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SEPTEMBER 1956

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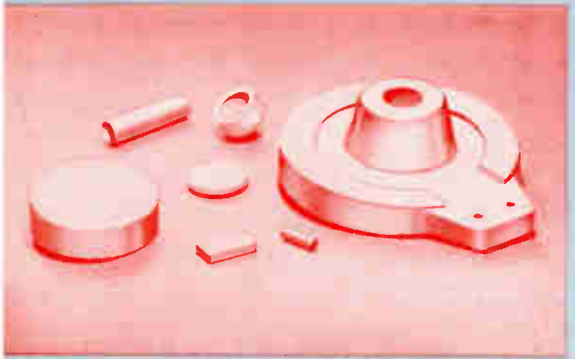

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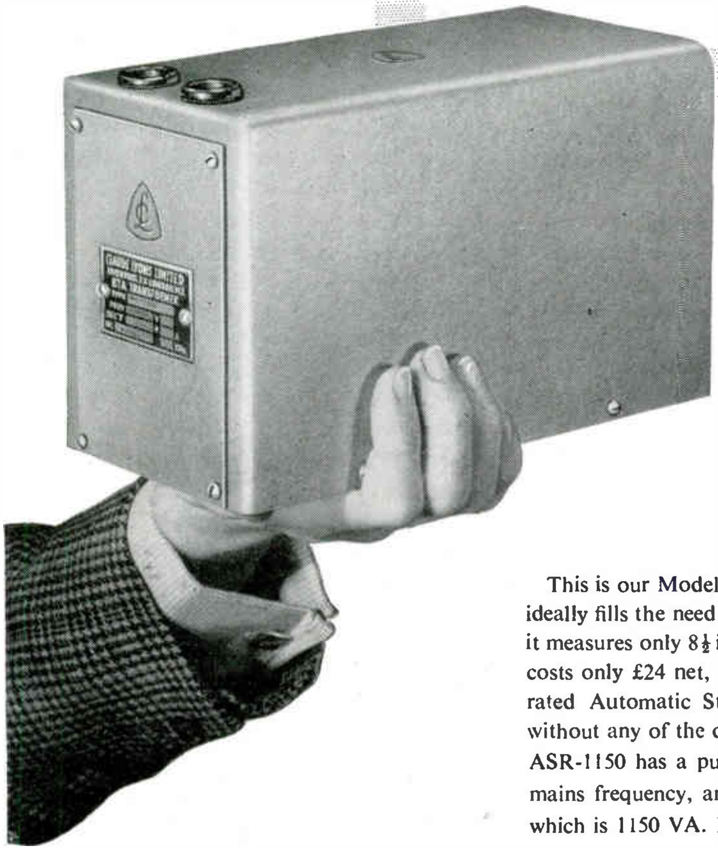

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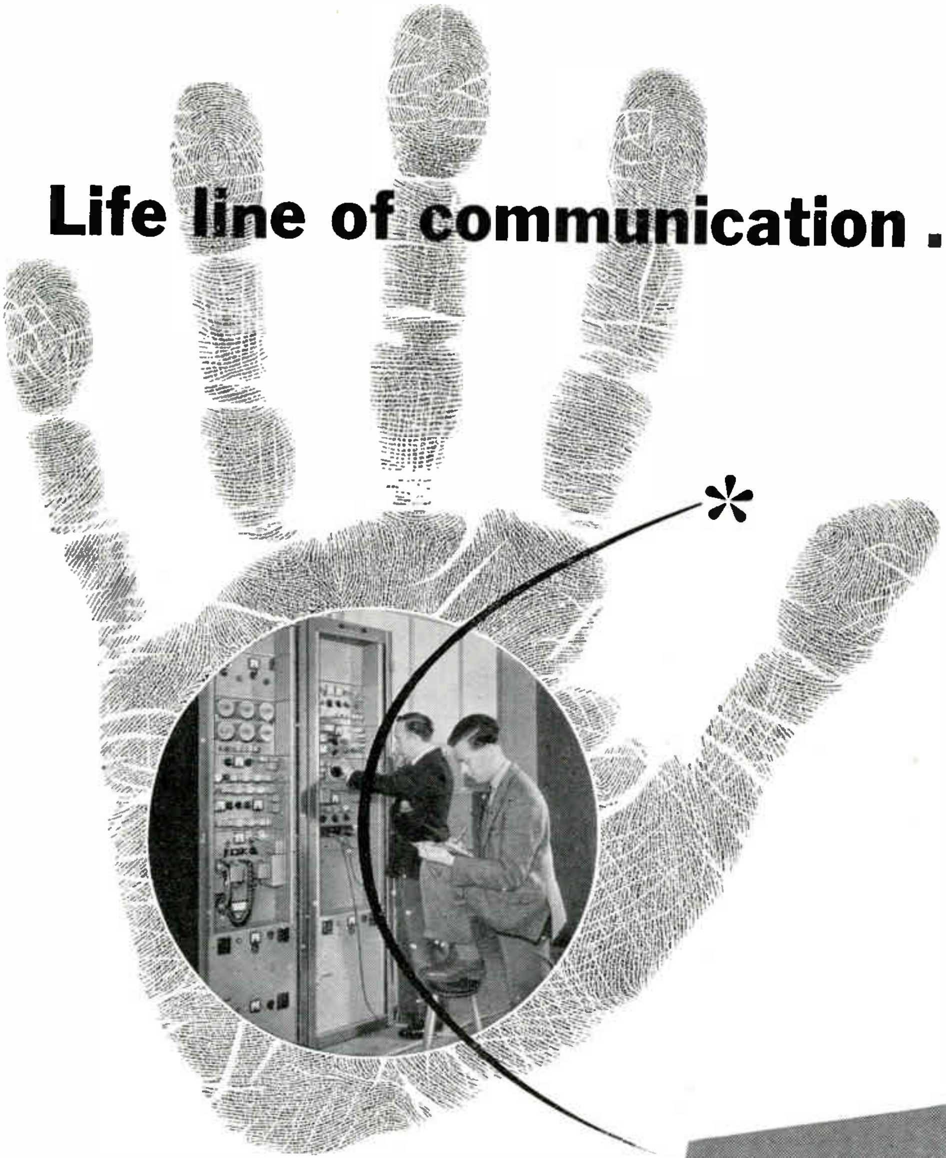

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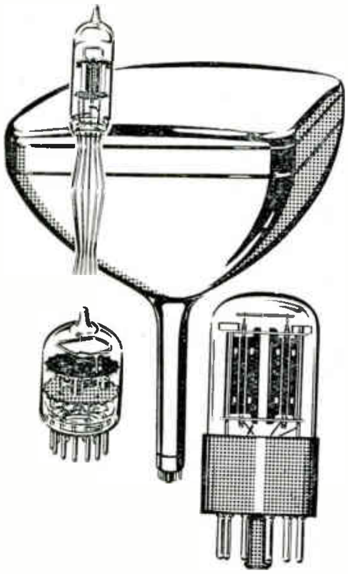

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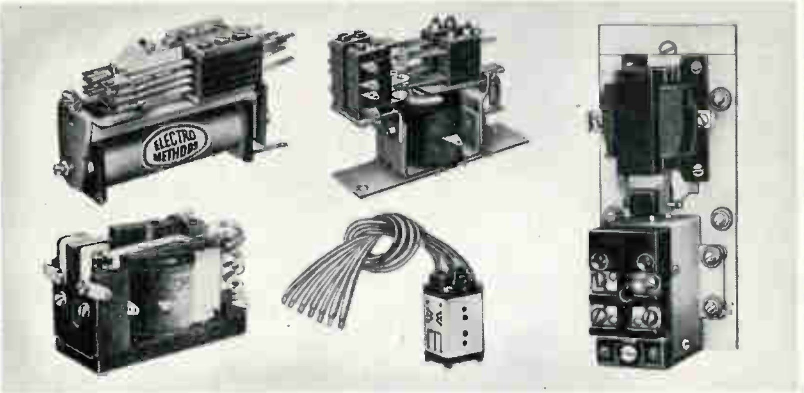
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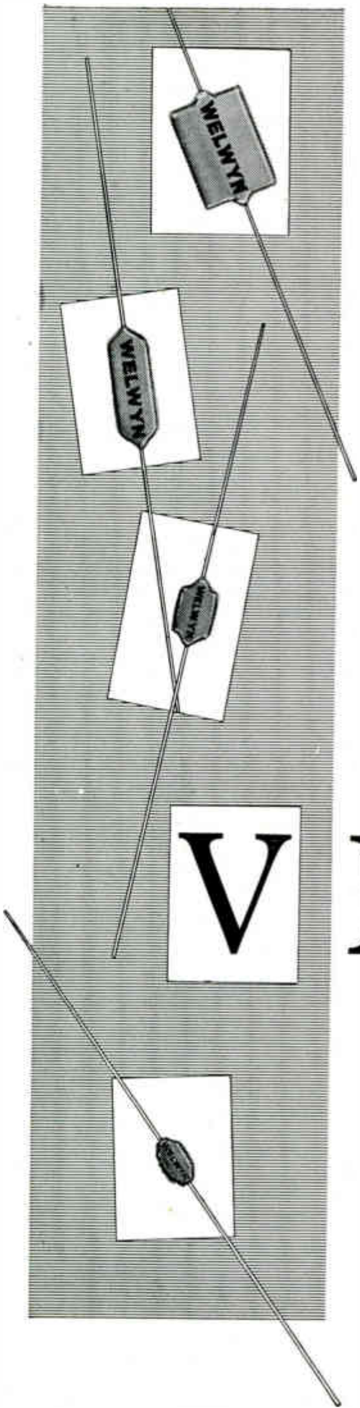

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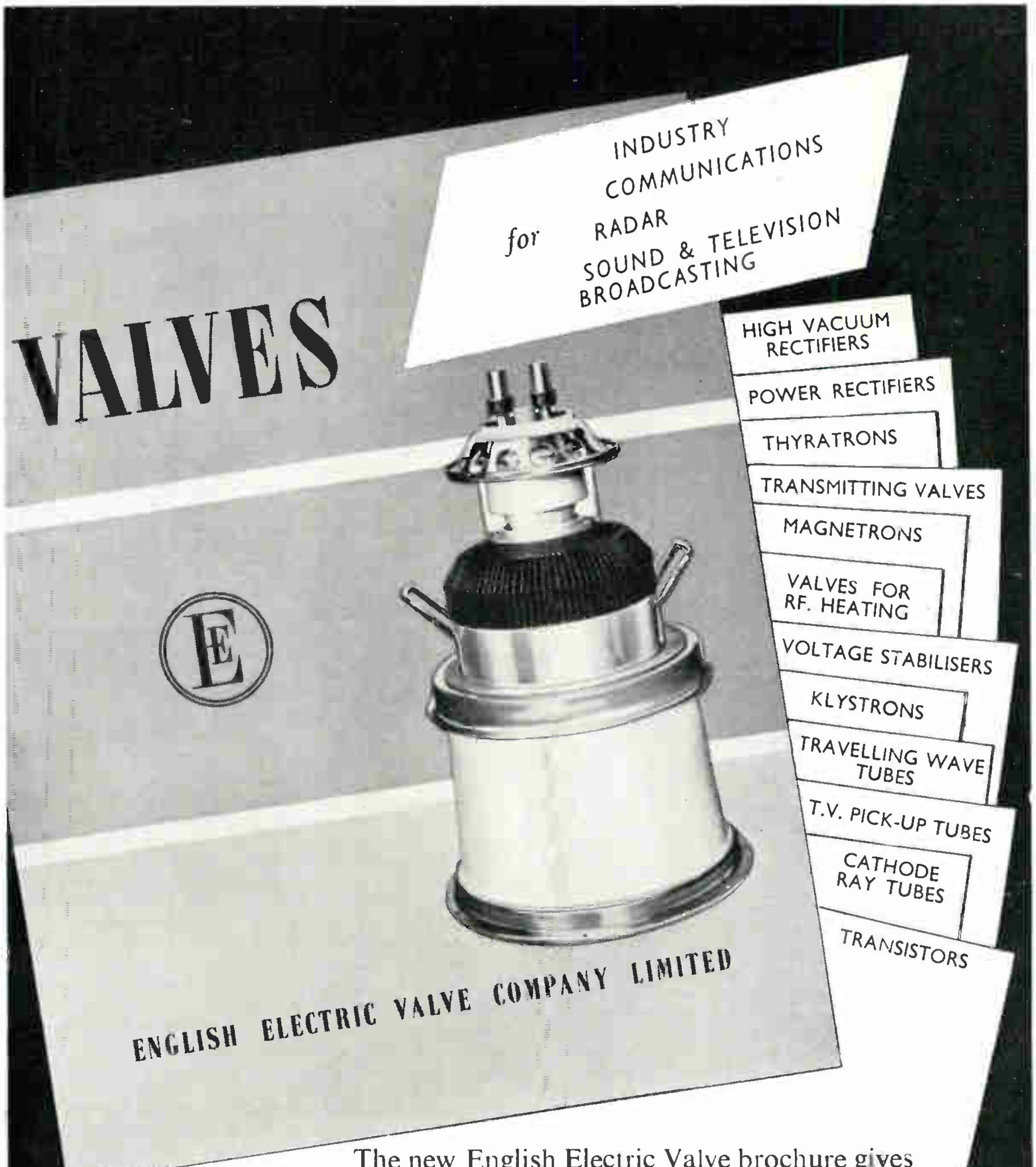

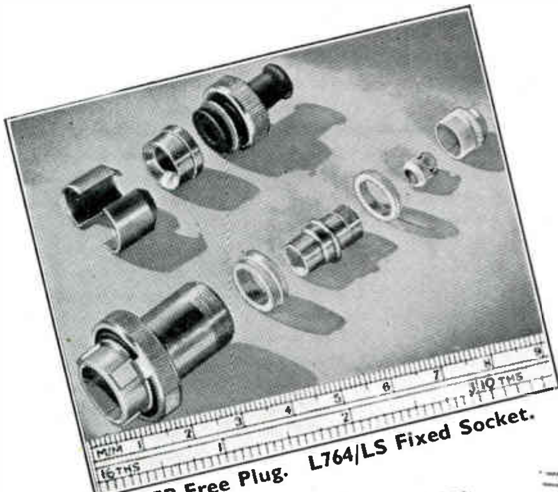

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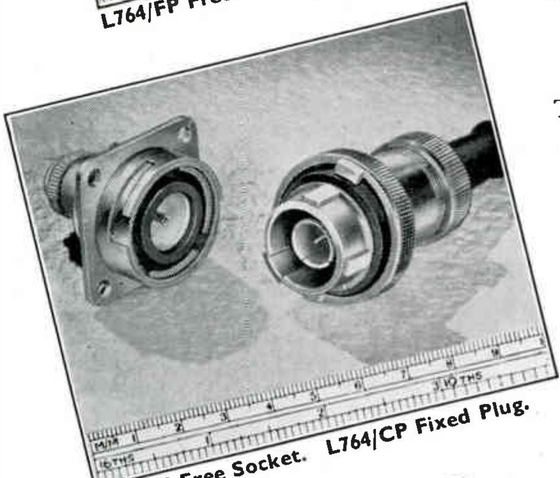

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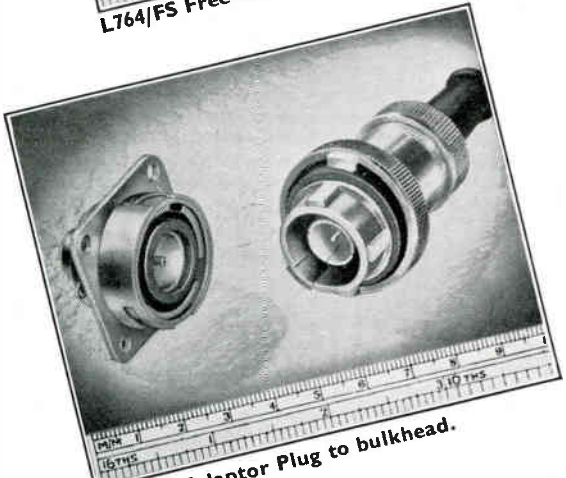

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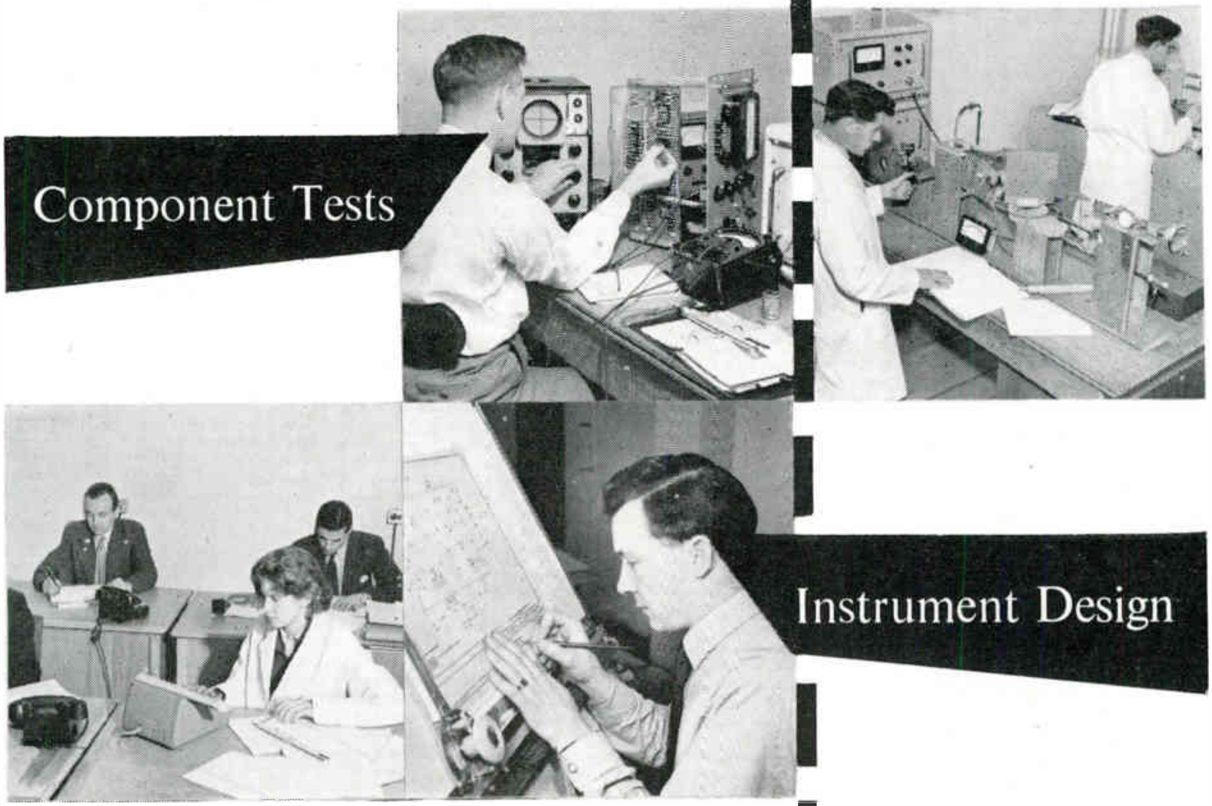

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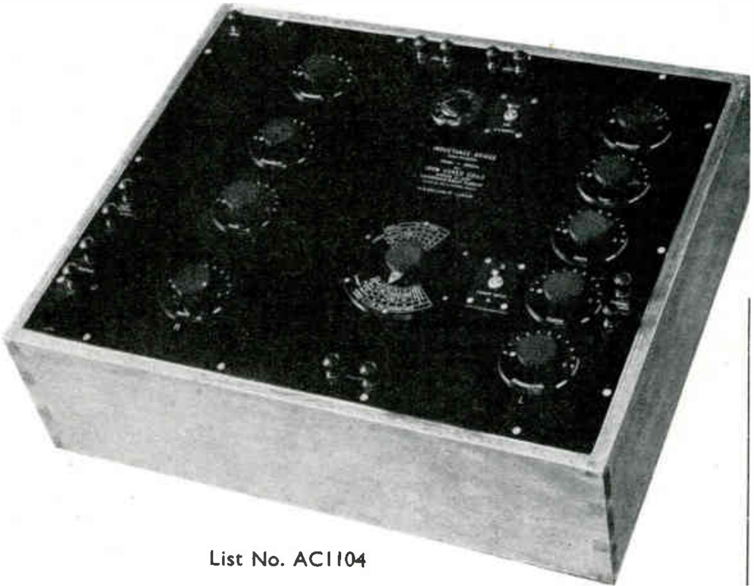

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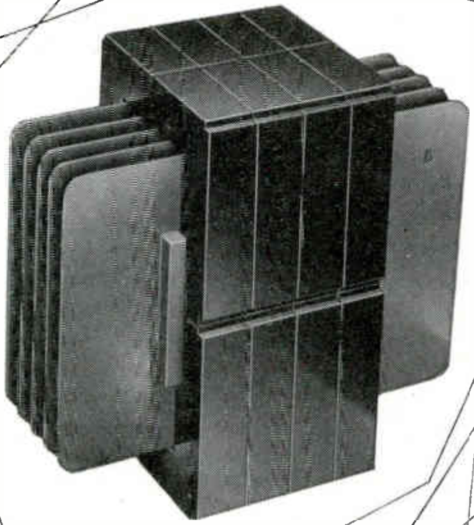

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Janet

KNOWN by the code name of Janet, a new long-range communication system has been developed by the Canadian Defence Research Board. Ranges of up to 1,000 miles with frequencies of 30 – 60 Mc/s are obtained using the trails of minute meteors as the reflecting medium.

The meteors and their ionized trails, which provide the reflections, are natural phenomena and it has long been known that they reflect radio waves. Indeed, in radio-astronomy, radar methods are used for tracking large meteors.

Communication by ionospheric scatter is, of course, well known and is considered to depend in part upon meteor trails. It provides more-or-less continuous communication but demands the use of high power.

Janet employs relatively low power and so permits communication only when the reflecting medium is in just the right state. This is when a meteor trail occurs at the right point in space relative to transmitter and receiver. The period of communication may be as short as a few tenths of a second or as long as a few seconds. However, it has been found that such bursts of communication may occur hundreds of times an hour.

So far as the medium is concerned, communication is highly irregular and the development which has taken place is in apparatus which is capable of utilizing such a variable path for the passing of messages. All messages are recorded on punched paper tape and are stored until communication is established and are then sent at high speed (of the order of 1,300 w.p.m.) while communication lasts. At the receiver, the message is recorded on magnetic tape and typed out in the intervals between communication.

A transmitter and receiver are used at each station and all operate continuously. When a meteor trail occurs in the right region, transmission takes place in both directions and the resulting outputs from the receivers trigger off the modulators and the messages stored at both ends are passed. When transmission is interrupted, the receiver outputs cease and the messages are stopped to await the next suitable meteor trail.

The transmitters, being produced by Redifon Ltd., have a power output of some 800 W and are used with Yagi aerial systems having a gain of about 10 dB.

The idea is certainly an ingenious one and we await further details with interest. At the moment, information is scanty and we feel some hesitation in commenting on it. We are a little disturbed, however, about the use of 40–60 Mc/s for such purposes. This is in the television band, and there would seem to be distinct possibilities of serious interference with television. However, much depends on field-strengths, bandwidths and precise frequency allocations and it may be that there is really no cause for disturbance. At 1,300 w.p.m., the bandwidth needed is clearly quite small and there would seem to be little difficulty in allocating frequencies so that they fall in the guard bands between the television frequencies.

W.T.C.

B

IMPEDANCE TRANSFORMERS

Experimental Results with Non-Uniform Lines

By **J. Willis,** B.Sc.(Eng.), A.M.I.E.E. and **N. K. Sinha,** Ph.D., B.Sc.(Eng.)*

(Faculty of Technology, University of Manchester)

SUMMARY.—The equipment required for the experimental investigation of the use of non-uniform transmission lines as impedance transformers is discussed and a termination developed to give negligible reflection over a wide frequency band. The reflection patterns for two types of tapered line have been obtained experimentally and compared with the theoretical patterns. The effect of attenuation in a practical non-uniform line impedance transformer has been shown to be negligible.

LIST OF SYMBOLS

x = Distance from the sending end of the non-uniform line
l = Length of the non-uniform line
$y = x/l$
$Z_0(x)$ = Nominal characteristic impedance of the non-uniform line
Z_1 = Value of Z_0 for $x = 0$
Z_2 = Value of Z_0 for $x = l$
λ = Free-space wavelength
Γ = Reflection-coefficient
$P(y) = d/dy\,(\log_e Z_0)$
d_0 = Inner diameter of the outer conductor of coaxial line
d_c = Outer diameter of the centre conductor of coaxial line
α = Attenuation constant
β = Phase-shift constant
γ = Propagation constant
R = Resistance per unit length of the line
L = Inductance per unit length of the line
C = Shunt capacitance per unit length of the line
G = Shunt conductance per unit length of the line

1. Introduction

IN a paper published recently[†], the theory of non-uniform line impedance transformers was discussed and methods were suggested for the design of such lines for optimum performance. There it has been pointed out that an exact solution of the differential equations for non-uniform lines is possible only in a few special cases. This has led to the development of a number of approximate solutions. Among these, the method using Fourier transforms provides the best approximate solution as regards simplicity and accuracy.

It can be shown that the reflection-coefficient at the sending-end of a loss-free non-uniform line impedance transformer, matched at the load-end, is given by

$$\Gamma = \int_0^1 \tfrac{1}{2}P(y)e^{-j4\pi yl/\lambda}\,dy \qquad \ldots \qquad \ldots \qquad (1)$$

It has been shown in the previous paper that optimum distributions of $P(y)$ can be obtained by finding a suitable Fourier series for this function, the coefficients of the various components of the series being adjusted so as to reduce the height of the side-lobes of the reflection pattern[†] to the desired value.

While the theory of non-uniform line impedance transformers has been discussed in a number of papers, very few give any experimental evidence in confirmation of the theory. Moreover, the theory used involves some approximations. It is, therefore, interesting to investigate the properties of practical non-uniform lines under actual working conditions.

This paper gives some experimental results obtained for the type of non-uniform lines considered in the previous paper.

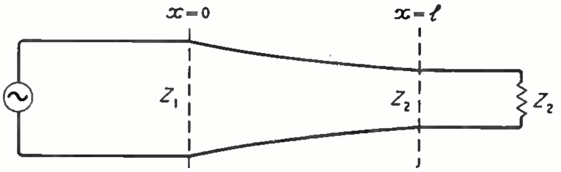

Fig. 1. *Schematic arrangement.*

2. General Description

The most straightforward procedure in verification of the theory is to measure the reflection-coefficient at different frequencies for a given length of taper. The schematic arrangement is shown in Fig. 1.

The non-uniform line is connected between two uniform lines of characteristic impedances equal to those at its respective ends. One of the uniform lines is terminated into its characteristic impedance, Z_2. The measurement of the voltage standing-wave ratio (v.s.w.r.) along the other uniform line at different frequencies will give the reflection pattern for the given non-uniform line.

Practical considerations suggest that it is best to use coaxial lines for the work. The centre conductor of the line can be shaped to obtain any desired taper, keeping the diameter of the outer conductor constant.

---

[*] Mr. Sinha is now at the Biha Institute of Technology, Sindri, India.

[†] "Non-Uniform Transmission Lines as Impedance Transformers", by J. Willis and N. K. Sinha. *Proc. Instn elect. Engrs*, Vol. 103, Part B, No. 8, March 1956, p.166.

MS accepted by the Editor, November 1955

3. Design of the Measuring Equipment

The main difficulty in the experimental work lies in the inability of the equipment to measure very low standing-wave ratios accurately. Since the main interest is in the side-lobes of the reflection pattern, this limitation becomes very serious. For the best results, therefore, it is essential that the equipment be designed very carefully with the minimum possible inherent reflection. The design of the equipment for the measurement of v.s.w.r. has been discussed in detail in references 2, 5, 10 and 11. By using these techniques, a standing-wave indicator capable of measuring a v.s.w.r. of 1·005 can be obtained.

A further difficulty is the requirement that one of the uniform lines be terminated in its characteristic impedance. The termination is required to give perfect match over the entire range of frequencies at which the measurements are to be made. The two types of termination generally used are (1) the disc resistor and (2) the cylindrical resistor enclosed in a coaxial jacket. The former is easier to design, but it must be backed by a short-circuited quarter-wave line[8] so that the size of the resistor is unduly increased. The latter can be much smaller in size, and does not need any adjustment over a wide range of frequency.

A general study of the cylindrical resistor enclosed in a coaxial jacket of high electrical conductivity, is given in references 6 and 9. In the latter, it has been shown that, making the characteristic impedance of the line formed by the resistor and its jacket about $1/\sqrt{4{\cdot}5}$ times the d.c. resistance of the resistor, and adding a compensating device to cancel the reactance thus caused, it is possible to get a v.s.w.r. of less than 1·01 so long as the length of the resistor does not exceed $\lambda/8$. The most convenient compensating device is a short-circuited transmission line connected in series with the resistor. The schematic arrangement is shown in Fig. 2.

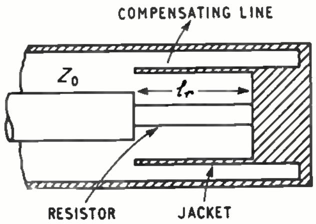

Fig. 2. *Line-compensated resistor.*

By a proper choice of the length of the compensating line and its characteristic impedance[9] a very good impedance match can be obtained over the given range of frequency (i.e., l_r is not greater than $\lambda/8$). Moreover, while designing the compensating line, the discontinuity capacitances caused by the changes in diameters can also be taken into account, thereby cancelling all reactances. Difficulty is experienced, however, in the accurate assessment of the discontinuity capacitances, which are of a very complex nature. The complexity of the discontinuities is further increased by the proximity of the short-circuits in the compensating line and the line formed by the resistor and its jacket. It is also possible that the contribution of the axial-field component in the resistive line to the general field distortion at the junction of the resistive element with the lossless line is not quite negligible. Hence it is not possible to calculate accurately the length of the compensating line that will cancel all reactances. This difficulty can be overcome by making the length of the compensating line adjustable, so that the desired compensation can be obtained under actual working conditions. One adjustment only of the length of the compensating line at the middle frequency in the band will ordinarily be sufficient, but under more rigorous conditions the length of the compensating line can be calibrated to give the best impedance match at all frequencies in the band.

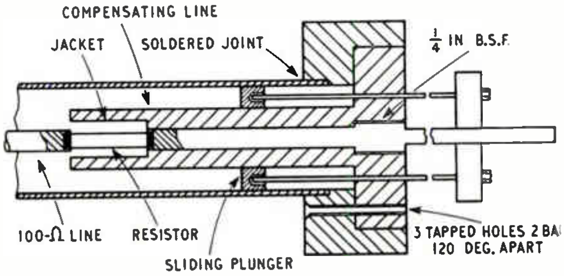

Fig. 3. *Termination for the* 100-*ohm line.*

The practical adaptation of these principles to terminate a 100-ohm line is shown in Fig. 3. A sliding short-circuiting plunger is used to adjust the length of the compensating line. The adjustment is made by moving the outer disc, the position of which on the central external rod can be calibrated for the frequency at which the best impedance match is obtained.

4. Tests on the V.S.W.R.-Measuring Equipment

To ascertain the accuracy of the equipment, the following tests were performed:

4.1. *Determination of the Standing-Wave Pattern when the Line is Approximately Matched*

The most severe test on the equipment is the determination of the standing-wave pattern when the line is approximately matched at the load-end, since even a very small change in the probe-output alters the standing-wave pattern appreciably. For this purpose, the line was approximately matched using a termination of the type described in Section 3, with inaccurate compensation, and the standing-wave pattern was determined. The standing-wave ratio was found to be

1·015, and even for this low v.s.w.r. the standing-wave pattern was found to differ only slightly from the ideal sine-curve. For example, the standing-wave pattern obtained at the signal frequency of 750 Mc/s is shown in Fig. 4. This indicates that the mechanical irregularities in the equipment are negligible, and that the equipment can be used for the measurement of low standing-wave ratios of the order of 1·01 with sufficient accuracy.

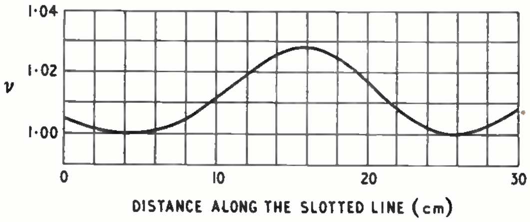

Fig. 4. *Standing-wave pattern at 750 Mc/s when the line is approximately matched; v = voltmeter reading normalized with respect to the minimum value.*

4.2. *Testing the Termination*

The termination shown in Fig. 3 was used to terminate a 100-ohm line and the standing-wave pattern was obtained. The length of the compensating line was adjusted to give the minimum v.s.w.r. in the frequency-band of 450 to 900 Mc/s, and it was found that one setting of the length was sufficient for the entire frequency-band. The reflection-coefficients measured at different frequencies have been plotted against frequency in Fig. 5. It can be concluded that the termination is practically reflection-free in the given frequency-band.

4.3. *Determination of the Standing-Wave Pattern for a Step-Discontinuity in the Centre Conductor, changing the Characteristic Impedance of the Line from 50 ohms to 100 ohms and Terminating the 100-ohm side by its Characteristic Impedance*

This test was performed to obtain an extra check upon the accuracy of the equipment. The schematic arrangement is shown in Fig. 6.

It can be shown theoretically that the standing-wave ratio will be 2·00 in the frequency-band of 450 to 900 Mc/s. The standing-wave patterns actually obtained at these frequencies agreed very closely with the theoretical sine-curves, and the v.s.w.r. was also found to be 2·00.

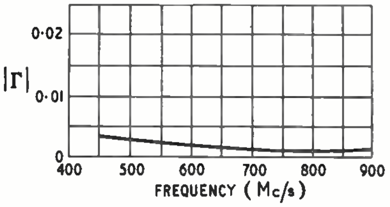

Fig. 5. *Frequency-characteristic of the termination.*

This test, therefore, confirms that the standing-wave detector and the termination give reasonably accurate results.

5. Tests on the Non-Uniform Lines

The experimental determination of the complete reflection pattern for a given non-uniform line involves the measurement of the standing-wave ratio for all frequencies from zero to infinity but, in practice, the measurement can be made only in a limited frequency-range, so that only a portion of the reflection pattern can be determined experimentally. The lower frequency-limit at which the v.s.w.r. can be conveniently measured is determined by the physical length of the slotted line, whereas the upper frequency-limit is determined by its transverse dimensions. In the present work, the frequency-range was limited to the available signal generator range of 450 to 900 Mc/s.

It was decided to verify the theory of non-uniform lines in the case of two types of taper, namely, (1) the simple linear taper of the centre conductor, and (2) the type for which,

$$P(y) \propto (\sin \pi y - \tfrac{1}{6} \sin 3\pi y).$$

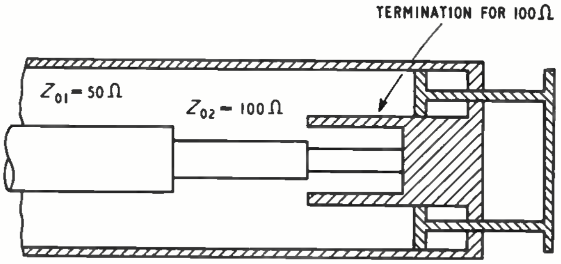

Fig. 6. *Schematic arrangement for the test.*

The former was selected mainly because it is the simplest type of non-uniform line to construct. Another reason for the choice was that, in this case, the side-lobes of the reflection pattern are sufficiently high for the reflection-coefficients to be measured quite accurately. Two lengths of the tapered section were constructed, one 25 cm long and the other 50 cm long, so that a large portion of the reflection pattern could be verified. With the available signal generator, the values of l/λ vary between 0·375 and 1·5 in this case, so that a part of the main-lobe and two side-lobes of the reflection pattern can be obtained experimentally.

The latter was selected mainly because it gives a v.s.w.r. of less than 1·01 for l/λ equal to or greater than one. This line was made 50 cm long, hence the v.s.w.r. will be less than 1·01 in the frequency-band of 600 to 900 Mc/s. A good check on the impedance-matching property of the optimized lines can be obtained thereby.

The combined reflection pattern obtained for the two lengths of straight taper is shown in Fig. 7. It will be seen that the difference between the theoretical and experimental values is very small.

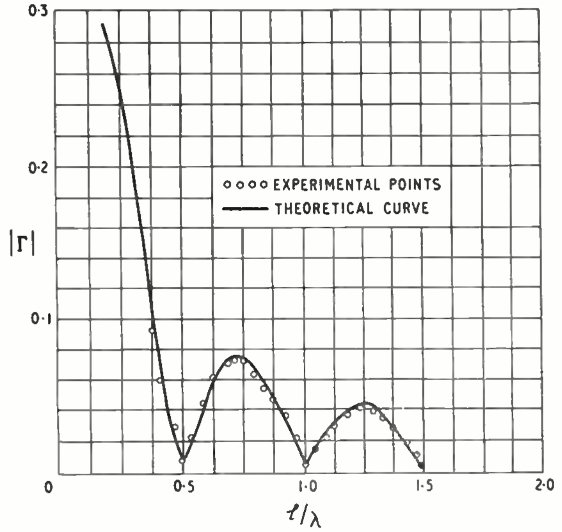

Fig. 7. *Reflection pattern for linear taper of the centre conductor.*

The reflection pattern for the line for which

$$P(y) \propto (\sin \pi y - \tfrac{1}{6} \sin 3\pi y)$$

is shown in Fig. 8. It will again be seen that the experimental points agree very closely with the theoretical curve. It may be noted that the small amount of frequency-sensitivity seen in the theoretical curve is almost completely absent from the experimental curve. The reason is that the inherent reflection present in the slotted line due to structural imperfections affects the accuracy of the measurement of standing-wave ratios less than 1·01.

