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THE JOURNAL OF RADIO RESEARCH & PROGRESS

MARCH 1954

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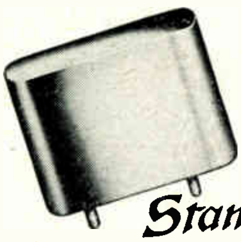

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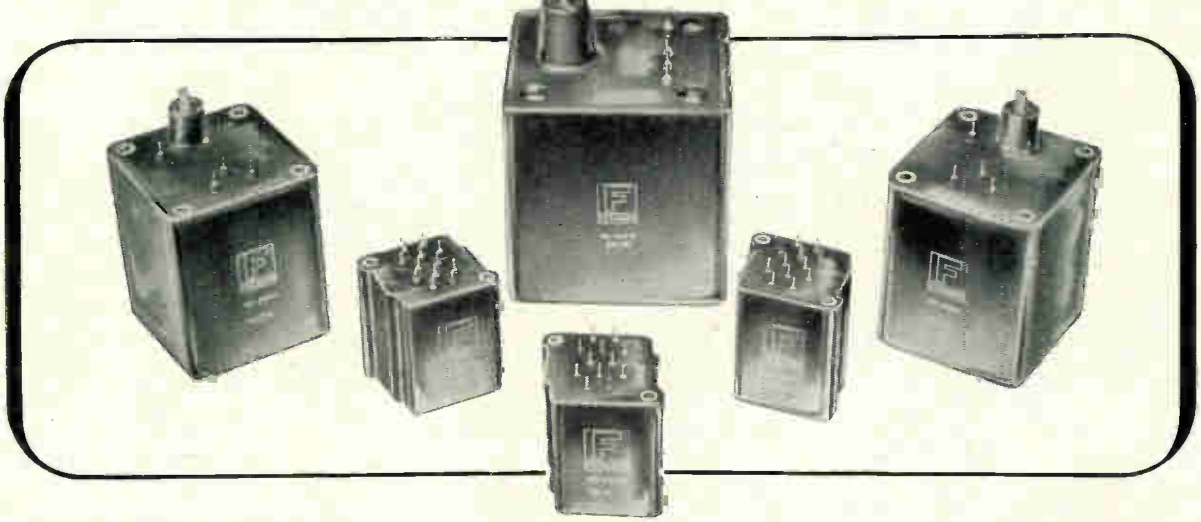

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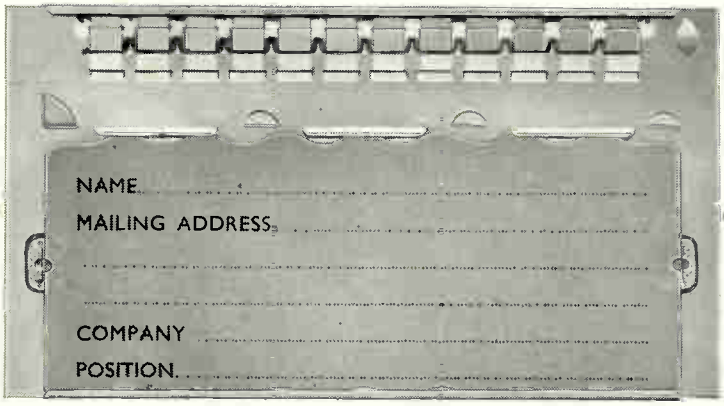

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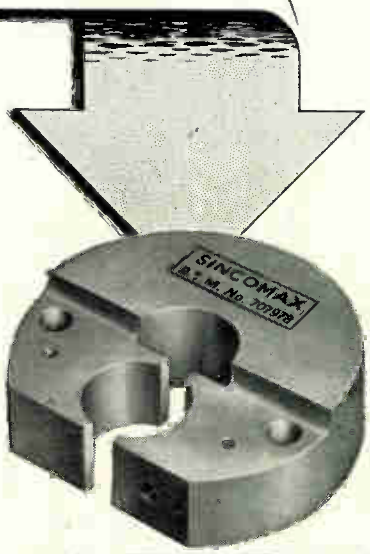

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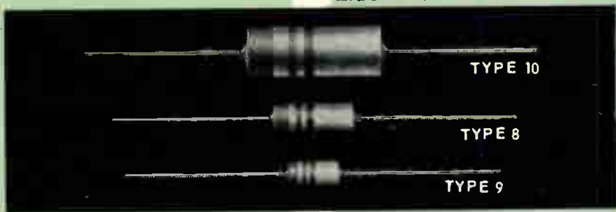

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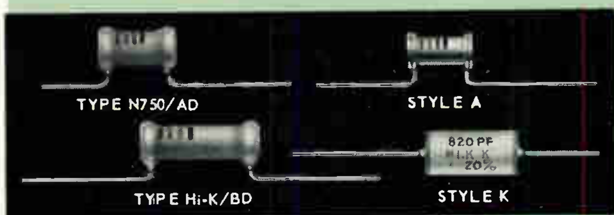

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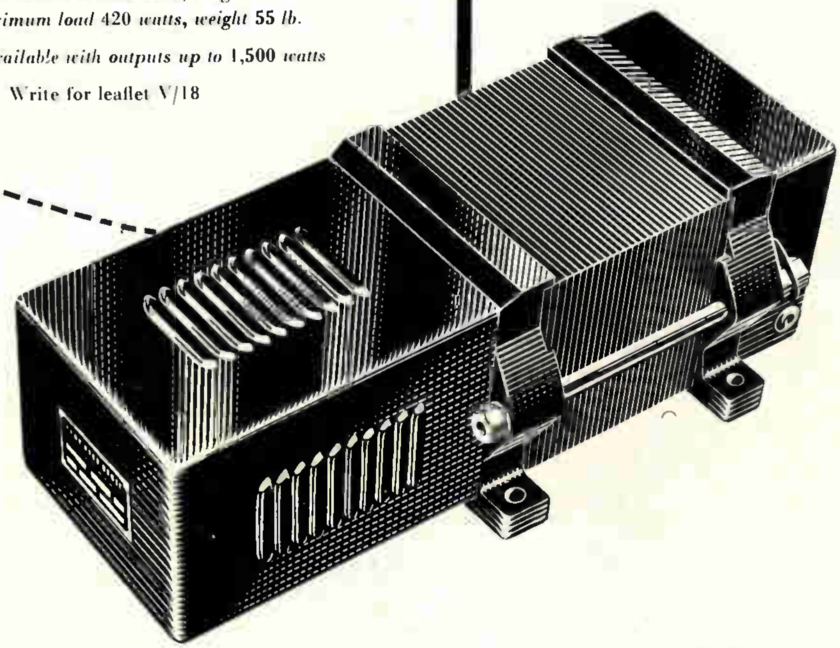

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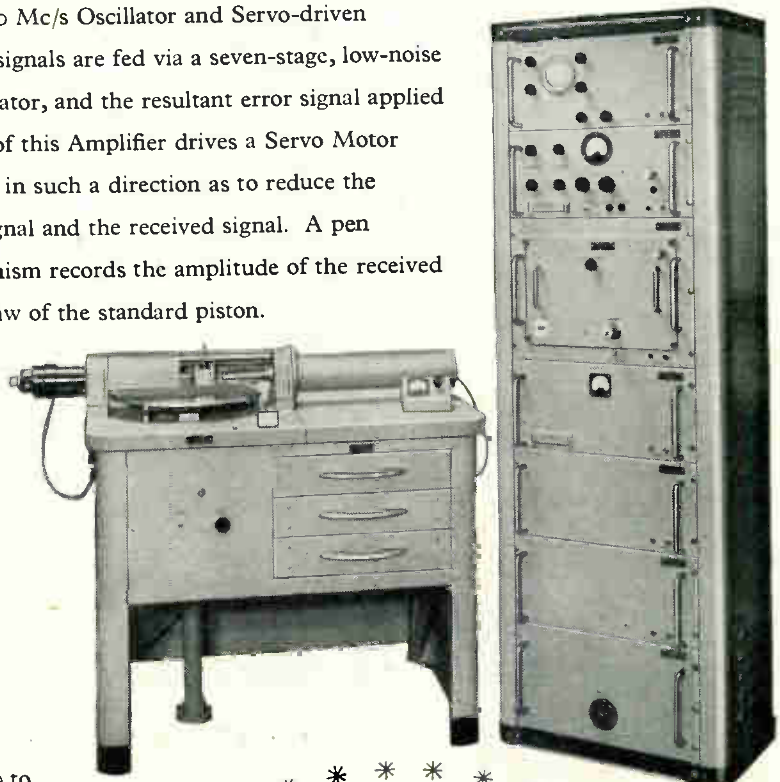

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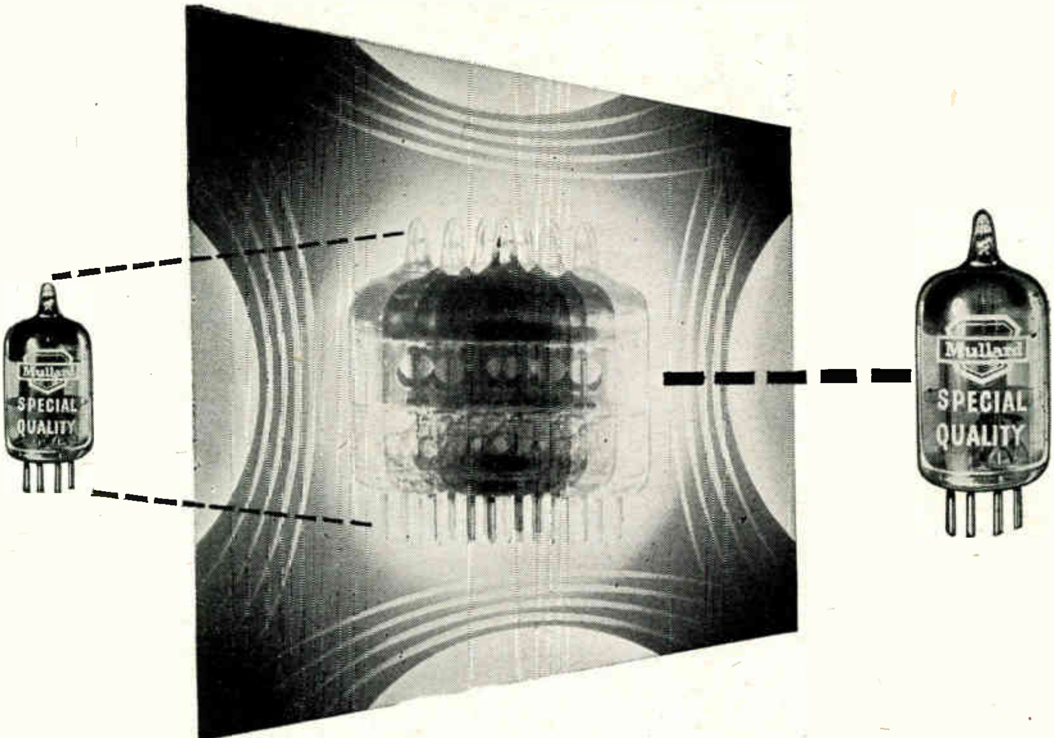

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Edwin H. Armstrong

By his death on 1st February the United States lost one of the outstanding personalities of the wireless world. Edwin Howard Armstrong was born in New York on 18th December 1890. He graduated in Electrical Engineering at Columbia University in 1913 and was awarded an honorary D.Sc. in 1929. He was an assistant in the electrical engineering department for a year after graduation, and then for 21 years collaborated with Michael Pupin in research at the Marcellus Hartley Research Laboratories in Columbia University. From 1934 until his death he was a Professor of Electrical Engineering in the University. During the first world war he spent two years, first as captain and then as major, in the Signal Corps, and in 1919 was made a Chevalier of the Légion d'Honneur.

The name of Armstrong is most closely associated with four inventions, viz. the regenerative circuit, 1912; the superheterodyne system of reception, 1917-18; the superregenerative circuit, 1920; and frequency modulation, 1935. He was a lad of 16 when in 1906 Lee de Forest patented the 3-electrode valve, which became known as the audion, and it was in 1912, while still a student at Columbia, that he was experimenting with an audion when he discovered the presence of h.f. current in the anode circuit, which led to his invention of regeneration and the valve oscillator, and endless patent litigation. In 1914 he published a correct explanation of the action of a triode and disproved some of the currently-accepted ideas; in 1915 he read a paper on regeneration before the Institute of Radio Engineers, and in 1916 another paper on the heterodyne detector. The impact of these papers may be judged from the fact that in the following year the Institute of Radio Engineers awarded him the first Medal of Honour for his work on regeneration and the production of oscillations. Seventeen years later there was a somewhat tragic sequel to this award for, following the adverse decision of the U.S. Supreme Court on the question of priority of invention of these discoveries, he returned the medal to the Institute in 1934. The Board of Directors, however, unanimously declined to accept it and reaffirmed the original award.

Though naturally not entirely unbiased, some light is thrown on this long drawn-out litigation by the autobiography of Lee de Forest, published in 1950. At the same time as Armstrong was experimenting with the audion in New York, Lee de Forest and two assistants were working on somewhat similar lines at Palo Alto in California, and the fight as to who was the prior inventor went on for 20 years.

In the autumn of 1913 de Forest read a paper on "The Audion Amplifier" before the I.R.E. at Columbia University and he says: "My demonstration of the crashing sounds emitted from my loudspeaker when I dropped a handkerchief on the table before the telephone receiver serving as my 'pick-up' aroused great astonishment and applause. On that occasion young Edwin H. Armstrong, wrapped in deepest mystery, had a small carefully-concealed box in an adjoining room into which neither I nor my assistant Logwood was permitted to peek. But when he led two wires to my amplifier input to demonstrate the squeals and whistles and signals he was receiving from some transmitter down the Bay, we thought we had a pretty fair idea of what the young inventor had concealed in his box of mystery. So we proceeded, meekly and obediently, to amplify whatever signals came over the wires from that room".

That is the first mention of Armstrong in de Forest's autobiography, but early in 1914 de Forest demonstrated his ultra-audion oscillator at the Bureau of Standards in Washington, and he says that Professor Pupin, whom he had long known as a kindly friend, loudly demanded "What right have you to have that here? That thing is not yours. That belongs to Armstrong." He says that he was too flabbergasted to reply, but gazed upon his surprising wrath and "continued the siren sounds." He proceeds, "Then I knew for a certainty what it was that Armstrong had had in his little magic box at Columbia. And that outburst by Professor Pupin was the opening gun of the bitterly contested patent battle to be waged for years in the Patent Office interference proceedings; and thereafter for years more until at long last the U.S. Supreme Court should finally decide the historic contest." Later de Forest says: "On January 15, 1920, I read my paper on the Audion and its evolution before the Franklin Institute at Philadelphia. It was well received, except by one E. H. Armstrong, who sought to show that it was he who had invented the feed-back circuit. 'All de Forest invented was the Audion! We'll concede that', he growled. Whereupon the chairman ordered him to sit down."

The feedback patent, which, after nearly 20 years' litigation, was finally awarded to de Forest, expired in 1941. It had been in turn awarded to Armstrong, then Langmuir, then again to Armstrong, and finally to de Forest. One can appreciate the feelings that prompted Armstrong to return the medal to the Institute.

Another of Armstrong's inventions, with much happier associations, is frequency modulation. This occurred to him as the result of some experiments he and Pupin made with the idea of eliminating static interference; experiments which, he says, were unsuccessful, but which laid the foundations of his system of reducing disturbance by using frequency modulation. In an outline of the history of f.m., which he gave before a section of the I.R.E. in 1946, he said that he started looking for a static eliminator back about 1914, and that he worked a little longer than most people did. He then hit upon the idea of frequency-shift keying and from that went on to frequency modulation. It is pleasing to note that towards the end of his autobiography de Forest says: "Major E. H. Armstrong deserves the greatest credit for the development of his system of frequency-modulation—brought out in spite of the skepticism of the profession, and a reluctant Federal Communications Commission. He has given to radio broadcasting a new arm; for this I salute him."

In 1935 the Radio Club of America founded a medal to be known as the Armstrong Medal. In 1941 Armstrong was awarded the Franklin Medal by the Franklin Institute, and in 1943 the Edison Medal by the American I.E.E.; he was also awarded medals by many other institutions.

In 1947 he received a Medal of Merit and a Presidential Citation for his contributions to military radio communications.

In "Radio: Beam and Broadcast", by A. H. Morse, published in 1925, the patent litigation up to that time is discussed very fully: the author concludes by saying that, "Armstrong's work in radio is such that, had he no patented or patentable inventions—and he has many—he would still rank as one of the foremost exponents of the art". This was before the invention of frequency modulation.

Since 1948 he had been working on what he called the multiplexed transmission of frequency-modulated signals, and as recently as last October he and J. S. Bose, also of Columbia University, read a paper on the subject and gave demonstrations before the Radio Club of America. The multiplex system enables two programmes to be broadcast simultaneously within the standard f.m. band of 200 kc/s. Earlier attempts at multiplexing were not very successful because of cross-modulation between the main and the auxiliary channel and of noise transfer from one to the other, but as the result of five years of work they claimed to have overcome the difficulties, and to be able to obtain results on their second or auxiliary channel superior to those obtained by ordinary amplitude-modulated stations.

One can only regret that so much of his life was overshadowed and embittered by such protracted patent litigation, but during the last 18 years he had the great satisfaction of seeing his frequency modulation becoming more and more highly appreciated, and replacing amplitude modulation on an increasing scale. His name will ever be associated with this outstanding achievement.

G. W. O. H.

HIGH-Q COUPLED TUNED CIRCUITS

By Haim D. Polishuk, M.Sc.

SUMMARY.—By means of a set of expressions developed as functions of a frequency ratio, some aspects of inductively-coupled high-Q resonant circuits are analysed. Considerations of finite, very high-Q circuits lead to simple relations determining impedance characteristics of a fundamental system, resonant frequencies, rate of frequency deviation, input conductance, stored energy and power dissipation ratios.

