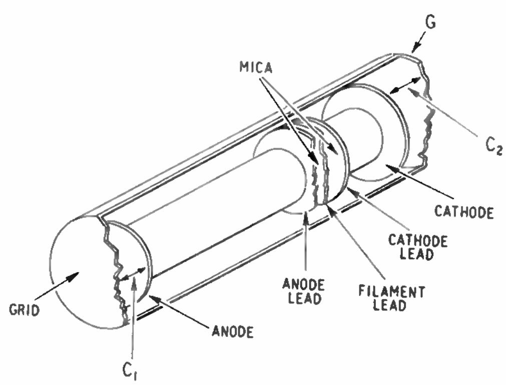

Fig. 1. *Basic construction of half-wave resonant line for disc-seal triode.*

capacitive arrangement. Then, provided a suitable interstage network is employed, the multistage amplifier can be constructed as an integral unit and considerable simplification obtained.

A coupling network for disc-seal triodes should have the following properties:—a large impedance transformation with good efficiency (the output and input impedances of driver and driven valve may easily be 10,000 ohms and

MS accepted by the Editor, September 1955

50 ohms, respectively); wide bandwidth; simple construction; and the introduction of power-supply leads and forced-air cooling should not affect the circuit operation.

A network that fulfils these requirements in some degree is that based on a half-wave resonant line, as shown in Fig. 1. Though normally of unity transformation, capacitive end-loading modifies this greatly; it may, like its lumped-circuit analogue, the resonant π, approach an impedance ratio determined by the square of the capacitance ratio. The maximum bandwidth obtainable with this circuit depends on a number of things but chiefly the anode–grid capacitance and anode-load resistance. Practical features include the introduction of power-supply leads and, where necessary, forced-air cooling at the voltage node point. Where forced cooling is not required the inner conductor provides a mass of metal in contact with the anode to limit rapid temperature changes. Suitably sized holes may be drilled in the outer conductor to permit air circulation. Exact tuning to resonance may be made by a capacitive screw parallel to the electric field at the high impedance end. Where operation over a wider range of frequencies is required a larger variable capacitance, as shown in Fig. 2, can be used. This design has the advantage of eliminating moving contacts. The greater coverage is obtained at the expense of bandwidth.

Analysis

Useful design equations can be derived by solving the circuit equations for the network, redrawn in Fig. 3. The A matrices for these four-poles connected in tandem, assuming a lossless transmission line, are:

$$\begin{Vmatrix} V_1 \\ I_1 \end{Vmatrix} = \begin{Vmatrix} 1 & 0 \\ jB_1 & 1 \end{Vmatrix} X \begin{Vmatrix} \cos\theta & jZ_0\sin\theta \\ j(\sin\theta)/Z_0 & \cos\theta \end{Vmatrix} X \begin{Vmatrix} 1 & R \\ jB_2 & jRB_2 + 1 \end{Vmatrix} X \begin{Vmatrix} V_2 \\ I_2 \end{Vmatrix} \quad .. \quad .. \quad (1)$$

where θ = electrical length of the transmission line: $= \frac{2\pi L}{\lambda}$;

L = physical length

λ = free-space wavelength

$B_1 = \omega C_1$; $B_2 = \omega C_2$; Z_0 = characteristic impedance of line as drawn in Fig. 3.

R = valve input resistance, $V_2 = 0$

Multiplying these matrices, beginning from the right:

$$\begin{Vmatrix} V_1 \\ I_1 \end{Vmatrix} = \begin{Vmatrix} 1 & 0 \\ jB_1 & 1 \end{Vmatrix} X \begin{Vmatrix} (\cos\theta - Z_0B_2\sin\theta) & [jZ_0\sin\theta + R(\cos\theta - Z_0B_2\sin\theta)] \\ j[(\sin\theta)/Z_0 + B_2\cos\theta] & [jR(\sin\theta)/Z_0 + \cos\theta(1 + jRB_2)] \end{Vmatrix} X \begin{Vmatrix} V_2 \\ I_2 \end{Vmatrix} \quad (2)$$

Completing the multiplication and taking the A_{22} term only we have:

$$I_1/I_2 = \cos\theta - Z_0B_1\sin\theta + jR[\cos\theta(B_1 + B_2) + \sin\theta\,(1/Z_0 - Z_0B_1B_2)] \quad .. \quad .. \quad (3)$$

The conditions for resonance may be obtained by equating $-B_1$ to the susceptance seen to the right of it in Fig. 3. The admittance, Y, to the right of B_1 is given by A_{22}/A_{21} in the right-hand matrix of (2); i.e.,

$$Y = \frac{jR\{(\sin\theta)/Z_0 + B_2\cos\theta\} + \cos\theta}{jZ_0\sin\theta + R(\cos\theta - Z_0B_2\sin\theta)} \quad .. \quad (4)$$

Rationalizing, and taking the imaginary part only, for resonance,

$$-B_1 = \frac{(\sin\theta + Z_0B_2\cos\theta)(\cos\theta - Z_0B_2\sin\theta)/Z_0 - Z_0(\sin\theta\cos\theta)/R^2}{(\cos\theta - Z_0B_2\sin\theta)^2 + Z_0^2(\sin^2\theta)/R^2} \quad .. \quad .. \quad (5)$$

Substituting for B_1 in (3) and simplifying

$$I_1/I_2 = \frac{\cos\theta - Z_0B_2\sin\theta + jZ_0(\sin\theta)/R}{(\cos\theta - Z_0B_2\sin\theta)^2 + Z_0^2(\sin^2\theta)/R^2} \quad .. \quad .. \quad (6)$$

or calling T, the current transformation I_2/I_1 at resonance we have

$$|I_2/I_1|^2 = T^2 = (\cos\theta - Z_0B_2\sin\theta)^2 + Z_0^2(\sin^2\theta)/R^2 \quad .. \quad .. \quad (7)$$

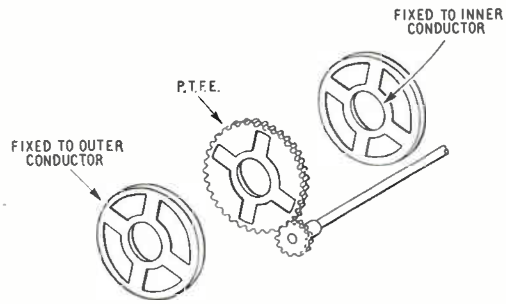

Fig. 2. *A variable capacitance in coaxial circuit.*

Design of Network

The design of a network requires equations (5) and (7). Generally, the practical problem is to obtain a specified transformation at a given frequency, in which case the equations must be rearranged in terms of whatever variables are chosen. Though four are available—Z_0, θ, B_1 and B_2—only three are really suitable, since large variations in the characteristic impedance, Z_0, are not practicable. The susceptances, B_1 and B_2, in conjunction offer the greatest design flexibility, since for a given transformation, the electrical length, θ, may then be any value less than a certain maximum, the shorter lengths being obtained with decreased bandwidth. The second and third cases occur when θ is employed in conjunction with either B_1 or B_2.

In obtaining simple design equations for the various cases it is helpful to make the approximation that both the resonant frequency, f, and transformation, T, are unaffected by the load resistance, R. Generally this will lead to only small error because, in the range of frequencies considered, the reactance of valve inter-electrode capacitances is such as to make the circuit a resonant device of reasonably high loaded Q. Where desired, the values obtained from the approximate equations may be substituted in the exact equations and better approximations obtained. However, this should not generally be necessary. Discarding the terms containing R in (5) and (7) we have:

$$-B_1 = \frac{\sin\theta + Z_0B_2\cos\theta}{Z_0(\cos\theta - Z_0B_2\sin\theta)} \quad .. \quad (5a)$$

and $$T = \cos\theta - Z_0B_2\sin\theta \quad .. \quad .. \quad (7a)$$

or $$-B_2 = \frac{T - \cos\theta}{Z_0\sin\theta}$$

Since $B_1 = \omega C_1$ and $B_2 = \omega C_2$ the design capacitances are:

$$-C_2 = \frac{T - \cos\theta}{\omega Z_0\sin\theta} \quad .. \quad .. \quad .. \quad (8)$$

$$-C_1 = \frac{\sin\theta + Z_0\omega C_2\cos\theta}{\omega Z_0 T} \quad .. \quad (9)$$

In designing the network an experimental value of θ is chosen and the current transformation, T, decided on (its sign will be negative). Equ. (8) is then solved and the result substituted in (9). If too large a value of θ is chosen, capacitance values that are zero or negative will be obtained. This method has its main application at the lower frequencies when it is desired to restrict the length of an amplifier by adding capacitances in shunt with the valve capacitances.

The case where the length, θ, is a parameter in conjunction with either C_1 or C_2 remains to be considered. The choice between C_1 and C_2 as the other parameter depends on practical considerations: the current transformation, T, required, the anode–grid capacitance of the driver valve, and the cathode–grid capacitance of the driven valve. Usually, the input capacitance of the latter will not be high enough to obtain the desired transformation, even when the driver valve output capacitance is quite small. In this case C_2 must be considered as the parameter to be employed with θ. Less frequently, if the required transformation is small and the input capacitance of the driven valve high, C_1 must be considered as the variable to be used with θ. Taking Equs. (5a) and (7a) and eliminating Z_0B_2 from their sum,

$$\cos\theta - Z_0B_1\sin\theta = 1/T$$

or $$\theta = \cos^{-1}\{(\cos\phi)/T\} - \phi \quad .. \quad .. \quad (10)$$

where $\phi = \tan^{-1} Z_0B_1$

Similarly, when θ and C_1 are the parameters:

$$\theta = \cos^{-1}(T\cos\psi) - \psi \quad .. \quad .. \quad (11)$$

where $\psi = \tan^{-1} Z_0B_2$

Equs. (10) and (11) give the maximum line length, in each case, which can provide the desired transformation and, since the minimum necessary capacitance is added, the widest bandwidth obtainable with this network. The value of C_2 or C_1 is of course obtained as before in Equs. (8) and (9), respectively.

One additional piece of information is required for constructional purposes: the position of the voltage node. Power supply leads may be introduced at this point which, since C_1 and C_2 are presumed unequal, is displaced from the centre. Calling the line lengths (to C_1 and C_2) on either side of the node θ_1 and θ_2, each combination θ_1C_1, θ_2C_2, as seen from the nodal point, must be series resonant; i.e. the susceptance is,

$$\tan(\theta_1 + \tan^{-1} Z_0B_1)/Z_0 = \infty \quad .. \quad (12)$$

$$\tan(\theta_2 + \tan^{-1} Z_0B_2)/Z_0 = \infty \quad .. \quad (13)$$

The distance at which the node occurs from the particular terminating capacitor is then:

$$\theta_1 = \pi/2 - \tan^{-1} Z_0B_1 \quad .. \quad .. \quad (12a)$$

$$\theta_2 = \pi/2 - \tan^{-1} Z_0B_2 \quad .. \quad .. \quad (13a)$$

Either (12a) or (13a) may be used.

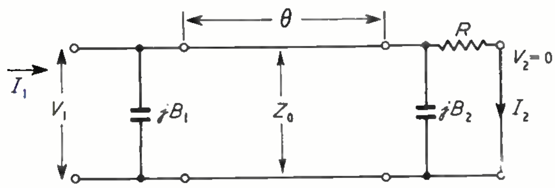

Fig. 3. *Equivalent circuit of half-wave line and valve.*

Example

A valve with an effective anode–grid capacitance of 3 pF, and requiring an anode load of 2,500 ohms, is to drive a valve with an input resistance of 100 ohms, and an effective cathode–grid capacitance of 10 pF. The design frequency is 300 Mc/s. There are no severe restrictions on length.

First, a suitable characteristic impedance must be chosen. Low values of Z_0 require a large value of θ, without any compensating advantage, while a high value of Z_0 results in large outer conductors. Choosing an intermediate value, let $Z_0 = 50\ \Omega$.

The transformation, T, required is,

$$T = -\sqrt{\frac{2500}{100}} = -5.$$

Since the amplifier may be of any reasonable length, θ may be used as a parameter in conjunction with a capacitance at either end.

Let $C_1 = 3{\cdot}5$ pF (this permits a small variable capacitance to obtain exact tuning).

θ and C_2 are to be found.

Substituting for ϕ in (10)

$$\theta = \cos^{-1}\{-(\cos 18{\cdot}25°)/5\} - 18.25°$$
$$\theta = 82{\cdot}7° \text{ or } L = \theta\lambda/2\pi = 23 \text{ cm}.$$

Substituting for θ in (8)

$$C_2 = 54{\cdot}9 \text{ pF}$$

Since the cathode–grid capacitance is 10 pF an additional 44·9 pF is required in shunt with it. Capacitances of this type are conveniently constructed from a section of very low characteristic impedance line, the equivalent capacitance, C, being given, for short lengths by:

$$C = \frac{100L_c}{3Z_{03}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

where C is in pF, Z_{03} is the characteristic impedance and L_c the length of the section in cm. Where necessary, correction for the discontinuity susceptance[3] may be made.

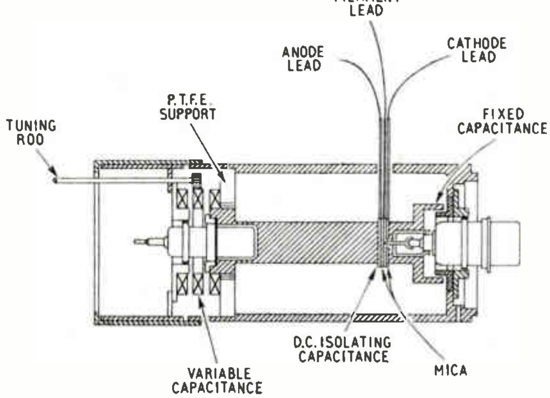

Fig. 4. *Detailed construction of line.*

Continuing with the example, the voltage node occurs at a distance θ_2 from C_2:

$$\theta_2 = \pi/2 - \tan^{-1} Z_0\omega C_2 = 10{\cdot}9°$$

or 3·0 cm from C_2.

The error resulting from neglecting the resistance terms in (5) and (7) may now be checked. Substituting for θ and C_2 we have the corrected values: $T = -5{\cdot}03$ and $C_1 = 3{\cdot}53$ pF, which is a negligible error.

The constructional details of a typical amplifier are shown in Fig. 4, which is an example of a design where the length has been reduced by increasing C_1 and C_2 beyond the minimum required to obtain the desired transformation. The variable capacitance, which contributes the major part of C_1, is of the type shown in Fig. 2. The inner conductor is supported at the driver valve end by a polytetrafluorethylene (P.T.F.E.) ring and at the other end by a fixed capacitance (the major part of C_2), which is free to move small amounts longitudinally, in order to take up expansion effects. Generally speaking, polythene insulation is to be avoided at the anode end of the line on account of the high operating temperatures. Power-supply leads are taken out at the zero potential point and, if the capacitance shown is of adequate value, additional by-passing external to the unit is not needed. If fixed bias is preferred to cathode bias, the usual type of annular grid capacitance may be constructed. However, this represents a common impedance between input and output circuits which can sometimes be troublesome. An additional point evident from Fig. 4 is that the external fixed capacitance at the cathode is not in shunt with the valve cathode–grid capacitance, but separated from it by a short section of line. In most cases this approximation is unlikely to lead to serious error. However it may be necessary to take it into account at the higher frequencies. Under these circumstances the input resistance and capacitance employed in the design equations are the equivalent values seen at the plane of the cathode terminal of the valve.

Conclusions

The network should be useful throughout the range of frequencies in which disc-seal triodes are applicable: about 300–3,000 Mc/s.

The transformation ratio tends, for large values of C_0, to $T = -\frac{C_2}{C_1}$; hence almost any desired transformation can be obtained. Dissipative loss is the practical limitation, but as this is quite small in coaxial line networks it should not constitute a serious restriction.

Throughout the paper reference to disc-seal triodes has been made exclusively. However, where suitable tetrodes are available the application is obvious. Generally, the transformation required should be less.

The type of construction shown in Fig. 4

readily lends itself to multistage amplifiers in which any number of stages can be built as a relatively compact integral unit. For example a three-stage amplifier of 30 dB gain, 100-watt output, operating at the low-frequency end of the 300–3,000 Mc/s range was approximately 13 in. long and 5 in. diameter.

The bandwidth obtainable can be found from equations derived in the appendix. Experience indicates that it is sufficient for a great many purposes. Where larger bandwidths than can be obtained with this network are required a coaxial construction based on Shea's impedance transforming filter is to be preferred[4].

Acknowledgments

The writer wishes to thank Electrical and Musical Industries for permission to publish this paper; also Mr. K. D. Mills, now of Canadian Westinghouse, Hamilton, Ont., for many helpful discussions on disc-seal triode amplifiers.

APPENDIX

Bandwidth

The frequency band over which the transformation is substantially constant can be calculated with the aid of Equ. (3). As discussed in the text the imaginary part of this equation is practically zero at resonance and so, if we define the cut-off frequencies as those at which the real and imaginary parts are equal, we have:

$$R\left[B_1\left(\frac{\cos\theta + (\sin\theta)/Z_0B_1}{\cos\theta - Z_0B_1\sin\theta}\right) + B_2\right] = \pm 1 \quad \ldots \quad (15)$$

or

$$R[\tan(\theta+\phi)/Z_0 + B_2] \pm 1 = 0 \quad \ldots \quad \ldots \quad (16)$$

where the notation is the same as that employed in (1) and (10).

Since the angular frequency, ω, is contained in θ, ϕ and B_2 the solution is rather tedious and an approximation giving the bandwidth directly is useful.

Putting $\omega = \omega_0(1+\delta)$, where ω_0 = angular resonant frequency, and substituting in (16)

$$R\left[\frac{\tan\left\{L\omega_0(1+\delta)/c + \tan^{-1}Z_0C_1\omega_0(1+\delta)\right\}}{Z_0} + \omega_0C_2(1+\delta)\right] \pm 1 \approx 0 \quad \ldots \quad \ldots \quad (17)$$

where L and c are the line length and velocity of light, respectively.

Assuming δ small ($\delta\tan\theta \approx \delta\theta$) and $\omega_0C_1Z_0$ a small angle, we have, expanding and neglecting δ^2 terms

$$R\left\{\frac{1}{Z_0}\left[\tan\left(\frac{\omega_0L}{c}+\tan^{-1}Z_0\omega_0C_1\right)+\delta\omega_0\left(\frac{L}{c}+Z_0C_1\right) + \delta\omega_0\left(\frac{L}{c}+Z_0C_1\right)\tan^2\left(\frac{\omega_0L}{c}+\tan^{-1}Z_0\omega_0C_1\right)\right] + \omega_0C_2+\delta\omega_0C_2\right\}$$
$$\pm 1 \approx 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (18)$$

And since $\left\{\tan(\omega_0L/c + \tan^{-1}Z_0\omega_0C_1)\right\}/Z_0 + \omega_0C_2 = 0$ and the response about resonance, to the order considered, is symmetrical we have:

$2\delta\omega_0/2\pi = 2\delta f$ = bandwidth

$$\approx \frac{1}{\pi R[\{L/cZ_0+C_1\}\{1+\tan^2(\omega_0L/c+\tan^{-1}Z_0\omega_0C_1)\}+C_2]} \quad \ldots \quad \ldots \quad (19)$$

Substituting the values from the example in the text in this equation gives: bandwidth = 5·5 Mc/s which is less than 10 per cent in error compared with the result obtained by trial solution of (16).

The main factors affecting bandwidth are evident from Equs. (16) and (19). The term in the square brackets of (16) is zero at resonance; hence for large values of B_2, tan $(\theta+\phi)$ is also large and this adversely affects bandwidth, (19). Obviously a narrow bandwidth results from a large transformation and both high anode load resistance and capacitance [these all lead to large values of tan $(\theta+\phi)$]. Similarly, (16) shows that high values of Z_0 increase bandwidth so that where the latter is important the highest characteristic impedance consistent with reasonable dimensions should be chosen.

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KLYSTRON CONTROL SYSTEM

By R. J. D. Reeves

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(Concluded from p. 167, July issue)

Part 3 (contd.)—Specimen Design for A.F.C. Frequency-Control Loop as a Sampling Servo

THE behaviour of the frequency-control loop as a sampling servo may be investigated without considering the influence of the mode-centring loop, to which it is implicitly coupled through the klystron. This is permissible because we can confine the interpretation of the results to that part of the error-frequency spectrum which is outside the province of the mechanical control or, alternatively, we can postulate that the magnitude of the reflector-voltage deviations that occur produce insufficient mode-centring errors to energize the centre-stable polarized relay in the motor circuit.

In this analysis the method of the z transform will be used whereby the substitution

$$z = \epsilon^{p\tau} \quad \ldots \quad (12)$$

is employed, τ being the repetition period.

From Equ. (9)

$$E_5 = -\frac{1}{kC}\frac{\alpha}{p(p+\alpha)}(I_A - I_B) \quad \ldots \quad (13)$$

where $\alpha = 1/CR$

From the z transform tables of Barker[2] the pulse transfer function (p.t.f.) of this control circuit is:

$$W(z) = -\frac{m\tau}{kC}\cdot\frac{(1-d)z}{(z-1)(z-d)} \quad \ldots \quad (14)$$

where $d = \epsilon^{-\tau/CR}$

and the duty ratio m is introduced so that I_A and I_B can be given their direct-current values.

Now if $I_A - I_B$ is considered to be related to the Miller output voltage increments by a constant transfer conductance β then the complete loop p.t.f. is:

$$W_l(z) = -\frac{m\beta\tau}{kC}\cdot\frac{(1-d)z}{(z-1)(z-d)} \quad \ldots \quad (15)$$

and the external p.t.f. of the feedback system is:

$$W_f(z) = \frac{W(z)}{1 - W_l(z)}$$

$$= -\frac{m\tau}{kC}\frac{(1-d)z}{z^2 - (1+d)z + d + \frac{m\beta\tau}{kC}(1-d)z} \quad \ldots \quad (16)$$

The characteristic function $Q(z)$ is:

$$z^2 + \left\{\frac{m\beta\tau}{kC}(1-d) - (1+d)\right\}z + d \quad (17)$$

Since the substitution (12) transforms the left-half p-plane to the interior of unit circle in the z-plane, the stability criterion requires all roots in the z plane to have a modulus less than unity.

This is succinctly expressed by the triad:

$$Q(1) > 0, \; Q(-1) > 0, \; Q(0) < 1 \quad \ldots \quad (18)$$

Only the second of these is non-trivial here. In this,

$$1 + (1+d) + \frac{m\beta\tau}{kC}(d-1) + d \text{ to be } > 0$$

or $$2(1+d) + \frac{m\beta\tau}{kC}(d-1) > 0$$

or $$\frac{m\beta\tau}{kC} < 2\frac{1+d}{1-d}$$

i.e., $$\beta < \frac{2kC}{m\tau}\cdot\frac{1+\epsilon^{-\tau/CR}}{1-\epsilon^{-\tau/CR}} \quad \ldots \quad (19)$$

Substituting the values from Fig. 13 we have:

$\tau/CR = 1$; $kC = 0{\cdot}002\ \mu$F;
$\tau = 500\ \mu$sec; $m = 0{\cdot}001$;

therefore, for stability, β must be less than 17 mA/V. The factor β is the product of a number of transfer functions many of which cannot be held particularly constant, so that it is desirable to work with a nominal value very much less than that stability limit. If the loop gain variation can be assessed then a maximum safe value for β can be computed.

It should be noted that in a comprehensive a.f.c. system of this type, it can be assumed that the reflector is working at mode centre, and the modulation coefficient in Mc/s per volt is not subject to variations due to permanent deviations from the centre. This removes one source of variations in β.

Further insight into the behaviour of the control loop may be obtained by finding the largest value of β which may be employed without over-correction; i.e., the critically-damped condition. The criterion for this is that the characteristic equation shall exhibit a double root on the real p-axis, and as the transformation (12) maps the real p-axis on to the positive half of the real z-axis, the characteristic equation in z [$Q(z) = 0$] will exhibit a corresponding double root.

$Q(z)$ is quadratic in z and has equal real roots when:

$$\left\{\frac{m\beta\tau}{kC}(1-d) - (1+d)\right\}^2 = 4d$$

i.e.,

$$\left(\frac{m\beta\tau}{kC}\right)^2 - 2\left(\frac{1+d}{1-d}\right)\frac{m\beta\tau}{kC} + 1 = 0 \qquad (20)$$

This is quadratic in β and, when the previously assumed values of τ and kC are substituted, the solutions are:

$\beta = 16{\cdot}3$ or $1{\cdot}0$

The first of these is near the stability boundary previously determined by equation (19) but it is the lower value of β which corresponds to a positive real root of $Q(z)$ and signifies critical damping.

The onset of ringing here has little to do with the sampling process but is a consequence of the fact that the loop is dominated by an integrator and one time constant. A similar loop with an attenuator m substituted for the sampling switch would also start to ring at approximately this value of β. Clearly, the extraneous time constant is not desirable if it is necessary to work near the shortest possible correction time compatible with the repetition time but, in this case, the repetition frequency is rather high (2 kc/s) and in the design of the system the correction rate was not a point at issue. Moreover, loop ringing from this cause is not an indication of approaching instability nor, in moderation, is it an undesirable property in an a.f.c. loop; so it is by no means essential to restrict β to values less than this. Taking $\beta = 1$ as a nominal design centre, the external pulse transfer function simplifies to:

$$W_f(z) = \frac{m\tau}{kC}\frac{(1-d)z}{(z-\sqrt{d})^2} \quad \cdot\cdot \quad \cdot\cdot \quad (21)$$

and this responds to unit impulse and unit step in the manner shown in Fig. 24.

If the time constant were eliminated, for example by interposing a cathode follower between the difference circuit and the Miller integrator, then it would be possible to improve the response time by a factor of two before approaching sampling limitations.

Mode-Centre Discriminator Characteristic

Unlike the frequency discriminator, the factors contributing to the pull-in characteristic of the mode-centring system are to a considerable extent outside design control. The mode shape has to be accepted per se and the sinusoid amplitude which, together with the mode width determines the capture range, needs to be as large as possible with due regard to the risk of pulling on to an adjacent mode during warm-up. A suitable amplitude for use with the R5222 klystron has been found to be about two mode widths (approximately 80 V) peak-to-peak. By assuming a parabolic form for the mode shape, an expression can be derived for the discriminator characteristic which should be reasonably descriptive of that actually realized, provided the crystal-current amplifier is a linear one and provided adjacent modes are spaced by at least two mode widths and do not oppose the pull in.

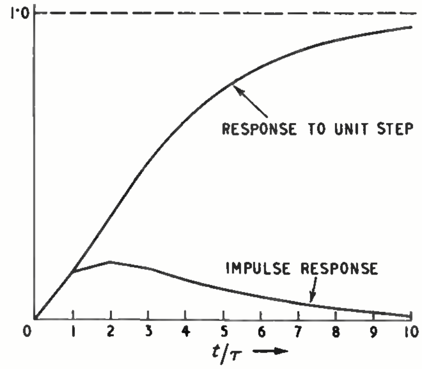


Fig. 24. *Computed transient response of frequency control loop.*

As described in Part 2, the mechanism of the discriminator is to project the mode shape on to a time scale in order that it may be operated on by a time discriminator. For the purpose of analysis, however, this process may be inverted and the time gates projected on to the voltage scale so as to eliminate the time variable. The relation between time and voltage is the sinusoid:

$$V = -V_s \sin \omega t$$
$$0 < t < 2\pi/\omega \quad \cdot\cdot \quad \cdot\cdot \quad \cdot\cdot \quad (22)$$

and it is clear that the early and late gates represent adjoining voltage intervals of length V_s with confluence at the mean reflector potential. But the integrating process in the time discriminator is carried out with respect to time, which is not linearly related to the reflector potential scale. The transformation is characterized by a weighting function derived from (22)

Thus $dV = \omega V_s \cos \omega t \, dt$

$$\text{or} \qquad dt = \frac{dV}{\omega V_s\sqrt{1 - V/V_s}} \quad \cdot\cdot \quad \cdot\cdot \quad (23)$$

The ω and V_s are scale factors; it is the term under the radical which influences the shape of the characteristic. As in the case of a pulsed frequency discriminator, the overall discrimination characteristic is not that of the discriminator itself but the product of the discriminator and the input 'spectrum', and the weighting function just derived acting on a parabolic mode produces a discrimination characteristic shown as A in Fig. 25.

To derive this, let V_m be the mode span and also the amplitude of the sinusoid; i.e., $V_s = V_m$. The effective discriminator law $f_1(V)$ is given by:

$$f_1(V) = \left.\begin{array}{ll} 0 & V < -V_m \\ (1 - V^2/V_m^2)^{-\frac{1}{2}} & -V_m < V < 0 \\ -(1 - V^2/V_m^2)^{-\frac{1}{2}} & 0 < V < V_m \\ 0 & V_m < V \end{array}\right\} \quad (24)$$

The mode shape is:

$$f_2(V) = \begin{cases} 0 & V < -V_m/2 \\ 1 - 4V^2/V_m^2 & -V_m/2 < V < V_m/2 \\ 0 & V_m/2 < V \end{cases} \quad (25)$$

The voltage scale can be normalized by putting $V/V_m = x$, and a misalignment variable μ introduced such that

$$\mu = \Delta / V_m \quad \ldots \quad \ldots \quad \ldots \quad (26)$$

where Δ is the voltage displacement between the reflector and mode centre.