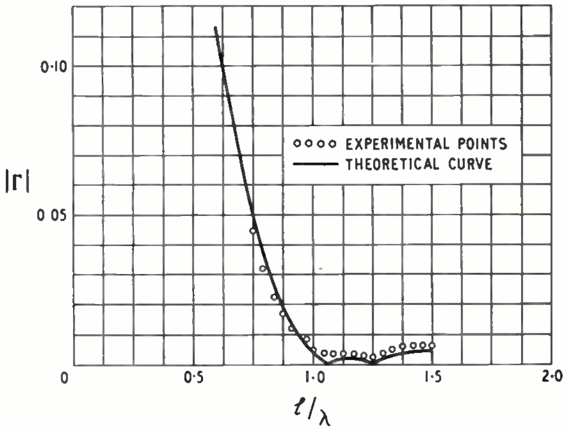

Fig. 8. *Reflection pattern for the line for which* $P(y) \propto (\sin \pi y - \frac{1}{6} \sin 3\pi y)$.

6. Conclusion

In the experimental work carried out, it has been shown that a sudden transition in the characteristic impedance from 50 ohms to 100 ohms causes a standing-wave ratio of 2·0, and that the reflection caused by this change in the characteristic impedance can be reduced if the change is introduced gradually in the form of a non-uniform line of continuously varying parameters.

A linear change in the diameter of the centre conductor to vary the characteristic impedance from 50 ohms to 100 ohms gives a maximum v.s.w.r. of 1·16 for l/λ greater than 0·41 and causes the line to be highly frequency-sensitive. Considerable improvement can be made by tapering the centre conductor to give one of the optimized distributions of $P(y)$. Thus, for l/λ greater than one and

$$P(y) \propto (\sin \pi y - \tfrac{1}{6} \sin 3\pi y),$$

a v.s.w.r. less than the measurable limit of 1·01 was obtained. These reflection patterns have been shown together in Fig. 9. The portions verified experimentally have been shown solid, and the dotted portions represent the remainder calculated theoretically.

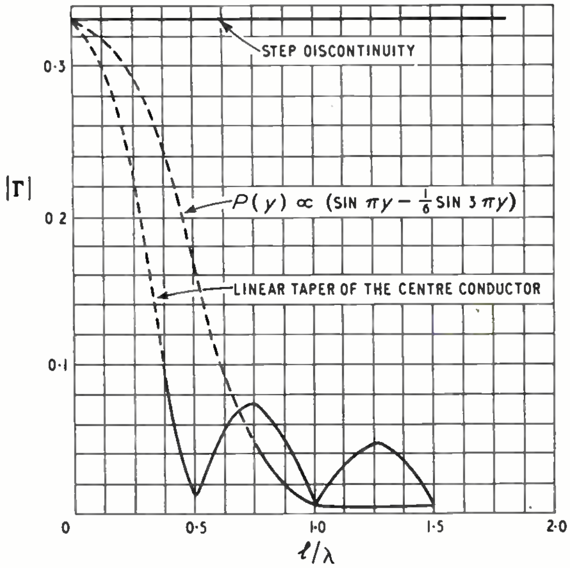

Fig. 9. *Comparison between the various reflection patterns.*

Acknowledgment

The work was carried out in the Electrical Engineering Laboratories of the Faculty of Technology, University of Manchester, and the authors are grateful for the constant interest and encouragement of Professor E. Bradshaw. Thanks are also due to Messrs. A. V. Roe and Company, Limited, of Manchester, for assistance in the

construction of the non-uniform sections of the experimental lines, and to Mr. C. T. Kohn for helpful advice.

APPENDIX 1

Reflection Pattern for Straight Taper of the Centre Conductor

The characteristic impedance of a coaxial line is given by

$$Z_0 = \frac{60}{\sqrt{\epsilon}} \log_e \frac{d_0}{d_c} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

When the diameter of the centre conductor is varied linearly,

$$Z_0 = \frac{60}{\sqrt{\epsilon}} \log_e (a - by) \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

$$\text{and } P(y) = -\frac{b}{(a - by) \log_e (a - by)} \quad \ldots \quad \ldots \quad (4)$$

where a and b are constants.

Substituting in equation (1),

$$|\,\Gamma\,| = \tfrac{1}{2}\int_0^1 \frac{-b}{(a - by)\log_e (a - by)}\, e^{-j4\pi yl/\lambda}\, dy \quad \ldots \quad (5)$$

A general solution of equation (5) is not possible, but it can be solved in special cases by finding a suitable approximate expression for $P(y)$. For example, if $Z_1 = 50$ ohms and $Z_2 = 100$ ohms, it can be shown that for an air-dielectric line, with an error of less than 1%,

$$P(y) \approx (0{\cdot}9841 - 0{\cdot}1663\, y + 0{\cdot}2976\, y^2) \log_e \frac{Z_2}{Z_1} \quad \ldots \quad (6)$$

Using this expression in equation (1), the solution for $|\,\Gamma\,|$ was obtained, and its value was calculated for different values of l/λ. The values obtained for integral values of $4l/\lambda$ are given in the following table:

$4l/\lambda$	1	2	3	4	5	6
$\|\,\Gamma\,\|$	0·218	0·0089	0·077	0·0038	0·046	0·0025

APPENDIX 2

Effect of Attenuation

One of the approximations made in deriving equation (1) was that the line was assumed loss free. Although no line can be loss free, all practical high-frequency lines have a low loss. The effect of attenuation in the case of the linear taper of the centre conductor will be investigated here.

If the attenuation in the line is not zero, equation (1) can be re-written as,

$$|\,\Gamma\,| = \int_0^1 \tfrac{1}{2} P(y)\, e^{-2yl\gamma}\, dy$$

$$= \int_0^1 \tfrac{1}{2} P(y)\, e^{-2(\alpha + j\beta)\, yl}\, dy \quad \ldots \quad \ldots \quad (7)$$

It can be shown that in a transmission line with low losses, to a very close approximation,

$$\alpha = \frac{R}{2Z_0} + \frac{G}{2} Z_0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

$$\text{and} \quad \beta = \omega\sqrt{LC} = \frac{2\pi}{\lambda} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

For an air-dielectric coaxial line, $G = 0$, and it can be shown that in this case[8]

$$\alpha = \frac{K\sqrt{f}}{d_0}\, \frac{1 + e^{Z_0/60}}{Z_0} \text{ nepers per unit length} \quad (10)$$

where f = frequency in cycles per second

and K = constant depending upon the resistivity of the conductors

= 83 × 10^{-9} for brass (approximately).

It is evident from equation (10) that for any given value of d_0 the attenuation constant will vary with Z_0. However, the variation is quite small between $Z_0 = 50$ ohms and $Z_0 = 100$ ohms, as shown in the following table:

Z_0 (ohms)	50	60	75	90	100
$\dfrac{1 + e^{Z_0/60}}{Z_0}$	0·0660	0·0620	0·0599	0·0620	0·0629

Hence an approximate solution of equation (7) can be obtained by assuming that the attenuation is independent of Z_0, and the error arising will be small if Z_0 varies between 50 ohms and 100 ohms. For a tapered line 50 cm long, and having d_0 equal to one inch, it will be assumed that α is constant at its value for $Z_0 = 50$ ohms. With this assumption, for brass conductors,

$$\alpha = \frac{0{\cdot}03737}{\sqrt{\lambda}} \text{ nepers per metre} \quad \ldots \quad \ldots \quad (11)$$

Substituting the values of α and β in equation (7), it is found that

$$|\,\Gamma\,| = \int_0^1 \tfrac{1}{2} P(y) \exp. \left[-2\left(\frac{0{\cdot}03737 l}{\sqrt{\lambda}} + j2\pi l/\lambda\right) y \right] dy$$

$$= \int_0^1 \tfrac{1}{2} P(y) \exp. \left[-(0{\cdot}05285\sqrt{l/\lambda} + j4\pi l/\lambda) y \right] dy \quad (12)$$

taking $l = 0{\cdot}5$ metre.

Substituting the approximate expression for $P(y)$ from equation (6), the values of $|\Gamma|$ can be obtained for different values of l/λ. It was found that attenuation causes a negligible change in the reflection pattern. The values of $|\Gamma|$ calculated with and without attenuation are given in the following table:

$4l/\lambda$	1	2	3	4	5	6
$\|\Gamma\|$ with attenuation	0·217	0·0090	0·077	0·0039	0·046	0·0026
$\|\Gamma\|$ without attenuation	0·218	0·0089	0·077	0·0038	0·046	0·0025

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OSCILLATOR FREQUENCY STABILITY

Load Coupled through Long Feeder

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SUMMARY.—It is shown that in addition to the well-known hysteresis effects which occur in an oscillator connected to a mismatched load through a long feeder, another type of instability is also possible. This takes the form of a periodic modulation of the oscillation frequency and can occur when the load is a resonant circuit. A basic theory is developed from which stability criteria appropriate to the two types of instability and to various circuit arrangements are derived. Instability can always be inhibited by choosing suitable values for the circuit parameters. It is shown that, in general, the hysteresis type of instability is likely to predominate.

1. Introduction

It is well known that frequency instability may arise in an oscillator circuit where a mismatched resistive load is connected to the generator through a long feeder. The instability is manifest in the form of a hysteresis effect when an attempt is made to tune the oscillator. Sudden and irreversible frequency changes take place at certain critical points, and there is a band or bands of frequencies over which the oscillator cannot be tuned at all. This type of behaviour has been described by several writers[1-6] and is fairly well understood.

However, a recent study[7] has disclosed, as a general possibility, the existence of another type of frequency instability. This takes the form of a periodic frequency modulation and may be initiated by adjusting some parameter of the circuit towards a critical value. This has been called 'periodic instability' and, unlike the 'aperiodic' type of instability responsible for hysteresis, periodic instability is reversible with respect to changes in the parameters whose adjustment produces it.

It is natural to enquire whether this new type of instability can exist in oscillators with long feeders, and the answer is that it may arise under certain conditions when the feeder is terminated by a resonant load. Thus, the criteria for the absence of hysteresis are not by themselves sufficient to guarantee stability; further conditions must be imposed if the frequency is not to be periodically unstable.

Problems of stability also arise when an oscillator is coupled through a comparatively short feeder to a resonant cavity (e.g., for the purpose of stabilizing the mean frequency) or to other devices in which the reactance changes rapidly with frequency. It is the object of this paper to determine the conditions necessary for complete stability. A theory of the 2-terminal oscillator is first worked out in general terms and the results are applied to the circuit arrangements involving feeders which arise most frequently in practice.

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2. List of Symbols

$F(p)$ = Frequency stability function. [see (3.12)]
l = Length of feeder.
n = Number of quarter-wavelengths in feeder.
p = $a + j\omega_d$, Characteristic complex frequency of the transient disturbance.
Q_0, Q_1 = External Q-factor of oscillator coil, Q-factor of load coil.
Q_0', Q_1' = Modified values of Q_0 and Q_1. [see (4.12)]
R = Impedance of oscillator network at frequency ω_0.
R_0 = $1/Y_0$. Characteristic impedance of feeder.
R_1 = Load resistance referred to feeder.
r_v = Ratio of group to phase velocities in the feeder.
v_g = Group velocity of waves in the feeder.
z = pl/v_g.
Z^+, Z^- = Impedance of the oscillator network at the complex frequencies $p + j\omega_0$, $p - j\omega_0$.
γ = $\alpha + j\beta$, Propagation constant of the feeder at frequency ω_0.
γ^+ = Propagation constant of feeder at frequency $p + j\omega_0$.
λ = Wavelength of a wave of frequency ω_0 in the feeder.
ω_0 = Frequency of steady oscillation.

3. General Theory

The procedure adopted is to calculate first the possible steady states of the oscillator; i.e., the states for which the system is in equilibrium with a periodic wave of constant amplitude and frequency. A small disturbance is then added to the steady state. If the magnitude of the disturbance decreases with time the equilibrium is stable and the possible steady state may be an actual steady state. If the disturbance tends to increase with time, equilibrium is unstable and the possible steady state cannot be physically realized.

Fig. 1 shows a 2-terminal oscillator consisting of a linear passive network Z connected across a nonlinear resistance element NL.R. which has a negative slope over part of its current-voltage characteristic. The current i in the element is assumed to be a continuous and single-valued

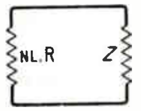


Fig. 1. *2-terminal oscillator.*

function of the voltage v. Thus $i = f(v)$. Z is assumed to have a significant value only near to the oscillation frequency so that all harmonic, low-frequency and direct voltages can be neglected.

For a steady oscillation the voltage across Z is therefore $v = V \cos \omega_0 t$. In the nonlinear element the current of fundamental frequency is $i = I \cos \omega_0 t$ where

$$I = (2/\pi) \int_0^\pi f(V \cos x) \cos x \, dx = V h(V) \quad (3.1)$$

This must be equal and opposite to the current in Z. Hence if $Z = R + jX$, the equation of the possible steady states is $-V/(R + jX) = Vh(V)$, or

$$X = 0 \text{ and } Rh(V) = -1 \quad \ldots \quad \ldots \quad (3.2)$$

the function $h(V)$ being defined by (3.1).

Suppose now that a small disturbance v_d is added to the steady-state voltage v. The current in the nonlinear element becomes $f(v + v_d) = f(v) + v_d f'(v)$. Since $f(v)$ is a periodic function of $\omega_0 t$, $f'(v)$ must also be periodic in $\omega_0 t$. Thus

$$f'(v) = \sum_{-\infty}^{\infty} G_n \exp(jn\omega_0 t) \quad \ldots \quad \ldots \quad (3.3)$$

where $$G_n = (1/\pi) \int_0^\pi f'(V \cos x) \cos nx \, dx \quad (3.4)$$

From (3.1), (3.2) and (3.4) it can be shown that

$$G_0 - G_2 = -1/R \quad \ldots \quad \ldots \quad \ldots \quad (3.5)$$

Using the differential operator D ($= d/dt$), the current in the network Z due to v_d can be written $[1/Z(D)]v_d$, and this is equal and opposite to the current in the nonlinear element also due to v_d. Hence

$$[1/Z(D)]v_d = -v_d f'(v) \quad \ldots \quad \ldots \quad (3.6)$$

If the linear network has lumped parameters $Z(D)$ is a rational function of D — the quotient of two polynomials. In this case (3.6) is a linear differential equation with periodic coefficients the solutions of which are known[8] to be of the form

$$v_d = \exp(at) \sum_{-\infty}^{\infty} V_n \cos[(n\omega_0 + \omega_d)t + \theta_n]$$

or, in complex notation,

$$v_d = V_d \exp(pt) \sum_{-\infty}^{\infty} u_n \exp(jn\omega_0 t) \quad \ldots \quad (3.7)$$

The actual voltage is to be taken as the real part of the last expression and $p = a + j\omega_d$ is a complex frequency characteristic of each solution. In general, the complete solution of (3.6) would be the sum of a number of such expressions with different values of p and u_n.

When the network has distributed parameters as, for example, when the load is coupled through a uniform feeder, the situation is less simple. A straightforward method would be to write down the partial differential equations for the feeder and to apply the boundary conditions appropriate to the two ends. However, a fresh analysis is unnecessary if only for the reason that the physical behaviour of a network with distributed parameters can always be approximated, to any required degree of accuracy, by a network with lumped parameters. It is perhaps also helpful to regard a transient state as a kind of steady state in which the system is in equilibrium with a group of sine waves having exponential amplitude factors. For all such waves the impedance of a linear network, whether with lumped or distributed parameters, is a constant quantity dependent only on the complex frequency of the applied wave. If the network contains distributed parameters, $Z(D)$ contains hyperbolic functions and (3.6) is not a differential equation in the ordinary sense. Nevertheless, the foregoing remarks indicate that the solutions are still of the form (3.7).

The values of p which satisfy (3.6) and (3.7) are found as follows. Since the network impedance is assumed to be negligible, except near to the oscillation frequency, only those components of v_d which are near to ω_0 need be considered.

$$v_d = V_d[u_1 \exp(p + j\omega_0)t + u_{-1} \exp(p - j\omega_0)t] \quad \ldots \quad \ldots \quad (3.8)$$

In order that no terms associated with harmonic frequencies should fall within the frequency band represented by this expression the imaginary part of p must be restricted so that the frequency ranges $p \pm \omega_0$, $p \pm 2\omega_0$ etc., do not overlap. Thus $-\tfrac{1}{2}\omega_0 < \omega_d < \tfrac{1}{2}\omega_0$.

Now $[1/Z(D)]\exp(p + j\omega_0)t = \exp(p + j\omega_0)t/Z(p + j\omega_0)$.

Hence the left-hand side of equation (3.6) becomes $V_d[(u_1/Z^+)\exp(p + j\omega_0)t + (u_{-1}/Z^-)\exp(p - j\omega_0)t]$ where $Z^+ = Z(p + j\omega_0)$ and $Z^- = Z(p - j\omega_0)$. The terms of corresponding frequencies on the right-hand side of (3.6) are, from (3.3) and (3.8) $-V_d(u_1 G_0 + u_{-1} G_2)\exp(p + j\omega_0)t - V_d(u_{-1} G_0 + u_1 G_2)\exp(p - j\omega_0)t$.

Equating terms of like frequencies gives

$$\left.\begin{aligned} a_1 u_1 + c_1 u_{-1} &= 0 \\ a_{-1} u_1 + c_{-1} u_{-1} &= 0 \end{aligned}\right\} \quad \ldots \quad \ldots \quad (3.9)$$

$$\text{where } \left.\begin{aligned} a_1 &= 1 + G_0 Z^+ & c_1 &= G_2 Z^+ \\ a_{-1} &= G_2 Z^- & c_{-1} &= 1 + G_0 Z^- \end{aligned}\right\} \quad (3.10)$$

In order that solutions of (3.9) other than $u_1 = u_{-1} = 0$ should be possible, it is necessary that $a_1 c_{-1} = c_1 a_{-1}$. Since all the coefficients are functions of p this equation can be written

$$D(p) = a_1 c_{-1} - c_1 a_{-1} = 0 \quad \ldots \quad \ldots \quad (3.11)$$

This is the characteristic equation of the transient states whose roots are the complex characteristic frequencies.

When $p = 0$, $Z^+ = Z^- = R$, and by using (3.5) it is easily shown that $D(0) = 0$. Hence $p = 0$ is a solution of (3.11), but this represents a wave of constant amplitude and frequency ω_0 and so corresponds merely to permanent infinitesimal changes in the amplitude and phase of the steady-state oscillation. All other roots represent transients of increasing or decreasing amplitudes. The stability criterion is, therefore, that all the roots of (3.11), other than 0, should have negative real parts, since this ensures that the transients ultimately vanish.

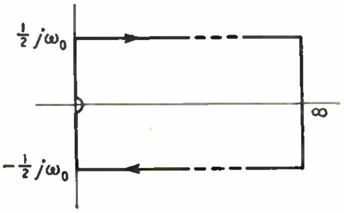


Fig. 2. *p-plane contour.*

Of special interest are oscillators in which the impedance Z is symmetrical with respect to the oscillation frequency; i.e., the real part of Z has even symmetry and the imaginary part odd symmetry with respect to ω_0. This, of course, can be realized only approximately and over a limited range of frequencies. Then $Zj(\omega_0 + \omega_d) = Z^*j(\omega_0 - \omega_d)$, or in terms of complex frequencies, $Z(p + j\omega_0) = Z^*(p^* + j\omega_0)$, where the asterisk denotes the complex conjugate value. Since for all impedances $Z^*(p^* + j\omega_0) = Z(p - j\omega_0)$, it follows that for symmetrical impedances $Z(p + j\omega_0) = Z(p - j\omega_0)$, or $Z^+ = Z^-$.

Assuming symmetry and using (3.5), expression (3.11) can be factorized to give

$$D(p) = F(p)\,A(p)$$

where $F(p) = 1 - Z^+/R$ .. .. .. (3.12)

and $A(p) = 1 + (G_0 + G_2)Z^+$

The oscillation is therefore unstable if any root of either $F(p) = 0$ or $A(p) = 0$ has a positive real part. To see the physical significance of these two conditions, suppose that in expression (3.8) $u_{-1} = -u_1$ and let $u_1 V_d = \frac{1}{2}bV\exp(j\theta)$, then the sum of the real part of the transient voltage v_d and the steady-state voltage $V\cos\omega_0 t$ is a frequency-modulated wave

$$V\cos[\omega_0 t + b\exp(at)\sin(\omega_d t + \theta)] \quad .. \quad (3.13)$$

Equations (3.9) reduce to the single equation $F(p) = 0$. Hence, if any root of this equation has a positive real part, the oscillation frequency is unstable.

Similarly, if $u_{-1} = u_1$ the sum of the real part of v_d and the steady-state oscillation is an amplitude-modulated wave

$$V[1 + b\exp(at)\cos(\omega_d t + \theta)]\cos\omega_0 t$$

Equations (3.9) reduce to the single equation $A(p) = 0$, and if this has any root with a positive real part the oscillation amplitude is unstable. As previously explained, the root $p = 0$, which is a root of $F(p) = 0$, corresponds to a small change in the amplitude and phase of the steady-state oscillation. Thus the general transient in a symmetrical-circuit oscillator takes the form of independent modulations of amplitude and frequency. Only frequency modulation is considered further.

Except for the simplest circuits the frequency stability equation $F(p) = 0$ is not readily soluble, but the information required about the nature of its roots can be obtained directly by plotting the locus of $F(p)$ in the complex plane when p moves once round the contour shown in Fig. 2. The frequency is unstable or stable as the locus does or does not enclose the origin. This follows from a theorem of Cauchy according to which the number of times which the locus of $F(p)$ encircles the origin when p describes any closed contour is $N - P$, where N is the number of zeroes and P the number of poles of $F(p)$ lying within the contour of p. Since Z is a passive impedance function, $F(p)$ can have no poles in the right-hand half-plane. Hence each encirclement indicates a root of the equation $F(p) = 0$ with a real positive part. The imaginary part of p is restricted to the range $\pm\frac{1}{2}\omega_0$, for the reason previously discussed, and the root $p = 0$, which is of no interest, is excluded by indenting the contour at the origin as shown in Fig. 2.

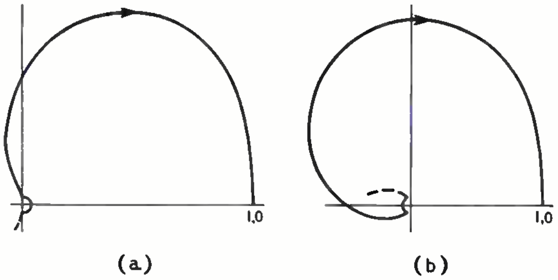
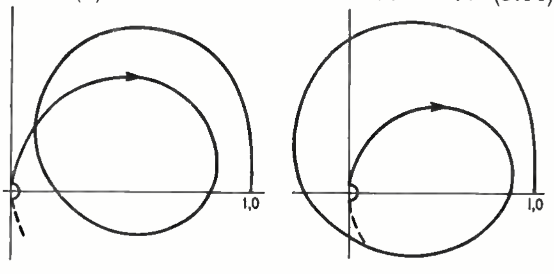


Fig. 3. *Aperiodic stability and instability;* $(n = 1, \alpha = 0)$. *For (a)* $Q_0 = 60$, $Q_1 = 40$; *and for (b)* $Q_0 = 40$, $Q_1 = 60$.

Typical loci of $F(p)$ are shown in Figs. 3 and 4. Owing to the shunting effect of stray capacitances, Z^+ is small for large values of p, and so $F(p) \to 1$ as $p \to \infty$. Only one half of each locus is plotted, namely from $p = 0$ to $p = \infty + \frac{1}{2}j\omega_0$, the other half being simply a mirror image with respect to the real axis. If the derivative $F'(0)$ $[= dF(p)/dp$ at $p = 0]$ is positive, the indentation in the p-plane contour is mapped into the right-hand half-plane as shown in Figs. 3(a), 4(a) and (b). If, however, $F'(0)$ is negative, the indentation falls into the left-hand half-plane as shown in Fig. 3(b). Inspection of these diagrams shows that the frequency will certainly be unstable if $F'(0) < 0$, for the locus must then make at least one encirclement of the origin. Hence a necessary criterion for stability is

$$F'(0) > 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.14)$$



(a) (b)

Fig. 4. *Periodic stability and instability*; ($n = 2, \alpha = 0$). *For* (*a*) $Q_0 = 10, Q_1 = 9$; (*b*) $Q_0 = 9, Q_1 = 10$.

In the simplest case of instability corresponding to Fig. 3(b) the equation $F(p) = 0$ has one real positive root $p = a$ and the instability takes the form of a unidirectional change of the frequency away from the value ω_0. This is shown by expression (3.13) when $\omega_d = 0$. Here the instability is of the aperiodic type. Since $F(p)$ is an analytic function of p its differential coefficient with respect to p is the same as with respect to $j\omega_d$. The real part of Z has even symmetry about ω_0 and so at this point $dR/d\omega_d = 0$. Hence, and from (3.12), the stability criterion (3.14) can be written as $-X' > 0$, where $X' = dX/d\omega_d$ at $\omega_d = 0$. This is the familar criterion used by all previous writers, though no very satisfactory proof seems hitherto to have been given. An equivalent form is $-d\phi/d\omega_d > 0$ where ϕ is the phase angle of Z. Although (3.14) has been derived on the assumption of circuit symmetry it is not difficult to show that it is valid also for asymmetrical networks.

It is clear, however, that condition (3.14), although necessary, is not sufficient to ensure stability for, even when the condition is satisfied, the frequency may still be unstable as shown by Fig. 4(b). Here the locus makes two encirclements showing that the frequency-stability equation has two roots (in this case complex conjugates) with positive real parts. This corresponds to periodic instability since the transient now has the form of a periodic frequency modulation of exponentially increasing magnitude as shown by expression (3.13). No very simple criterion for periodic stability can be given but a few special cases are treated analytically in later Sections.

4. Application to the 'Long-Line' Oscillator

For the most part, oscillators in which the load is coupled through a long feeder use magnetron, klystron or other types of microwave generator. It is characteristic of such devices that the equivalent admittance, at the oscillation frequency, of the space charge or electron beam has a susceptive as well as a conductive component, both of which may depend on the amplitude and frequency of oscillation. Thus the internal operation of the generator cannot be represented in any simple way.

A discussion of the effects of electronic admittance variation on frequency stability is beyond the scope of the present inquiry. The purpose of the foregoing remarks is simply to indicate that some error must be expected when stability criteria based on the assumption that the valve can be represented as a nonlinear resistor are applied to magnetron, klystron and similar types of generators.

A further difficulty is that the analysis of the previous Section applies only to continuous-wave steady-state operation, but many microwave oscillators are pulse modulated and this introduces new features into the stability conditions. If the pulse length is shorter than twice the time required to traverse the feeder the load can have no influence on the performance of the generator. When the pulse length is longer than this value the reflected wave (assuming the feeder to be mismatched) reacts on the generator to modify the initial frequency. From Domb's study[9] of this effect is would appear that shortly after the arrival of the first reflection the oscillator has settled down to its steady-state frequency to which the stability criteria may therefore be applied. With these reservations the results of the general theory will be applied to the problem of the long-line oscillator. Only frequency-symmetrical networks are covered by this theory but this is not a serious drawback as will be explained later.

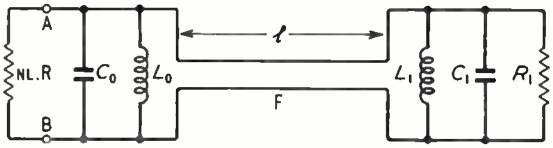


Fig. 5. *Basic oscillator circuit.*

Fig. 5 shows the arrangement to be examined. The generator is represented by the nonlinear resistance element NL.R. and the resonant circuit L_0C_0. Any dissipation in this circuit can be incorporated into NL.R. The network $L_1C_1R_1$ represents the load which is coupled to the generator through a uniform feeder F of length l. In practice the feeder would be connected at both ends through transformers or impedance-matching networks, but the effect of these is simply to alter the scale of the load and generator impedances and to introduce new reactive elements which, as a first approximation, can be incorporated into the load and generator impedances and into the feeder length. The impedances shown in Fig. 5 are therefore these transformed or 'referred' impedances. Although Fig. 5 is by no means a general or exact representation of the actual oscillator it is sufficiently accurate at frequencies near to ω_0, and only such frequencies are of interest for the present purpose.

The impedance Z of the general theory is the impedance measured between terminals A and B with NL.R. removed. In order that this impedance should be symmetrical with respect to ω_0 the two resonant circuits must be tuned to ω_0 and the feeder must be an integral number of quarter-wavelengths long at this frequency. Thus

$$L_0C_0 = L_1C_1 = 1/\omega_0^2 \text{ and } l = n\lambda/4 \quad .. \quad (4.1)$$

where λ is the wavelength in the feeder. It might seem that this restriction on the feeder length constitutes a serious limitation, but in most applications the length will seldom be known exactly and, with a long feeder, it may easily vary by several wavelengths when the oscillation frequency is varied. It is necessary and sufficient to consider the extreme conditions and these arise when the feeder is an odd or even number of wavelengths long.

At the complex frequency $p + j\omega_0$ the admittance of the load circuit is

$$Y_1^+ = 1/R_1 + 1/(p + j\omega_0)L_1 + (p + j\omega_0)C_1$$

Assuming $|p|$ to be small compared with ω_0, the admittance can be written as

$$\left.\begin{aligned} Y_1^+ &= (1 + 2Q_1p/\omega_0)/R_1 \\ \text{where} \quad Q_1 &= R_1/\omega_0L_1 \end{aligned}\right\} \quad .. \quad (4.2)$$

Similarly the admittance of L_0 and C_0 is

$$\left.\begin{aligned} Y_c^+ &= 2Q_0p/\omega_0R_0 \\ \text{where} \quad Q_0 &= R_0/\omega_0L_0 \end{aligned}\right\} \quad .. \quad .. \quad (4.3)$$

In these expressions R_0, which is arbitrary, will be taken as the characteristic impedance of the feeder. The value of Q_0 thus defined is sometimes called the 'external Q-factor' since it indicates the extent to which the oscillatory circuit is damped by external loading.

Two parameters suffice to specify the steady-state performance of the feeder—the characteristic admittance Y_0 and the propagation constant $\gamma = \alpha + j\beta$. For coaxial or 2-wire lines at high frequencies Y_0 is resistive ($= 1/R_0$) and substantially independent of frequency. At the complex frequency $p + j\omega_0$ the value of the propagation constant is obtained by replacing $j\omega_0$ by $p + j\omega_0$ in the expression for γ. Thus

$$\gamma^+ = [\{R + (p + j\omega_0)L\}\{G + (p + j\omega_0)C\}]^{\frac{1}{2}}$$

where R, G, L and C have the usual significance (line constants per unit length). Ignoring the slight variation of R and G with frequency and assuming, as is usual, that $R \ll \omega_0L$ and $G \ll \omega_0C$ this expression becomes

$$\gamma^+ = \gamma + p\beta/\omega_0 = \gamma + p/v_p$$

where v_p is the phase velocity of waves in the line.

This result can easily be generalized to cover any uniform feeder, for if p is small

$$\gamma^+ = \gamma + p(\partial\gamma/\partial p) = \gamma + p[\partial(\alpha + j\beta)/\partial j\omega_d]$$

In practical feeders α is small compared with β and its rate of change with frequency is altogether negligible compared with the rate of change of β. Hence $\gamma^+ = \gamma + p(\partial\beta/\partial\omega_d)$; but the quantity $\partial\beta/\partial\omega_d$ defines the group velocity v_g, and so

$$\gamma^+ = \gamma + p/v_g \quad .. \quad .. \quad .. \quad (4.4)$$

In the case of the coaxial line the phase and group velocities are equal under the assumed conditions. Hence (4.4) is valid in all cases.

For all practical waveguides α is small and v_g at the frequency ω_0 is given by

$$v_g = v(1 - \omega_c^2/\omega_0^2)^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (4.5)$$

where v is the phase velocity in the unbounded medium and ω_c the cut-off frequency of the guide. The phase velocity of waves in the guide is $v_p = v(1 - \omega_c^2/\omega_0^2)^{-\frac{1}{2}}$ and the ratio of the two velocities is

$$r_v = v_g/v_p = 1 - \omega_c^2/\omega_0^2 \quad .. \quad .. \quad (4.6)$$

From (4.1) $l/v_g = n\pi/2r_v\omega_0$ .. .. (4.7)

For waveguides the characteristic admittance Y_0 must be replaced by the wave admittance Y_w defined in terms of the transverse electric and magnetic forces. Unfortunately Y_w varies with frequency, but except near to the cut-off frequency the variation is not rapid. Thus for all H-waves

$$Y_w^+ \doteq Y_w[1 - jp/\omega_0(\omega_0^2/\omega_c^2 - 1)]$$

ω_c will usually be of the order of $0{\cdot}6\omega_0$, and since $|p| \ll \omega_0$ the variation of Y_w^+ with p can be neglected.

If a uniform feeder of length l with the parameters Y_0 and γ^+ is terminated by an admittance Y_1^+, the sending-end admittance is

$$Y_s^+ = Y_0(Y_1^+ + Y_0 \tanh \gamma^+l)/(Y_0 + Y_1^+ \tanh \gamma^+l) \quad .. \quad .. \quad (4.8)$$

The total admittance of the network to the right of terminals A,B in Fig. 5 is $Y_c^+ + Y_s^+ = 1/Z^+$. Using (4.2), (4.3), (4.4) and (4.8) the frequency stability function $F(p)$ can be written as

$$F(p) = 1 - Z^+/R = \frac{a_1z + a_2z^2 + (a_3 + a_4z + a_5z^2) \tanh z}{b_0[b_1 + b_2z + b_3z^2 + (b_4 + b_5z + b_6z^2)\tanh z]} \quad .. \quad .. \quad (4.9)$$

in which $z = pl/v_g = pn\pi/2r_v\omega_0$ .. .. (4.10)

and

$a_1 = Q_0'(R_1/R_0 + T)^2 + (Q_1'R_1/R_0)(1 - T^2)$
$a_2 = Q_0'Q_1'(R_1/R_0 + T)T$
$a_3 = \{(R_1/R_0)^2 - 1\}(1 - T^2)$
$a_4 = Q_0'(1 + TR_1/R_0)(R_1/R_0 + T) - Q_1'(1 - T^2)$
$a_5 = Q_0'Q_1'(R_1/R_0 + T)$

$$
\begin{aligned}
b_0 &= R_1/R_0 + T \\
b_1 &= 1 + TR_1/R_0 \\
b_2 &= Q_0'(R_1/R_0 + T) + Q_1' \\
b_3 &= Q_0'Q_1'T \\
b_4 &= b_0 \\
b_5 &= Q_0'(1 + TR_1/R_0) + Q_1'T \\
b_6 &= Q_0'Q_1' \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4.11)
\end{aligned}
$$

where $T = \tanh \gamma l$ and

$$Q_0' = 4Q_0 r_v/n\pi \quad Q_1' = 4Q_1 r_v/n\pi \quad \ldots \quad (4.12)$$

Since the feeder length is assumed to be an integral number of quarter wavelengths at the oscillation frequency, the total phase shift along the feeder is $\beta l = \frac{1}{2}n\pi$. Then

$$
\begin{aligned}
T = \tanh \gamma l &= \tanh(\alpha l + \tfrac{1}{2}jn\pi) \\
&\left.\begin{aligned} &= \tanh \alpha l \text{ if } n \text{ is even} \\ &= \coth \alpha l \text{ if } n \text{ is odd} \end{aligned}\right\} \quad (4.13)
\end{aligned}
$$

Stability can always be determined by plotting the locus of $F(p)$, but even in the simplest cases this is a very laborious procedure. The stability criterion is also expressed by requiring that all the roots of $F(p) = 0$, other than 0, should lie in the left-hand half-plane. Since the denominator of (4.9) has no poles except at ∞, and since z is a real positive multiple of p, this is equivalent to demanding that all the roots other than 0 of the equation

$$a_1 z + a_2 z^2 + (a_3 + a_4 z + a_5 z^2)\tanh z = 0 \quad (4.14)$$

should lie in the left-hand half-plane. A complete solution of this problem will not be attempted, for in most cases of practical interest one or more of the coefficients is small enough to be neglected and the simplified equation is easily treated.

5. Aperiodic Stability

In Section 3 is was shown that a necessary condition for stability is $F'(0) > 0$, the frequency being aperiodically unstable when this condition is not fulfilled. Since $F(0) = 0$ the derivative can be written as $F'(0) = \lim_{p \to 0} F(p)/p$. Also the product $b_0 b_1$ in the denominator of (4.9) is positive. Hence the criterion for aperiodic stability can be expressed as

$$a_1 + a_3 > 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.1)$$

Substituting according to (4.11) and (4.13) gives, if n is even

$$Q_0' > \frac{[1 - (R_1/R_0)^2 - Q_1'R_1/R_0]\,\mathrm{sech}^2\,\alpha l}{(R_1/R_0 + \tanh \alpha l)^2} \quad (5.2)$$

and if n is odd

$$Q_0' > \frac{[Q_1'R_1/R_0 + (R_1/R_0)^2 - 1]\,\mathrm{sech}^2\,\alpha l}{[1 + (R_1/R_0)\tanh \alpha l]^2} \quad (5.3)$$

When n is even the effect of Q_1 is to improve stability, and when n is odd the stability margin is decreased. In cases where the feeder length is not known exactly both (5.2) and (5.3) must be satisfied. The effect of attenuation is always to improve stability. A number of special instances of (5.2) and (5.3) are now considered in detail.