1. Introduction

THE general subject of inductively-coupled resonant circuits has been treated by many writers and explored with exhaustive rigour. However, present advances in practical analysis of electronic systems, and in particular those related to the u.h.f. domain, suggest an attempt at a somewhat different approach to the investigation of the performance of high-Q coupled tuned circuits. These circuits, apart from constituting the basic frequency-selective communication elements, appear now fundamental in the study of the physical characteristics of an increasing number of u.h.f. applications. For example, electron-tube systems designed for frequency modulation, stabilization and control, where coupled resonant cavities are predominantly employed and for which information of an essentially different nature is sought.

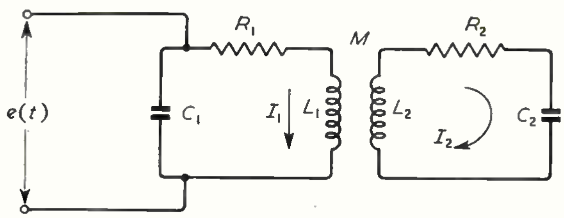

Fig. 1. *Inductively-coupled tuned circuits.*

A fundamental treatment is presented here,* which is also applicable, in many respects, to lower-frequency systems, in which a set of parameters is analytically developed and examined, with the aim of predicting in a general and practical way the steady-state behaviour (excluding mode phenomena) of tightly-coupled high-Q resonant circuits. In expounding the aspects of such circuits a derived group of simple compact expressions is made to determine such information as: effects of tuned-circuit coupling, resultant general resonant frequencies, power dissipation ratio, stored-energy ratio, frequency-deviation rate, resonant conductance characteristics, system effective Q, etc.

MS accepted by the Editor, May 1953

* In a way, an outgrowth of some of the ideas introduced in the works of Sherman, Tellegen, Cuccia and others. See References.

Throughout the following discussion, repetition of elementary or well-known principles has been purposely avoided, except where it is warranted by giving a clearer interpretation of the subject matter.

2. Characteristics of Coupled Impedance

Fig. 1 represents a generalized circuit of an inductively-coupled two-mesh network, excited by a voltage $e(t) = E_0 e^{j\omega_0 t}$, to which a considerable variety of practical systems can be reduced.

Analysis has shown that the series impedance reflected into the primary circuit from the secondary is

$$Z_k = \frac{-(j\omega M)^2}{R_2 + j(\omega L_2 - 1/\omega C_2)} \quad \cdots \quad (1)$$

It should be remembered that this expression of the coupled impedance would not change if, instead of the primary being a tank circuit, a series resonant circuit (C_1 in series with R_1 and L_1) were considered.

The following basic definitions will be used:

$\omega = 2\pi \times$ frequency

$\omega_1 =$ resonant angular frequency of isolated primary circuit $= (L_1C_1)^{-\frac{1}{2}}$

$\omega_2 =$ resonant angular frequency of isolated secondary circuit $= (L_2C_2)^{-\frac{1}{2}}$

$Q_1 = \omega_1 L_1/R_1 = 1/\omega_1 C_1 R_1$

$Q_2 = \omega_2 L_2/R_2 = 1/\omega_2 C_2 R_2$

$k =$ effective coefficient of coupling $= M(L_1L_2)^{-\frac{1}{2}}$.

To express Z_k as a function of a frequency ratio, let

$$t = \omega/\omega_2 \quad \cdots \quad (2)$$

then, substituting in (1),

$$Z_k = \frac{\omega^2 M^2}{R_2\left(1 + jQ_2\dfrac{t^2-1}{t}\right)} \quad \cdots \quad (3)$$

which, after rationalizing and separating, may be put in the form:

$$Z_k = k^2\frac{L_1}{L_2}R_2\left(\frac{t^2}{1-t^2}\right)^2 + jk^2\omega_2 L_1\frac{t^3}{1-t^2} \quad (4)$$

where a major simplification was rendered possible by introducing the practical assumption that Q_2 is of very large magnitude, or that

$$1/Q_2^2 \to 0 \quad \cdots \quad (5)$$

Considering Z_k as given by (4), it follows that the coupled reactance will remain inductive as long as $t^2 < 1$ or, for all values of $\omega < \omega_2$; whereas, when $t^2 > 1$, or for all values of $\omega > \omega_2$, it will appear capacitive. Moreover, it is noted that beyond the close vicinity of the singularity at $t = 1$, Z_k may be regarded as purely reactive. Fig. 2 reveals the general behaviour of the coupled resistance, R_k, and reactance, X_k, for varying values of t. It is further observed that the coupled reactance will display a maximum at $t = \sqrt{3}$ or, $\omega = \sqrt{3}\omega_2$, and will vary asymptotically between $-\infty$ and the line described by $X_k = -(k^2\omega_2 L_1)\, t$. Concurrently, R_k will vary between $+\infty$ and the line $R_k = k^2 R_2 L_1/L_2 =$ constant.

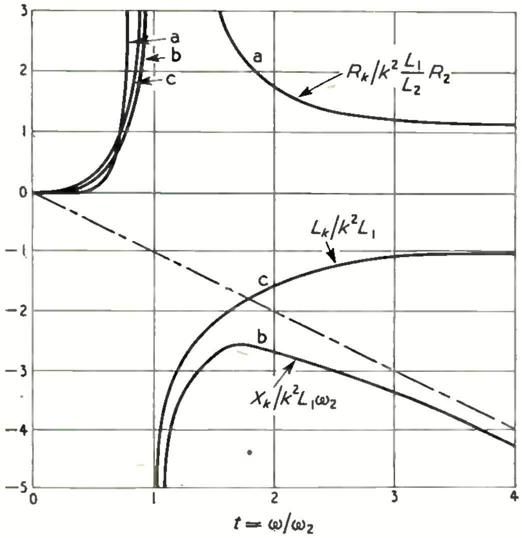

Fig. 2. *General behaviour of coupled resistance, reactance and effective inductance as a function of the ratio* ω/ω_2.

The effective coupled inductance may now be given directly by

$$L_k = \frac{X_k}{\omega} = L_1 k^2 \frac{t^2}{1 - t^2} \quad \ldots \quad \ldots \quad (6)$$

a plot of which, as a function of t, is also shown in Fig. 2.

In order to effect a more convenient change of frequency parameters, let us now consider the particular case where $\omega = \omega_0$, the general system resonant angular frequency, and let

$$s = \frac{\omega_0}{\omega_1} \text{ and } p = \frac{\omega_2}{\omega_1} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

Hence, $t = s/p$ and Z_k, as it is expressed in (4), may be transformed into

$$Z_k = R_1 \cdot \frac{p}{k^2}\frac{Q_1}{Q_2}\left(\frac{s^2 k^2}{s^2 - p^2}\right)^2 - j\omega_0 L_1 \cdot \left(\frac{s^2 k^2}{s^2 - p^2}\right) \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

Putting

$$\beta = \frac{s^2 k^2}{s^2 - p^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

and

$$\alpha = \frac{p}{k^2}\frac{Q_1}{Q_2}\beta^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

it follows that the inductive branch of the primary circuit could be represented by the equivalent series impedance

$$Z_e = R_1(1 + \alpha) + j\omega_0 L_1 (1 - \beta) \quad \ldots \quad (11)$$

It is thus evident that when $\omega = \omega_0$ the effect of coupling a secondary circuit is to increase the resistive component of the primary impedance by a fractional coefficient α and to reduce the primary inductance by a fractional coefficient β.

3. Resonant Frequencies

When the entire system, considered in the region where $kQ_2 \gg 1$, and reduced effectively to an equivalent circuit composed of impedance $1/j\omega C_1$ in parallel with Z_e, exhibits resonance, the general resonant angular frequency will take the form:

$$\omega_0 = 1/\sqrt{L_1(1-\beta)\cdot C_1}$$
$$= \omega_1/\sqrt{1-\beta} \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

or, $\quad s^2 = 1/(1 - \beta) \quad \ldots \quad \ldots \quad (13)$

Although conditions justifying relation (12) are to be referred to later in this discussion, it may also be arrived at by starting with a series-resonant primary circuit, developing (by means of Kirchhoff's loop equations) the expression for the driving-point impedance and applying the general resonant condition when voltage is in phase with primary current. From (9) and (13), eliminating s and solving for β,

$$\beta = \frac{(p^2 - 1) \pm \sqrt{(p^2 - 1)^2 + 4k^2p^2}}{2p^2} \quad \ldots \quad (14)$$

Fig. 3 illustrates the general behaviour of β as a function of p and k, showing variations of both positive and negative roots of β. Considering limiting conditions, it appears that the positive root of β varies asymptotically between $\beta = +1$ and $\beta = k^2$ for all values of k, while the negative root varies between $\beta = 0$ and $\beta = -\infty$, approximating to the hyperbolic relation of $\beta = -p^{-2}$ for small values of p $(1 \gg p^2 > 0)$.

Knowing the value of β, s can be determined readily from (13); furthermore, by substituting (9) in (13), s is expressed directly in terms of p and k, as given by

$$s = \left[\frac{(p^2 + 1) \pm \sqrt{(p^2 - 1)^2 + 4k^2p^2}}{2(1 - k^2)}\right]^{\frac{1}{2}} \quad (15)$$

Evidently, therefore, knowledge of the isolated frequencies $\omega_2/2\pi$ and $\omega_1/2\pi$ (and k) enables one to determine immediately the value of s and, consequently, the two possible values of $\omega_0/2\pi$ ($= s \times \omega_1/2\pi$), the resultant general (upper and lower) resonant frequencies.

The existence of both positive and negative values of β is supported by the reasoning that at frequencies below $\omega_2/2\pi$ and $\omega_1/2\pi$ the total reactance of the primary circuit is effectively capacitive; hence, the coupled reactance is rendered inductive by β appearing as a negative quantity ($s < 1$). At frequencies above $\omega_2/2\pi$ and $\omega_1/2\pi$, however, the total primary reactance is inductive and upon being balanced by the coupled capacitive reactance ($s > 1$ and positive β), the system will display resonance. It should be observed, moreover, that $1 - \beta$ is always a positive quantity. As a direct result from these conclusions, it follows further that ω_0 can never have a real value within the numerical range $\omega_1 - \omega_2$.

If ω_2 and ω_1 differ only by a very small fractional value such that their ratio may be written as

$$p = 1 \pm 2\Delta \quad .. \quad (16)$$

where, in the power series expansion of p, any but the first-power terms of Δ are negligibly small, the expression for s, as given by (15), reduces to

$$s = \frac{1 \pm \Delta}{\sqrt{1 \pm k}} \quad .. \quad .. \quad (17)$$

Equation (15) also suggests that the upper and lower frequencies become farther apart as k increases in magnitude.

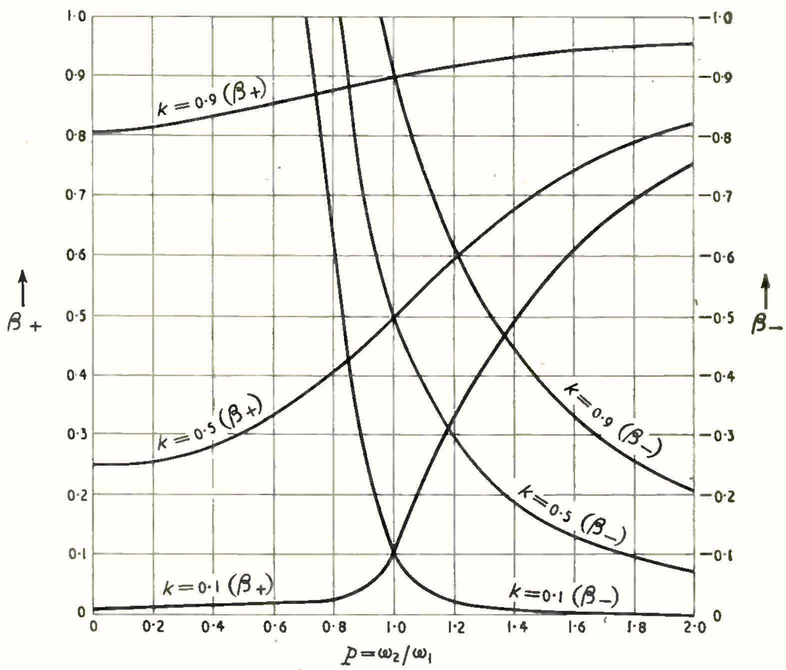

Fig. 3. *Variations of positive and negative values of β as a function of the ratio ω_2/ω_1 for three values of k.*

4. Effects of Resonant Circuit Coupling on Input Conductance

From (11) the total input admittance as seen by the generator will be

$$Y = \frac{1}{R_1(1 + \alpha) + j\omega_0 L_1(1 - \beta)} + j\omega_0 C_1 \quad (18)$$

and provided $\omega_0 L_1 (1 - \beta) \gg R_1 (1 + \alpha)$, or:

$$s\,\frac{1 - \beta}{1 + \alpha} \gg \frac{1}{Q_1} \quad .. \quad .. \quad (19)$$

(18) becomes

$$Y = \frac{R_1(1 + \alpha)}{\omega_0^2 L_1^2 (1 - \beta)^2} + \frac{1}{j\omega_0 L_1 (1 - \beta)} + j\omega_0 C_1$$

$$= \frac{B_1}{Q_1}\left[\frac{1 + \alpha}{s^2(1 - \beta)^2} + j\frac{Q_1}{s}\left[(s^2 - 1) - \frac{\beta}{1 - \beta}\right]\right] \quad .. \quad .. \quad .. \quad (20)$$

where B_1 is the magnitude of either primary susceptance at resonance; hence, setting the input susceptance equal to zero yields equation (13).

Since the input conductance at resonance is

$$G_0 = \frac{B_1}{Q_1} \cdot \frac{1 + \alpha}{1 - \beta} = G_1 \cdot \frac{1 + \alpha}{1 - \beta} = G_1 \phi \quad .. \quad (21)$$

where $G_1 = C_1 R_1/L_1$ is the conductance of the isolated primary circuit at resonance, it may be stated that inductively coupling a secondary circuit to the primary, effectively changes the ratio R_1 and L_1 by a factor ϕ, where

$$\phi = \frac{1 + \alpha}{1 - \beta} = (1 + \alpha)\, s^2 \quad .. \quad .. \quad (22)$$

Furthermore, in view of provision (19), assuming a high-Q circuit, it follows that the resistive, dynamic impedance of a parallel resonant circuit at resonance, $Z_d = L_1/R_1 C_1$, will change by the factor ϕ^{-1} when a secondary tuned circuit is inductively coupled to it; i.e.,

$$Z_d = \frac{L_1}{R_1 C_1} \cdot \left(\frac{1 - \beta}{1 + \alpha}\right) \quad .. \quad .. \quad .. \quad (23)$$

In order to arrive at the often instructive condition under which the conductance G_0 will have the same value at both upper and lower values of ω_0, let components involving the two possible values of s be denoted by the numerical subscripts 1 and 2, then,

$$\phi_1 = \phi_2 \quad \text{or} \quad \frac{1+\alpha_1}{1-\beta_1} = \frac{1+\alpha_2}{1-\beta_2}$$

which leads to the following required condition:

$$p^2 + k^2 \frac{Q_2}{Q_1} p - (1 - k^2) = 0 \quad \ldots \quad \ldots \quad (24)$$

solving for k would indicate immediately that this condition exists only for values of $p < 1$.

Returning to the definition of ϕ as given by (22), let

L_e = equivalent total inductance = $L_1(1 - \beta)$

R_e = equivalent total resistance = $R_1(1 + \alpha)$,

then,

$$\phi = \frac{1+\alpha}{1-\beta} = \frac{R_e/R_1}{L_e/L_1} = \frac{L_1/R_1}{L_e/R_e} = s\frac{Q_1}{Q_0} \quad \ldots \quad (25)$$

where Q_1 = Q of isolated primary and Q_0 = Q of coupled primary at resonance.

In the particular case where $p = 1$, it follows that

$$\beta = \pm k,\ \alpha = Q_1/Q_2,\ s = (1 \pm k)^{-\frac{1}{2}},$$

$$G_0 = \frac{B_1}{Q_1}\phi = B_1\left(\frac{1}{Q_1} + \frac{1}{Q_2}\right)\frac{1}{1 \pm k}$$

$$\text{and} \quad \frac{1}{Q_0} = \frac{\phi}{sQ_1} = \left(\frac{1}{Q_1} + \frac{1}{Q_2}\right)\frac{1}{\sqrt{1 \pm k}}.$$

5. Frequency Deviation Rate

Expression (15) is the solution of the quadratic equation

$$(1 - k^2)s^4 - (1 + p^2)s^2 + p^2 = 0 \quad (26)$$

which enables one to determine a relationship between small variations of ω_2 and their corresponding effect upon ω_0. It may be shown that

$$\frac{\delta\omega_0}{\delta\omega_2} = \frac{ps}{p^2 + k^2/\beta^2} \quad \ldots \quad \ldots \quad \ldots \quad (27)$$

or, in terms of a fractional ratio,

$$\frac{\delta\omega_0/\omega_0}{\delta\omega_2/\omega_2} = \frac{p^2}{p^2 + k^2/\beta^2} \quad \ldots \quad \ldots \quad \ldots \quad (28)$$

6. Power Dissipation Ratio

Let P_1 and P_2 denote, respectively, power dissipated in the primary and secondary circuits, then,

$$\frac{P_1}{P_2} = \frac{R_1}{R_2}\left(\frac{I_1}{I_2}\right)^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (29)$$

Applying Kirchhoff's loop equation and allowing for practical values of Q_1 and Q_2 it follows that

$$\frac{P_1}{P_2} = -\frac{p}{s^2 k^2}\frac{1}{Q_1 Q_2} - j\frac{1}{Q_1}\frac{2}{s\beta} + \frac{k^2 Q_2}{p\,Q_1\,\beta^2}$$

$$\approx \frac{k^2 Q_2}{p\,Q_1}\frac{1}{\beta^2} = \frac{1}{\alpha} \quad \ldots \quad \ldots \quad \ldots \quad (30)$$

Here, if $P_1 = P_2$, α should equal 1; this implies that effective coupled resistance equals primary resistance, which therefore, fulfils the known condition for maximum transfer of power.