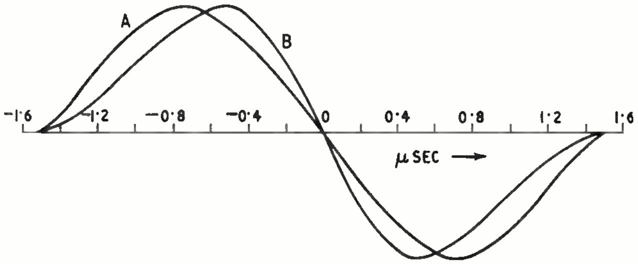


Fig. 25. *Computed characteristic of mode centre discriminator.*

Reference will now be made to Fig. 26.

$$F_1(x) = \frac{1}{\sqrt{(1 - x^2)}} \text{ or } 0 \quad \ldots \quad \ldots \quad (27)$$

$$F_2(x) = \begin{cases} 0 & x < \mu - \tfrac{1}{2} \\ 1 - 4(x - \mu)^2 & \mu - \tfrac{1}{2} < x < \mu + \tfrac{1}{2} \\ 0 & \mu + \tfrac{1}{2} < x \end{cases} \quad (28)$$

The integrated product of these two curves is a function of μ and can be obtained in two parts, depending on whether μ is greater or less than $\tfrac{1}{2}$

$$\text{Centre:} \quad \int_{\mu - \frac{1}{2}}^{0} \frac{1 - 4(x - \mu)^2}{\sqrt{1 - x^2}} dx - \int_{0}^{\mu + \frac{1}{2}} \frac{1 - 4(x - \mu)^2}{\sqrt{1 - x^2}} dx \quad (29)$$

Valid for $0 < \mu < \tfrac{1}{2}$

$$\text{Skirts:} \quad \int_{\mu - \frac{1}{2}}^{1} \frac{1 - 4(x - \mu)^2}{\sqrt{1 - x^2}} dx \quad (30)$$

Valid for $\tfrac{1}{2} < \mu < 1\tfrac{1}{2}$

The indefinite integral concerned is found to be

$$-(1 + 4\mu^2) \sin^{-1} x + 2(x - 4\mu)\sqrt{1 - x^2} \quad (31)$$

and substituting limits, the centre portion of the discrimination characteristic is given by:

$$\epsilon = -16\mu + (1 + 4\mu^2)\left[\sin^{-1}(\mu - \tfrac{1}{2}) + \sin^{-1}(\mu + \tfrac{1}{2})\right] + (6\mu - 1)\sqrt{\tfrac{3}{4} - \mu - \mu^2} + (6\mu + 1)\sqrt{\tfrac{3}{4} + \mu - \mu^2} \quad \ldots \quad (32)$$

and the skirts by:

$$\epsilon = (1 + 4\mu^2)\cos^{-1}(\mu - \tfrac{1}{2}) - (6\mu + 1)\sqrt{\tfrac{3}{4} + \mu - \mu^2} \quad \ldots \quad \ldots \quad \ldots \quad (33)$$

This is the expression that produces the curve A of Fig. 25.

For comparison, the characteristic curve B that would result from an unweighted voltage discriminator (obtained from a rectilinear mapping waveform) is also drawn. It is seen that the sinusoidal discriminator exhibits a lower error sensitivity at the origin but, due to the weighted extremities, it produces a stronger pull-in signal. Since the main purpose of the large amplitude sinusoid is to accomplish a good pull-in performance this is considered a useful property.

By-Pass Gearbox and Flash-Back Mechanism

Wide-range frequency search is accomplished by the sawtooth motion of the klystron-cavity tuning plunger. When the required frequency is found, the tuning mechanism then forms part of a closed loop and a slower rate of tuning is required to ensure loop stability. To this end a by-pass gearbox has been developed which is effectively equivalent to the slipping-ball epicyclic type of tuning mechanism, and permits two distinct transmission ratios. Fig. 27 illustrates the method employed.

The input pinion (1) is secured to its shaft and transmits the drive through the spur reduction (2), (3), (4) to the output pinion (5). This provides the slow rate of tuning. Also on the shaft is a stack of tab washers, each of which is capable of a certain amount of lost motion before engaging the next one.

The input pinion engages the first of these washers, and sustained rotation in one direction will accumulate all of them until finally torque is transmitted to the ball clutch device (6). This clutch links the direct transmission to the

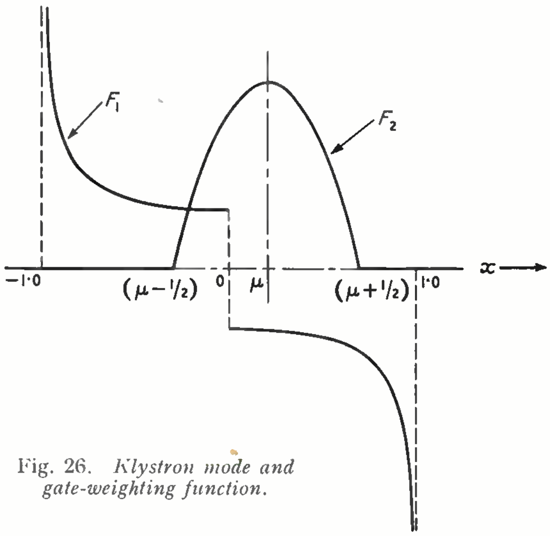


Fig. 26. *Klystron mode and gate-weighting function.*

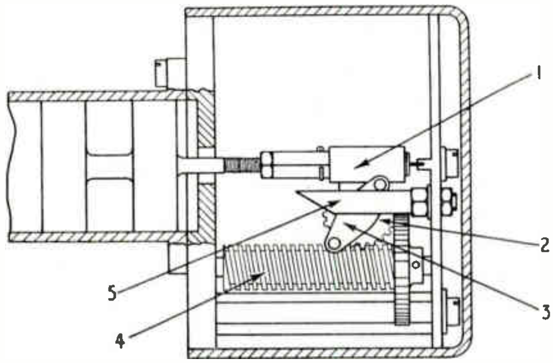
output pinion through two steel balls trapped in conical depressions in the clutch plates. The function of these is to resolve part of the applied torque into an axial thrust in order to push the output pinion out of engagement with gear (4) for the direct drive condition. A reversal of the motor removes this thrust and a return spring (not shown) then causes the output pinion to re-engage gear (4).

The features of this design to notice are that both the spur reduction and the low gear interval (number of tab washers) can be chosen freely, and at no time is excessive friction present in the mechanism. It can therefore be incorporated in small position-control systems without absorbing appreciable power from the motor.

A control system incorporating this type of mechanism exhibits the behaviour characteristic of a manual operation in that a rapid search results in an overshoot followed by a slow and careful approach to the correct setting from the other direction.

This mechanism would be an encumbrance in the search condition if the motor were called upon to reverse at the extremes of the piston travel, for then the low gear interval would have to be traversed before the return sweep could get properly under way. Another consideration which favours unidirectional search is that unless the motor were reversed by reversing the search bias in the control unit, there would be a phase ambiguity when the loop is closed. Consequently a flash-back mechanism has been adopted which simulates the performance of a step cam (with linear stroke), and returns the piston to the start of the sweep without interrupting the motor supply.

The functioning of this device is shown in Fig. 28. The piston is spring loaded against a travelling carriage (1) bearing a pinion (2) and crank (3) coupled together. The pinion engages with the worm (4) so that, as the carriage is pressed back by the piston spring, the crank rotates until one of the two pins it carries engages the peg (5). Rotation of the worm shaft then causes the carriage to travel with the crank pin sliding along the peg and, if the direction of travel is to the left in the figure, the pin approaches the extremity. Beyond this point, the pinion is free to turn and there is nothing to prevent the carriage being returned by the spring until the worm wheel revolves half circle and the other crank pin engages. The pinion diameter therefore determines the stroke. It can be seen that the flash back is a trigger action which does not depend on the motor once it is initiated.



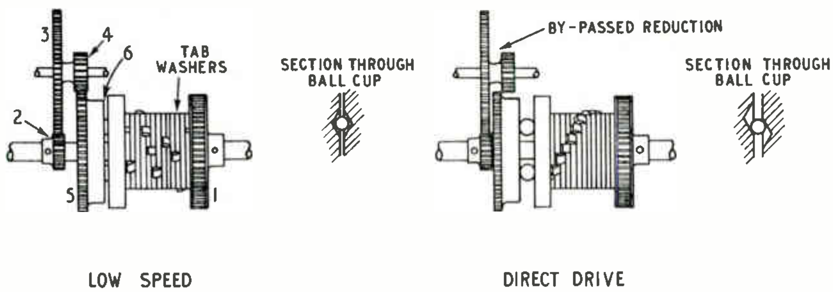
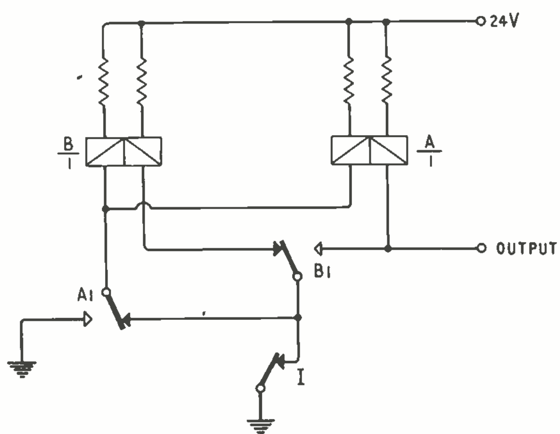


Fig. 27 (left). *By-pass mechanism.*

Fig. 28 (above). *Flash-back mechanism.*

Fig. 29 (below). *Basic scaler circuit.*



Binary Scaler

Because of the policy of employing unstabilized power supplies in the system, it was felt that a scaling circuit using valves might be unreliable. Moreover, the high counting speed afforded by a valve is quite unnecessary here, and so a simple relay scaler was considered to be well worth the introduction of a 24-V supply.

This circuit employs miniature high-speed relays with double-wound armatures and single change-over contacts. The system is basically that of Fig. 29 where I is an independent input contact. The phasing of the coils is such that if both windings are energized, the relay is not operated. The input relay (in this case the lock-on relay) and the two scaling relays together have eight possible states, and in the following table these states are listed in order of transition. The prime denotes the prefix 'not'.

Table of Relay States

	Contact	Armature	
1	I′ A′ B′	A′ B′	
2	I A′ B′	A B′	Inconsistent
3	I A B′	A B′	
4	I′ A B′	A B	Inconsistent
5	I′ A B	A B	
6	I A B	A′ B	Inconsistent
7	I A′ B	A′ B	
8	I′ A′ B	A′ B′	Inconsistent

In the first column, the condition of the contacts is postulated and, in the second, the condition of the armatures is determined by inspection of the circuit. It is seen that half of these are not self-consistent, but the removal of the inconsistency in the contacts leads naturally to the next state. Evidently the mechanism of a scaler is such that the input contact introduces inconsistent or unstable states into the circuit, and the wiring is such that this leads to a new stable state. Of the eight states only two can be stored without the help of the input relay or, what is more to the point here, there are two alternative states when the lock-on relay has operated, namely 3 and 7. In the main circuit diagram, Fig. 13, the lock-on relay is D corresponding to I in the table.

When the equipment is first switched on none of the relays is operated and this is state 1. The first operation of the lock-on relay shifts the scaler to state 3 and, if the loop phasing is suitable it stays there but, if not, the relay D opens and closes again, thus shifting the scaler to state 7. The phase-reversing relay C is so wired to the scaler that the relay is operated in state 7 but not operated in 3, so one or other of these conditions must be suitable for the control system.

Conclusion

The concept of the control plane, introduced for the purpose of describing the properties of a klystron and the behaviour of klystron control systems, has culminated in the construction of a map-painting device, with the aid of which a comprehensive a.f.c. system has been developed. Retention of the 'two-dimensional' outlook in discussing the performance enables one to escape such paradoxes as arise from attempting to associate a particular control with a particular task. It is sufficient to assert that the controls move jointly to annul both types of error. Yet, at the same time, the lack of inertia in the reflector control enables stability problems in two dimensions to be avoided. The velocity lag of the reflector due to the Miller integrator is not sufficient to cause appreciable deviation from the search track or frequency contour on account of the motor velocity, particularly when the extra gear reduction has been brought in. So that, provided the 'target' point is a fixed one, the joint control setting is confined to one or other of these loci.

The salient features of the a.f.c. system which has been described can be summarized as follows:

The fact that a definite relay operation marks the transition from search to follow, lends itself to the 'counting down' method of correcting control loop phase by trial and error. This method is foolproof in the sense that no circumstances can conspire to defeat its successful operation; only definite circuit faults can interfere with it.

The large amplitude sinusoid transient on the klystron reflector ensures easy mode finding, a good centring criterion, and leaves the controls unmodulated at the time when the receiver is being used.

Stabilized supplies are not necessary, because the significant properties of the klystron are under direct control. The supplies should, however, be adequately smoothed.

Finally, the by-pass gearbox concisely solves the difficulties of mechanical tuning by allowing an elementary constant speed on–off servo motor to be used without sacrificing setting accuracy. This mechanism effectively modifies the properties of the motor but does not demand any additional information from the control system.

The system described here is not restricted to a particular class of radar but the components of the discriminator circuits have to be chosen for the particular pulse length and repetition rate in mind.

Related Systems

In the light of this development work, it is possible to envisage more specialized methods of controlling klystrons for a.f.c. which may be attractive in particular circumstances. For example, in the system described above, the sinusoid amplitude is recommended to be about two mode widths peak-to-peak. If it is reduced to something less than a quarter of this magnitude, the system would degenerate to a mode-peak-finding servo with a restricted range of pull-in.

However, once pull-in had occurred it would be true to say that the klystron is frequency modulated with a deviation-time characteristic much the same in shape as the sinusoid itself.

Then, if the sinusoid could be accommodated within the time interval of the transmitted pulse, a similar f.m. transient would be available at the beat frequency (i.f.). This, together with a coherent time discriminator, could operate on a straightforward i.f. amplifier to produce a frequency-discriminator characteristic, thus dispensing with a conventional frequency discriminator altogether. Such an arrangement would have the drawback mentioned above but exhibit the following desirable properties:

The sinusoid would not occupy any of the usable part of the time scale. It could be triggered by the transmitter pulse.

The 'frequency discriminator' would be easier to design and produce than the Weiss or other types.

The discriminator would be coherent with the beat note sign and the binary scaler would be unnecessary.

Of course the use of such a system hinges on the practicability of accommodating the sinusoid 'inside' the transmitter pulse. With a typical i.f. of 30 Mc/s the pulse would need to be at least 2 μsec long to produce a carrier train long enough to frequency modulate.

Another variant of this method places no restriction on the transmitted pulse length but on the other hand severely restricts the rate of tuning-error correction. In this arrangement, the sinusoid is dispensed with altogether and the klystron reflector is modulated instead by a derivative of the transmitter pulse which has been amplitude modulated by a low-frequency sine wave (see Fig. 30). Using this waveform, the neighbourhood of the reflector potential is explored in discrete samples and error information can be extracted from the mode and frequency discriminators after one complete cycle of the sine wave. The time taken to accumulate a sufficient number of sample deviations is evidently proportional to the repetition period and so the system is best suited to radar equipments with high repetition rates. As such radars are essentially short range and therefore usually have short pulses, this a.f.c. system may be considered to be complementary to the previous one described.

Both of the above systems are being investigated. The simpler frequency discriminator and absence of the binary scaler promised an economy in components but, on the other hand, the reduced sinusoid amplitude requires a more sensitive mode-centre discriminator because the crystal-current variations at mode centre are comparatively small. Furthermore, it is desirable to use a separate crystal for mode-centring information when measurements are being performed during the transmitter pulse because the transmitter makes an unwanted contribution to the mixer crystal current at that time.

It may be necessary to augment this discriminator with some form of reflector scanning to restore the mode pull-in range.

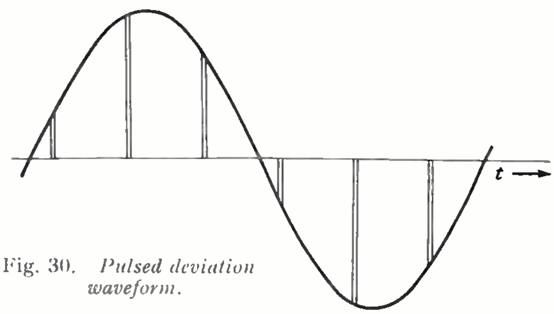


Fig. 30. *Pulsed deviation waveform.*

Acknowledgments

When the development of this system was commenced, the reports of S. Ratcliffe (now published[3]) were already to hand and did much to clarify the problem and unify the diverse opinions at that time. His recommendations constitute a guide to good practice in radar a.f.c. and no contemporary design can be said to be uninfluenced by them.

The method of interconnecting the error circuits and the klystron controls was proposed by V. J. Cox, who also introduced the innovation of the wide amplitude sinusoid for mode centring. These features are the basis of the system.

The circuit of the binary scaler is that described by B. E. Swire[4] and its use here to combat instability constitutes an elementary example of a type of circuit discussed at length by Dr. Ross-Ashby and classified as ultra-stable[5].

The step cam simulator in the gearbox is an invention of S. Zillwood Milledge[6].

Much of the initial development and experimental work was carried out by R. Beaven.

To these, and to the Directors of E. K. Cole Ltd., who granted permission to publish the paper, the writer is duly grateful.

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BACK-SCATTER IONOSPHERIC SOUNDER

Single-Station Equipment for Oblique Incidence Propagation Studies

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(Official communication from D.S.I.R. Radio Research Station, Slough)

SUMMARY.—High-frequency ionospheric propagation can be studied by observation of scattered echoes received by way of the ionosphere from irregularities on the earth's surface. The paper describes an equipment developed for propagation investigations by this method. The design of a suitable 150-kW pulse transmitter which can be simply tuned to any frequency in the band 10–27 Mc/s is discussed. To confine the observations to certain chosen directions, three-wire rhombic aerials are employed, the same aerials being used for both transmission and reception by employing a tunable transmit–receive switch. A receiver, which is of a type developed for ionospheric-absorption measurements, provides an output suitable for the presentation of the received echoes on a normal time-base display. To provide permanent records, photographs are taken of this display and, in addition, continuous range-time ($p't$) recordings are made which show the variation with time of the echo pattern. Echoes are received from ranges up to about 3,000 km by single-hop F2-layer propagation and up to 12,000 km by multi-hop propagation.

The same transmitter and receiver are also used in conjunction with a continuously-rotating Yagi aerial and a plan-position indicator. By the use of a speeded-up ciné film technique, the changes occurring in this display during a complete day may be seen in a few minutes, giving the observer a demonstration of the changing pattern of ionization in the ionospheric layers as the sun's illumination moves over the area surveyed.

1. Introduction

IN the planning and day-to-day operation of long-distance h.f. communication, a means of measuring directly the maximum-usable frequency for propagation between transmitting and receiving stations is very desirable. A new method, by which such measurements may be made at a single station without the co-operation of distant observers, has recently come into prominence. In this technique, pulses of radio waves are radiated from a directional aerial along the path to be studied. As in normal h.f. communication, energy which is emitted below a certain critical angle of elevation is reflected by the ionosphere and returned to the earth's surface at distances from the transmitter greater than the skip distance. A small part of this incident energy is returned to the vicinity of the transmitter by scattering from irregularities on the ground (Fig. 1). This scattered energy can be detected at the transmitter in the form of weak echoes of the transmitted pulse, the time delay of the earliest echoes to arrive being a measure of the oblique range to the edge of the skip zone. If the height of the reflecting layer is known, it is possible to use the oblique range to calculate the skip distance. The maximum-usable frequency for the chosen path is then the frequency for which the measured skip distance is the same as the distance to the receiving station.

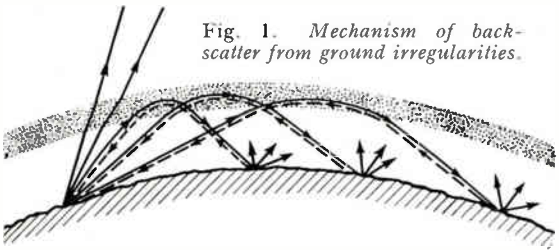


Fig. 1. *Mechanism of back-scatter from ground irregularities.*

MS accepted by the Editor, September 1955

The present paper discusses the requirements for a pulse sounder for making such measurements and describes the design of a particular equipment developed at the Radio Research Station. The theory of propagation of scattered echoes and the methods of analysing results have been studied in two earlier papers [1,2] and will not therefore be discussed in detail here.

2. General Considerations

The essential components of a pulse sounder for back-scatter observations are a pulse transmitter, directional transmitting and receiving aerials, and a pulse receiver with a suitable time-base display. A simplification of the aerial system is made possible by the use of a single aerial arranged for common transmitter–receiver operation.

The most flexible system would have a transmitter and receiver tunable to any desired frequency in the h.f. communication band and coupled to an aperiodic rotatable aerial. With such an arrangement it would be possible to measure the m.u.f. for communication to any point within the range of the equipment, or alternatively to study the large-scale movements and changes taking place in the ionospheric layers over the area. However, the design of a suitable aperiodic rotating aerial presents considerable engineering problems and in the present system some compromise has had to be made between the requirements for variation of direction and variation of frequency.

The aerial system, which is arranged for common transmitter–receiver operation, comprises four aperiodic aerials of fixed azimuths and a rotating aerial with a fixed operating frequency. The aperiodic aerials are used over the whole of the frequency band 10–27 Mc/s covered by the associated pulse transmitter and receiver. Permanent records of the echoes obtained are made by taking photographs of the normal time-base display while, to study the variation of echo range with time, continuous recording on moving film is adopted.

For displaying the echoes obtained with the rotating aerial, use is made of the plan-position indicator, first suggested for application to back-scatter research by Newbern Smith[3] and later developed by Villard and Peterson[4] and de Bettencourt[5]. This is a very convenient method of presentation, especially if an outline map is superimposed on the face of the c.r. tube, since the zones of the earth from which echoes are being returned, and to which radio communication is therefore possible, are at once obvious.

To assist in the study of the diurnal changes in size and position of these 'illuminated' zones, photographs are taken on ciné film at intervals of about a minute and after processing are projected at 16 frames a second. The showing of such a film gives in a few minutes a very clear demonstration of the changing pattern of ionization as the sun's illumination moves across the area surveyed.

In the following account of the development of the back-scatter sounder, the transmitter, receiver and fixed aerials are considered first, since together they comprise a complete equipment for the study of propagation in certain chosen directions. The rotating aerial, plan-position indicator and associated ciné camera are then discussed together since their design is interrelated.

3. Transmitter. Factors affecting Design

The factors governing the design of a transmitter for back-scatter work are the peak power in the pulse, the pulse width and the pulse repetition frequency. There is, in addition, the need for a simple tuning arrangement so that the frequency can easily be changed.

The choice of pulse repetition frequency (p.r.f.) is governed by the range from which echoes are received which, for high-power transmission, is frequently 5,000 km and under favourable conditions can extend up to 12,000 km corresponding to a total echo time delay of 80 ms. In this equipment the normal p.r.f. is 25 c/s (40 ms period) with an alternative of $12\frac{1}{2}$ c/s (80 ms period) available when required.

The duration of the radiated pulse need not be less than 100 μs for back-scatter measurements since accurate range discrimination is not needed and, in addition, pulses shorter than this would generate too much interference to stations working on adjacent frequencies. A receiver bandwidth sufficiently wide for reception of short pulses would also increase interference from adjacent stations and make detection of echoes difficult.

In view of the poor signal-to-noise ratio and limited range of the echoes obtained in preliminary experiments, in which a 10-kW transmitter radiating 140-μs pulses was used, it was decided to design for a power exceeding 100 kW. An alternative method of improving the signal-to-noise ratio of back-scatter echoes adopted by Villard and Peterson[4] is to use a low-power transmitter (1–10 kW) radiating long pulses (1–2·5 ms). This system leads to a simpler equipment which is probably sufficiently accurate for operational use in the measurement of skip distance. It has, however, been found that the higher range discrimination obtained with the short-pulse equipment is preferable for research work and has led to some interesting results concerning the time variation of the scatter pattern (see Section 8).

3.1. *Transmitter. Main framework*

The transmitter was designed round the power supply and valves of a radar transmitter, R.A.F. type MB2[6], which originally generated 10-μs pulses of 300-kW peak power at a p.r.f. of 25 c/s on either of two predetermined frequencies. The valves in this transmitter had been developed from c.w. types in the early days of radar and consequently had a higher anode dissipation than was necessary for 10-μs pulses. This fortunate circumstance made it possible to obtain a power output of 150 kW for 100-μs pulses without exceeding the permissible dissipation. With later radar valves, the small allowable dissipation would have limited the power output while, with c.w. valves, the high emission necessary (70 A for the output valves) could only have been obtained with very large water-cooled types having unnecessarily high maximum dissipation.

Fig. 2 shows the r.f. compartments of the modified transmitter. Only minor changes were necessary to the power supply compartments in the lower part, but the pulse generator and radio-frequency compartments were stripped completely, apart from the valves and valve mountings.

The method of modulation, by interruption of a bias current through the oscillator grid leak, was left unchanged, but new pulse generating and monitoring units were built and mounted on a rack beside the transmitter. These circuits follow conventional modern practice and include provision for measurement of the duration of the radiated r.f. pulse.

3.2. *Transmitter. R.f. circuits*

To satisfy the requirement for a simple tuning arrangement to cover the frequency range 10–25 Mc/s, new r.f. circuits were designed to replace the existing tuned-anode–tuned-grid arrangement with its multiplicity of controls and restricted coverage.

Variable inductors were adopted for tuning in preference to variable capacitors because of the larger frequency range ($2\frac{1}{2}$:1) achievable with the former, and the smaller volume occupied by the complete tuned circuit assembly. The complete r.f. circuit of the transmitter is shown in Fig. 3, and is seen to consist of a Colpitts oscillator coupled to a tuned amplifier.

In the oscillator tuned circuit, a variable inductor is employed having a single rotating wiper which is electrically connected to one end of the coil, and which can be wound inwards from that end of the coil. Although the tuned circuit is balanced with respect to earth, no undesired unbalance is introduced by this unsymmetrical wiper arrangement since any unbalanced stray capacitance introduced is small compared with the balanced capacitance to earth provided by the potentiometer chain.

The power amplifier, however, is tuned by a variable inductor having two wiper arms which are wound in with opposite directions of rotation from the two ends of the coil. This is necessary to keep the coil electrically symmetrical, since the aerial-coupling coil is moved in and out of a space between the centre turns of the tuning inductor. To provide the required insulation, the coupling coil is moulded in synthetic resin, the complete moulding being free to slide between vertical guides. The vertical position of this coil, and therefore the degree of coupling, can be controlled by a knob on the front panel of the transmitter operating through a cam mechanism.

In order to achieve the close coupling required between the tuned circuit and the aerial coil, this coil is tuned by a shunt variable capacitor. The Q factor of this circuit is very low, varying between 1 and 2 over the band, so that the tuning is not critical. In practice three settings of this control are used for the frequency ranges 10–12, 12–16 and 16–27 Mc/s. When the transmitter is operating into a feeder impedance of 600 ohms, no adjustment of the coupling coil is required, the

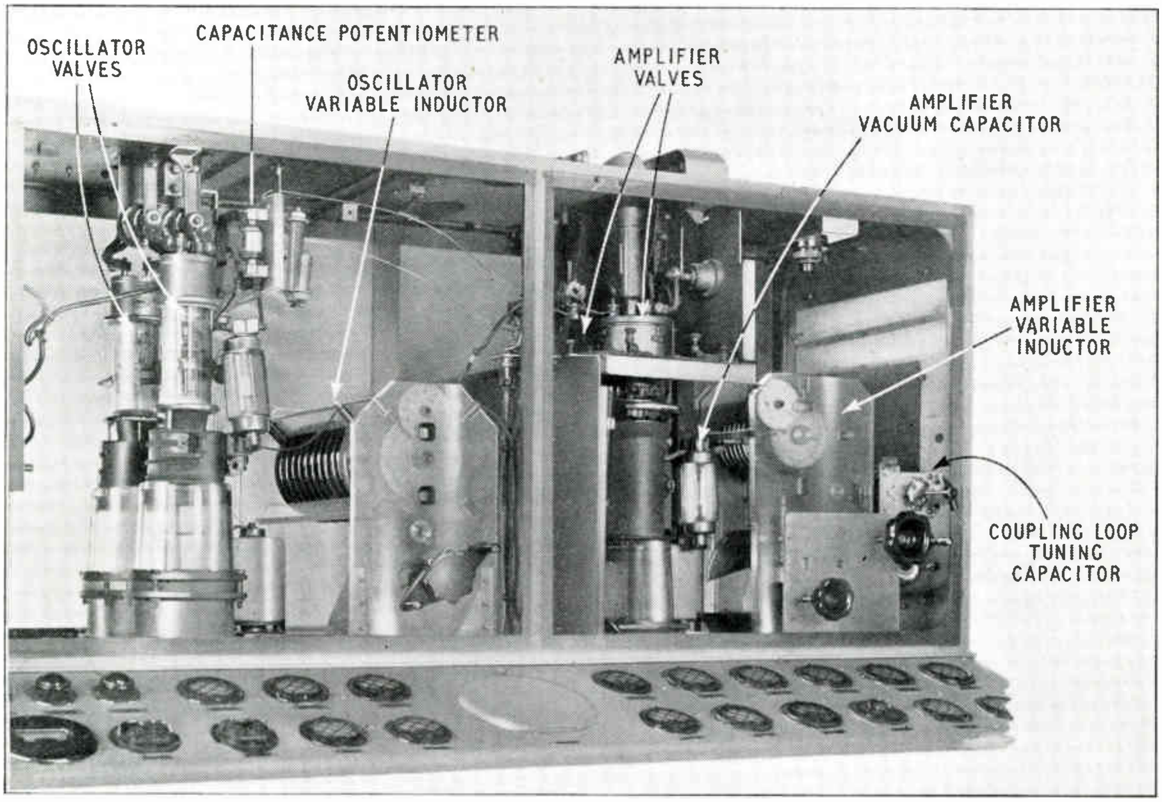
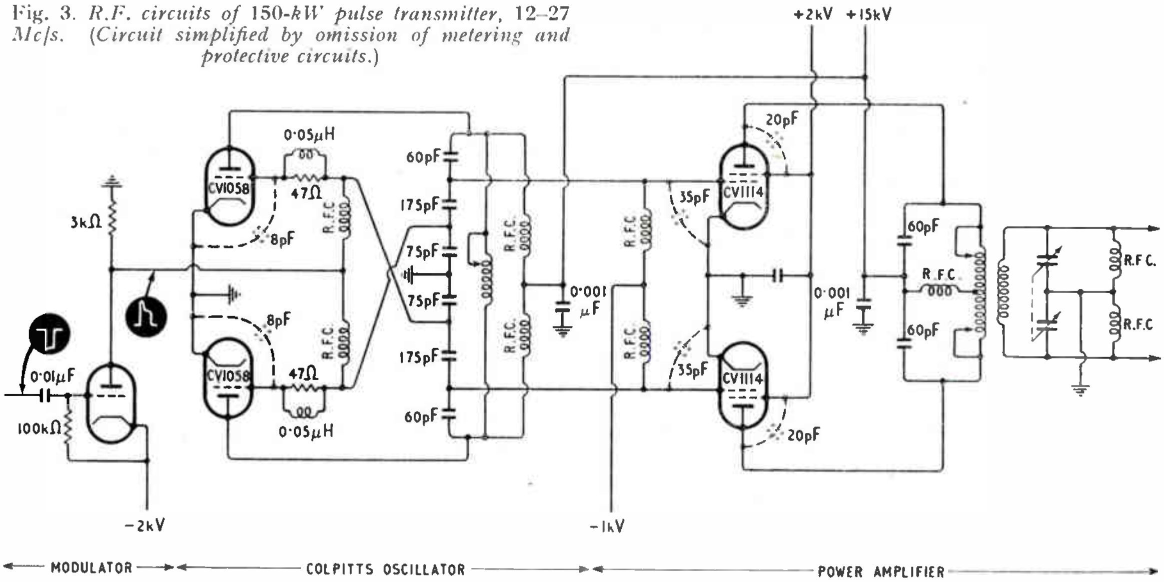


Fig. 2. *Transmitter–R.F. compartments.*

coil being left at the position where it is coaxial with the tuning coil.