First, suppose that the load is matched to the feeder at the oscillation frequency; i.e., $R_1 = R_0$. Then (5.2) is always satisfied and (5.3) becomes (using (4.12))

$$Q_0/Q_1 > \exp(-2\alpha l) \quad \ldots \quad \ldots \quad \ldots \quad (5.4)$$

This is satisfied for all values of αl if $Q_0 > Q_1$. Fig. 3(a) and (b) show loci of $F(p)$ corresponding to $Q_0 > Q_1$ (stable) and $Q_0 < Q_1$ (unstable) for the case of a loss-free quarter-wave feeder with $r_v = 1$.

Next, suppose that the load is almost entirely resistive over a wide frequency range or that the feeder is very long. In either case $Q_1'(= 4Q_1 r_v/n\pi)$ is negligible and criteria (5.2) and (5.3) become, if n is even

$$Q_0 > \frac{(\pi l/\lambda r_v)[(R_0/R_1)^2 - 1]}{[\cosh \alpha l + (R_0/R_1)\sinh \alpha l]^2} \quad \ldots \quad (5.5)$$

and if n is odd

$$Q_0 > \frac{(\pi l/\lambda r_v)[(R_1/R_0)^2 - 1]}{[\cosh \alpha l + (R_1/R_0)\sinh \alpha l]^2} \quad \ldots \quad (5.6)$$

It is seen that when n is even aperiodic instability can exist only when $R_1 < R_0$, and if n is odd instability exists only when $R_1 > R_0$. If the attenuation were zero it would always be possible to find a feeder length such that no matter how closely the load were matched the frequency would be unstable. The presence of attenuation modifies this conclusion, for the right-hand sides of these inequalities, instead of approaching ∞ as l increases, pass through a maximum and then decrease to zero. Thus, depending on the value of R_1/R_0, there exists a critical value of Q_0 for which the oscillation has aperiodic stability whatever the length of feeder.

To find this critical value it will be supposed that the load is fairly well matched; i.e., $R_1/R_0 = 1 \pm d$, where d is small. The maximum values of the right-hand sides of (5.6) and (5.5) can then be calculated approximately and are found to be

$$Q_m = \pi d/\alpha\lambda e r_v \quad \ldots \quad \ldots \quad \ldots \quad (5.7)$$

where e is the base of Naperian logarithms. Hence if $Q_0 > Q_m$ stability is assured for all lengths of feeder. For example, a rectangular waveguide for operation at 10,000 Mc/s might have $\alpha\lambda = 0{\cdot}0007$ and $r_v = 0{\cdot}57$. With $d = 0{\cdot}1$, corresponding to a standing-wave ratio of 1·1, this would give $Q_m = 290$.

In deriving formula (5.7) it was assumed that Q_1' was negligible compared with $(R_1/R_0)^2 - 1$ in (5.2) and (5.3). Formula (5.7) is therefore valid only if the quantity $2Q_1 r_v/n\pi d$ is much less than 1.

If the feeder length is given and the ratio

R_1/R_0 is regarded as the unknown (Q_1 still being taken as 0) it is again possible to find a value of Q_0 for which aperiodic stability is guaranteed whatever the value of R_1. As R_1/R_0 is increased or decreased away from 1 expressions (5.5) and (5.6) tend asymptotically to the limiting value

$$Q_0 > \pi l/\lambda r_v \sinh^2 \alpha l$$

This is equivalent to equation (36) of Käch[6]. In practice no very great attenuation could be tolerated. For example, with a total attenuation of 3 dB at 10,000 Mc/s and with $\alpha\lambda = 0{\cdot}0007$ and $r_v = 0{\cdot}57$, the required value of Q_0 is 22,000 which is impracticably large.

Formulae (5.5) and (5.6) can also be expressed in terms of the standing-wave ratio r in the feeder. If the attenuation is zero $r = R_1/R_0$ or $r = R_0/R_1$ as R_1/R_0 is greater or less than 1. When attenuation is present the standing-wave ratio has no very precise physical significance, but it may be defined formally at any point in the feeder in terms of the amplitudes of the forward and backward travelling waves. Thus at a distance l from the load the standing-wave ratio is

$$r_0 = (r + \tanh \alpha l)/(1 + r \tanh \alpha l) \quad .. \quad (5.8)$$

where r is defined above. Using this expression (5.5) and (5.6) can be reduced to the single criterion

$$Q_0 > (n\pi/4r_v)(r_0^2 - 1) \quad .. \quad .. \quad (5.9)$$

Allowing for the difference of notation this is the same as formulae (9.31) and (9.32) of Pierce and Shepherd[3] who considered only even values of n and zero attenuation. The expression is also equivalent to equations (33) and (34) of Käch[6].

The effect of a mismatched load on oscillator performance is often specified in terms of the 'pulling-figure'—the amount by which the oscillation frequency varies as a load producing a specified standing-wave ratio is moved along the feeder. Using (4.8) and (5.8) it is easily shown that the total change of susceptance at the sending-end terminals of the feeder produced by moving the load is $\pm \frac{1}{2}(r_0 - 1/r_0)/R_0$. Provided this is small compared with $\omega_0 C$, the total change $\Delta\omega$ in the oscillation frequency is $\Delta\omega/\omega_0 = \frac{1}{2}(r_0 - 1/r_0)/Q_0$. Hence if the pulling is not to exceed a certain specified value, $Q_0 > \frac{1}{2}(r_0 - 1/r_0)\omega_0/\Delta\omega$. Comparing this with the previous formulae it is seen that there is no relation between the pulling figure and the criteria for frequency stability.

6. Periodic Stability

The criteria derived in the last Section, though necessary, are not sufficient to guarantee stability; for the frequency may still be periodically unstable when these conditions are satisfied. To decide the question of periodic stability the roots of the characteristic equation (4.14) must be examined in greater detail. This will now be done for three particular cases.

It is first assumed that the load is purely resistive; i.e., $Q_1 = 0$. (4.11) then shows that the coefficients a_2 and a_5 are zero, and the characteristic equation becomes

$$a_1 z + (a_3 + a_4 z)\tanh z = 0 \quad .. \quad .. \quad (6.1)$$

It can be shown[10] that the conditions for all the roots of this equation, other than 0, to lie in the left-hand half-plane are

$$\left.\begin{array}{ll} a_1 + a_3 > 0 \text{ if } a_4 > 0 \\ a_1 + a_3 < 0 \quad a_4 < 0 \end{array}\right\} \quad .. \quad .. \quad (6.2)$$

Since a_4 is positive the first condition applies and this is simply the criterion (5.1) for aperiodic stability. It follows that periodic instability cannot exist with a purely resistive load.

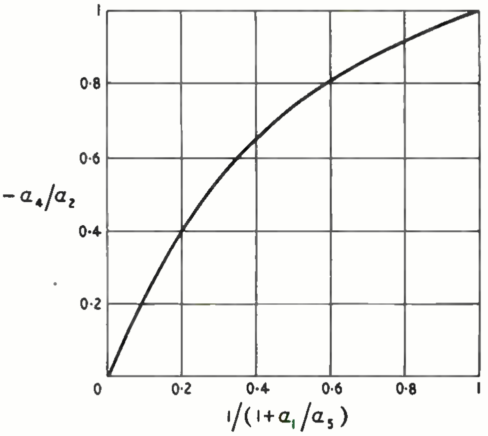


Fig. 6. *Critical values of* a_1/a_5 *and* $-a_4/a_2$.

Next it is supposed that the load is resonant but matched to the feeder at the oscillation frequency; i.e., $R_1 = R_0$. Then, from (4.11), $a_3 = 0$ and after removing the factor z, the characteristic equation is

$$a_1 + a_2 z + (a_4 + a_5 z)\tanh z = 0 \quad .. \quad (6.3)$$

Assuming that $a_1 > 0$, which is the criterion for aperiodic stability, the conditions for all the roots to lie in the left-hand half-plane are[10]

$$a_2 > 0 \quad a_5 > 0$$

$$\text{and } -a_4/a_2 < y_1 \cot y_1 \quad .. \quad .. \quad .. \quad (6.4)$$

where y_1 is the smallest positive root of the equation

$$y \tan y = a_1/a_5 \quad .. \quad .. \quad .. \quad (6.5)$$

(4.11) shows that a_2 and a_5 are positive and so the first two conditions are always satisfied. The third condition (6.4) can be represented graphically. Fig. 6 shows the critical values of $-a_4/a_2$ calculated from (6.4) and (6.5), plotted as a function of $1/(1 + a_1/a_5)$. Only points lying below the graph represent stable states.

From (4.11) the values of a_4/a_2 and a_1/a_5 with $R_1 = R_0$ are

$$\left.\begin{aligned} a_4/a_2 &= (1 - \coth \gamma l)/Q_0' + (1 + \coth \gamma l)/Q_1' \\ a_1/a_5 &= (1 - \tanh \gamma l)/Q_0' + (1 + \tanh \gamma l)/Q_1' \end{aligned}\right\} \quad \ldots \quad \ldots \quad (6.6)$$

If the feeder length is an odd number of quarter-wavelengths (4.13) and the above give

$$a_4/a_2 = (1 - \tanh \alpha l)/Q_0' + (1 + \tanh \alpha l)/Q_1'$$

which is always positive. Hence (6.4) is satisfied and periodic instability cannot exist with odd values of n.

If n is even

$$\left.\begin{aligned} a_4/a_2 &= (1 - \coth \alpha l)/Q_0' + (1 + \coth \alpha l)/Q_1' \\ a_1/a_5 &= (1 - \tanh \alpha l)/Q_0' + (1 + \tanh \alpha l)/Q_1' \end{aligned}\right\} \quad \ldots \quad \ldots \quad (6.7)$$

These expressions together with Fig. 6 enable the stability of any given arrangement to be determined but they do not afford a ready means of finding the critical value of any particular parameter; e.g., Q_0. However, with the help of (6.7), expressions (6.4) and (6.5) can be recast in the equivalent forms

$$\left.\begin{aligned} Q_0' &> 2(1 - \tanh \alpha l)\tan y/y(\tan^2 y + \tanh \alpha l) \\ Q_1' &< 2(1 + \tanh \alpha l)\tan y/y(\tan^2 y - \tanh \alpha l) \end{aligned}\right\} \quad \ldots \quad \ldots \quad (6.8)$$

For any given value of the total attenuation αl, corresponding critical values of Q_0' and Q_1' can be calculated by giving y a succession of positive values less than $\frac{1}{2}\pi$ and such that $\tan^2 y > \tanh \alpha l$. Fig. 7 shows a few graphs obtained in this way. Only points lying above the respective graphs represent stable states as it is only for such points that Q_0' is greater than, or Q_1' is less than, the critical value. This method will give a complete solution of the problem provided only a sufficient number of graphs are constructed to cover the required ranges of αl, Q_0' and Q_1'.

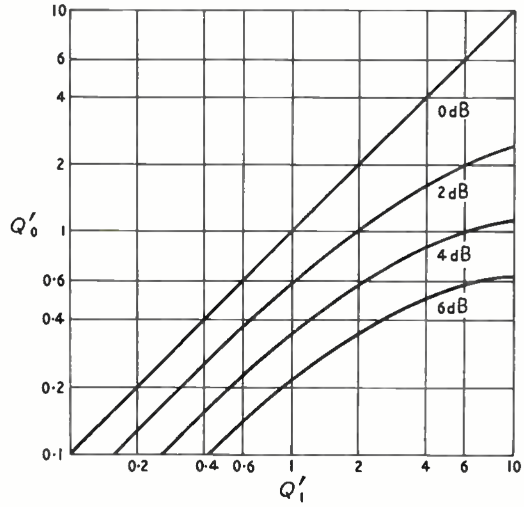


Fig. 7. *Critical values of Q_0' and Q_1' for various values of total attenuation.*

Two general trends can be discerned in Fig. 7. When Q_0' and Q_1' are small the graphs become parallel straight lines with a slope of unity on the logarithmic scale. It follows that the limiting critical values of Q_0 and Q_1 are related by the equation $Q_0/Q_1 = f(\alpha l)$. When Q_1' is large Q_0' tends asymptotically to a limit which depends only on αl. The value of this limit and of the function $f(\alpha l)$ will be deduced later. When the attenuation is zero the critical values of Q_0' and Q_1' are equal. Hence if $Q_0 > Q_1$ the frequency has periodic stability for all values of αl. This is also clear from (6.7) which shows that a_4/a_2 is then positive and criterion (6.4) is therefore satisfied. Fig. 4(a) and (b) show loci of $F(p)$ for $Q_0 > Q_1$ (stable) and $Q_0 < Q_1$ (unstable) calculated from (4.9) for a loss-free half-wave line with $r_v = 1$. As shown in the previous Section the condition $Q_0 > Q_1$ also guarantees aperiodic stability for all values of αl when $R_1 = R_0$.

Periodic stability is also assured for all values of l and Q_1 if

$$Q_0 > \pi/\alpha\lambda r_v \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6.9)$$

This can be deduced from expressions (6.8). As y decreases from $\frac{1}{2}\pi$ to its lower limit of $\tan^{-1}(\tanh^{\frac{1}{2}} \alpha l)$ the critical value of Q_1' increases from 0 to ∞ and the critical value of Q_0' increases continuously from 0 to an upper limit. It follows that stability is assured for all values of Q_1' when Q_0' is greater than this limit. Substituting the lower limit of y into the expression for Q_0' and using (4.12) gives

$$Q_0 > (\pi l/\lambda r_v)(1 - \tanh \alpha l)/\tanh^{\frac{1}{2}} \alpha l \tan^{-1}(\tanh^{\frac{1}{2}} \alpha l) \quad \ldots \quad \ldots \quad (6.10)$$

The right-hand side is greatest when αl is small and this leads at once to (6.9). For a waveguide at 10,000 Mc/s with $\alpha\lambda = 0{\cdot}0007$ and $r_v = 0{\cdot}57$ the critical value of Q_0 given by (6.9) is 7,900—an impracticably large figure. However, at lower frequencies with coaxial cables more reasonable values of Q_0 are obtained. For example, with the cable used in the experiments at a frequency of 10 Mc/s, the critical value of Q_0 is 39. Although the most severe requirement arises when αl is small the value of this quantity has no great influence on the critical value of Q_0. Thus for a total attenuation of 3 dB the value of Q_0 for the waveguide is reduced to 5,900.

More definite forms of the relation between the critical values of Q_0 and Q_1 can be obtained for the two limiting cases in which both Q_0' and Q_1' are either large or small. When Q_0' and Q_1' are large a_1/a_5 is small and the solution of equation (6.5) is approximately

$$y_1^2 = (a_1/a_5)(1 - a_1/3a_5) \quad \ldots \quad \ldots \quad (6.11)$$

The criterion (6.4) then becomes $-a_4/a_2 < 1 - a_1/3a_5$ which is a good approximation for values of a_1/a_5 up to 0·3. Using (6.7) the criterion can be written

$(3 - 2 \tanh \alpha l - \tanh^2 \alpha l)/Q_0' - (3 + 2 \tanh \alpha l - \tanh^2 \alpha l)/Q_1' < 3 \tanh \alpha l$

If the total attenuation is small $\tanh \alpha l \approx \alpha l$ and the above expression reduces to

$$(1 - 2\alpha l/3)/Q_0 - (1 + 2\alpha l/3)/Q_1 < \alpha \lambda r_v/\pi \quad (6.12)$$

From this the approximate limiting value of Q_0 as $Q_1 \rightarrow \infty$ follows at once. The exact value is given by (6.10).

Expression (6.12) may be compared with the criterion for aperiodic stability under the same conditions, namely $R_1 = R_0$ and a small total attenuation. If αl is small the criterion (5.4) can be written $(1 - \alpha l)/Q_0 - (1 + \alpha l)/Q_1 < 0$. If this inequality is satisfied then (6.12) is also satisfied provided $1/Q_0' + 1/Q_1' < 3$, and this is certainly true under the assumed conditions of large Q_0' and Q_1'. It is concluded that in those cases where, because of variations in the oscillator frequency, the electrical length of the feeder may range over an interval of half a wavelength or more, the dominant type of instability under the conditions assumed above is aperiodic.

It is also possible to calculate the characteristic modulation frequency ω_d at the inception of periodic instability. At the critical point between stability and instability the amplitude of the principal transient is stationary, neither increasing nor decreasing, and the characteristic equation has then a pair of purely imaginary roots. Thus $z = \pm jy = \pm \frac{1}{2} jn\pi\omega_d/\omega_0 r_v$. Hence ω_d can be calculated from (6.5) and (6.7). This identification of y with the root of (6.5) owes its validity to the fact that expressions (6.5) and (6.4) (which also becomes an equation in the critical case) are obtained from the characteristic equation (6.1) by writing $z = jy$.

Using the approximate solution (6.11) valid for large values of Q_0' and Q_1'

$$\omega_d/\omega_0 = (2r_v/n\pi)(a_1/a_5)^{\frac{1}{2}}(1 - a_1/6a_5) \quad .. \quad (6.13)$$

When a_1/a_5 is not small (6.4) and (6.5) must be solved by the usual methods of successive approximations to find Q_0 and y. A start can be made with the approximate value of Q_0 given by (6.12) or Fig. 7.

Finally, if Q_0 and Q_1 are small or if the feeder length is great then Q_0' and Q_1' are small and the coefficients a_2 and a_5 in the characteristic equation (4.14) are negligible compared with the others. It is no longer necessary to assume that $R_1 = R_0$. The equation becomes

$$a_1 z + (a_3 + a_4 z)\tanh z = 0$$

This is the same as equation (6.1) and the criteria (6.2) therefore apply. Since for aperiodic stability $a_1 + a_3 > 0$ the sole criterion for periodic stability is $a_4 > 0$. From (4.11) and (4.13) it can be seen that if n is odd $\text{sech}^2 \gamma l$ is negative and a_4 is therefore positive. Accordingly, periodic instability is impossible when n is odd. If n is even the stability criterion becomes

$$Q_0/Q_1 > \text{sech}^2 \alpha l/[1 + (R_1/R_0) \tanh \alpha l](R_1/R_0 + \tanh \alpha l) \quad .. \quad .. \quad .. \quad .. \quad .. \quad (6.14)$$

The frequency is stable for all values of αl if $Q_0/Q_1 > R_0/R_1$ or, from (4.2) and (4.3), $C_0 > C_1$. The frequency is stable for all values of R_1/R_0 if $Q_0/Q_1 > 2 \,\text{cosech}\, 2\alpha l$. If the load is matched to the feeder at the oscillation frequency, $R_1 = R_0$, and (6.14) becomes $Q_0/Q_1 > \exp(-2\alpha l)$. This is the same as the criterion (5.4) for aperiodic stability which applies when n is odd. The physical explanation of this correspondence is that as the feeder length becomes longer and longer the imaginary part $j\omega_d$ of the complex characteristic frequency p becomes smaller and smaller in accordance with (6.13), and so, in the end, periodic and aperiodic instability become indistinguishable.

It seems safe to say that in all cases where the feeder length is not known precisely, stability considerations should be based on the criterion for aperiodic stability, since it is usually aperiodic instability which arises first as Q_0 is decreased.

7. Experimental Results and Conclusions

Although the main application of the theory is probably to microwave oscillators, the apparatus required to test the stability criteria can be more cheaply constructed, and the various parameters more easily and certainly measured, at lower frequencies. Accordingly the experiments were carried out at a frequency of 10 Mc/s. This choice, of course, imposes limitations on the Q-factor values and feeder lengths which can conveniently be used, but there is no reason to suppose that different results would be obtained at higher frequencies.

A triode oscillator was used, as shown in Fig. 8, regeneration being effected by mutual-inductance coupling between the grid and anode coils. Since the theory has been developed only for 2-terminal oscillators, its application to the 4-terminal network of Fig. 8 is perhaps not obvious. However, it can easily be shown that, as far as small frequency changes in symmetrical networks are concerned, the circuit to the left of the dashed line in Fig. 8 (including the mutual inductance) can be replaced by a nonlinear resistor connected across terminals A, B, provided either that the amplification factor of the valve is large or that the coefficient of coupling between grid and anode coils is 1. If the grid-leak and capacitor are replaced by a direct connection or by a grid-bias battery the equivalence holds also for amplitude changes and asymmetrical networks.

The feeder was a coaxial-cable connected at both ends to taps on the coils. Neglecting losses, a tapped coil behaves as a perfect transformer with an inductance connected in parallel with one pair of terminals and a second (leakage) inductance connected in series with the other pair. Two capacitors were therefore placed in series with the cable as shown to neutralize the leakage inductances at the oscillation frequency and thus to improve the symmetry of the network with respect to frequency. With the values of capacitance used (2,500 – 5,000 pF) the resultant reactances in series with the cable were negligible over a wide frequency range.

By means of a movable dust-core the inductance of the oscillator grid coil, and thus the value of Q_0, could be adjusted, the capacitance being varied simultaneously to keep the circuit tuned to the frequency ω_0. A calibrated receiver with beat-frequency oscillator was used to monitor the oscillation frequency. An extreme roughness of beat note indicated the threshold of aperiodic instability, while periodic instability was manifest in the appearance of two side frequencies corresponding to the modulation frequency ω_d.

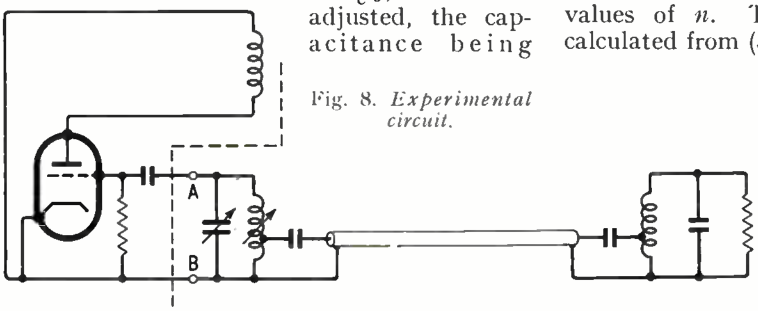


Fig. 8. *Experimental circuit.*

In carrying out the experiments the value of Q_0 was slowly decreased until instability was detected. The critical value of Q_0 was then determined by measuring first the intrinsic Q-factor Q_i of the coil with the cable disconnected, and then the total Q-factor Q_L with the cable connected and terminated by its characteristic impedance R_0. From these values the external Q-factor Q_0 is $Q_0 = Q_iQ_L/(Q_i - Q_L)$. The experimental results were as follows.

At a frequency of 10 Mc/s the constants of the cable were $R_0 = 73\,\Omega$, $\alpha = 0{\cdot}00407$ neper/metre, $\lambda = 19{\cdot}6$ m, $r_v = 1$. From these figures, $\alpha l = 0{\cdot}02n$ and $\alpha\lambda = 0{\cdot}08$ neper.

Test 1. Aperiodic stability with resistive load ($Q_1 = 0$). The load circuit (including the series capacitor) shown in Fig. 8 was removed and replaced by a resistor R_1. For two values of R_1 the critical values of Q_0 were found for various lengths of line. Theoretical values of Q_0 were calculated from (5.5) and (5.6).

TEST 1

R_1 (ohms)	n	Q_0 Meas.	Q_0 Calc.
19	2	16·8	16·3
	4	26·1	25·3
	12	35·3	33·8
237	3	16·5	15·7
	5	21·9	21·1
	11	28·4	27·0

Test 2. Aperiodic stability with resonant load ($R_1 = R_0$). For this test the load was matched to the cable at the oscillation frequency. As shown in Section 5 instability exists only with odd values of n. Theoretical values of Q_0 were calculated from (5.4).

TEST 2

n	Q_1	Q_0 Meas.	Q_0 Calc.
3	25·5	23·2	22·6
5	25·5	20·6	20·9
11	38·9	25·3	25·1

Test 3. Periodic stability with resonant load ($R_1 = R_0$). The circuit arrangement was the same as in test 2 but only even values of n were used. At the inception of instability the modulation frequency ω_d was also measured.

TEST 3

n	Q_1	Q_0 Meas.	Q_0 Calc.	$\omega_d/2\pi$ (Mc/s) Meas.	$\omega_d/2\pi$ (Mc/s) Calc.
2	38·9	17·7	18·8	1·08	1·10
2	25·5	14·8	14·8	1·20	1·26
4	38·9	17·2	18·0	0·79	0·76
10	38·9	16·2	15·6	0·46	0·46

Theoretical values of Q_0 and ω_d were calculated from (6.12) and (6.13) except for the last result which was obtained by solving (6.4) and (6.5) by successive approximations as described in Section 6.

In carrying out this test a type of hysteresis effect was observed with $n = 2$ and $Q_1 = 25{\cdot}5$. When Q_0 had been decreased to the critical value at which instability set in (and it is these values which are tabulated) it was found that in order to restore stability Q_0 had to be increased to a value a few per cent higher. This effect is associated with the large value of modulation frequency

(1·26 Mc/s) for at this frequency the network impedance–frequency characteristic has become markedly asymmetrical, and frequency modulation is then inevitably accompanied by amplitude modulation. Frequency instability by itself is independent of the properties of the maintaining system, but when amplitude modulation is also present the non-linear characteristic of the amplifier is brought into play. At lower modulation frequencies where the network impedance–frequency characteristic is more highly symmetrical no hysteresis effect could be detected.

It was also found that when Q_0 was reduced well below the value at which instability began a second critical point was reached where the frequency changed suddenly to a new stable value close to one of the side-frequencies $\omega_0 \pm \omega_d$. This was due to the inevitable asymmetry of the network characteristic which favoured one of the side-frequency components at the expense of the other.

In all three tests the theoretical and experimental results are in reasonable agreement. Tests 2 and 3 confirm the conclusion reached in Section 6 that for approximately the same lengths of feeder, e.g., $n = 10$, $n = 11$, the critical value of Q_0 required for aperiodic stability is much greater than for periodic stability.

In practical applications, particularly at microwave frequencies, the results would be influenced by irregularities in the impedance and propagation constant at the feeder and by reflections from junctions and bends. Also, as mentioned previously, the equivalent circuit of the oscillator may not be quite so simple as the basic scheme of Fig. 5. Again it may not always be possible to obtain the desired high value of Q_0. The generator oscillatory circuit L_0C_0, which has justifiably been assumed loss-free for the purpose of the analysis, has in fact an intrinsic Q-factor Q_i. If Q_0 becomes comparable with Q_i much of the total available power is dissipated in the oscillatory circuit instead of being transferred to the load. Hence in practice Q_0 cannot be more than a small fraction of Q_i.

From the practical point of view the problem of a microwave transmitter connected to its radiator by a long waveguide has already been solved in a very satisfactory manner[11] by introducing a unilateral ferrite transducer between the generator and the guide. This allows free transmission of energy to the radiator but suppresses all waves reflected back to the generator, thus making instability impossible. However, for longer wavelengths where this technique cannot be applied or for some of the problems mentioned in the Introduction, the theory of stability presented here may still find a useful application.

Acknowledgment

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APPENDIX

Wideband Networks

It was assumed in Section 3 that the network impedance Z has a significant value only near to the frequency ω_0; in particular it was supposed to be negligible along the lines $a \pm \frac{1}{2}j\omega_0$ in Fig. 2. Although this assumption is justified for most practical oscillators it is of some interest to determine what modification is required in the analysis of Section 3 when the network impedance has a significant value over a wide band of frequencies.

Voltages and currents of frequencies p and $p \pm 2j\omega_0$ must now be considered since their magnitudes are comparable with those of frequencies $p \pm j\omega_0$ when p is close to $a \pm \frac{1}{2}j\omega_0$. On the other hand it can be assumed that Z is negligible at frequencies of $2\omega_0$ and beyond. Hence, if attention is confined to positive values of ω_d, it is sufficient to consider four terms in the expression for the complex transient voltage, namely

$$v_d = V_d \exp(pt) \sum_{-2}^{1} u_n \exp(jn\omega_0 t)$$

where, as before, the actual voltage is the real part of this expression.

At the frequency $p + jn\omega_0$ let the network impedance be Z_n and let the current in the non-linear resistor be i_n. Then $i_n = -V_d u_n / Z_n$. But $i_d = v_d f'(v)$ where $f'(v)$ is given by (3.3). Hence the four equations for u_n can be written as

$$\begin{bmatrix} 1 + G_0Z_1 & G_1Z_1 & G_2Z_1 & G_3Z_1 \\ G_1Z_0 & 1 + G_0Z_0 & G_1Z_0 & G_2Z_0 \\ G_2Z_{-1} & G_1Z_{-1} & 1 + G_0Z_{-1} & G_1Z_{-1} \\ G_3Z_{-2} & G_2Z_{-2} & G_1Z_{-2} & 1 + G_0Z_{-2} \end{bmatrix} \begin{bmatrix} u_1 \\ u_0 \\ u_{-1} \\ u_{-2} \end{bmatrix} = 0 \qquad \text{.. A.1}$$

The characteristic frequencies of the transients are given by the equation $D(p) = 0$, where $D(p)$ is the determinant of the first matrix, remembering that only solutions with $0 < \omega_d < \frac{1}{2}\omega_0$ are valid.

If the locus-plot method is used to determine stability only one half of the locus, corresponding to positive values of ω_d, should be drawn: the other half is a mirror image of this. When Z_0 and Z_{-2} are negligible the determinant reduces to (3.11).

It is obvious that Z_0 and Z_{-2} can influence the stability only if Z has a value at the frequencies $\frac{1}{2}\omega_0$ or $1\frac{1}{2}\omega_0$ comparable with its value R at ω_0.

The possibility of the transient wave producing pure frequency modulation may be investigated by writing $u_{-1} = -u_1$ and $u_{-2} = -u_0$. Equations A.1 become

$$\begin{bmatrix} 1 + (G_0 - G_2)Z_1 & (G_1 - G_3)Z_1 \\ 0 & 1 + (G_0 - G_2)Z_0 \\ 1 + (G_0 - G_2)Z_{-1} & 0 \\ (G_1 - G_3)Z_{-2} & 1 + (G_0 - G_2)Z_{-2} \end{bmatrix} \begin{bmatrix} u_1 \\ u_0 \end{bmatrix} = 0 \qquad \text{.. A.2}$$

Since the general solution is any linear combination of the individual solutions of (A.2) it is sufficient to consider these elementary solutions. Apart from the trivial case of $u_1 = u_0 = 0$ three possibilities exist for u_1 and u_0: either may be zero and the other non-zero, or both may be non-zero.

If $u_0 = 0$ then $G_1 - G_3 = 0$, $Z_{-1} = Z_1$ and $1 - Z_1/R = 0$ the last equation following from (3.5). The first condition means that the steady-state current of second-harmonic frequency must be zero; for the amplitude of this current is

$$I_2 = (2/\pi)\int_0^\pi f(V \cos x) \cos 2x \, dx$$

while, from (3.4)

$$G_1 - G_3 = (1/\pi)\int_0^\pi f'(V \cos x) (\cos x - \cos 3x) \, dx = 2I_2$$

The second condition requires the network impedance to be symmetrical with respect to ω_0 over the range $\frac{1}{2}\omega_0$ to $1\frac{1}{2}\omega_0$, and the third equation gives the complex frequency of the modulation. Stability can be determined by solving this equation or by plotting the locus of $1 - Z_1/R$.

Similarly if $u_1 = 0$ equations (A.2) become $G_1 - G_3 = 0$, $Z_{-2} = Z_0$ and $1 - Z_0/R = 0$. The second equation requires the network impedance to be symmetrical with respect to ω_0 in the ranges 0 to $\frac{1}{2}\omega_0$ and $1\frac{1}{2}\omega_0$ to $2\omega_0$. The complex modulation frequency is now $j\omega_0 + p^*$ where p (with ω_d positive) is the root of the third equation.

Finally u_0 and u_1 may both be non-zero. Since frequency stability or instability can hardly depend on the amplitude of the steady-state oscillation, $G_1 - G_3 = 0$. Then $Z_0 = Z_1 = Z_{-1} = Z_{-2}$, and the complex modulating frequencies are p and $j\omega_0 + p^*$, where p is the root of the equation $1 - Z_0/R = 0$ with ω_d positive. Thus Z must now be symmetrical not only about ω_0 but also, over small ranges, about the frequencies $\frac{1}{2}\omega_0$ and $1\frac{1}{2}\omega_0$. Such a characteristic is not likely to be obtained except by special design.

It must be concluded that periodic instability in oscillators with networks having significant values of impedance at $\frac{1}{2}\omega_0$ or $1\frac{1}{2}\omega_0$ will always take the form of mixed amplitude and frequency modulation. Even when the network impedance has the required symmetry independent modulations of amplitude and frequency can exist only when the steady-state second-harmonic current is zero.

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HIGH-FREQUENCY ELECTRONIC COUNTER

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SUMMARY.—A binary counter has been developed which is characterized by a higher counting rate than that hitherto achieved. The article outlines the principles involved and describes a practical arrangement.

1. Introduction

SOME of the television systems[1] now under development include the use of a sub-carrier, the frequency of which lies within the limits of the video spectrum.

The sub-carrier is in turn modulated by signals additional to, and independent of, those required by a normal black-and-white system and, in order to reduce cross-talk between the modulated sub-carrier and the black-and-white signals to the minimum, the sub-carrier frequency is usually chosen to be an odd multiple of half the line-scanning frequency.

In such a television system, therefore, it is necessary to relate both line and frame repetition frequencies to that of the sub-carrier. This may be effected by a chain of frequency dividers and multipliers, as illustrated in Fig. 1, where a sub-carrier, of frequency f_s, is generated in the unit A and is fed to a frequency-dividing and multiplying circuit B.

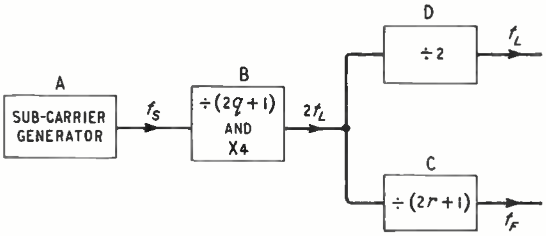

Fig. 1. *Arrangement of counters in a television system employing a band-shared sub-carrier.*

The frequency division effected in B has a divisor which is an odd integer $(2q + 1)$ and the divider output is, in the majority of systems[2], then multiplied by four. With suitable choice of f_s and q, the output from the multiplier can constitute a source of twice line-scan frequency $2f_L$ which may be fed to the customary frame and

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line-frequency divider circuits (C and D). In the arrangement illustrated the frame frequency f_F has been related to twice the line frequency by an odd integer $(2r + 1)$, a condition necessary to produce the normal form of interlaced scanning raster.

The sub-carrier frequency chosen for a particular television system may (with British and American scanning standards) lie in the range 2–4 Mc/s, and it is necessary, therefore, that a frequency divider or counter should be developed which will accept an input within such a frequency range and operate satisfactorily when counting by a fairly large odd number which may be prime.

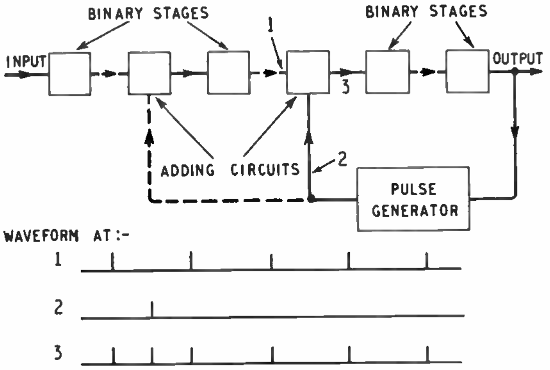

Fig. 2. *Binary cascade with additive feedback.*

2. General Considerations

A well-known form of pulse counter or frequency divider which may be considered to fulfil the requirements listed above is the triggered binary cascade[3].

In such an arrangement, each binary stage delivers one output pulse for every two input pulses. Evidently n such stages arranged in cascade will have an overall divisor or count of 2^n. If pulses derived from the output are re-inserted at suitable points, which may include the input, in such a manner that the added pulses occur during the intervals between the normal triggers, the cascade may be arranged to have an overall count equal to any integer between unity and 2^n. Such an arrangement is illustrated in Fig. 2, where the waveform diagrams show the derived feedback pulses added to the normal trigger pulses.

The upper limit to the input pulse repetition frequency, beyond which a binary cascade fails to operate satisfactorily, is determined by two factors. First, due to the presence of stray reactance, triggering of the first binary stage will be followed by a finite recovery period during which the circuit will fail to respond to any further trigger. In these conditions, therefore, the maximum input repetition frequency will be such that the interval between input pulses just exceeds the duration of the first-stage recovery period. Secondly, if feedback pulses derived from the cascade output are added to the input-pulse train, as shown in Fig. 2, the maximum usable input repetition frequency will fall to a value equal to or less than half that acceptable when operating without feedback. The factor of two relating these limits will result when the feedback pulse is arranged to occur exactly midway between two normal trigger pulses.

From the above discussion it will be seen that, in order to satisfy the requirements demanded by the application described in Section 1, the first counter stage must be characterized by a recovery period equal to or less than $0{\cdot}125\ \mu$sec.

A modified form of the binary cascade counter[4] has been developed wherein the second of the two limiting factors described above has been eliminated.

3. Gated Counter

In the modified arrangement a pulse, derived from the output of the cascade, is used to suppress one or more of the normal triggers driving various binary stages in the cascade. A simple example illustrating this principle is shown in Fig. 3, where a cascade of n stages is driven from the output of a gating circuit consisting of a simple electronic switch.