7. Stored Energy Ratio

Let W_1 and W_2 represent the energy stored in the primary and secondary circuits, respectively, then,

$$\frac{W_1}{W_2} = \frac{Q_1}{Q_2}\frac{P_1/\omega_1}{P_2/\omega_2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (31)$$

and, by substituting (30),

$$\frac{W_1}{W_2} = \left(\frac{k}{\beta}\right)^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (32)$$

Should $W_1 = W_2$, it follows that p must equal 1, or $\omega_1 = \omega_2$.

Use of (32) may now be made to express the ratio of energy stored in the secondary circuit to the total energy stored in the system; i.e.,

$$\frac{W_2}{W_1 + W_2} = \frac{1}{1 + W_1/W_2} = \frac{1}{1 + (k/\beta)^2} \quad (33)$$

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IRREGULAR TRANSMISSION LINES

Extension of Kennelly's Method of Successive Reflections

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SUMMARY.—The Kennelly method of successive reflections is developed to provide general expressions for the voltage and current in an irregular line. The irregularities may have any magnitude, and the labour of summing the reflections is reduced by considering the waves in groups. The expressions are given in terms of the reflection coefficients of the local deviations of the characteristic impedance from a defined reference impedance, and they are later simplified for the common practical conditions in which the impedance deviations are small, e.g., the coaxial cable used for wideband telephony and television transmission. The latter formulae are given in series form for the case where the impedance distribution consists of abrupt steps, and as integrals where the distribution is continuous. Finally, the effects of line irregularities on the open- and short-circuit impedances are briefly considered.

LIST OF PRINCIPAL SYMBOLS

The M.K.S. system is used

$j = \sqrt{-1}$
f = frequency in cycles per second
$\omega = 2\pi f$
R = resistance of uniform line per metre
L = inductance of uniform line per metre
C = capacitance of uniform line per metre
G = leakance of uniform line per metre
V = potential difference
I = current
E = e.m.f. of generator
P = propagation coefficient
γ = propagation coefficient per metre
α = attenuation coefficient, nepers per metre
β = phase-change coefficient, radians per metre
Z = characteristic impedance
Z_m = mean characteristic impedance
Z_r = reference impedance
l = length of line
x = distance of point X from sending end O
p = reflection coefficient
m = transmission coefficient
q = transmitted echo coefficient
M = number of irregular sections in line
σ = deviation of local characteristic impedance from Z_r
S = deviation of local characteristic impedance Z_m

Subscripts

AB pertaining to line AB
A or B pertaining to end A or B of line AB
X pertaining to point X
G pertaining to generator
T pertaining to termination
r pertaining to reference impedance

1. Introduction

PROFESSOR A. E. Kennelly presented his method of obtaining the voltages and currents in a transmission line by means of successive reflections in 1907;[1] the paper was limited to the smooth line with various terminal conditions, and since then the method has been extensively taught as an attractive adjunct to more formal treatments. The principle has been extended to irregular lines (e.g., by Aguillon[6] and Schelkunoff[8]) who obtained their results in terms of the reflections between successive portions of the line; such expressions, however, are somewhat cumbersome and difficult to interpret in practical cases. Others (e.g., Didlaukis and Kaden,[3] Merz and Pfleger[4]) have used the device of decomposing the reflection at any one point into two components, each relative to the mean characteristic impedance, but they deal only with small irregularities.

In this paper the reflections are considered relative to a common reference impedance, and the general case is first established in which the irregularities may have any magnitude; this requires the clear definition of such terms as 'reference impedance' and 'principal wave'. Subsequent sections deal with the nominally homogeneous line in which the irregularities are relatively small, and the nature of the resulting approximations is made apparent.

The line with small irregularities has been the subject of much investigation owing to its importance for coaxial cables used for the transmission of wideband telephony and television. The attractiveness of the method of successive reflections lies in the simple mathematical processes used, and in the close analogy to the actual occurrence of the echoes.

2. Voltage and Current Distribution in the Uniform Line

Before dealing with the irregular line, it is desirable to consider briefly the properties of the uniform line. If we have an infinitely long line with uniformly distributed 'primary parameters', viz., resistance, inductance, capacitance and leakance, all per unit length, and apply at the near end a sinusoidal voltage of frequency f and r.m.s. value V_0, the steady-state voltage and current at a point x metres from the sending end are given by

$$\left.\begin{aligned} V_x &= V_0 \exp(-\gamma x) \\ I_x &= \frac{V_0}{Z} \exp(-\gamma x) \end{aligned}\right\} \qquad \ldots \quad \ldots \quad (2\cdot1)$$

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MS accepted by the Editor, May 1953.

where

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)} \quad (2\cdot2)$$

$$Z = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \quad .. \quad .. \quad .. \quad (2.3)$$

The same distribution of voltage and current occurs if the line is of finite length and terminated at its far end by an impedance equal to its characteristic impedance, Z.

3. The General Irregular Line

3.1. *The Reference Line*

In the general case, irregularities in a line may occur as variations from point to point in any of the four primary parameters, R, L, G, C; correspondingly, there will be variations along the line in the secondary parameters, characteristic impedance and propagation coefficient; i.e., both Z and γ are variables whose value may be designated as Z_x and γ_x respectively at a point X, distant x metres from the sending end. It is only the variation of the local characteristic impedance Z_x along the line which gives rise to reflection effects, and to evaluate them the real line is compared with a hypothetical 'reference line' which retains the same distribution of local propagation coefficient γ_x, but is reflectionless in that it has a uniform characteristic impedance Z_r throughout its length. The value of the 'reference impedance' is arbitrary: for a nominally homogeneous line it is chosen to be close to the average characteristic impedance of the irregular line (defined later), and sometimes it is made equal to this value. The reference line is terminated by an impedance Z_r, and the internal impedance of the generator also has this value.

If such a terminated reference line is fed at the near end O by a generator of impedance Z_r and e.m.f. E, the voltage and current at X are

$$\left.\begin{aligned} V_x &= \tfrac{1}{2}E \exp(-P_{ox}) \\ I_x &= \tfrac{1}{2}E \exp(-P_{ox})/Z_r \end{aligned}\right\} \quad .. \quad .. \quad (3.1)$$

where

$$P_{ox} = \int_0^x \gamma_x dx \quad .. \quad .. \quad .. \quad .. \quad (3.2)$$

3.2. *Method of Successive Reflections*

Kennelly[1] showed that the steady-state complex waves of voltage and current existing when a sine-wave e.m.f. is being sent into a line can be resolved into a series of simple waves, and that the series can be formulated by considering the transmission of fictitious waves of voltage and current which are assumed to reach their steady-state values without any build-up period.

When a wave travelling along a line reaches a discontinuity in impedance, a part of the wave is reflected back and a new wave passes on. Another way of regarding this phenomenon is to consider that the passage of the wave across the boundary between two lines of different characteristic impedances leaves it unchanged, but a pair of equal subsidiary waves is thereby generated, one of which travels on with the originating wave, while the other is reflected back in the reverse direction.

The method of successive reflections consists of introducing hypothetical sine-wave voltage and current waves (the principal waves) at the sending end and following their courses along the line; at every discontinuity they each generate a pair of subsidiary waves, and every subsidiary wave when it in turn crosses a discontinuity generates a further pair of subsidiary waves, the process being continued ad infinitum. We trace the courses of all these waves, and obtain the steady-state voltage and current at any point by adding the separate values of all the waves at that point. The values concerned are vectors, the modulus being the r.m.s. value of the wave and the angle the phase relative to a convenient datum, e.g., the generator e.m.f.; for brevity we shall refer to the magnitude, it being understood that both modulus and angle are thereby implied. In general the process of tracing the waves and adding their magnitudes is a tedious one, but by dealing with the waves in groups the labour is considerably reduced.

The principal waves of voltage and current in an irregular line are defined as the steady-state waves which would flow in the reference line terminated by the reference impedance, when fed by a sine-wave generator having the given e.m.f. and of internal impedance equal to the reference impedance.

It is convenient to distinguish the various waves in the following manner:—plus and minus signs indicate respectively progression in the direction from source to termination and vice versa; a letter indicates the point at which the wave is generated and a number the order of the wave generated at that point, e.g., $+$O1 designates the principal wave, which is the first generated at the origin, and $+$A2 refers to the second forward-travelling wave generated at A.

3.3. *Reflection and Transmission Coefficients*

If V, I, are the magnitudes of the originating voltage and current waves respectively at the boundary between two semi-infinite lines (Fig. 1), then the magnitudes of the subsidiary voltage and current waves V_s, I_s, are given by

$$\left.\begin{aligned} V_s &= pV \\ I_s &= -pI \end{aligned}\right\} \quad .. \quad .. \quad .. \quad .. \quad (3.3)$$

where

$$p = \frac{Z_2 - Z_1}{Z_2 + Z_1} \quad .. \quad .. \quad .. \quad .. \quad (3.4)$$

Z_2, Z_1, being the respective characteristic impedances of the lines entered and left by the originating wave.

The reflection coefficient of a single discontinuity is defined as the vector ratio of the magnitudes of the reflected and incident waves; similarly, the transmission coefficient is the vector ratio of the magnitudes of the transmitted and incident waves. Referring to Fig. 1, the voltage reflection coefficient is

$$p = \frac{V_S}{V} = \frac{Z_2 - Z_1}{Z_1 + Z_2} \quad \ldots \quad (3.5)$$

The current reflection coefficient is

$$p' = \frac{I_S}{I} = \frac{Z_1 - Z_2}{Z_1 + Z_2} = -p \quad \ldots \quad (3.6)$$

The voltage transmission coefficient is

$$m = \frac{V + V_S}{V} = \frac{2Z_2}{Z_1 + Z_2} = 1 + p \quad \ldots \quad (3.7)$$

The current transmission coefficient is

$$m' = \frac{I + I_S}{I} = \frac{2Z_1}{Z_1 + Z_2} = 1 - p \quad \ldots \quad (3.8)$$

It will be seen that, for a single discontinuity, the voltage and current reflection coefficients are equal and of opposite sign, whereas the voltage and current transmission coefficients are unequal.

The concept may be extended to cover reflection from and transmission through the whole or any portion of a line. In this case, the reflection coefficient p is defined as the vector ratio of the sum of the reflected waves at the near end of the portion to the principal wave at that point; similarly the transmission coefficient m is the vector ratio of the sum of all the transmitted waves both principal and subsidiary at the far end of the portion to the principal wave at that point. The transmitted echo coefficient q, corresponding to the German term 'Mitfluszfaktor' and the French term 'coefficient de traînage', is the vector ratio of the sum of the subsidiary transmitted waves at the far end of the portion to the principal wave at that point; it is thus equal to $m - 1$.

The coefficients will vary according to the impedances of the generator and termination. When the termination and generator have the same impedance, they are said to be matched, and unless the contrary is stated, the coefficients used below refer to matched terminal impedances equal to the reference impedance. Further, the coefficients refer to the voltage waves unless otherwise stated.

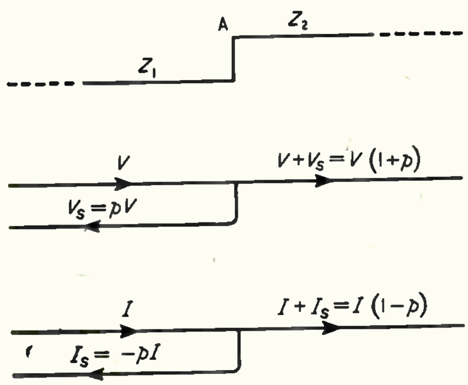

Fig. 1. *Transmitted and reflected waves at a single impedance discontinuity.*

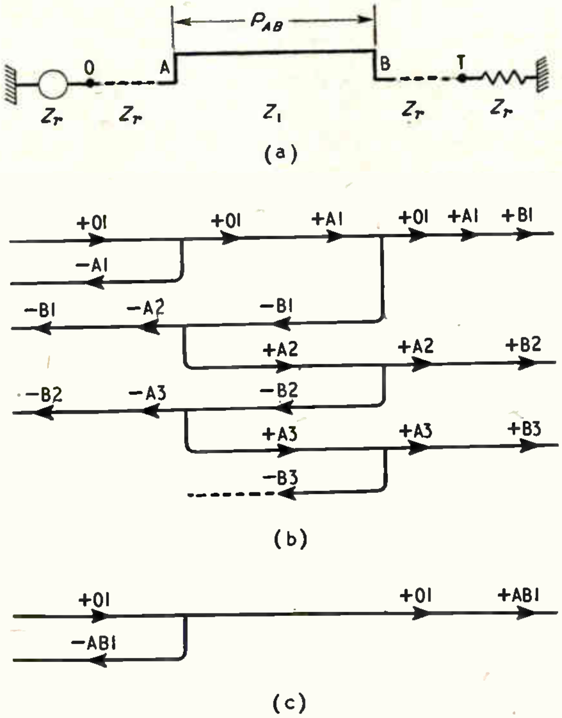

Fig. 2. *Line with one rectangular deviation.*

3.4. *Line with One Rectangular Deviation*

Consider a line of characteristic impedance Z_r, with generator at O and termination at T, both of impedance Z_r [Fig. 2(a)]; inserted in the line between points A and B is a portion of characteristic impedance Z_1 and propagation coefficient P_{AB}, termed a 'rectangular' deviation, from the shape of the diagram. The reflection coefficients relating to the discontinuities at A and B have opposite signs, since, for example, forward-travelling waves at A pass from Z_r to Z_1, whereas at B they pass from Z_1 to Z_r. Forward-travelling waves in portion BT are absorbed at T without reflection, and similarly backward-travelling waves in AO are absorbed at O without reflection.

Considering the voltage along the line [Fig. 2(b)], let the magnitude of the principal wave + 01 at A be V; then its magnitude at B is

$V \exp(-P_{AB})$. At A, two subsidiary waves $\pm$ A1 of magnitude Vp_A are generated, where

$$p_A = \frac{Z_1 - Z_r}{Z_1 + Z_r} \quad \ldots \quad (3.9)$$

Wave $-$ A1 travels back to the source, is absorbed there, and does not generate any further subsidiary waves; $+$ A1 travels forward with the principal wave, making the sum of the two waves at B equal to $V(1 + p_A) \exp(-P_{AB})$.

At B, a pair of subsidiary waves $\pm$ B1 are generated, each of magnitude $-Vp_A(1 + p_A) \exp(-P_{AB})$. The sum of $+$ O1, $+$ A1 and $+$ B1 leaving B towards T is thus

$$V(1 - p^2_A) \exp(-P_{AB}).$$

Let us now trace $-$ B1 travelling from B to A. When it reaches A its magnitude is $-Vp_A(1 + p_A) \exp(-2P_{AB})$; it continues on towards O and in crossing the junction at A, a pair of new waves $\pm$ A2 is generated of magnitude

$$Vp^2_A(1 + p_A) \exp(-2P_{AB}).$$

Of these, $-$ A2 travels on to the source and $+$ A2 goes forward to B. The sum of the waves $-$ A1, $-$ B1, $-$ A2 returning towards O at this stage is

$$Vp_A\{1 - (1 - p^2_A) \exp(-2P_{AB})\}.$$

Wave $+$ A2 travelling forward has a magnitude $Vp^2_A(1 + p_A) \exp(-3P_{AB})$ at B; it goes on towards T, and in crossing the junction at B it generates $\pm$B2 of magnitude $-Vp^3_A(1 + p_A) \exp(-3P_{AB})$, so that the total going forward to T is now $V[(1 - p^2_A) \exp(-P_{AB}) + (p^2_A - p^4_A) \exp(-3P_{AB})]$. Wave $-$ B2 returns to A, and the process of reflection back and forth between A and B is continued ad infinitum. The magnitudes of the principal and subsidiary waves on the source side of junction A and on the termination side of junction B are given in Table 1.

TABLE 1

Waves in Line with One Rectangular Deviation

Wave	Magnitude in OA at A	Magnitude in BT at B
+ O1	V	$V \exp(-P_{AB})$
$-$ A1	Vp_A	—
+ A1	—	$Vp_A \exp(-P_{AB})$
+ B1	—	$-Vp_A(1 + p_A) \exp(-P_{AB})$
$-$ B1	$-Vp_A(1 + p_A) \exp(-2P_{AB})$	—
$-$ A2	$Vp^2_A(1 + p_A) \exp(-2P_{AB})$	—
+ A2	—	$Vp^2_A(1 + p_A) \exp(-3P_{AB})$
+ B2	—	$-Vp^3_A(1 + p_A) \exp(-3P_{AB})$
$-$ B2	$-Vp^3_A(1 + p_A) \exp(-4P_{AB})$	—
$-$ A3	$Vp^4_A(1 + p_A) \exp(-4P_{AB})$	—
+ A3	—	$Vp^4_A(1 + p_A) \exp(-5P_{AB})$
+ B3	—	$-Vp^5_A(1 + p_A) \exp(-5P_{AB})$
$-$ B3	$-Vp^5_A(1 + p_A) \exp(-6P_{AB})$	—
etc.	- - -	- - -

The total voltage at A is

$$V_A = V[1 + \{1 - \exp(-2P_{AB})\}\{p_A + p^3_A \exp(-2P_{AB}) + p^5_A \exp(-4P_{AB}) + - - - \}] \quad \ldots \quad (3.10)$$

$$= \frac{V(1 + p_A)\{1 - p_A \exp(-2P_{AB})\}}{1 - p^2_A \exp(-2P_{AB})} \quad \ldots \quad (3.11)$$

The total voltage at B is

$$V_B = V \exp(-P_{AB}) \{1 - p^2_A + p^2_A \exp(-2P_{AB}) - p^4_A \exp(-2P_{AB}) + p^4_A \exp(-4P_{AB}) - -\} \quad \ldots \quad (3.12)$$

$$= \frac{V(1 - p^2_A) \exp(-P_{AB})}{1 - p^2_A \exp(-2P_{AB})} \quad \ldots \quad (3.13)$$

The voltage at A, as shown by equation (3.10), consists of the principal wave and a series containing only odd powers of p_A. The voltage at B consists of the principal wave and a series of even powers of p_A.