The transmitter is normally operated with a d.c. pulse power input to the oscillator of 20 kW, and to the amplifier of 240 kW, the h.t. to both stages being 10 kV. Under these conditions a peak r.f. output of 110 kW is obtained.

Fig. 3. *R.F. circuits of 150-kW pulse transmitter, 12–27 Mc/s. (Circuit simplified by omission of metering and protective circuits.)*



When the frequency is varied, the power remains approximately constant at 110 kW from 10 to 23 Mc/s; above this range it drops rapidly, falling to 70 kW at 25 Mc/s. It is found that the frequency stability of the transmitter is high. This is attributed to the high Q factor of the oscillator-tuned circuit (50–200), the avoidance of phase shift in the feedback network and the stability of the inductors and vacuum capacitors.

4. Rhombic Aerials

For the study of propagation in directions from Slough which are of particular interest, two horizontal rhombic aerials have been erected. Open-wire feeders are provided from both ends of each aerial to the building in which the transmitter is situated; with this arrangement the direction of shoot can be reversed by interchanging the connections of the transmitter and terminating resistance. The aerials are identical in size and shape, each having a semi-side angle of 70°, a length of side of 64·6 metres and a height above ground of 13·7 metres.

A peak r.f. voltage of 13·5 kV is developed across the 600-ohm feeders at 150 kW transmitted power, and adequate spacing and insulation to withstand this voltage has therefore been necessary at all points on the system. By the adoption of three-wire construction for the rhombic conductors, a constant impedance–frequency characteristic has been achieved and standing waves minimized.

The calculated azimuthal beamwidth of the aerials for common TR operation at 17 Mc/s is ±5° to half-power points. Maximum radiation in the vertical plane takes place at an angle of elevation of 17°, with half-power response at 12° and 22°.

No experimental measurements of the directivity of the aerials have been made with the exception of a brief investigation of the relative response in forward and backward directions. The measured value of this back-to-front ratio was 15–20 dB for one-way propagation and 30–40 dB for echo reception. Comparisons of the echoes received with the rhombic aerials and those observed with the rotatable aerial show satisfactory rejection by the rhombics of echoes from directions different from that of the main lobe, but investigation of this is still in progress.

5. Transmit–Receive Switch

To make possible the use of a common aerial for transmission and reception a transmit–receive (TR) switch capable of protecting the receiver during the transmitted pulse has been developed. Use could not be made in this application of the conventional radar type of TR switch consisting of short-circuited $\lambda/4$ transmission lines, since operation at a number of frequencies was desirable. To overcome this difficulty, a balanced artificial line is employed, consisting of one prototype low-pass filter section with fixed inductors as the series arms and a variable capacitor as the centre shunt arm. The complete unit is connected between the transmitter terminals and the receiver, the aerials being connected directly to the transmitter (see Fig. 4).

An argon-filled spark gap (CV 1507) of the type described by Banwell[7], is used as the switching element and is shunted across the variable capacitor. When the transmitter is radiating, the spark gap conducts, the receiver is short-circuited and the impedance of two right-hand 17-μH coils (Fig. 4) is shunted across the transmitter terminals. Since this impedance is 2,500 ohms inductive at 10 Mc/s, and still greater at higher frequencies, the only effect of the TR switch on the transmitter is to alter the tuning of the coupling coil very slightly. As this is in a low-Q circuit, the effect is negligible.

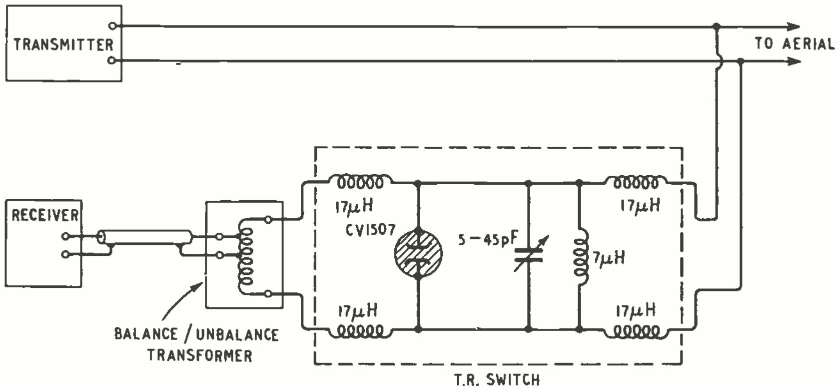


Fig. 4. *Transmit–receive switch circuit.*

In the interval between transmitted pulses, the spark gap is non-conducting and, by adjustment of the tuning capacitor, the network may be made electrically λ/2 long. This is achieved in practice by tuning the capacitor until the echoes observed with the receiver are of maximum strength. Since the network is λ/2 long and symmetrical, the impedance seen by the aerial is equal to the impedance of the receiver (neglecting losses), and the matching of the receiver to the aerial is unaffected. A wideband transformer matches the 100-ohm unbalanced receiver impedance to the 600-ohm balanced feeder.

The frequency coverage of the switch is governed by the ratio of maximum to minimum capacitance of C. This ratio has been made high by employing a capacitor with two stators and a butterfly-section rotor; it is used in a balanced condition with the rotor at earth potential although not physically connected to earth. An increase of the effective capacitance ratio is achieved by the inclusion of the 7-μH inductance which reduces the minimum capacitance from 5 pF to zero at 25 Mc/s, at the same time diminishing the maximum at 10 Mc/s from 45 pF to 11 pF. With these values the switch can be tuned satisfactorily over the range 10–25 Mc/s, the insertion loss in the receiving condition being 1 dB at 10 Mc/s, 3 dB at 20 Mc/s and 5 dB at 25 Mc/s.

It will be noticed that, in the receiving condition, the coupling coil of the transmitter is still connected across the aerial feeders. When the transmitter is quiescent, the power-amplifier tuned circuit has a high Q and a tuning point can be found, close to the resonant frequency of the circuit, for which the coupled reactance appearing in series with the output circuit cancels out the coupling-coil reactance. A low resistance is thus thrown across the aerial feeder and the received echoes are severely attenuated. It is found, however, that the power-amplifier tuned circuit can be detuned slightly to avoid this condition without affecting the power radiated by the transmitter, since the Q of the tuned circuit when transmitting is low.

6. Receiver

The receiver is of a type developed at the Radio Research Station for the measurement of ionospheric absorption by a pulse technique. A detailed account of the design has appeared elsewhere[8], and accordingly only a few features of interest will be discussed here. The receiver is arranged to deliver push-pull deflection voltages to the Y-plates of a cathode-ray tube, and to have a high degree of linearity between input and output voltages for the range of amplitudes which can be conveniently observed on the screen of the tube. In addition, the sensitivity of the receiver is unaffected by the presence of pulse or keyed c.w. transmissions strong enough to cause overloading. As a result, when the receiver is used with the transmitter and TR switch already described, no decrease of sensitivity after the pulse can be detected.

The Y-plates of the c.r. tube are connected direct to the load resistance of two diode detectors giving positive and negative d.c. outputs respectively of up to 300 volts. This d.c. coupling method eliminates any vertical drift of the time-base when keyed c.w. interference is present and results in a very satisfactory display for visual observation.

An overall gain of 170 dB is achieved, which is sufficient to give full deflection on the c.r. tube screen for thermal noise in the first tuned circuit. The bandwidth is 12 kc/s between half-power points.

7. Time-Base Generator and Display Circuits

The arrangements for synchronizing the transmitter pulse, time-base and display range-markers are shown in the schematic diagram of Fig. 5. 25-c/s or 12½-c/s square waves derived from a stable oscillator by frequency division are used to synchronize the circuits.

Two cathode-ray tubes are available for display, one with a green screen for visual observation and the other with a blue screen for photography. The waveforms applied to the two tubes are identical and are indicated in Fig. 5. A 25-c/s time-base is normally used for visual observation since the flicker of a 12½-c/s time-base is found to be fatiguing to the eyes. It is, however, essential to use 12½-c/s if any echoes of greater time delay than 40 ms are present.

200-km intervals with every fifth mark enlarged. A 3-kc/s Hartley oscillator provides the timing source, the oscillation being interrupted during the flyback of the time-base and started again at the beginning of the sweep so as to provide a stationary pattern of markers. The 50-km (330-μs) markers are obtained from the 3-kc/s sine wave after suitable shaping, while the 200-km (1·33-ms) and 1,000-km (6·67-ms) markers are obtained from the same waveform by frequency division in two phantastrons. After suitable mixing and amplification, the markers are combined with the signal from the receiver so that the range marks appear superimposed on the echo pattern as downward-going pulses. For photographic recording it is found that analysis of the records is greatly eased if separate exposures of the range marks and the echo pattern are made on the same film, the time-base being slightly displaced downward for the range mark exposure. An example of a photograph obtained by this method is shown in Fig. 6. The transmitter pulse is delayed so as to occur after the beginning of the time-base sweep, the delay being such that the start of the pulse is coincident with the first 200-km marker.

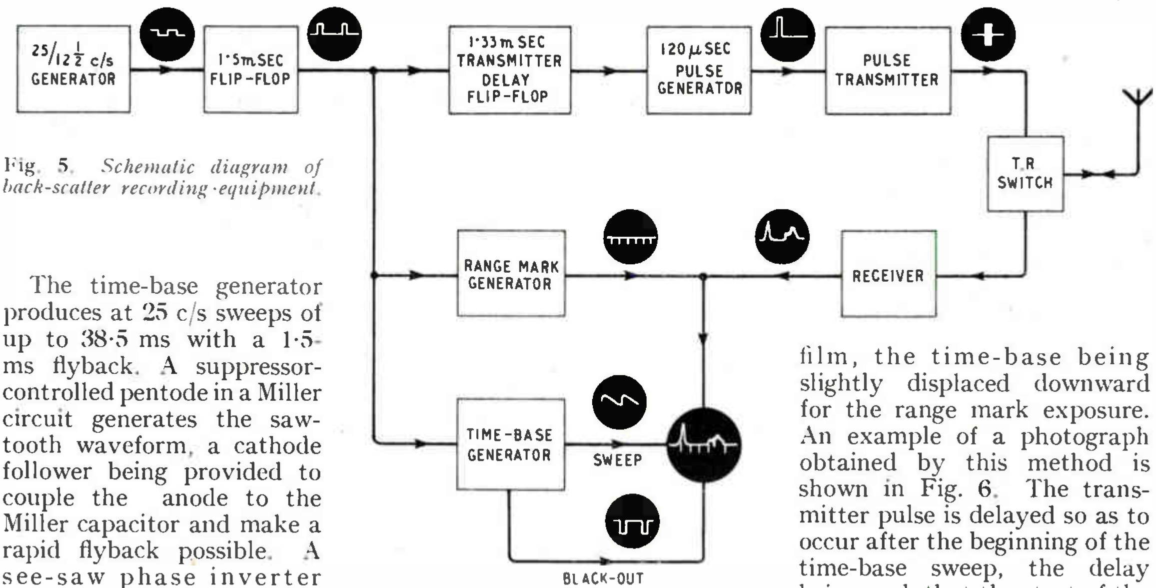


Fig. 5. *Schematic diagram of back-scatter recording equipment.*

The time-base generator produces at 25 c/s sweeps of up to 38·5 ms with a 1·5-ms flyback. A suppressor-controlled pentode in a Miller circuit generates the saw-tooth waveform, a cathode follower being provided to couple the anode to the Miller capacitor and make a rapid flyback possible. A see-saw phase inverter is d.c. coupled to the Miller valve, and d.c. coupling to the X plates of the c.r. tubes is adopted. By this means, any drifting of the position of the time-base when the sweep speed is changed is eliminated. A negative-going black-out pulse is taken from the screen of the Miller valve and applied to the grids of the c.r. tubes. Several alternative sweep durations are available (see Table 1) so that back-scatter echoes of various ranges, meteor echoes or pulse transmissions from distant stations may each be observed on a time-base of convenient length. Ranges given in the table are strictly 'equivalent free-space ranges' and assume uniform free-space velocity of propagation. The corrections necessary for accurate work are discussed in Section 8.

Range markers are provided either at 50-km intervals with every fourth mark enlarged, or at

A further type of photographic record which has yielded very useful information is the continuous

TABLE 1

Sweep Duration (ms)	Range (km)	Type of Echo Observed
2·3	350	Meteors. Pulse transmissions from distant stations.
6	900	Meteors. Back-scatter reflected by sporadic-E ionization.
17	2,600	Single-hop back-scatter.
36	5,400	Single- and double-hop back-scatter.
55	8,200	Multi-hop back-scatter.
75	11,200	Multi-hop back-scatter.

range-time recording ($p't$) of which an example is shown in Fig. 7. To obtain such records a linear time-base, brilliance-modulated by the signal, is photographed, the sense of the modulation being such that an echo blacks out the spot. Film is drawn through the camera in a direction at right angles to the image of the time-base line. To provide range and time calibrations, a clock is arranged to change the modulation from signal to range markers for a few seconds every 10 minutes. A further time identification is given by omitting this calibration at the hour.

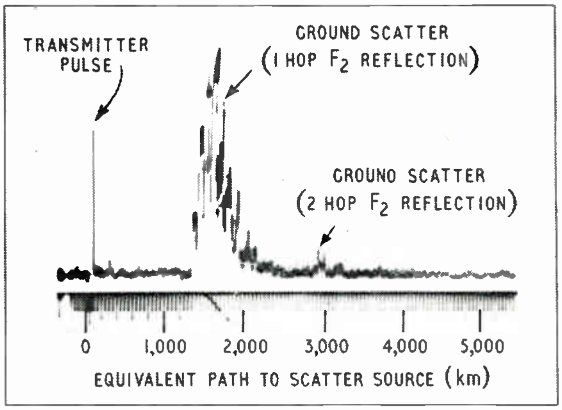


Fig. 6. *Typical scatter pattern for winter noon.* 1110 *G.M.T.*, 13.11.1951 *aerial, rhombic* 80° *E of N; frequency* 18·5 *Mc/s.*

8. Discussion of Results obtained with fixed Directional Aerials

Although it is not proposed here to analyse in detail the results obtained with the present equipment, a brief discussion of the photographs given in Figs. 6 and 7 may be of interest. Fig. 6 is a typical example of the echo pattern seen on a linear time-base display when propagation is taking place by way of the F layer alone. The lack of echoes at a shorter range than 1,350 km is explained by the skip phenomenon; since no energy was reflected back to the earth's surface in the skip zone, no energy could be returned to the transmitter by scattering. Strong echoes were, however, received from just beyond this skip zone, since the energy reaching this region was enhanced by skip focusing.

The enhanced intensity of the echoes from the neighbourhood of the skip distance is a fortunate circumstance for skip-distance measurement, since echoes from this area can be distinguished above background noise at times when echoes from greater distances are too weak to detect. A measurement of the skip distance can thus be made whenever back-scatter echoes can be seen. To obtain the skip distance from the equivalent free-space range of the leading edge of the scatter pattern (1,350 km in Fig. 6) a correction must be applied to allow for the path obliquity and the low velocity of propagation in the layer. This correction, which must be subtracted from the free-space range, is of the order of 150 km for distances greater than 1,000 km; values for various layer heights have been calculated and given in graphical form elsewhere[1].

A feature of the echo pattern of Fig. 6 which should be mentioned is the group of 'second-hop' echoes at 2,800 to 3,200 km range. This is due to energy which on the outward journey suffered two reflections from the ionosphere with an intermediate reflection at the ground. These echoes were also enhanced in intensity by the skip focusing phenomenon referred to previously.

An example of a continuous range-time ($p't$) record of back-scatter is given in Fig. 7. The observation was made at Slough in February 1955 at a frequency of 19 Mc/s using a rhombic aerial directed towards the south. The scatter is indicated by the black areas, the echoes from the first skip focusing region being recorded at ranges of 2,000 to 3,000 km before finally fading out at 1830 GMT. Other multiply-reflected groups of scatter can be seen at greater ranges, but it will be noticed that the ranges are not necessarily multiples of the range of the first group, and that one

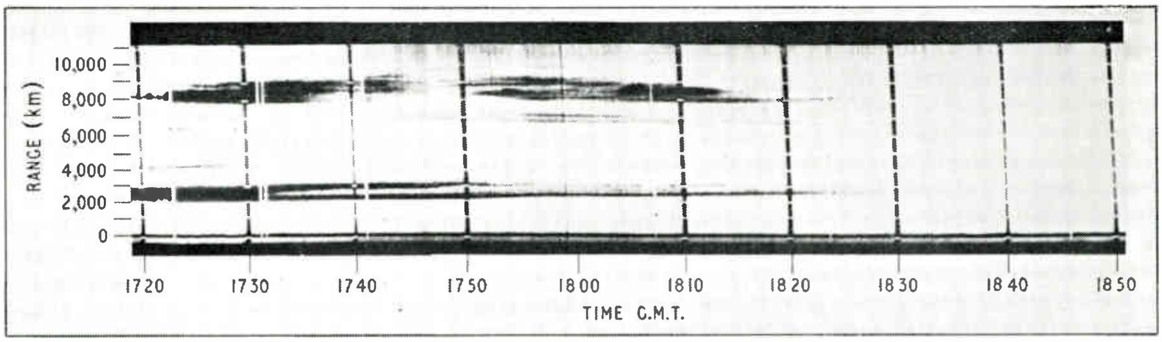


Fig. 7. *Example of continuous range-time* ($p't$) *recording of back-scatter. (Single-hop and multi-hop echoes can be distinguished.) Rhombic directed* 139·5° *E*, 21*st February* 1955*; frequency* 19 *Mc/s.*

'multiple-hop echo' persists after the first-hop echo has faded out. From experimental information such as this, it appears that the mode of propagation of energy over long distances can be very complex. An investigation of these phenomena is in progress.

9. Back-Scatter Plan-Position Indicator. General Considerations

In principle, the back-scatter plan-position indicator (p.p.i.) is identical with that used in radar, the differences being due to the very much greater range of the echoes and the very much longer wavelength. As a consequence of the long wavelength, the rotating aerial system needed to get the angular resolution possible with a radar aerial would be prohibitively large, and an inferior performance has to be tolerated. The present Yagi aerial has a beamwidth for common TR working of 40° between 3-dB points, which does not give sufficient resolution to register correctly ionospheric changes taking place over a small range of azimuth. In spite of this limitation, however, it has provided much useful information about geographical and temporal changes in the ionosphere.

The long range from which the echoes are received imposes an upper limit on the speed of rotation of the aerial and time-base because of the low p.r.f. necessary (25 c/s for a range of 6,000 km from Section 3). For a satisfactory display, it has been found that at least one radial line per degree of rotation is needed, so that at 25 c/s the time of rotation must not be less than 40 ms $\times$ 360 = 15 secs. The maximum speed of rotation is thus 4 r.p.m. at 25 c/s, or 2 r.p.m. at $12\frac{1}{2}$ c/s.

9.1. *Rotating Aerial*

The type of directional aerial which was adopted for the p.p.i. equipment was a four-element horizontal Yagi. For its small size, about $\lambda/2$ square, and simple construction, such an array gives a directivity that could only be appreciably improved upon by a considerably larger and more complex aerial. A disadvantage is that its use is limited to within about $\pm 2\%$ of the designed frequency but, for the present purpose, it was decided to accept this limitation, and an operating frequency of 17 Mc/s was chosen. Scatter observations at this frequency give information about daytime propagation for lengths of hop of the order encountered in long-distance communication (1,500–3,000 km).

The aerial, illustrated in Fig. 8, occupies an area in the horizontal plane of 30 ft by 23 ft and is mounted on a tower 30 ft high. The driven element lies across the centre of a rotating wooden framework and consists of two telescopic rods which can be adjusted in length to give a resistive input impedance at the centre of the element. A reflector is spaced $0{\cdot}2\lambda$ behind and two directors $0{\cdot}1\lambda$ and $0{\cdot}2\lambda$ in front of the driven element. The two directors and the reflector each have at their centres a tuning stub with a short-circuiting bar, the position of which can be adjusted manually from the centre of the framework by means of an insulated rod. With this arrangement, it is possible to adjust the electrical length of the elements to give the optimum gain consistent with a good back-to-front ratio.

The wooden framework supporting the elements rotates about a central spindle which is mounted in ball-races fixed to the tower. By means of a

Fig. 8. *Rotating Yagi array.*

C

sliding key the spindle is constrained to rotate with the framework, although the weight of the framework is not supported by the spindle. The same spindle passes downwards into a metal box where it drives a magslip transmitter through a 30:1 step-up gear ratio. This magslip is electrically connected to a magslip receiver which rotates the time-base coils of the c.r. tube indicator through a 30:1 step-down gear ratio.

The weight of the rotating wooden framework is carried by four wheels which run on a 6-ft diameter circular track of 2-in. angle iron, the track being divided into four insulated arcs to reduce any distortion of the aerial polar diagram. The framework is caused to rotate by a fifth wheel driven by a d.c. motor through a gearbox. The pressure of the wheel on the track is increased by a helical spring to provide the necessary amount of friction.

R.f. power transfer from the 600-ohm feeder to the rotating centre element of the aerial (impedance 25 ohms) is accomplished by inductive coupling between two coils mounted coaxially with the centre spindle. The inner, fixed, coil consists of four turns of 3/8-in. wide strip wound in a helix $5\frac{1}{2}$ in. in diameter and is connected across the 600-ohm feeder with a $20-30$ pF shunt tuning capacitor. The rotating coil is $7\frac{1}{2}$ in. in diameter and consists of a single turn of 3-in. wide strip tuned by a 400-pF 'pot' type mica capacitor. An electrostatic screen, in the form of a cylindrical shell having a gap in its circumference, is incorporated between the primary and secondary coils to prevent capacitive coupling. Connection between the aerial and the single-turn coil is by a short length of balanced transmission line of 25 ohms characteristic impedance made of two strip conductors 1 in. wide insulated from each other by a 1/8-in. thick sheet of polystyrene.

The impedance of the driven element of the Yagi aerial can vary between 20 and 50 ohms when the lengths of the directors and reflector are changed[9] and this impedance is transformed to 600 ohms by the coupling coils. A variation of the transformation ratio over the required range is effected by moving the outer, single-turn coil axially, thus varying the inductive coupling between the coils.

To measure the performance of the aerial after erection, a field was set up by means of an elevated horizontal loop transmitter at 200 metres range, and the voltage appearing across the 600-ohm coil terminals was measured. Adjustments were then made to the reflector and director tuning stubs to obtain the best compromise between high gain in the forward direction and a good front/back ratio.

The measured azimuthal beamwidth for 3-dB drop in response, after squaring the polar diagram for common TR working, was 42°, and the back-to-front ratio 38 dB for the same conditions. No measurements have been made in the vertical plane, but the angle of elevation for maximum radiation obtained by calculation is 25°.

The measured gain of the array relative to a half-wave dipole was 6 dB, this measurement being obtained by comparing the Yagi pick-up with that of a reference dipole fixed temporarily to the tower before the erection of the Yagi.

9.2. *P.P.I. Display*

For visual observation of a p.p.i. display, it is necessary to use a c.r. tube with an afterglow of sufficient duration to make the whole display visible simultaneously. As discussed in Section 9, a time-base rotation speed of not greater than 2 r.p.m. is necessary with a back-scatter p.p.i. when operated at a p.r.f. of $12\frac{1}{2}$ c/s, so that an afterglow of at least 30 secs is required. The c.r. tube used (Type CV464) has a 9-in. diameter screen with a fluoride coating giving a suitable long persistence orange afterglow with no initial flash. The tube has electrostatic focusing and requires magnetic deflection by external coils. Magnetic deflection is necessary since the high beam current needed for a satisfactory p.p.i. display precludes the use of electrostatic deflection plates in the c.r. tube.

A rotating time-base is produced by passing a sawtooth current waveform through a pair of deflecting coils mounted around the neck of the c.r. tube, the coils being rotated in synchronism with the aerial using the magslip synchronous link referred to in Section 9.1. The rotating-coil assembly forms part of an ex-Service p.p.i. console which also includes display centring facilities.

A time-base generator of the type described by Williams, Howell and Briggs[10] is used, suitable modifications being included to permit operation with a flyback time small compared with the sweep duration.

9.3. *Presentation of the Signal*

For back-scatter echoes it has been found preferable to show the echoes on the p.p.i. as dark patches on a light background; with the normal method of operation, it was found that the time-base was brightened by interference from other transmissions and the afterglow persisted for several revolutions of the display. With the system adopted this was overcome and, in addition, the sensitivity for weak echoes was improved.

Range markers are applied to the time-base as brightening pulses which produce circles at radial intervals of 200 km or 1,000 km when the p.p.i. is operating. For convenience, an outline map of the area covered is drawn on the face of the c.r. tube so that the location of the ground areas from which the scattered echoes are being returned can be seen.

The circuits which combine the signal, range marker and flyback-suppression waveforms into a form suitable for application to the c.r. tube have been designed to retain the original d.c. level of the signal independent of the shape of the echo pattern or of the amount of interference present. By this means the brightness of the background remains constant in the spacing intervals of telegraph interference, the time-base being blacked out only during the instants when the interfering carrier is being received. Interference does not affect the brightness of the range circles.

If care is not taken to maintain the d.c. level of the signal, the background illumination in the spacing intervals of an interfering c.w. transmission is brightened or even defocused, causing mutilation of the display; this is unsatisfactory for visual observation and very serious for photographic recording.

Two features of the circuit, which are made necessary by the low repetition frequencies of 25 c/s and $12\frac{1}{2}$ c/s required for scatter work, are the use of long time-constants in the coupling circuits to the c.r. tube, and the achievement of a high degree of smoothing in the negative e.h.t. supply. The latter is required because of the brilliance modulation produced by the ripple currents which flow through the necessarily large grid and cathode coupling capacitors. The brilliance modulation produced by any residual ripple in the supply is reduced by the use of identical coupling capacitors for the grid and the cathode. Elimination of brilliance modulation of the display by mains ripple is more important for photography than for visual observation because of the smaller range of luminosity which can be registered by photographic emulsions.

9.4. *Photography of the P.P.I. Display*

Permanent records of the p.p.i. display patterns are obtained by photography of the display, a ciné camera being employed to provide the 'speeded up' ciné films referred to in Section 2.

For this purpose, the aerial and time-base are rotated at 1 r.p.m., and a single frame of 16-mm ciné film is exposed for each rotation. The shutter of the camera is closed only during the instant at which the film is wound on, so that the complete 'paint' produced by one rotation of the time-base is photographed. To provide a record of the time, a watch is illuminated for one second during each exposure. After processing, the film is projected at the normal speed of 16 frames a second, so that the changes occurring during 24 hours may be seen in $1\frac{1}{2}$ minutes.

Another type of photographic record which has proved useful for some purposes is an azimuth-range plot in Cartesian co-ordinates. This is produced by a similar technique to the range-time recordings referred to in Section 7. The difference here, however, is that the film is kept stationary while a horizontal brilliance-modulated time-base is moved slowly in a vertical direction, the vertical displacement at any time being proportional to the angle through which the aerial has turned. This type of record is made with the same c.r. tube and camera as is used for normal time-base display photography.

9.5. *Discussion of Results obtained with the P.P.I.*

As an example of the results obtained with the back-scatter p.p.i., some still photographs taken from a ciné film of the kind described in Section 9.4 are shown in Fig. 9. The frequency of transmission was 17 Mc/s, which was above the maximum frequency for which oblique rays could be reflected by the night-time ionosphere, but was low enough for reflection to take place from those areas of the ionosphere illuminated by the sun.

In the morning, back-scatter was first received from ground areas to the south-east after sunrise in the F layer of the ionosphere. As the day progressed, scatter was also received from the south, west and north. In the photograph for 1000 UT, a complete ring of scatter can be seen with a minimum range (approximately equal to the skip distance) of 1,500 – 2,000 km. Propagation on 17 Mc/s by way of the F layer was thus possible in all directions at this time. A second arc can also be seen to the south outside the main ring of scatter. This indicates that energy was being returned from ground areas illuminated by two-hop rays; that is, rays which on their outward and inward journeys were reflected twice from the layer with an intermediate reflection at the ground.

In the photograph for 2100 UT, scatter is being received by way of the F layer only from the west, the rest of the area being in darkness. The short-range echoes recorded from 1240 UT to 2100 UT represent ground scatter reflected by localized clouds of 'sporadic-E' ionization.

Within the first ring of scatter is the skip zone to which no communication is possible by normal ionospheric reflection. Between the first and subsequent rings are zones where the field strength is low, but not necessarily so low that communication is impossible; to receive scatter from such ranges, higher power, longer pulses, or improved aerials and receiving systems would be required.