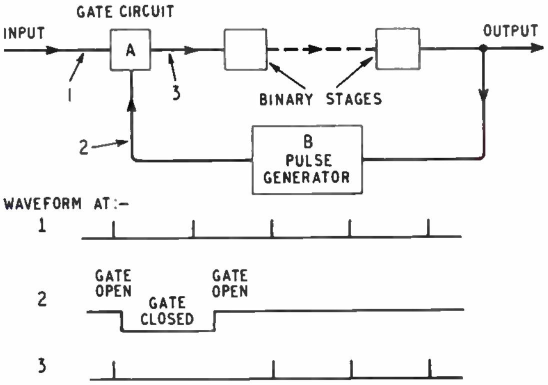

Fig. 3. *Binary cascade with gating feedback.*

Fig. 3 shows an input-pulse train (1) fed to a gate circuit A which is, in turn, operated by a control pulse (2) derived from the cascade output by means of the pulse generator B. The gate output waveform (3) constitutes the drive to a series of binary stages and, if the cascade consists of n such stages, 2^n pulses of the waveform (3) will occur for every output pulse from the cascade. If each control pulse (2) is arranged to remove one pulse from the gate output, then each output pulse from the cascade will correspond to $2^n + 1$ pulses of the waveform (1). These operations are illustrated in the waveform diagrams of Fig. 3.

It follows that if each control pulse is arranged to remove x input pulses, the overall count will be $2^n + x$. If the repetition frequency of the input pulses does not vary by more than one octave, the control pulse (2) may have a constant duration ; however, operation may be made independent of input repetition frequency below a certain upper limit if the gate circuit A and the pulse generator B are of the form shown in Fig. 4.

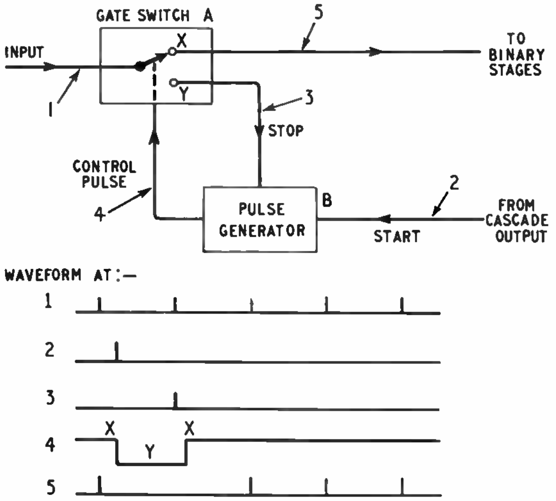

Fig. 4. *Automatic control of the gating pulse duration.*

In this case, the gate circuit A is arranged as a double-throw electronic switch controlled, as before, from the pulse generator B. The switch normally connects the input waveform (1) to the binary cascade (switch position X). The cascade output pulse (2) is fed to the pulse generator B as a 'start' pulse and initiates the control pulse (4) which, in turn, operates the electronic switch (position Y). The next input pulse is thus diverted into the pulse generator as a 'stop' pulse (3). The waveform diagrams of Fig. 4 illustrate these operations and show that the trailing edge of the control waveform always occurs immediately following the trailing edge of the pulse gated out. A pulse counter may be inserted in the 'stop' pulse circuit, in order that the gate circuit may remove two or more pulses per operation.

In a general arrangement several such gate circuits may be inserted at various points in the binary cascade. Each of these gate circuits may then be operated by suitable control pulses derived from the cascade output.

It can be shown (see Appendix) that if such an arrangement contains n binary stages, where each stage is preceded by a gate circuit removing one input pulse per cascade output pulse, the count may be arranged to have any integral value between 2^n and $2^{n+1} - 1$.

4. Practical Example

A complete counter, based upon the principles outlined, has been developed in connection with an investigation into the properties of dot-interlace[5] as a bandwidth-saving device. Such an application is very similar in requirements to those outlined in Section 1 although, in this case, the operating range of input-pulse repetition frequency is somewhat higher. A block schematic diagram of the counter (Fig. 5) shows a cascade of four binary stages arranged to count by any integer within the limits of 16 and 31 inclusive.

The input-pulse train is applied to the first gate circuit G_1 wherein one input pulse may be removed for each gating pulse derived from P_1; that is, for each cascade output pulse. The output of the gate G_1 drives the first binary stage S_1.

Short pulses representing the output of S_1 now form the input to the double-throw switch circuit

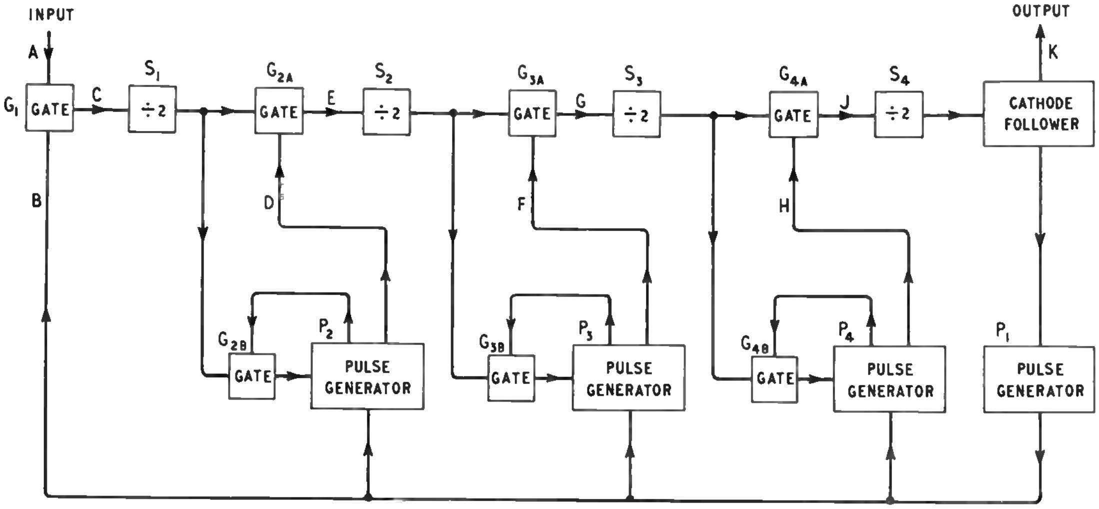

Fig. 5. *Schematic diagram of a gated counter.*

formed by G_{2A} and G_{2B}. The principle of operation of this arrangement has been outlined above and illustrated in Fig. 4. The two gates G_{2A} and G_{2B} have identical input waveforms but are operated by control pulses of opposite polarity such that, in the normal condition, G_{2A} is open and G_{2B} is closed. A cascade output pulse fed through P_1 will actuate P_2 causing G_{2A} to close and G_{2B} to open. The next input pulse to the gates will now be routed to P_2 thus terminating the control pulse. The circuit has now been returned to the normal condition (G_{2A} open, G_{2B} closed) and will remain so until the next cascade output pulse.

The remaining binary and gate stages of the cascade are similar in design and performance. By means of switches each of the gating circuits may be arranged either to remain open continuously or to operate as described. Thus, one stage input pulse per cascade output pulse may be removed at will from the input to any of the binary stages in the cascade. In this way the cascade count may be varied over the range of 16 (all gates open continuously) to 31 (all gates pulse-operated) inclusive.

In order to furnish more detailed design information, circuits of the basic binary stage and the two forms of gating arrangement are described below.

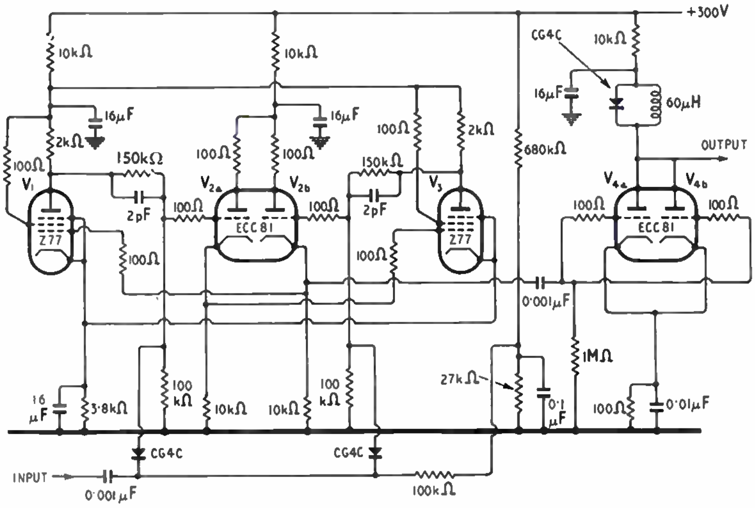

Fig. 6. *Binary stage suitable for high-frequency operation.*

4.1. *Binary Stage*

Fig. 6 shows the circuit of a binary stage as incorporated in the cascade. The valves V_1, V_2 and V_3 form a directly-coupled multivibrator wherein the cross-coupling feedback paths are routed through the cathode followers formed by V_{2A} and V_{2B}. By this means, the recovery time of the circuit is reduced to a minimum in that grid current in either V_2 or V_3 cannot cause charging of the cross-coupling capacitors. In addition, the capacitance appearing across the load resistors of V_1 and V_3 is reduced to a minimum. The input pulses, of negative polarity, are applied through crystal rectifiers to the grids of the cathode followers V_{2A} and V_{2B}. The bias on the rectifiers is such that a negative input pulse is applied to that grid of V_2 having the greater positive potential with respect to earth. The rectangular voltage waveform appearing at the cathode of V_{2B} forms the drive to V_4. The resulting anode current of V_4 flows through the pulse-generating circuit formed by the resonance of the anode load inductance with stray capacitance. A crystal rectifier is connected in such a way as to damp all oscillation other than that resulting from a cessation of anode current in V_4. A positive voltage pulse of half-sinusoid shape appears at the anode of V_4 for every two pulses applied at the stage input.

4.2. *Gating Circuits*

As will be evident from Fig. 5, two types of gating arrangement are utilized in the complete counter. The first, used in the gate G_1, is of the type discussed with reference to Fig. 3 and consists simply of an amplifier accepting input trigger pulses of positive sign at the control grid and control pulses of negative polarity at the suppressor grid. A control switch is provided whereby the control pulses may be removed from the suppresssor grid, resulting in a continuous and uninterrupted pulse output from the gate. Control pulses of positive polarity are derived from the pulse generator P_1 (Fig. 5) wherein the rectangular waveform at the cascade output is converted into a train of pulses having a duration, polarity and timing such that the gate G_1 removes one cascade input pulse for each cascade output pulse. The circuit arrangement used for P_1 is very similar to that associated with V_4 in Fig. 6. The output pulses from P_1 are also used as trigger pulses for the other gates (G_2, G_3 and G_4) in the counter. The circuit arrangement used for these gates is of the type illustrated in Fig. 4 and a detailed circuit diagram of one such stage is shown in Fig. 7.

Input pulses of positive polarity are applied to the control grid of V_1 and, in the absence of gating pulses at the suppressor grid, are passed from the anode circuit of V_1 to the next binary stage

(Fig. 4, gate switch A, position X). The ungated input pulses appear at the cathode of V_1 and are fed to an amplifier V_5. At this point in the discussion it will be assumed, for the sake of simplicity, that the high-speed bistable stage formed by V_2, V_3 and V_4, is in that state of equilibrium where V_2 is cut off and V_4 conducting. A trigger pulse derived from the cascade output is amplified in V_6 and is passed through a suitably-biased crystal rectifier to the anode of V_2, causing a change in the circuit conditions of V_2, V_3 and V_4 such that V_2 conducts and V_4 is cut off. The resulting negative-going voltage transition occurring at the cathode of V_{3A} is fed to the suppressor grid of V_1, cutting off the pulse drive to the following binary stage. A similar transition of positive polarity appearing at the cathode of V_{3B} is fed to the suppressor grid of V_5 so that the next input pulse appears at the anode of V_5 (Fig. 4, gate switch A, position Y). This pulse, fed through a suitably-biased rectifier, causes the bistable circuit to revert to the first condition of equilibrium. The resulting positive-going voltage transition at the cathode of V_{3A} terminates the gating pulse to V_1 and a similar negative transition at the cathode of V_{3B} results in anode current cut-off in V_5. The circuit has thus completed one gating cycle and will repeat the above operations whenever a trigger pulse is received from the cascade output. It will be appreciated that the circuit shown relies on rectification for bias setting at the grids of the coincidence gates V_1 and V_5. The rectification is effected either by grid current or by means of anode current in auxiliary diodes. The grid time-constants shown are suitable for operation with a cascade whose output repetition frequency is fairly high and these constants should be increased when the gating circuit is required to operate at lower repetition frequencies.

As in the case of the gate G_1, all the remaining gate circuits are provided with a control switch whereby the gating process may be discontinued. Such a switch is shown in Fig. 7, in series with the h.t. supply to valves V_2 and V_4. When this switch is opened, gating pulses are removed from the suppressor grid of V_1.

5. Results and Conclusions

The complete counter unit, as outlined above and illustrated schematically in Fig. 5, has proved to be fully practicable and reliable. In order to provide some evidence of correct operation and to illustrate further the operating sequence, a series of oscilloscope photographs is provided in Fig. 8. The traces show waveforms at various points in the complete circuit when an input-pulse train having a repetition frequency of 5·5 Mc/s is applied to the counter, a value of input repetition frequency equal to the video sampling rate used in some experiments carried out on a dot interlace television system as mentioned in Section 4.

In the waveforms illustrated all the gate circuits are in the pulse-operated condition and, as there are four binary stages ($n = 4$), the overall divisor has the value 31 ($2^{n+1} - 1$). Thus, for an input repetition frequency of 5·5 Mc/s, the repetition frequency at the output will be 177 kc/s.

The code letters beside each photograph refer to a similar set in Fig. 5 and illustrate the waveforms appearing at the corresponding points indicated in that schematic diagram.

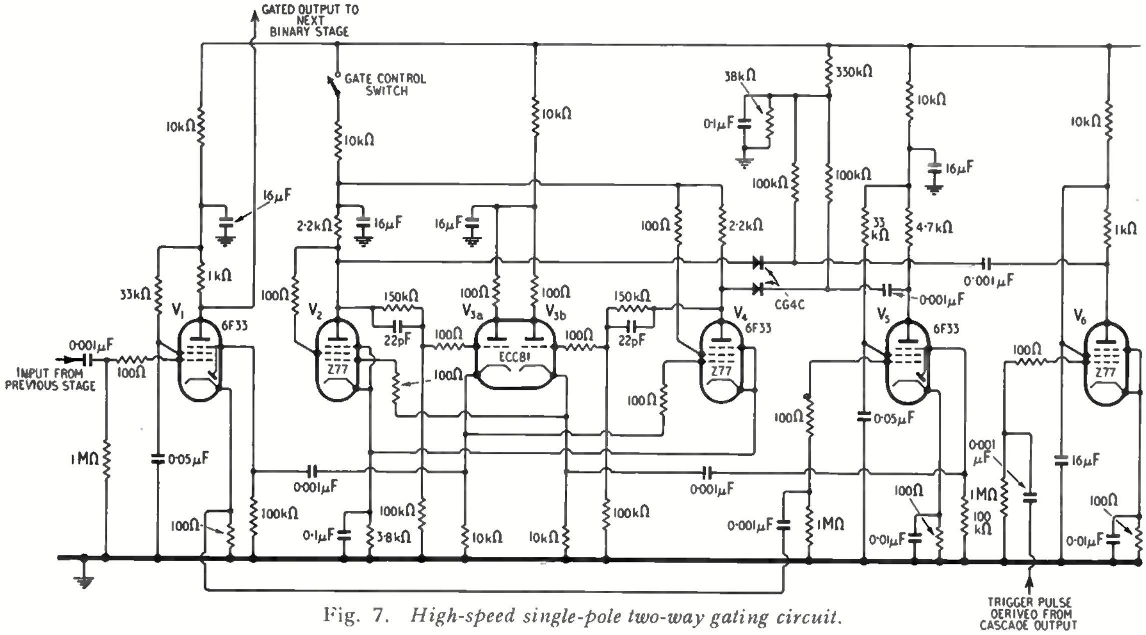

Fig. 7. *High-speed single-pole two-way gating circuit.*

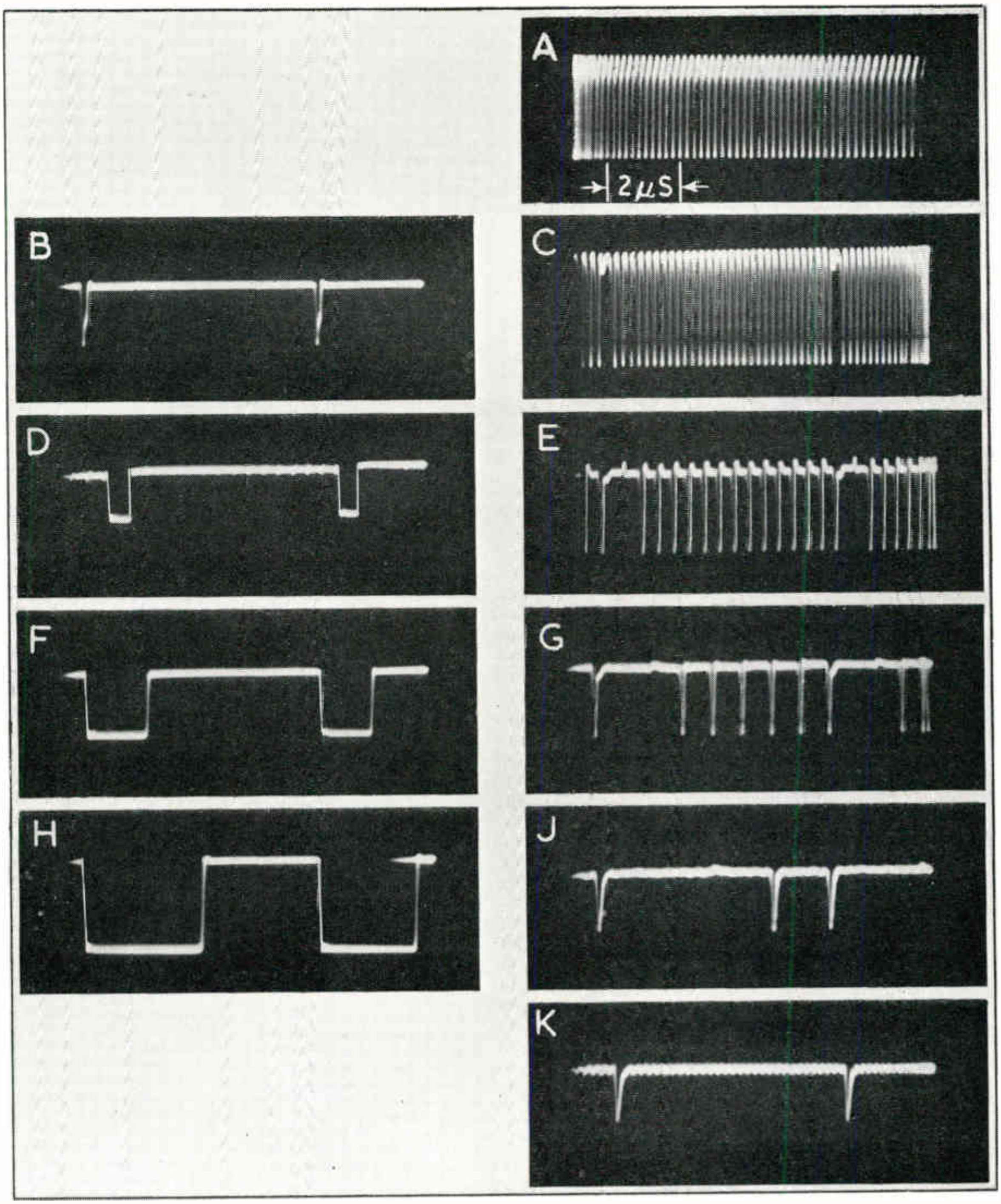

Fig. 8. *Waveform at various points within the counter of Fig. 5.*

A counting arrangement of the type described should prove valuable in many applications, particularly where high operating frequencies are encountered. The circuit provides convenient means for changing the overall count, a feature which may prove valuable in future colour-television systems. Further developments of the arrangement can effect a saving in the total number of valves employed.

A complete counter based on the foregoing work has been built and has given trouble free operation since its inception, a period of 700 working hours.

Acknowledgment

The authors wish to thank the Chief Engineer of the British Broadcasting Corporation for permission to publish this article.

APPENDIX

Fig. 9 shows an arrangement of n binary stages, a gating circuit being provided at the input of certain stages.

For the purpose of analysis, loops A, B and N are indicated in the diagram, loop A embracing a stages, loop B embracing b stages, etc.

If each cascade output pulse suppresses one input pulse at the first gate in each loop, the divisor D_A of loop A will be

$$D_A = 2^a + 1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

For loop B

$$\begin{aligned} D_B &= 2^{b-a}\,(2^a + 1) + 1 \\ &= 2^b + 2^{b-a} + 1 \end{aligned}$$

Similarly for loop N

$$D_N = 2^n + 2^{n-a} + 2^{n-b} + 2^{n-c} + \ldots\ldots + 2^{n-m} + 1$$

where m is the number of binary stages enclosed by the penultimate loop. In general

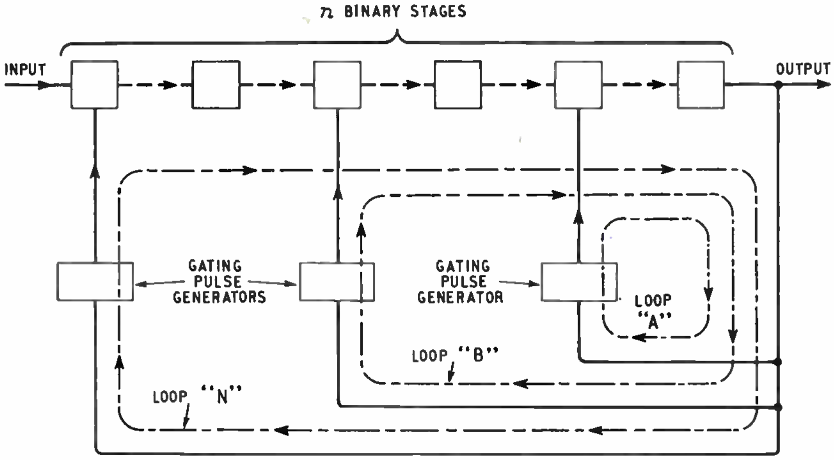

Fig. 9. *General arrangement of gating binary stages in a gated counter.*

$$D_N = 1 + 2^n + \sum_{\lambda=m}^{a} 2^{n-\lambda} \qquad (2)$$

When each stage of the cascade is preceded by a gating circuit removing one stage-input pulse per cascade-output pulse, the total number of loops will equal the total number of stages n.

Hence, from (2)

$$\begin{aligned} D_N &= 1 + 2^n + \sum_{\lambda=n-1}^{1} 2^{n-\lambda} \\ &= \sum_{\lambda=0}^{n} 2^{\lambda} = 2^{n+1} - 1 \end{aligned}$$

since D_n is a geometrical progression of $n + 1$ terms, with first term 1, and ratio 2.

REFERENCES

[1] Petition of the National Television System Committee for Adoption of Transmission Standards for Color Television, July 1953.

[2] I. C. Abrahams, "Choice of Chrominance Sub-carrier Frequency in the N.T.S.C. Standards", *Proc. Inst. Radio Engrs*, January 1954, Vol. 42, No. 1.

[3] A. V. Lord and C. B. B. Wood, "A Variable Definition Camera Channel for the Appraisal of Television Standards", *Proc. Instn elect. Engrs*, Part IIIA, No. 20, p. 811, April-May 1952.

[4] Patent Application 17897/52.

[5] Wilson Boothroyd, "Dot Systems of Colour Television", *Electronics*, Part I, p. 88, December 1949. J. Haantjes and K. Teer, "Multiplex Television Transmission", *Wireless Engineer*, September and October 1954.

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.

The Bifilar-T Trap

SIR,—Your readers may be interested in further information regarding the bifilar-T trap which you discussed in recent issues of *Wireless Engineer* and which is being used in colour television sets in this country: the bifilar-T trap, as used in television circuitry, is discussed in the following R.C.A. Laboratory Bulletins:—

Benjamin Fisher and Jack Avins, "An Analysis of the Bifilar-T Trap Circuit", RCA Industry Service Laboratory Bulletin LB-961, September 16, 1954.

Morris D. Nelson and Jack Avins, "The Design of IF Amplifiers for Color Television Receivers", RCA Industry Service Laboratory Bulletin LB-950, May 20, 1954.

It may be of interest to know that the bifilar-T trap has been used at frequencies as low as 50 kc/s in this country. A composite filter which is used in the Hallicrafters' HT-30 transmitter in combination with other circuit elements for the generation of single-sideband suppressed-carrier telephony signals employs the 50-kc/s version of the bifilar-T trap. The filter, which was designed by Wm. Counts of the Hallicrafters Company, achieves over 40-dB suppression of the unwanted sideband and has a cut-off of approximately 50 dB in 300 c/s, starting from the 3-dB point on the carrier side of the passband.

RICHARD F. BURNS

Beloit Research and Development Co.,
Beloit, Wisconsin, U.S.A.
24th July 1956.

Constant-Frequency Oscillators

SIR,—Mr. Lukaszewicz's assumption, in the August issue of *Wireless Engineer*, p. 201, that the current ratio n_{g1} is real is equivalent to assuming from the outset that the oscillation frequency is independent of μ; for the expression for i_c shows, when the harmonic voltages are zero, that i_{a1} $(1 + n_{g1})$, and so also i_{a1} and i_{g1}, must have the same phase as $v_{g1} + v_{a1}/\mu$. As neither i_a nor i_g are functions of $v_g + v_a/\mu$ this requirement can be satisfied only if both v_{g1} and v_{a1} are in phase (or antiphase) with i_{a1}. Changes in μ can then affect only the magnitudes but not the phases of i_{a1} and i_{g1}, and so the oscillation frequency is independent of μ. Thus Mr. Lukaszewicz's proof is based on circular reasoning.

With regard to the effects of harmonics, none of the papers to which Mr. Lukaszewicz refers shows how the oscillation frequency can be made independent of the harmonic content of the input and output voltages. However, the criterion derived for the stability of sinusoidal oscillations can easily be extended to cover nonsinusoidal operation.

Harmonic voltages influence the oscillation frequency by changing the phases of the input and output currents of fundamental frequency through intermodulation in the nonlinear amplifier. If the input and output voltages are of the form $V_1 \cos \omega t + \sum_{2}^{\infty} V_n \cos (n\omega t + \theta_n)$ the condition for the input and output currents of fundamental frequency to be of the form $I_1 \cos \omega t$, independent of the values of V_n, is that $\theta_n = 0$ for all n. Thus the harmonic currents and voltages must have the same phase, from which it follows that the input, output and transfer impedances of the network must be resistive at the oscillation frequency and all its harmonics.

A. S. GLADWIN

University of Sheffield.
23rd July 1956.

NEW BOOKS

Taschenbuch der Hochfrequenztechnik

By H. MEINKE and F. W. GUNDLACH. Pp. 1408 + xxviii with 1856 illustrations. Springer-Verlag, Reichpietschufer 20, Berlin, W.35. Price D.M. 69.

Although called a 'pocket-book' it should be noted that it has 1436 pages and weighs 3 lb. Professors Meinke and Gundlach are the directors of the high-frequency institutes of the technical universities of Munich and Berlin-Charlottenburg respectively, but the book is the combined output of thirty-seven German experts in the various fields, of whom particulars are given in the introduction. The book is not to be regarded as a text-book but as a reference book in which the high-frequency engineer can find curves, formulae and data which will give him the scientific basis for the research or development work on which he is engaged. It might justifiably be called an encyclopaedia in one volume.

The book is divided into 25 chapters, not numbered but lettered from A to Z, and each chapter is then divided into numbered sections. These are set out in a 17-page table of contents, giving also the names of the authors who have contributed to each chapter: the subdivision of the chapter between the various authors is given in a footnote at the beginning of each chapter. Each chapter ends with an extensive index to the literature referred to, the total number of references being over 2,000. The book concludes with the usual subject index. A slip giving a list of nine errata is inserted in the book, but it overlooks the two spellings, Oersted and Oerstedt within four pages of one another, doubtless due to different authors: there is also a mistake in the chapter heading of p. 1312. On the whole, the book appears to have been prepared with great care.

The opening chapter entitled "circuit elements" begins with the fundamental laws of magnetism and skin effect, and then, after 42 pages devoted to coils, etc., of various types, devotes the next 40 pages to the electric field and capacitors: then follows h.f. resistance, etc., piezo effect, and quartz crystals, and the chapter concludes with 119 references. Chap. B deals with circuits with concentrated or lumped elements, whereas Chap. C deals with homogeneous conductors, especially h.f. cables: in both cases the treatment is very thorough both mathematically and graphically. The following four chapters are devoted to waveguides, both hollow and solid of the Goubau type, the various elements and devices that enter into the construction of lines and waveguides and with cavity resonators and filters. Chap. H of 143 pages deals very thoroughly with every type of h.f. aerial, and the following chapter with the radiated waves, their reflection, refraction, etc.

With Chap. K we turn to semiconductors, thermistors, transistors, etc., followed by the construction and properties of ordinary valves, and then those of the klystron and allied types; then follow chapters on amplifiers of all types and applications, and on the use of valves as rectifiers. Chap. Q deals with the superposition or mixing of different frequencies. Chap. R with the production of oscillatory currents, Chap. S with impulse circuits such as the flip-flop and multivibrator, and Chap. T with the various sources of noise. Chap. U of 100 pages is devoted to modulation and demodulation, while Chap. V is a relatively short chapter by Kupfmüller on the general principles of information transmission. Chapters W and X are also short chapters entitled "senders" and "receivers" respectively, discussing such things as the various types of modulation, long, medium, and short waves, single-sideband transmission and reception. Chap. Y of about 100 pages by 7 contributors deals with h.f. measurement of every kind. The final chapter is a very thorough discussion of transformers and rectifiers with choking coils, smoothing capacitors and filters.

The book is an outstanding production, containing the essential material of every branch of the subject, arranged and set out in an exemplary manner, together with a liberal supply of international references.

G.W.O.H.

Television Engineering: Vol. 2. Video-Frequency Amplification

By S. W. AMOS, B.Sc.(Hons.), A.M.I.E.E. and D. C. BIRKINSHAW, M.B.E., M.A., M.I.E.E. A B.B.C. Engineering Training Manual. Pp. 270. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 35s.

Das Ohr als Nachrichtenempfänger

By R. FELDTKELLER and E. ZWICKER. Pp. 90. S. Hirzel Verlag, Birkenwaldstrasse 185, Stuttgart N., Germany. Price D.M.14.

Wireless Servicing Manual (9th Edn.)

By W. T. COCKING, M.I.E.E. Pp. 268 + viii. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 17s. 6d.

R.F. Transmission Lines
Edited by ALEXANDER SCHURE, Ph.D., Ed.D. Electronic Technology Series No. 166–8. Pp. 63. Price $1.25.

Amplitude Modulation
Edited by ALEXANDER SCHURE, Ph.D., Ed.D. Electronic Technology Series No. 166–9. Pp. 56. Price $1.25.

Blocking Oscillators
Edited by ALEXANDER SCHURE, Ph.D., Ed.D. Electronic Technology Series No. 166–10. Pp. 64. Price $1.25.

Picture Book of TV Troubles: Vol. 5, Horizontal Output and H-V Circuits
By John F. Rider Laboratories Staff. Pp. 108. Price $1.80.

Radio Receiver Laboratory Manual
By ALEX. W. LEVEY, B.A., M.S. Pp. 112. Price $2.

The above five books can be obtained from John F. Rider Publisher Inc., 480 Canal Street, New York 13, N.Y., U.S.A.

Guide to Broadcasting Stations 1956–1957. 9th Edition
Compiled by the staff of *Wireless World*. Pp. 80. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 2s. 6d. (postage 4d.).

British Plastics Year Book 1956. 26th Edition
Pp. 740. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 35s.

Electrical Who's Who 1956-57
Pp. 458. Published by *Electrical Review* Publications Ltd., and distributed by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 21s.

Metal Transfer between Palladium and Silver Contacts at Low Inductance
By J. RIDDLESTONE. Report No. U/T133. Pp. 10. Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 12s. 6d.

A Stable Synchronous Detector for Audio-Frequency Measurements
By P. G. KENDALL. Report No. V/T125. Pp. 18. Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 12s. 6d.

Radio Valve Data. 5th Edition
Compiled by the staff of *Wireless World*, this book contains full operating data on over 2,500 types of British and American radio valves, 37 transistors and 300 cathode-ray tubes. The main tables give electrical characteristics of each valve and classify the valves into current, replacement or obsolete types, as recommended by the makers. An index enables any valve to be found immediately in the tables, while the full list of equivalents has been enlarged. Base connections are shown diagrammatically, the main tables being keyed to the series of diagrams.

Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 4s. 6d. (postage 6d.).

OBITUARY

We regret to record the death of Labouchere Hillyer Bainbridge-Bell, O.B.E., M.C., M.A., on 7th August after a short illness. Born in 1893, "B-B" served in World War I with R.E. Signals and later as wireless officer in the R.F.C. and R.A.F. He was on the research staff of the Radio Communication Co. from 1920–26 and then joined the Radio Research Station, Slough.

He was one of the pioneer workers on radar from 1935–1939, after which he joined the Admiralty Signals and Radar Establishment, where he remained until his retirement in 1953. The Royal Commission on Awards to Inventors awarded him £2,400 for his contributions to the development of radar transmitters and receivers, and an optical convertor.

Since his "retirement" he has been a committee secretary in the electrical division of the British Standards Institution.

MEETINGS

Brit.I.R.E.

26th September. "Some Aspects of Transistor Progress," by H. W. Loeb, Ph.D., to be held at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

Television Society

21st September. "Recent Advances in Colour Display Tubes", by Dr. R. R. Law, at 7 o'clock at 164 Shaftesbury Avenue, London, W.C.2.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for July 1956

Date 1956 July	MSF 60 kc/s Frequency deviation from nominal*: parts in 10^9
1	N.M.
2	−3
3	−2
4	−2
5	−2
6	−1
7	N.M.
8	N.M.
9	−2
10	−2
11	−2
12	−2
13	−2
14	−1
15	−1
16	−2
17	−2
18	−2
19	−2
20	−2
21	−1
22	−1
23	−1
24	−1
25	−2
26	−2
27	−2
28	N.M.
29	−2
30	−1
31	−1

N.M. = Not Measured.

*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

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

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses.

ACOUSTICS AND AUDIO FREQUENCIES

534.01 **2597**

Group Theory of Vibrations of Symmetric Molecules, Membranes, and Plates.—M. A. Melvin & S. Edwards, Jr. (*J. acoust. Soc. Amer.*, March 1956, Vol. 28, No. 2, pp. 201–216.) "It is shown that the detailed group-theoretical analysis of molecular vibrations can be extended to continuous bodies of various shapes by regarding them as the limits of discrete systems with the number of particles becoming indefinitely large."

534.121.2 **2598**

On the Vibrations of Triangular Membranes.—S. K. L. Rao. (*J. Indian Inst. Sci.*, Section B, Jan. 1956, Vol. 38, No. 1, pp. 1–3.) Analysis is presented for the free-edge case.

534.2 **2599**

The Propagation and Reflection of Sound Pulses of Finite Amplitude.—T. F. W. Embleton. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 382–395.) "Experimental results are discussed covering many aspects of the propagation and reflection of finite amplitude sound pulses and weak shock fronts. These are compared with theory and show amongst other features (*a*) that an N-shaped wave form tends to shorten on reflection and (*b*) that a shock front disappears on reflection at an open-ended tube."

534.23 **2600**

Determination of the Amplitude Distribution on Plane Surfaces from the Directional Distribution of the Radiation Fields.—K. Fehér. (*Arch. elekt. Übertragung*, March & April 1956, Vol. 10, Nos. 3 & 4, pp. 125–131 & 163–173.) Theory based on Fourier analysis of the radiation pattern is supported by results of measurements on vibrating plates.

534.232-8 **2601**

Experimental Characteristics of Continuously-Variable-Resonant-Frequency Crystal Systems.—F. Dunn, F. J. Fry & W. J. Fry. (*J. acoust. Soc. Amer.*, March 1956, Vol. 28, No. 2, pp. 275–280.) The characteristics of the transducer described in 2813 of 1955 (Fry et al.) are presented graphically and are discussed.

534.24 + [538.566 : 535.42 **2602**

Variational Method for the Calculation of the Distribution of Energy reflected from a Periodic Surface: Part 1.—W. C. Meecham. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 361–367.)

534.612 **2603**

Anomalous Behavior of Rayleigh Disk for High-Frequency Waves.—J. Awatani. (*J. acoust. Soc. Amer.*, March 1956, Vol. 28, No. 2, pp. 297–301.)

534.75 : 533.723 **2604**

How Loud is Silence?—C. E. White. (*Audio*, March 1956, Vol. 40, No. 3, pp. 17–19, 68.) A quantitative discussion of the relation between thermal noise level and hearing threshold.

534.78 : 621.39 **2605**

Speech Bandwidth Compression.—W. E. Kock. (*Bell Lab. Rec.*, March 1956, Vol. 34, No. 3, pp. 81–85.) The basic principles of operation of three systems, the 'Vocoder', 'Audrey' and 'Vobanc', are described.

534.845 **2606**

Measurements on Resonant Absorbent Acoustic Structures.—E. Brosio. (*Alta Frequenza*, Feb. 1956, Vol. 25, No. 1, pp. 32–37.) Laboratory measurements on plastic membranes are reported. Curves show the variation of absorption coefficient with frequency for different distances of the membrane from the wall and for different materials, etc.

534.85/.86 : 534.76 **2607**

Two-Channel Stereophonic Sound Systems.—F. H. Brittain & D. M. Leakey. (*Wireless World*, July 1956, Vol. 62, No. 7, pp. 331–334.) Continuation of paper abstracted in 1946 of July, giving practical details of the equipment used.

534.86 : 061-3(47) **2608**

Scientific Symposium on Electroacoustics.—B. D. Tartakovski. (*Uspekhi fiz. Nauk*, Feb. 1956, Vol. 58, No. 2, pp. 347–358.) Summaries are given of 17 papers read at the symposium held at Kiev, 1st–5th July 1955.