The current in the line is obtained from the voltage equations by reversing the sign of the odd powers of p_A, the sign of the even powers remaining unchanged. If I is the magnitude of the principal current wave at A, the current at A, I_A, is given by

$$I_A = \frac{I(1 - p_A)\{1 + p_A \exp(-2P_{AB})\}}{1 - p^2_A \exp(-2P_{AB})} \quad (3.14)$$

The current at B is

$$I_B = \frac{I(1 - p^2_A) \exp(-P_{AB})}{1 - p^2_A \exp(-2P_{AB})} \quad \ldots \quad (3.15)$$

The impedance at A looking towards B is from (3.11) and (3.14)

$$Z_{AB} = \frac{Z_r(1 + p_A)\{1 - p_A \exp(-2P_{AB})\}}{(1 - p_A)\{1 + p_A \exp(-2P_{AB})\}} \quad \ldots \quad (3.16a)$$

$$= Z_1 \frac{1 - p_A \exp(-2P_{AB})}{1 + p_A \exp(-2P_{AB})} \quad \ldots \quad (3.16b)$$

$$= Z_1 \frac{Z_r \cosh P_{AB} + Z_1 \sinh P_{AB}}{Z_r \sinh P_{AB} + Z_1 \cosh P_{AB}} \quad \ldots \quad (3.17)$$

The voltage reflection coefficient of portion AB at A is, from equation (3.11)

$$p_{AB} = \frac{p_A\{1 - \exp(-2P_{AB})\}}{1 - p^2_A \exp(-2P_{AB})} \quad .. \quad (3.18)$$

and by symmetry, the voltage reflection coefficient at B, p_{BA}, is equal to p_{AB}. From equation (3.14) it is seen that the current reflection coefficient is equal and opposite to the voltage reflection coefficient.

The voltage transmission coefficient is from (3.13)

$$m_{AB} = \frac{1 - p^2_A}{1 - p^2_A \exp(-2P_{AB})} = 1 - p_A p_{AB} \quad .. \quad .. \quad .. \quad (3.19)$$

Equation (3.15) shows that the current transmission coefficient is equal to the voltage transmission coefficient.

We may form the subordinate waves caused by the passage of the principal wave through the portion AB into two groups. The first group consisting of all waves travelling back from A is designated — AB1; the second, containing all subordinate waves travelling forward from the remote end B is designated + AB1, and we may draw Fig. 2(c) to represent the same series of waves as is shown in Fig. 2(b).

3.5. *Line with Two Rectangular Deviations*

Consider a line OT of impedance Z_r (Fig. 3) in which are inserted a smooth portion AB of impedance Z_1 and propagation coefficient P_{AB} and a second smooth portion CD of impedance Z_2 and propagation coefficient P_{CD}. From Fig. 3 we can construct Table 2, which gives the magnitudes of the various wave-groups at A, B, C and D. The total voltage at A is

$$V_A = V[1 + p_{AB} + p_{CD}m^2_{AB} \exp(-2P_{AB} - 2P_{BC}) + p_{BA}p^2_{CD}m^2_{AB} \exp(-2P_{AB} - 4P_{BC}) + ---] \quad .. \quad .. \quad .. \quad (3.20)$$

$$= V\left[1 + p_{AB} + \frac{p_{CD}m^2_{AB} \exp(-2P_{AC})}{1 - p_{BA}p_{CD} \exp(-2P_{BC})}\right] \quad .. \quad .. \quad .. \quad (3.21)$$

The total voltage at D is

$$V_D = V\{m_{AB}m_{CD} + p_{BA}p_{CD}m_{AB}m_{CD} \exp(-2P_{BC}) + p^2_{BA}p^2_{CD}m_{AB}m_{CD} \exp(-4P_{BC}) + ---\} \exp(-P_{AD}) \quad .. \quad .. \quad .. \quad (3.22)$$

$$= \frac{V m_{AB}m_{CD} \exp(-P_{AD})}{1 - p_{BA}p_{CD} \exp(-2P_{BC})} \quad .. \quad .. \quad (3.23)$$

The voltage reflection coefficient for the portion AD is, from (3.21)

TABLE 2

Line with Two Rectangular Deviations

Magnitude of Voltage Waves relative to the Magnitude of the Principal Wave at the Same Point

Wave group	Magnitude at A	Magnitude at B	Magnitude at C	Magnitude at D
+ OI	1	1	1	1
− AB1	p_{AB}	—	—	—
+ AB1	—	$m_{AB} - 1$	$m_{AB} - 1$	$m_{AB} - 1$
+ CD1	—	—	—	$m_{AB}(m_{CD} - 1)$
− CD1	$p_{CD}m_{AB} \exp(-2P_{AB} - 2P_{BC})$	$p_{CD}m_{AB} \exp(-2P_{BC})$	$p_{CD}m_{AB}$	—
− AB2	$p_{CD}m_{AB}(m_{AB} - 1) \exp(-2P_{AB} - 2P_{BC})$	—	—	—
+ AB2	—	$p_{BA}p_{CD}m_{AB} \exp(-2P_{BC})$	$p_{BA}p_{CD}m_{AB} \exp(-2P_{BC})$	$p_{BA}p_{CD}m_{AB} \exp(-2P_{BC})$
+ CD2	—	—	—	$p_{BA}p_{CD}m_{AB}(m_{CD} - 1) \exp(-2P_{BC})$
− CD2	$p_{BA}p^2_{CD}m_{AB} \exp(-2P_{AB} - 4P_{BC})$	$p_{BA}p^2_{CD}m_{AB} \exp(-4P_{BC})$	$p_{BA}p^2_{CD}m_{AB} \exp(-2P_{BC})$	—
− AB3	$p_{BA}p^2_{CD}m_{AB}(m_{AB} - 1) \exp(-2P_{AB} - 4P_{BC})$	—	—	—
+ AB3	—	$p^2_{BA}p^2_{CD}m_{AB} \exp(-4P_{BC})$	$p^2_{BA}p^2_{CD}m_{AB} \exp(-4P_{BC})$	$p^2_{BA}p^2_{CD}m_{AB} \exp(-4P_{BC})$
+ CD3	—	—	—	$p^2_{BA}p^2_{CD}m_{AB}(m_{CD} - 1) \exp(-4P_{BC})$
etc.	- - -	- - -	- - -	- - -

$$p_{AD} = p_{AB} + \frac{p_{CD} m^2_{AB} \exp(-2P_{AC})}{1 - p_{BA} p_{CD} \exp(-2P_{BC})} \quad (3.24)$$

The voltage transmission coefficient for AD is, from (3.23)

$$m_{AD} = \frac{m_{AB} m_{CD}}{1 - p_{BA} p_{CD} \exp(-2P_{BC})} \quad \ldots \quad (3.25)$$

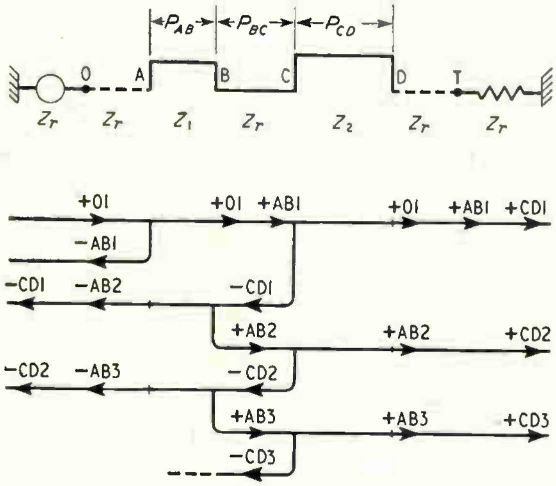

Fig. 3. *Line with two rectangular deviations.*

If generator and termination are interchanged in Fig. 3, we obtain the reflection and transmission coefficients for transmission through the line from D to A. From (3.24) and (3.25) we obtain from considerations of symmetry

$$p_{DA} = p_{DC} + \frac{p_{BA} m^2_{CD} \exp(-2P_{BD})}{1 - p_{BA} p_{CD} \exp(-2P_{BC})} \quad (3.26)$$

$$m_{DA} = \frac{m_{AB} m_{CD}}{1 - p_{BA} p_{CD} \exp(-2P_{BC})} = m_{AD} \quad (3.27)$$

If the two portions are adjacent, $P_{BC} = 0$. Then for two adjacent rectangular deviations,

$$p_{AC} = p_{AB} + \frac{p_{BC} m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA} p_{BC}} \quad \ldots \quad (3.28)$$

$$p_{CA} = p_{CB} + \frac{p_{BA} m^2_{BC} \exp(-2P_{BC})}{1 - p_{BA} p_{BC}} \quad \ldots \quad (3.29)$$

$$m_{AC} = m_{CA} = \frac{m_{AB} m_{BC}}{1 - p_{BA} p_{BC}} \quad \ldots \quad \ldots \quad (3.30)$$

By following a similar procedure for the current waves, we obtain equations corresponding to (3.24), (3.25), (3.26) and (3.27); we see that for two rectangular deviations the voltage and current reflection coefficients at the same end are equal and opposite to each other, while the voltage and current transmission coefficients are equal to each other and are the same for either direction of transmission.

3.6. *Line with M Adjacent Rectangular Deviations*

If the line contains three rectangular deviations adjacent to each other, AB, BC, CD, we treat it as two portions AC, CD, and by following the process used for two rectangular deviations we arrive at the equations

$$p_{AD} = p_{AC} + \frac{m^2_{AC} p_{CD} \exp(-2P_{AC})}{1 - p_{CA} p_{CD}}$$
$$= p_{AB} + \frac{m^2_{AB} p_{BC} \exp(-2P_{AB})}{1 - p_{BA} p_{BC}} + \frac{m^2_{AC} p_{CD} \exp(-2P_{AC})}{1 - p_{CA} p_{CD}} \quad \ldots \quad (3.31)$$

$$m_{AD} = \frac{m_{AC} m_{CD}}{1 - p_{CA} p_{CD}} = \frac{m_{AB} m_{BC} m_{CD}}{(1 - p_{BA} p_{BC})(1 - p_{CA} p_{CD})} \quad \ldots \quad \ldots \quad \ldots \quad (3.32)$$

When the line contains M adjacent rectangular deviations AB, BC . . . MN, we obtain by continuing the process

$$p_{AN} = p_{AB} + \frac{m^2_{AB} p_{BC} \exp(-2P_{AB})}{1 - p_{BA} p_{BC}} + \frac{m^2_{AC} p_{CD} \exp(-2P_{AC})}{1 - p_{CA} p_{CD}} + \cdots + \frac{m^2_{AM} p_{MN} \exp(-2P_{AM})}{1 - p_{MA} p_{MN}} \quad \ldots \quad \ldots \quad \ldots \quad (3.33)$$

$$m_{AN} = m_{NA} = \frac{m_{AB} m_{BC} \ldots\ldots m_{MN}}{(1 - p_{BA} p_{BN})(1 - p_{CB} p_{CN}) \ldots\ldots (1 - p_{LM} p_{MN})} \quad \ldots \quad (3.34)$$

$$= \frac{m_{AB} m_{BC} \ldots\ldots m_{MN}}{(1 - p_{BA} p_{BC})(1 - p_{CA} p_{CD}) \ldots\ldots (1 - p_{MA} p_{MN})} \quad \ldots \quad (3.35)$$

3.7. *Line with Deviations of any Form*

A deviation AB of any form may be regarded as one composed of a large number of adjacent rectangular deviations of very short length. The forward-travelling subsidiary waves may be grouped together to form a single wave-group + AB1, and the backward-travelling subsidiaries may be grouped to form a second wave-group − AB1, the whole process being represented by Fig. 2(c). Thus Sections (3.5) and (3.6), with the contained equations (3.20) to (3.35) inclusive and Table 2, apply mutatis mutandis to lines with deviations of any form.

The following relations pertain to a line AB containing deviations of any form, with matched terminal conditions:—

(*a*) The voltage and current reflection coefficients at the same end are equal and opposite in sign to each other.

(*b*) It follows from (*a*) that if p_{AB} is the voltage reflection coefficient, Z_{AB} the impedance looking into the line at A and Z_r the impedance of the generator and termination

$$V_A = V(1 + p_{AB})$$
$$I_A = I(1 - p_{AB})$$

whence $$Z_{AB} = \frac{Z_r(1 + p_{AB})}{1 - p_{AB}} \quad \ldots \quad \ldots \quad (3.36)$$

$$p_{AB} = \frac{Z_{AB} - Z_r}{Z_{AB} + Z_r} \quad \ldots \quad \ldots \quad \ldots \quad (3.37)$$

(*c*) The reflection coefficients at end B in general bear no relation to the reflection coefficients at end A.

(*d*) The voltage and current transmission coefficients are equal to each other.

(*e*) The voltage and current transmission coefficients are the same for either direction of transmission; this may be deduced directly from the Reciprocity Theorem.

3.8. *Irregular Line with General Terminal Conditions*

If an irregular line is terminated with an impedance Z_T other than the reference impedance Z_r, the voltage reflection coefficient p_{ABT} may be obtained from equation (3.28) in its general application by substituting p_T for p_{BC}, where

$$p_T = \frac{Z_T - Z_r}{Z_T + Z_r} \quad \ldots \quad \ldots \quad \ldots \quad (3.38)$$

Thus $$p_{ABT} = p_{AB} + \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA} p_T} \quad (3.39)$$

Similarly, for the opposite direction of transmission

$$p_{BAT} = p_{BA} + \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{AB} p_T} \quad (3.40)$$

The voltage transmission coefficient m_{ABT} is obtained from equation (3.30) by substituting $(1 + p_T)$ for m_{BC}. Thus

$$m_{ABT} = \frac{m_{AB}(1 + p_T)}{1 - p_{BA} p_T} \quad \ldots \quad \ldots \quad (3.41)$$

$$m_{BAT} = \frac{m_{AB}(1 + p_T)}{1 - p_{AB} p_T} \quad \ldots \quad \ldots \quad (3.42)$$

The current reflection coefficient in terms of the voltage coefficients for the component parts is

$$p'_{ABT} = -p_{AB} - \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA} p_T} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.43)$$

Similarly the current transmission coefficient is

$$m'_{ABT} = \frac{m_{AB}(1 - p_T)}{1 - p_{BA} p_T} \quad \ldots \quad \ldots \quad (3.44)$$

The current reflection coefficient is equal and opposite to the voltage reflection coefficient, so that the relationships between impedance and reflection coefficients, equations (3.36) and (3.37), hold good. The voltage and current transmission coefficients, however, are no longer equal to each other, and furthermore, they differ for the two directions of transmission.

The voltage at the sending end is

$$V_A = V(1 + p_{ABT})$$
$$= V\left\{1 + p_{AB} + \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA} p_T}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.45)$$

where V is the magnitude of the principal voltage wave at the sending end. The current at the sending end is

$$I_A = I\left\{1 - p_{AB} - \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA} p_T}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.46)$$

where I is the magnitude of the principal current wave at the sending end. Thus the sending-end impedance is

$$Z_{ABT} = \frac{Z_r(1 + p_{ABT})}{1 - p_{ABT}} = Z_r\left[\frac{(1 + p_{AB})(1 - p_{BA} p_T) + p_T m^2_{AB} \exp(-2P_{AB})}{(1 - p_{AB})(1 - p_{BA} p_T) - p_T m^2_{AB} \exp(-2P_{AB})}\right] \quad \ldots \quad (3.47)$$

If the generator impedance is changed and its e.m.f. remains unaltered at E, the principal voltage wave, by definition, is unaffected. If the new value of the generator impedance is Z_G, the voltage at the sending end of the line terminated by Z_T becomes $EZ_{ABT}/(Z_G + Z_{ABT})$. The corresponding value of the principal wave is $\frac{1}{2}E$, the new reflected wave is $\frac{1}{2}E(Z_{ABT} - Z_G)/(Z_{ABT} + Z_G)$, and thus the new reflection coefficient p_{GABT} is

$$p_{GABT} = \frac{Z_{ABT} - Z_G}{Z_{ABT} + Z_G} \quad \ldots \quad \ldots \quad \ldots \quad (3.48)$$

which is in agreement with the accepted definition of reflection coefficient. From equations (3.47) and (3.48) we have

$$p_{GABT} = \frac{(p_{AB} + p_G)(1 - p_{BA} p_T) + p_T m^2_{AB} \exp(-2P_{AB})}{(1 + p_{AB} p_G)(1 - p_{BA} p_T) + p_G p_T m^2_{AB} \exp(-2P_{AB})} \quad \ldots \quad (3.49)$$

where $p_G = (Z_r - Z_G)/(Z_r + Z_G) \quad \ldots \quad (3.50)$

The effect of changing the generator impedance from Z_r to Z_G is to alter the received voltage in the ratio $(Z_{ABT} + Z_r)/(Z_{ABT} + Z_G)$. Since the principal wave is unaltered, the new transmission coefficient m_{GABT} becomes

$$m_{GABT} = \frac{m_{ABT}(Z_{ABT} + Z_r)}{Z_{ABT} + Z_G} = \frac{m_{AB}(1 + p_G)(1 + p_T)}{(1 + p_{AB}p_G)(1 - p_{BA}p_T) + p_G p_T m^2_{AB} \exp(-2P_{AB})} \quad .. \quad (3.51)$$

If $Z_T = Z_G$ (i.e., the terminations are matched at the new value Z_G instead of Z_r) $p_G = -p_T$, and

$$p_{GABG} = \frac{(p_{AB} + p_G)(1 + p_{BA}p_G) - p_G m^2_{AB} \exp(-2P_{AB})}{(1 + p_{AB}p_G)(1 + p_{BA}p_G) - p^2_G m^2_{AB} \exp(-2P_{AB})} \quad .. \quad (3.52)$$

$$m_{GABG} = \frac{m_{AB}(1 - p^2_G)}{(1 + p_{AB}p_G)(1 + p_{BA}p_G) - p^2_G m^2_{AB} \exp(-2P_{AB})} \quad .. \quad (3.53)$$

In the above, the coefficients p_{AB}, p_{BA}, m_{AB} relate to the reference impedance Z_r. Changing the reference impedance will not alter either the actual line voltages or the principal voltage wave, and hence p_{GABG} and m_{GABG} are unaffected by a change in the reference impedance, e.g., from Z_r to Z_G. Thus equations (3.52) and (3.53) give the change in the reflection and transmission coefficients respectively when the reference impedance is changed from Z_r to Z_G.