10. Conclusions

The equipment described in this paper was developed for an experimental investigation of h.f. propagation by the back-scatter technique. The 150-kW pulse transmitter has been used in conjunction with the rhombic ærials to study propagation over the band 10–27 Mc/s in certain fixed directions. Ground scatter propagated by

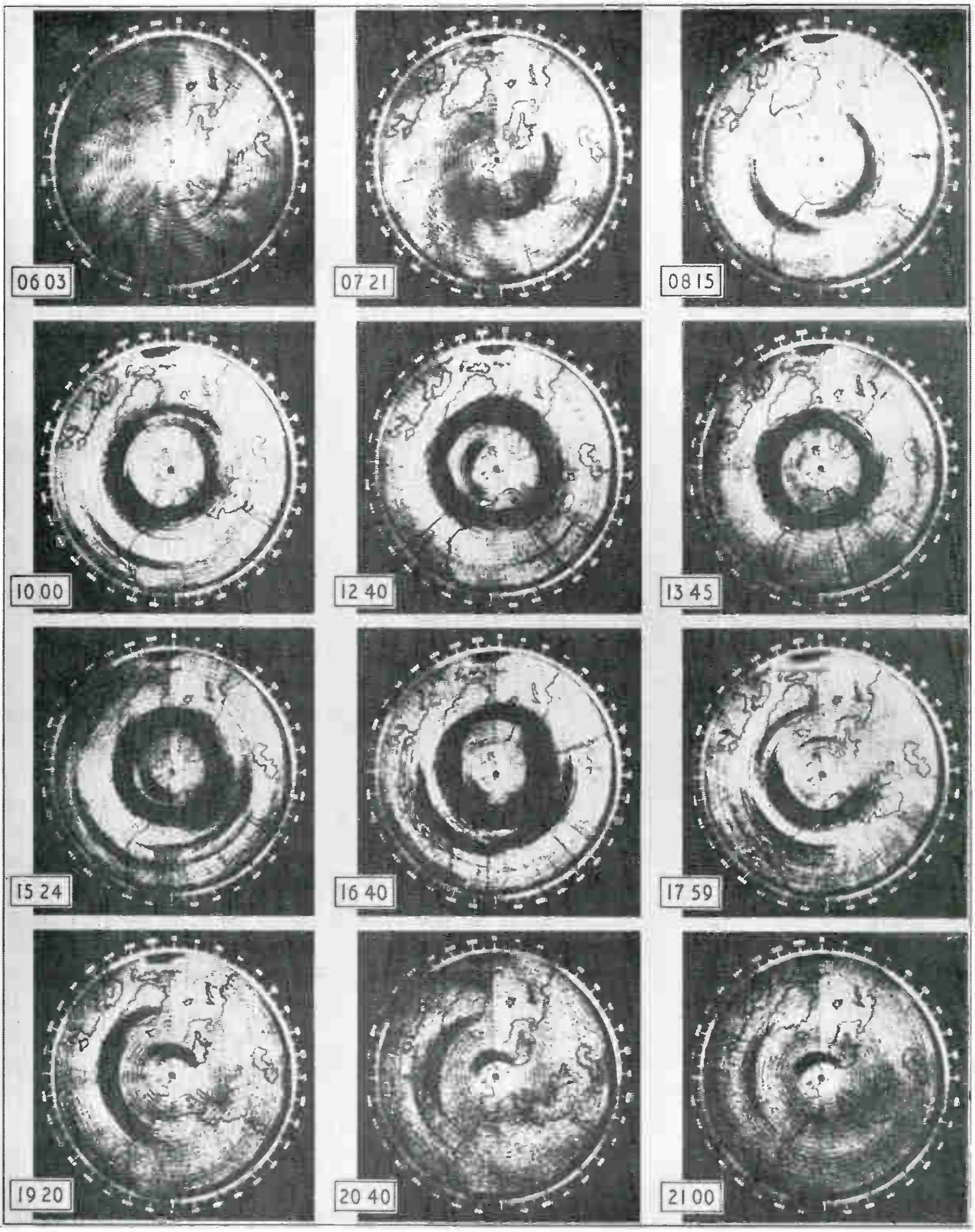


Fig. 9. *Variation of back-scattered echoes over the period* 0600–2100 *UT, 7th October* 1954.

way of the F, E and Es layers has been observed, the maximum single-hop ranges for F2 propagation being normally about 3,000 km, while, in addition, multi-hop echoes from ranges up to 12,000 km have been observed under favourable conditions. Information obtained with this equipment is found to be of considerable value in elucidating the various modes of propagation of radio waves over long distances.

The plan-position indicator in its present form is limited in angular resolution by the small aperture in wavelengths of the aerial but, nevertheless, provides a valuable method of observing the zones of the earth's surface to which radio waves are returned by the ionosphere. Such information could not be obtained by other means at present available. The area of the earth surveyed is normally 3,000 km in radius but can be very much greater under favourable conditions. A valuable addition to the p.p.i. is the speeded-up cinematograph facility, by means of which a vivid picture is obtained of the diurnal changes in the horizontal distribution of ionization in the ionospheric layers.

Acknowledgments

The authors wish to acknowledge the help and advice throughout the work of Mr. A. F. Wilkins, and the co-operation of Messrs. A. Wilson and E. Oakman in the mechanical design. They also wish to thank Mr. Caradoc Williams of the Royal Aircraft Establishment for making available the p.p.i. console.

The work described above was carried out as part of the programme of the Radio Research Board. This paper is published by permission of the Director of Radio Research of the Department of Scientific and Industrial Research.

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CORRESPONDENCE

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

Constant-Frequency Oscillators

SIR,—I was interested to see Mr. A. S. Gladwin's article in *Wireless Engineer*, January 1956, in which the conditions are derived for the frequency of a regenerative oscillator to be independent of changes in the input and output resistances of the maintaining amplifier.

In this article, the harmonic frequencies of grid and anode currents have not been considered. I hope it will be of interest to compare the method developed by the author with the one which I described some time ago. This method takes into account the non-linearities of grid and anode circuits and, when the harmonic currents are not taken into consideration, the results are comparable with those obtained by Gladwin.

The general system reviewed is demonstrated in Fig. 1. The quadripole N is considered as being both linear and passive, hence its properties can be determined by means of equations

$$-V_g = Z_{gg} I_g + Z_{ag} I_a \quad \quad (1)$$

$$-V_a = Z_{ag} I_g + Z_{aa} I_a \quad \quad (2)$$

where all magnitudes V, I and $Z = R + jX$ are functions of the angular frequency ω.

The currents and voltages shown in Fig. 1 are, in these conditions, definite periodic functions of time. The electrical relation in the quadripole N will not vary if we replace the grid and anode circuits of the valve by generators of infinite internal resistance and identical current outputs as in the oscillator under consideration. The equivalent system so obtained is shown in Fig. 2. It is a linear system, to which the law of superposition can be applied.

Let us further assume the fact that the cathode current of the valve is a one-valued function of the equivalent potential on the grid surface.

$$i_c = i_a + i_g = f(v_c) = f\left(v_g + \frac{v_a}{\mu}\right)$$

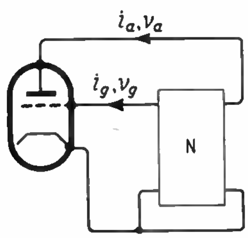

Fig. 1.

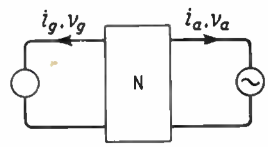

Fig. 2.

Having taken this into consideration and expressing voltages and currents in the form of harmonic series, we find—as we already know from Ref. 1.

$$\mathrm{Im}\left\{\sum_{k=1}^{\infty} k\left(V_{gk} + \frac{1}{\mu} V_{ak}\right) \cdot \left(I_{gk}^* + I_{ak}^*\right)\right\} = 0 \quad \quad (3)$$

where V_{gk} denotes the kth harmonic of grid voltage, etc., whereas I_{gk} and I_{ak} denote conjugate values up to I_{gk} and I_{ak}.

Let us assume that I_{a1} is real and positive, and let us indicate $n_{ak} = I_{ak}/I_{a1}$, $n_{gu} = I_{gk}/I_{a1}$. We shall, by substituting (1) and (2) in formula (3), arrive at

$$\text{Im}\left\{\sum_{k=1}^{\infty}\left(n_{ak}^* + n_{gk}^*\right)\left[\left(Z_{gg} + \frac{1}{\mu}Z_{ag}\right)_k n_{gk} + \left(Z_{ag} + \frac{1}{\mu}Z_{aa}\right)_k n_{ak}\right]\right\} = 0 \quad (4)$$

where the index k next to the bracket indicates that the expression contained in the bracket should be considered as relevant to the kth harmonic. This formula permits us to expand the well-known Groszkowski formula; knowing the function $Z_{gg}(\omega)$, $Z_{ag}(\omega)$, $Z_{aa}(\omega)$ and the harmonic content of the grid and anode currents, it enables the frequency of oscillations ω to be determined.

In the case when the oscillator frequency depends chiefly upon the fundamental frequencies of the grid and anode currents, we may not take into account in formulae (4) the terms expressing the influence of higher harmonic frequencies. Providing that the value of n_{g1} is real, which is the case when the stability criterion (6) is fulfilled, and starting from Equ. (4), we arrive at

$$\left(X_{ag} + \frac{X_{aa}}{\mu}\right)_1 = -\left(X_{gg} + \frac{X_{ag}}{\mu}\right)_1 n_{g1} \quad (5)$$

It may be seen from this that, when the following conditions for the oscillator frequency are simultaneously fulfilled

$$X_{ag} = 0,\ X_{aa} = 0,\ X_{gg} = 0 \quad (6)$$

the frequency is independent both of the amplifier's input resistance expressed by n_{g1} and of the valve μ. This criterion implies that the input, output and transfer impedances of the feedback network must be resistive at the oscillation frequency. This criterion has been related to the amplification factor μ of the valve instead of to its output resistance, because its value is less dependent on the external circuit and therefore it can be more easily determined.

In my paper[3] the reactances have been computed which, introduced into the grid and anode leads, fulfil the stability condition for the tuned-anode, tuned-grid, Colpitts, Clapp and Hartley oscillators. The fallacy of Llewellyn's formulae for a real circuit has been shown by an example in which the stabilizing reactance, calculated by means of these formulae, increases the dependence of frequency on the input resistance of the amplifier.

L. B. LUKASZEWICZ

Warsaw, Poland.
28th May 1956.

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STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for June 1956

Date 1956 June	MSF 60 kc/s Frequency deviation from nominal*: parts in 10^9
1	+4
2	+3
3	+3
4	+5
5	+4
6	+4
7	+5
8	N.M.
9	N.M.
10	N.M.
11	N.M.
12	+4
13	+4
14	+4
15	+4
16	+5
17	+4
18	+5
19	+5
20	+5
21	+5
22	+5
23	+5
24	+5
25	+5
26	N.T.
27	N.T.
28	+5
29	+5
30	−3

N.M. = Not Measured. N.T. = No Transmission.

*Nominal frequency is defined to be that frequency corresponding to a value of 9 192 631 830 c/s for the N.P.L. caesium resonator.

ABSTRACTS and REFERENCES

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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

534-16 : 061.3 2271

Conference on 'Sound and Vibrations in Solid Bodies', Göttingen, 19th–22nd April 1955.—(*Akust. Beihefte*, 1956, No. 1, pp. 49–227.) The text is given of 35 papers, the majority in German and the remainder in English; English, French and German summaries are provided.

534.121.1 2272

On the Flexural Vibrations of Circular and Elliptical Plates.—W. R. Callahan. (*Quart. appl. Math.*, Jan. 1956, Vol. 13, No. 4, pp. 371–380.) The frequency equations for the normal modes of vibration are studied.

534.2-8 2273

A Simple Method for the Visualization of Ultrasonic Fields.—Y. Torikai & K. Negishi. (*J. phys. Soc. Japan*, Dec. 1955, Vol. 10, No. 12, p. 1110.) A method using ordinary photographic paper is outlined.

534.2-8-14 2274

The Propagation of Ultrasonics in Suspensions of Particles in a Liquid.—J. Busby & E. G. Richardson. (*Proc. phys. Soc.*, 1st Feb. 1956, Vol. 69, No. 434B, pp. 193–202.) Measurements at frequencies between 1 and 10 Mc/s are reported, on suspensions of glass spheres (monodisperse) and silica particles (polydisperse) of radius 8–100 μ.

534.6 2275

An Apparatus for measuring Air-Flow Resistance of Acoustical Materials.—H. J. Sabine. (*ASTM Bull.*, Jan. 1956, No. 211, pp. 29–32.)

621.395.616 2276

Artificial Stabilization of the MR-103 Type Condenser Microphone.—T. Hayasaka, K. Masuzawa & M. Suzuki. (*Rep. elect. Commun. Lab., Japan*, Oct. 1955, Vol. 3, No. 10, pp. 59–60.) Titanium is used as diaphragm material on account of its strength. To obtain the same stability as would be provided by aging for a year or more at normal temperature, it is only necessary to heat the microphone for 5 hours at 200°C.

621.395.623.7 2277

Miniature Loudspeakers for Personal Radio Receivers.—J. C. Bleazey, J. Preston & E. G. May. (*RCA Rev.*, March 1956, Vol. 17, No. 1, pp. 57–67.) Two experimental loudspeakers are described in which the cone housing and the magnet occupy the same space, thus reducing the overall depth. Directional characteristics, distortion and frequency response are similar to those of conventionally constructed loudspeakers.

621.395.623.8 : 621.396.975 2278

Wireless Sound Systems.—C. W. Hargens. (*J. Franklin Inst.*, Nov. 1955, Vol. 260, No. 5, pp. 351–356.) Description of a system installed at the Franklin Institute in a hall with a reverberation time of several seconds. Miniature transistor-equipped receivers are used. The carrier frequency is between 550 and 1 600 kc/s, the particular value being chosen to meet a Federal Communications Commission requirement regarding field strength at distance $\lambda/2$. Any public-address amplifier can serve as modulator. The transmitter aerial is a long conductor making a loop round the hall; the receiver aerials are ferrite-core types.

621.395.625.2 : 621.396.712.3 2279

Reproducing Equipment for Fine-Groove Records.—G. V. Buckley, W. R. Hawkins, H. J. Houlgate & J. N. B. Percy. (*B.B.C. Engng Div. Monographs*, Feb. 1956, No. 5, pp. 1–19.) Description of a reproducing desk designed to facilitate the location of desired excerpts.

621.395.625.3 2280

Mechanical Aspects of Magnetic-Recorder Design.—G. P. Bakos. (*Tijdschr. ned. Radiogenoot.*, Jan. 1956, Vol. 21, No. 1, pp. 17–37. In English.) A review of modern practice, covering tape, sheet and disk machines, as well as multichannel equipment.

AERIALS AND TRANSMISSION LINES

621.315.212.1.011.3 **2281**

The Inductance of Two Elliptic Tubes.—E. E. Jones. (*Brit. J. appl. Phys.*, Feb. 1956, Vol. 7, No. 2, pp. 56–58.) The inductance is calculated of cables comprising two confocal or concentric elliptic tubes of nonmagnetic material.

621.372 **2282**

An Investigation of the Properties of Radial Cylindrical Surface Waves launched over Flat Reactive Surfaces.—W. M. G. Fernando & H. E. M. Barlow. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 307–318.) Experiments were made using a vertical dipole source arranged at various heights above the centre of a horizontal metal disk inductively loaded either by means of a thin dielectric coating or by forming a series of concentric corrugations. Theory developed by Cullen (22 of 1955) is applied; the observations are in good agreement with the theoretical predictions both as regards field distributions and launching efficiency, and it is confirmed that a launching efficiency approaching 80% is attained for a particular height of the dipole.

621.372.2 : 621.317.34 : 621.317.729 **2283**

An Investigation into some Fundamental Properties of Strip Transmission Lines with the Aid of an Electrolytic Tank.—J. M. C. Dukes. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 319–333.) A technique was developed by means of which the line parameters could be rapidly evaluated with a useful degree of accuracy for a range of dimensions for which rigorous solutions by direct analysis are not readily available, this range including lines with characteristic impedance between 20 and 150 Ω. The investigations covered the balanced-parallel-plate line, the strip-above-ground line, and the sandwich, or tri-plate, line. The validity of formulae derived by other workers is discussed and new methods for calculating the line parameters are developed. The results indicate that the dominant mode in a microstrip line is closer to the TEM mode than has been supposed hitherto. The sandwich line has some theoretical advantages over the strip-above-ground line, but these may be offset by practical disadvantages.

621.372.2 : 621.385.029.6 **2284**

Interpretation of Wavelength Measurements on Tape Helices.—C. P. Allen & G. M. Clarke. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 171–176.) An unexpected region of dispersion observed by Sensiper (1247 of 1955) is found to be due to the finite length of the helix. The effect may be important in relation to the design of travelling-wave devices.

621.372.8 **2285**

A New Treatment of Lossy Periodic Waveguides.—P. N. Butcher. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 301–306.) The new treatment is based on introduction of a 'complex Q factor', Q_c; the propagation coefficient of a mode in a lossy guide at the frequency ω is equal to that of the corresponding mode in a loss-free guide at the frequency $\omega(1 - j/2Q_c)$. An explicit formula is given for Q_c for the case of small losses.

621.372.8 **2286**

Junction Admittance between Waveguides of Arbitary Cross-Sections.—E. D. Farmer. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 145–152.) If the dominant modes of the adjoining waveguides have similar patterns over the coupling aperture, the junction can be represented approximately by a two-terminal network. A general definition of characteristic impedance is introduced enabling the junction to be regarded as an 'impedance mismatch' together with a shunt susceptance 'junction effect'. The limits of applicability of the theory are assessed by making calculations for some special cases, including a junction between a rectangular and a hexagonal guide.

621.372.8 **2287**

Microwave Propagation in Anisotropic Waveguides.—A. E. Karbowiak. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 139–144.) Analysis is presented based on the surface-impedance approach developed previously (3484 of 1955). The corrugated surface and the conducting helix are two particular cases of the anisotropic surface considered. All E and H_0 modes are shown to be stable whatever the orientation of the principal axes of the surfaces; higher-order H modes are unstable unless the principal axes coincide with the coordinate axes of the surface, but a certain combination of H waves ('spinning H wave') can be propagated.

621.372.8 : 538.221 **2288**

Attenuation and Permeability of Ferromagnetic Waveguides between 9 000 and 9 675 Mc/s.—J. Allison & F. A. Benson. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 205–211.) "Measurements of the attenuations produced by air-filled rectangular waveguides of nickel, mild steel, mumetal, radiometal and rhometal have been made in the frequency range 9 000–9 675 Mc/s. The permeabilities of the materials have been determined from these measurements and a knowledge of the roughness and resistivity of each waveguide internal surface. The effects of temperature on the h.f. permeabilities have also been studied, and some qualitative results are included on the effect of superimposing a steady magnetic field on the h.f. one."

621.372.8 : 538.221 : 538.6 **2289**

Equation of Circularly Polarized Waves in a Gyro-paramagnetic Medium.—J. Soutif-Guicherd. (*C. R. Acad. Sci., Paris*, 12th March 1956, Vol. 242, No. 11, pp. 1418–1421.) Analysis is outlined for propagation in a waveguide containing a medium whose permeability is represented by a tensor. The propagation coefficient is expressed in a form susceptible to limited development for the case of a paramagnetic medium; the field equations for a circularly polarized wave are derived.

621.372.8 : 621.3.012.8 **2290**

The Calculation of the Equivalent Circuit of an Axially Unsymmetrical Waveguide Junction.—R. E. Collin & J. Brown. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 121–128.)

621.372.8 : 621.318.134 **2291**

Temperature Behavior of Ferrimagnetic Resonance in Ferrites located in Waveguide.—B. J. Duncan & L. Swern. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 209–215.) The investigation described is an extension of that reported previously (2192 of 1955). Measurements were made on MgMn and NiZn ferrites over the temperature range from 25°C to the Curie point in each case. Temperature variation of the resonance-line width and the apparent gyromagnetic ratio was observed. The effect on the microwave transmission properties is discussed.

621.372.8 : 621.372.2 **2292**

The Excitation and Propagation of E_{0n} Modes in a Circular Waveguide with Coaxial Lines at Input and Output.—A. Sander. (*Arch. elekt. Übertragung*, Feb. 1956, Vol. 10, No. 2, pp. 77–85.) Analysis is presented in which the concepts of 'field' and 'hybrid' quadripoles and the corresponding matrices are introduced.

621.372.8 + 621.396.677.85] : 621.372.43 **2293**
The Design of Quarter-Wave Matching Layers for Dielectric Surfaces.—R. E. Collin & J. Brown. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 153–158.) "A quarter-wave transformer to match the junction between an empty waveguide and one completely filled with a dielectric may be made from a waveguide partially filled with dielectric. A method of designing such a transformer, when all the waveguides have the same cross-section, is described, and experimental results are given to show that this design is satisfactory. A similar arrangement can be used to match the surfaces of a dielectric lens: slots are cut on the surface and design information is given for slots parallel or perpendicular to the electric field of the wave incident on the surface. Measured reflection coefficients for a surface matched in this way are in good agreement with calculated values."

621.396.67 : 001.4 **2294**
Russian Antenna Terminology.—G. F. Schultz. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 692.) A short list of representative terms is given with the English equivalents.

621.396.674.3 : 621.397 **2295**
Wide-Band Television Aerials.—M. G. O'Leary. (*Wireless World*, June 1956, Vol. 62, No. 6, pp. 288–291.) An illustrated review of current North American practice in the design of combined aerial systems for reception in bands I and III.

621.396.676.012.12 **2296**
The Radiation Pattern of an Antenna mounted on a Surface of Large Radius of Curvature.—J. R. Wait. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 694.) Calculations are made of the radiation pattern of a dipole or a slot on a conducting sphere of large radius, by applying van der Pol-Bremmer theory.

621.396.677.71 : 621.397.61 **2297**
The Omniguide Antenna—an Omnidirectional Waveguide Array for U.H.F.-Television Broadcasting.—O. M. Woodward, Jr, & J. Gibson. (*RCA Rev.*, March 1956, Vol. 17, No. 1, pp. 13–36.) Detailed description of an aerial comprising an octagonal-section inner waveguide surrounded by eight ridged waveguides with offset longitudinal slots. The picture and sound signals are diplexed, using either a combining filter and single feed line or a separate coaxial-line sound input with a special diplexer. The construction is of aluminium with a thin covering of fibre glass for weather protection.

621.396.677.85 **2298**
Successive Approximation and Expansion Methods in the Numerical Design of Microwave Dielectric Lenses.—R. L. Sternberg. (*J. Math. Phys.*, Jan. 1956, Vol. 34, No. 4, pp. 209–235.)

AUTOMATIC COMPUTERS

681.142 **2299**
The Short Electronic Analogue Computer.—R. J. A. Paul. (*Overseas Engr*, Jan. & Feb. 1956, Vol. 29, Nos. 337 & 338, pp. 205–208 & 251–252.) Description of the design and operation of a general-purpose computer designed for quantity production and capable of single-shot and repetitive operation.

681.142 **2300**
Tridac, a Large Analogue Computing Machine.—F. R. J. Spearman, J. J. Gait, A. V. Hemingway & R. W. Hynes. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 375–390. Discussion, pp. 390–395.) A detailed description; a shorter account was abstracted previously (943 of 1955).

681.142 **2301**
Function Generators based on Linear Interpolation with Applications to Analogue Computing.—E. G. C. Burt & O. H. Lange. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 51–58.) By using suitable combinations of diode circuits and high-gain feedback amplifiers it is possible to generate functions without restriction to monotonic characteristics. Experimental results are presented for a sin x generator in which the error is about $1\frac{1}{2}$% of the maximum output.

681.142 **2302**
Construction and Method of Operation of Modern Integrating Equipment [differential analysers].—H. Hoffmann. (*Elektrotech. Z.*, *Edn A*, 11th Jan. & 1st Feb. 1956, Vol. 77, Nos. 2 & 3, pp. 41–52 & 77–83.) General principles are discussed and a detailed description is given of an installation in Germany. The results are presented to three or four significant figures by counter mechanisms, and in the form of curves on function benches. Curves of empirical functions are dealt with by photoelectric scanning. Errors do not exceed 0·1‰–1‰.

681.142 : [621.314.63 + 621.314.7 **2303**
Engineering Multistage Diode Logic Circuits.—B. J. Yokelson & W. Ulrich. (*Elect. Engng, N.Y.*, Dec. 1955, Vol. 74, No. 12, p. 1079.) Design of computers using crystal diodes and transistors is discussed. Transistor input circuits directly coupled to multistage logic circuits may avoid the need for intermediate amplifier stages.

681.142 : 621.314.7 **2304**
Transistor Circuits for Analog and Digital Systems.—F. H. Blecher. (*Bell Syst. tech. J.*, March 1956, Vol. 35, No. 2, pp. 295–332.) A summing amplifier, an integrator and a voltage comparator using junction transistors are described, together with a voltage encoder made up from them, for translating voltages into equivalent time intervals for analogue-to-digital conversion.

681.142 : 621.314.7 **2305**
An Experimental Transistorized Calculator.—G. D. Bruce & J. C. Logue. (*Elect. Engng, N.Y.*, Dec. 1955, Vol. 74, No. 12, pp. 1044–1048.) The machine is functionally identical with the IBM Type-604 calculating punch, but the valves are completely replaced by transistors and Ge diodes.

681.142 : 621.37 **2306**
An A.M.-A.M. Multiplier.—L. Lukaszewicz. (*Bull. Acad. polon. Sci.*, *Classe* 4, 1955, Vol. 3, No. 3, pp. 145–148. In English.) A relatively simple purely electronic multiplier circuit for differential analysers is described. Working with an upper frequency limit of 10 kc/s for both factors, accuracy is within about 0·3% of full scale.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.011 **2307**
Abac of the Function $2J_1(z)/zJ_0(z)$ for studying the Initial Complex Permeability of Circular-Cross-Section Conductors at High Frequency.—J. Benoit

& E. Naschke. (*J. Phys. Radium*, Jan. 1956, Vol. 17, No. 1, pp. 77–78.) The impedance of the conductor is measured and the parameter z is then found from the abac, using a known formula; the complex permeability μ is then derived using a given relation between μ and z. This abac supplements that presented by Prache (1875 of 1950), which was not applicable to good conductors.

621.3.011 : 621.396.822 **2308**

Physical Sources of Noise.—J. R. Pierce. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, pp. 601–608.) The principal types of electrical noise encountered in circuits and valves are identified and the mechanisms giving rise to them are discussed. Equations used to represent noise phenomena are derived.

621.3.011.21 : 621.375.13 **2309**

The Impedance Concept.—C. G. Mayo & J. W. Head. (*Wireless Engr*, April & May 1956, Vol. 33, Nos. 4 & 5, pp. 96–102 & 121–128.) Impedances and associated transfer functions are expressed in terms of a variable $p = \alpha + j\omega$ which is closely associated with time differentiation. The fundamental properties of the 'p world' are discussed. A general condition for an algebraic equation to be free from roots with positive real parts is obtained; a network whose characteristic equation has this property is stable. Conditions are deduced for a system to have a damping rate at least equal to a specified value. The effect of adding terms in p^4 and p^5 on the roots of a given cubic in p is examined. The effect on the gain and maximum obtainable feedback of the addition of a 'step circuit' to a three-stage *RC* amplifier is considered in detail.

621.3.066.6 : 621.318.5 **2310**

Properties and Comparative Tests on Relay Contacts.—T. Gerber. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Jan. 1956, Vol. 34, No. 1, pp. 1–26. In French.) See 2545 of 1955.

621.314.222 : 621.397.6 **2311**

Toroidal Transformers pass Video Bandwidths.—G. W. Gray. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 150–153.) Television video transformers are wound on supermalloy tape-wound toroids having a low-frequency permeability of 70 000 diminishing with increasing frequency; a bandwidth of 6 Mc/s is obtainable. These transformers may be used for matching a 50-Ω coaxial cable and for interstage coupling in transistor video amplifiers.

621.314.222.012.3 **2312**

[Power-] **Transformer Design Chart.**—R. Lee & N. E. Mullinix. (*Trans. Inst. Radio Engrs*, April 1955, No. PGCP-3, pp. 10–14; *Electronics*, April 1956, Vol. 29, No. 4, pp. 184–186.) The chart gives data for designing two-winding 60-c/s l.v. transformers.

621.316.8.029.6 : 621.315.212 : 621.372.22 **2313**

The Theory and Design of Coaxial Resistor Mounts for the Frequency Band 0 – 4 000 Mc/s.—I. A. Harris. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 1–10.) A design is described in which the resistive inner conductor has uniform diameter while the outer conductor has a tractrix profile. Lead-in cones are designed to avoid discontinuity at the connections. Experimental results indicate that the impedance is within 1% of the d.c. resistance, with an extremely small phase angle, at all frequencies up to the highest measured, namely 3·45 kMc/s.

621.316.86 : 546.281.26 **2314**

The Operating Mechanism of Voltage-Dependent Silicon-Carbide Resistors.—K. Zückler. (*Z. angew. Phys.*, Jan. 1956, Vol. 8, No. 1, pp. 34–40.) Measurements on aggregates of SiC particles, such as pressed powder, show how thermal effects depend on grain size and the duration of the current pulse. Thermal and field effects can be separated by reference to resistance/voltage characteristics at different temperatures for single contacts between crystals or between a crystal and a metal knife-edge.

621.316.86 : 621.3.012.8 **2315**

The Specification of the Properties of the Thermistor as a Circuit Element in Very-Low-Frequency Systems.—C. J. N. Candy. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 398–409.) "An analysis based on sinusoidal applied voltages shows that a conductor whose resistance is a function of temperature may be represented by an equivalent circuit having a semicircular impedance locus. An expression for the distortion of the waveform is also obtained, and this is found to be small provided that the alternating current is less than a quarter of the steady polarizing current which flows in the conductor. The impedance loci of a bead-type thermistor are plotted by means of a null technique. A typical impedance varied from a negative resistance of 3 000 ohms at very low frequencies to a pure inductance of 2 000 H at 0·3 c/s and then to a positive resistance of 5 000 ohms at high frequencies. The use of the equivalent circuit is illustrated by designing phase-shift networks suitable for use in the stabilizing of very-low-frequency control systems. These circuits may be used in systems where either a.c. or d.c. data transmission is employed."

621.316.86.002.2 **2316**

Problems Encountered and Procedures for obtaining Short-Term Life Ratings on Resistors.—W. T. Sackett, Jr. (*Trans. Inst. Radio Engrs*, April 1955, No. PGCP-3, pp. 15–29.) Account of investigations made at the Battelle Memorial Institute on the extent to which length of life must be sacrificed when composition resistors are operated at high temperature. A machine system for handling the data is described.

621.318.435.3 : 621.316.722 **2317**

A.C. Controlled Transductors.—A. G. Milnes & T. S. Law. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 81–94.) Analysis of the behaviour of the single-core auto-self-excited transductor is made for the condition when the control circuit has finite resistance. A.c. control of full-wave transductors and some push-pull circuits with half-wave and full-wave outputs are referred to.

621.318.435.3.011.6 **2318**

The Residual Time-Constant of Self-Saturating (Auto-Excited) Transductors.—U. Krabbe. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 71–80.) Theoretical and experimental evidence is presented indicating that the main winding of a self-saturating transductor influences the time constant for small signals to an extent dependent on the blocking intervals of the rectifiers and on the main-winding resistance. The blocking interval is in turn dependent on the output amplitude; this is consistent with the normal experience that transductor response becomes faster as the output increases.

621.318.57 : 621.374.32 : 621.387 **2319**

A Digital Differential.—W. H. P. Leslie. (*Electronic Engng*, May 1956, Vol. 28, No. 339, pp. 190–193.) A simultaneous bidirectional counter circuit is described in which a dekatron valve is used to indicate the running difference in count between two independent pulse trains; the circuit can also be used in frequency- and speed-control applications.

621.318.57 : 621.397.61 **2320**

Electronic Switches for Television.—Spooner. (See 2551.)

621.319.4 **2321**

The Effective Leakage Resistance of Several Types of Capacitors.—R. W. Tucker & S. D. Breskend. (*Trans. Inst. Radio Engrs*, April 1955, No. PGCP-3, pp. 3–9.) A rapid method of measuring leakage resistance based on rate of charge is described. Variation of leakage resistance with time was measured for commercial capacitors of values ranging from 0·001 to 0·033 μF, with various dielectrics, at temperatures ranging from 73° to 212°F in most cases. The best d.c. properties were exhibited by a capacitor having a polytetrafluoroethylene dielectric.

621.319.4 : 621.314.63 **2322**

A Variable-Capacitance Germanium Junction Diode for U.H.F.—Giacoletto & O'Connell. (See 2559.)