621.395.623.7 + 621.395.625.3 + 621.375.029.3] : 061.4 **2609**

Developments in Sound Reproduction.—(*Wireless World*, July 1956, Vol. 62, No. 7, pp. 335–339.) Equipment shown at the London Audio Fair, the British Sound Recording Association's exhibition and the Radio Components Show is described.

621.395.625.3 **2610**

New 16-mm Magnetic Signal-Level Test Film.—(*J. Soc. Mot. Pict. Telev. Engrs*, Feb. 1956, Vol. 65, No. 2, p. 110.) A film providing a reference level for measurements based on work by Schwartz et al. (1864 of 1955).

621.395.625.3 **2611**

Field Strength and Gap Distribution Function in the [magnetic] Reproducing Head with and without Tape.—J. Greiner. (*NachrTech.*, Feb. 1956, Vol. 6, No. 2, pp. 63–70.) Analysis is presented for six different types of gap. The field distribution is closest to ideal for the ring head, the longitudinal component having a nearly rectangular waveform and the transverse component being largely suppressed.

621.395.625.3 : 538.221 **2612**

The Process of the Magnetization of Magnetic Tape.—W. Guckenburg. (*J. Soc. Mot. Pict. Telev. Engrs*, Feb. 1956, Vol. 65, No. 2, pp. 69–72.) A method for making visible a magnetic recording on tape involves softening the agent binding the magnetic particles so that the magnetic forces between the particles can produce mechanical displacement. It is possible to examine recordings of wavelengths $< 0{\cdot}4$ mil. The azimuth angles of the recording head can be measured to within $\pm 1'$ of arc.

AERIALS AND TRANSMISSION LINES

621.372 **2613**

Electromagnetic Properties of a Medium comprising Thin Layers.—S. M. Rytov. (*Zh. eksp. teor. Phys.*, Nov. 1955, Vol. 29, No. 5(11), pp. 605–616.) A medium comprising alternate thin layers of two different isotropic materials behaves effectively as a uniform but anisotropic medium. The tensors of the effective permittivity and permeability are derived as functions of the parameters of the materials and of the frequency. The losses and boundary conditions at the surface of the medium are also considered. The theory is relevant to laminated lines of the general type described by Clogston (e.g. 2908 of 1951).

621.372.2 **2614**

Line Transmission Circuits.—E. D. Fitton & R. E. Howland. (*Wireless Engr*, June 1956, Vol. 33, No. 6, pp. 143–150.) An examination is made of effects in transmission-line pairs and associated apparatus due to longitudinal currents and voltages which may be introduced by either e.m. or e.s. coupling. Complex waveforms transmitted along a line in the presence of such currents or voltages will suffer undesired modification. To keep this effect as small as possible, not only should the line pairs be screened and twisted, but the terminal-to-earth impedances should be accurately balanced. Details of suitable techniques are discussed, with numerical illustrations.

621.372.2 **2615**

Investigation of the Energy Exchange and the Field Distribution for Parallel Surface-Wave Transmission Lines.—D. Marcuse. (*Arch. elekt. Übertragung*, March 1956, Vol. 10, No. 3, pp. 117–124.) The coupling between two parallel surface-wave lines is calculated by considering them as a two-wire system, different initial conditions being represented by the superposition of co-phase and opposed-phase waves on the two lines. With identical lines, the whole of the current fed into one of them is coupled into the other at a distance along the line termed the 'exchange length'. The presence of a dissimilar conductor near a surface-wave line is shown to impair the field concentration.

621.372.2 : 621.396.677.75 **2616**

Diffraction of Surface Electromagnetic Waves. Application to the Theory of the Dielectric Aerial.—G. Weill. (*Ann. Radioélect.*, July 1955, Vol. 10, No. 41, pp. 228–255.) Radiation losses from dielectric-coated single conductors are analysed and related to the operation of dielectric aerials. Diffraction of the surface wave at discontinuities of the dielectric permittivity or surface impedance is particularly considered. Methods used and results obtained in measurements of phase along a line with variable characteristics are discussed; phase-velocity anomalies have been observed on rhombic aerials. The characteristics of some end-fire aerials $80\,\lambda$ long are described.

621.372.22 **2617**

Bibliography of Nonuniform Transmission Lines.—H. Kaufman. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. AP-3, No. 4, pp. 218–220.)

621.372.8 : 538.221 : 538.6 **2618**

Calculation of the Faraday Effect in a Gyroparamagnetic Medium.—J. Sontif-Guicherd. (*C. R. Acad. Sci., Paris*, 9th April 1956, Vol. 242, No. 15, pp. 1868–1871.) Continuation of work reported previously (2289 of August) on propagation in waveguides containing a gyromagnetic medium. Formulae are derived for the absorption and the rotation of the plane of polarization.

621.372.8 : 621.316.726 **2619**

Propagation of Electromagnetic Waves in Circular Waveguides with Finite Wall Conductivity, at Frequencies near Cut-Off.—W. Schaffeld & H. Bayer. (*Arch. elekt. Übertragung*, March 1956, Vol. 10, No. 3, pp. 89–97. Correction, *ibid.*, April 1956, Vol. 10, No. 4, p. 173.) Analysis is presented applicable to all possible E and H modes. Calculations of the propagation constants are based on the assumption of an infinitely thick wall, this approximation being satisfactory for all actual thicknesses $> 0{\cdot}1$ mm. The results were verified experimentally for H_{11} mode propagation. The high slope of the attenuation/frequency characteristic near cut-off is used as the basis of a method for stabilizing klystron oscillators; the effectiveness of the method is improved by introducing a suitable gas filling in the waveguide.

621.372.8 : 621.385.029.6 **2620**

Nonlinear Phenomena in a Waveguide in the Presence of an Electron Beam with Nearly Equal Electron and Wave Velocities.—Loshakov. (See 2914.)

621.396.67 **2621**

On an Error in the Use of the Method of Integral Equations in the Theory of Aerials.—B. V. Braude. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 10, pp. 1819–1824.)

621.396.674.3 **2622**

Some Comments on Wide-Band and Folded Aerials.—E. O. Willoughby. (*Proc. Instn Radio Engrs, Aust.*, March 1956, Vol. 17, No. 3, pp. 79–87.) "The impedance-frequency characteristic of simple cylindrical aerials is discussed and it is shown that the bandwidth may be considerably improved by the use of appropriate correcting networks. The folded type of aerial automatically makes use of some of these principles. Folded aerials with equal and unequal legs are considered and experimental results illustrating the analysis are given."

621.396.676 : 621.398 **2623**

A Multiple Telemetering Antenna System for Supersonic Aircraft.—R. E. Anderson, C. J. Dorrenbacher, R. Krausz & D. L. Margerum. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. AP-3, No. 4, pp. 173–176.) A system comprising three independent aerials for three separate telemetering transmitters operating in the frequency band 216–235 Mc/s makes use of the existing angle-of-attack indicator and ram-pressure tubes.

621.396.676.029.6 : 621.3.012.12 **2624**

Patterns of Stub Antennas on Cylindrical Structures.—J. R. Wait & K. Okashimo. (*Canad. J. Phys.*, Feb. 1956, Vol. 34, No. 2, pp. 190–202.) A theoretical investigation relevant to microwave aerials for aircraft is reported. Radiation patterns are presented for radial electric dipoles located on an insulated cylinder and on a cylindrically tipped half-plane. The patterns are in reasonable agreement with those obtained experimentally by Bain (*Stanford Research Inst. tech. Rep.* No. 42, April 1953).

621.396.676.2 **2625**

Current Distribution on Wing-Cap and Tail-Cap Antennas.—I. Carswell. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. AP-3, No. 4, pp. 207–212.)

621.396.677 **2626**

A New Antenna Feed having Equal E- and H-Plane Patterns.—A. C[h]lavin. (*Trans. Inst. Radio Engrs*, July 1954, Vol. AP-2, No. 3, pp. 113–119; *Proc. Instn Radio Engrs, Aust.*, March 1956, Vol. 17, No. 3, pp. 88–93. Abstract, *Proc. Inst. Radio Engrs*, July 1954, Vol. 42, No. 7, p. 1197.) The design of feeds for circular paraboloids is discussed.

621.396.677.3 **2627**

Cross Section of Colinear Arrays at Normal Incidence.—J. M. Minkowski & E. S. Cassedy. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 313–317.) The back-scattering cross-section of collinear arrays of thin dipoles is derived by the variational method, for normally incident waves. The case of the two-dipole array is investigated particularly. Measurements made using the method described by Scharfman & King (2310 of 1954) confirm the validity of the theory.

621.396.677.7/.8 **2628**

Horn-Parabola Aerials for Wide-Band Directional Radio Systems.—H. Laub & W. Stöhr. (*Frequenz.*, Feb. 1956, Vol. 10, No. 2, pp. 33–44.) Detailed discussion is presented of the radiation properties of aerials comprising parabolic sectors illuminated at high angle and formed as integral structures with the primary radiator. A particular aerial designed for operation at 4 kMc/s centre frequency can be adapted to operate at 6 kMc/s by suitably modifying the waveguide-to-horn transition in the primary radiator. Two channels can be provided by radiating waves polarized at right angles to one another. Another type of aerial suitable for television transmissions is a paraboloid of revolution excited axially; this can be provided with extensions to reduce the intensity of side lobes.

621.396.677.71 **2629**

Radiation Patterns of Slotted-Elliptic Cylinder Antennas.—J. Y. Wong. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. AP-3, No. 4, pp. 200–203). Continuation of theoretical work reported previously (3482 of 1953). The results can be applied to determine the patterns radiated by very thin slotted cylinders such as wing and tail surfaces of aircraft.

621.396.677.71 **2630**

The Application of Mathieu Functions in computing the Field Distribution of an Aerial from its Directional Characteristic.—A. A. Pistol'kors. (*NachrTech.*, March 1956, Vol. 6, No. 3, pp. 128–129.) German version of paper abstracted previously from the Russian (3468 of 1954).

621.396.677.833 **2631**

The Curved Passive Reflector.—E. Bedrosian. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. AP-3, No. 4, pp. 168–173.) Analysis for aerial reflectors with slightly curved surfaces indicates that with appropriate illumination the gain can be increased indefinitely by increasing the size. In systems in which the reflector is at the top of a tower and the illuminating aerial at the foot, the effect of reducing tower height is to widen the main lobe of the radiated pattern and to reduce the level of side lobes.

AUTOMATIC COMPUTERS

681.142 **2632**

A New Serial Digital Decoder.—S. V. Soanes. (*Electronic Engng*, June 1956, Vol. 28, No. 340, pp. 247–249.) Intermediate storage and an amplifier feedback loop are used, making the decoder practically independent of clock timing pulses. It can also be used in an analogue system to solve certain types of polynomial equation.

681.142 **2633**

Interconnection of Electronic Computers.—(*Tech. News Bull. nat. Bur. Stand.*, March 1956, Vol. 40, No. 3, pp. 33–35.) Brief account of experiments on the joint operation of the SEAC and DYSEAC machines on business data-processing work; the former machine transmits control signals to the latter via a cable.

681.142 **2634**

Design and Construction of Small Automatic Computers with Programming Arrangement, at the Higher Technical School in Dresden.—I. Lemann. (*Avtomatika i Telemekhanika*, Jan. 1956, Vol. 17, No. 1, pp. 3–18.) Illustrated description of a computer which includes about 600 valves and measures 290 × 180 × 60 cm; the control desk is separate. A magnetic-drum store is used.

681.142 **2635**

Principles and Application of Electronic Analogue Computers.—P. Heggs. (*Electronic Engng*, March–June 1956, Vol. 28, Nos. 337–340, pp. 120–122, 168–170, 212–215 & 257–259.) Typical examples of electrical analogues and the equipment for producing them are discussed and general design considerations are presented. The Saunders-Roe general-purpose analogue computer is described.

681.142 **2636**

New Electronic Analogue Apparatus of the Institute of Automatics and Telemechanics of the U.S.S.R. Academy of Sciences.—V. V. Gurov, B. Ya. Kogan, A. D. Talantsev & V. A. Trapeznikov. (*Avtomatika i Telemekhanika*, Jan. 1956, Vol. 17, No. 1, pp. 19–35.) An illustrated description, including block and circuit diagrams, of the EMU-5 comprising a unit for solving linear differential equations of up to the sixth order, a unit for solving nonlinear differential equations and a power supply unit as well as additional special-purpose units.

681.142 **2637**

Design of a Timing Device and Nonlinear Units for an Electronic Differential Analyser.—V. C. Rideout, N. S. Nagaraja, S. Sampath, V. N. Chiplunkar & L. S. Manavalan. (*J. Indian Inst. Sci.*, Section B, Jan. 1956, Vol. 38, No. 1, pp. 66–79.)

681.142 : 621.3 **2638**

Basic Circuits used in Digital Automation.—M. L. Klein, F. K. Williams & H. C. Morgan. (*Instrum. & Automation*, Feb. 1956, Vol. 29, No. 2, pp. 271–279.) Commonly used circuits are described from a practical point of view, with circuit diagrams and details of components.

681.142 : 621.374.32 **2639**

An Economical Relay-Operated Accumulator.—J. K. Wood. (*Electronic Engng*, June 1956, Vol. 28, No. 340, pp. 250–253.) Design details are given of a binary adder with a maximum capacity of about 2^{24}.

681.142 : 621.385.832 **2640**

The Hyperbolic-Field Tube, an Electron-Beam Tube for Multiplication in Analogue Computers.—Schmidt. (See 2924.)

CIRCUITS AND CIRCUIT ELEMENTS

621.3.012.1 : 621.372.4 **2641**

Impedance and Admittance Surfaces.—R. Merten. (*Arch. Elektrotech.*, 3rd Feb. 1956, Vol. 42, No. 4, pp. 205–216.) Three-dimensional locus diagrams are used to investigate the variation of impedance (or admittance) and phase displacement in two-pole circuits in response to variations of frequency, resistance, inductance or capacitance. The impedance and admittance surfaces include straight lines corresponding to the important special case of zero phase displacement, when the impedance is independent of the damping or detuning.

621.3.066.6 **2642**

Bridge and Short-Arc Erosion of Copper, Silver, and Palladium Contacts on Break.—W. B. Ittner, III. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 382–388.)

621.314.22.029.3 : 621.375.23 **2643**

Transformer Design for 'Zero' Impedance Amplifiers.—N. R. Grossner. (*Audio*, March 1956, Vol. 40, No. 3, pp. 27–30, 69.) Lamination-weight reductions of up to 42% may be obtained without increased distortion in a transformer designed for an a.f. 'zero-impedance' output stage [e.g. 1390 of 1950 (Miller)]. Design formulae are given.

621.316.726 : 621.396.6 **2644**

The Stabilidyne.—M. Colas. (*Onde élect.*, Feb. 1956, Vol. 36, No. 347, pp. 83–93.) A method for applying the harmonics of a quartz crystal oscillator to control the frequency of a receiver or transmitter is described. For reception, the signal frequency and a suitable harmonic of the crystal oscillator are separately mixed with oscillations from a common local oscillator and the two products are then mixed to obtain a frequency which is the difference between that of the signal and the crystal harmonic. Stability of the order of ± 50 c/s with a signal frequency of 30 Mc/s is readily obtained. The characteristics of several industrial equipments are described.

621.316.727 **2645**

A 90°-Phase-Shift Circuit for a Wide Frequency Range.—O. Limann. (*Elektronik*, Feb. 1956, Vol. 5, No. 2, p. 46.) A CR and a RC network are combined in such a way that the undesired phase changes at the outputs of the individual networks due to a frequency change cancel one another in the combined output.

621.318.424 **2646**

Calculations for Ferroxcube-Pot-Cored Coils.—J. Arrazau. (*Onde élect.*, March 1956, Vol. 36, No. 348, pp. 252–267.) A method of calculating core dimensions and windings is presented, giving results accurate to within 10–15%.

621.318.5 **2647**

Ferroresonant Computing Circuits.—R. S. Arbon & G. Phylip-Jones. (*Wireless World*, July 1956, Vol. 62, No. 7, pp. 324–330.) The basic ferroresonant circuit and applications to switching and counting devices are described.

621.318.57 **2648**

The Equilibrium States of a Bistable Flip-Flop from the Point of View of Reliable and Stable Operation.—M. Bataille. (*Onde élect.*, Feb. 1956, Vol. 36, No. 347, pp. 94–103.) The influence of individual components on the functioning of the Eccles-Jordan circuit is discussed and permissible tolerances for given performance are determined.

621.319.4 : 621.375.5 **2649**

Influence of an Alternating Voltage and a Direct Voltage on a Nonlinear Capacitor.—J. C. Hoffmann. (*C. R. Acad. Sci., Paris*, 23rd April 1956, Vol. 242, No. 17, pp. 2122–2124.) Families of curves are presented showing measured variations of capacitance and $\tan\delta$ as functions of a direct voltage and a 2-kMc/s voltage, applied simultaneously, for a capacitor with $BaTiO_3$ dielectric. The curves facilitate determination of optimum working point for dielectric amplifiers.

621.372.41 : 534.01 **2650**

Linear Systems.—B. Gross. (*Nuovo Cim.*, 1956, Supplement to Vol. 3, No. 2, pp. 235–296. In German.) The method of analysis presented previously (2245 of 1953) is developed; the treatment is applicable to all linear passive resonator systems, whether damped or undamped.

621.372.41 : 534.01 **2651**

Possibility of Free Oscillations in a Variable-Parameter Resonant System.—E. Cambi. (*Nuovo Cim.*, 1956, Supplement to Vol. 3, No. 2, pp. 137–181. In English.) Comprehensive general analysis is presented for time-variable linear systems.

621.372.412 + 621.373.421.13 + 537.227/228.1 **2652**

Papers presented at the 2nd Conference on Piezoelectricity (Moscow, 26th–29th April 1955).—(See 2770.)

621.372.412 : 621.372.5 **2653**

The Equivalent Network of a Piezoelectric Crystal with Divided Electrodes.—B. van der Veen. (*Philips Res. Rep.*, Feb. 1956, Vol. 11, No. 1, pp. 66–79.) A general equivalent circuit is worked out for the crystal treated as a quadripole, for frequencies close to that of mechanical resonance.

621.372.413 **2654**

Spherical-Frustum Cavities.—G. Boudouris. (*Onde élect.*, Feb. 1956, Vol. 36, No. 347, pp. 104–121.) Symmetrical spherical-frustum cavities are studied as intermediate cases between the sphere and the cylinder. Resonance wavelengths and Q factors are determined by Abele's method (3823 of 1947). A wavemeter using a hemispherical cavity partly filled with Hg is proposed. Curves are presented showing the variation of Q with cavity size, for $\lambda \sim 3$ cm and 10 cm.

621.372.413 **2655**

Theory of Coupled Endovibrators [cavity resonators]**: Part 2.**—A. I. Akhiezer & G. Ya. Lyubarski. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 9, pp. 1597–1603.)

Continuation of work noted previously (658 of 1955). A mathematical analysis is given of the propagation of waves in a chain of cavity resonators coupled by long narrow slots.

621.372.413 **2656**

Electromagnetic Oscillations in a Parabolic Tube as a Particular Case of the Interaction of Two Cavities through a Throat.—E. R. Mustel'. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 10, pp. 1788–1799.) Free oscillations in a tube of parabolic profile and rectangular cross-section are considered. The tube is regarded as consisting of two cavities interacting through the throat. The wave equation is derived and solutions are found for the cases where the two cavities are (*a*) identical and (*b*) not identical. Experimental results are in good agreement with the theoretical conclusions.

621.372.413 : 621.317.335.3 **2657**

Calculation of the Natural Frequency of a Π-type [single re-entrant] **Cavity Partly Filled with an Absorbing Dielectric.**—V. L. Patrushev. (*C. R. Acad. Sci. U.R.S.S.*, 21st March 1956, Vol. 107, No. 3, pp. 409–412. In Russian.) The system considered comprises a re-entrant cylindrical cavity resonator with a solid dielectric specimen in the form of a truncated cone placed between the base of the cylinder and the butt end of the inner conductor. Formulae derived for the natural frequency and the damping can be used also to determine the components of the complex dielectric constant of the specimen; this analysis also provides the theoretical basis of the measurement method described by Works (173 of 1948) and others.

621.372.413 : 621.318.134 **2658**

Ferrites in Resonant Cavities.—R. A. Waldron. (*Brit. J. appl. Phys.*, March 1956, Vol. 7, No. 3, p. 114.) A formula is derived for the frequency shift produced by introducing a sphere of ferrite into a resonant cavity.

621.372.5 **2659**

Parallel-T *RC* Network.—G. V. Buckley. (*Wireless Engr*, July 1956, Vol. 33, No. 7, pp. 168–173.) A simplified design method is presented based on finding an equivalent network which is more amenable to mathematical treatment.

621.372.5.01 **2660**

A Note on Bandwidth.—A. Nathan. (*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 788–790.) The concept of bandwidth is examined in relation to networks such as integrators, which are not designed to provide faithful transmission of a waveform. The bandwidth of such a network is defined as the maximum bandwidth of the input signal for which the output does not differ from that of an ideal network by more than a prescribed amount.

621.372.54 **2661**

Resistance-Capacitance Filter Networks with Single-Component Frequency Control.—W. K. Clothier. (*Trans. Inst. Radio Engrs*, March 1955, Vol. CT-2, No. 1, pp. 97–102. Abstract, *Proc. Inst. Radio Engrs*, May 1955, Vol. 43, No. 5, p. 641.)

621.372.54.029.42 : 621.375 **2662**

A Practical Method of designing *RC* Active Filters.—R. P. Sallen & E. L. Key. (*Trans. Inst. Radio Engrs*, March 1955, Vol. CT-2, No. 1, pp. 74–85.) A method for designing filters for the frequency range below about 30 c/s, with sharp cut-off, is based on consideration of five basic variables, namely, two resistances, two capacitances, and the gain; from these, further practical parameters are derived by taking the products of resistance and capacitance, the ratio of resistances, and the ratio of capacitances. The active elements can in many cases be simple cathode-follower circuits. Design data for a number of different cases are tabulated.

621.372.542.3.029.4 : 621.375.23 **2663**

The Design of Low-Frequency High-Pass *RC* Filters.—D. D. Crombie. (*Electronic Engng*, June 1956, Vol. 28, No. 340, pp. 254–256.) The design of a twin-T network incorporated in a feedback amplifier circuit is discussed and details are given relating frequency response to phase shift in the amplifier. The use of compensating sections for securing a flat pass-band characteristic is considered and a practical example is worked out.

621.372.543.3 **2664**

New Rejector Circuit: Bifilar-T Trap.—H. J. Orchard: W. P. Wilson. (*Wireless Engr*, July 1956, Vol. 33, No. 7, pp. 175–177.) Comments on 1993 of July (Cocking).

621.372.57 **2665**

Theory of Noisy Four-Poles.—H. Rothe & W. Dahlke. (*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 811–818.) English version of paper originally published in German (2568 of 1955).

621.373.4 **2666**

Nonlinear Coupled Systems.—L. Sideriades. (*C. R. Acad. Sci., Paris*, 4th April 1956, Vol. 242, No. 14, pp. 1784–1787.) Analysis applicable to valve oscillator circuits generally is presented. Different types of oscillator are distinguished topologically.

621.373.421.1 **2667**

Amplitude Limitation in *LC*-Oscillators.—Z. Akçasu. (*Wireless Engr*, June 1956, Vol. 33, No. 6, pp. 151–155.) "An *LC*-oscillator which includes two biased diodes in the grid circuit to limit oscillation amplitude is analysed. Amplitude of oscillation and harmonic distortion are calculated and represented by curves. From these curves it is observed that oscillations can be modulated linearly; no frequency modulation occurs during amplitude modulation and harmonic distortion is very low. Also the circuit is found to be adequate for high frequency stability. The distinctive feature of the circuit is shown to be that the static conditions of the valve, such as bias voltage and direct anode current, are independent of the oscillation amplitude. A practical circuit is described."

2668

621.375.029.3 + 621.395.623.7 + 621.395.625.3]:061.4

Developments in Sound Reproduction.—(See 2609.)

621.375.13 **2669**

Docile Behavior of Feedback Amplifiers.—S. J. Mason. (*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 781–787.) "A docile amplifier is one that remains stable when connected to any passive network of a specified class. A simplified geometrical approach is used to derive the docility criteria for passive-end-loading, ideal-transformer feedback, bilateral passive feedback, and arbitrary passive feedback."

621.375.221.2 **2670**

Notes on the Design of Distributed Amplifiers.—G. Fidecaro & A. M. Wetherell. (*Nuovo Cim.*, 1st Feb. 1956, Vol. 3, No. 2, pp. 359–370. In English.) The treatment used takes account of the self-capacitance of the coils and the effect of using anode and grid lines with different propagation speeds; the latter effect can be useful in avoiding the large increase in gain of the *m*-derived filter-type amplifier at the upper end of the band.

621.375.232.9 2671

Differential Amplifiers with Asymmetrical Output.—E. Giua. (*Alta Frequenza*, Feb. 1956, Vol. 25, No. 1, pp. 4–14.) The basic circuit discussed comprises a pair of similar triodes with equal resistances in anode and cathode leads; when equal-phase voltages are applied to the two grids, voltages in phase opposition are produced at the cathode of one valve and the anode of the other; the output is taken from the mid-point of the circuit connecting these two points. Theory of operation is presented and two experimental models are described.

621.375.3 2672

Design of Push-Pull Magnetic Power Amplifiers.—N. P. Vasil'eva. (*Avtomatika i Telemekhanika*, Jan. 1956, Vol. 17, No. 1, pp. 53–65. Addendum, *ibid*, April 1956, Vol. 17, No. 4, p. 361.) The method is described in detail and is illustrated by discussion of a 120-W amplifier with a power amplification of 500 and internal feedback.

621.375.3 2673

Principles of Construction of Magnetic Amplifiers with a Low Sensitivity Threshold.—M. A. Rozenblat. (*Avtomatika i Telemekhanika*, Jan. 1956, Vol. 17, No. 1, pp. 66–77.)

621.375.3 2674

High-Frequency Operation of Magnetic Amplifiers.—H. W. Collins. (*Elect. Engng, N.Y.*, Jan. 1956, Vol. 75, No. 1, p. 53.) Digest of paper published in *Trans. Amer. Inst. elect. Engrs*, Part I, *Communication and Electronics*, Sept. 1955, Vol. 74, pp. 500–505. Operation at high frequency (e.g. 200 kc/s) makes possible power gains and bandwidths unattainable at power frequencies, since a given power can be controlled with a smaller core.

621.375.4 : 621.314.7 2675

[The design of circuits using] **Junction Transistors at High Frequencies.**—J. Vasseur. (*Onde élect.*, March 1956, Vol. 36, No. 348, pp. 230–251.) Methods of stabilizing transistor amplifiers are discussed and formulae are presented for calculating the characteristics of a linear amplifier at any frequency, and for determining the principal parameters of junction transistors with common-emitter, common-base, or common-collector connections. Curves are given of maximum gain as a function of frequency.

GENERAL PHYSICS

53.05 2676

The Successive Derivation of Experimental Laws.—P. Vernotte. (*C. R. Acad. Sci., Paris*, 16th April 1956, Vol. 242, No. 16, pp. 1966–1968.) Refinement of the method of smoothing experimental curves described previously (2345 of August).

530.162 : 519.2 2677

On the Use of Gram-Charlier Series to represent Noise.—C. W. Horton. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 350–355.) The stochastic time series produced by the random occurrence of identical events is considered. If the waveforms corresponding to the individual events and to the resulting autocorrelation function and power spectrum are each represented by a Gram-Charlier series, relatively simple relations exist between the different sequences of coefficients. If the noise bandwidth is not too great, the number of terms in the series is small enough to permit computation. The formulae are applied to the analysis of experimental data for noise associated with reverse current in a Si diode.

534.2-16 : 537.21 2678

On the Theory of the Acousto-Electric Effect.—A. Van Den Beukel. (*Appl. sci. Res.*, 1956, Vol. B5, No. 6, pp. 459–468.) When an acoustic wave passes through an insulated solid it gives rise to an electric field in the direction of propagation. The influence on this phenomenon of thermal lattice vibrations at temperatures above the Debye temperature is investigated theoretically. The calculations indicate that the field is proportional to both the intensity and frequency of the acoustic wave. The effect is so small that it would not generally be observable in Cu, but is larger by several orders of magnitude in Ge.

535.37 : 061.3(47) 2679

4th Symposium on Luminescence (Molecular Luminescence and Luminescence Analysis).—B. S. Neporent & P. P. Feofilov. (*Uspekhi fiz. Nauk*, Jan. 1956, Vol. 58, No. 1, pp. 151–164.) Brief summaries are given of about 50 papers read at the symposium held at Minsk, 20th–25th June 1955.

535.515 2680

Birefringence resulting from the Application of an Intense Beam of Light to an Isotropic Medium.—A. D. Buckingham. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 344–349.)

537/538 2681

A New Model of Classical Electron.—P. Caldirola. (*Nuovo Cim.*, 1956, Supplement to Vol. 3, No. 2, pp. 297–343. In English.)

537.122 2682

Electron Physics Tables.—L. Marton, C. Marton & W. G. Hall. (*Nat. Bur. Stand. Circulars*, 30th March 1956, No. 571, 83 pp.) Eight parameters are tabulated relating to the energy and motion of electrons accelerated by a potential difference.

537.122 2683

Magnetic Moment of the Electron.—P. Kusch. (*Science*, 10th Feb. 1956, Vol. 123, No. 3189, pp. 207–211.) A survey of experimental and theoretical work, indicating evidence of anomalies.

537.22 : 621.315.616 2684

Electrostatic Charges in Plastics.—S. M. Skinner, J. Gaynor & G. W. Sohl. (*Mod. Plast.*, Feb. 1956, Vol. 33, No. 6, pp. 127–136, 246.) "Experimental evidence is presented that the 'static' charge on plastics is a volume charge distribution rather than a surface distribution. The charge contained in a plastic that has been in contact with metal is found to drain out of the plastic by a flow process which depends both upon the resistivity of the plastic and upon the possibility of neutralization of surface charges by opposite charges external to the plastic such as in air."

537.312.8 2685

Field Dependence of Magnetoconductivity.—J. W. McClure. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1642–1646.) A theoretical calculation is made of the dependence of the elements of the conductivity tensor on the magnetic field for the case of a crystal with arbitrary energy-band structure. The results are the same as would be given by a superposition of electron gases whose cyclotron frequencies are related harmonically. The strengths of the harmonics depend on the band structure. The diagonal elements of the conductivity tensor are monotonically decreasing functions of the magnetic field strength.

537.5 **2686**

The Characteristics of a Discharge at a Probe at a Positive Potential and the Measurement of the Associated Gas Density.—B. N. Klyarfel'd, A. A. Timofeev, N. A. Neretina & L. G. Guseva. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 9, pp. 1581–1596.)

537.5 **2687**

On the Floating Probe Method for the Measurement of Ionized Gas.—K. Yamamoto & T. Okuda. (*J. phys. Soc. Japan*, Jan. 1956, Vol. 11, No. 1, pp. 57–68.) Revised expressions are obtained for the positive-ion current and electron temperature for the usual double-probe method. A triple-probe method is proposed for measurement of energy distribution in electrodeless or h.f. discharges and the applicability of the techniques is discussed.

537.5 : 538.566 **2688**

Formulae for the Mean Losses of Energy in Collisions of Slow Electrons moving in Diatomic Gases.—L. G. H. Huxley. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 44–53.) Approximate formulae are derived which correspond closely with results of experiments for electrons of low energy. The formulae are relevant to the theory of interaction of radio waves.

537.52 : 538.561 **2689**

Two-Electrode High-Frequency Discharge at Pressures from 100 mm Hg to Atmospheric.—G. S. Solntsev & M. M. Dmitrieva. (*Zh. eksp. teor. Phys.*, Nov. 1955, Vol. 29, No. 5(11), pp. 651–657.) An experimental investigation is reported of discharges in nitrogen and argon at frequencies of 35 to 36 Mc/s and 1·5 Mc/s. Variation of running-voltage with electrode separation and variation of electric field with pressure are shown graphically and photographs of discharges are reproduced.

537.533 **2690**

Theoretical Interpretation of Field Emission Experiments.—T. J. Lewis. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1694–1698.) Experimental results obtained by various workers on field emission from tungsten and barium-on-tungsten surfaces are discussed in relation to theories regarding the nature of the surface potential barrier and the distortion of the field by space charge.

537.56 : 538.56 **2691**

Kinetic Theory of the Lorentz Gas: Case of 'Maxwellian' Molecules.—M. Bayet. (*J. Phys. Radium*, Feb. 1956, Vol. 17, No. 2, pp. 167–168.) Discussion of differences between the views and results of the author (e.g. 2925 of 1954) and those of Jancel & Kahan (1366 of May, 2196 of 1954, etc.).

537.56 : 538.6 **2692**

Use of the Boltzmann Equation for the Study of Ionized Gases of Low Density.—(*Phys. Rev.*, 1st April 1956, Vol. 102, No. 1, pp. 12–27.)

Part 1.—K. M. Watson (pp. 12–19).

Part 2.—K. A. Brueckner & K. M. Watson (pp. 19–27).

The behaviour of the gas in a strong magnetic field is discussed.

537.562 : 538.56 **2693**

On the Dipole Resonant Mode of an Ionized Gas Column.—G. H. Keitel. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 144–147.) Calculations show that the multiple resonances found by Makinson & Slade (3532 of 1954) were created by the discontinuities in their approximation to the Gaussian function, and that the actual Gaussian distribution exhibits only one resonance. See also *Proc. Inst. Radio Engrs*, Oct. 1955, Vol. 43, No. 10, pp. 1481–1487.

538.3 **2694**

Fundamental Equations of a Classical Non-conservative Electromagnetism.—É. Durand. (*C. R. Acad. Sci., Paris*, 9th April 1956, Vol. 242, No. 15, pp. 1862–1865.)

538.311 : 621.318.4 **2695**

The Computation of Coils for producing Uniform Magnetic Fields and Constant Field Gradients.—W. Berger & H. J. Butterweck. (*Arch. Elektrotech.*, 3rd Feb. 1956, Vol. 42, No. 4, pp. 216–222.) Calculations for Helmholtz-coil systems are presented. For the field at the mid-point on the axis to be uniform, the second derivative of the field in the axial direction must be zero at that point; for the field gradient to be constant, the third derivative must vanish. Families of curves suitable for design purposes are derived.

538.566 **2696**

Incidence of Electromagnetic Waves on Double Infinite Grids.—Ya. N. Fel'd. (*C. R. Acad. Sci. U.R.S.S.*, 1st March 1956, Vol. 107, No. 1, pp. 71–74. In Russian.) The system considered comprises a double grid of parallel metal rods; the grids are spaced a apart and the rods in each grid are spaced l apart, the rods in one grid being staggered by an amount d relative to the rods in the other grid; the radius of the rods is r_0. Calculations are made of the reflection coefficient $|R|$ and the refractive index $|Q|$ corresponding to three values of a/λ, for $l = 0{\cdot}2\lambda$, $d = 0{\cdot}1\lambda$ and $r_0 = 0{\cdot}01\lambda$, for normal incidence; with $a/\lambda = 0{\cdot}25$, $|R| = 0{\cdot}994$ and $|Q| = 0{\cdot}110$.

538.566 : 535.13 **2697**

A Method for integrating Maxwell's Equations.—R. Vallée. (*Onde élect.*, Feb. 1956, Vol. 36, No. 347, pp. 122–133.) Maxwell's equations for propagation of e.m. waves are integrated for the case where the functions representing the wave contours are separable. Applications are discussed showing the relation between the e.m. theory and geometrical optics.

538.566 : 535.42] + 534.24 **2698**

Variational Method for the Calculation of the Distribution of Energy reflected from a Periodic Surface: Part 1.—W. C. Meecham. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 361–367.)

538.566 : 535.42 **2699**

Experimental Study of the Diffraction of Microwaves by Rotationally Symmetrical Apertures.—A. Boivin, A. Dion & H. P. Koenig. (*Canad. J. Phys.*, Feb. 1956, Vol. 34, No. 2, pp. 166–178. In French.) Measurements at 1·25 cm λ have been made using circular and annular apertures. The results indicate that diffraction calculations based on Kirchhoff's approximation are accurate to within 5% at planes as close as twice the diameter of the aperture, the accuracy improving as the distance increases.

538.566 : 535.42 **2700**

Rigorous Solution of a Particular Diffraction Phenomenon.—P. Poincelot. (*Ann. Télécommun.*, March 1956, Vol. 11, No. 3, pp. 50–56.) Diffraction of a plane e.m. wave by a perfectly conducting infinitely thin screen is analysed, using an infinite system of algebraic equations and an infinite number of unknowns, for the case of the electric vector parallel to the screen edges. The procedure is to calculate the vector potential for the surface assuming a sinusoidal distribution of parallel straight-line currents. Extension of the method to the more general case of arbitrary direction of electric vector would be feasible using electronic computers.

538.566 : 537.56 **2701**

Structure of a Magnetohydrodynamic Shock Wave in a Plasma of Infinite Conductivity.—H. K. Sen. (*Phys. Rev.*, 1st April 1956, Vol. 102, No. 1, pp. 5–11.) The analysis presented is relevant to problems of solar r.f. radiation, the ionosphere, and cosmic rays.

538.566 : 537.56 : 621.385.029.6 **2702**

Growing Electric Space-Charge Waves.—J. H. Piddington. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 31–43.) Theory presented previously, purporting to explain the operation of the electron-wave valve and the origin of solar r.f. emission, is shown to be unsound; alternative theory is given. See also 2258 of July.