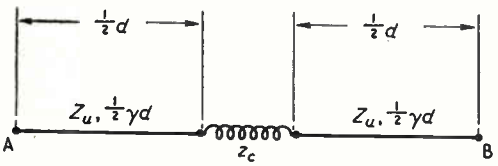

Fig. 4. *Section of loaded cable.*

3.9. *Localized Irregularities*

A localized irregularity is one in which a relatively large impedance deviation has such a small propagation coefficient that it is effectively concentrated at a single point; e.g., a series inductor or a shunt capacitor. The reflection and transmission coefficients can be obtained directly from the definitions and the elementary circuit diagrams, but it is instructive to see how they follow from the general case. The propagation coefficient being very small, the reflection coefficient is from equation (3.18)

$$p_{AB} = \frac{2P_{AB}p_A}{1 - p^2_A(1 - 2P_{AB})}$$

$$= \frac{2P_{AB}(Z^2_1 - Z^2_r)}{4Z_1Z_r + 2P_{AB}(Z_1 - Z_r)^2} \quad .. \quad (3.54)$$

If the deviation is due to a relatively large series impedance z_c associated with a small shunt admittance y_c (such as a loading coil), $Z^2_1 = z_c/y_c$ is large compared with Z^2_r, and hence

$$p_{AB} = \frac{P_{AB}Z_1}{2Z_r + P_{AB}Z_1}$$

Since $p_{AB} = \sqrt{z_c y_c}$, we have

$$p_{AB} = \frac{z_c}{2Z_r + z_c} \quad .. \quad .. \quad .. \quad (3.55)$$

From equation (3.19), since $p_A \approx 1$,

$$m_{AB} = 1 - \frac{z_c}{2Z_r + z_c}$$

$$= \frac{2Z_r}{2Z_r + z_c} \quad .. \quad (3.56)$$

On the other hand if the shunt admittance is relatively large and the series impedance small, Z^2_1 can be neglected relative to Z^2_r, and $p_A \approx -1$. Whence

$$p_{AB} = \frac{-P_{AB}Z_r}{2Z_1 + P_{AB}Z_r} = \frac{-y_cZ_r}{2 + y_cZ_r} \quad .. \quad (3.57)$$

$$m_{AB} = 1 - \frac{y_cZ_r}{2 + y_cZ_r} = \frac{2}{2 + y_cZ_r} \quad .. \quad (3.58)$$

It is interesting to use these relations to obtain Campbell's formula for the loaded cable. Referring to Fig. 4, AB represents a loading coil of impedance z_c inserted between two portions of cable, each of length $\frac{1}{2}d$, of characteristic impedance Z_u and propagation coefficient γ per unit length. If we choose the reference impedance to be Z_u, we have

$$p_{AB} = \frac{z_c \exp(-\gamma d)}{z_c + 2Z_u}; \; m_{AB} = \frac{2Z_u}{z_c + 2Z_u} \quad .. \quad .. \quad .. \quad (3.59)$$

The impedance with end B open-circuited is obtained from equation (3.47), for which $p_T = +1$; whence

$$Z_{op} = Z_u \left[\frac{1 - p^2_{AB} + m^2_{AB} \exp(-2\gamma d)}{(1 - p_{AB})^2 - m^2_{AB} \exp(-2\gamma d)}\right]$$

Similarly with end B short-circuited, $p_T = -1$,

and $$Z_{sh} = Z_u \left[\frac{(1 + p_{AB})^2 - m^2_{AB} \exp(-2\gamma d)}{1 - p^2_{AB} + m^2_{AB} \exp(-2\gamma d)}\right]$$

If P' is the propagation coefficient per unit length of the loaded cable, then

$$\tanh^2 P'd = \frac{Z_{sh}}{Z_{op}}$$

$$= 1 - \frac{4m^2_{AB} \exp(-2\gamma d)}{\{1 - p^2_{AB} + m^2_{AB} \exp(-2\gamma d)\}^2}$$

Whence

$$\cosh P'd = \frac{1 - p^2_{AB} + m^2_{AB} \exp(-2\gamma d)}{2m_{AB} \exp(-\gamma d)}$$

and substituting from (3.59) we have

$$\cosh P'd = \cosh \gamma d + \frac{z_c}{2Z_u} \sinh \gamma d \quad .. \quad (3.60)$$

which is Campbell's well-known formula.

4. Line with Small Irregularities

4.1. *Simplification when Impedance Deviations are Small*

If the impedance deviations are small relative to the reference impedance, the reflection coefficients p_A, p_B, etc., are small compared with unity. The coefficients for one deviating smooth portion from (3.18) and (3.19) simplify to

$$p_{AB} = p_A \{1 - \exp(-2P_{AB})\} \quad .. \quad (4.1)$$

$$m_{AB} = 1 - p^2{}_A \{1 - \exp(-2P_{AB})\} \quad .. \quad (4.2)$$

Considering M adjacent smooth portions, we find by substituting (4.1) and 4.2) in equation (3.33) that terms of the type $m^2{}_{AB}p_{BC}/(1 - p_{BA}p_{BC})$ reduce to p_{BC}. Thus we have

$$p_{AN} = p_{AB} + p_{BC} \exp(-2P_{AB}) + p_{CD} \exp(-2P_{AC}) + - - - - - - + p_{MN} \exp(-2P_{AM}) \quad .. \quad .. \quad (4.3)$$

Equation (4.3) shows that the reflected wave from each deviating portion is the same as if the line between it and the source were smooth; further, only single reflections and consequently first powers of reflection coefficients are of importance. The corresponding wave-diagram is shown in Fig. 5.

The transmission coefficient for two deviating portions, from (3.25) reduces to

$$\begin{aligned} m_{AD} &= m_{AB}m_{CD} \{1 + p_{BA}p_{CD} \exp(-2P_{BC})\} \\ &= 1 - p^2{}_A \{1 - \exp(-2P_{AB})\} \\ &\quad - p^2{}_C \{1 - \exp(-2P_{CD})\} \\ &\quad + p_A p_C \exp(-2P_{BC}) \{1 - \exp(-2P_{AB})\} \\ &\quad \{1 - \exp(-2P_{CD})\} \quad .. \quad .. \quad .. \quad (4.4) \end{aligned}$$

Only second powers of reflection coefficients and double reflections are concerned; the corresponding wave-diagram is shown in Fig. 6.

For M adjacent smooth portions, the transmission coefficient, from (3.34) becomes

$$m_{AN} = m_{AB}m_{BC}m_{CD} \ldots \ldots m_{MN} \, (1 + p_{BA}p_{BC} + p_{CA}p_{CD} + - - - - + p_{MA}p_{MN}) \quad (4.5)$$

$$\begin{aligned} &= 1 - p^2{}_A \{1 - \exp(-2P_{AB})\} \\ &\quad - p^2{}_B \{1 - \exp(-2P_{BC})\} - \\ &\quad - - - - \quad - p^2{}_M \{1 - \exp(-2P_{MN})\} \\ &\quad + p_{BC}p_{BA} + p_{CD} \{p_{CB} + p_{BA} \exp(-2P_{BC})\} \\ &\quad + - - - - + p_{MN} \{p_{ML} + p_{LK} \exp(-2P_{LM}) \\ &\quad + - - - - + p_{BA} \exp(-2P_{BM})\} \\ &= 1 - \sum_{F=A}^{M} p^2{}_F \{1 - \exp(-2P_{FG})\} + \\ &\qquad \sum_{F=B}^{M} p_{FG} \left\{ \sum_{D=B}^{F} p_{DC} \exp(-2P_{DF}) \right\} \\ &= 1 - \sum_{F=A}^{M} p^2{}_F \{1 - \exp(-2P_{FG})\} \\ &\quad + \sum_{F=B}^{M} p_F \{1 - \exp(-2P_{FG})\} \\ &\left[\sum_{D=B}^{F} p_C \{1 - \exp(-2P_{CD})\} \exp(-2P_{DF}) \right] \quad (4.6) \end{aligned}$$

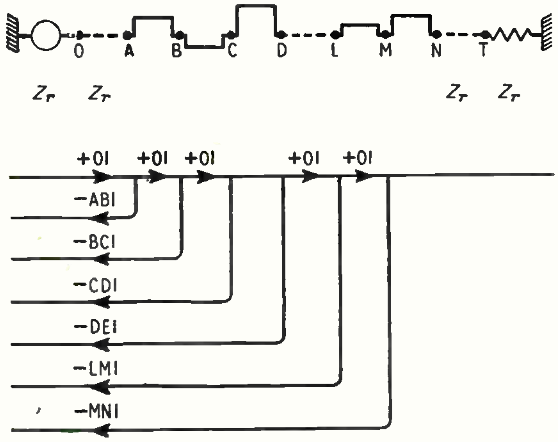

Fig. 5. *Single reflections in line with small rectangular deviations.*

By similar reasoning to the above, we can see that (4.3) and (4.5) apply also to an arrangement of M adjacent irregular portions.

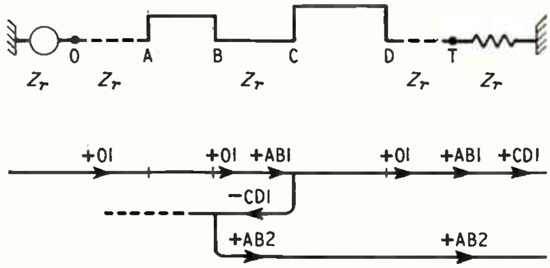

Fig. 6. *Double reflection in line with two small rectangular deviations.*

4.2. *Irregular Line with General Terminal Conditions*

Consider the irregular line AB treated in Section (3.8) in which the generator impedance is changed from Z_r to Z_G and the terminating impedance from Z_r to Z_T; when the line irregularities are small the reflection coefficient p_{GABT} in (3.49) becomes

$$p_{GABT} = \frac{(p_{AB} + p_G)(1 - p_{BA}p_T) + p_T \exp(-2P_{AB})}{1 + p_{AB}p_G - p_{BA}p_T + p_G p_T \exp(-2P_{AB})}$$

If $p_G p_T \exp(-2P_{AB})$ is small compared with 1, which is often the case,

$$p_{GABT} = p_{AB} + p_G + p_T \exp(-2P_{AB}) - p_{AB}p^2{}_G \quad .. \quad .. \quad .. \quad .. \quad (4.7)$$

From (3.51) we obtain for the transmission coefficient

$$m_{GABT} = m_{AB} (1 + p_G)(1 + p_T) \{1 - p_{AB}p_G + p_{BA}p_T - p_G p_T \exp(-2P_{AB})\} \quad .. \quad .. \quad .. \quad (4.8)$$

If q_{AB} denotes the transmitted echo coefficient when generator and termination are equal to Z_r, and q_{GABT} the value when these impedances are respectively Z_G and Z_T, then

$$q_{GABT} = (1 + p_G)(1 + p_T)\{q_{AB} - p_{AB}p_G + p_{BA}p_T - p_G p_T \exp(-2P_{AB})\} \quad \ldots \quad (4.9)$$

In (4.7) we recognise in p_{AB} the term representing the single reflections within the line; in p_G the first-order reflected wave due to the mis-match between the generator and line; in $p_T \exp(-2P_{AB})$ the reflection from the mis-match between termination and line, modified by the propagation coefficient due to a double traverse of the line; and in $p^2{}_G p_{AB}$ the third-order reflection between generator and line which may be appreciable if the mis-match is large. In (4.9) we distinguish q_{AB} due to double reflections within the line; $p_{AB}p_G$ representing single reflections in the line reflected again at the generator; $p_{BA}p_T$ representing reflection from the termination reflected again in the line; and $p_G p_T \exp(-2P_{AB})$ representing double reflection between termination and generator.

If $Z_G = Z_T$ and the mismatch between line and terminal impedances is small, then

$$p_{GABG} = p_{AB} + p_G\{1 - \exp(-2P_{AB})\} \quad (4.10)$$

$$m_{GABG} = m_{AB} - p^2{}_G - p_G(p_{AB} + p_{BA}) + p^2{}_G \exp(-2P_{AB}) \quad \ldots \quad (4.11)$$

$$q_{GABG} = q_{AB} - p_G(p_{AB} + p_{BA}) + p^2{}_G \exp(-2P_{AB}) \quad \ldots \quad (4.12)$$

4.3. *Irregular Line with Small Impedance Deviations*

For a nominally homogeneous line OL of length l, we may define the average characteristic impedance Z_m as

$$Z_m = \frac{1}{l}\int_0^l Z_x dx \quad \ldots \quad (4.13)$$

Thus we may write

$$Z_x = Z_m + S_x \quad \ldots \quad (4.14)$$

$$= Z_r + \sigma_x \quad \ldots \quad (4.15)$$

where Z_r is a reference impedance sufficiently close to Z_m to make $(Z_r - Z_m)^2/Z_m{}^2$ negligible compared with 1; σ_x is the local deviation from this reference impedance, and S_x is the particular value of the deviation when the reference impedance is equal to the mean impedance.

Similarly for the nominally homogeneous line the average propagation coefficient per unit length, γ, is defined as

$$\gamma = \frac{1}{l}\int_0^l \gamma_x dx \quad \ldots \quad (4.16)$$

$$\text{and} \quad \gamma_x = \gamma + g_x \quad \ldots \quad (4.17)$$

If σ_x/Z_x is small, then g_x/γ_x will be smaller. This follows because the principal deviations are due to inductance and capacitance variations, and these in turn are produced mainly by variations in conductor dimensions and in effective permittivity. The former produce local changes in L and C which to a first approximation add for Z_x but cancel for γ_x, and it is only changes in the dielectric which affect both Z_x and γ_x to the same degree.

Considering the line with one deviating portion discussed in Section (3.4), as the length of AB becomes progressively smaller and in the limit approaches dx, the propagation coefficient P_{AB} becomes $\gamma_x dx$. The reflection and transmission coefficients from (4.1) and (4.2) become

$$p_{AB} = 2p_x\gamma_x dx$$

$$= 2p_x\gamma dx \text{ (since } g_x/\gamma \text{ is small)} \quad (4.18)$$

$$m_{AB} = 1 - 2p^2{}_x\gamma dx \quad \ldots \quad (4.19)$$

$$\text{where } p_x = \sigma_x/2Z_r \quad \ldots \quad (4.20)$$

An irregular line is composed of a large number of adjacent small portions such as AB, each contributing a term $2p_x \exp(-2P_{ox})dx$ to the reflection coefficient. Replacing P_{ox} by γx introduces a negligible error when g_x/γ is small, and thus for the irregular line, we have from (4.3)

$$p_r = \frac{\gamma}{Z_r}\int_0^l \sigma_x \exp(-2\gamma x)dx \quad \ldots \quad (4.21)$$

where p_r denotes the reflection coefficient with respect to Z_r. When the mean impedance is selected as reference impedance, p is written without a suffix as this is a frequent case, and we have

$$p = \frac{\gamma}{Z_m}\int_0^l S_x \exp(-2\gamma x)dx \quad (4.22)$$

$$= p_r + \frac{\Delta Z}{2Z_m}\{1 - \exp(-2\gamma l)\} \quad (4.23)$$

where $\Delta Z = Z_r - Z_m$.

Similarly for the transmission coefficient, we have from (4.6)

$$m_r = 1 - \frac{\gamma}{2Z^2{}_r}\int_0^l \sigma^2{}_x dx + \frac{\gamma^2}{Z^2{}_r}\int_0^l \sigma_x \exp(-2\gamma x)\int_0^x \sigma_y \exp(2\gamma y)dy\, dx \quad \ldots \quad (4.24)$$

$$\text{or } m = 1 - \frac{\gamma}{2Z^2{}_m}\int_0^l S^2{}_x dx + \frac{\gamma^2}{Z^2{}_m}\int_0^l S_x \exp(-2\gamma x)\int_0^x S_y \exp(2\gamma y)\, dydx \quad \ldots \quad (4.25)$$

To appreciate the physical basis of the integral forms of the expressions for the reflection and transmission coefficients, we revert to the line built up of a number of adjacent deviating portions. From this it is apparent that equation (4.21) contains the reflection from a given point as the difference of two components, viz., the ordinates of the infinitesimal portions on either side of the point. For example, in considering the 'tail' of a television signal,[3,5] one computes the reflection coefficient due to irregularities situated at distances greater than a given value from the origin. If we divide p_r as given by equation (4.21) into two parts representing reflection from O to B ($x = b$) and from B to L, Fig. 7, we obtain

$$p_{OB} = \frac{\gamma}{2Z_r}\int_0^b \sigma_X \exp(-2\gamma x)dx \quad .. \quad (4.26a)$$

$$p_{BL} = \frac{\gamma}{2Z_r}\int_b^l \sigma_X \exp(-2\gamma x)dx \quad .. \quad (4.26b)$$

and have thereby added unnecessarily $-\sigma_B \exp(-2\gamma b)$ to equation (4.26a) and $+\sigma_B \exp(-2\gamma b)$ to equation (4.26b). For a physical division of the line, with termination of each part by Z_r, equations (4.26a) and (4.26b) would of course be correct. The difference is brought out by throwing equation (4.21) into an alternative form by integrating it by parts. Thus we obtain

$$p_r = \frac{1}{2Z_r}\left[\int_0^l \sigma'_X \exp(-2\gamma x)\,dx + \sigma_O - \sigma_L \exp(-2\gamma l)\right] \quad (4.27)$$

where $\sigma'_X = \dfrac{\partial \sigma_X}{\partial x}$ and σ_O, σ_L are the values of the impedance deviations at the beginning and end of the line. On breaking up the reflection coefficient, the two parts corresponding to equations (4.26a) and (4.26b) are

$$p_{OB} = \frac{1}{2Z_r}\left[\sigma_O + \int_0^b \sigma'_X \exp(-2\gamma x)\,dx\right] \quad (4.28a)$$

$$p_{BL} = \frac{1}{2Z_r}\left[\int_b^l \sigma'_X \exp(-2\gamma x)dx - \sigma_L \exp(-2\gamma l)\right] \quad .. \quad (4.28b)$$

and in this form no unnecessary terms are introduced. On the other hand, these expressions are not correct if the line is physically divided and each section is terminated by Z_r. To appreciate this aspect, we notice that in equation (4.27) the term $\sigma_O/2Z_r$ represents the reflection coefficient for the step between the generator and the entrance to the line, and $\sigma_L \exp(-2\gamma l)/2Z_r$ the reflection coefficient for the step between the end of the line and the terminal impedance.