621.319.4 : 621.372.542.2 : 621.318.134 **2323**

Cascaded Feedthrough Capacitors.—H. M. Schlicke. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, pp. 686–691.) By interspersing lossy ferrite washers between the stacked ceramic disks of capacitors of the type described previously (1279 of 1955), the filtering properties for v.h.f. and u.h.f. are greatly improved; such constructions are thus useful for miniaturized low-pass filters. Properties of suitable ferrites are discussed.

621.37/.39(083.74) **2324**

National Bureau of Standards Preferred Circuits Program.—J. H. Muncy. (*Elect. Engng, N.Y.*, Dec. 1955, Vol. 74, No. 12, pp. 1088–1090.) See 342 of February.

621.372 **2325**

Invariance and Mutual Relations of Electrical Network Determinants.—I. Cederbaum. (*J. Math. Phys.*, Jan. 1956, Vol. 34, No. 4, pp. 236–244.) Work by earlier authors, e.g. Tsang (48 of 1955), is generalized. The basic values of the impedance and admittance determinants are connected by a simple relation involving the determinant of the branch parameter matrix.

621.372 **2326**

Nonlinear Network Problems.—G. Birkhoff & J. B. Diaz. (*Quart. appl. Math.*, Jan. 1956, Vol. 13, No. 4, pp. 431–443.) General analysis is presented for flow problems; a number of theorems are proved. Relaxation methods are used.

621.372 : [621.385.3 + 621.314.7 **2327**

Transformation of the Matrices of Generalized Admittances (Impedances) for Various Triode Connections.—E. I. Adirovich. (*Zh. tekh. Fiz.*, Aug. 1955, Vol. 25, No. 8, pp. 1436–1443.) The usual three sets of connections for triode valves and for transistors are examined.

621.372.4/.5 : 621.3.011 **2328**

The Correlation between Decay Time and Amplitude Response.—S. Demczynski. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 64–70.) An investigation is made of the relation between (*a*) the decay time and the delay time of the indicial response, and (*b*) the bandwidth and peak values of the steady-state amplitude response, for various minimum-phase lumped-parameter networks. Formulae are derived expressing the functional relation between decay time and the ratio f_3/f_6, where f_3 is the bandwidth at -3 dB and f_6 that at -6 dB. A formula for delay time is derived which is valid for multistage circuits.

621.372.41 : 621.3.015.3 **2329**

Energy Considerations for Growth and Decay Transients in a Simple Resonator Circuit.—G. Čremošnik. (*Arch. elekt. Übertragung*, Feb. 1956, Vol. 10, No. 2, pp. 65–72.) Analysis is presented for a series *RLC* circuit, values of current, voltage, etc., being determined in terms of the characteristic resistance $K = \sqrt{L/C}$. The solution of the differential equations is simplified by taking the energy of the circuit as the basic time variable, since this is fixed by the initial conditions.

621.372.412 **2330**

40–50-Mc/s Overtone Quartz Crystal Units.—K. Takahara, M. Kobayashi, I. Ida & Y. Arai. (*Rep. elect. Commun., Lab., Japan*, Oct. 1955, Vol. 3, No. 10, pp. 46–50.) The experimental crystal described is a circular plate carrying an evaporated metal film, held at diametrally opposite points by springs attached to the lead terminals. Details are given of the lapping process and the frequency adjustment.

621.372.5 **2331**

The Most Elementary Geometrical Representation of Loss-Free Linear Quadripoles.—J. de Buhr. (*Nachrichtentech. Z.*, Feb. 1956, Vol. 9, No. 2, pp. 80–84.) "It is possible to describe impedance transformations in lossless and linear quadripoles by geometrical quantities and by cascade parameters. An unambiguous geometrical representation in the form of a system of two transformation lines equivalent to the one transformation line of an impedance transformation is also possible and this leads to a new and unified method of representing the three different transformations by linear quadripoles and by elliptical and hyperbolic quadripoles as well as by the parabolic reactance quadripole. This gives for the linear quadripoles an intuitive and elementary form of treatment which has proved to be very useful for the solution of many quadripole problems. An impedance transformation using the images with respect to two transformation lines is given for the example of a parabolic reactance quadripole such as a series capacity."

621.372.542.4 : 621.396.41 **2332**

Interference Spectra and Aerial Filters. A Note on the Problem of the Simultaneous [two-way] Operation of Directional Radio Systems with Pulse Modulation.—A. Käch. (*Nachrichtentech. Z.*, Feb. 1956, Vol. 9, No. 2, pp. 63–69.) The design of continuously tunable multi-circuit diplexing filters for u.h.f. communication systems is discussed. A frequency separation of 75 Mc/s is assumed between the associated transmitter and receiver, and the asymmetrical nature of the transmitter spectrum is taken into account.

621.373 : 621.316.729 **2333**

Theory of Synchronization of Self-Oscillations of Arbitrary Form.—I. I. Minakova & K. F. Teodorchik. (*C. R. Acad. Sci. U.R.S.S.*, 1st Feb. 1956, Vol. 106, No. 4, pp. 658–660. In Russian.) Analysis is given for an oscillation containing only a few harmonic components. The effect of applying a sinusoidal force, of a frequency near the third harmonic, is investigated by a method involving the use of Fourier-series coefficients.

621.373.42 : 621.316.729 **2334**

Discrimination of a Synchronized Oscillator against Interfering Tones and Noise.—D. G. Tucker & G. G. Jamieson. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 129–138.) The discrimination exercised by a nonlinear regenerative tuned circuit against unwanted signals accompanying a synchronizing tone is due partly to the frequency response of the system and partly to the nonlinearity, provided that the synchronizing signal has a greater amplitude than the unwanted signals after allowing for frequency response. The phenomenon is analysed, and measurements of discrimination against noise are reported; the degree of discrimination can be very great when the synchronizing frequency is very close to the natural frequency of the circuit. When the synchronizing tone is absent or is not dominant there is no reduction of the interference intensity or bandwidth.

621.373.421 **2335**

A Wide-Range *RC* Phase-Shift Oscillator.—W. Fraser. (*Electronic Engng*, May 1956, Vol. 28, No. 339, pp. 200–202.) An oscillator with a frequency range from below 1 c/s to over 100 kc/s is described; d.c. coupling is used. A polyphase version is also described.

621.373.421 + 621.375.23] : 621.385.3.029.6 **2336**

A Grounded-Grid Valve System with High Stability Characteristics.—Exley & Young. (See 2589.)

621.373.421.11 **2337**

Frequency Stability of *LC* Oscillators with Large Grid and Anode Capacitances.—J. Groszkowski. (*Bull. Acad. polon. Sci., Classe* 4, 1955, Vol. 3, No. 3, pp. 149–155. In English.) General analysis is given for the Clapp circuit. Various factors affecting the frequency, and the optimum distribution of instability components among the circuit elements and supply voltages are discussed. See also 3170 of 1954 (Clapp).

621.373.43/.44 **2338**

The Generation and Application of Rectangular Pulses.—R. S. Sidorowicz. (*A.T.E. J.*, Jan. 1956, Vol. 12, No. 1, pp. 23–42.) A survey of various known techniques, covering both relaxation oscillators and monostable circuits. A delay-line pulse generator, a free-running multivibrator and a cathode-coupled monostable multivibrator are discussed in detail. The suitability of a valve for switching applications can be estimated on the basis of a figure of merit given by the ratio between the mutual conductance g_m and the total interelectrode and stray capacitance. Transition times are about 30 mμs for circuits using high-g_m double triodes or pentodes and of the order of 100 mμs for circuits with low-g_m valves. 49 references.

621.373.431 **2339**

Study of a Flip-Flop with Four Positions of Equilibrium by the Methods of Topological Analysis.—L. Sideriades. (*C. R. Acad. Sci., Paris*, 19th & 26th March 1956, Vol. 242, Nos. 12 & 13, pp. 1583–1586 & 1704–1707.) Analysis is presented in general terms for a two-stage circuit, assuming square-law valve characteristics. Three possible states identified are (*a*) static, (*b*) dynamic, and (*c*) impulse. The Eccles-Jordan and multivibrator circuits are particular cases. An experimental circuit has been designed; its performance agreed well with the predictions.

621.373.431.1 : 621.314.7 **2340**

Multivibrator Circuits using Junction Transistors.—A. E. Jackets. (*Electronic Engng*, May 1956, Vol. 28, No. 339, pp. 184–189.) Conventional circuits operating predictably at frequencies up to at least 10 kc/s are described.

621.373.44 : 621.387 **2341**

Reduction of the Minimum Striking Voltage of Hydrogen Thyratrons.—A. E. Barrington. (*Electronic Engng*, May 1956, Vol. 28, No. 339, p. 219.) An auxiliary tripping circuit is described by means of which the output voltage of a line-type thyratron pulse generator is made continuously variable from 0–20 kV.

621.373.52 : 621.398 **2342**

A Temperature-Stable Transistor V.C.O. [voltage-controlled oscillator].—F. M. Riddle. (*Trans. Inst. Radio Engrs*, Nov. 1954, No. PGRTRC-2, pp. 11–15. Abstract, *Proc. Inst. Radio Engrs*, April 1955, Vol. 43, No. 4, p. 514.) An oscillator for telemetry purposes is described.

621.375.225.029.3 **2343**

Cascode A.F. Amplifier.—L. B. Hedge. (*Wireless World*, June 1956, Vol. 62, No. 6, pp. 283–287.) A cathode-coupled phase inverter circuit using cascode-connected twin triodes is described, as part of a high-fidelity a.f. amplifier which does not require a specially designed output transformer.

621.375.3.012 **2344**

Analysis of a Differential Magnetic Amplifier with Flux Reset Control.—C. A. Belsterling. (*J. Franklin Inst.*, Dec. 1955, Vol. 260, No. 6, pp. 485–505.)

GENERAL PHYSICS

53.05 **2345**

The Smoothing of Non-formulated Experimental Laws by an Averaging Operation involving No Spurious Deviations.—P. Vernotte. (*C. R. Acad. Sci., Paris*, 26th March 1956, Vol. 242, No. 13, pp. 1697–1699.) A section of an experimental curve comprising *M* points is assimilated to a second-degree polynomial and the required ordinates are hence calculated without introducing spurious undulations.

530.152.15 **2346**

A Simplified Mathematical Approach to Hysteresis Losses.—H. L. Armstrong. (*Elect. Engng, N.Y.*, Dec. 1955, Vol. 74, No. 12, p. 1060.) The hysteresis loop such as a normal *B/H* curve is approximated by an ellipse, features resulting from harmonics (i.e. nonlinearities) being neglected; calculations are thus simplified.

535.343.4 **2347**

The Absorption Spectrum of Nitric Oxide in the Far Ultraviolet.—J. Granier & N. Astoin. (*C. R. Acad. Sci., Paris*, 12th March 1956, Vol. 242, No. 11, pp. 1431–1433.)

535.42 **2348**

On Asymptotic Series for Functions occurring in the Theory of Diffraction of Waves by Wedges.—F. Oberhettinger. (*J. Math. Phys.*, Jan. 1956, Vol. 34, No. 4, pp. 245–255.) An asymptotic expansion of the integral expression for diffraction by a wedge, at distances large compared with λ, is obtained as the sum of a Fresnel integral, as leading term, and an asymptotic series of inverse powers of the distance; for small values of the distance the expansion takes the form of a series involving Bessel functions.

537/538 2349

Multipotentials of Multipoles.—P. de Belatini. (*Bull. tech. Univ. Istanbul*, 1955, Vol. 8, pp. 57–74. In English.) General theory is presented, applicable equally to magnetic or dielectric multipoles. Every multipole is shown to be associated with a scalar or vector multipotential which has spherical symmetry; from the equation of this multipotential the usual scalar potential can be obtained by successive derivations.

537.21 2350

The Electrostatic Centre of a Conductor.—R. Cade & D. O. Vickers. (*Proc. phys. Soc.*, 1st Feb. 1956, Vol. 69, No. 434B, pp. 175–179.)

537.221 : 537.533 2351

Variation of Volta Potential [work function] with Temperature.—G. C. Mönch. (*Z. Phys.*, 17th Jan. 1956, Vol. 144, Nos. 1–3, pp. 263–268.) Experimental results show that the measured work functions of Ag_2S, AgI and Cu_2O depend on the experimental conditions rather than on the electron concentration or structural phase changes. This was investigated in greater detail by Böttger (2352 below).

537.221 : 537.533 2352

Investigation of the Temperature Dependence of the Electron Work Function of Metals and Semiconductors.—O. Böttger. (*Z. Phys.*, 17th Jan. 1956, Vol. 144, Nos. 1–3, pp. 269–295.) The variation of the work function of copper and nickel sheets was determined from the I/V characteristics of a special diode with a tungsten filament, as a function of time, temperature (100° – 300°K) and degree of vacuum. The temperature dependence was also investigated for *p*-type Cu_2O, *p*-type NiO and *n*-type CuO. Results, presented graphically, indicate that for work-function measurements on metals a vacuum better than 10^{-8} Torr is required.

537.228.2 2353

On the Molecular Theory of Electrostriction.—B. K. P. Scaife. (*Proc. phys. Soc.*, 1st Feb. 1956, Vol. 69, No. 434B, pp. 153–160.) The case of a sphere of fluid dielectric subjected to a uniform external field is discussed from both macroscopic and microscopic points of view. That part of the spur of the stress tensor $3\Delta P$ which depends quadratically on the applied field is calculated for both nonpolar and dipolar dielectrics; the Lorenz-Lorentz and Debye theories lead to the result that ΔP is zero, but more modern theories lead to a different result.

537.312.62 : 538.569.4 2354

Millimeter-Wave Absorption in Superconducting Aluminum.—M. A. Biondi, M. P. Garfunkel & A. O. McCoubrey. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1427–1429.) Available experimental evidence indicates that for wavelengths above ~ 1 cm the absorption is different for the normal and the superconducting states. Measurements are reported on a high-purity-Al waveguide; the ratio of surface resistivities for the superconducting and normal states is plotted as a function of temperature for various mm values of λ. The results are discussed in relation to alternative energy-gap models.

537.312.62 : 538.569.4 2355

Very-High-Frequency Absorption in Superconductors.—M. J. Buckingham. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1431–1432.) Measurements by Blevins et al. (1356 of May) indicate that the temperature at which the absorption departs from that in the normal state differs from the transition temperature T_0 by an amount strongly dependent on the frequency. A brief discussion shows that this dependence follows immediately from the concept of a gap in the electron-energy-level spectrum of a superconductor.

537.52 2356

Glow-to-Arc Transition.—W. S. Boyle & F. E. Haworth. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 935–938.) Conditions for the glow-to-arc transition at moderately high pressures (50–1 300 mm Hg) have been studied experimentally. Over this pressure range the transition is certain to occur only when the field reaches a critical value; this result is consistent with a field-emission mechanism for the transition.

537.525 2357

Theory of the High-Frequency Discharge in Gases at Low Pressures. Determination of Starting Conditions.—J. Salmon. (*J. Phys. Radium*, Jan. 1956, Vol. 17, No. 1, pp. 33–36.) Continuation of work reported previously (2910 of 1955). The importance of secondary emission from the walls is emphasized. Experimental and theoretical curves of starting voltage as a function of pressure for frequencies of 25, 42·8 and 70·6 Mc/s are compared.

537.525.9.08 2358

Method of determining the Cathode Fall [of potential] in a [cold-cathode] Glow Discharge.—K. Rademacher & K. Wojaczek. (*Naturwissenschaften*, Feb. 1956, Vol. 43, No. 4, p. 78.) A brief account is given of a method involving the use of a hot-cathode discharge in one cross-arm of a cruciform tube with its positive column surrounding the cold cathode in the other arm.

537.533 2359

Experimental Verification of the Wave-Mechanical Theory of Field Electron Emission.—R. Haefer. (*Acta phys. austriaca*, Jan. 1956, Vol. 10, Nos. 1/2, pp. 149–161.) Methods described by Drechsler & Henkel (522 of 1955) are used to calculate the current density and field strength at a tungsten point and hence to estimate the accuracy of results obtained previously (1680 of 1941). Consideration is extended to the case when the tungsten is coated with foreign atoms.

537.533 : 621.38.032.212 2360

Electron Emission from Cold Metal Surfaces at Medium Field Strengths (~10^4 V/cm).—K. Kerner. (*Z. angew. Phys.*, Jan. 1956, Vol. 8, No. 1, pp. 1–8.) Report and discussion of measurements of the field emission of Fe, Al and Ag cathodes. Ag gave the highest emission; Fe the lowest. See also 3193 of 1954 (Kerner & Raether).

537.56 2361

Dynamics of Ionized Media.—S. Gasiorowicz, M. Neuman & R. J. Riddell, Jr. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 922–934.) "The behavior of an ionized plasma is discussed in an approximation in which an individual particle is assumed to obey a Fokker-Planck equation, and where its interaction with the environment is incorporated in the coefficients of the partial differential equation."

538.221 2362

The Study of Ferromagnetism in the Institute of Physics at the University of Ferrara.—A. Drigo. (*Ricerca sci.*, Jan. 1956, Vol. 26, No. 1, pp. 138–143.) A short report outlining some of the more important results achieved. Both thin-film and massive specimens have been studied. Research on internal dissipation is being pursued.

538.3 **2363**

Electromagnetic Momentum and Electron Inertia in a Current Circuit.—E. G. Cullwick. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 159–170.) The magnetic energy of a current circuit is identified with the kinetic energy of the mass equivalent of the total e.m. energy of the conduction electrons. The concept of e.m. momentum in a current circuit is used to determine the force on the end wire of a long rectangular circuit and to bring the known effects of electron inertia in a circuit within the scope of e.m. theory.

538.561 : [537.533.9 + 537.591.8 **2364**

Radiation emitted by a Uniformly Moving Electron in Electron Plasma in a Magnetic Field.—A. A. Kolomenski. (*C. R. Acad. Sci. U.R.S.S.*, 21st Feb. 1956, Vol. 106, No. 6, pp. 982–985. In Russian.) Results of the theoretical considerations presented indicate that Čerenkov-type e.m. radiation may be produced by charged particles not necessarily moving at relativistic speeds, e.g. cosmic particles in the ionosphere. The frequencies of the radiated ordinary waves lie in the range $\omega < \omega_0$, where ω_0 is the plasma angular frequency, that of extraordinary waves in the range $\omega_0 < \omega < \sqrt{\omega_0^2 + \omega_H^2}$ where ω_H is the gyrofrequency. Extraordinary waves only are produced (*a*) in weak magnetic fields and (*b*) by relativistic electrons.

538.566 : 535.13 **2365**

Investigation of the Propagation of [optical-type] **Signals in Dispersive Media, using an Acoustic Model.**—T. Ankel. (*Z. Phys.*, 17th Jan. 1956, Vol. 144, Nos. 1–3, pp. 120–131.) The theory of propagation of e.m. waves in a dispersive medium, as developed by Sommerfeld and Brillouin, is experimentally verified by measurements on an acoustic model which comprises a long hollow tube with closely spaced Helmholtz resonators along it.

538.566 : 535.42 **2366**

An Approximate Theory of the Diffraction of an Electromagnetic Wave by an Aperture in a Plane Screen.—R. F. Millar. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 177–185.) Theory based on the Sommerfeld half-plane solution is developed. For certain regions the field can be conceived as arising from the flow of electric and magnetic currents along the edge of the half-plane. This concept is extended to apertures of arbitrary form, the case of the circular aperture being studied particularly; the theory is supported by results of measurements.

621.3.013.78 : 538.221 **2367**

The Magnetic Screening Effect of Iron Tubes.—P. Hammond. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 112–120.) The problem is approached by considering the induced pole strength on the surface of the iron; the distribution of pole strength in general produces a magnetic field which varies from place to place over the screened region. Observations support the calculated values of screening ratio.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 : 551.5 **2368**

Radio Astronomy and the Fringe of the Atmosphere.—A. C. B. Lovell. (*Quart. J. R. met. Soc.*, Jan. 1956, Vol. 82, No. 351, pp. 1–14.) A survey presenting results of investigations on scintillations of radio stars in relation to the atmosphere in the 400-km altitude region, on meteor echoes, and on echoes from aurorae. The determination of the total electron content in the earth–moon space by the study of lunar echoes is discussed.

523.16 : 621.396.822 : 551.510.535 **2369**

Cosmic Radio-Frequency Radiation near One Megacycle.—G. Reber & G. R. Ellis. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 1–10.) Observations were made of cosmic radiation at 2·13, 1·435, 0·9 and 0·52 Mc/s during the period March–October 1955, at Hobart, Tasmania. Photographs of specimen records are reproduced. For values of the critical frequency near the observing frequency there is strong correlation between critical frequency and received amplitude; for lower values of critical frequency the received amplitude increases to an independent limiting value. The greatest intensity of the radiation arriving from the zenith when the plane of the galaxy was overhead was 10^{-19} W/m^2 per c/s per steradian at 2·13 Mc/s. (The name 'jansky' is suggested for the corresponding unit.) Only ordinary ionospheric propagation was important in the observations recorded.

523.78 : 538.56.029.6 **2370**

Observations of R.F. Emission from the Sun during the Solar Eclipse of 30th June 1954 at Byurakan [Armenian S.S.R.].—V. A. Sanamyan & G. A. Erznkanyan. (*Dokl. A. N. Arm. S.S.R.*, 1955, Vol. 20, No. 5, pp. 161–164. In Russian. *Referativnyi Zh., Fizika*, March 1956, No. 3, Abstract 8172.) Results, presented graphically, of intensity measurements during this partial eclipse (97% of total) show a decrease of up to 75% at 1·5 m λ and of up to 35% at 4·2 m λ. The diameter of the sun is 1·2 and 1·7 times the optical diameter at 1·5 m λ and 4·2 m λ, respectively.

550.38 : 523.165 **2371**

On Deriving Geomagnetic Dipole-Field Coordinates from Cosmic-Ray Observations.—J. A. Simpson, F. Jory & M. Pyka. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 11–22.) The coordinates of an equivalent dipole representing the external geomagnetic field can be determined from measurements of the nucleonic component longitude and latitude effects in the region of the geomagnetic equator. The measurement method and the relevant theory are outlined.

550.380.3 **2372**

Note on the Adjustment of Isomagnetic Charts to Mutual Consistency.—A. J. Zmuda. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 57–58.)

550.385 **2373**

Variations in Strength of Wind System, in the Dynamo Mechanism for the Magnetic Diurnal Variation, deduced from Solar-Flare Effects at Huancayo, Peru.—S. E. Forbush. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 93–105.)

551.510.41 : 523.78 **2374**

Electrophotometric Investigation of Atmospheric Ozone during the Solar Eclipses of 25th February 1952 and 30th June 1954.—Sh. A. Bezverkhni, A. L. Osherovich & S. F. Rodionov. (*C. R. Acad. Sci. U.R.S.S.*, 1st Feb. 1956, Vol. 106, No. 4, pp. 651–654. In Russian.)

551.510.52 : 621.396.11.029.62 **2375**

Abnormal V.H.F. Propagation.—Hooper. (See 2517.)

551.510.53 **2376**

Atmospheric Temperatures and Winds between 30 and 80 km.—W. G. Stroud, W. Nordberg & J. R. Walsh. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 45–56.) Rocket experiments made in New Mexico between July 1950 and September 1953 are described and the results are analysed. The mean altitude distribution of temperature exhibits a maximum of about 270°K at 50 km, with a lapse rate of about 2·5°/km above the peak. The highest wind speed was observed during winter; its value was 104 m/s at 55 km.

551.510.53 **2377**

Arctic Upper-Atmosphere Pressure and Density Measurements with Rockets.—H. E. LaGow & J. Ainsworth. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 77–92.) Report of measurements made during 1953 and 1954 using rockets launched at an altitude of about 25 km from balloons; the greatest altitude reached was about 80 km. Results deviated in some cases from previous rocket measurements.

551.510.535 **2378**

Electron Distribution in the Ionosphere.—G. A. M. King. (*J. atmos. terr. Phys.*, March 1956, Vol. 8, No. 3, pp. 184–185.) Addendum to an earlier note (117 of 1955).

551.510.535 **2379**

Irregularity and Regularity of the Sporadic-E Layer.—K. Rawer. (*Geofis. pura appl.*, 1955, Vol. 32, No. 3, pp. 170–224. In German.) From observations at recording stations much information is obtained about the highest vertical-incidence reflection frequency fE_s, but less about the blanketing frequency f_bE_s. Results must be interpreted in statistical terms. Time- and distance-correlation functions are established. Diurnal, seasonal and geographic regularities are discussed. A sharp maximum in fE_s occurs at the magnetic equator. No well-defined influence of the solar cycle has been found and only a very weak lunar-tide effect. Observations of the variation of reflection coefficient with frequency have been made apart from the routine evaluations. In temperate latitudes in about a third of all cases there is no partial reflection; in other cases local variations of electron concentration are such that the peak-value/mean-value ratio is between 1 and 2; higher ratios are rare. At low latitudes the variation may be more important. Ionograms of different stations have been classified for transparency, scatter, angle of incidence and layer development. Diffuse echoes exist often near the magnetic equator. In most cases E_s ionization originates as a thin layer of constant altitude. Transitory downward movements are responsible for E_{2s} in daytime. A cumulo-cirrus cloud layer is a good model for E_s ionization. Possible ionization processes are discussed. About 50 references.

551.510.535 **2380**

Temperature Distribution of the Ionosphere under Control of Thermal Conductivity.—F. S. Johnson. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 71–76.) Bates' theory (988 of 1952) is extended. The energy absorbed in the F region is assumed to be conducted downward into a denser region where it is dissipated by infrared emission. Calculations indicate that the atmosphere is isothermal above about 250 km and that there is a very strong temperature gradient between 100 and 200 km. The temperature in the isothermal region must be assumed to be 1 100°K to meet the requirement for the atmosphere near 300 km to support an F_2 region. The low temperature at 80 km is due primarily to the lack of absorbed energy there rather than to the presence of a strongly emitting layer.

551.510.535 **2381**

A New Method for obtaining Electron-Density Profiles from *P′-f* Records.—J. E. Jackson. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 107–127.) "A practical and accurate method for reducing *P′-f* records to electron densities *vs* true height is described and used to analyse *P′-f* records taken at White Sands. Direct measurements of electron densities in the ionosphere obtained with the aid of rockets are used to check the method. Results obtained by these two independent techniques are shown to be in excellent agreement. Twenty *P′-f* records were reduced for the period from 1948 to 1954, all of which reveal a considerable degree of regularity in the height of the daytime E_1 and F_2 regions. Some of the profiles obtained are shown. One of the illustrations shows a one-hour sequence, where the F_2 virtual height varied from 650 km to 410 km, whereas the true height remained essentially unchanged."

551.510.535 **2382**

Airborne Ionospheric Measurements in the North Pole Area.—G. Gassmann. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 136–138.) A brief preliminary report.

551.510.535 : 523.78 : 621.396.11 **2383**

Ionospheric Observations at Banaras during the Total Solar Eclipse on 20th June 1955.—Banerjee, Surange & Sharma. (See 2514.)

551.510.535 : 621.3.082.7 **2384**

Polarization of the Echoes from the Ionosphere.—J. K. D. Verma & R. Roy. (*Indian J. Phys.*, Jan. 1956, Vol. 30, No. 1, pp. 36–46.) Details are given of an improved type of radio polarimeter, similar in principle to that evolved by Eckersley & Farmer (1968 of 1946), for operation in conjunction with high-resolution sounding equipment. With this arrangement it is possible to separate normal echoes from those received from thin E_s layers or cloud-type irregularities. Photographs of some observed polarization patterns are reproduced and briefly discussed.

551.510.535 : 621.396.812.3 **2385**

The Fading of Radio Waves of Frequencies between 16 and 2 400 kc/s.—Bowhill. (See 2519.)

551.510.535 : 621.396.812.3 **2386**

The Fading Periods of the E-Region Coupling Echo at 150 kc/s.—Parkinson. (See 2520.)

551.510.535 : 621.396.812.3 **2387**

The Determination of the Horizontal Velocity of Ionospheric Movements from Fading Records from Spaced Receivers.—D. W. G. Chappell & C. L. Henderson. (*J. atmos. terr. Phys.*, March 1956, Vol. 8, No. 3, pp. 163–168.) A method is presented which does not require a long sample of record and which is valid for any distribution of orientation of 'lines of maximum amplitude'. The derived formula is compared with that of Mitra (96 of 1950). See also 1418 of May (Court).

551.510.535 : 621.396.812.3 **2388**

A Determination of Ionospheric Winds for a 24-Hour Period.—G. W. G. Court & E. S. Gilfillan. (*J. atmos. terr. Phys.*, March 1956, Vol. 8, No. 3, pp. 169–170.) Results are given of an analysis, using the method proposed by Court (1418 of May), of the fading records obtained at spaced receivers during an arbitrarily chosen 24-h period. A diurnal variation of wind direction appears to be indicated.

551.594.1 **2389**

On the Deviations of the Course of Elements of Atmospheric Electricity on Continents from the Worldwide Course.—R. Mühleisen. (*J. atmos. terr. Phys.*, March 1956, Vol. 8, No. 3, pp. 146–157.) Extensive recordings show that continental deviations from the normal oceanic diurnal pattern of potential-gradient and air-earth-current variations are caused mainly by positive space charges produced by urbanization, industry and traffic and distributed by air movements.

551.594.5 : 551.510.535 **2390**

Relationships between Aurora and Sporadic-E Echoes at Barrow, Alaska.—R. W. Knecht. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 59–69.) Report of observations of visual aurora made simultaneously with ionospheric soundings during March 1951; the observations for three nights are described in detail. Analysis of the results shows that E_s echoes at frequencies >7 Mc/s tend to occur when the aurora is near the zenith, that there is a direct relation between the brightness of inactive aurorae and the top frequency of E_s echoes, and that E_s echo ranges correspond with estimated slant ranges of visible auroral forms.

551.594.6 **2391**

The Annual Variations of the Atmospherics—Existence and Explanation of a Second Maximum in Winter, if Only Strong Impulses are Counted.—R. Reiter. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 23–26.) Records obtained at Munich of the numbers of atmospherics received in frequency ranges 10–50 kc/s and 4–12 kc/s over a period of five years are analysed and evaluated from the meteorological point of view.

551.594.6 **2392**

Stanford-Seattle Whistler Observations.—J. H. Crary, R. A. Helliwell & R. F. Chase. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 35–44.) Observations of times of occurrence of whistlers were made at Seattle, Washington, and Stanford, California, for two hours every week from October 1951 to October 1952, in order to determine the percentage of whistlers received simultaneously at both locations; the figure obtained was about 22%. This result is examined in relation to theories of whistler origin and propagation; it gives support to Storey's theory (142 of 1954). See also 1666 of 1955 (Koster & Storey).

551.594.6 : 551.510.535 **2393**

The 'Nose' Whistler—a New High-Latitude Phenomenon.—R. A. Helliwell, J. H. Crary, J. H. Pope & R. L. Smith. (*J. geophys. Res.*, March 1956, Vol. 61, No. 1, pp. 139–142.) Spectrograms of a type of whistler observed at College, Alaska, made by analysing tape recordings, are reproduced and discussed. The initial, or 'nose', frequency depends primarily on gyrofrequency, hence such observations should enable the effects of gyrofrequency and plasma frequency on dispersion to be separated, thus leading to more reliable estimates of the ionization density in the outer ionosphere.