538.569.4 : 547.556 **2703**

Some Measurements on the Spectral Line Shape and Width of a Paramagnetic Resonance Absorption Line.—F. Bruin & M. Bruin. (*Physica*, Feb. 1956, Vol. 22, No. 2, pp. 129–140.) Measurements on αα-diphenyl-β-picryl hydrazyl at a frequency of about 20 Mc/s are reported.

538.691 **2704**

The Motion of Charged Particles in Weakly Variable Magnetic Fields.—G. Hellwig. (*Z. Naturf.*, July 1955, Vol. 10a, No. 7, pp. 508–516.) Analysis is simplified by considering in place of the actual particle, which follows a helical path, an equivalent particle following a mean path and having a magnetic moment.

548.0 : 539.11 **2705**

Interaction of Excitons with Lattice Vibrations in Polar Crystals: Part 1.—H. J. G. Meyer. (*Physica*, Feb. 1956, Vol. 22, No. 2, pp. 109–120.)

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 **2706**

Early History of Radio Astronomy.—G. C. Southworth. (*Sci. Mon.*, Feb. 1956, Vol. 82, No. 2, pp. 55–66.)

523.16 **2707**

Cosmic Radio Sources Observed at 600 Mc/s.—J. H. Piddington & G. H. Trent. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 74–83.) A survey has been made over most of the celestial sphere between declinations 90° S and 51° N, using a narrow pencil beam. 49 discrete sources giving flux densities of about 10^{-24} W/m^2 per c/s were identified, including 18 which may not have been previously reported. Nearly all the discrete sources are associated with irregularities of the background radiation.

523.16 **2708**

Radio Emission from Novae and Supernovae.—B. Y. Mills, A. G. Little & K. V. Sheridan. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 84–89.) "Attempts have been made to observe the radio emission at 3·5 m from two supernovae and ten novae. Kepler's star was the only reasonably certain identification. A comparison with radio observations of other supernova remnants suggests a constant ratio between the present radio emission and the maximum emission of light. It is concluded that for common novae, which are not detectable as radio sources, this ratio must be smaller than for supernovae. The galactic radio emission near the plane of the Milky Way could be largely the integrated emission of supernova remnants but common novae could not contribute appreciably."

523.16 **2709**

The Masses of the Magellanic Clouds from Radio Observations.—F. J. Kerr & G. de Vaucouleurs. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 90–111.)

523.16 : 523.4 **2710**

18·3-Mc/s Radiation from Jupiter.—C. A. Shain. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 61–73.) An examination of records at Sydney shows that bursts at 18·3 Mc/s observed in 1950–1951 and previously ascribed to a terrestrial cause were in fact due to radiation from Jupiter; this confirms the observations of Burke & Franklin (2933 of 1955). Some new observations are also mentioned. The usefulness of Jupiter radiation for studying propagation conditions near the sun is pointed out. See also 406 of February.

523.16 : 523.991 **2711**

Observation of an Eclipse of the Crab Nebula.—A. Boischot, E. J. Blum, M. Ginat & E. Le Roux. (*C. R. Acad. Sci., Paris*, 9th April 1956, Vol. 242, No. 15, pp. 1849–1852.) Report of observations at frequencies of 169 and 900 Mc/s during the occultation of the Crab nebula by the moon, on 24th January 1956. The radio source corresponds closely to the visible structure of the nebula; it is deduced from this result that the electron density in the lunar atmosphere is $< 10^4$/cm^3.

523.165 : 523.746 **2712**

The Daily Variation of the Cosmic Ray Intensity Measured near the 1954 Sunspot Minimum.—M. Possener & I. J. van Heerden. (*Phil. Mag.*, March 1956, Vol. 1, No. 3, pp. 253–260.)

523.5 : 551.510.535 **2713**

A Note on the Interpretation of Transient Echoes from the Ionosphere.—A. C. B. Lovell. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 293–294.) Comment on a note by Shain & Kerr (3075 of 1955). Recent radio-echo work on meteors shows that a midday maximum is often observed in the rate of occurrence of meteors. Observations with narrow-beam aerials on 70 Mc/s show that a tendency during the months October–March for the main peak to occur at 0600 is completely reversed from April to September, when the major peak occurs during the daytime.

523.7 : 538.12 **2714**

The Sun's General Magnetic Field.—H. Alfvén. (*Tellus*, Feb. 1956, Vol. 8, No. 1, pp. 1–12.)

523.75 : 551.594.6 **2715**

The Solar Outburst, 23 February 1956. Observations by the Royal Greenwich Observatory.—T. Gold & D. R. Palmer. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 287–291.) Cosmic-ray, photographic and magnetic observations are presented; records of the intensity of atmospherics on a frequency of 27 kc/s show a very substantial decrease in received signal level at 0345 U.T., which appears to be attributable to the cosmic-ray increase associated with the flare.

523.75 : 551.594.6 2716

A Long-Wave Anomaly associated with the Arrival of Cosmic-Ray Particles of Solar Origin on 23 February 1956.—M. A. Ellison & J. H. Reid. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 291–293.) Records of atmospherics received on a frequency of 24 kc/s at the Royal Observatory, Edinburgh, show a sudden decrease coinciding with the time of arrival of solar cosmic-ray particles in the dark hemisphere of the earth.

523.75 : 621.396.11 : 551.510.535 2717

Some Unusual Radio Observations made on 23 February 1956.—J. S. Belrose, M. H. Devenport & K. Weekes. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 281–286.) Records of sky-wave signals obtained at Cambridge, England, on frequencies 70–300 kc/s showed very strong absorption during the occurrence of the solar flare of this date; on 16 kc/s the main effect was a decrease of 7–8 km in the reflection height. On frequencies 1·5–8 Mc/s, at Upsala, almost complete absorption occurred from sunrise until the late afternoon.

55 : 621.396.934 2718

Symposium on the U.S. Earth Satellite Program—Vanguard of Outer Space.—(*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 741–767.) The text is given of seven papers presented at a symposium held in New York in March 1956, dealing with various aspects of the U.S.A. plans for launching earth satellites during the International Geophysical Year, 1957–1958.

550.384 2719

The Crust as the Possible Seat of Earth's Magnetism.—J. S. Chatterjee. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 233–239.) Magnetic material in the earth's crust, to a depth of 20 km, will be highly permeable as a result of temperature and pressure conditions. Interaction between solar corpuscular streams and a very weak initial magnetic field in the crust will magnetize it to saturation; the estimated magnetic moment of the shell agrees with the observed magnetic moment of the earth.

550.385.24 : 523.746.5 2720

Long-Period Variations in Geomagnetic Activity.—E. J. Chernosky. (*Trans. Amer. geophys. Union*, Aug. 1955, Vol. 36, No. 4, pp. 591–595.) Analysis of data shows that correlation between the sunspot number R and the magnetic u figure is markedly improved by taking means for the 11-year sunspot-number cycle and for the 22-year sunspot-magnetism cycle in place of annual means.

551.510.53 : 534.22 2721

Theory of the Rocket-Grenade Method of determining Upper-Atmospheric Properties by Sound Propagation.—G. V. Groves. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 189–203.) Theory applicable to projected experiments is developed from earlier work (2046 of July); a knowledge of the composition of the atmosphere and of the velocity of the sound of the explosions is assumed.

551.510.535 2722

Electron Distribution in the Ionosphere.—G. A. M. King & C. H. Cummack. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 270–273.) Analysis of *h'f* records by the method described earlier [117 of 1955 (King)] suggests that the ionosphere consists of three Chapman layers, E, F_1 and F_2, and that the temperature is uniform.

551.510.535 2723

Effective Tilts of the Ionosphere at Places about 1 000 km apart.—H. A. Whale. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 301–310.) Fuller account of work described previously (1978 of 1955).

551.510.535 2724

The Rates of Production and Loss of Electrons in the F Region of the Ionosphere.—J. A. Ratcliffe, E. R. Schmerling, C. S. G. K. Setty & J. O. Thomas. (*Phil. Trans. A*, 1st March 1956, Vol. 248, No. 956, pp. 621–642.) From the results of Schmerling & Thomas (2726 below) the rates of production and loss of electrons in the region are deduced. Bradbury's theory of the formation of the F layers (1757 and 2184 of 1938) is shown to be self-consistent; it gives a scale height of 45 km for the ionizable constituent of the atmosphere between 180 and 350 km. This result agrees better with the atmospheric *R* model deduced by Bates from rocket experiments (*Rocket Exploration of the Upper Atmosphere*, 1954, pp. 347–356) than with the *G* model deduced from experiments made on the ground. Limits are established for the movements caused by electron diffusion under gravity.

551.510.535 2725

The Formation of the Ionospheric Layers F_1 and F_2.—J. A. Ratcliffe. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 260–269.) It is shown that an electron loss coefficient varying with height in the manner suggested previously (2724 above) would explain the known facts about the splitting of the F layer and might also be a factor in determining the height of the peak of electron density in the F_2 layer.

551.510.535 2726

The Distribution of Electrons in the Undisturbed F_2 Layer of the Ionosphere.—E. R. Schmerling & J. O. Thomas. (*Phil. Trans. A*, 1st March 1956, Vol. 248, No. 956, pp. 609–620.) The variation of electron density with height is deduced from $h'(f)$ records obtained at Watheroo, Huancayo and Slough, and the form of the typical F layer for magnetically quiet days is described in a series of curves; detailed tabulated results are available at the Cavendish Laboratory, Cambridge, England.

551.510.535 2727

Processes controlling Ionization Distribution in the F_2 Region of the Ionosphere.—D. F. Martyn. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 161–165.) Rocket measurements at heights approaching 200 km suggest that the atmospheric density in the F_2 region may be some 30 times less than previously deduced from radio experiments. If the new value were correct, diffusion of F_2 ionization under the forces of gravity and of its own pressure gradient would be likely to affect the shape and height of the region notably. An investigation was made of the possible effects of diffusion processes at such levels. The results indicate that a region with arbitrary height distribution of ionization will by diffusion assume the form of a Chapman region after a time which, for F_2 levels, is a few hours if the radio determinations of density are correct, but only a few minutes if the rocket determinations are correct. It is suggested that there must be a systematic error in the rocket observations.

551.510.535 2728

Observations and Analysis of Ionospheric Drift.—D. G. Yerg. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 247–259.) Spaced-receiver fading observations made at Puerto Rico during 1954–1955 on 2·33 and 4·57 Mc/s indicate average drift speeds of 19 m/s and 12 m/s respectively. The 2·33-Mc/s data are thought to apply to the E layer, and the 4·57-Mc/s data to the F_1 layer. Owing to random changes, the method of similar fades is less reliable than the correlation method of evaluation.

551.510.535 **2729**

Automatic Recording of Ionospheric Characteristics.—K. Bibl. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, p. 295.) Following the proposals of Nakata et al. (2937 of 1954) a device is proposed which gives a direct record of m.u.f.

551.510.535 **2730**

Ionospheric Recorders and Sporadic E.—J. A. Thomas, A. C. Svenson & H. E. Brown. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 159–161.) Brief report of tests made at Brisbane, disproving the statement, which has been made by various workers, that the observed frequency characteristics of the E_s region vary rapidly with the overall sensitivity of the recording *P′f* equipment.

551.510.535 : 523.16 : 550.385 **2731**

Spread F-Layer Echoes and Radio-Star Scintillation.—R. W. Wright, J. R. Koster & N. J. Skinner. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 240–246.) Correlation is noted between observations of radio-star scintillations at one station in equatorial W. Africa and of spread F layers at another, 510 km distant. Disturbed magnetic conditions, in winter, cause decreased F-layer spread.

551.510.535 : 523.78 **2732**

Ionospheric Observations during the Solar Eclipse of June 20, 1955.—A. K. Saha, S. Ray, S. Datta & R. K. Mitra. (*Sci. & Cult.*, Feb. 1956, Vol. 21, No. 8, pp. 475–477.) Observations made at Haringhata, 28 miles N.E. of Calcutta, are reported. The recorder used provided a frequency sweep from 1 to 13 Mc/s in 1 min 55 sec. The observed variation of f_0E shows that the disappearance and reappearance of the ionizing radiation source for the E layer was not symmetrical with respect to the time of the eclipse maximum. The ionization of the F_1 layer also showed a marked drop during the eclipse. An observed drop in the ionization of the F_2 layer may or may not have been an eclipse effect.

551.510.535 : 525.624 **2733**

Lunar Variations in the Ionosphere.—R. A. Duncan. (*Aust. J. Phys.*, March 1956, Vol. 9, No. 1, pp. 112–132.) The global pattern of the observed lunar variations of the height and electron density of the F_2 region is summarized, new analyses being presented for Canberra (f_0F_2), Brisbane ($h'F_2$) and Washington ($h'F_2$ and f_0F_2). The height variation has an amplitude of 1–3 km; maximum height occurs at 06 lunar hours at moderate latitudes and at 09 lunar hours at the geomagnetic equator. The variation of f_0F_2 has an amplitude of 2–4%; the maximum occurs at about 09 lunar hours at moderate geomagnetic latitudes and at 04 lunar hours near the geomagnetic equator. Theory is developed on the basis of a current system at a height of about 100 km. The tidal winds needed to drive the current, the potential distribution in the dynamo layer, and the resulting periodic vertical drifts of ionization in the higher layers are calculated. The lunar variations in f_0F_2 are calculated taking into account probable height variations of recombination coefficient and ionization production rate; the results are in good agreement with observations. It is concluded that the amplitude of the lunar tidal wind near the E layer is about 45 times greater than that on the ground.

551.510.535 : 551.557 **2734**

Influence of Variable Flow of Positive Solar Particles on the Wind in the Ionosphere.—V. V. Shuleikin & L. A. Korneva. (*C. R. Acad. Sci. U.R.S.S.*, 1st March 1956, Vol. 107, No. 1, pp. 59–62. In Russian.) Qualitative results of a calculation of the interaction of electrodynamic and hydrodynamic forces in the ionosphere, at a height where the two forces are of the same order of magnitude, indicate a distribution of wind velocity and direction (fig. 2a) similar to that observed by Hoffmeister (1932 of 1949) and shown in fig. 2b. Fig. 1 shows the variation of the E–W and N–S components and of the resultant of the wind velocity over a 27-day period.

531.510.535 : 621.396.11 **2735**

Oblique Transmission by the Meteoric E-Layer.—Naismith. (See 2871.)

551.576/.578 : 621.396.969.36 **2736**

The Nature and Detectability of Clouds and Precipitation as determined by 1·25-cm Radar.—Plank, Atlas & Paulsen. (See 2749.)

551.59 : 538.566.029.6 : 523.72 **2737**

Measurement of Atmospheric Absorption on 9 350 Mc/s, using Solar R.F. Radiation.—P. André, I. Kazes & J. L. Steinberg. (*C. R. Acad. Sci., Paris*, 23rd April 1956, Vol. 242, No. 17, pp. 2099–2101.) Measurements were made at various times of day, using a radiotelescope described previously [1636 of 1955 (Kazes & Steinberg)]. Only a part of the attenuation observed during sunset can be attributed to absorption by oxygen and water vapour; the remainder, about 35%, is so far unexplained.

551.593 **2738**

The Height of Emission of the 5577 Line of the Air-Glow as observed on the Jungfraujoch.—H. Elsässer & H. Siedentopf. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 222–232. In German.) A mean altitude of 90 ± 10 km is deduced.

551.594.5 : 621.396.11.029.62 **2739**

A Theory of Scattering by Nonisotropic Irregularities with Application to Radar Reflections from the Aurora.—H. G. Booker. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, pp. 204–221.) The existence and aspect sensitivity of auroral v.h.f. echoes can be explained as back scatter from nonisotropic columns of ionization parallel to the earth's magnetic field, of length about 40 m and diameter 1 m, caused by turbulence in an E region having a maximum electron density about 100 times the normal value; but the theory fails to explain the rapid fading rates associated with auroral echoes.

551.594.6 : 621.396.933 **2740**

Low-Frequency Atmospheric Noise Levels in Southern and Central Africa.—D. Hogg. (*Trans. S. Afr. Inst. elect. Engrs*, Dec. 1955, Vol. 46, Part 12, pp. 341–348.) Detailed report of measurements made to determine the interfering effect of atmospherics on radio navigation aids. Results are presented graphically and discussed with reference to local thunder conditions. See also 2305 of 1955.

523.5 : 061.3 **2741**

Meteors. [Book review]—T. R. Kaiser (Ed.). Publishers : Pergamon Press, London and New York, 1955, 204 pp., 55s. (*J. Franklin Inst.*, Feb. 1956, Vol. 261, No. 2, p. 275.) The text is given of the papers presented at the symposium reported previously (1016 of 1955).

LOCATION AND AIDS TO NAVIGATION

534.88-14 **2742**

Underwater Echo-Ranging.—D. G. Tucker. (*J. Brit. Instn Radio Engrs*, May 1956, Vol. 16, No. 5, pp. 243–269.) A review covering basic principles, engineering aspects, and various applications. 66 references.

621.396.93 **2743**

D.F. Plotting Aid.—H. G. Hopkins. (*Wireless Engr*, July 1956, Vol. 33, No. 7, pp. 173–175.) The simple aid described is in the form of a transparent graticule which is placed on the map over the most probable position of the transmitter to facilitate the determination of the area within which the transmitter lies with a given probability.

621.396.93 : 621.396.11.029.55 **2744**

An Automatic Direction Finder for recording Rapid Fluctuations of the Bearing of Short Radio Waves.—H. A. Whale & W. J. Ross. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 311–320.) The signals in two pairs of aerials placed at the corners of a rectangle 10 m × 5 m are combined so that a required 90° phase shift is automatically maintained at all frequencies up to about 17 Mc/s; sense is determined manually. The accuracy of the system is discussed; the effective aperture must be small if it is to follow bearing fluctuations when there is an appreciable spread of the component waves in the incoming signal.

621.396.933 : 551.594.6 **2745**

Low-Frequency Atmospheric Noise Levels in Southern and Central Africa.—Hogg. (See 2740.)

621.396.969.13 **2746**

The Radar Measurement of Low Angles of Elevation.—J. S. Hey & S. J. Parsons. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 321–328.) "The errors which occur in the measurement of low angles of elevation by centimetric radar on a flat ground site are estimated theoretically and compared with experimental measurements. It is demonstrated that a very considerable improvement in angular accuracy is obtained by erecting a screen to intercept the ground-reflected wave. The diffraction effects due to the screen are discussed."

621.396.969.3 **2747**

The Effect of A.G.C. on Radar Tracking Noise.—R. H. Delano & I. Pfeffer. (*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 801–810.) Low-frequency components of the noise arising from the fluctuating properties of the target echo are enhanced by the a.g.c. action. This disadvantage could be avoided by slowing down the a.g.c. response, but such a solution might be unsatisfactory for other reasons, e.g. in the case of a radar system closing rapidly on a target. The solution presented is to place a nonlinear filter in the a.g.c. path, providing a fast response to rising signals and a slow response to decaying signals.

621.396.969.35 **2748**

Multipath Phase Errors in C.W.-F.M. Tracking Systems.—T. E. Sollenberger. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. AP-3, No. 4, pp. 185–192.) Errors in missile-tracking systems due to reflections from the ground and from neighbouring objects are discussed. Use of frequency modulation permits discrimination against the relatively weak interfering signals. The phase error can be reduced indefinitely by increasing the bandwidth used.

621.396.969.36 : 551.576/.578 **2749**

The Nature and Detectability of Clouds and Precipitation as determined by 1·25-cm Radar.—V. G. Plank, D. Atlas & W. H. Paulsen. (*J. Met.*, Aug. 1955, Vol. 12, No. 4, pp. 358–378.) Results are presented of a survey of the frequency of occurrence of various cloud types from their echo characteristics. With most types, temperature is the most important factor affecting detectability; the presence of ice crystals increases detectability. The 1·25-cm radar equipment used would detect only about 15% of clouds of common types at ranges up to 1 mile. The characteristic features of stratiform precipitation are discussed.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.7 : 621.311.6 **2750**

Stabilized Power Supply for an Ionization Gauge for Industrial Use.—R. P. Henry. (*Le Vide*, Jan./Feb. 1956, Vol. 11, No. 61, pp. 28–33.) Neon stabilizers are used for the (positive) grid potential. A triode stabilizing circuit in the filament supply compensates for variations in the grid current of the gauge.

533.5 **2751**

Some Particular Features of the Ionization Method of producing a Very High Vacuum.—N. D. Morgulis. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 9, pp. 1667–1670.) Experiments made to investigate the nature of the method are briefly reported and a number of practical suggestions are offered.

533.56 **2752**

Experimental Study of a Rotary Molecular Pump.—G. Mongodin & F. Prevot. (*Le Vide*, Jan./Feb. 1956, Vol. 11, No. 61, pp. 3–13.)

535.215 **2753**

Spectral Distribution of Photoconductivity.—H. B. DeVore. (*Phys. Rev.*, 1st April 1956, Vol. 102, No. 1, pp. 86–91.) "A theoretical analysis of the shape of photoconductivity spectral distribution curves is presented, based upon the effects of surface and volume recombination of the charge carriers liberated by the light. Representative curves of photoconductivity *vs* absorption are computed and compared with experimental observations. As an application of this analysis, experimental data for antimony sulfide are compared with a theoretical curve, and the difference is found to be resolvable into two bands representing nonphotoconductive transitions."

535.215 : 537.311.33 : 546.289 **2754**

The Energy Distribution of Electrons in the External Photoeffect of Germanium containing Impurities.—A. N. Arsen'eva-Geil'. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 9, pp. 1544–1546.) Experimental V/I characteristics are plotted indicating that photoelectrons are emitted from two energy regions. When the Ge layer is heated to 60°–100°C, an irreversible change in the contact-potential difference between the collector and the emitter takes place, and the number of photo-electrons is considerably increased.

535.215 : 537.311.33 : 546.482.21 **2755**

Comparison of Surface-Excited and Volume-Excited Photoconduction in Cadmium Sulfide Crystals.—R. H. Bube. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1668–1676.) Measurements have been made of the spectral response, the variation of the photocurrent with illumination intensity, the quenching effect of infrared radiation, the decay time of the photocurrent, and the effect of thermal stimulation. The results can be largely explained by assuming that the surface is inherently less sensitive than the interior of the crystals, the surface sensitivity being highly dependent on the surrounding atmosphere.

535.215 : 537.311.33 : 546.482.21 : 537.312.8 **2756**

Change of Photocurrent of CdS Single Crystal in a Magnetic Field.—S. Tanaka, T. Masumi & S. Iijima. (*J. phys. Soc. Japan*, Jan. 1956, Vol. 11, No. 1, pp. 90–91.) Experiments indicate that the photocurrent increases or decreases, depending on the direction of the magnetic field.

535.215 : 546.57 **2757**

Photoemission from Silver into Sodium Chloride, Thallium Chloride and Thallium Bromide.—W. J. Turner. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1653–1660.) Experiments yielding negative results are reported.

535.37 : 546.472.21 **2758**

Investigation of the Origin of Electron Localization Levels in Zinc Sulphide [ZnS-Cu] Phosphors.—N. V. Zhukova. (*Zh. eksp. teor. Phys.*, Nov. 1955, Vol. 29, No. 5(11), pp. 680–692.) Three thermoluminescence intensity maxima were observed; these occured at (*a*) − 120°C, due to excess Zn in the ZnS lattice, at (*b*) − 60°C, and at (*c*) + 20°C, due to Cu luminescence centres. The shape of the curve over different temperature ranges is related to the composition. The quenching effect of Fe, Ni and Co was investigated at temperatures from − 180° to + 60°C. Results are presented graphically.

535.37 : 546.472.21 **2759**

Conductivity Measurements and Spectrographic and X-Ray Investigations on Zinc Sulphide Crystals.—J. Krumbiegel & K. H. Jost. (*Z. Naturf.*, July 1955, Vol. 10a, No. 7, pp. 526–529.) The conductivity measurements indicate that the photosensitivity maximum occurs at a wavelength of 3 520 Å. The spectrographic investigation indicates that crystals with different-coloured luminescence do not necessarily contain different impurities.

535.376 **2760**

Contribution to the Study of Quenching and Sensitizing Effects of Electric Fields.—H. E. Gumlich. (*J. Phys. Radium*, Feb. 1956, Vol. 17, No. 2, pp. 117–121.) The luminescence of ZnS–CdS mixtures activated by Mn and excited by ultraviolet or X rays was investigated experimentally. With ultraviolet excitation an applied field has a quenching effect, with X-ray excitation it produces permanent enhancement of the luminescence. See also 2081 of July (Destriau et al.).

535.376 **2761**

The Temperature Dependence of Brightness Waves in Electroluminescence.—D. Hahn & F. W. Seemann. (*Z. Naturf.*, July 1955, Vol. 10a, No. 7, pp. 586–587.) A number of phosphors have been studied. Oscillograms are reproduced showing the change in the form of the brightness waves of two phosphors at temperatures between − 95° and + 110°C in a 500-c/s field.

535.376 : [546.472.21 + 546.48.47.221 **2762**

Spectral Energy Distribution Curves of ZnS:Ag and ZnCdS:Ag after Thermal Vacuum Treatment.—C. H. Bachman, M. L. Sawner & W. Allen. (*J. electrochem. Soc.*, Feb. 1956, Vol. 103, No. 2, pp. 117–122.) Phosphor screens of thickness comparable to that used in c.r. tubes were maintained at temperatures between 300° and 800°C for 5–30 min in vacuum; measurements were then made of the spectral energy distribution under bombardment by a diffuse 1 000-V electron beam. The heating produces both general reductions and spectral redistributions of emission. The results are discussed in relation to the ion-burn effect in c.r. tubes.

535.376 : 546.472.21 **2763**

Electrophotoluminescence Effects.—F. Matossi & S. Nudelman. (*J. electrochem. Soc.*, Feb. 1956, Vol. 103, No. 2, pp. 122–127.) A study is reported of the frequency and field-strength dependence of the intensity quenching and the intensity ripple occurring on application of an electric field to a phosphor; 28 different ultraviolet-excited ZnS phosphors of cubic and hexagonal structure were investigated.

535.376 : 546.472.21 **2764**

Electroluminescence in Zinc Sulfide.—W. A. Thornton. (*Phys. Rev.*, 1st April 1956, Vol. 102, No. 1, pp. 38–46.) Simple theory based on single-level electron trapping and a field-controlled thermal release process is developed to explain the observed dependence of the electroluminescence waveform and the integrated light output on voltage, frequency and temperature.

537.226/.228 : 546.431.824-31 **2765**

Role of Domain Processes in Polycrystalline Barium Titanate.—M. McQuarrie. (*J. Amer. ceram. Soc.*, 1st Feb. 1956, Vol. 39, No. 2, pp. 54–59.) Discussion of results obtained by various workers indicates that while the high initial dielectric constant of polycrystalline $BaTiO_3$, and possibly also the frequency variation of the initial dielectric constant, can be accounted for without making assumptions regarding domain-wall motion, effects associated with the 'poling' and aging processes can be explained more satisfactorily in terms of movements of both 90° and 180° walls.

537.226/.227 : 546.431.824-31 **2766**

Retarded Polarization Phenomena in $BaTiO_3$ Crystals.—H. H. Wieder. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 413–416.) An investigation was made of the relation between the applied electric field and the resulting polarization of *c*-domain $BaTiO_3$ crystals in the tetragonal crystal phase for field strengths < 1 kV/cm. The results indicate that the processes involved are the same as for greater field strengths. No threshold value of field strength was found for the propagation of antiparallel nuclei.

537.226.31 **2767**

Dielectric Losses in Ionic Dielectrics in Strong Electric Fields.—L. E. Gurevich & V. N. Gribov. (*Zh. eksp. teor. Phys.*, Nov. 1955, Vol. 29, No. 5(11), pp. 629–636.) Dielectrics in which the ions in the crystal lattice exist in two nearly equal energy states are considered theoretically. Polarization, low-frequency and high-frequency losses are calculated.

537.226.31 : 549.514.51 **2768**

Electric Polarizability of Colour Centres in Quartz Crystals and Glasses.—J. Volger & J. M. Stevels. (*Philips Res. Rep.*, Feb. 1956, Vol. 11, No. 1, pp. 79–80.) Relaxation losses induced in clear crystals by irradiation at low temperatures are attributed to orientational polarizability of colour centres generated by impurities, such that transitions occur between equivalent positions of trapped electrons or holes. The effect has not been observed in glasses.

537.226.8 2769

Effects of Pressure on the Complex Dielectric Constant of Liquids.—P. Caillon & E. Groubert. (*C. R. Acad. Sci., Paris*, 9th April 1956, Vol. 242, No. 15, pp. 1855–1856.) Measurements on chlorodiphenyl at a frequency of 127 kc/s indicate that the characteristic variation of dielectric constant with pressure at normal temperature is similar to that with temperature at normal pressure.

537.227/228.1 + 621.372.412 + 621.373.421.13 2770

Papers presented at the 2nd Conference on Piezoelectricity (Moscow, 26th–29th April 1955).—(*Bull. Acad. Sci. U.R.S.S., sér. phys.*, Feb. 1956, Vol. 20, No. 2, pp. 163–272. In Russian.) The following 15 papers are collected in this issue:—

New Ferroelectrics and Antiferroelectrics of the Oxygen-Octahedral Type.—G. A. Smolenski (pp. 163–177).

X-Ray Structural Investigation of Solid Solutions of Ferroelectrics with Perovskite-Type Structure.—Yu. N. Venevtsev & G. S. Zhdanov (pp. 178–184).

Nonlinear Properties of Ferroelectrics.—T. N. Verbitskaya (pp. 185–194).

Stability of the Piezoelectric Effect in Polycrystalline Barium Titanate.—I. P. Kozlobaev (pp. 195–198).

Effect of Pressure on the Dielectric Properties of Ferroelectric Ceramics.—I. A. Izhak (pp. 199–205).

Fusion of Barium Titanate by Conduction Currents.—N. S. Novosil'tsev, O. I. Prokopalo & A. F. Yatsenko (pp. 206–210).

Some Physical Properties of Ferroelectric-Salt Crystals exposed to Radioactive Irradiation.—I. S. Zheludev & V. A. Yurin (pp. 211–214).

Some Physical Properties of Ferroelectric-Salt Crystals.—I. Ya. Eisner (pp. 215–218).

Investigation of New Piezoelectric Crystals.—V. A. Koptsik (pp. 219–225).

Piezoelectric Properties of Wood and Cellulose Materials.—V. A. Bazhenov (pp. 226–230).

Thermal Mechanical Oscillations (Fluctuations) of Piezoelectric Crystals.—K. V. Goncharov & V. A. Krasil'nikov (pp. 231–236).

New Quartz Parameters and Engineering Method of Quartz Oscillator Design.—E. I. Kamenski (pp. 237–250).

Parasitic Oscillations of Piezoelectric Plates with Fundamental Longitudinal Oscillations.—E. G. Bronnikova (pp. 251–260).

Theory of the Compound Piezoelectric Vibrator.—V. A. Solov'ev & I. G. Mikhailov (pp. 261–267).

Piezoelectric Resonators with Crystals having Structural Defects.—M. I. Yaroslavski (pp. 268–272).

537.227 2771

X-Ray and Neutron Diffraction Study of Ferroelectric $PbTiO_3$.—G. Shirane, R. Pepinsky & B. C. Frazer. (*Acta cryst.*, 10th Feb. 1956, Vol. 9, Part 2, pp. 131–140.) Detailed account of work noted previously from shorter paper (2312 of 1955).

537.227 2772

Guanidine Vanadium Sulfate Hexahydrate: a New Ferroelectric Material.—J. P. Remeika & W. J. Merz. (*Phys. Rev.*, 1st April 1956, Vol. 102, No. 1, p. 295.) A brief note on the preparation and properties of this material; the shape of the 60-c/s hysteresis loop is more nearly rectangular than that of the corresponding compound with aluminium in place of the vanadium [2415 of August (Holden et al.)].

537.227 : [546.431.824-31 + 546.824-3] : 548.0 2773

An Explanation of the Structures of Hexagonal Barium Titanate and Titanium Dioxide.—P. Vousden. (*Acta cryst.*, 10th Feb. 1956, Vol. 9, Part 2, pp. 141–142.)

537.227 : 547.476.3 2774

On Ferroelectric Barkhausen Pulses of Rochelle Salt.—R. Abe. (*J. phys. Soc. Japan*, Feb. 1956, Vol. 11, No. 2, pp. 104–111.) Experiments are described in which Barkhausen pulses were observed on applying an electric field to the crystal. The volumes whose polarization reversal corresponds to single pulses are estimated to be of the order of 10^{-9} cm^3. From the field-strength threshold values it is inferred that the pulses occur when a domain wall passes across a hollow in a crystal.

537.311.33 2775

The Voltage/Current Characteristic of the *n-p* Junction for a Weak Signal.—E. I. Rashba. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 9, pp. 1663–1667.) Published literature on the subject is reviewed and inaccuracies in a paper by Shockley (379 of 1950) are pointed out. A statistical system of equations (1) determining the dynamic characteristic of a *p-n* junction is quoted and applied to the case of small alternating voltages, of the order of a few hundred mV, superimposed on a constant reverse bias. Methods are indicated for an approximate solution of these equations for various conditions, and formulae are derived for determining the capacitance of the junction.

537.311.33 2776

Theoretical Study of the Current/Voltage Characteristic of a Semiconductor *p-i-p* Structure, taking Account of Ionization of the Medium due to Carriers.—A. Leblond. (*C. R. Acad. Sci., Paris*, 9th April 1956, Vol. 242, No. 15, pp. 1856–1859.) In the structure considered, the major part of an applied voltage is across the intrinsic middle region, since the adjacent *p* regions have much higher conductivity. Theory is developed affording an explanation of the negative region of the I/V characteristic which has been observed experimentally; this negative characteristic is a consequence of ionization which occurs in the vicinity of the two junctions, where very strong fields develop at high current values.

537.311.33 2777

Diffusion Effects in Drift-Mobility Measurements in Semiconductors.—J. P. McKelvey. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 341–343.) A simple method of measurement, using low-strength steady fields between the emitter and collector, gives results of satisfactory accuracy if an appropriate correction is made for diffusion effects.

537.311.33 : 061.3 2778

Research in Semiconductors: Symposium at Ottawa.—T. H. K. Barron. (*Nature, Lond.*, 5th May 1956, Vol. 177, No. 4514, p. 833.) Brief report of a symposium held in February 1956.

537.311.33 : 535.215 2779

The Photoelectric Properties of some Compounds with Zinc-Blende Structure.—N. A. Goryunova, V. S. Grigor'eva, B. M. Konovalenko & S. M. Ryvkin. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 10, pp. 1675–1682.) Experiments were conducted with compounds of indium and gallium having the same crystal structure as zinc blende. All these materials are semiconductors and sensitive to light. Spectral characteristics are shown, together with tables of experimental data.

537.311.33 : 535.215 : 538.63 2780

Theory of the Photomagnetoelectric [PME] Effect in Semiconductors.—W. van Roosbroeck. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1713–1725.) "Through an ambipolar treatment, the underlying general theory for current carrier transport with magnetic field, which can provide . . . unrestricted results for the Hall, Suhl, and magnetic rectifier effects, is first developed. The PME effect is considered in detail for the infinite slab with strongly absorbed steady radiation on one surface and parallel, steady, uniform magnetic field. Small Hall angles and constant surface recombination velocities and lifetime are assumed. Small-signal theory is given as well as nonlinear theory for arbitrary light intensity. The latter provides methods for determining lifetime that require only negligible dark-surface concentration of added carriers, as well as a method for determining surface recombination velocity; curves for these are given for germanium."

537.311.33 : 541.57 2781

Chemical Bond in Semiconductors.—E. Mooser & W. B. Pearson. (*Phys. Rev.*, 1st March 1956, Vol. 101, No. 5, pp. 1608–1609.) Semiconductivity results from the existence in a solid of essentially covalent bonds, with filled *s* and *p* sub-shells occurring in at least one of any two atoms connected by a bond. This property allows a sharp distinction to be made between semiconductors and metals. A simple rule is given for predicting whether a given compound will be semiconducting from a knowledge of the stoichiometric formula and the valencies of the constituent atoms. The formation of a continuous network of bonds distinguishes semiconductors from molecular crystals.

537.311.33 : 546.23 2782

Conductivity Measurements on Highly Purified Selenium.—F. Eckart. (*Ann. Phys., Lpz.*, 1st Feb. 1956, Vol. 17, Nos. 2/3, pp. 84–93.) A continuation of earlier work (3582 of 1954) is reported. The activation energy, determined in the temperature range 18°–40°C, was 1·2–1·6 eV for a specimen remelted several times in vacuum. After heat treatment in air the activation energy dropped to 0·14–0·19 eV and the conductivity increased by a factor of 10^6.

537.311.33 : 546.26 2783

Thermoelectric Power, Electrical Resistance, and Crystalline Structure of Carbons.—E. E. Loebner. (*Phys. Rev.*, 1st April 1956, Vol. 102, No. 1, pp. 46–57.) Report of measurements on soft and hard carbons; the influence of heat-treatment temperature was investigated.

537.311.33 : 546.26-1 2784

Electrical and Optical Properties of a Semiconducting Diamond.—I. G. Austin & R. Wolfe. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 329–338.) The resistivity, Hall coefficient and infrared absorption spectrum of a type-IIb diamond have been investigated over a wide range of temperatures. The material behaves like a normal *p*-type semiconductor. Photoconductivity was detected at − 155°C over the wavelength range 0·9–3·6 μ. A model energy-band structure is proposed.

537.311.33 : 546.26-1 2785

Electrical Measurements on Type-IIb Diamonds.—H. B. Dyer & P. T. Wedepohl. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 410–412.) The rectification characteristics, resistance linearity, temperature dependence of conductivity and Hall coefficient of type-IIb diamonds have been determined. Conductivity at room temperature is found to be related to the strength of infrared absorption bands.