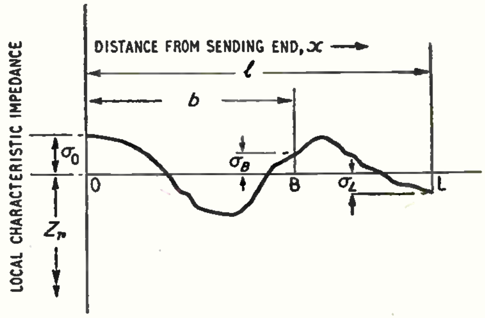

Fig. 7. *Variation of impedance along irregular line.*

Thus $\dfrac{1}{2Z_r}\displaystyle\int_0^l \sigma'_X \exp(-2\gamma x)\,dx$ represents the reflection coefficient of the line when the generator and terminal impedances are respectively equal to the impedances of the portions of line immediately adjacent to them. With an irregular line, these impedances are in practice indeterminate, as they depend on the length over which the impedance may be regarded as uniform, so that for measurement purposes it is usually preferable to use the form of equation (4.21).

Similar considerations apply to the integral form of the equation for the transmission coefficient. In equation (4.24) the interaction between adjacent infinitesimal portions is contained partly in the first term and partly in the second; furthermore the division into parts again introduces unnecessary terms. This may be avoided by throwing (4.24) into an alternative form by integrating by parts, when we obtain

$$m_r = 1 + \frac{1}{4Z^2_r}\Bigg[\sigma_O\sigma_L \exp(-2\gamma l) - \tfrac{1}{2}(\sigma^2_O + \sigma^2_L) - \sigma_O\int_0 \sigma'_X \exp(-2\gamma x)dx + \sigma_L\int_0^l \sigma'_X \exp\{-2\gamma(l-x)\}\,dx - \int_0^l \sigma'_X \exp(-2\gamma x)\int_0^x \sigma'_Y \exp(2\gamma y)dy\,dx\Bigg] \quad (4.29)$$

Here the term $-\dfrac{1}{4Z^2_r}\displaystyle\int_0^l \sigma'_X \exp(-2\gamma x)\int_0^x \sigma'_Y \exp(2\gamma y)dy\,dx$ represents the transmitted echo coefficient when the generator and termination equal the respective impedances of the portions immediately adjacent to them.

Equation (4.27) may also be put into the form

$$p_r = \frac{1}{2Z_r} \sum_{x=0}^{x=L} \exp(-2\gamma_x)\delta Z_x \quad \ldots \quad (4.30)$$

where δZ_x is the change of impedance at X, and the sum includes the steps at the beginning and end of the line. In this form, the equation is useful when we wish to consider the effects of abrupt changes of impedance.

5. Effect of Small Line Irregularities on the Open- and Short-Circuited Impedances

When a uniform line is open-circuited at its distant end, its input impedance is

$$Z_{op} = Z \coth \gamma l \quad \ldots \quad (5.1)$$

When the distant-end is short-circuited, the input impedance becomes

$$Z_{sh} = Z \tanh \gamma l \quad \ldots \quad (5.2)$$

If a line AB has small irregularities and is terminated by an impedance Z_T, the input impedance is from equation (3.47)

$$Z_{AT} = Z_m \left[\frac{1 + p_{AB} + p_T \exp(-2\gamma l)/(1 - p_{BA}p_T)}{1 - p_{AB} - p_T \exp(-2\gamma l)/(1 - p_{BA}p_T)}\right] \quad \ldots \quad (5.3)$$

where p_{AB}, p_{BA}, are the reflection coefficients at A and B respectively with the distant end terminated by Z_m, and $p_T = (Z_T - Z_m)/(Z_T + Z_m)$. When the distant end is open, $p_T = +1$, and when it is closed $p_T = -1$. Thus the input impedance of an irregular line with the distant end open is

$$Z_{Aop} = Z_m \left[\frac{1 + p_{AB} + \exp(-2\gamma l)/(1 - p_{BA})}{1 - p_{AB} - \exp(-2\gamma l)/(1 - p_{BA})}\right] \quad \ldots \quad (5.4)$$

When the distant end is closed, the input impedance becomes

$$Z_{Ash} = Z_m \left[\frac{1 + p_{AB} - \exp(-2\gamma l)/(1 + p_{BA})}{1 - p_{AB} + \exp(-2\gamma l)/(1 + p_{BA})}\right] \quad \ldots \quad (5.5)$$

Provided $p_{AB} + p_{BA}$ is small compared with $1 - \exp(-2\gamma l)$, which is generally the case,

$$Z_{Aop} = Z_m \coth \gamma l \left[1 + \frac{p_{AB} + p_{BA}}{1 - \exp(-2\gamma l)} + \frac{p_{AB} - p_{BA}}{1 + \exp(-2\gamma l)}\right] \quad (5.6)$$

Similarly, provided $p_{AB} - p_{BA}$ is small compared with $1 + \exp(-2\gamma l)$,

$$Z_{Ash} = Z_m \tanh \gamma l \left[1 + \frac{p_{AB} + p_{BA}}{1 - \exp(-2\gamma l)} + \frac{p_{AB} - p_{BA}}{1 + \exp(-2\gamma l)}\right] \quad (5.7)$$

Thus a correction factor K_{AB} which gives the influence of irregularities on the open- and short-circuited input-impedances of the corresponding uniform line, is

$$K_{AB} = 1 + \frac{p_{AB} + p_{BA}}{1 - \exp(-2\gamma l)} + \frac{p_{AB} - p_{BA}}{1 + \exp(-2\gamma l)} \quad \ldots \quad (5.8)$$

Equivalent formulae are quoted by Kaden,[2] and by Parcé,[7] but proofs are not given. Thus under these conditions, the apparent characteristic impedance is

$$Z' = \sqrt{Z_{Aop}Z_{Ash}} = Z_m K_{AB} \quad \ldots \quad (5.9)$$

The apparent propagation coefficient is

$$P' = \tanh^{-1}\sqrt{Z_{Ash}/Z_{Aop}} = \gamma l \quad \ldots \quad (5.10)$$

Hence when measuring by the 'open and closed' method, small line irregularities would have an appreciable effect on the apparent characteristic impedance, but none on the attenuation and phase-change coefficients. Caution is necessary, however, in applying the last conclusion to measurements made when the line is in resonance.

6. Conclusion

The Kennelly method of successive reflections has been shown to yield expressions by simple mathematical processes which are in agreement with those derived by more formal methods. The relative coefficients may be calculated and measured, and the results applied to the evaluation of the quality of irregular lines for the transmission of broad-band telephony and television, but the discussion of these topics is outside the scope of this paper.

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THE E-H SURFACE WAVE

By A. E. Karbowiak

SUMMARY—The basic formulae for the E-H surface wave (which is a mixture of two surface waves; the E- and H- modes) are given. The cylindrical guide that is conducting in a helical direction is analysed in detail and the canonical frequency equation is put into a very simple form by making suitable approximations. Finally, it is shown, that although a travelling E-H surface wave can be supported by a helically-conducting guide, it is not possible to have a pure E-H surface wave on a transmission line terminated by a short-circuiting plate. Yet two similar E-H surface waves travelling in opposite directions on the same line give rise to an elliptically-polarized surface wave.

1. Introduction

THE wave mode usually associated with a single-wire transmission line[1] is the E-mode that is evanescent over the wave front. This is a form of electromagnetic wave which propagates without radiation along the outside of a single cylindrical guide[6] and is characterized by the presence of an axial component of the electric field vector and absence of the longitudinal component of the magnetic field vector (E-mode). In the plane normal to the axis of the guide the electromagnetic field extends to infinity in the radial direction, but the energy density of the field decays monotonically with radial distance at a rate determined by the surface properties of the guide. At large distances from the guide the field quantities decay approximately exponentially and usually most of the energy of the wave is constrained to flow in the immediate neighbourhood of the guide. Such a field is called evanescent. The surface wave on the *outside* of the guide is often accompanied by a guided wave *inside* the guide which is not a surface wave but whose nature is a function of the physical configuration of the guide structure, and is irrelevant except in so far that it provides the necessary guide surface impedance. The performance of a single-wire transmission line is governed by its radial decay coefficient, and this depends solely on the guide radius and the surface impedance.[2,3] Of course, it is assumed that most of the power is carried on the outside of the guide and scarcely any on the inside. This $E_{0\times}$ mode (where $\times$ signifies evanescent nature of the wave in the radial direction) has been investigated in detail[2,3], and there are at least two distinct methods of decreasing the lateral spread of the field (i) by coating the wire with a layer of dielectric and (ii) by corrugating the surface of the guide.

It has been known for some time that a helix made of a conducting wire will support a wave mode which has found particular application in the travelling-wave valve[4]. The wave associated with this structure possesses axial components of both electric and magnetic field, and since the wave is evanescent over the wave front on the outside of the helix we shall call the wave mode exterior to the helix the E-H surface wave ($EH_{0\times}$mode). Kaden[5] recognized the bearing of this type of wave on possible future development in ultra-high-frequency transmission lines and suggested the use of a stranded conductor for single-wire transmission lines. It is the purpose of this paper to present the basic formulae of the E-H surface wave and to investigate some of its characteristics when supported by a helically-conducting guide.

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2. Field Equations of the Progressive E-H Surface Wave

Let us describe the electromagnetic field in terms of the cylindrical co-ordinates: r, ϕ, z (Fig. 1). Assuming negligible losses the field outside the cylindrical guide radius s is derived from the wave function*

$$F_1(r,z) = H_0^{(1)}(jur) \,.\, e^{j(\omega t - \beta z)} \quad \ldots \quad (1)$$

where $\beta^2 - u^2 = k^2 = \omega^2\mu_0\kappa_0 \quad \ldots \quad \ldots \quad (2)$

and u = radial propagation coefficient

β = axial propagation coefficient

$H_n^{(1)}$ = Hankel function of order n

μ_0, κ_0 = permeability and permittivity of free-space respectively, in m.k.s. system of units.

Omitting the factor $e^{j(\omega t - \beta z)}$ the field components of the E-H surface wave become

$$\left.\begin{aligned} E_{z1} &= A_1 H_0^{(1)}(jur) , \\ H_{z1} &= B_1 H_0^{(1)}(jur) \\ E_{r1} &= A_1 \frac{\beta}{u} H_1^{(1)}(jur) , \\ H_{r1} &= B_1 \frac{\beta}{u} H_1^{(1)}(jur) \\ H_{\phi 1} &= A_1 \frac{\omega\kappa_0}{u} H_1^{(1)}(jur) , \\ E_{\phi 1} &= -B_1 \frac{\omega\mu_0}{u} H_1^{(1)}(jur) \end{aligned}\right\} \quad \ldots \quad \ldots \quad (3)$$

where A_1, B_1 are two independent constants.

Inside the guide (radius s) the electromagnetic

* Stratton, J. A. "Electromagnetic Theory" (McGraw-Hill), 1941, p. 360. Schelkunoff, S. A. "Electromagnetic Waves" (D. Van Nostrand Co.), 1943, p. 406.

field is derived from the wave function

$$F_2(r_1 z) = J_0(hr) \cdot e^{j(\omega t - \beta z)} \quad .. \quad .. \quad (4)$$

where $\beta^2 + h^2 = k_1^2 = \omega^2 \mu_1 \kappa_1$ .. .. .. (5)

and h = radial propagation coefficient

μ_1, κ_1 = permeability and permittivity of the dielectric inside the guide

J_n = Bessel function of order n.

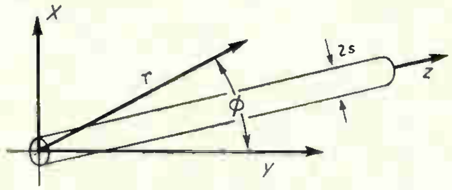

Fig. 1. *The co-ordinate system.*

The field components inside the guide will thus become (the exponential factor is understood);

$$\left.\begin{aligned} E_{z2} &= A_2 J_0(hr) \; , \\ H_{z2} &= B_2 J_0(hr) \\ E_{r2} &= A_2 \frac{j\beta}{h} J_1(hr) \; , \\ H_{r2} &= B_2 \frac{j\beta}{h} J_1(hr) \\ H_{\phi 2} &= A_2 \frac{\omega j \kappa_0}{h} J_1(hr) \; , \\ E_{\phi 2} &= -B_2 \frac{j\omega\mu}{h} J_1(hr) \end{aligned}\right\} \quad .. \quad .. \quad (6)$$

where A_2, B_2 are two different constants.

The particular relation between the constants A_1, B_1 and A_2, B_2 will depend on the nature of the guide but, whatever these constants are, the equations (3) represent the field of an E-H surface wave provided u lies in the fourth quadrant of the Argand diagram.[2,3] If $B_1 = 0$ then the remaining equations of (3) represent a pure E-surface wave and if $A_1 = 0$ then (3) represents an H-surface wave. It is essential for the existence of the H-surface wave that the lines of magnetic field strength shall penetrate the guide surface. The field thus can be evanescent on the outside of the guide and yet lines of magnetic field strength form closed loops in the plane containing the guide axis.

3. The Helically-Conducting Guide

Suppose that the guide is conducting in the helical direction ψ as shown in Fig. 2, and non-conducting in the direction normal to this. Thus the boundary conditions to be imposed on (3) and (5) are:—

(i) The tangential electric field must be continuous across the guide surface; i.e.,

$$\left.\begin{aligned} E_{z1} &= E_{z2} \qquad (r = s) \\ E_{\phi 1} &= E_{\phi 2} \qquad (r = s) \end{aligned}\right\} \quad .. \quad (7)$$

(ii) There is no electric field strength at the surface of the guide in the conducting direction; thus

$$\left.\begin{aligned} E_{z1} \sin\psi + E_{\phi 1} \cos\psi &= 0 \qquad (r = s + 0) \\ E_{z2} \sin\psi + E_{\phi 2} \cos\psi &= 0 \qquad (r = s - 0) \end{aligned}\right\} \quad (8)$$

(iii) The component of magnetic field strength in the direction of the helix must be continuous across the guide surface; thus

$$H_{z1} \sin\psi + H_{\phi 1} \cos\psi = H_{z2} \sin\psi + H_{\phi 2} \cos\psi \quad (r = s) \quad .. \quad (9)$$

Relations (7), (8) and (9) lead to four independent equations involving the coefficients A_1, B_1 and A_2, B_2 wherefrom upon elimination we obtain the equation

$$\frac{H_0^{(1)}(jus) J_0(hs)}{H_1^{(1)}(jus) J_1(hs)} \times \frac{uh}{j\omega^2 \mu_1 \kappa_1} = \chi \cot^2\psi \quad .. \quad (10)$$

where

$$\chi = \frac{us \dfrac{H_0^{(1)}(jus)}{H_1^{(1)}(jus)} + j\dfrac{\kappa_0}{\kappa} \, . \, hs . \dfrac{J_0(hs)}{J_1(hs)}}{us \dfrac{H_0^{(1)}(jus)}{H_1^{(1)}(jus)} + j \, . \, hs . \dfrac{J_0(hs)}{J_1(hs)}} \quad .. \quad (11)$$

and, from (2) and (5)

$$h^2 + u^2 = \omega^2 \mu (\kappa_1 - \kappa_0) \quad .. \quad .. \quad (12)$$

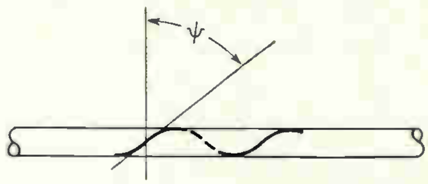

Fig. 2. *Cylindrical guide conducting in the direction of a helix.*

Thus, given the radius of the guide and the lay of the helix then from equations (10)–(12) the decay coefficient u could in principle be calculated; however, it is a laborious procedure. If $\kappa_1 = \kappa_0$ as in a travelling-wave valve[4] then $\chi = 1$ and (10) could be solved by graphical means. But if the guide were made by winding a bunch of wires in a helical manner around the circumference of a dielectric rod then, of course, $\kappa_1 \neq \kappa_0$ and a different approach would be necessary. The expression (10) simplifies notably if we assume that the guide radius is small and that the decay coefficient is small in comparison with h. We then obtain $\chi = \kappa_0/\kappa_1$ and the frequency equation (10) becomes

$$\frac{H_0^{(1)}(jus) J_0(hs)}{H_1^{(1)}(jus) J_1(hs)} uh = jk_0^2 \cot^2\psi \quad .. \quad (13)$$

This equation could be solved for u graphically but at this stage further approximations are legitimate. We may take

$$h \approx h_0 = \omega\sqrt{\mu(\kappa_1 - \kappa_0)} \quad .. \quad .. \quad (14)$$

and replace the Hankel functions occurring in (13) by their small argument approximations :

$$\text{Thus :—} \quad \left.\begin{aligned} H_0^{(1)}(jus) &\approx j\frac{2}{\pi}\log_e(0{\cdot}89us) \\ H_1^{(1)}(jus) &\approx -\frac{2}{\pi us} \end{aligned}\right\} \quad (15)$$

With these simplifications (13) reduces to

$$\xi \log_e \xi = -(0{\cdot}89)^2 \frac{J_1(h_0 s)}{J_0(h_0 s)} \cdot \frac{(k_0 s \cot\psi)^2}{h_0 s} \quad .. \quad (16)$$

where[2],[3] $\xi = (0{\cdot}89us)^2$

Now, the fundamental equation is[2]

$$\xi \log_e \xi = \eta \quad .. \quad .. \quad .. \quad .. \quad (17)$$

where

$$\eta = -2{\cdot}(0{\cdot}89)^2 k_0^2 s x_s \quad .. \quad .. \quad (18)$$

X_s = surface reactance of a guide carrying an E surface wave

and

$$Z_0 = \sqrt{\mu_0/\kappa_0} = 377 \text{ ohms.}$$

Thus, equating (16) and (18) we get

$$X_s = \frac{1}{2}\frac{Z_0}{\sqrt{1 - \kappa_0/\kappa}} \cdot \frac{J_1(h_0 s)}{J_0(h_0 s)} \cot^2\psi \qquad (\kappa_0 \neq \kappa_1) \quad .. \quad (19)$$

and

$$X_s = \frac{Z_0}{4} k_0 s \cot\psi \quad \text{if } \kappa_1 = \kappa_0 \quad .. \quad .. \quad (20)$$

We shall refer to (19) and (20) as the equivalent surface reactance of a helically-conducting guide. These formulae are simple to use and curves shown in Fig. 3 were calculated using equation (20).