551.594.6 : 551.510.535 **2394**

The Interpretation of Pulse Trains associated with Lightning Flashes.—W. O. Schumann. (*Z. angew. Phys.*, Jan. 1956, Vol. 8, No. 1, pp. 24–28.) A treatment of the propagation of atmospherics by earth and ionosphere reflections, assuming a radiating dipole source. See also 717 of 1955 (Hepburn & Pierce).

551.510.535 **2395**

Proceedings of the Fourth Meeting of the Mixed Commission on the Ionosphere. [Book Review]—Publishers: Union Radio-Scientifique Internationale, Brussels, 1954, 238 pp., 43s. (300 Belgian Fr. or $6.) (*Brit. J. appl. Phys.*, Feb. 1956, Vol. 7, No. 2, p. 83.) Contains papers presented in Brussels in August 1954, and discussions on them.

LOCATION AND AIDS TO NAVIGATION

621.396.933.1 **2396**

Beam Deflection Tube simplifies Radio Compass.—J. M. Tewksbury. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 166–167.) A design is described in which two miniature Type-6AR8 beam-deflection valves replace seven ordinary valves, thus reducing the size and weight of the equipment.

621.396.96 + 621.396.932 **2397**

Modernisation of Radio and Radar Equipment in H. M. Telegraph Ships.—W. Dolman & P. W. J. Gammon. (*P.O. elect. Engrs' J.*, Jan. 1956, Vol. 48, Part 4, pp. 204–207.)

621.396.96 **2398**

Radar P.P.I. Display uses Precision Interlace.—A. Shulman. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 168–171.) Target position data from automatic tracking computers are presented continuously in the form of marker dots on the p.p.i. screen by combining the two sets of scanning waveforms.

621.396.96 **2399**

Radar Polarization Power Scattering Matrix.—E. M. Kennaugh : C. D. Graves. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 695.) Comment on 1425 of May and author's reply.

621.396.963.3 : 621.396.822 **2400**

Visual Detectability of Signals in Noise.—J. W. R. Griffiths. (*Wireless Engr*, May 1956, Vol. 33, No. 5, pp. 118–120.) The variation of output-signal/noise ratio as a function of 'contrast' (using this term in the sense of a bias) is investigated for different input-signal/noise ratios. The results agree qualitatively with experimental results on probability of detection in very simple systems.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 **2401**

Photoconductivity of Some Cyanine Dyes.—R. C. Nelson. (*J. opt. Soc. Amer.*, Jan. 1956, Vol. 46, No. 1, pp. 10–13.)

535.215 **2402**

Sensitization of Photoconductivity in Cadmium Sulfide [by cyanine dyes].—R. C. Nelson. (*J. opt. Soc. Amer.*, Jan. 1956, Vol. 46, No. 1, pp. 13–16.)

535.215 : 537.323 : 546.817.221 **2403**

Thermoelectric Force Measurements on Illuminated Lead Sulphide.—H. A. Müser. (*Z. Phys.*, 17th Jan. 1956, Vol. 144, Nos. 1–3, pp. 56–65.) Experiments indicate that the true thermoelectric force is not affected by illumination; apparent variations of thermoelectric force are due to photovoltaic effects.

535.215 : 546.482.21 **2404**

Photoelectromagnetic Effect in Insulating CdS.—H. S. Sommers, Jr, R. E. Berry & I. Sochard. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 987–988.) "The short-circuit photoelectromagnetic current in insulating crystals of cadmium sulfide has been measured in a batch of electroluminescent crystals. The product $(\text{mobility})^3 \times (\text{lifetime})$ is found to be 1 $\text{cm}^6/\text{volt}^3\text{sec}^2$. The sensitivity of the equipment is sufficient to detect the photoelectromagnetic effect for crystals whose product is as low as 10^{-5} $\text{cm}^6/\text{volt}^3\text{sec}^2$."

535.37 **2405**

Associated Donor-Acceptor Luminescent Centers.—J. S. Prener & F. E. Williams. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, p. 1427.) Brief discussion of the properties of (Zn, Cd) (S, Se) phosphors activated with Cu, Ag, Au, P, As or Sb and co-activated with Cl, Br, I, Al, Ga or In.

535.37 : 535.215 **2406**

Dielectric Changes in Inorganic Phosphors.—S. Kronenberg & C. A. Accardo. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 989–992.) ZnS-CdS phosphors were investigated by using them as dielectrics in capacitors and exposing them to light. Observed capacitance changes are attributed partly to photoconduction effects and partly to true variations of dielectric constant.

535.37 : 535.215 : 546.472.21 **2407**

Determination of the Ratio of Effective Cross-Sections of Capture and Recombination of Optical [photo-liberated] Electrons in ZnS-Cu,Co Crystal Phosphors.—Syuĭ Syuĭ-Yun. (*C. R. Acad. Sci. U.R.S.S.*, 11th Feb. 1956, Vol. 106, No. 5, pp. 818–821. In Russian.)

535.37 : 546.48.185.161 **2408**

Lead- and Manganese-Activated Cadmium Fluorophosphate Phosphors.—R. W. Wollentin. (*J. electrochem. Soc.*, Jan. 1956, Vol. 103, No. 1, pp. 17–23.)

535.376 **2409**

Influence of Temperature on the Electroluminescence of Zinc Sulphides.—J. Mattler. (*J. Phys. Radium*, Jan. 1956, Vol. 17, No. 1, pp. 42–51.) An extended account of the investigation described previously (1362 of 1955).

535.376 : 546.472.21 **2410**

Time-Average Electroluminescence Output of some Zinc Sulfide Phosphors.—S. Nudelman & F. Matossi. (*J. electrochem. Soc.*, Jan. 1956, Vol. 103, No. 1, pp. 34–38.) "Dependence of time-average electroluminescence output on field strength and frequency is observed for frequencies up to 20 kc/s for green and blue emission. The field dependence can be described either by a power law or by an exponential law. The frequency dependence is discussed in terms of theoretical relations connecting the light output to recombination characteristics or to polarization effects. The polarization effects are of minor importance. Light outputs from sinusoidal and square wave excitation are compared."

535.376 : 546.472.21 : 537.226.2 **2411**

Dielectric Behavior of Electroluminescent Zinc Sulfides.—W. Lehmann. (*J. electrochem. Soc.*, Jan. 1956, Vol. 103, No. 1, pp. 24–29.) Measurements were made at voltages up to 600 V r.m.s. and frequencies up to >20 kc/s; the measurement cell and technique are discussed. Both the real and the imaginary parts of the dielectric constant vary inversely with frequency. The results support previous assumptions that the excitation mechanism for electroluminescence is different from that for photoluminescence, while the emission mechanisms are similar.

537.226/.227 **2412**

Behaviour of Ferroelectric $KNbO_3$ in the Vicinity of the Cubic-Tetragonal Transition.—S. Triebwasser. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 993–997.) Measurements on $KNbO_3$ single crystals are reported. From the values found for dielectric constant and spontaneous polarization a determination can be made of the first three terms of the power series expressing the free energy in terms of the polarization. The behaviour of the crystals in the cubic and tetragonal phases is in reasonable agreement with predictions based on Devonshire's theory for $BaTiO_3$ (663 of 1950 and 1341 of 1952); the corresponding constants for the two materials are of the same order of magnitude.

537.226/.227 : 546.431.824-31 **2413**

A Microstructure Study of Barium Titanate Ceramics.—F. Kulcsar. (*J. Amer. ceram. Soc.*, 1st Jan. 1956, Vol. 39, No. 1, pp. 13–17.) Polishing and etching techniques for preparing polycrystalline $BaTiO_3$ for metallographic examination are described. Photomicrographs are reproduced and discussed. A companion paper by Cook (*ibid.*, pp. 17–19) analyses some of the domain patterns found.

537.226/.227 : 546.431.824-31 **2414**

A Modified Replica Technique and its Application to the Examination of Etched Single Crystals of Barium Titanate.—D. S. Campbell & D. J. Stirland. (*Brit. J. appl. Phys.*, Feb. 1956, Vol. 7, No. 2, pp. 62–65.)

537.227 **2415**

Properties of Guanidine Aluminum Sulfate Hexahydrate and Some of its Isomorphs.—A. N. Holden, W. J. Mertz, J. P. Remeika & B. T. Matthias. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 962–966.) Report of an experimental study of this new class of ferroelectrics (2987 of 1955). The crystals are trigonal, with the ferroelectric direction along the trigonal axis. The 60-c/s hysteresis loops are often biased or double, the shape being correlated with the location of the specimen in the mother crystal. At room temperature the saturation polarization is about $0{\cdot}35\,\mu C/cm^2$ and the coercive force at 60 c/s is 1–3 kV/cm; these quantities increase with falling temperature. The small-signal dielectric constant is about 6 along the axis and about 5 perpendicular to it. The switching characteristics resemble those of $BaTiO_3$, but the present crystals are considerably slower.

537.228.1 : 548.5 **2416**

The Laboratory Production of Large Water-Soluble Crystals.—E. A. Taylor. (*P.O. elect. Engrs' J.*, Jan. 1956, Vol. 48, Part 4, pp. 219–223.) The production of synthetic crystals having useful piezoelectric properties is described.

537.311.3 **2417**

The Conductivity of an Antimony-Caesium Layer.—L. I. Shafratova-Ekertova. (*Zh. tekh. Fiz.*, Aug. 1955, Vol. 25, No. 8, pp. 1357–1363.) If an Sb-Cs layer is in contact with two metallic electrodes and a constant potential difference is applied to the electrodes, the current through the layer increases with time. A report is presented on an experimental investigation into the physical nature of this phenomenon; the results obtained are interpreted theoretically. It is suggested that the phenomenon is due to polarization of the layer in a sense facilitating the passage of current.

537.311.3 : 539.23 **2418**

On the Measurement of Electric Constants of Thin Metallic Films.—G. Bonfiglioli, E. Coen & R. Malvano. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 201–203.) For thin films, whose detailed geometrical form is usually unknown, it is impossible to determine the Hall coefficient and conductivity separately, but their product—the Hall mobility of the carriers—can be determined. Measurements on Au films evaporated on to mica bases are reported; the mobility is independent of film thickness between 100 and 600 Å, but its value is only about a quarter of the bulk mobility. The structure of thin films is discussed in the light of this result.

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537.311.3 : 546.841.4-31 **2419**

Polarization in Thorium Oxide Crystals.—W. E. Danforth & J. H. Bodine. (*J. Franklin Inst.*, Dec. 1955, Vol. 260, No. 6, pp. 467–483.) Description and discussion of phenomena observed when a constant current is passed through a thoria crystal in vacuum at temperatures between 900° and 1 300°C. Resistivity varied from 6 000 to 400 Ω.cm over this temperature range. Conduction seems to be almost entirely ionic, the electron current being <1% of the total.

537.311.31 + 537.311.33 **2420**

On the Transport Properties of Metals and Semiconductors.—D. Ter Haar. (*Physica*, Jan. 1956, Vol. 22, No. 1, pp. 61–68.) Simple kinetic theory is used to derive approximate expressions for the thermal conductivity, electrical conductivity, thermoelectric power, Hall constant and magnetoresistance of metals and semiconductors.

537.311.31 **2421**

Modulation of Conductivity by Surface Charges in Metals.—G. Bonfiglioli, E. Coen & R. Malvano. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1281–1284.) Measurements were made on thin films of Au, Bi and Sb; a large surface charge was induced by application of an electric field. A tentative interpretation of the observed conductivity changes is offered. See also 2418 above.

537.311.32 + 536.21] : 546.26 **2422**

The Thermal and Electrical Conductivities of Deposited Carbon.—A. R. G. Brown, W. Watt, R. W. Powell & R. P. Tye. (*Brit. J. appl. Phys.*, Feb. 1956, Vol. 7, No. 2, pp. 73–76.) Measurements were made in the temperature range 20°–200°C on commercial graphite and deposited carbon formed at 1 800°, 1 900°, 2 000° and 2 100°C. The thermal conductivities of the specimens deposited at 2 000° and 2 100°C were respectively 20% and 40% greater than that of copper. The electrical resistivity at 20°C was about $24{\cdot}5 \times 10^{-5}$ Ω.cm for carbon deposited at 2 100°C compared with $76{\cdot}2 \times 10^{-5}$ for commercial graphite or 323×10^{-5} for carbon deposited at 1 800°C. The results are tabulated.

537.311.33 **2423**

Transport and Deformation-Potential Theory for Many-Valley Semiconductors with Anisotropic Scattering.—C. Herring & E. Vogt. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 944–961.) A theory of transport phenomena is presented based on assumptions regarding the scattering processes which are less restrictive than those made previously [e.g. 2642 of 1955 (Herring)]. Three relaxation times are assumed, corresponding to the three principal directions of the ellipsoidal energy surfaces. Expressions for carrier mobility, Hall effect, magnetoresistance, piezoresistance and h.f. dielectric constant are derived in terms of the relaxation-time tensor. The deformation-potential approach of Bardeen & Shockley (3032 of 1950) is generalized to suit the many-valley model. The results are used for correlating mobility, piezoresistance, etc. for n-type Si and Ge.

537.311.33 **2424**

Effects of Pressure on the Electrical Properties of Semiconductors.—D. Long. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1256–1263.) Continuing previous work (e.g. 161 of January), various measurements have been made on Ge, InSb, InAs, GaSb, Te and Mg_2Sn at pressures up to 2 000 atm. The results are used to deduce the pressure dependence of carrier concentration, mobility, energy gap and effective mass. Whereas in Ge and Mg_2Sn the energy gap increases with increased pressure, in Te it decreases.

537.311.33 **2425**

Simultaneous Transport of Heavy and Light Holes in Semiconductors with a Degenerate Valence Band.—E. S. Rittner. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1291–1294.) "A theoretical study is presented of the motion in an n-type semiconducting filament of an injected narrow pulse of slow and fast holes subject to drift, diffusion, recombination, and reversible interband transitions. For low injection level and for interband transition times which are small compared to the recombination lifetime and to the observation time but large compared to the time between collisions, it is shown that both sets of holes propagate and broaden as a single pulse with a group mobility and diffusivity heavily weighted by that of the slower holes. This explains why only a single pulse is observed at the collector in drift mobility experiments."

537.311.33 **2426**

Degeneracy of the Electron Gas in Semiconductors.—A. G. Samoilovich & L. L. Korenblit. (*Uspekhi fiz. Nauk*, Dec. 1955, Vol. 57, No. 4, pp. 577–630.) A survey of work on factors affecting and effects of the electron-gas degeneracy. 42 references, about half of which are to Russian literature.

537.311.33 **2427**

A Formula for the Voltage/Current Characteristic of an *n-p* Junction.—V. L. Bonch-Bruevich & E. Ya. Pumper. (*Zh. tekh. Fiz.*, Aug. 1955, Vol. 25, No. 8, pp. 1520–1521.) If formula (1) proposed by Shockley (*Theory of Electronic Semiconductors*, 1953) is correct, then the ratio of the forward and reverse currents, for the same absolute value of the applied voltage, should be independent of the nature of the semiconductor. Such a general conclusion does not seem to be justifiable, hence the accuracy of the formula is questionable.

537.311.33 : 535.215 **2428**

Photoelectric Phenomena with Copper Phthalocyanine.—H. Baba, H. Chitoku & K. Nitta. (*Nature, Lond.*, 7th April 1956, Vol. 177, No. 4510, p. 672.) Experiments are briefly reported, the results of which indicate that this material is a semiconductor exhibiting photoconductive and photovoltaic properties.

537.311.33 : 535.215 : 546.682.86 **2429**

Photoconductive and Photoelectromagnetic Effects in InSb.—S. W. Kurnick & R. N. Zitter. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 278–285.) Measurements on single-crystal plates of p-type InSb were made at temperatures of 77° and 301°K. Electropolished and mechanically polished specimens yielded very different results. A simple two-dimensional theoretical model is used to interpret the results; it is assumed that hole-electron pairs are produced by the illumination at the surface only.

537.311.33 : 537.32 : 621.362 **2430**

Increasing the Efficiency of Semiconductor Thermocouples.—A. F. Ioffe, S. V. Aĭrapetyants, A. V. Ioffe, N. V. Kolomoets & L. S. Stil'bans. (*C. R. Acad. Sci. U.R.S.S.*, 21st Feb. 1956, Vol. 106, No. 6, p. 981. In Russian.) Results of theoretical considerations indicate that for maximum efficiency a high ratio of charge-carrier mobility to thermal conductivity is desirable. This can be achieved by using an isomorphous impurity to decrease the thermal conductivity; the charge-carrier mobility remains practically unchanged. The maximum efficiency occurs, theoretically, when the thermal e.m.f. of each branch of the thermocouple is about ±200 μV/degree.

537.311.33 : 546.23 2431

Influence of Light on the Dipole Absorption of E.M. Radiation by Selenium.—Y. Meinnel, J. Meinnel & Y. Balcou. (*J. Phys. Radium*, Jan. 1956, Vol. 17, No. 1, pp. 78–79.) Experiments with powder specimens of Se show that the activation energy is considerably lower for the illuminated than for the unilluminated material.

537.311.33 : [546.28 + 546.289 2432

Electrolytic Shaping of Germanium and Silicon.—A. Uhlir, Jr. (*Bell Syst. tech. J.*, March 1956, Vol. 35, No. 2, pp. 333–347.) Barrier effects and other phenomena occurring in the electrolytic etching of semiconductors, especially Ge, are described and techniques for using them in the shaping of semiconductor devices are discussed. Auxiliary techniques for localizing the action include optical illumination. Suitable electrolytes for etching Ge and Si are indicated.

537.311.33 : [546.28 + 546.289 2433

Infrared Absorption and Oxygen Content in Silicon and Germanium.—W. Kaiser, P. H. Keck, & C. F. Lange. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1264–1268.) "An optical absorption band at 9 μ has been correlated with the oxygen content in silicon. Pulled silicon crystals were found to contain up to 10^{18} oxygen atoms per cm^3 which seem to originate from the quartz crucible. The oxygen concentration in silicon crystals prepared by the floating zone technique in vacuum was found to be less than 10^{16} oxygen atoms per cm^3. The 9 μ absorption due to silicon-oxygen bond stretching vibrations provides a possibility for a quantitative oxygen analysis of high sensitivity. A corresponding absorption in germanium at 11·6 μ is believed to be due to a germanium-oxygen vibration."

537.311.33 : [546.28 + 546.289 2434

Surface States on Silicon and Germanium Surfaces.—H. Statz, G. A. deMars, L. Davis, Jr, & A. Adams, Jr. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1272–1281.) Measurements of the conductivity of *p*-type inversion layers on *n*-type crystals are reported and discussed. The steady-state conductance is related to a high density of surface states outside the oxide film which forms on the surface, while the non-steady-state conductance is related to states located at the semiconductor/oxide interface; the energy levels of the latter states are 0·455 and 0·138 eV below the middle of the energy gap for Si and Ge respectively. The mechanism of charge transfer through the oxide film is not yet clear.

537.311.33 : [546.28 + 546.289 2435

Effect of Dislocations on the Minority Carrier Lifetime in Semiconductors.—A. D. Kurtz, S. A. Kulin & B. L. Averbach. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1285–1291.) "The density of random dislocations in germanium and silicon crystals has been measured by means of X-ray rocking curves and by etch pit counting. Data obtained by the two methods are in good agreement, and dislocation densities in the range 10^4–$10^7/cm^2$ were found. The minority carrier lifetime was shown to vary with the dislocation density, and the results could be expressed in terms of a recombination efficiency per unit length of dislocation line, $\sigma_R = 1/N_D\tau$ (where N_D = dislocation density, τ = lifetime). σ_R was found to decrease with increasing resistivity of germanium and was higher for silicon than for germanium of comparable purity."

537.311 33 : [546.28 + 546.289 2436

Ionization by Collision in Silicon and Germanium.—E. Groschwitz. (*Z. Phys.*, 10th Jan. 1956, Vol. 143, No. 5, pp. 632–636.) The ionization coefficient α of an electronic semiconductor is calculated as a function of the electric field strength. Comparison with experimental results [1079 of 1954 (McKay & McAfee)] indicates that ionization by collision is determined by the interaction of the conduction electrons with acoustic as well as optical energy quanta.

537.311.33 : [546.28 + 546.289] : 621.311.6 2437

The Electron-Voltaic Effect in Germanium and Silicon *P-N* Junctions.—P. Rappaport, J. J. Loferski & E. G. Linder. (*RCA Rev.*, March 1956, Vol. 17, No. 1, pp. 100–128.) Extension of the investigation reported previously [1799 of 1954 (Rappaport)] of the voltage produced across the junction as a result of β-particle bombardment. Measurements on large-area alloy junctions are reported. The maximum efficiency of conversion of the radioactive power is probably $\not>$ 5% for Si; measured values of 2·5% were obtained. The life of the devices may be limited by the damage due to the high-energy bombardment.

537.311.33 : 546.28 2438

Photographs of the Stress Field around Edge Dislocations.—W. L. Bond & J. Andrus. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, p. 1211.) Infrared photographs obtained with Si crystals are reproduced.

537.311.33 : 546.28 : 621.314.7 2439

Surface Treatment of Silicon for Low Recombination Velocity.—A. R. Moore & H. Nelson. (*RCA Rev.*, March 1956, Vol. 17, No. 1, pp. 5–12.) Surface recombination velocities comparable with those for Ge can be obtained for *p*-type Si by treating the surface chemically so as to produce films of aniline-like aromatic liquids or of salts of sodium-dichromate type. Some details are given of the techniques involved and of the resulting improvement in the current amplification factor of *n-p-n* transistors. The treatment also eliminates channelling leakage at junctions. This is consistent with the theory that the films cause the energy bands to curve upwards at the surface.

537.311.33 : 546.289 2440

Effects of the Dislocations on Minority Carrier Lifetime in Germanium.—J. Okada. (*J. phys. Soc. Japan*, Dec. 1955, Vol. 10, No. 12, pp. 1110–1111.) A quantitative study is made, based on measurements of dislocation density, recombination velocity and carrier lifetime; the results are compared with theoretically deduced relations between these quantities. The density of active recombination centres along a dislocation is deduced to be about 6×10^5/cm.

537.311.33 : 546.289 2441

Effect of Electric Field on Surface Recombination Velocity in Germanium.—J. E. Thomas, Jr, & R. H. Rediker. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 984–987.) Experiments are described confirming theoretical predictions of correlation between surface recombination velocity and surface potential for *n*-type Ge. The results also give support to explanations of semiconductor excess noise based on the assumption of surface traps. The influence of the ambient atmosphere is studied.

537.311.33 : 546.289 2442

Relaxation Effects in Recombination Velocity on Germanium Surfaces under Transverse Electrostatic Fields.—A. Many, Y. Margoninski, E. Harnik & E. Alexander. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1433–1434.) Relaxation effects in surface recombination velocity were observed using the experimental technique described by Henisch & Reynolds (3652 of 1955). An explanation given previously in connection with surface conductivity [e.g. 3649 of 1955

(Kingston)] is applicable in this case also. The experimental results are correlated with corresponding data on surface conductivity in a separate paper (*ibid.*, pp. 1434–1435).

537.311.33 : 546.289 **2443**

Delay Time of Plastic Flow in Germanium.—J. R. Patel. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1436–1437.) Some experimental results are reported and discussed.

537.311.33 : 546.289 **2444**

Simple Method of Revealing *p-n* Junctions in Germanium.—R. W. Jackson. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 309–310.) Details are given of an electrolytic etching method in which the Ge slice has a silver electrode painted on one side and the electrolyte is prevented from wetting this side.

537.311.33 : 546.289 : 621.396.822 **2445**

Excess Noise Spectra in Germanium.—F. J. Hyde. (*Proc. phys. Soc.*, 1st Feb. 1956, Vol. 69, No. 434B, pp. 242–245.) Spectral distributions are investigated in which the noise varies as f^{-m} over a wide range of frequencies, where m is not equal to unity. A diagram shows the spectrum for an n-type Ge filament, synthesized from two f^{-1} arc cot ($\omega\tau$) spectra with limiting relaxation times τ_1 and τ_2 of 2×10^{-4} and 5×10^{-7} sec respectively. By superposing two basic spectra of this type, such as are postulated to arise from two recombination-centre levels, it is possible to generate an exponent which is practically constant at 1·24 over three decades of frequency. See also 2558 below.

537.311.33 : 546.561-31 **2446**

Lattice Defects and Dipole Absorption of E.M. Radiation by Cuprous Oxide.—J. Meinnel, E. Daniel & Y. Colin. (*J. Phys. Radium*, Jan. 1956, Vol. 17, No. 1, pp. 79–80.) Experiments have been made on a number of samples at temperatures from 77° to 350°K and at frequencies from 50 c/s to 28 Mc/s. Strong dipole absorption bands were observed in all cases. Activation energies between 0·18 and 0·44 eV are deduced.

2447

537.311.33 + 538.22] : [546.823.171 + 546.823.261] : 539.23

Some Electrical Properties of Titanium Nitride and Titanium Carbide.—A. Münster & K. Sagel. (*Z. Phys.*, 17th Jan. 1956, Vol. 144, Nos. 1–3, pp. 139–151.) Full report of experiments noted in 1386 of 1955 (Münster et al.). The semiconductor properties observed in TiN and TiC films deposited on SiO_2 may be due to inclusion of oxygen atoms.

537.311.33 : 546.863.683.231 **2448**

Electron Diffraction Determination of the Structure of $Tl_2Sb_2Se_4$.—Z. G. Pinsker, S. A. Semiletov & E. N. Belova. (*C. R. Acad. Sci. U.R.S.S.*, 21st Feb. 1956, Vol. 106, No. 6, pp. 1003–1006. In Russian.)

537.311.33 : 546.873.241 : 536.21 **2449**

The Thermal Conductivity of Bismuth Telluride.—H. J. Goldsmid. (*Proc. phys. Soc.*, 1st Feb. 1956, Vol. 69, No. 434B, pp. 203–209.) Measurements over the temperature range 150°–300°K indicate that the electronic contribution to the heat conduction is considerably greater for specimens in which the charge carriers are intrinsically excited than for specimens in which most of the carriers arise from an impurity concentration. This result can be explained by a theory which takes into account the transfer of ionization energy down a temperature gradient.

538.22 : 546.3-1-71-59 **2450**

Ferromagnetic and Antiferromagnetic Properties of the System Gold-Manganese.—A. Kussmann & E. Raub. (*Z. Metallkde*, Jan. 1956, Vol. 47, No. 1, pp. 9–15.) Experiments have established the existence of the ferromagnetic phase Au_4Mn. The phase Au_2Mn exhibits ferromagnetism and antiferromagnetism. The phase AuMn may also be antiferromagnetic.

538.221 **2451**

Intradomain Magnetic Saturation and Magnetic Structure of γ-Fe_2O_3.—W. E. Henry & M. J. Boehm. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1253–1254.) "The average moment for γ-Fe_2O_3 was found to be 1·18 Bohr magnetons per iron atom, which supports a preferential distribution of iron vacancies on octahedral sites in a spinel structure. A sample motion ballistic method was used for direct measurement of magnetic moments."

538.221 **2452**

Ferromagnetic Domain Nucleation in Silicon Iron.—L. F. Bates & D. H. Martin. (*Proc. phys. Soc.*, 1st Feb. 1956, Vol. 69, No. 434B, pp. 145–152.) "Powder deposit patterns obtained by the authors on single crystals of 3% silicon iron are consistent with a description of the processes of domain phase creation in terms of nucleation at inclusions in the surfaces. Domain nucleation is discussed in relation to various magnetic properties."

538.221 **2453**

Variation of the Magnetic Anisotropy Energy of Ni and of Ni-Cu Alloys as a Function of Temperature.—M. Sato & Y. Tino. (*J. Phys. Radium*, Jan. 1956, Vol. 17, No. 1, pp. 5–8.) Theory is based on consideration of the magnetic interactions between atoms in a crystal lattice. The anisotropy constant can be expressed as an exponential function of the square of the absolute temperature.

538.221 : 537.311.33 **2454**

Induced Ferromagnetism demonstrated by Addition of Lithium Ions to Nickel Oxide.—N. Perakis, A. Serres, G. Parravano & J. Wucher. (*C. R. Acad. Sci., Paris*, 5th March 1956, Vol. 242, No. 10, pp. 1275–1277.)

538.221 : 538.569.4 **2455**

Resonance of Ferrites at the Compensation Point in a Circularly Polarized Field (Ferrimagnetic Resonance).—J. Paulevé & B. Dreyfus. (*C. R. Acad. Sci.*, Paris, 5th March 1956, Vol. 242, No. 10, pp. 1273–1275.) Measurements on ferrites of composition $Li_{0.5}Fe^{+++}_{2.5-a}Cr^{+++}_aO_4$ in a circularly polarized u.h.f. field indicate that two types of resonance line can be distinguished in the neighbourhood of the compensation temperature; the gyromagnetic ratio corresponding to one of these is of sign opposite to that of the electron.

538.221 : 621.318.1 **2456**

Ferromagnetism in Relation to Engineering Magnetic Materials.—F. Brailsford. (*Proc. Instn elect. Engrs*, Part A, Feb. 1956, Vol. 103, No. 7, pp. 39–51.) ". . . a review is given of theoretical and experimental work mainly within the past ten years. This includes an account of ferromagnetic domains and of the small-particle theory of high coercivity. A description of the ferrites and of ferrimagnetism is given, and this is followed by a discussion of recent observations and ideas on the magnetic phenomena occurring at frequencies up into the microwave region."

538.632 **2457**
Significance of Hall-Effect Measurements on Alloys.—B. R. Coles. (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1254–1255.) Hall-effect data for a number of alloys are examined in the light of the accepted theory of this effect. It is concluded that assumptions made about the relaxation time which seem appropriate when scattering by lattice vibrations predominates are not valid when scattering by solute atoms becomes significant.

539.234 **2458**
Influence of the Thickness of Thin [evaporated] **Films on their Structure: Case of the Alloy Cu-Be.** —A. Viswanathan. (*C. R. Acad. Sci., Paris*, 19th March 1956, Vol. 242, No. 12, pp. 1586–1587.)

548.0 : [546.47 + 546.289 **2459**
Investigations of Texture in Thin Zinc and Germanium Films.—A. Segmüller. (*Z. Kristallogr.*, Jan. 1956, Vol. 107, Nos. 1/2, pp. 18–34.) An electron-optical crystallographic investigation at temperatures between 90° and 770°K is reported. Good single-crystal texture may be obtained at relatively low temperatures by depositing the Zn or Ge on a zinc-blende cleavage plane.