537.311.33 : 546.26-1 2786

Some Physical Consequences of Elementary Defects in Diamonds.—F. C. Champion. (*Proc. roy. Soc. A*, 6th March 1956, Vol. 234, No. 1199, pp. 541–556.) Using the concept of the defect bond, a qualitative theory is developed of the physical properties of pure diamond, including the electrical properties and the electronic energy levels.

537.311.33 : [546.28 + 546.289 2787

Influence of Holes and Electrons on the Solubility of Lithium in Boron-Doped Silicon.—H. Reiss & C. S. Fuller. (*J. Metals, N.Y.*, Feb. 1956, Vol. 8, No. 2, pp. 276–282.) Fuller details are given of work reported previously (2011 of 1955). Experimental results support the theoretical prediction that increase of acceptor (boron) content leads to increased solubility of donor (lithium) in the boron-doped Si; the expected temperature variation is observed. Qualitative results for Ge indicate that doping with a donor decreases the solubility of another donor.

537.311.33 : 546.28 2788

Spiral Etch Pits in Silicon.—W. Bardsley & B. W. Straughan. (*J. Electronics*, March 1956, Vol. 1, No. 5, pp. 561–562.)

537.311.33 : 546.28 2789

Radiation resulting from Recombination of Holes and Electrons in Silicon.—J. R. Haynes & W. C. Westphal. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1676–1678.) Recombination radiation produced following application of current pulses to Si *p-n* junctions has been investigated using a PbS cell. The results indicate that the radiation at room temperature is a property of the intrinsic material; additional radiation observed at 77°K is associated with the presence of impurities.

537.311.33 : 546.28 2790

Drift and Conductivity Mobility in Silicon.—G. W. Ludwig & R. L. Watters. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1699–1701.) The drift mobility of minority carriers has been measured at temperatures between 120° and 400°K for *p*-type specimens and between 78° and 400°K for *n*-type specimens, using a pulsed-field method. Formulae are derived for the temperature variation of the mobilities; the validity of these formulae is confirmed by the results of conductivity measurements over the same temperature range.

537.311.33 : 546.281.26 2791

Energy-Band Structure of the Carborundum SiC Crystal.—S. Kobayasi. (*J. phys. Soc. Japan*, Feb. 1956, Vol. 11, No. 2, pp. 175–176.) Brief preliminary report of computations.

537.311.33 : 546.289 2792

On the Impurity Conduction in Germanium.—Y. Kanai & R. Nii. (*J. phys. Soc. Japan*, Jan. 1956, Vol. 11, No. 1, pp. 83–84.) The work of Hung & Gliessmann (1696 of 1955) and of Fritzsche & Lark-Horovitz (2018 of 1955) is confirmed by an investigation of Ni-doped Ge, in which impurity-type conduction is shown to occur at higher temperatures than with normal Ge.

537.311.33 : 546.289 2793

Thermally Induced Acceptors in Germanium.—R. A. Logan. (*Phys. Rev.*, 1st March 1956, Vol. 101, No. 5, pp. 1455–1459.) Previous investigations (e.g. 170 of 1954) are extended. Results indicate that acceptor centres formed by rapid quenching from high temperatures are either vacant lattice sites or a chemical impurity with atomic radius smaller than that of Ge. The annealing process depends on both the density of dislocations and the concentration of Cu; no mechanism has yet been proposed capable of explaining the observed characteristics of the annealing process.

537.311.33 : 546.289 2794

The Effect of Heat Treatment on the Lifetime of Minority Current Carriers in Germanium (the Kinetics of the Formation of Defects during Heat Treatment).—T. V. Mashovets & S. M. Ryvkin. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 9, pp. 1530–1543.) If Ge is heated to relatively low temperatures (400°–550°C) the lifetime of the minority carriers is decreased when the temperature and duration of heating are increased. This is explained by the formation of defects which act as recombination centres. From a study of the process of appearance of the defects, data have been obtained on their energy structure. For the temperature range investigated, this process is different from that involved in the formation of thermal defects in Ge at higher temperatures.

537.311.33 : 546.289 : 537.533 2795

Temperature Variations of the Work Function of *n*-Type and *p*-Type Germanium.—A. R. Shul'man & A. N. Pisarevski. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 9, pp. 1547–1555.) Results of an experimental investigation indicate that there is a definite temperature dependence of the work function and of the position of the chemical potential level and that in each case it is different for *n*-type and *p*-type Ge. The experiments are described, and a number of curves are plotted. A theoretical interpretation of the results is given.

537.311.33 : 546.289 : 538.63 2796

The Resistance Variation of Ge Single Crystals in a Magnetic Field at 10°–300°K.—G. Lautz & W. Ruppel. (*Z. Naturf.*, July 1955, Vol. 10a, No. 7, pp. 521–526.) Measurements of the variation of transverse resistance have been made on *p*- and *n*-type specimens in magnetic fields of strengths up to 24 kG. The results are not in agreement with theories based on semiconductor isotropy, such as that of Appel (450 of 1955); measured values are much higher than calculated ones. For a particularly pure *n*-type specimen at 11°K a variation of 1 200% was observed without any indication of saturation. The mechanism giving rise to this variation is not yet understood, but quantization of the electron paths at low temperatures may be the explanation.

537.311.33 : 546.289.05 2797

Electrolytic Stream Etching of Germanium.—M. V. Sullivan & J. H. Eigler. (*J. electrochem. Soc.*, Feb. 1956, Vol. 103, No. 2, pp. 132–134.) The stream of 0·1% KOH solution used for the etching is restricted to a junction area by means of a special jig. The technique and results obtained are described.

537.311.33 : 546.3-1 : 541.5 2798

On the Valence and Atomic Size of Silicon, Germanium, Arsenic, Antimony, and Bismuth in Alloys.—L. Pauling & P. Pauling. (*Acta cryst.*, 10th Feb. 1956, Vol. 9, Part 2, pp. 127–130.)

537.311.33 : 546.461-31 2799

The Mechanism of Growth of Cuprous Oxide Crystals at High Temperature.—A. I. Andrievski & M. T. Mishchenko. (*C. R. Acad. Sci. U.R.S.S.*, 1st March 1956, Vol. 107, No. 1, pp. 81–83. In Russian.) Photographs of Cu_2O surfaces after heating at a temperature of 1 020°C for 90 and 157 hours are presented and discussed.

537.311.33 : 546.471.95 2800

The Semiconductor Properties of $ZnAs_2$.—C. Fritzsche. (*Ann. Phys., Lpz.*, 1st Feb. 1956, Vol. 17, Nos. 2/3, pp. 94–101.) The preparation of $ZnAs_2$ and similar compounds is briefly described and the results of conductivity and rectification measurements are presented graphically. The highest observed forward/reverse current ratio in a $ZnAs_2$ point-contact diode was 3 000 : 1 at 3 V. This ratio depends on the orientation of the crystal, the best results being obtained when the current flow is in the direction of the highest resistance.

537.311.33 : 546.57.241.1 2801

Electrical and Optical Properties of Silver Telluride Ag_2Te.—J. Appel. (*Z. Naturf.*, July 1955, Vol. 10a, No. 7, pp. 530–541.) An extensive experimental investigation of the semiconductor properties of Ag_2Te is reported. A phase transition occurs at 150°C, associated with marked variations of the electrical properties. From the temperature variation of the properties of stoichiometric *n*-type specimens a covalent metallic bond is inferred for the low-temperature (β) phase. Impurities such as Ge, Sn and Sb have a strong effect on carrier concentration and mobility. Temperature variation of the properties in the high-temperature (α) phase indicates that Ag ions as well as electrons participate in the conduction. Discussion of the mobility values in the light of Howarth & Sondheimer's theory (381 of 1954) leads to a value of 0·4 m for the apparent mass of the carriers. A value of 0·67 eV is obtained for the energy gap of the β phase from optical absorption measurements.

537.311.33 : 546.682.86 2802

Elastic Constants of Indium Antimonide.—L. H. DeVaux & F. A. Pizzarello. (*Phys. Rev.*, 1st April 1956, Vol. 102, No. 1, p. 85.) Values of the elastic constants derived from sound-velocity measurements are given.

537.311.33 : 546.682.86 2803

The Conductivity of Indium Antimonide at Low Temperature.—J. Bok. (*C. R. Acad. Sci., Paris*, 23rd April 1956, Vol. 242, No. 17, pp. 2114–2117.) Measurements were made of the electric field strength as a function of current strength at a temperature of 20°K using two specimens with different resistivities. In each case the curve obtained first rises in accordance with Ohm's law, then turns horizontal, and finally rises sharply again. The significance of this characteristic is discussed with reference to theory advanced by Conwell (3328 of 1953) in relation to Ge.

537.311.33 : 546.682.86 2804

Effects at High-Angle Grain Boundaries in Indium Antimonide.—I. M. Mackintosh. (*J. Electronics*, March 1956, Vol. 1, No. 5, pp. 554–558.) Experiments on *n*- and *p*-type filament specimens at room temperature and lower temperatures are reported.

537.311.33 : 546.682.86 2805

Low-Temperature Magnetoresistance Anomalies in Indium Antimonide.—I. M. Mackintosh. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 403–406.) The observation of Fritzsche & Lark-Horovitz (160 of January), that the magnetoresistive ratio of InSb becomes negative below about 8°K, may be explained by changes in the concentration of charge carriers which occur when the impurity levels supplying these carriers are split in a magnetic field, although serious quantitative discrepancies are found on attempting to verify the theory.

537.311.33 : 546.682.86 2806

Population Changes with Magnetic Field.—K. W. H. Stevens. (*Proc. phys. Soc.*, 1st March 1956, Vol. 69, No. 435B, pp. 406–407.) The relative change in the number of conduction electrons on application of a magnetic field is determined by a method alternative to that of Mackintosh (2805 above). The possibility of a reversal in the sign of the magnetoresistance at low temperature is confirmed.

537.311.33 : 546.682.86 : 535.215 **2807**

Recombination Radiation from InSb.—T. S. Moss & T. H. Hawkins. (*Phys. Rev.*, 1st March 1956, Vol. 101, No. 5, pp. 1609–1610.) Radiation produced by the recombination of optically produced excess carriers has been detected in the wavelength region near the absorption edge. From the magnitude of the effect it is deduced that the fraction of total recombinations which are radiative approaches 100%.

537.311.33 : 546.682.86.05 : 669.054 **2808**

Effect of Zone-Refining Variables on the Segregation of Impurities in Indium-Antimonide.—T. C. Harman. (*J. electrochem. Soc.*, Feb. 1956, Vol. 103, No. 2, pp. 128–132.) Zinc and tellurium can be removed from the indium used in the preparation of InSb by electrolytic refining and zone-refining, respectively. The compound is further purified by zone-refining.

537.311.33 : 548.1 **2809**

Junction Rectification as a Function of Crystal Orientation.—W. Kossel, E. Menzel & G. Naumann. (*Z. Naturf.*, July 1955, Vol. 10a, No. 7, pp. 590–592.) Experiments with junctions of Cu and Cu_2O single crystals are described and discussed. Forward current is greater and reverse current is smaller for an octahedral crystal surface than for a dodecahedral surface, and the forward/reverse current ratio is better for the octahedral surface.

537.311.33 : 669.046.54/.55 **2810**

Zone-Melting Processes for Pure Compounds AB with a Negligible Vapour Pressure.—J. van den Boomgaard. (*Philips Res. Rep.*, Feb. 1956, Vol. 11, No. 1, pp. 27–44.) Expressions are derived for deviations from the stoichiometric composition as a function of position along a rod of a binary semiconductor subjected to zone melting.

537.311.33.07 **2811**

Micromanipulators.—W. L. Bond. (*Bell Lab. Rec.*, March 1956, Vol. 34, No. 3, pp. 90–92.) An illustrated note on two devices for controlling and locating metal contacts on a semiconductor surface in research.

538.22 + 537.311.3 **2812**

Magnetic and Electrical Properties of Manganese Telluride.—E. Uchida, H. Kondoh & N. Fukuoka. (*J. phys. Soc. Japan*, Jan. 1956, Vol. 11, No. 1, pp. 27–32.) The temperature variation of susceptibility may be explained by assuming the presence of two phases corresponding to MnTe and $MnTe_2$, possessing different susceptibilities. The electrical properties show anomalies at the Néel point; at higher temperatures the material behaves as a semiconductor, at lower temperatures as a metal. A change in crystalline structure at about 130°C is indicated.

538.22 **2813**

Magnetic Properties of Nickel Telluride.—E. Uchida & H. Kondoh. (*J. phys. Soc. Japan*, Jan. 1956, Vol. 11, No. 1, pp. 21–27.) $NiTe_x$ is ferromagnetic in the range $0{\cdot}1 \leqslant x \leqslant 0{\cdot}65$. There is a transition at $x = 0{\cdot}33$ from a heterogeneous phase beginning at $x = 0$ to a homogeneous phase. In the range $0{\cdot}7 \leqslant x \leqslant 2{\cdot}0$ the material is paramagnetic, but its behaviour is anomalous at high temperatures.

538.22 **2814**

Condition for Resonance in a Nearly Compensated Ferrimagnetic.—K. F. Niessen. (*Philips Res. Rep.*, Feb. 1956, Vol. 11, No. 1, pp. 57–65.) The resonance condition is calculated for a ferrimagnetic with two sublattices having slightly different properties. The theory is applicable to an antiferromagnetic in whose sublattice a relatively small number of magnetic ions have been replaced by non-magnetic ones.

538.22 **2815**

Domain Walls in Antiferromagnets and the Weak Ferromagnetism of α-Fe_2O_3.—Y. Y. Li. (*Phys. Rev.* 1st March 1956, Vol. 101, No. 5, pp. 1450–1454.)

538.22 : 538.652 **2816**

Magnetostrictive Effects in an Antiferromagnetic Hematite Crystal.—H. M. A. Urquhart & J. E. Goldman. (*Phys. Rev.*, 1st March 1956, Vol. 101, No. 5, pp. 1443–1450.) "Magnetostrictive distortions in an antiferromagnetic natural single crystal of hematite have been studied in the region of the transition near − 25°C, where the antiferromagnetic axis spontaneously shifts its crystallographic direction by 90°. The magnetostriction is shown to be closely related to the parasitic magnetization and is interpreted in terms of the existence of domain walls separating antiferromagnetic domains."

538.221 **2817**

Ferromagnetic Relaxation and Gyromagnetic Anomalies in Metals.—C. Kittel & A. H. Mitchell. (*Phys. Rev.*, 1st March 1956, Vol. 101, No. 5, pp. 1611–1612.) A new mechanism is proposed which may contribute to relaxation in all ferromagnetic metals and which appears to account for both the apparent frequency dependence of the observed g values and the apparent inaccuracy of the theoretical connection between microwave and magnetomechanical studies.

538.221 : 538.569.4 **2818**

Ferromagnetic Resonance Absorption in a Nickel Single Crystal at Low Temperatures.—K. H. Reich. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1647–1648.) Measurements have been made at 9 kMc/s and at 24·3 kMc/s. Values are derived for the spectroscopic splitting factor, the resonance line width and the anisotropy contents and for their variation over a range of low temperatures.

538.221 : 538.632 **2819**

Hall Effect and Magnetic Properties of Armco Iron.—S. Foner. (*Phys. Rev.*, 15th March 1956, Vol. 101, No. 6, pp. 1648–1652.) Experimental results presented previously [3625 of 1953 (Foner & Pugh)] are analysed in detail. Over a wide range of values of the magnetizing field, the Hall effect in armco iron is given by the sum of the ordinary and extraordinary effects, the extraordinary Hall constant being independent of the magnetizing field strength.

538.221 : 548.0 **2820**

Deformations in Perovskites composed of Rare Earths and Trivalent Transition Elements.—F. Bertaut & F. Forrat. (*J. Phys. Radium*, Feb. 1956, Vol. 17, No. 2, pp. 129–131.) A crystallographic study of bodies represented by the general formula A_2O_3, B_2O_3, where A is a rare earth and B one of the transition elements. The subject is important in relation to the magnetic properties of ferrites.

538.221 : 621.318.134 **2821**

Magnetic Properties of Gadolinium Ferrites.—R. Pauthenet. (*C. R. Acad. Sci., Paris*, 9th April 1956, Vol. 242, No. 15, pp. 1859–1862.) Measurements on $Fe_2O_3.Gd_2O_3$ and $5Fe_2O_3.3Gd_2O_3$ are reported and discussed.

538.221 : 621.318.134 **2822**

On the Magnetism of the Ferrites (La, Sr)FeO_x with Perovskite Structure.—H. Watanabe. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A*, Feb. 1956, Vol. 8, No. 1, pp. 14–23.) Thermomagnetic studies are reported; the magnetic properties of this system of solid solutions are strongly dependent on preliminary heat treatment.

538.221 : 621.318.2 **2823**

The Definition and Determination of the Coercive Force of Permanent Magnets taking Account of Irreversible After-Effect.—A. Kussmann & O. Yamada. (*Arch. Elektrotech.*, 3rd Feb. 1956, Vol. 42, No. 4, pp. 237–244.) Calculations and measurements indicate that as a consequence of the irreversible after-effect the static coercive force of ferromagnetic materials varies with time; for alni and alnico permanent magnets the variation may amount to several per cent. A more precise definition of coercive force is required, including reference to the measuring time and an index characterizing the after-effect. The appropriate commutation rate for taking hysteresis curves is discussed.

538.224 : 546.3-1-56 **2824**

The Magnetic Susceptibilities of some Diamagnetic Alloys: the Primary Solid Solutions of Zinc, Gallium, Germanium and Arsenic in Copper.—W. G. Henry & J. L. Rogers. (*Phil. Mag.*, March 1956, Vol. 1, No. 3, pp. 237–252.) A method of alloy preparation is described. Results of measurements, by a modified Gouy method, of the rate of change of diamagnetic susceptibility with concentration of the solid solutions are presented. Conclusions are drawn regarding the states occupied by the electrons.

538.652 : 546.3-1-72-621 **2825**

Dynamic Magnetostrictive Properties of Alfenol.—C. M. Davis & S. F. Ferebee. (*J. acoust. Soc. Amer.*, March 1956, Vol. 28, No. 2, pp. 286–290.) Report of an experimental investigation of a cold-rolled Al-Fe alloy containing between 11% and 16% Al. The electromechanical coupling coefficient is comparable to that of Ni.

549.514.51 **2826**

Dislocations, Relaxations, and Anelasticity of Crystal Quartz.—H. E. Bömmel, W. P. Mason & A. W. Warner. (*Phys. Rev.*, 1st April 1956, Vol. 102, No. 1, pp. 64–71.) Experimental evidence indicates that the Q of quartz crystals varies as an inverse function of frequency between 1 and 100 Mc/s at room temperature; this variation is consistent with the existence of two relaxation processes, with time constants of 10^{-13} and $7{\cdot}7 \times 10^{-10}$ sec respectively; the first of these is probably associated with lattice distortion due to impurities, and the second with dislocation loops. An observed long-term aging effect may be due to closer pinning of dislocations by impurity atoms. A frequency standard of improved time stability might be obtained by maintaining the crystal at the temperature of liquid helium.

621.315.612 **2827**

Fundamental Factors controlling Electrical Resistivity in Vitreous Ternary Lead Silicates.—S. W. Strauss, D. G. Moore, W. N. Harrison & L. E. Richards. (*J. Res. nat. Bur. Stand.*, March 1956, Vol. 56, No. 3, pp. 135–142.) Resistivity measurements were made on a number of vitreous ternary lead silicates of widely varied compositions, as well as on vitreous silica and quartz, over the temperature range 200°–500°C, with an applied direct field of 525 V/cm. The results are presented as log-resistivity/composition curves for specimens containing alkali and alkaline-earth ions, and as log-resistivity/temperature curves for specimens containing other ions.

621.315.616 **2828**

Materials used in Radio and Electronic Engineering: Part 4—Plastics.—(*J. Brit. Instn Radio Engrs*, May 1956, Vol. 16, No. 5, pp. 283–294.) A survey including information about the physical properties and commercial availability of numerous plastics, together with British Standards and more than 50 references.

621.315.616 : 621.3.002.2 **2829**

Casting Resins insulate and protect Electronic Components.—H. L. Loucks. (*Mater. & Meth.*, Feb. 1956, Vol. 43, No. 2, pp. 90–94.) Polyester and epoxy resins, foam-type resins such as polyisocyanates and polystyrenes, and elastomeric resins such as polysulphides and silicone rubber compounds are discussed; factors to be considered in choosing the appropriate resin for a particular application are indicated; methods of embedment are outlined.

MATHEMATICS

512.3 **2830**

On Generalized Tchebycheff Polynomials.—J. L. Walsh & M. Zedek. (*Proc. nat. Acad. Sci., Wash.*, Feb. 1956, Vol. 42, No. 2, pp. 99–104.)

517 **2831**

The Method of Comparison Equations in the Solution of Linear Second-Order Differential Equations (Generalized W.K.B. Method).—R. B. Dingle. (*Appl. sci. Res.*, 1956, Vol. B5, No. 5, pp. 345–367.)

519.272 **2832**

A Simple Interpretation of the Complex Correlation Coefficient.—H. J. Linn & K. Pöschl. (*Arch. elekt. Übertragung*, March 1956, Vol. 10, No. 3, pp. 105–106.)

51 : 621.3 **2833**

Mathematische Methoden in der Hochfrequenztechnik. [Book Review]—K. Pöschl. Publishers: Springer, Berlin, 331 pp., D.M. 36. (*Wireless Engr*, June 1956, Vol. 33, No. 6, p. 156.) The first ten chapters develop the mathematics and the last five deal with its application to field problems, cavity resonators, waveguides, aerials, magnetrons, space-charge waves, etc.

MEASUREMENTS AND TEST GEAR

531.711 + 531.761 **2834**

The Standard of Length and the Standard of Time.—A. Perard. (*Nature, Lond.*, 5th May 1956, Vol. 177, No. 4514, pp. 850–851.) Critical comments on the arguments advanced by Clemence (1153 of April).

531.765 : 621.374.3 **2835**

Time-to-Pulse-Height Converter for Measurement of Millimicrosecond Time Intervals.—W. Weber, C. W. Johnstone & L. Cranberg. (*Rev. sci. Instrum.*, March 1956, Vol. 27, No. 3, pp. 166–170.) Details are given of a circuit designed to measure the time between a neutron-detector signal and the next subsequent pulse of a reference series.

538.56 : 535.51.088.2 **2836**

Errors in Measurements of an Elliptically Polarized Electromagnetic Field.—O. M. Barsukov. (*Bull. Acad. Sci. U.R.S.S., sér. géophys.*, Feb. 1956, No. 2, pp. 226–231. In Russian.) The ratio of the principal axes and the orientation of the polarization ellipse relative to a given direction can be calculated, using the set of equations (4), from the measured ratio of the components of field strength in two known directions and the phase difference between them. The effect of an error in the orientation of the pick-up loop is considered theoretically and results of calculations are presented graphically. The graphs should be useful for finding the conditions for minimizing the effect of an error.

621.3.011.4(083.74) **2837**

A New Theorem in Electrostatics and its Application to Calculable Standards of Capacitance.—A. M. Thompson & D. G. Lampard. (*Nature, Lond.*, 12th May 1956, Vol. 177, No. 4515, p. 888.) It is shown that, for the class of cylindrical capacitors whose cross-section has at least one axis of symmetry and is bounded by a closed curve, the capacitance can be calculated from only one length determination. A preliminary study is made of a capacitance standard constituted by the space between four parallel circular cylinders whose cross-sections are arranged in a square.

621.3.018.41(083.74) + 621.396.91 **2838**

Improvements in Standard Frequencies broadcast by Radio Stations WWV and WWVH.—(*Tech. News Bull. nat. Bur. Stand.*, March 1956, Vol. 40, No. 3, pp. 37–38.) The accuracy of standard frequencies and time signals has been increased; a new uniform time, designated UT2, is used for reference.

621.3.018.41(083.74) + 621.396.91] : 529.786 **2839**

MSF Standard Frequencies expressed in Terms of the Caesium Resonance.—L. Essen. (*Wireless Engr*, July 1956, Vol. 33, No. 7, p. 178.) A note explaining a modification of the basis of the reports of standard-frequency transmissions published monthly in *Wireless Engineer*.

621.317.2 : 621.3 **2840**

Testing of Components and Valves at the Laboratoire Central des Industries Électriques.—M. A. Dauphin. (*Onde élect.*, March 1956, Vol. 36, No. 348, pp. 176–185.) An account of equipment used for electrical and life testing and quality control, and of methods used for checking the climatic and mechanical endurance of finishes.

621.317.2 : 621.373.4.029.5/.64 **2841**

The Signal Generator and its Uses in Modern Telecommunications.—J. F. Golding. (*Brit. Commun. Electronics*, Feb. 1956, Vol. 3, No. 2, pp. 75–81.) A general discussion of the signal generator as a piece of receiver test equipment. The principal characteristics of representative British-made apparatus for frequencies up to 4 kMc/s are tabulated.

621.317.3 : 621.314.7 : 546.289 **2842**

Measurements on Alloy-Type Germanium Transistors and their Relation to Theory.—Evans. (See 2903.)

621.317.32 **2843**

Measurement of Electric Field Distributions.—R. Justice & V. H. Rumsey. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. AP-3, No. 4, pp. 177–180.) A method which eliminates the need for a transmission line between observation point and detecting apparatus is based on introducing a thin straight conductor to act as a reflector of the field. Applications mentioned include measurements on slot aerials.

621.317.326 **2844**

Voltage Calibration System for Pulse-Height Measurement.—W. A. Rhinehart & D. J. Zaffarano. (*Nucleonics*, Feb. 1956, Vol. 14, No. 2, pp. 54, 56.) Description of a c.r.o. method of measuring pulse height by comparison of the pulse waveform with a direct voltage, the two displays alternating at mains frequency on a long-persistence screen.

621.317.335.3 + 621.317.411 **2845**

Extension of the 'Thin-Sample Method' for the Measurement of Initial Complex Permeability and Permittivity.—E. E. Conrad, C. S. Porter, N. J. Doctor & P. J. Franklin. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 346–350.) The method described e.g. by Birks (2807 of 1948) is adapted for use with a commercial dielectric-filled slotted line. The frequency range is 5 Mc/s–1 kMc/s. Errors and corrections are discussed.

2846

621.317.335.3 + 621.317.411] : 621.318.134 : 621.372.413

Measurement of Microwave Dielectric Constants and Tensor Permeabilities of Ferrite Spheres.—E. G. Spencer, R. C. LeCraw & F. Reggia. (*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 790–800.) Detailed account of a cavity-perturbation method using circularly polarized waves. Experimental results obtained with a polycrystalline MgMn ferrite are presented. See also 2366 of 1955.

621.317.335.3 : 621.372.413 **2847**

Calculation of the Natural Frequency of a Π-type [single re-entrant] Cavity Partly Filled with an Absorbing Dielectric.—Gatrushev. (See 2657.)

621.317.411 : 621.372.413 **2848**

A Re-entrant Cavity for Measurement of Complex Permeability in the Very-High-Frequency Region.—R. D. Harrington, R. C. Powell & P. H. Haas. (*J. Res. nat. Bur. Stand.*, March 1956, Vol. 56, No. 3, pp. 129–134.) The equipment described is suitable for measurements on toroidal cores at frequencies from 60 to 180 Mc/s. Design problems are discussed, calibration techniques described, and some measurement results presented.

621.317.44 : 621.384.612 **2849**

A Magnetic Differential Probe. Its Employment for the Determination of the Static Median Magnetic Surface in the Gap of a Synchrotron.—G. D. Palazzi. (*Nuovo Cim.*, 1st Feb. 1956, Vol. 3, No. 2, pp. 336–349. In English.) The probe comprises two thin ferromagnetic wires subjected to opposing magnetic fields at a frequency of 1 kc/s. The position of the probe is determined for which the components of the magnetic field along the two wires, parallel to the radius of the synchrotron and lying in a vertical plane, are equal and opposite. The technique used for preparing the wires is explained in some detail.

621.317.725.029.6 : 621.372.56 **2850**

Stable Radiofrequency Voltmeters.—(*Tech. News Bull. nat. Bur. Stand.*, Feb. 1956, Vol. 40, No. 2, pp. 29–30.) The voltmeter described, developed by Selby & Behrent at the N.B.S., comprises a waveguide piston attenuator together with a frequency-insensitive thermoelement and d.c. millivoltmeter. The piston houses the thermoelement and a built-in probe for calibrating one r.f. voltage level. The voltage range is from 0·1 V to several hundred volts, at frequencies up to about 1 kMc/s.

621.317.729 **2851**

Determination of the Intensity of the Electron Current in a Vacuum by the Use of a Rubber Membrane.—V. M. Kel'man & I. F. Krasnov. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 10, pp. 1714–1725.)

The rubber-membrane method of investigating electron trajectories is modified so that, for the case of a cathode operating with space-charge limitation, all parameters of a two-dimensional electron beam in a two-dimensional electric field can be determined if the shapes and potentials of the electrodes are known.

621.317.729 : 621.385.2 **2852**

The Solution of the Problem of a Planar Diode with a Limited-Width Emitting Surface by Use of a Rubber Membrane.—I. F. Krasnov & V. M. Kel'man. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 10, pp. 1726–1734.) A description is given of the apparatus used for determining the density distribution of the current at the cathode of a diode consisting of two long parallel electrodes, with emission only from a narrow middle strip of the cathode. A number of experimental curves are shown.

621.317.729.087.6 : 621.396.62 **2853**

Instruments for Recording and Automatic Analysis of Field-Strength Measurements.—H. J. Griese & E. Haberkant. (*Elektronische Rundschau*, Feb. 1956, Vol. 10, No. 2, pp. 43–46.) Modern technique is reviewed and a null instrument for field-strength measurements is described. It includes a standard signal generator and an automatically operated piston-type attenuator. The field strength is recorded by cutting a continuously moving metal foil, and this record is analysed by a simple scanning device.

621.317.733 : 621.317.33 **2854**

Bridge for Measurement of the Differential Resistance of Nonlinear Elements.—M. Mancianti. (*Alta Frequenza*, Feb. 1956, Vol. 25, No. 1, pp. 15–31.) The variation of the unbalanced bridge voltage as a function of the input voltage is shown on an oscillograph. By observing the disappearance of the derivative of the unbalanced voltage, the relation between the unknown differential resistance and the three known bridge resistances can be established. Results of measurements on a triode valve are presented.

621.317.75.029.42 : 621.396.822 **2855**

Low-Frequency Power Spectrum Analyzer.—T. E. Firle. (*Rev. sci. Instrum.*, March 1956, Vol. 27, No. 3, pp. 140–143.) A system devised for measurements of semiconductor noise in the frequency range 0·000 06–0·02 c/s [3426 of 1955 (Firle & Winston)] involves making a variable-area film recording of the noise, reproducing this at a speed increased up to 500 000-fold, and picking up the signal with a photocell whose output is fed to an a.f. analyser.

621.317.755 **2856**

A Cathode-Ray Oscillograph for the Measurement of Very Short, Aperiodic, Single, High-Voltage Phenomena.—F. Brüninghaus. (*Arch. Elektrotech.*, 3rd Feb. 1956, Vol. 42, No. 4, pp. 245–256.) A comparison of various beam-forming systems indicates that a gun with a thermionic cathode designed on the Steigerwald principle (*Optik, Stuttgart*, 1949, Vol. 5, p. 469) gives the best results in respect of small spot size and beam aperture. The signal deflection is effected by means of a parallel-wire system and the timebase deflection by a pair of plates. A timebase and blanking circuit is described giving a fixed response delay and a linear timebase adjustable between 10^{-7} and 10^{-9} sec with an oscillogram size of 6 × 9 cm.

621.317.794 **2857**

A Simple Theory for Solid-Backed Bolometers.—L. M. Roberts & S. J. Fray. (*J. sci. Instrum.*, March 1956, Vol. 33, No. 3, pp. 115–119.) A theory of the speed of response of solid-backed bolometers is developed and is applied to measurements on Nb_4N_3 superconducting bolometers. Constructional details of the bolometers used in the experimental part of the investigation are given and their characteristics are tabulated.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

621.384.612 **2858**

The Acceleration of Protons to Energies above 10 GeV.—M. L. Oliphant. (*Proc. roy. Soc. A*, 6th March 1956, Vol. 234, No. 1199, pp. 441–456.) Text of Bakerian Lecture. Methods of accelerating protons are reviewed with particular reference to proton synchrotrons. The new 10-GeV, 15-ft-radius proton synchrotron at Canberra will use magnetic fields of up to 80 000 G produced by passing currents of the order of 10^6 A in opposite directions through two suitably arranged field coils. The homopolar generator is also described.

621.384.612 **2859**

The Nonlinear Theory of Betatron Oscillations in the Strong-Focusing Synchrotron: Part 1.—Y. Orlov. (*Nuovo Cim.*, 1st Feb. 1956, Vol. 3, No. 2, pp. 252–259. In English.) Resonances due to errors in the field gradient are examined analytically.

621.384.612 **2860**

An Analysis of Injection Phenomena in the Birmingham Proton Synchrotron.—C. A. Ramm, R. F. Coe & T. B. Vaughan. (*J. sci. Instrum.*, March 1956, Vol. 33, No. 3, pp. 102–106.)

621.385.833 **2861**

Electron-Optical Image of an Atomic Beam.—L. Marton, D. C. Schubert & S. R. Mielczarek. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, p. 419.) The shadow technique (see e.g. 199 of 1950) is used to demonstrate the scattering of an electron beam by an atomic beam projected across its path.

621.385.833 **2862**

The Aperture Error of Magnetic Electron Lenses.—W. Glaser. (*Optik, Stuttgart*, 1956, Vol. 13, No. 1, pp. 7–12.) Discussion indicates that lower limits previously published for the aperture errors of rotationally symmetrical lenses cannot be confirmed.

621.385.833 **2863**

Pulsed T-F [temperature-and-field] **Emission Electron Projection Microscopy.**—W. P. Dyke & J. P. Barbour. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 356–360.)

621.386.8 : 621.397.611.2 : 620.179.1 **2864**

Large-Area Photoconductive X-Ray Pickup-Tube Performance.—J. Jacobs & H. Berger. (*Elect. Engng, N.Y.*, Feb. 1956, Vol. 75, No. 2, pp. 158–161.) Discussion of the general characteristics and the detection sensitivity of a low-velocity-scan vidicon tube and of some of its industrial applications. The advantages and disadvantages of film, direct fluoroscopy, direct-image intensifying tube and scanned-image pick-up tube for observing X-ray images are listed.

621.387.424 **2865**

Double Pulses in Rare-Gas/Halogen Geiger Counters.—D. van Zoonen. (*Appl. sci. Res.*, 1956, Vol. B5, No. 5, pp. 368–386.)

621.396.934 : 55 **2866**

Symposium on the U.S. Earth Satellite Program —Vanguard of Outer Space.—(See 2718.)

642.6 : 681.142 **2867**

Machine Translation of Languages: Fourteen Essays. [Book Review]—W. N. Locke & A. D. Booth (Eds). Publishers: Chapman & Hall, London, 48s. (*Engineering, Lond.*, 10th Feb. 1956, Vol. 181, No. 4698, p. 136.) This book includes papers given at a conference held in 1952 at the Massachusetts Institute of Technology, revised and supplemented, with a bibliography of 40 other papers. Both engineering and linguistic problems are discussed. The central engineering problem is the development of a large, cheap storage unit to hold the stem dictionary, in conjunction with a rudimentary computer.

PROPAGATION OF WAVES

538.566 **2868**

The Frequency Dependence of the Propagation of Electromagnetic Waves in Conducting Media.—J. G. Smit. (*NachrTech.*, Feb. & March 1956, Vol. 6, Nos. 2 & 3, pp. 71–75 & 121–125.) Theory is presented based on Maxwell's equations. Universal curves are prepared from considerations of the critical wavelength in the medium, the phase velocity in the nondispersive frequency range, and the reference frequency for the normalized representation. The reduced curves are constituted, to a first approximation, by two straight lines in a double-logarithmic coordinate system, intersecting at the point corresponding to unity normalized group delay time and unity normalized frequency. Formulae are derived for attenuation, refractive index and delay time for both dispersive and nondispersive ranges. Values of important parameters are tabulated for salt water, fresh water and various types of ground.

621.396.11 **2869**

Amplitude and Phase Pulsations of a Wave propagated in a Slightly Inhomogeneous Atmosphere.—V. I. Tatarski. (*C. R. Acad. Sci. U.R.S.S.*, 11th March 1956, Vol. 107, No. 2, pp. 245–248. In Russian.) The modification of the distant field by an atmosphere in which the scale of the refractive-index inhomogeneities is large compared with the wavelength is considered by a statistical method. The expressions obtained are simpler than those derived earlier by Obukhov (*Bull. Acad. Sci. U.R.S.S.*, 1953, No. 2, pp. 155–165, in Russian). See also 2024 of 1949 (Krasil'nikov).

621.396.11 : 551.510.52 **2870**

Tropospheric Scatter Propagation and a Theoretical Study of the Transmission Loss.—J. A. Fejer. (*Trans. S. Afr. Inst. elect. Engrs*, Dec. 1955, Vol. 46, Part 12, pp. 348–363. Discussion, pp. 364–367.) The internal-reflection theory of u.s.w. propagation beyond the horizon [240 of January (Carroll & Ring)] is critically examined; it is concluded that reflections from a smoothly varying atmosphere are too weak to account for observed field strengths. The transmission loss for propagation beyond the horizon is calculated on the assumption of scattering by turbulent fluctuations, for the case of identical transmitting and receiving aerials. For given values of distance and aerial aperture, there is a minimum value of transmission loss; this value is calculated for both the Booker-Gordon (1757 of 1950) and Villars-Weisskopf (244 of January) theories. Some applications of tropospheric scattering to communications are discussed briefly.