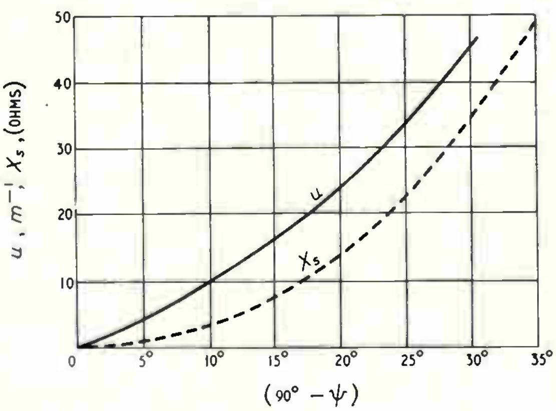

Fig. 3. *The radial propagation coefficient u and the surface reactance X_s as a function of the lay angle ψ.*

4. The E-H Surface Wave other than Progressive

In Section 2 we have established the possible existence of a progressive E-H surface wave. In practical applications, however, more often than not a partial standing wave will be encountered. We shall next enquire what is the field distribution of an E-H surface wave supported by a transmission line short-circuited at one end. Suppose the short-circuit occurs at $z = 0$ then the boundary condition to be satisfied at this point is $E_r(r,0) = E_\phi(r,0) = 0 \quad .. \quad .. \quad .. \quad (21)$

while the boundary condition to be satisfied at the surface of the guide is

$$E_{\phi 1}(s, z) = \tau E_{z1}(s, z) \quad .. \quad .. \quad (22)$$

where τ is a factor depending on the nature of the guide.* It is not difficult to show that the boundary conditions (21) and (22) cannot be simultaneously satisfied. The inference can be drawn that a *pure* E-H surface wave may exist as a travelling wave, but is not possible on a short-circuited transmission line. The physical reason for this is that a 'right-handed' E-H surface wave (surface wave supported by a right-handed helix) is reflected from a short-circuiting plate as a 'left-handed' E-H surface wave (capable of being supported by a left-handed helix) and this cannot be supported by a right-handed helical guide necessary for the support of the outgoing wave.

Nevertheless it is possible, at least mathematically, to have two right-handed/left-handed E-H surface waves travelling in opposite directions on a right-handed/left-handed helical guide, but the resultant field does not possess the character of a standing wave (where the transverse component of the electric vector exhibits successive nodes and anti-nodes). This field is an elliptically polarized E-H surface wave whose plane of polarization is turning clockwise/anticlockwise with respect to an observer moving along the line.

Acknowledgments

The author acknowledges gratefully helpful discussions with Professor H. M. Barlow and Dr. A. L. Cullen of University College, London.

REFERENCES

[1] G. Goubau. "Surface Waves and their Application to Transmission Lines", *J. Appl. Phys.*, 1950, Vol. 21, p. 1119.
[2] H. M. Barlow and A. E. Karbowiak. "An Investigation of the Characteristics of Cylindrical Surface Waves", *Proc. Instn elect. Engrs.* 1953, Vol. 100, Pt. III, p. 321.
[3] H. M. Barlow and A. L. Cullen. "Surface Waves", *Proc. Instn elect. Engrs*, 1953, Vol. 100, Pt. III, p. 329.
[4] J. R. Pierce. "Travelling Wave Tubes", 1950, D. van Nostrand Co., Inc., New York.
[5] H. Kaden. "Fortschritte in der Theorie der Drahtwellen", *Arch. elect. Übertragung*, 1951, Vol. 5, p. 398.
[6] Editorial. *Wireless Engineer*, July 1950, Vol. 27, p. 195.

* In the case of the helical guide it takes the form given by (8); i.e., $\tau = \tan\psi$.

TAPPED INDUCTANCES

Calculation of Tapping Points

By C. R. Cosens, M.A.

INDUCTORS for use at audio-frequencies are conveniently wound as 'Maxwell coils'; i.e., they are circular coils of square cross-section, such that the inner diameter of the coil is twice the side of the square. It is sometimes desirable to provide tappings at specified fractions of the total inductance, and it is the object of this note to derive a simple method of calculating at what fraction n of the total turns a tapping must be made in order that the inductance measured between the inner end of the winding and the tapping shall be a specified fraction l of the inductance of the whole Maxwell coil. The simple formulae derived give an accuracy of 3 parts in 1,000, without reference to tables; they are based on equations and tables in Chapter 13 of F. W. Grover's "Inductance Calculations," Van Nostrand, New York, 1946.

From equation (94) of this chapter we find that the inductance L_M (microhenrys) of a complete Maxwell coil of width b (cm), having N_M turns, is given by:

$$L_M = 0{\cdot}02549\, N_M^2 \times b \quad \ldots \quad (1)$$

whence, putting τ = number of turns per sq. cm. of cross-section,

$$b = 2{\cdot}083 \times (L_M/\tau)^{1/5} \quad \ldots \quad (2)$$

and then

$$N_M = \tau b^2 \quad \ldots \quad (3)$$

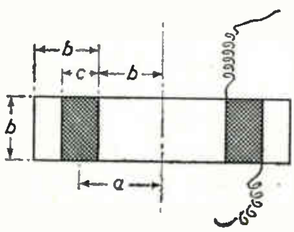

Fig. 1. *Sectional view of coil considered; full Maxwell coil shown in outline.*

The inductance of any circular coil of rectangular cross-section can be found in terms of the three dimensions a, b and c shown in Fig. 1, and of the turns N. For the special case of part of a Maxwell coil, from the inner end to the tapping, $2a = 2b + c$, or $2a/b = 2 + c/b$ (since the inner diameter of the coil is $2b$). The turns $N = \tau bc$, but for the whole Maxwell coil, to which the suffix $_M$ refers, $c_M = b$, so $N_M = \tau b^2$, hence $n = N/N_M = c/b$. It follows that the ratios

$$c/b = n,\ 2a/b = (n+2),\ \text{and}\ c/2a = n/(n+2) \quad (4)$$

MS accepted by the Editor, May 1953

can all be expressed in terms of the single variable n.

In terms of these ratios, Grover's Table 36 gives K ('Nagaoka's constant'), which takes account of the axial separation of the turns; and double-entry tables 22-25 give k, which takes account of their radial separation. Tabulating, to four decimals, to argument $n = 0{\cdot}0\ (0{\cdot}1)\ 1{\cdot}3$, these ratios, K, k, and $K' = K - k$, we have, from equation 99 (omitting a constant multiplier)

$$L \propto N^2 \times \left(2\frac{a}{b}\right) \times a \times K'$$

or

$$\frac{2L}{b} \propto N^2 \times \left(2\frac{a}{b}\right)^2 \times K' = N^2[(n+2)^2 K'] \quad (5)$$

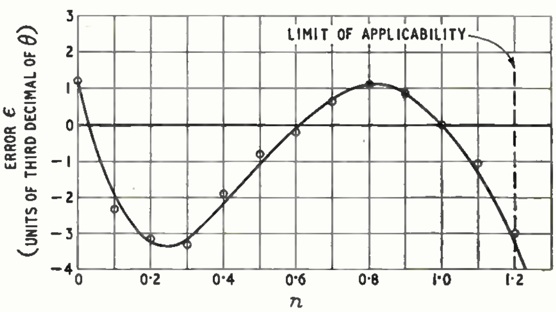

Fig. 2. *Error curve for the value of θ.*

For the complete Maxwell coil the square bracket [ ] is a constant, say β so that equation (5) gives $2L_M/b \propto N_M^2\beta$, and hence

$$l = \frac{L}{L_M} = \left(\frac{N}{N_M}\right)^2 \times [(n+2)^2 K']/\beta = n^2\phi, \quad (6)$$

say, where the numerical value of β is to be determined so that $\phi = [(n+2)^2\ K']/\beta$ shall equal 1 when $n = 1$, $l = 1$.

After some tedious computing we have a table of ϕ to argument n. But no table is satisfactory unless it can easily be interpolated; tables relating ϕ to l, n or n^2 all offer interpolation difficulties near zero, where the differences are not only large, but apparently divergent. The trouble is overcome if instead of ϕ we tabulate its reciprocal $\theta = 1/\phi$ to argument n. Having tabulated to four decimals, we round θ to three, and find, somewhat surprisingly, that we only incur errors between +1 and −3 in the third decimal place if we write

$$\theta = 1 + 0{\cdot}230\,(1-n),\ \text{where}\ 0 < n < 1{\cdot}2;\ 0 < l < 1{\cdot}5 \quad (7)$$

Since over this range $1{\cdot}23 > \theta > 0{\cdot}98$, the error is less than 3 in 1,000.

Then $l = n^2/\theta$, or $n = \sqrt{l\theta}$ .. .. (8)

When seeking n for given l, we can avoid the solution of a cubic in n by using the method of iteration, thus:

$$n_0 = \sqrt{l},\ \theta_r = 1 + 0{\cdot}230(1 - n_r),\ n_{r+1} = \sqrt{l\theta_r} \quad (9)$$

Convergence is rapid, n_4 nowhere differs from n_3 by more than half a unit in the third decimal place.

(Values of n and l greater than unity obviously refer to a coil having additional turns wound over and above those of a true Maxwell coil, this may sometimes be convenient.)

It may be of some slight (though purely academic) interest, to plot the errors of the empirical formula $\theta = 1 + 0{\cdot}230\ (1 - n)$. This is shown in Fig. 2 where

ϵ = (empirical) — (computed from Grover).

Since only four decimals and linear interpolation in Grover's tables were written throughout, plotted points may be expected to be unreliable within about $\pm 0{\cdot}03$.

The shape of the curve is strongly reminiscent of a cubic, with zero quadratic term. This suggests the possibility that if θ, defined as n^2/l, could be expanded in ascending powers of n, from the theoretical formulae used by Grover to compute his tables (they are not specified, presumably combinations of elliptic integrals) the coefficient of n^2 in the expansion $\theta = a + bn + cn^2 + dn^3 + \ldots$ would be found to vanish. This would explain the unexpected closeness of the linear approximation $\theta \approx 1 + 0{\cdot}230\ (1 - n)$ [better than 3 parts in 1,000]. Admittedly this is a shot in the dark.

For practical purposes, of course, since the number of turns will not, in general, form complete layers, as the formula assumes, accuracy better than $\pm 1\%$ would be quite illusory.

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.

Output Impedance Theorem

SIR,—I have noticed the great interest of *Wireless Engineer* in new circuit theorems, and I therefore submit the following:—

In the general case when a constant-voltage generator, c.v.g. or e.m.f., or a constant-current generator, c.c.g., in the equivalent circuit described by Thévenin or Norton, is independent of a voltage applied to the terminals AB of the equivalent circuit, the output impedance is defined as the inner impedance, with the added series or parallel impedance, contributed by the equivalent c.v.g. or c.c.g., interpreted as an impedance with the aid of the compensation theorem.

When the internal c.v.g. or c.c.g. is a function of the applied voltage V_{AB}, and proportional to it, this relation may be expressed via a known proportionality constant k. It is then possible to write down directly the output impedance Z_{AB}, if use is made of a new theorem, which has the form:

Theorem: If in a linear, active, one-pair terminal network, described by Thévenin's or Norton's theorems, the c.v.g. or the series injected voltage from the c.c.g., is proportional to the voltage V_{AB} applied to the terminals AB, and k times V_{AB}, the output impedance is the passive network output impedance, divided by $(k + 1)$.

A passive network obtains when all c.v.gs are short-circuited, and all c.c.gs open-circuited. This theorem makes unnecessary the in-between application of the compensation theorem (which application is usually made unconsciously, anyhow), and yields the answer more or less directly.

As an example, consider a simple cathode follower, Fig. 1(a), with its series equivalent circuit in Fig. 1(b), which is a Thévenin circuit. Since $k = \mu$, the above theorem states that $Z_{AB} = r_a/(\mu + 1)$, which is the correct result. If the parallel equivalent circuit for a cathode follower is used or, alternatively, the circuit used that results when the voltage source in Fig. 1(b) is represented as a current source, the Norton circuit in Fig. 1(c) results. Then the 'series injected' voltage from the c.c.g. is $(\mu V_{AB}/r_a) \times r_a = \mu V_{AB}$, thus $k = \mu$, and as before $Z_{AB} = r_a/(\mu + 1)$. Since in many feedback

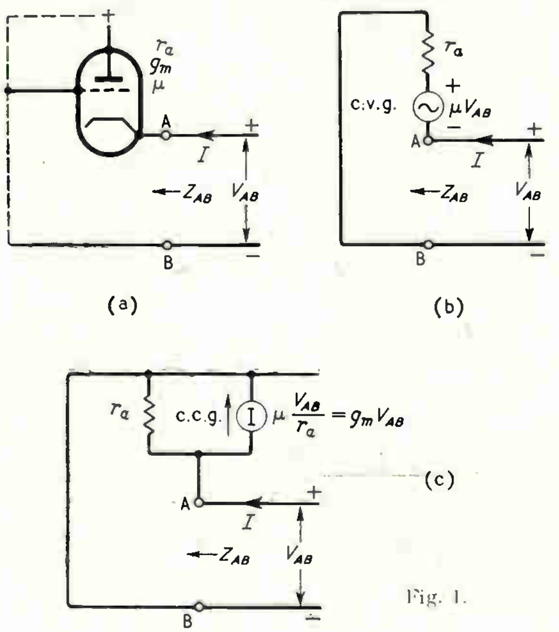

Fig. 1.

circuits k, or the general form of k, is known, Z_{AB} can be written down upon inspection, not necessitating calculation.

With reference to this theorem, I take the liberty to call to general attention the unfortunate fact that not only are there about as many formulations of Thévenin's and Norton's theorems as there are languages, but within each language, such as the English, there are about a dozen different wordings of each theorem. In so far as different languages permit, not only could one single formulation of each theorem be agreed upon, but actually *only one formulation for both of them*. Thus the "Thévenin-Norton theorem," (perhaps in the future called *"the General Theorem of the Equivalent Source"*), would read:

Theorem: A linear, active, one-pair terminal network providing between its terminals AB the open circuit voltage V_{AB}, or short-circuit current I, may be replaced by an *equivalent source* of impedance Z_{AB}, which is the passive network looking-in impedance through the terminal pair, provided with the series c.v.g. V_{AB}, or shunt c.c.g. I.

There are other pairs of network theorems which may be 'internationalized,' standardized, and unified, into c.v.g.-c.c.g. formulation in accordance with the principle indicated above.

HARRY STOCKMAN.

Scientific Specialties Corporation,
Boston 35, Massachusetts, U.S.A.
28th December 1953.

A Circuit Problem

SIR,—In a letter by R. N. Bracewell,[1] which appeared in the January issue of this journal, attention was drawn to the following electric circuit problem: To connect the smallest possible number of 1-ohm resistors into a two-terminal network in such a way that no two resistors carry equal currents and so that the resistance of the combination is 1 ohm. The trivial case of one single resistor is excluded.

Although the solution of this curious problem is unknown to me, I should like to point out that it is not identical with the network given by Bracewell. His network, consisting of 26 resistors, is in fact a re-drawing of a planar graph equivalent to the perfectly squared square of Fig. 9 in a paper[2] cited by Bracewell, which at that time (1940) was the simplest known. Since then, T. H. Willcocks[3], of Bristol, has constructed such a square of order 24. The corresponding network is shown in Fig. 1, built up from only 24 resistors, that is, two less than in Bracewell's case.

Some time ago I solved an analogous but simpler problem[4]: To connect the smallest possible number of 1-ohm resistors into a planar two-terminal network without series or parallel connections or zero currents so that the resistance of the combination is 1 ohm. This smallest number is 13. One of the two solutions to the second problem is shown in Fig. 2; the alternative is the dual of Fig. 2.

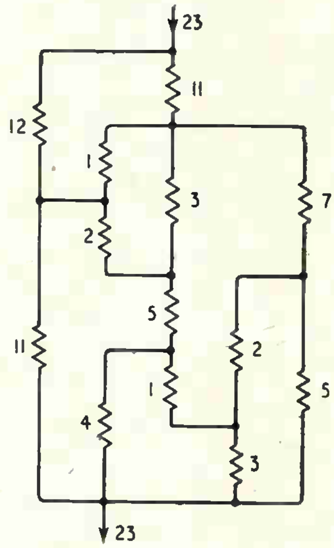

Fig. 2.

The numbers in Figs. 1 and 2 denote relative values of currents.

C. J. BOUWKAMP.

Philips Research Laboratories,
Eindhoven, Holland.
10th January, 1954.

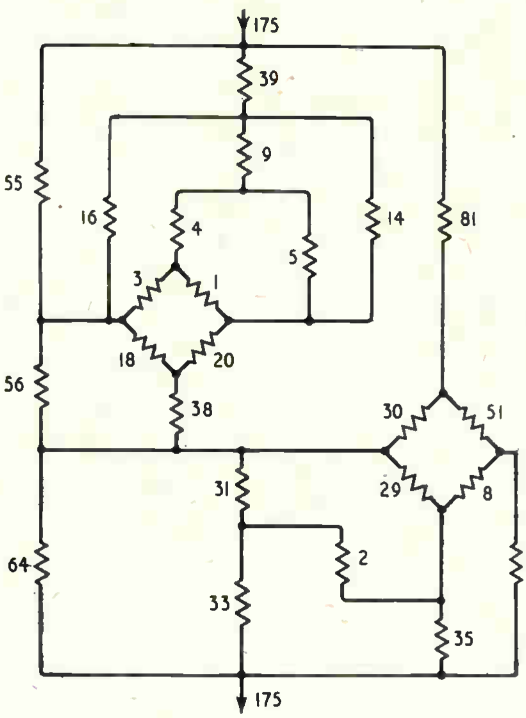

Fig. 1.