548.0 : 549.514.51 **2460**
Laws of Intergrowth of Oriented Rutile Inclusions in Quartz.—J. von Vultée. (*Z. Kristallogr.*, Jan. 1956, Vol. 107, Nos. 1/2, pp. 1–17.)

621.3.066.6 : 537.311.4 **2461**
Contact Resistance and Surface of Contact.—K. Millian & W. Rieder. (*Z. angew. Phys.*, Jan. 1956, Vol. 8, No. 1, pp. 28–34.) An investigation of the influence of contact pressure, aging and surface treatment, including greasing, on the contact resistance of crossed cylinders of Cu, Ag and W. For Cu and for heat-treated W the contact resistance increases exponentially with time.

621.315.612 **2462**
Boron Nitride.—K. M. Taylor. (*Mater. & Meth.*, Jan. 1956, Vol. 43, No. 1, pp. 88–90.) Physical properties of this ceramic insulating material are indicated.

621.315.615 : 537.52 **2463**
Breakdown Field Strength in Dielectric Liquids with Different Molecular Structure.—E. Musset, A. Nikuradse & R. Ulbrich. (*Z. angew. Phys.*, Jan. 1956, Vol. 8, No. 1, pp. 8–15.) Report of measurements made on some 30 organic liquids at atmospheric pressure, using d.c. and 50-c/s a.c.

621.315.616 : 537.533.9 **2464**
Electrons produce High-Temperature Dielectric. —J. B. Meikle & B. Graham. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 146–149.) A modified polyethylene irradiated by high-energy electrons has a volume resistivity of $10^{19}\,\Omega$.cm, dielectric constant of 2·3 and power factor $<0{\cdot}0007$, while retaining the other physical properties of normal polyethylene; the new material is stable up to 300°C. Technique involved in the use of the electron accelerator in the processing of cable insulation etc. is outlined.

MATHEMATICS

517 : 519.241.1 **2465**
A Short Table of the Laguerre Polynomials.—L. J. Slater. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 46–50.) A function referred to in connection with correlation analysis [2352 of 1955 Lampard)] is tabulated.

517.5 **2466**
The Method of Stationary Phase.—G. Braun. (*Acta phys. austriaca*, Jan. 1956, Vol. 10, Nos. 1/2, pp. 8–33.) The method presented is useful for evaluating an integral encountered in diffraction theory.

517.5 **2467**
On the Error Function of a Complex Argument.—J. Kestin & L. N. Persen. (*Z. angew. Math. Phys.*, 25th Jan. 1956, Vol. 7, No. 1, pp. 33–40. In English.) A simplified method of dealing with the error function is presented, based on a transformation. Both the real and the imaginary components can be split into two parts, of which the first can be expressed by elementary functions while the second can be represented by two integrals which can be easily evaluated.

517.9 **2468**
Integration of a Nonlinear Integral Equation.—P. Lévy. (*C. R. Acad. Sci., Paris*, 5th March 1956, Vol. 242, No. 10, pp. 1252–1255.) The equation discussed is that relating the kernel and the covariance of a random Laplace function $\Phi(t)$.

519.281.2 **2469**
Two Methods of obtaining Least-Squares Lines.—I. H. Sher. (*Science*, 20th Jan. 1956, Vol. 123, No. 3186, pp. 102–104.)

518.2 **2470**
Index Mathematischer Tafelwerke und Tabellen aus allen Gebieten der Naturwissenschaften. [Book Review]—K. Schütte. Publishers: R. Oldenbourg, Munich, 1955, 143 pp., 14.50 D.M. (*Nature, Lond.*, 28th April 1956, Vol. 177, No. 4513, p. 767.)

MEASUREMENTS AND TEST GEAR

529.7 **2471**
Atomic and Astronomical Time.—L. Essen & J. V. L. Parry. (*Nature, Lond.*, 21st April 1956, Vol. 177, No. 4512, pp. 744–745.) The National Physical Laboratory quartz clock has been calibrated at regular intervals by reference to the Cs resonator (3686 of 1955). A curve shows the frequency deviation over the period from June 1955 to January 1956, and a second curve shows the deviation from the Greenwich monthly revised values. The difference between these two curves represents the variation of the unit of astronomical time in terms of the Cs standard. Further curves show the Greenwich values reassessed after a long period, and astronomical observations, both in terms of the Cs standard.

621.3.001.3(083.74) : 621.318.423 **2472**
The Effect of Humidity on the Stability of Inductance Standards.—G. H. Rayner & L. H. Ford. (*J. sci. Instrum.*, Feb. 1956, Vol. 33, No. 2, pp. 75–77.) The changes in inductance of the National Physical Laboratory substandard inductance coils for a 10% increase in relative humidity range from $+0{\cdot}7$ part in 10^4 on a 100μ-H coil to $-0{\cdot}25$ part in 10^4 on a 10 000-μH coil. The changes may be partly explained by dimensional changes in the formers of the coils.

621.317.3 : 621.396.822 **2473**
Fluctuations in a Loaded Line.—V. S. Troitski. (*Zh. tekh. Fiz.*, Aug. 1955, Vol. 25, No. 8, pp. 1426–1435.) In measuring noise in a dipole connected to the noise meter by a long line, conditions may be created under

which the intrinsic noise of the meter input is reflected from the dipole, and thus the signal to be measured is changed by an unknown quantity. Conditions necessary for the measurement of weak noise are discussed, sources of errors are indicated, and methods for their elimination are proposed.

621.317.3 : [621.396.96 + 621.397.5 **2474**

Video Measurements employing Transient Techniques.—H. A. Samulon. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, pp. 638–649.) Equipment and waveforms suitable for testing television, radar and other systems are reviewed, and methods of measurement and evaluation of the response characteristics are discussed. The effect on the transient response of small variations in the transfer function of the system is examined. Criteria for assessing transient response are listed.

621.317.3(083.74) : 621.372.029.3 **2475**

I.R.E. Standards on Audio Systems and Components: Methods of Measurement of Gain, Amplification, Loss, Attenuation, and Amplitude-Frequency-Response, 1956.—(*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, pp. 668–686.) Standard 56 I.R.E.3.S1.

621.317.33.084.2 : 537.311.33 **2476**

A Four-Point Probe Apparatus for measuring Resistivity.—D. B. Gasson. (*J. sci. Instrum.*, Feb. 1956, Vol. 33, No. 2, p. 85.) Description of apparatus with probe spacing of 1 mm and minimum surface leakage path of 1 cm which has been developed for measuring resistivities of semiconductors.

621.317.335.3 **2477**

Line Corrections in Permittivity Measurements at Frequencies below 50 Mc/s.—R. Guillien. (*J. Phys. Radium*, Jan. 1956, Vol. 17, No. 1, pp. 52–56.) Classical line theory is used to determine the corrections necessary to take account of the line joining the specimen to the measuring apparatus in measurements at Mc/s frequencies. Formulae are derived giving ϵ' and ϵ'' directly in terms of the measured value of the apparent dielectric constant.

621.317.335.3.029.64 **2478**

A Centimetre-Wave Parallel-Plate Spectrometer.—P. H. Sollom & J. Brown. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 419–428.) The instrument described is based on the same general principles as that of Culshaw (1135 of 1954), but the radiation is enclosed between two parallel disks of diameter about 4 ft whose spacing, which is equal to the height of the specimen, is only 3/16 in. The radiation is injected by means of a sectoral horn free to move over a 90° sector of the disk circumference, and is detected by a similar horn or a waveguide located anywhere on the circumference.

621.317.337 : 621.372.412 : 537.228.1 **2479**

A New Method for measuring the Quality Factor Q of Piezoelectric Crystals.—H. Mayer. (*C. R. Acad. Sci., Paris*, 12th March 1956, Vol. 242, No. 11, pp. 1428–1430.) H.f. oscillations exciting the crystal at its resonance frequency are interrupted by means of a vibrator at 100 c/s. During the interruptions the crystal executes damped oscillations; these are displayed on a c.r.o. and the Q factor hence determined. For glucinium sulphate the Q value obtained is 6 700 in vacuum, 3 300 in air.

621.317.34 : 621.317.729 : 621.372.2 **2480**

An Investigation into some Fundamental Properties of Strip Transmission Lines with the Aid of an Electrolytic Tank.—Dukes. (See 2283.)

621.317.341.029.63 : 621.315.212 **2481**

Determination of the Attenuation of Coaxial Cables in the Frequency Range 300–1 000 Mc/s by Measurement of the Input and Output Voltage.—E. Scheffler & U. Queck. (*Nachrichtentech. Z.*, Feb. 1956, Vol. 9, No. 2, pp. 60–62.) The method described is suitable for tests on production lengths of cable. Details are included of a simple transformer section for use with specimens whose characteristic impedance differs from that of the test equipment.

621.317.342 : 621.317.755 **2482**

Group-Delay Measurements.—C. J. Heuvelman & A. van Weel. (*Wireless Engr*, May 1956, Vol. 33, No. 5, pp. 107–113.) "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 mμs can be achieved. The frequency range is 20–45 Mc/s."

621.317.361 : 621.384.612 **2483**

Bevatron-Frequency Measurement System.—W. M. Brobeck & W. C. Struven. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 182–187.) Digital counter techniques in conjunction with a c.r.o. display are used to monitor the relation of oscillator frequency to magnetic-field intensity during the acceleration period of the bevatron.

621.317.373 : 621.317.755 **2484**

Phase-Angle Measurement.—C. H. Vincent. (*Wireless Engr*, May 1956, Vol. 33, No. 5, pp. 113–117.) A c.r.o. method due to Fleming (*J. Instn elect. Engrs*, Nov. 1925, Vol. 63, No. 347, pp. 1045–1046) is discussed in which X and Y deflections are adjusted for equality and the phase difference is deduced from the resulting ellipse. Analysis indicates that lack of accuracy due to geometrical factors [1740 of 1953 (Benson)] is avoidable if reasonable precautions are taken.

621.317.42 **2485**

Methods of Measurement of Magnetic Field.—V. Andresciani. (*Ricerca sci.*, Jan. 1956, Vol. 26, No. 1, pp. 25–63.) A survey including methods based on the Hall effect in semiconductors and on nuclear magnetic resonance. 60 references.

621.317.42 **2486**

General Conditions to be satisfied by an Exploring Coil for measuring an Arbitrary Magnetic Field at a Point, giving Fourth-Order Terms.—P. Gautier. (*C. R. Acad. Sci., Paris*, 26th March 1956, Vol. 242, No. 13, pp. 1707–1710.) The possibility of eliminating the second-order terms with an exploring coil of finite volume is linked with the fact that the induction satisfies the Laplace equation.

621.317.42 : 621.317.715 **2487**

Characteristic Properties of Overdamped Galvanometers used as Partial Fluxmeters.—É. Selzer. (*C. R. Acad. Sci., Paris*, 12th March 1956, Vol. 242, No. 11, pp. 1422–1425.)

621.317.7 : 621.374.3 **2488**

A Novel Circuit for Electronic Measurements.—Abdel-Halim Ahmed. (*Elect. Engng, N.Y.*, Dec. 1955, Vol. 74, No. 12, p. 1049.) Digest of paper in *Trans. Amer. Inst. elect. Engrs*, Part I, *Communication and Electronics*, May 1955, Vol. 74, pp. 194–204. A square wave is applied to two valves operated as cathode followers, in push-pull, so that they are cut off alternately in phase with the a.c. signal input and at the signal frequency. The resulting average anode current is a measure of $I \cos \phi$, or $V \cos \phi$, where I, V and $\cos \phi$ are the current, voltage and power factor of the circuit measured. The instrument may be adapted to measure any of these quantities, or the power.

621.317.72 **2489**

A Note on the Theory of Oscillating-Electrode Voltmeters.—J. Rawcliffe. (*Proc. Instn elect. Engrs*, Part A, Feb. 1956, Vol. 103, No. 7, pp. 55–56.) "It has been tacitly assumed hitherto that the theory of the oscillating-electrode voltmeter derived for direct voltages applies equally well for alternating voltages if r.m.s. values are substituted for direct values. A rigorous treatment shows that this is not the case."

621.317.72 : 621.316.722.4 **2490**

A Voltage Divider containing a Nonlinear Unit.—L. L. Alston. (*Proc. Instn elect. Engrs*, Part A, Feb. 1956, Vol. 103, No. 7, pp. 52–54.) Analysis is presented for a voltage divider in which the low-voltage arm is shunted by a SiC resistor; the arrangement was designed primarily for measuring the burning voltage of an arc.

621.317.729 : 621.372 **2491**

The Determination of Complicated Wave Fields by means of Multidimensional *LC* Networks.—H. Schneider. (*Nachrichtentech. Z.*, Feb. 1956, Vol. 9, No. 2, pp. 70–76.) Networks of the general type described by Spangenberg et al. (3066 of 1949) have been designed at Darmstadt, using cable sections for the individual elements. As an example of use of the model, the determination of the field near a slot aerial is described.

621.317.729 : 621.396.621.54 **2492**

New Field Intensity Measuring.—Fuse & Soma. (See 2525.)

621.317.737 : 621.385.029.6 **2493**

An X-Band Magnetron Q-Measuring Apparatus.—J. R. G. Twisleton. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 339–343.) The apparatus described is of the type in which a directional coupler is used in conjunction with a frequency-sweep oscillator and c.r.o. to monitor the power reflected from the magnetron cavity. The measurement accuracy attainable by this method is discussed.

621.317.763.029.6 **2494**

The Rod Wavemeter for the Frequency Range 180–80 000 Mc/s—Construction and Measurement Results.—U. Adelsberger. (*Arch. elekt. Übertragung*, Feb. 1956, Vol. 10, No. 2, pp. 51–57.) A type of wavemeter developed at the Physikalisch-Technische Bundesanstalt comprises a coaxial line with sliding inner conductor (rod) of length less than that of the outer conductor; the line is thus open at one end and resonates when its length is an odd multiple of $\lambda/4$. This is advantageous from the point of view of accuracy, since the resonance positions for even generator harmonics do not coincide with those for odd harmonics. A model for mm-λ measurements has the outer conductor built up of quadrantal sections internally silvered and polished.

621.317.784.029.6 : 621.372.413 **2495**

A Resonant-Cavity Torque-Operated Wattmeter for Microwave Power.—R. A. Bailey. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 59–63.) The force on a small vane in a resonant cavity is a simple function of the Q factor, the power absorbed in the cavity, and the perturbation of the resonance frequency due to the vane. A sensitive measurement method based on these relations is described. Results obtained by this method and by the water-calorimeter method are compared. See also 220 of 1955 (Bailey et al.).

621.317.799 : 621.373.52 : 621.396.96.001.4 **2496**

Transistor Generator simulates Radar Target.—W. Eckess, J. Deavenport & K. Sherman. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 179–181.) Pulse-forming circuits for use in testing radar sets are described; either Ge or Si transistors may be used.

621.317 **2497**

Precision Electrical Measurements. Proceedings of a Symposium held at the National Physical Laboratory on 17–20 November, 1954. [Book Review]—Publishers: H.M. Stationery Office, London, 1955, 349 pp., 27s. 6d. (*Brit. J. appl. Phys.*, Feb. 1956, Vol. 7, No. 2, p. 82.) The scope of the 26 papers ranges from precision methods of measuring physical properties, such as dielectric constant, to general surveys of testing techniques, such as impulse testing, and includes the appraisal of special properties of new materials, such as the microwave performance of magnetic dielectrics.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

621-52 **2498**

An Introduction to the Analysis of Nonlinear Control Systems with Random Inputs.—J. F. Barrett & J. F. Coales. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 190–199.) In nonlinear systems with random inputs the probability distribution of the input has to be combined with that of the output in order to obtain that of the error function on which the output depends. When this is attempted, simultaneous integral equations are obtained; approximation methods of dealing with these are discussed. The possibility of using topological methods to investigate the stability of the systems is examined.

621-52 **2499**

A Three-Dimensional Machine-Tool Control System.—(*Electronic Engng*, May 1956, Vol. 28, No. 339, pp. 204–207.) Programming instructions taken from design drawings are worked out by an independent digital computer and recorded on magnetic tape which is used in a control unit to operate the machine tool. For measurement purposes an optical diffraction grating system is associated with each plane of the tool and in combination with a photosensitive detector produces a pulse train which is locked to the command pulse train through a servomechanism.

621.317.39 + 621-52 **2500**

Electronics in the Process Industries.—J. M. Carroll. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 138–145.) Measurement and control techniques used in chemical, petroleum and other continuous-flow plants are described.

621.317.39 : 620.179.1 **2501**

Prescribed-Function Vibration Generator.—P. M. Honnell. (*J. Brit. Instn Radio Engrs*, April 1956, Vol. 16, No. 4, pp. 187–198.) Details are given of an arrangement developed for testing mechanical systems. It comprises a mask profiled to represent the prescribed function (e.g. a square or triangular waveform) rotating in front of a photocell, a vibrating platform being driven by the photocell amplifier.

621.317.79 : 539.1 : 538.569.4 **2502**

The Measurement, by Nuclear Resonance, of Light Water Concentration in Mixtures of Light and Heavy Water.—A. M. J. Mitchell & G. Phillips. (*Brit. J. appl. Phys.*, Feb. 1956, Vol. 7, No. 2, pp. 67–72.) Two techniques for inducing r.f. power absorption are described, one suitable for H_2O concentrations in the range 7–100%, the other for low concentrations. In both cases the signal output rises almost linearly with H_2O concentration. A continuous flow method is also described.

621.384.6 **2503**

Design of the Pole Faces for Circular Particle Accelerators with the Electrolytic Tank.—F. Amman & L. Dadda. (*Nuovo Cim.*, 1st Jan. 1956, Vol. 3, No. 1, pp. 184–187. In English.)

621.385.833 **2504**

On the Magnification and Resolution of the Field-Emission Electron Microscope.—D. J. Rose. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 215–220.) Analysis of electron trajectories indicates that the existence of small protrusions on the field-emission tip may give rise to local areas of enhanced magnification; a resolution of 3 Å may be attained at these regions, so that some of their atomic detail should be observable.

621.385.833 **2505**

A Favorable Condition for seeing Simple Molecules in a Field-Emission Microscope.—J. A. Becker & R. G. Brandes. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 221–223.) Experimental evidence is presented confirming the analysis developed by Rose (2504 above).

621.385.833 **2506**

General Expressions and Typical Curves of Electro-optical Characteristics of Magnetic Electron Lenses.—P. Durandeau. (*C. R. Acad. Sci., Paris*, 26th March 1956, Vol. 242, No. 13, pp. 1710–1712.)

621.385.833 **2507**

Phase Contrast and Interchromatic Contrast: New Observation Methods in Electron Microscopy.—M. Locquin. (*C. R. Acad. Sci., Paris*, 26th March 1956, Vol. 242, No. 13, pp. 1713–1716.) Contrast is considerably increased by using an objective diaphragm with thinned edge in conjunction with illumination by a hollow cone of electrons.

621.385.833 **2508**

Investigation of Cylindrical Magnetic Lenses with Iron Armouring.—V. M. Kel'man & S. Ya. Yavor. (*Zh. tekh. Fiz.*, Aug. 1955, Vol. 25, No. 8, pp. 1405–1411.)

621.385.833 **2509**

Electron-Optical Equations for Wide Beams, taking Account of Chromatic Aberrations, and their Application to the Investigation of the Motion of Particles in Axially Symmetrical Fields.—Yu. V. Vandakurov. (*Zh. tekh. Fiz.*, Aug. 1955, Vol. 25, No. 8, pp. 1412–1425.)

621.386.8 : 621.383.2 : 620.179.1 **2510**

Intensification of the X-Ray Image in Industrial Radiology.—A. Nemet & W. F. Cox. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 345–355. Discussion, pp. 355–359.) The influence of brightness, blurring and contrast on the image resolution is examined. The improvement obtained by use of the image intensifier tube [1098 of 1953 (Teves & Tol)] is indicated.

621.387.424 **2511**

Analysis of Spuriousness of Geiger-Müller Tubes at High Temperatures.—S. P. Puri & P. S. Gill. (*Indian J. Phys.*, Jan. 1956, Vol. 30, No. 1, pp. 1–9.)

621.383 **2512**

Die Anwendung der Photozellen. [Book Review]—P. Goerlich. Publishers: Akademische Verlagsgesellschaft Geest & Portig K.G., Leipzig, 1954, 468 pp., DM 29. (*J. opt. Soc. Amer.*, Jan. 1956, Vol. 46, No. 1, pp. 73–74.) Comprises six chapters, dealing with the properties of photocells, the basic associated circuitry, applications for switching and control operations, photometry and recording, sound reproduction and image reproduction.

PROPAGATION OF WAVES

621.396.11 **2513**

Estimating the Ratio of Steady Sinusoidal Signal to Random Noise from Experimental Data.—M. L. Phillips. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 692.) A family of curves is presented and a procedure is indicated facilitating determination of the required ratio, which is of particular interest in studies of scatter propagation, from observed values of the envelope of received field intensities.

621.396.11 : 551.510.535 : 523.78 **2514**

Ionospheric Observations at Banaras during the Total Solar Eclipse on 20 June 1955.—D. K. Banerjee, P. G. Surange & S. K. Sharma. (*J. sci. industr. Res.*, Nov. 1955, Vol. 14A, No. 11, pp. 517–521.) Field-strength measurements were made on signals from Colombo on 30·51 m λ and from Delhi on 30·71 m λ; vertical-incidence measurements were also made. The results are shown graphically and discussed; they indicate that the ionospheric eclipse lasted longer than the optical eclipse. An increase of the strength of the Colombo signals during the eclipse is attributed to reduction of absorption in the lower layers, while a reduction of the strength of the signals from Delhi is attributed to the reduced reflection coefficient associated with lowering of the electron density.

621.396.11.029.55 : 551.510.535 **2515**

Directional Observations on H.F. Transmissions over 2 100 km.—E. N. Bramley. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 295–300.) Direction-of-arrival measurements have been made using a wide-aperture spaced-loop direction finder. Pulse transmissions were used for most of the experiments, and first- and second-order F-reflections could usually be identified at 11 Mc/s. The bearing fluctuations of these echoes included a lateral-deviation component of about the magnitude expected from previous experiments at shorter distances. The rapid fluctuations were appreciably larger than at 700 km (3389 of 1955); night-time observations on 5 Mc/s indicated a standard deviation of 1·5° for individual bearings in an hourly period. The corresponding figure for the 1F echo in the day-time on 11 Mc/s was only 0·6°. The results were unaffected by changes made in the transmitting aerials and by ionospheric and magnetic storms.

621.396.11.029.62 : 523.5 2516

Observations of Short Bursts of Signal from a Distant 50-Mc/s Transmitter.—B. H. Briggs. (*J. atmos. terr. Phys.*, March 1956, Vol. 8, No. 3, pp. 171–183.) Analysis of reception over a distance of about 500 km strongly suggests that the majority, if not all, of the signals are deflected from meteor trails. In many cases the reflection point appears to be near the receiver rather than at the mid-point of the transmission path.

621.396.11.029.62 : 551.510.52 2517

Abnormal V.H.F. Propagation.—A. H. Hooper. (*Wireless World*, June 1956, Vol. 62, No. 6, pp. 295–298.) A method is indicated for constructing a graph showing variations of r.f. refractive index of the troposphere with height, using data derived from the daily meteorological observations of air pressure, dew point and temperature.

621.396.81.029.62 : 621.396.3 2518

V.H.F. Trans-horizon Communication Techniques.—Ringoen & Smith. (See 2532.)

621.396.812.3 : 551.510.535 2519

The Fading of Radio Waves of Frequencies between 16 and 2 400 kc/s.—S. A. Bowhill. (*J. atmos. terr. Phys.*, March 1956, Vol. 8, No. 3, pp. 129–145.) Night-time experiments using continuous waves reflected from the lowest ionosphere at nearly vertical incidence are discussed. Shallow fading with a quasi-period of 7 min is found in the frequency range 16–70 kc/s; above 70 kc/s fading with a quasi-period of about 1 min appears, increasing in depth with frequency. Ionosphere irregularities corresponding to ground dimensions of 5 km and 1 km, respectively, are indicated. The slow fading is due mainly to random ionospheric velocities of about 40 m/s, superimposed on which is a smaller, very variable, drift velocity. A D-region model is suggested.

621.396.812.3 : 551.510.535 2520

The Fading Periods of the E-Region Coupling Echo at 150 kc/s.—R. W. Parkinson. (*J. atmos. terr. Phys.*, March 1956, Vol. 8, No. 3, pp. 158–162.) From analysis of echoes returned from the coupling region lying below the main E layer, two dominant distributions of the fading periods have been found, centred on periods of 2 and 7 min. Possible causative mechanisms are discussed.

RECEPTION

621.376.33 2521

Theory of Detection of Frequency-Modulated Oscillations.—V. K. Turkin & G. A. Levin. (*C. R. Acad. Sci. U.R.S.S.*, 21st Feb. 1956, Vol. 106, No. 6, pp. 999–1002. In Russian.) The transmission of a f.m. signal through a tuned circuit or band-pass filter followed by a square-law detector is considered using new functions which are defined by series involving Bessel functions. The a.f. output is calculated for a particular case.

621.396.3 : 621.396.82 2522

Waveform of Radiotelegraph Signals and Interference between Adjacent Channels.—J. Marique. (*Ann. Télécommun.*, Feb. 1956, Vol. 11, No. 2, pp. 26–32.) The problem is attacked from the same general viewpoint as previously (3396 of 1955), consideration being given to the further case of pulses whose flanks are halves of Gaussian curves. The results indicate that no particular advantage accrues from use of this waveform.

621.396.621 : 621.376.3 : 621.396.82 2523

Impulse Noise in Narrow-Band F.M. Receivers.—S. P. Lapin & J. J. Suran. (*Elect. Engng, N.Y.*, Dec. 1955, Vol. 74, No. 12, p. 1091.) Digest of paper in *Trans. Amer. Inst. elect. Engrs*, Part 1, *Communication and Electronics*, Sept. 1955, Vol. 74, pp. 450–454. Loss of signal due to noise transients is minimized by rounding the band-pass characteristic of the receiver so that, after the initial maximum, the amplitude of the transient decays more rapidly than in filters having a flat band-pass response curve.

621.396.621.029.62 : 621.376.332 2524

Unconventional F.M. Receiver.—M. G. Scroggie. (*Wireless World*, June 1956, Vol. 62, No. 6, pp. 258–262.) Complementary details are given of the receiver embodying the pulse-counter discriminator described previously (1861 of June). A single intermediate frequency of the order of 150 kc/s is used, to suit the discriminator.

621.396.621.54 : 621.317.729 2525

New Field Intensity Measuring.—S. Fuse & S. Soma. (*Rep. elect. Commun. Lab., Japan*, Oct. 1955, Vol. 3, No. 10, pp. 55–58.) The sensitivity of a double-heterodyne receiver used for measuring field strength and spurious signals is improved by narrowing the bandwidth. The problem of local-oscillator frequency stability is dealt with by sweeping the frequency of the second oscillator.

621.396.621.54 : 621.398 2526

Telemetering Receiver conserves Bandwidth.—M. S. Redden, Jr, & H. W. Zancanata. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 174–178.) A crystal-controlled double-superheterodyne receiver covering the range 216–247 Mc/s is described. Two second-i.f. amplifiers are provided, one with a bandwidth of 100 kc/s, for reception of p.w.m./f.m. data, and the other with a bandwidth of 500 kc/s, for f.m./f.m. data.

621.396.822 2527

Methods of solving Noise Problems.—W. R. Bennett. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, pp. 609–638.) "A tutorial exposition is given of various analytical concepts and techniques of proved value in calculating the response of electrical systems to noise waves. The relevant probability theory is reviewed with illustrative examples. Topics from statistics discussed include probability density, moments, stationary and ergodic processes, characteristic functions, semi-invariants, the central limit theorem, the Gaussian process, correlation, and power spectra. It is shown how the theory can be applied to cases of noise and signal subjected to such operations as filtering, rectification, periodic sampling, envelope detection, phase detection and frequency detection."

621.396.823 2528

Limits for Radio Interference in Germany and Other Countries.—G. Use. (*Elektrotech. Z., Edn A*, 11th Jan. 1956, Vol. 77, No. 2, pp. 33–40.) The methods of measurement of radio interference and the recommended limits are summarized for nine European countries, North America and Japan. 19 references.

STATIONS AND COMMUNICATION SYSTEMS

621.376.2 : 621.3.012.1 2529

A Vector Method for Amplitude-Modulated Signals.—C. J. N. Candy. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 410–415. Discussion, pp. 415–418.) Notation and analysis are presented facilitating calculations of the output of a demodulator. Examples show that when modulation frequency is comparable with carrier frequency, the modulation (or signal) may be appreciably modified by impedances in the carrier channel. A complementary operational method for determining the response of circuits to nonsinusoidal a.m. signals is also described.

621.39.001.11 **2530**

Some Terminology and Notation in Information Theory.—I. J. Good. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 200–204.)

621.39.001.11 **2531**

The Arithmetical Characterization of Messages, and its Use for determining Correcting Networks.—M. Bayard & R. Roquet. (*Ann. Télécommun.*, Feb. 1956, Vol. 11, No. 2, pp. 33–45.) The message, or 'modulation phrase', is uniquely characterized by an 'index-number'; in the case of two-position telegraphy, which is examined in detail, this is given by

$$I = \sum_{n=0}^{n} \frac{\alpha_n}{2^n},$$

where n is the number of individual signals making up the message and α_n is the amplitude of an individual signal. For a given transmission system a curve can be traced showing the distortion of a reference signal at zero time as a function of I; from such curves, which take account of the effect of future signals, the appropriate correcting networks can be determined for obtaining a desired modification of the 'modulation phrase'.

621.396.3 : 621.396.81.029.62 **2532**

V.H.F. Trans-horizon Communication Techniques.—R. M. Ringoen & J. W. Smith. (*Electronics*, May 1956, Vol. 29, No. 5, pp. 154–159.) Possible techniques are reviewed with emphasis on the equipment requirements. It should be feasible to establish teleprinter links over distances up to 1 500 miles, in auroral regions, with reliability better than 99%.

621.396.3.029.55 **2533**

Observations and Experience at the Frankfurt a. Main Radio Exchange with the T.O.M. (Teletype on Multiplex) Equipment operated on Short-Wave Transmission Paths.—M. Corsepius & K. Vogt. (*Nachrichtentech. Z.*, Feb. 1956, Vol. 9, No. 2, pp. 55–59.) The observations indicate the improvements obtained by use of an automatic error-correction system. See also 2507 of 1954 (Hayton et al.).

621.396.41 : 621.376.5 : 621.396.65 **2534**

Pulse-Time-Modulation Terminals for Music Transmission over Radio Links.—R. F. Rous. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 283–292. Discussion, pp. 292–294.) A microwave link intended primarily for television is used alternatively to accommodate three music circuits and one engineer's circuit. Measurements indicate that signal/noise and signal/crosstalk ratios are satisfactory; operating over a 25-mile path there was a 20-dB margin in the signal/noise ratio over the value recommended by the C.C.I.R. The multiplexing circuit is described and performance figures are given.