621.396.11 : 551.510.535 **2871**

Oblique Transmission by the Meteoric E-Layer.—R. Naismith. (*Wireless Engr*, July 1956, Vol. 33, No. 7, pp. 159–162.) A report is presented on transmissions effected during the winter of 1951 and the summer of 1952 over distances of 900–1 900 km between England and Norway, on frequencies of 22·7, 25 and 27 Mc/s. The observations indicate that propagation took place by way of the meteoric E-layer (2666 of 1954). The results confirm that this layer may enable long-distance communication to be maintained at frequencies higher than those normally propagated by way of the E and F layers.

621.396.11 : 551.510.535 **2872**

Focusing on a 'Rippled' Ionosphere.—K. Rawer. (*J. atmos. terr. Phys.*, May 1956, Vol. 8, Nos. 4/5, p. 296.) Exact formulae are given for the field strength produced by echoes of orders 1–4, assuming reflection by spherically shaped ripples in the ionosphere.

621.396.11 : 551.510.535 : 523.75 **2873**

Some Unusual Radio Observations made on 23 February 1956.—Belrose, Devenport & Weekes. (See 2717.)

621.396.11.029.55 : 621.396.93 **2874**

An Automatic Direction Finder for recording Rapid Fluctuations of the Bearing of Short Radio Waves.—Whale & Ross. (See 2744.)

621.396.11.029.6 : 535.42 **2875**

A Simple Theory of Diffraction of Radio Waves beyond the Optical Horizon.—H. Poeverlein. (*Z. angew. Phys.*, Feb. 1956, Vol. 8, No. 2, pp. 90–95.) The propagation of waves of wavelength less than about 10 m is treated by repeated application of Huygens' principle. Reflection from the earth's surface is taken into account.

621.396.11.029.6 : 621.396.96 **2876**

Prediction of Oceanic Duct Propagation from Climatological Data.—L. J. Anderson & E. E. Gossard. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. AP-3, No. 4, pp. 163-167.) Procedure is indicated whereby data obtained from routine shipboard observations of sea and air temperature, humidity and wind speed are combined to permit prediction of the coverage of low-sited microwave radar systems. Maps are presented for an area in the N.W. Pacific showing the probability of extended coverage for the radar X bands in July and December.

621.396.11.029.62 : 551.594.5 **2877**

A Theory of Scattering by Nonisotropic Irregularities with Application to Radar Reflections from the Aurora.—Booker. (See 2739.)

621.396.11.029.6 **2878**

UKW-Fernempfangsbeobachtungen, ihre Bedeutung für Meteorologie und Funktechnik. [Book Review]—L. Klinker. Publishers: Akademie-Verlag, Berlin, 1955, 68 pp., D.M. 12.50. (*Frequenz*, Feb. 1956, Vol. 10, No. 2, pp. 60–61.) Theory of u.s.w. radio propagation is presented and observations over 200-km paths with different weather conditions are analysed. Diurnal and annual field-strength variations are discussed. The common occurrence of high field strengths at distances of several hundred kilometres with m-λ transmissions is considered in relation to the planning of broadcasting services.

RECEPTION

621.376.33 : 621.372.5 2879

Response of Nonlinear Circuits to Oscillations modulated in Amplitude and Frequency according to an Arbitrary Law.—E. De Castro. (*Ricerca sci.*, Feb. 1956, Vol. 26, No. 2, pp. 470–481.) Fourier-series analysis is presented relevant to the operation of limiter circuits; idealized characteristics are assumed, with different properties in the positive and negative regions.

621.396.621 : 621.376.3 2880

Crystal-Controlled F.M. Receiver.—D. N. Corfield. (*Wireless World*, July 1956, Vol. 62, No. 7, pp. 312–316.) Circuit and constructional details are given of a fixed-tuned receiver for the three British f.m. broadcast frequencies. Three overtone crystals are used generating the local-oscillator frequencies directly, with manually operated selection switch.

621.396.621 : 621.396.812.3 2881

Improvement of Reception by Diversity Operation.—R. Heidester & E. Henze. (*Arch. elekt. Übertragung*, March 1956, Vol. 10, No. 3, pp. 107–116.) Calculations are made of the time averages of the signal/noise ratio for space-diversity and frequency-diversity systems; a value is derived for the average error figure in frequency-shift telegraphy. The probabilities of the signal/noise ratio exceeding or falling below a given value are determined. A practical diversity circuit is described.

STATIONS AND COMMUNICATION SYSTEMS

621.396 : 621.376.3 2882

Spain and Frequency Modulation.—F. Moyano Reina. (*Rev. española Electrónica*, Feb. & March 1956, Vol. 3, Nos. 15 & 16, pp. 54–57, 79 & 51–53 . . 57.) Frequency allocations and coverage problems are discussed with special reference to Spain, and the advantages, both for peace-time and war-time, of v.h.f. operation with f.m. are indicated. An appropriate development plan has been laid before the Government by the First Congress of Telecommunication Engineers.

621.396.41 : 621.396.822.1 2883

Spectral Density of Cross-Modulation Noise.—R. Codelupi. (*Alta Frequenza*, Feb. 1956, Vol. 25, No. 1, pp. 38–64.) Detailed analysis is presented for a multi-channel transmission system considered as a cascaded series of alternate nonlinear and phase-distorting quadripoles, and assuming that the probability distribution at the input is Gaussian.

SUBSIDIARY APPARATUS

621.314.1 : 621.373.52 : 621.314.7 2884

The Design and Operation of Transistor D.C. Converters.—(*Mullard tech. Commun.*, Feb. 1956, Vol. 2, No. 17, pp. 157–204.) Circuits are discussed in which a junction transistor is made to oscillate and thus to chop the current from a battery; the chopped current is fed to a transformer or ringing choke, and the stepped-up-voltage output is rectified and smoothed. Design procedures are described in detail. See also 573 of February.

621.314.63 : [546.28 + 546.289 2885

Germanium and Silicon Power Rectifiers.—T. H. Kinman, G. A. Carrick, R. G. Hibberd & A. J. Blundell. (*Proc. Instn elect. Engrs*, Part A, April 1956, Vol. 103, No. 8, pp. 89–107. Discussion, pp. 107–111.) The development of *p-n*-junction power rectifiers is reviewed and the special features of a unit rated up to 2 kW are described. For a shortened version, see *J. Instn elect. Engrs*, March 1956, Vol. 2, No. 15, pp. 144–151.

621.314.63 : 546.289 2886

Germanium Power Rectifiers.—M. Sassier. (*Onde élect.*, March 1956, Vol. 36, No. 348, pp. 224–229.) The production and characteristics of Ge junction rectifiers capable of handling current densities of the order of $100\ \mathrm{A/cm^2}$ at an ambient temperature of 60°C are described and compared with those of other rectifiers. Some suitable circuits are indicated.

621.316.722.1 2887

An A.C. Voltage Stabilizer.—F. A. Benson & M. S. Seaman. (*Electronic Engng*, June 1956, Vol. 28, No. 340, pp. 260–265.) A temperature-limited diode placed in one arm of a resistance bridge controls the output voltage through a saturable reactor and autotransformer.

621.352.3 2888

Wafer Cells.—R. W. Hallows. (*Wireless World*, July 1956, Vol. 62, No. 7, pp. 341–343.) The Burgess (U.S.A.) dry battery is described and discharge characteristics are given. The cells are of sandwich construction, hermetically sealed, and the construction affords substantial savings in size and weight as compared with earlier types of dry battery.

TELEVISION AND PHOTOTELEGRAPHY

621.397(083.7) 2889

I.R.E. Standards on Facsimile: Definitions of Terms, 1956.—(*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 776–781.) Standard 56 I.R.E. 9. S1.

621.397.26 : 621.396.65.029.63 2890

The Microwave System between London and Windsor in Canada.—A. D. Hodgson & G. M. B. Wills. (*G.E.C. Telecommun.*, Feb. 1956, No. 21, pp. 4–24.) The television link described provides two one-way reversible channels and includes four repeater stations separated by up to 26·4 miles; the f.m. transmitters operate in the 1·7–2·3-kMc/s band with output power of about 2 W.

621.397.5 : 535.623 2891

Colour Television.—H. Anglès d'Auriac. (*Onde élect.*, Feb. & March 1956, Vol. 36, Nos. 347 & 348, pp. 134–144 & 277–282.) The development and present practice of colour television in the U.S.A. are reviewed, in order to point the way for development of a European service. Differences in economic and technical factors between the two continents are emphasized.

621.397.62 2892

Some Remarks on the Radio-Frequency Phase and Amplitude Characteristics of Television Receivers.—A. van Weel. (*J. Brit. Instn Radio Engrs*, May 1956, Vol. 16, No. 5, pp. 271–280.) "The influence on the picture of the steady state characteristics of the radio frequency part of a television receiver is considered especially for the frequencies close to the carrier frequency (the so-called Nyquist flank). It follows from numerical calculations that the shape of the amplitude characteristics of this Nyquist flank has but little influence on the picture quality. The performance of a receiver will be substantially the same in combination with a double-sideband transmitter as with a vestigial-sideband transmitter, provided the latter has been compensated for its own phase errors. The performance of a vestigial-sideband transmitter should be monitored with a phase-linear receiver, of which the exact shape of the Nyquist flank is not very critical."

621.397.62 : 621.373.43 **2893**

Television Sweep Generation with Resonant Networks and Lines.—K. Schlesinger. (*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 768–775.) Circuits for producing horizontal-deflection current waveforms with economical use of power are discussed. Such waveforms can be obtained by synthesis from a limited number of harmonics of a sinusoidal oscillation. Satisfactory linearity can be obtained using only four harmonics, if their relative amplitudes are slightly adjusted, but to achieve a retrace time not greater than 15% eight harmonics must be used. Various circuits using shock excitation of multiresonators have been tried. The best multiresonator found was a delay line just under $\lambda/2$ long; a construction which minimizes dispersion is described.

621.397.62 : 621.397.8 **2894**

Television Pattern Eliminator.—(*Wireless World*, July 1956, Vol. 62, No. 7, p. 307.) Band-I interference experienced when receiving band III with a band-I set and converter is balanced out by an equal, oppositely phased signal.

621.397.7 **2895**

Südwestfunk Television Studio Technique.—(*Tech. Hausmitt. NordwDtsch. Rdfunks*, 1956, Vol. 8, Nos. 1/2, pp. 1–39.) Eight individual papers are presented, dealing with various aspects of the Baden-Baden television centre; these include the general plan, the program handling equipment, the lighting and back-projection, the transmission chain, and the use of 16-mm film.

621.397.7 **2896**

The New B.B.C. Television Station at the Crystal Palace.—(*J. Telev. Soc.*, Jan.–March 1956, Vol. 8, No. 1, pp. 35–36 . . 40.) A brief description of this station, which took over the service from Alexandra Palace in March 1956. The station transmits on 45 Mc/s (vision) and 41·5 Mc/s (sound) with a vestigial-upper-sideband characteristic.

621.397.8 **2897**

Definition of the Signal/Noise Ratio due to Statistical Fluctuations in Television.—R. Theile & H. Fix. (*Arch. elekt. Übertragung*, March 1956, Vol. 10, No. 3, pp. 98–104.) The amplitude distribution of fluctuations in television signals is discussed; oscillograms obtained with different pickup systems are compared. Experiments to determine the disturbing effect of fluctuations at different brightness levels are reported. A new method is proposed for defining signal/noise ratio based on measurements at three signal levels, corresponding respectively to black, white, and a selected grey.

621.397.8 : 535.623 **2898**

Television Picture Quality.—W. T. Cocking. (*Wireless Engr*, July 1956, Vol. 33, No. 7, pp. 157–158.) A brief discussion of factors affecting vertical and horizontal picture definition, in relation to the decision yet to be made regarding the line standard to be adopted for colour television in Great Britain.

621.397.82 **2899**

Interference with Television Reception: some Causes and Cures.—R. A. Dilworth. (*J. Telev. Soc.*, Jan.–March 1956, Vol. 8, No. 1, pp. 3–15.) Complaints of interference received by the British Post Office in 1954–1955 were attributed to commutator motors, contact devices, power lines, filament lamps, discharge lamps, receiver oscillators, ignition, transmitters, industrial and medical equipment, and faulty electric wiring, in descending order of frequency of occurrence. No serious difficulty is foreseen in suppressing interference generated by motor-driven machines, but other sources still present many practical problems.

TRANSMISSION

621.396.61 : 621.376.22 **2900**

Anode Self-Modulation, a High-Frequency-Engineering Paradox.—F. H. Lange. (*NachrTech.*, Feb. 1956, Vol. 6, No. 2, pp. 58–62.) Anode self-modulation is a term applied to an a.m. process for a transmitter output stage in which a.f. and h.f. control are effected in the grid circuit. The arrangement is equivalent to a reflex type of constant-current anode-voltage modulator using a.f. choke. Features distinguishing the operation of this circuit from the ordinary grid modulator are indicated.

VALVES AND THERMIONICS

621.314.63 : 546.28 **2901**

The Blocking Properties of Alloyed Si-Junction Rectifiers.—A. Herlet & H. Patalong. (*Z. Naturf.*, July 1955, Vol. 10a, No. 7, pp. 584–586.) Rectifiers of this type generally have a *p-s-n* structure [2776 of 1955 (Herlet & Spenke)]. The relation between the breakdown voltage and resistivity has been investigated for specimens with high-resistivity *p*-type middle zones; the relation is not linear. It is deduced that the critical field strength depends markedly on the resistivity.

621.314.7 **2902**

The Determination of Base Thickness in Alloy-Junction Transistors by Etching.—J. Rolfe. (*Brit. J. appl. Phys.*, March 1956, Vol. 7, No. 3, pp. 109, 112.) The geometry of In *p-n* junctions in Ge is investigated by using a short-duration (20 or 30 s) C.P.4 etch [1928 of 1951 (Haynes & Shockley)]. The method is described and photographs of junctions are shown.

621.314.7 : 546.289 : 621.317.3 **2903**

Measurements on Alloy-Type Germanium Transistors and their Relation to Theory.—D. M. Evans. (*J. Electronics*, March 1956, Vol. 1, No. 5, pp. 461–476.) Two methods of determining the current amplification α are described. On the basis of an injection ratio of unity, the frequency dependence of α is compared with the theoretical variation of the base transport factor β obtained from the equations of the one-dimensional minority-carrier-diffusion theory. The comparison confirms the applicability of this theory, and further confirmation is obtained by consideration of the variation of emitter/base impedance with emitter current. The results are applied to show that the mobility of holes in *n*-type Ge varies as $T^{-2\cdot3}$ and that the effective diffusion constant is doubled in going from small to large emitter currents. Three methods for estimating the effective base thickness are described.

621.314.7.012.8 **2904**

Transistor Equivalent Circuits.—J. Gaschi. (*Onde élect.*, March 1956, Vol. 36, No. 348, pp. 268–276.) Equivalent circuits representing the behaviour of fused-junction *p-n-p* transistors at high frequencies are discussed based on the solution of the diffusion equation; eight elements are involved. Practical formulae for the principal parameters are derived.

621.383.2 **2905**

The Time Lag and other Undesirable Phenomena observed in Vacuum Photo-tubes at Weak Illumination: Part 1.—M. Sugawara. (*J. phys. Soc. Japan*, Feb. 1956, Vol. 11, No. 2, pp. 169–175.) Experiments have been made to determine the causes of nonlinearity and time-varying response in photoemissive cells. Abnormal effects are mainly due to photoemissive materials such as Cs adhering to parts of the cell wall in poor contact with the photocathode.

621.385 **2906**

Origin and Analysis of Gas in Electron Tubes.—S. J. Stoll. (*Brit. J. appl. Phys.*, March 1956, Vol. 7, No. 3, pp. 94–96.) The gas liberated during electron bombardment of the anode is mainly CO which is probably produced by a reaction between the CO_2 and the Ba absorbed during cathode conversion. By keeping the anode at 600°C or higher temperatures during cathode conversion and removing the CO_2 by pumping, valves have been made which were relatively free of gas and required no aging.

621.385 **2907**

Axially Symmetrical Electron Beams of Given Shape.—V. T. Ovcharov. (*C. R. Acad. Sci. U.R.S.S.*, 1st March 1956, Vol. 107, No. 1, pp. 47–50. In Russian.) Equations are derived for the field required to produce a beam of given shape. Space-charge effects are taken into account.

621.385.012 **2908**

An Analysis of Grid Current.—W. Knappe. (*Frequenz*, Feb. 1956, Vol. 10, No. 2, pp. 44–50.) The d.c. and first three harmonic components of grid current are calculated as functions of the fraction of the cycle during which grid current flows. The overall r.m.s. value and the separate r.m.s. values for even and odd harmonics are also determined for various V_g/I_g characteristics. Results are shown graphically.

621.385.029.6 **2909**

Space-Charge Effects in Dense, Velocity-Modulated Electron Beams.—M. Weinstein & H. M. Von Foerster. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 344–346.) The motion of electrons in the drift space of a klystron is examined; the de-bunching effect is analysed using a coordinate system moving at a speed equal to the initial speed of the electrons, space-periodic rather than time-periodic distributions being considered. A discrete spectrum of beam oscillations is deduced, with the plasma frequency as limiting frequency. The results are supported by observations with a beam analyser [e.g. 2379 of 1955 (Purl & Von Foerster)].

621.385.029.6 **2910**

Calculation of the Performance Chart of Magnetrons.—W. Praxmarer. (*NachrTech.*, March 1956, Vol. 6, No. 3, pp. 97–104.) From consideration of limiting conditions and estimates of mean values, analytical relations are derived between anode voltage, anode current, overall efficiency and power of a magnetron, thus permitting advance calculation of the characteristics. Predictions have been checked by measurements on various types of magnetron at wavelengths between 1·21 and 33·5 cm with pulsed and continuous operation. No large errors result from space charge, but the effect of the load on the efficiency is difficult to predict; the theoretical results are however sufficiently accurate for practical purposes.

621.385.029.6 **2911**

Design Information on Large-Signal Traveling-Wave Amplifiers.—J. E. Rowe. (*Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, pp. 818–819.) Addendum to 1589 of May.

621.385.029.6 : 537.533 **2912**

Excitation of Space-Charge Waves in Drift Tubes.—M. Scotto & P. Parzen. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 375–381.) "An analysis has been made of the effect of initial conditions on the excitation of electromagnetic waves in a drift tube. The method employs the Laplace transform which directly includes the initial quantities. Field quantities which have been transformed with respect to the longitudinal coordinate are solved for and the results then inverted. Explicit expressions are then obtained for the velocity, charge density, and current density modulations as a series of modes."

621.385.029.6 : 538.566 : 537.56 **2913**

Growing Electric Space-Charge Waves.—Piddington. (See 2702.)

621.385.029.6 : 621.372.8 **2914**

Nonlinear Phenomena in a Waveguide in the Presence of an Electron Beam with Nearly Equal Electron and Wave Velocities.—L. N. Loshakov. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 10, pp. 1768–1787.) By considering a model consisting of a waveguide with a dielectric in which free movement of electrons is postulated, theory based on the method of successive approximations is developed. The theory is used to estimate nonlinear phenomena characterizing the interaction of the beam with the field of the travelling wave for nearly equal velocities of the electrons and waves.

621.385.029.6 : 621.374.4 **2915**

The Frequency-Multiplier Klystron.—V. J. Norris. (*J. Electronics*, March 1956, Vol. 1, No. 5, pp. 477–486.) "The factors controlling design and performance of frequency-multiplier klystrons are examined and the conclusions drawn are checked against the performance of the VX 8175, a tube driven at 937·5 Mc/s and delivering about 100 mW of c.w. power at 9 375 Mc/s. Good agreement between theory and practice is found despite limitations of the former."

621.385.032.213 **2916**

Measurement of the Cathode Temperature in Triodes by the Method of Initial Current.—A. E. Gershberg. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 10, pp. 1703–1713.) Development of a method described e.g. by Ikehara (3405 of 1954).

621.385.032.216 **2917**

Current/Voltage Characteristics of the Oxide-Coated Cathode at Low Activation Energies.—R. E. J. King. (*Research, Lond.*, March 1956, Vol. 9, No. 3, pp. S9–S10.) The I/V characteristics in the temperature range 300°–600° K have been determined by applying a sinusoidal voltage across the coating and a small series resistance, and observing the variation of the voltage across the latter. Assuming the characteristic to be represented by an equation of the form $I = aV + bV^2 + \dots$, the coefficients of the power series can be evaluated from the harmonics in the observed variation. The deviation from linearity decreases with increasing temperature over the range examined. Possible mechanisms giving rise to the observed results are briefly discussed.

621.385.032.216 **2918**

Impregnated Barium Dispenser Cathodes containing Strontium or Calcium Oxide.—I. Brodie & R. O. Jenkins. (*J. appl. Phys.*, April 1956, Vol. 27, No. 4, pp. 417–418.) Tests have been made on cathodes of the type described by Levi (3125 of 1955) modified by addition of CaO or SrO to the barium silicate or barium aluminate impregnant. Emission/temperature characteristics are shown; the additions lead to increased emission in all cases.

621.385.15 **2919**

The Secondary-Emission Valve and its Application.—A. H. Atherton. (*J. Telev. Soc.*, Jan.–March 1956, Vol. 8, No. 1, pp. 23–29.) Consideration is confined to valves with a single stage of multiplication. By comparison with the conventional valve, the secondary-emission valve has the advantage that a high gain-bandwidth product can be obtained more easily in practice, and that an output in phase with the input is obtained from the dynode. Difficulties in achieving stability of characteristics over the lifetime are discussed and two commercially available stable types are briefly described. The required operating voltages and the noise are both high compared with the values for conventional valves. The use of secondary-emission valves merits consideration when designing for bandwidths > 10 Mc/s.

621.385.2 : 621.317.729 **2920**

The Solution of the Problem of a Planar Diode with a Limited-Width Emitting Surface by Use of a Rubber Membrane.—Krasnov & Kel'man. (See 2852.)

621.385.4/.5 **2921**

Non-additivity in Selenium Photocells with Barrier Layers under the Influence of an External Voltage.—Z. A. Gol'dman. (*Zh. tekh. Fiz.*, Sept. 1955, Vol. 25, No. 10, pp. 1689–1695.) If a Se photocell is simultaneously illuminated by light waves of different wavelengths, the resulting photocurrent may greatly exceed the sum of the currents obtained with separate illuminations. Experiments have shown that short-wave illumination removes the barrier layer and the resistance due to it, so that the decrease in the resistance of the Se caused by long-wave illumination results in an amplification of the photocurrent.

621.385.832 **2922**

Deposition and Removal of Electric Charges on Insulators by Secondary Emission: Part 2.—M. Barbier. (*Ann. Radioélect.*, July 1955, Vol. 10, No. 41, pp. 303–323.) Experiments are reported providing the basis for the theory presented previously (2262 of July). Special c.r. tubes were used to facilitate observations of the electron movements with different field distributions. Results indicate that a high-voltage beam should be used for writing and a low-voltage beam for reading, in conjunction with a perfect insulator.

621.385.832 : 681.142 **2923**

Coplanar-Mesh Storage.—G. R. Hoffman. (*Brit. J. appl. Phys.*, March 1956, Vol. 7, No. 3, pp. 102–108.) A storage system is described using a c.r. tube with a target consisting of a sheet of mica on to which a conducting mesh has been evaporated. In this system the writing is controlled by the bright-up pulses alone and transient voltages on the mesh are eliminated.

621.385.832 : 681.142 **2924**

The Hyperbolic-Field Tube, an Electron-Beam Tube for Multiplication in Analogue Computers.—W. Schmidt. (*Z. angew. Phys.*, Feb. 1956, Vol. 8, No. 2, pp. 69–75.) The tube comprises three deflector systems and a pair of target anodes. The first and third deflectors are pairs of X and Y plates, respectively, the second comprises four cross-connected plates with hyperbolic section in the xy plane, oriented with the asymptotes along the axes. The deflection of the electron beam in the y direction in the second deflector is proportional to the x displacement produced by the first deflector. A control voltage depending on the difference between the currents collected by the two target anodes is fed back to the third deflector to produce equal currents in the target anodes; its value is then proportional to the required product of the voltages applied to the first and second deflectors.

621.387 **2925**

Experiments with Gas-Filled Triodes.—J. A. Kok. (*Appl. sci. Res.*, 1956, Vol. B5, No. 6, pp. 445–453.) "In this paper experiments are described showing the different types of electrical discharges in a gas-filled triode. The determining parameters are the following: the cathode emission, the spacing of cathode, grid and anode, the diameter of the meshes of the grid, the potentials of the grid and the anode, the gas pressure and the differential ionization function of the gas. The anode voltage may be concentrated in a space charge sheath. If this space charge sheath is located at the grid, the anode current may be modulated with moderate grid potentials. If not, much larger voltages are required for modulation."

621.387 **2926**

The Hydrogen Thyratron.—D. Charles & R. J. Warnecke. (*Ann. Radioélect.*, July 1955, Vol. 10, No. 41, pp. 256–302.) A detailed study is reported of the pulsed operation of the medium-power thyratron Type-T.G.200. The variations of grid and anode currents and voltages were measured both during the passage of the pulses and during the intervals. An estimate was made of the power required to control the valve with positive grid. The curve showing dissipated power as a function of time is characterized by a peak corresponding to the initiation of ionization. Bombardment of the anode by ions in the period immediately after the pulse must be taken into account in developing new valves. 49 references.

621.387 **2927**

Investigation of a New Continuously Controllable Gas Discharge using a Cold Cathode.—C. H. Hertz. (*Ark. Fys.*, 7th Feb. 1956, Vol. 10, Part 3, pp. 213–245. In German.) An account is given of the design and operation of a corona valve developed as a result of experiments described previously (e.g. 1938 of 1955). A negative point corona serves as cathode, and the anode system comprises an array of fine tungsten wires arranged in parallel grooves cut in a brass plate serving as control grid; the operation depends on the provision of a very strong electric field in the neighbourhood of the anode wires. When such a discharge is operated in hydrogen at a pressure of 150 mm Hg its characteristics resemble those of a vacuum valve, the amplification factor being 50–100. The internal resistance is negative. Use of the valve as an amplifier may be restricted by considerations of noise and frequency range, but it should be useful for stabilization.

MISCELLANEOUS

621.3.002.2 : 68 **2928**

Dip Soldering.—H. G. Manfield. (*Wireless World*, July 1956, Vol. 62, No. 7, pp. 304–306.) A simple method evolved at the British Radar Research Station for use with printed circuits is described.

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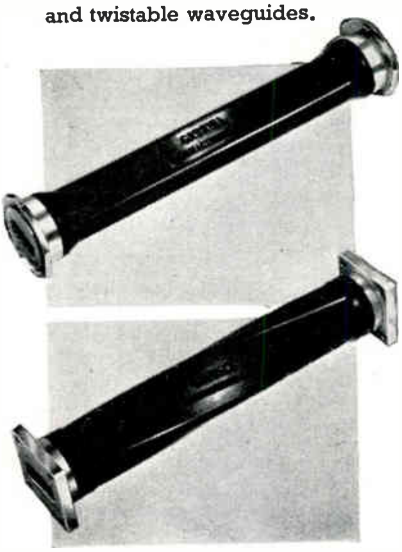

- Two types: Flexible – twistable.
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- Twistable waveguides are designed to take a plus or minus 30 degree twist per foot.
- A standard range of "Waveflex" waveguides is made in lengths from 3" to 36" fitted with standard flanges. We shall be interested to investigate special guides to meet particular requirements.
- "Waveflex" flexible waveguides to match rigid guides in WG. 10, 15 and 16 are in production, the final range will include WG. 11, 18 and 22.
- "Waveflex" flexible waveguides are approved by the Radar Research Establishment of the Ministry of Supply, and by the Admiralty Signals and Radar Establishment. We are fully approved for A.I.D. and A.R.B.

HERE ARE THE TEST DETAILS

A typical specification of WG. 16. V.S.W.R. ·97 minimum per end termination.
Attenuation ·15 DB/ft. maximum.
Band width 8.2 to 10.7 k.m. c/s.

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WAVEFLEX

WAVEGUIDES

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One of the Tecalemit Group of Companies

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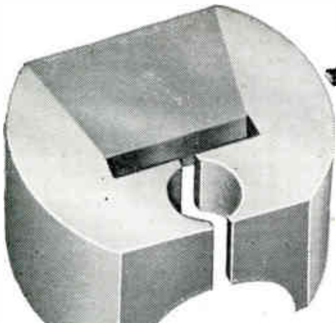

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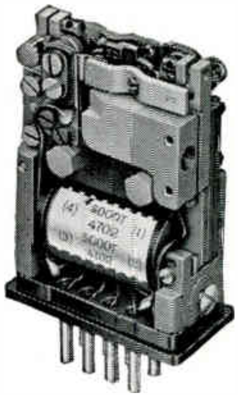
Photograph by courtesy of British Physical Laboratories Ltd.

TYPE 51A

CARPENTER POLARIZED RELAY



For circuits employing a polarized relay where a high order of relay stability is required, e.g., in aircraft control systems, we are now able to offer the *Type* 51A *Carpenter polarized relay.*

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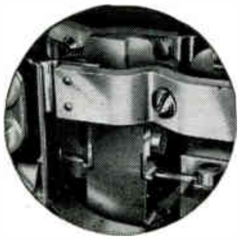

To learn more about this relay send for Leaflet F.3526.

DIMENSIONS *(excluding connecting pins or tags).* **Height: 2¼ in. Width: 1½ in. Depth: ¾ in.**

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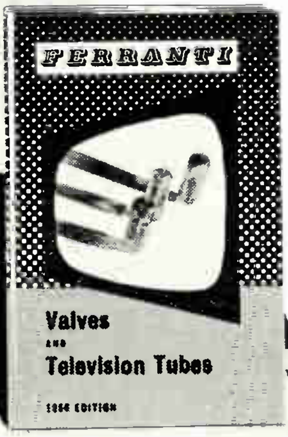
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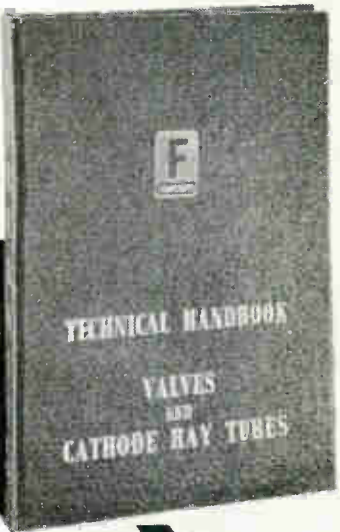
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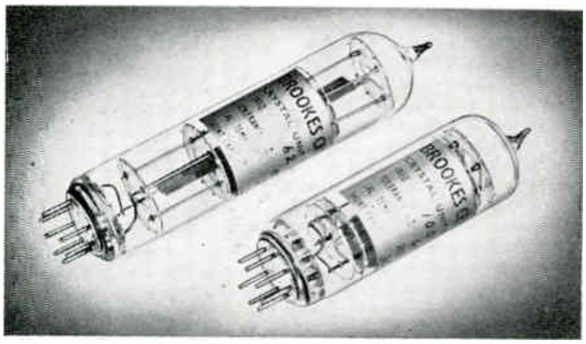

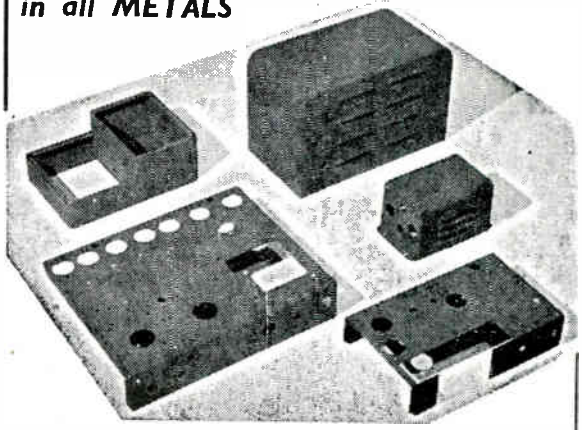

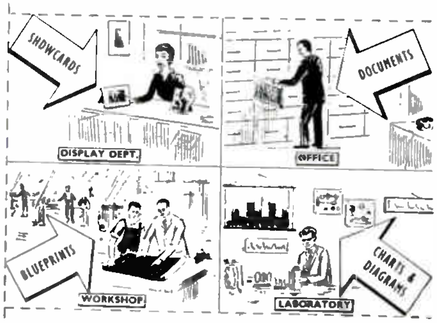
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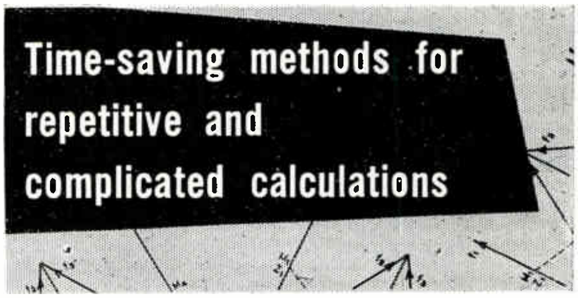

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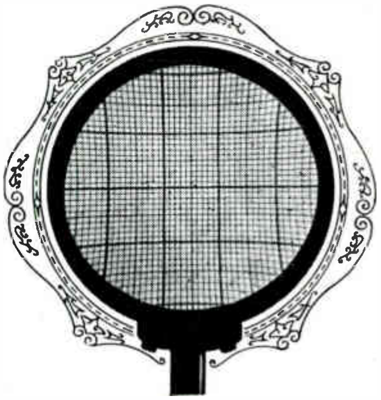

Actual camera shot of graph paper through a spherical magnifier at 2X magnification.

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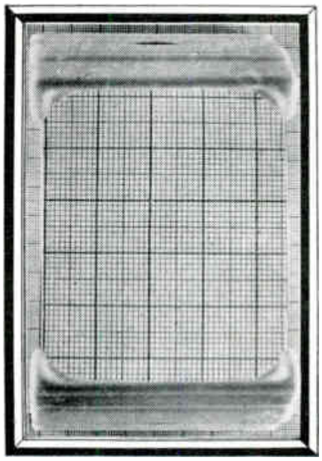

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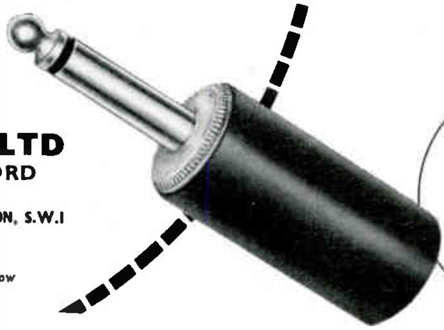

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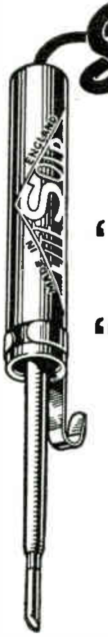

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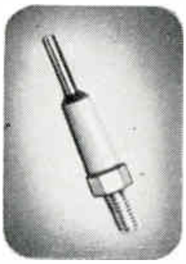

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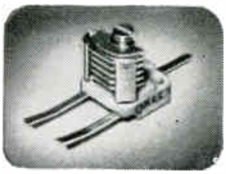

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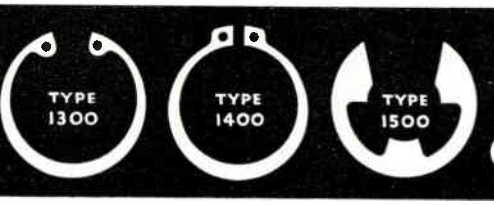

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1906-1956

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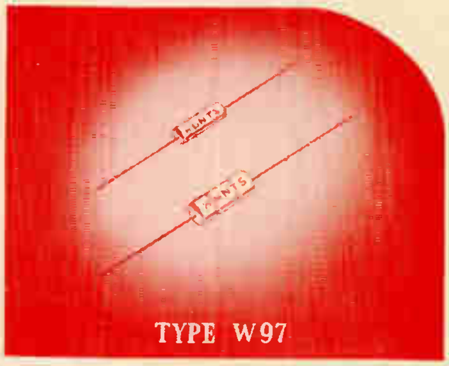

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BM11	0.004	0.500	0.180
BM9	0.005	0.610	0.135
BM12	0.005	0.500	0.180
BM13	0.01	0.500	0.180
BM14	0.02	0.610	0.180
BM15	0.03	0.610	0.260
BM16	0.04	0.610	0.260
	400 volts D.C.	Wkg.	
BM4	0.0004	0.610	0.135
BM5	0.0005	0.610	0.135
BM6	0.001	0.610	0.135
BM18	0.002	0.500	0.180
BM19	0.003	0.500	0.180
BM20	0.005	0.610	0.180
BM21	0.01	0.610	0.260
	600 volts D.C.	Wkg.	
BM25	50 pF.	0.500	0.180
BM1	0.0001	0.610	0.135
BM25	0.0001	0.500	0.180
BM2	0.0002	0.610	0.135
BM27	0.0002	0.500	0.180
BM28	0.00022	0.500	0.180
BM29	0.00025	0.500	0.180
BM3	0.0003	0.610	0.135
BM30	0.0003	0.500	0.180
BM36	0.0004	0.500	0.180
BM31	0.0005	0.500	0.180
BM32	0.001	0.500	0.180
BM33	0.002	0.610	0.260
BM34	0.003	0.610	0.260
BM35	0.004	0.610	0.260

W97 IS A 'MUST'
for the
MAKERS OF ELECTRONIC EQUIPMENT

A. H. Hunt (Capacitors) Ltd, Wandsworth S.W.18 · BAT 1083
And in Canada: HUNT CAPACITORS (Canada) Ltd., AJAX, ONTARIO.

REGISTERED TRADE MARK

HUNTS

CAPACITORS

THE TRADE MARK OF RELIABILITY