621.396.65 : 621.396.41 **2535**

Radio-Link Network.—S. Montagnani. (*Poste e Telecomunicazioni*, Dec. 1955, Vol. 23, No. 12, pp. 884–894.) Account of the Bologna-Pisa trans-Appennine extension to the network described previously [2423 of 1955 (Bernardi)].

621.396.65.029.62 : 621.396.41 **2536**

Very-High-Frequency Radio Link between Puerto Rico and the Virgin Islands.—R. McSweeny. (*Elect. Commun.*, Dec. 1955, Vol. 32, No. 4, pp. 238–247; *Trans. Amer. Inst. elect. Engrs*, Part I, *Communication and Electronics*, Jan. 1956, Vol. 74, pp. 781–785.) Illustrated description of a two-stage link system with f.m. operation at frequencies between 150 and 160 Mc/s, providing several telephone and teleprinter channels.

621.396.65.029.63 : 621.396.41 **2537**

Microwave Relay System between Saint John and Halifax.—H. C. Sheffield. (*Elect. Commun.*, Dec. 1955, Vol. 32, No. 4, pp. 214–236; *Trans. Inst. Radio Engrs*, May 1956, Vol. CS-4, No. 2, pp. 144–167.) Detailed account of a time-division-multiplex radio link with five intermediate unattended repeaters. The 2-kMc/s transmission band is used. There are two multiplex equipments, each providing 32 voice channels, and three sets of r.f. equipment. Possible causes of interference are discussed and some performance figures are given.

621.396.71 **2538**

The New High-Frequency Transmitting Station at Rugby.—C. F. Booth & B. N. MacLarty. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 263–278. Discussion, pp. 278–282.) Comprehensive description of this British Post Office radio-communication station. A short account was abstracted previously (569 of February).

621.396.932 + 621.396.96 **2539**

Modernisation of Radio and Radar Equipment in H. M. Telegraph Ships.—W. Dolman & P. W. J. Gammon. (*P.O. elect. Engrs' J.*, Jan. 1956, Vol. 48, Part 4, pp. 204–207.)

621.396.975 : 621.395.623.8 **2540**

Wireless Sound Systems.—Hargens. (See 2278.)

SUBSIDIARY APPARATUS

621.311.6 : 537.311.33 : [546.28 + 546.289 **2541**

The Electron-Voltaic Effect in Germanium and Silicon *P-N* Junctions.—Rappaport, Loferski & Linder. (See 2437.)

621.311.6 : 621.383.5 : 539.165 **2542**

The Effect of Radioactive Radiation on a Photocell.—Pasynkov. (See 2567.)

621.311.6 : 621.39 **2543**

Automatic Control of Power Equipment for Telecommunications and Other Essential Services.—A. Watkins. (*J. Brit. Instn Radio Engrs*, April 1956, Vol. 16, No. 4, pp. 227–238.) "Two types of no-break generating sets are described: an all-electric battery operated equipment, and a diesel electric equipment. Detailed descriptions are given of three electronic devices used with these sets: (*a*) a static exciter automatic voltage regulator making use of two saturated transductors; (*b*) an alternator synchronizer in which the generator and mains voltages are compared in a triode circuit; (*c*) speed regulator using a thyratron which feeds the control field of the d.c. motor and also incorporates alarm and protection devices."

621-526 **2544**

Servomechanism Analysis. [Book Review]—G. J. Thaler & R. G. Brown. Publishers: McGraw-Hill, New York and London, 1953, 414 pp., 60s. (*Nature, Lond.*, 28th April 1956, Vol. 177, No. 4513, p. 766.) Gives the mathematical background for the analysis and design of servomechanisms, including a clear introduction to the theory of Laplace transformations.

TELEVISION AND PHOTOTELEGRAPHY

621.397.241 **2545**

The Provision of Circuits for Television Outside Broadcasts.—M. B. Williams & J. B. Sewter. (*P.O. elect. Engrs' J.*, Oct. 1955 & Jan. 1956, Vol. 48, Parts 3 & 4, pp. 166–170 & 234–238.) Technique and equipment for transmitting video signals over telephone pairs is described, including a new video repeater [see also 275 of January (Sewter & Wray)] and equipment for injecting vision signals into main coaxial-cable television links operated in the frequency ranges 3–7 Mc/s and 0·5–4 Mc/s.

621.397.26 : 621.396.65 **2546**

Microwave Television Radio Relay System.—O. H. Appelt, K. Christ & K. Schmid. (*Elect. Commun.*, Dec. 1955, Vol. 32, No. 4, pp. 248–254.) English version of paper originally published in German (538 of 1954).

621.397.5 **2547**

Phonevision—an Effective Method for Subscription Television.—A. L. C. Webb & A. Ellett. (*J. Brit. Instn Radio Engrs*, April 1956, Vol. 16, No. 4, pp. 205–219.) Paper reprinted from *Proc. Instn Radio Engrs, Aust.*, Oct. 1955, Vol. 16, No. 10, pp. 341–353.

621.397.5 : 535.623 **2548**

The Principles of N.T.S.C. Color Television.—C. J. Hirsch. (*J. Instn elect. Engrs*, Feb. 1956, Vol. 2, No. 14, pp. 89–97.)

621.397.5 : 778.5 **2549**

Television Studio Practices relative to Kinescope Recording.—H. Wright. (*J. Soc. Mot. Pict. Telev. Engrs*, Jan. 1956, Vol. 65, No. 1, pp. 1–6.) The problem of maintaining the correct brightness levels is considered in relation to the signal waveform.

621.397.5(083.74) **2550**

Fundamentals of the Television Standards adopted in Uruguay.—M. Giampietro. (*Rev. telegr. Electronica*, Jan. 1956, Vol. 44, No. 520, pp. 11–12, 16.) The various considerations such as mains frequency, international interchangeability, requirements for colour operation and magnetic recording, involved in the choice of standards are indicated. The standards adopted are 525 lines 60 fields for monochromatic operation and N.T.S.C. standards for colour, in accordance with F.C.C. recommendations except in respect of the difference between maximum and minimum transmitter levels and the channel spacings.

621.397.61 : 621.318.57 **2551**

Electronic Switches for Television.—A. M. Spooner. (*Electronic Engng*, May 1956, Vol. 28, No. 339, pp. 196–199.) Circuits for switching between video signals are discussed. The causes of switching transients are indicated and a transient-free switch is described in which a cathode-coupled triode pair, with a pentode for the common cathode impedance, feeds a series-connected double diode.

621.397.611.2 **2552**

The Problem of Inertia Effects in the Vidicon.—W. Heimann. (*Arch. elekt. Übertragung*, Feb. 1956, Vol. 10, No. 2, pp. 73–76.) Inertia effects were shown previously (2451 of 1955) to be due to photoelectric inertia in the target and to the nature of the charge-storage and signal-generating mechanisms, the latter being the more important. Experiments were made using target layers of different thicknesses and different scanned areas; the results confirmed the importance of obtaining the appropriate value for the capacitance of the picture elements. Measurements were made of the layer thickness by means of an interference microscope, and values of the capacitance were hence determined.

621.397.7 **2553**

Television Satellite Systems.—C. B. Plummer. (*Trans. Inst. Radio Engrs*, March 1955, No. PGBTS-1, pp. 65–66.) A brief discussion of television coverage problems in the U.S.A. precedes separate papers dealing with particular installations, as follows:—

U.H.F. Satellite Transmitter-Receiver Design and Operation.—L. Katz & T. B. Friedman (pp. 67–74; abstract, *Proc. Inst. Radio Engrs*, May 1955, Vol. 43, No. 5, p. 640).

The Engineering Aspects of a U.H.F. Booster Installation—J. Epstein (pp. 75–80; abstract as above).

A Report on U.H.F. Satellite Operation.—J. R. Whitworth (pp. 81–82).

An Experimental On-Channel Satellite Booster System.—J. H. DeWitt, Jr, G. A. Reynolds & L. E. Rawls (pp. 83–102).

621.397.7 : 535.623 : 621.3.06 **2554**

Color Video Switching.—W. B. Whalley & R. S. O'Brien. (*J. Soc. Mot. Pict. Telev. Engrs*, Jan. 1956, Vol. 65, No. 1, pp. 16–19.) Precautions taken to minimize the effect of capacitances in the studio switching equipment on the phase and amplitude response to the chrominance signal are described.

621.397.743 : 621.317.2 **2555**

The New Independent-Television Network.—S. H. Granger. (*P.O. elect. Engrs' J.*, Jan. 1956, Vol. 48, Part 4, pp. 191–197.) The structure of the system is outlined, with descriptions of the London studio links and inter-city networks and details of overall performance.

TRANSMISSION

621.396.61 : 621.375.232 **2556**

A Method of deriving Overall Negative Feedback Voltage in Transmitters.—D. Smart. (*J. Brit. Instn Radio Engrs*, April 1956, Vol. 16, No. 4, pp. 221–223.) Greater ease of frequency changing, greater linearity and reduced phase shift, drift and cost result if the feedback voltage is derived from a resistor in the earth return of the power amplifier valve rather than by the conventional method of rectifying part of the modulated output.

VALVES AND THERMIONICS

621.3.011 : 621.396.822 **2557**

Physical Sources of Noise.—Pierce. (See 2308.)

621.314.63 : 546.289 : 621.396.822 **2558**

Measurement of Noise Spectra of a Germanium *p-n* Junction Diode.—F. J. Hyde. (*Proc. phys. Soc.*, 1st Feb. 1956, Vol. 69, No. 434B, pp. 231–241.) "Measurements have been made of the excess noise generated in a fused-alloy-type *p-n* junction diode in the frequency range 0·12 c/s to 2 Mc/s at 29°C with the reverse direct current I as parameter. The observed noise spectral density may be synthesized from three well-defined types of component: (*a*) an extensive component proportional to f^{-1} directly observed over five decades, and by synthesis assumed to exist over as many as seven decades of frequency; (*b*) a component proportional to $(1 + \omega^2\tau_1^2)^{-1}$ associated with a single relaxation time τ_1; (*c*) a uniform component associated with the 'shot' noise of the measured current I, for frequencies less than $1/2\pi\tau_p$ where τ_p is the hole lifetime. τ_1 was found to increase with increasing I while the intensity of the f^{-1} component increased more rapidly than in proportion to I^2."

621.314.63 : 621.319.4 **2559**

A Variable-Capacitance Germanium Junction Diode for U.H.F.—L. J. Giacoletto & J. O'Connell. (*RCA Rev.*, March 1956, Vol. 17, No. 1, pp. 68–85; *RCA Special Publication, Transistors I*, 1956, pp. 221–238.) The significance of various design factors for the performance of alloy-junction diodes is considered with reference to use of the diodes as voltage-controlled capacitors when biased in the reverse direction. For a particular diode with a bias of 6 V the capacitance was 38 $\mu\mu$F and the voltage variation of capacitance was 3 $\mu\mu$F/V; the lead inductance was 2·6 mμH and the effective series resistance 0·5 Ω. The Q value was very high at the lower radio frequencies, decreasing to 17 at 500 Mc/s.

621.314.632 : 546.817.221 **2560**

Analysis of H_2S-Treated PbS Point-Contact Rectifiers.—V. G. Bhide, J. N. Das & P. V. Khandekar. (*Proc. phys. Soc.*, 1st Feb. 1956, Vol. 69, No. 434B, pp. 245–248.) Measurements were made on natural and synthetic crystals originally of n-type but converted to p-type, to a certain depth, by heating in a H_2S atmosphere and used in combination with various metal points. The values obtained for α, the slope of the semi-log plot of the I/V characteristic, are near the theoretical value of 40 V^{-1}, whereas the values of α for the original n-type material are considerably lower. The significance of the results is discussed briefly.

621.314.7 **2561**

Some Experiments on, and a Theory of, Surface Breakdown [in transistors].—C. G. B. Garrett & W. H. Brattain. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 299–306.) The experiments were performed on n-p-n alloy-junction transistors as used by Wahl & Kleimack (2243 of July). The procedure followed was to measure photocurrent point by point for voltages first below and then above breakdown value. Results indicate that surface breakdown, like body breakdown, is an avalanche process; the multiplication sets in at a particular spot. High breakdown voltage is encouraged by arranging that the polarity of the surface charge is such as to produce a 'channel' over the material of the higher-resistivity side, and by surrounding the unit with a medium of high dielectric constant.

621.314.7 **2562**

Uniform Planar Alloy Junctions for Germanium Transistors.—C. W. Mueller & N. H. Ditrick. (*RCA Rev.*, March 1956, Vol. 17, No. 1, pp. 46–56; *RCA Special Publication, Transistors I*, 1956, pp. 121–131.) Technique is described for obtaining flat junctions, by separating the wetting from the alloying steps. As a consequence, the upper limit on operating frequency is considerably raised.

621.314.7 **2563**

***P-N-P* Transistors using High-Emitter-Efficiency Alloy Materials.**—L. D. Armstrong, C. L. Carlson & M. Bentivegna. (*RCA Rev.*, March 1956, Vol. 17, No. 1, pp. 37–45; *RCA Special Publication, Transistors I*, 1956, pp. 144–152.) "The addition of small percentages of gallium or aluminum to indium, for use as the emitter alloy, produces greatly improved high-current characteristics. As compared with pure indium, the use of gallium alloys improves emitter efficiency by about 3·5 times, and the use of aluminum-bearing alloys by about 10 times. Techniques for preparation of the alloys and results of tests on transistors using the various emitters are described. Volume lifetime is measured as a function of injection level to permit comparison with the theoretical equations for current amplification factor. These measurements are discussed briefly, and a revised equation for current amplification factor at high currents is given."

621.314.7 : 537.311.33 : 546.28 **2564**

Surface Treatment of Silicon for Low Recombination Velocity.—Moore & Nelson. (See 2439.)

621.383.4 : 546.289 : 621.396.822 **2565**

Technique for Improving the Signal-to-Noise Ratios of Single-Crystal Photoconductive Detectors.—R. M. Page, R. W. Terhune & J. Hickmott, Jr. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 307–308.) Correlation technique adapted from that used by Montgomery (122 of 1953) is briefly described. The detector is a Ge filament, and the light source a neon lamp modulated at 1 kc/s.

621.383.5 : 537.311.33 **2566**

Photovoltaic Effect in GaAs *p-n* Junctions and Solar Energy Conversion.—D. A. Jenny, J. J. Loferski & P. Rappaport. (*Phys. Rev.*, 1st Feb. 1956, Vol. 101, No. 3, pp. 1208–1209.) Measurements on several cells are reported and the results are compared with theoretical predictions. The highest value obtained for the efficiency of conversion of solar energy is 6·5%, which is of the same order as values obtained for Si and CdS, but higher values are to be expected as the technique of preparing the cells is improved.

621.383.5 : 539.165 : 621.311.6 **2567**

The Effect of Radioactive Radiation on a Photocell.—V. V. Pasynkov. (*Zh. tekh. Fiz.*, Aug. 1955, Vol. 25, No. 8, pp. 1376–1385.) Experiments conducted on a Se barrier-layer photocell indicate that the effect of β-radiation is similar to that of a light beam. It is suggested that with the aid of artificial radioactive isotopes small low-power electric batteries can be constructed which would not be damaged by short circuits and which would have a very long working life.

621.385 : 537.533 **2568**

Instability of Electron Beams subjected to a Magnetic Field.—B. Epsztein. (*C. R. Acad. Sci., Paris*, 12th March 1956, Vol. 242, No. 11, pp. 1425–1428.) Analysis is presented to explain the breaking-up of a tubular beam observed by Webster (*J. appl. Phys.*, Nov. 1955, Vol. 26, No. 11, pp. 1386–1387). Instability can also occur without a magnetic field. The energy brought into play is derived entirely from the mutual repulsion of the electrons.

621.385.001.4 **2569**

A Simple Optical Method for determining Grid-Cathode Spacing in Electronic Valves.—W. Guber & W. Stetter. (*Nachrichtentech. Z.*, Feb. 1956, Vol. 9, No. 2, pp. 77–79.)

621.385.029.6 **2570**

The Design of High-Power Traveling-Wave Tubes.—M. Chodorow & E. J. Nalos. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, pp. 649–659.) The design of valves for pulsed powers of the order of 1 MW is discussed. Some success has been achieved with an experimental valve operating in the 3-kMc/s band, using a disk-loaded waveguide for slowing the wave. From results of measurements on this valve it is inferred that bandwidths of 10–20% should be attainable with reasonable efficiency. Modifications in attenuator, focusing and coupling systems likely to lead to improved performance are indicated.

621.385.029.6 **2571**

A Large-Signal Theory of Traveling-Wave Amplifiers.—P. K. Tien. (*Bell Syst. tech. J.*, March 1956, Vol. 35, No. 2, pp. 349–374.) The work of Nordsieck (2497 of 1953) and Tien et al. (1822 of 1955) is extended to take fully into account the effects of space-charge repulsion and of a finite coupling between electron beam and circuit. The energy associated with the backward wave is calculated and its effect on efficiency is discussed. Assuming typical values for the various parameters, values ranging from 23% to 40% are found for the saturation efficiency. Curves and tables are presented showing the voltage and phase of the circuit wave, the velocity spread of electrons and the fundamental component of the charge-density modulation.

621.385.029.6 **2572**

Travelling-Wave Tubes.—F. N. H. Robinson. (*Research, Lond.*, Jan. 1956, Vol. 9, No. 1, pp. 27–31.) Recent developments are briefly surveyed; space-periodic beam-focusing arrangements, nonreciprocal attenuators, improvements in noise figure, and backward-wave valves are mentioned. Over 30 references.

621.385.029.6 **2573**

Phase-Angle Distortion in Traveling-Wave Tubes.—W. R. Beam & D. J. Blattner. (*RCA Rev.*, March 1956, Vol. 17, No. 1, pp. 86–99.) A theoretical study is made of variations of phase velocity with supply voltages, signal level and matching conditions; Pierce's first-order theory (*Traveling-Wave Tubes*, 1950) is used. The results are in good agreement with measurements on a valve operating at 3 kMc/s, in which the following phase shifts were observed: 50° for 1% change in helix voltage; 2° for 1% change in first-anode voltage; about 0·1° for 1% change in magnet current; 6° for each mW increase of output power; 6° for each mW of power lost by reflection at the output coupler.

621.385.029.6 **2574**

Bihelical Traveling-Wave Tube with 50-dB Gain at 4 000 Mc/s.—W. P. G. Klein. (*Elect. Commun.*, Dec. 1955, Vol. 32, No. 4, pp. 255-262.) A 5-W valve suitable for microwave relay systems is discussed. In order to maintain the gain as near as possible to the small-signal value, two helices are provided. having separate d.c. circuits and coupled only by the beam; an attenuating section is arranged between the two helices, the second of which is shorter than the first. Measurements on several experimental valves are reported.

621.385.029.6 **2575**

On the Space Charge affected by the Magnetic Field.—Y. Yasuoka. (*J. phys. Soc. Japan*, Dec. 1955, Vol. 10, No. 12, pp. 1102–1109.) A study has been made of effects due to dense space charge constrained by a strong magnetic field. Special experimental tubes were used, with a tungsten-filament cathode and copper-block anode, and the cathode back-heating was measured in the absence and in the presence of the magnetic field. The measurements confirm the theory that the outermost electrons of the space-charge cloud are scattered by mutual interaction and have excess energies, thus giving rise to the back heating. When the anode voltage is made sufficiently high, these electrons are captured and oscillations, probably of plasma type, occur.

621.385.029.6 **2576**

Development of Traveling-Wave Tubes for 4 000-Mc/s Band.—K. Sato, D. Kobayashi, A. Kondo & J. Koyama. (*Rep. elect. Commun. Lab., Japan*, Oct. 1955, Vol. 3, No. 10, pp. 11–16.) Details are given of the design, construction and performance of several helix-type valves developed in Japan.

621.385.029.6 **2577**

The Cascade-Bunching of Electrons in Application to the Theory of the Multi-resonator Magnetron.—V. N. Shevchik. (*Zh. tekh. Fiz.*, Aug. 1955, Vol. 25, No. 8, pp. 1462–1470.) Attempts have been made in the literature to consider the operation of a magnetron from the standpoint of the interaction of the electron stream with the h.f. fields localized directly at the anode slots, as distinct from the method of the travelling wave; this treatment is developed further. A detailed analysis of the operation of a magnetron with a 'thick' cathode is given, the results are in good agreement with experimental data.

621.385.029.6 : 621.317.737 **2578**

An X-Band Magnetron Q-Measuring Apparatus.—Twisleton. (See 2493.)

621.385.029.6 : 621.373.423 **2579**

A Reflex-Klystron Oscillator for the 8–9-mm Band.—D. J. Wootton & A. F. Pearce. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 104–111.) Detailed description of the Type-VX5023 klystron; it is continuously tunable over the wavelength range 8–9 mm and is suitable for use in superheterodyne receivers and as a source for laboratory measurements.

621.385.029.65 **2580**

A Millimetre-Wave Magnetron.—J. R. M. Vaughan. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 95–103.) A detailed description is given of a fixed-tuned rising-sun magnetron Type-VX5027, for high-power pulse operation at 8·6 mm λ, designed in accordance with established principles. Design problems, performance and test procedure are discussed.

621.385.032.2 : 537.533 **2581**

A Detailed Analysis of Beam Formation with Electron Guns of the Pierce Type.—W. E. Danielson, J. L. Rosenfeld & J. A. Saloom. (*Bell Syst. tech. J.*, March 1956, Vol. 35, No. 2, pp. 375–420.) The theory of Cutler & Hines (2154 of 1955) is extended to cover the case when spread caused by thermal electron velocities is not small compared with nominal beam size; a lens correction for the finite size of the anode aperture is worked out. Charts are presented facilitating the choice of design parameters to produce a prescribed beam and experimental results confirming the theory are given.

621.385.032.21 **2582**

Some New Thermionic Cathodes.—F. A. Vick. (*Sci. Progr.*, Jan. 1956, Vol. 44, No. 173, pp. 65–71.) A brief progress review.

621.385.032.213.1 **2583**

Mutual Heating in Transmitting-Valve Filament Structures.—W. J. Pohl. (*Proc. Instn elect. Engrs*, Part C, March 1956, Vol. 103, No. 3, pp. 224–230.) Methods of calculating the effects of mutual heating between individual elements are described. A set of universal curves to facilitate application of the results to cylindrical structures is presented.

621.385.032.216 **2584**

Cathode Interface Impedance Desimplified.—H. B. Frost. (*Trans. Inst. Radio Engrs*, April 1955, No. PGRQC-5, pp. 27–33. Abstract, *Proc. Inst. Radio Engrs*, July 1955, Vol. 43, No. 7, p. 896.) To represent the cathode-interface impedance accurately, a *RC* network containing four elements is required. Gradual and sudden valve failures due to the growth of this impedance are discussed in relation to system reliability.

621.385.032.216 2585

Conduction Mechanism in Oxide-Coated Cathodes.—E. B. Hensley. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 286–290.) "Measurements have been made on a system composed of two parallel planar cathodes so arranged that their surfaces may be pressed together or separated by a small gap. Low-field conductivity measurements show that above approximately 700°K, the conductance of the system does not depend on physical contact between the cathode surfaces. This result supports the theory that the high-temperature conductivity is a property of the electron gas in the cathode pores. The ratio of conductivity to thermionic emission was measured under conditions designed to preserve the state of activation of the cathode surface. The results agreed with the theoretically predicted ratio and demonstrate that the higher values previously reported were caused by a lower activation on the surface than in the interior of the cathode."

621.385.032.216 2586

Equivalent Circuit for the Oxide-Coated Cathode.—R. E. J. King. (*J. appl. Phys.*, March 1956, Vol. 27, No. 3, pp. 308–309.) A new interpretation is presented of the equivalent circuit proposed by Tomlinson (3409 of 1954) to represent the two-mechanism conduction process in the cathode coating.

621.385.032.216 2587

Effects of Electrolysis in the Thorium Oxide Emitter.—D. L. Goldwater. (*J. Franklin Inst.*, March 1956, Vol. 261, No. 3, pp. 331–341.) The significance of electrolysis as a factor making for reduced life in thoria cathodes is discussed on the basis of studies on thoria crystals reported by Danforth & Bodine (2419 above), actual life data, and observations of the electrolysis of sintered thoria specimens.

621.385.032.7 2588

Electron Bombardment of the Glass Envelope of a Receiving Valve.—G. H. Metson & D. J. Sargent. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 334–338.) On being bombarded by electrons, the potential of the valve envelope is driven towards cathode potential if its initial value is such that the secondary emission coefficient δ is < 1, and towards anode potential if δ is > 1; this latter condition, termed 'lock-up', is stable. Experimental and theoretical investigations for a pentode with an oxide cathode indicate that the mechanisms by which the envelope acquires the initial positive potential corresponding to $\delta > 1$ include anode-voltage leakage, capacitive transfer of anode voltage, and photoelectric emission.

621.385.3.029.6 : [621.373.421 + 621.375.23 2589

A Grounded-Grid Valve System with High Stability Characteristics.—F. Exley & R. E. Young. (*Electronic Engng*, May 1956, Vol. 28, No. 339, pp. 202–203.) An arrangement suitable for an oscillator or r.f. amplifier using a 'lighthouse'-type valve is described in which the anode and cathode coaxial lines extend on either side of the grid plane.

621.385.832 2590

Some Half-Tone Charge-Storage Tubes.—R. S. Webley, H. G. Lubszynski & J. A. Lodge. (*Proc. Instn elect. Engrs*, Part B, May 1956, Vol. 103, No. 9, pp. 395–397.) Discussion on 3453 of 1955.

621.385.832 2591

Progress in the Development of Post-Acceleration and Electrostatic Deflection.—K. Schlesinger. (*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, pp. 659–667.) Practical forms of the single-deflection-centre 'deflectron' system (3290 of 1952) are formed by printing the electrodes on the insides of glass cylinders or cones. A post-acceleration, or intensifier, system suitable for use with this deflection system comprises a long drift space terminated by a double metal mesh close up to the screen, generally as described by Allard (1032 of 1951). Undesired secondary emission from this mesh is suppressed by providing an insulating coating on the first surface of the mesh while connecting the support metal to a potential lower than that of the drift space.

621.314.7 2592

Transistors and Other Crystal Valves. [Book Review]—T. R. Scott. Publishers: Macdonald and Evans, London, 1955, 258 pp., 45s. (*Brit. J. appl. Phys.*, Feb. 1956, Vol. 7, No. 2, pp. 82–83.) "This book has been written for engineers who may have to use crystal valves, rather than for those engaged in developing or designing them."

MISCELLANEOUS

061.4(43) : [621.39 + 621.317.7 2593

A Good Standard in Leipzig.—(*Funk-Technik, Berlin*, March 1956, Vol. 11, No. 6, pp. 155–163.) Radio and television receivers, magnetic tape recorders, valves, measuring instruments, components and other equipment shown at the Leipzig Industrial Fair are briefly described. East German, U.S.S.R., Czechoslovak, Hungarian and other products were exhibited.

621.3 : (06) 2594

Transactions of the I.R.E. 1955 Index.—(*Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, 24 pp. following p. 732.) Includes contents lists, author and subject indexes and 'nontechnical index'.

621.37/.39].004.6 2595

Reliability in Complex Electronic Equipment.—G. H. Scheer. (*Elect. Engng, N.Y.*, Dec. 1955, Vol. 74, No. 12, pp. 1062–1065.) A statistical study is presented of operational failures of various types of components used in air-borne military equipment; ways of reducing failures are briefly indicated.

621.37/.39].004.6 2596

The Definition of Terms of Interest in the Study of Reliability.—C. R. Knight, E. R. Jervis & G. R. Herd. (*Trans. Inst. Radio Engrs*, April 1955, No. PGRQC-5, pp. 34–56. Abstract, *Proc. Inst. Radio Engrs*, July 1955, Vol. 43, No. 7, p. 896.)

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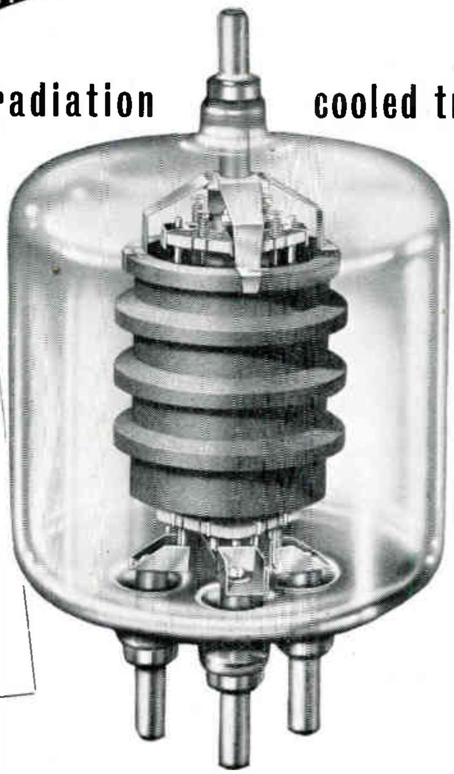

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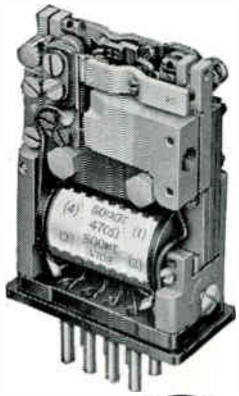

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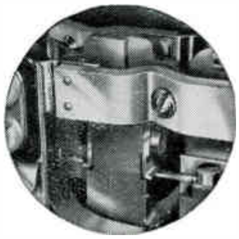

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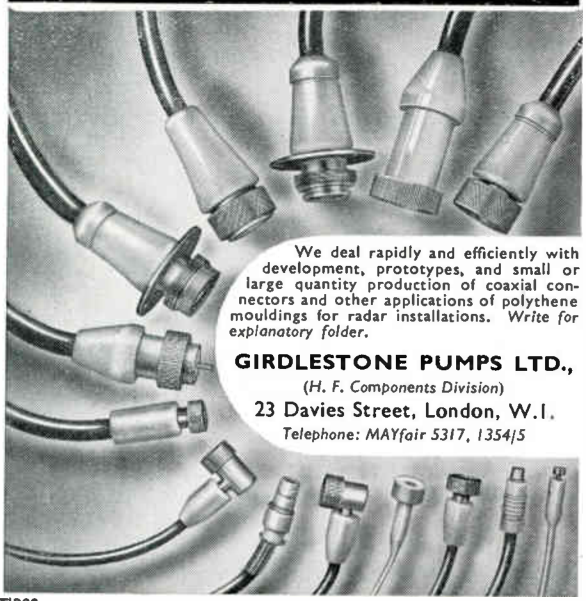

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