[1] R. N. Bracewell, *Wireless Engr*, January 1954, Vol. 31, p. 27.

[2] R. L. Brooks, C. A. B. Smith, A. H. Stone and W. T. Tutte, *Duke math. J.* 1940, Vol. 7, pp. 312-340.

[3] T. H. Willcocks, *Fairy Chess Rev.*, Aug./Oct. 1948, Vol. 7, *Canad. J. Math.*, 1951, Vol. 3, pp. 304-308.

[4] C. J. Bouwkamp, *Proc. kon. ned. Akad. Wet. Amst.*, 1946, Vol. 49, pp. 1176-1188, Ibid., 1947, Vol. 50, pp. 58-78, pp. 1296-1299.

"WIRELESS ENGINEER" INDEXES

The annual indexes for 1953, both to *Wireless Engineer* articles and to Abstracts and References, are included in this issue. They are placed at the end so that by opening the staples they can readily be removed for binding with the 1953 Volume.

When binding, it is usually most convenient to separate the editorial and abstracts pages of each issue and to assemble them together in two blocks. The order of assembly for binding should then be: Index to Articles and Authors, all Editorial pages, all Abstracts pages, Index to Abstracts. It has been found that this grouping considerably facilitates reference.

NEW BOOKS

Probability and Information Theory, with Applications to Radar

By P. M. Woodward, B.A. Pergamon Press, Ltd., 242 Marylebone Road., London, N.W.1. Pp. 128 + x. Price 21s.

This book is one of the Pergamon Science series of monographs under the general title of 'Electronics and Waves' and under the general editorship of D. W. Fry of Harwell. Mr. Woodward is a mathematician in the Theoretical Physics division of the Telecommunications Research Establishment at Malvern. He is a well-known expert on communication theory, and has a marked ability to explain a point clearly and concisely in a lecture or discussion. The same clarity pervades much of the writing of the present book, which is intended to explain the theory by easy stages for the reader who has no highly advanced mathematical knowledge but wishes to link practical intuition and experience with mathematical theory. The illustrative numerical examples are excellent; by following them in detail, the reader can be sure that he has grasped the application of basic principles to artificially simple cases.

But in order that the book could be published quickly and at a reasonable price, it has had to be drastically condensed. It is a very fine achievement by Mr. Woodward to have produced at all a book of 125 pages which covers in essence so much ground. At the same time there is necessarily a hard core of mathematics for which this condensation may tend to decrease an engineer's initially insufficient mathematical confidence in himself. Key steps by which relevant results can be derived from Mr. Woodward's equations are indicated, but the significance of some equations is not easy to grasp. This is especially true where the equations are in an unfamiliar form because Mr. Woodward has neatly and usefully introduced certain new functions.

The first two chapters are concerned with probability theory, waveform analysis and noise. "They provide the code in which so much of the mathematical theory of electronics and radar is nowadays expressed." Chapter 3 is a summary of Shannon's original work[1]. Chapter 4 is concerned with the reception of a signal in noise by a communication system, while Chapter 5 is concerned with radar reception. Chapter 6, dealing with the mathematical analysis of radar information, is a revised account of work carried out by Mr. Woodward in partnership with Mr. I. L. Davies[2]. In Chapter 7 the transmitted radar signal is considered for a stationary target.

Information theory is by its essential nature a mathematical subject, and this fact must be faced by anyone interested; Mr. Woodward's book is a great help to those who are capable of facing it. J. W. H.

[1] "The Mathematical Theory of Communication", by C. E. Shannon and W. Weaver. Urbana: University of Illinois Press, 1949.

[2] *Phil. Mag.*, 1950, Vol. 41, p. 1001, and *Proc. Instn elect. Engrs* (Part III), 1952, Vol. 99, p. 37.

Fundamentals of Electronic Motion

By Willis W. Harman. Pp. 319 + x. McGraw-Hill Publishing Co., Ltd., 95 Farringdon Street, London, E.C.4. Price 46s. 6d.

In a lengthy preface the author, who is Associate Professor of Electrical Engineering at Stanford University, says that this is a book on analysis and that "the fact that it is written about electron tubes is to a certain extent incidental." Furthermore, he says that "Many educators feel that the answer to the problem imposed by the fabulously increasing body of engineering knowledge is increased concentration on general philosophies, understandings and attitudes, with correspondingly decreased emphasis on current engineering practice and specific design techniques. This book is written in that spirit." The author goes on to say that electron-tube analysis best demonstrates the philosophies and techniques of mathematical physics, for "particle dynamics, electromagnetic fields, and wave phenomena are all represented". His primary object is "to nurture the ability to deal with new problems and new situations".

He intends the book for the user of electron tubes; to give a general understanding rather than specialized information. The presentation is mathematical, but the author claims that no initial knowledge of mathematics beyond the calculus is necessary. Other mathematical techniques are explained as they are needed.

Chapter 1 covers the basic laws of electric and magnetic fields and their mathematical expression in the form of partial differential equations. These are in the curl, div, grad form and include the Laplace and Poisson equations. Approximate methods of field determination are also treated.

Chapter 2 deals with the motion of an electron in a static electric field and includes electron lenses. Chapter 3 is entitled "Electron Properties and Sources". Starting with the electron microscope, one proceeds through a discussion on electron diffraction, the electron as a wave packet and electron motion in solids to thermionic emission. Next, in Chapter 4, comes electron motion in a magnetic field, and in Chapter 5, negative and positive space charge. Chapters on motion in time-varying fields, space-charge waves and velocity modulation, travelling-wave amplification, magnetrons, and relativistic electro-dynamics follow.

The book is not easy reading. It is one for study and it has its limitations although, within those limitations, it is very good. Its most valuable feature is the way in which problems are translated into mathematical form. This is where the novice usually runs into difficulty. Occasionally, a somewhat greater clarity of explanation would be desirable but, usually, this is all very well done.

It is also a good point that the solution of the resulting equations is carried out fairly fully. Since this is not a mathematical textbook, the author might have been forgiven for omitting this aspect. It is a fact, however, that it is much easier to learn mathematics in conjunction with an application of them than in the dreadfully arid atmosphere of the usual mathematics book. It is to the author's credit that he has evidently realized this.

On the whole, the author has done very well what he set out to do and has produced a very useful book. The student should be warned that in many cases things are not as simple as they are made to appear and one must disagree with the author's statement that the book is for "the user of electron tubes". In the ordinary meaning of these words the book is not for the user. It is for a rather specialized class of user who must know a great deal about what goes on inside a valve (and even this class will find it incomplete) but it is much more a basic textbook for the budding valve designer, who again will have to supplement it with a great deal of more technological material. W. T. C.

Relays for Electronic and Industrial Control

By R. C. Walker, B.Sc.(Lond.), A.M.I.Mech.E., A.M.I.E.E. Pp. 303 + xi. Chapman & Hall, Ltd., 37 Essex Street, Strand, London, W.C.2. Price 42s.

The opening words of the author's preface well explain the scope of this book; they are:—"The object of this book is to bring together in collected form for handy reference the principal features and potentialities of relays as switching devices". Although quite a lot of information about the mechanical and electrical sides of actual relays is included, the book is not so much for the designer of relays as for the designer of equipment which incorporates them. In spite of this, there is a great deal of information about the magnetic circuit, forms of contact, temperature rise of coils and so on.

The treatment is descriptive rather than analytic and is largely non-mathematical, but not entirely so.

W. T. C.

Data and Circuits of Television Receiver Valves

By J. JAGER. Pp. 216 + xi. Book IIIc of "Electronic Valves" in the Philips Technical Library. Cleaver Hume Press Ltd., Wright's Lane, Kensington, London, W.8. Price 21s.

A major part of this book comprises data on valves, types ECC81, EF80, EB91, PL83, PL82, ECL80, PL81, PY80, PY81, PY82, EY51, and c.r. tubes, types MW36-44, MW36-24 and MW43-43. The data are of similar type to those given in valve-makers' catalogues but are much more comprehensive.

In addition, there are several pages of text for each valve in which its television applications are described and typical circuits are given. The practice described is continental, with f.m. sound and negative modulation, so that certain parts of it are inapplicable to British television, in particular the detector and video circuits.

Static Electrification

Pp. 104 + iv. The Institute of Physics, 47 Belgrave Square, London, S.W.1. Price 25s.

Twenty-four papers presented at a Symposium held by the Institute of Physics on 25th-27th March, 1953.

PREMIUMS FOR TECHNICAL WRITING

The Radio Industry Council has announced that six further premiums for technical writing have been awarded. They are of 25 guineas each to:—

G. G. Gouriet, A.M.I.E.E., for his article "Spectrum Equalization" which appeared in *Wireless Engineer*, May 1953.

A. W. Keen, M.I.R.E., A.M.I.E.E., for his article "Triode Transformation Groups", *Wireless Engineer*, October 1953.

A. H. Beck, B.Sc.(Eng.), A.M.I.E.E., and A. D. Brisbane, for their article "A Cylindrical Magnetron Ionization Gauge", *Vacuum*, April 1953.

D. McMullan, M.A., Ph.D., for his article "The Scanning Electron Microscope and the Electron-Optical Examination of Surfaces", *Electronic Engineering*, February 1953.

H. M. Davis, B.Sc., A.R.I.C., and Joyce Seaborn, B.Sc., for their article "A Linear Sweep Cathode-Ray Polarograph", *Electronic Engineering*, August 1953.

J. R. Pollard, M.A., M.I.E.E., M.I.R.E., for his article "Selective Calling for Radio-Telephone Systems", *Electronic Engineering*, December 1953.

The presentation of the awards is to be made at a luncheon of the Public Relations Committee of the Radio Industry Council on 11th March 1954.

MEETINGS

I.E.E.

10th March. "A Study of some of the Properties of Matter affecting Valve Reliability", by E. A. O'Donnell Roberts, M.Sc., Ph.D.

22nd March. "Colour Television", by C. J. Hirsch.

23rd March. "An Experimental and Theoretical Approach to the Teaching of Electromagnetism using the Rationalized M.K.S. System", by F. A. Meier, M.A., at 6 o'clock.

5th April. "Technical Problems involved in Receiving Alternative Television Programmes", discussion to be opened by F. R. W. Strafford and K. I. Jones.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, and will commence at 5.30 except where otherwise stated.

Brit.I.R.E.

31st March. "Radio Astronomy", by R. Hanbury Brown, to be held at London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.2, commencing at 6.30.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for January 1954

Date 1954 Jan.	Frequency deviation from nominal: parts in 10^8 MSF 60 kc/s 1429-1530 G.M.T.	Frequency deviation from nominal: parts in 10^8 Droitwich 200 kc/s 1030 G.M.T.	Lead of MSF impulses on GBR 1000 G.M.T. time signal in milliseconds
1	−1·2	+4	−18·5
2	N.M.	+5	N.M.
3	N.M.	N.M.	N.M.
4	−1·2	+4	−22·3
5	−1·3	+5	−23·3
6	−1·2	+6	−25·2
7	−1·3	+6	−27·4
8 *	—	+1	—
9	1·1	0	N.M.
10	−1·3	+1	N.M.
11	−1·2	+1	−32·9
12	−1·3	+1	−34·0
13	N.M.	+2	−36·2
14	−1·3	+1	−38·1
15	N.M.	+2	−39·0
16	N.M.	+2	−41·6
17	−1·0	+2	−42·7
18	−1·1	+1	−44·6
19	N.M.	+3	−46·0
20	−1·1	+2	−46·7
21	−1·1	+2	−49·3
22	−1·1	+1	−51·0
23	−1·1	−2	N.M.
24	−1·0	+2	N.M.
25	−1·0	+5	−54·3
26	−1·0	+6	−55·5
27	−1·0	+6	−57·1
28	−1·0	+6	N.M.
29	−1·1	+6	−59·9
30	−1·1	0	N.M.
31	−1·0	−1	N.M.

The values are based on astronomical data available on 1st February 1954.

The transmitter employed for the 60-kc/s signal is sometimes required for another service.

N.M. = Not Measured. * = No MSF Transmission.

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

534.213.4 611

The Transient Motion of Sound Waves in Tubes.—J. D. Pearson. (*Quart. J. Mech. appl. Math.*, Sept. 1953, Vol. 6, Part 3, pp. 313–335.) Using Heaviside operators, a formula is obtained for the velocity potential in an infinite tube of uniform cross-section, and an asymptotic solution is derived by the method of steepest descent. For a tube of slightly variable cross-section a series solution is obtained. The case of a tube of nearly rectangular cross-section with a longitudinal harmonic distortion is considered in detail.

534.213.4 : 534.61 612

Experiments on the Propagation of Plane Sound Waves in Tubes.—D. E. Weston & I. D. Campbell. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 769–774.) For measurements in the adiabatic region an acoustic interferometer was used, with a magnetostriction source. Values of attenuation and velocity were determined with tubes of radius 0·013 cm and upward, at frequencies from 10 to 20 kc/s, for various tube materials and gases. The results confirm the modified Kirchhoff's formula. For the transition region between adiabatic and isothermal flow, measurements were made with tubes of radius 0·02 cm. The attenuation results are a little higher than the calculated values, the velocity results are in general agreement with theoretical values.

534.4 : 534.78 613

Speech Communication Research.—G. Fant. (*IVA, Stockholm*, 1953, Vol. 24, No. 8, pp. 331–337. In English.) The formation of a speech-communication research group of the Division of Telegraphy and Telephony of the Swedish Royal Institute of Technology is announced and an outline is given of its programme, which covers both engineering and linguistic aspects. Methods for measuring the efficiency of communication systems for handling messages in Swedish are being studied.

534.6 : 534.321.9 614

Acoustic-Optical Image Conversion.—G. Spengler. (*NachrTech.*, Sept. 1953, Vol. 3, No. 9, pp. 399–402.) A survey is made of the principal methods used in the visual presentation of sound and ultrasonic fields in solids, liquids and gases. The characteristics of an ideal converter system are discussed and the problem of eliminating spurious effects due to reflections from the converter is considered.

534.614 615

The Velocity of Sound in Air at Low Pressures.—D. E. Caro & L. H. Martin. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 760–768.) Loudspeakers were arranged at the ends of a tube and measurements were made of the time of transit of a pulse between two microphones mounted about 4 m apart in the wall of the tube, using the two loudspeakers alternately. Frequencies of 250 c/s and 1 kc/s were used. The mean velocity at 20°C is found to be 343·40 ± 0·02 m/s, and is independent of pressure over the range 5–760 mm Hg.

534.846.6 616

Investigation of the Acoustics of Large Halls using Models.—R. Lamoral & R. Trembasky. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 570–575.) 1-ms pulses of a 30-kc/s signal from an ionophone were transmitted via a tube to a 1/30-scale model. Echoes received on a miniature microphone in the model were recorded by c.r.o.

621.395.61 : 621.375.132 617

Note on the Application of Negative Feedback to Electroacoustic Devices.—P. Poincelot. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 576–577.) The improvement of the response curve of an electrodynamic microphone on application of negative feedback [1068 of 1950 (Chavasse & Poincelot)] is mentioned as an illustration of the advantages of this technique.

621.395.623.7 618

Power Capacity of Loudspeakers.—P. S. Veneklasen. (*Trans. Inst. Radio Engrs*, Sept./Oct. 1953, Vol. AU-1, No. 5, pp. 5–6.) The power-handling capacity is determined by observing the departure from linearity of the acoustic-output/electric-input curves, using octave bands of thermal noise. This method is under consideration for inclusion in a new I.R.E. standard, and comments are invited by the I.R.E. Electroacoustics Committee.

621.395.625.3 : 534.862 : 534.76 **619**

Stereophony in the Cinema.—J. Moir. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 6–9.) Systems using multiple magnetic sound tracks in conjunction with wide screens are described.

621.395.625.3 : 679.5 **620**

The Manufacture of Magnetic Tapes.—C. P. Fagan. (*Plastics*, Sept. 1953, Vol. 18, No. 194, pp. 323–324.) Materials and processes used in the manufacture of plastic-based tapes are described; advantages of polyester-resin base materials are mentioned.

AERIALS AND TRANSMISSION LINES

621.315.212 : 621.372.2 **621**

Highly Flexible Coaxial Cable with Helical Outer Conductor.—H. Weiss. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 516–526.) Cable sections suitable for replacing rotary joints are studied, the attenuation being of only secondary importance in this case. The amounts of power transmitted internally and externally are calculated separately; the externally transmitted power becomes zero for a helix pitch of 90° (i.e., ordinary coaxial cable). Dielectric and ohmic losses are discussed and the effect of the distribution of the outer conductor is investigated.

621.315.212 : 621.372.8 **622**

The Transverse Electromagnetic Lecher Wave in Coaxial Cable as a Degenerate Waveguide Wave.—H. Kleinwächter. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 467–469.) The transverse Lecher wave, which is a degenerate E_0 wave, is shown to be the only mode without an axial component which can be propagated in a coaxial cable without attenuation.

621.372.2 **623**

An Investigation of the Characteristics of Cylindrical Surface Waves.—H. M. Barlow & A. E. Karbowiak. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 321–328. Discussion, pp. 341–347.) An account is given of an experimental study using a frequency of about 10 kMc/s. For accurate work, the line used was about 4 ft long, short-circuited at both ends by transverse metal plates and excited at resonance, the usual launching horns being dispensed with. Descriptions are given of an axial standing-wave indicator and an instrument for determining the radial field distribution, both designed as far as possible to avoid disturbing the field. Measurements of the decay coefficients of No. 24 s.w.g. Cu wire thickly coated with polythene diverged widely from the values derived from Goubau's approximate theory. On revising the assumptions in the theory, values in agreement with the experimental results were obtained. The surface-wave resonator can also be used for measuring the surface reactance of corrugated surfaces.

621.372.2 **624**

Surface Waves.—H. M. Barlow & A. L. Cullen. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 329–341. Discussion, pp. 341–347.) Unified theory is presented for various forms of surface wave, namely the Zenneck wave, the radial cylindrical surface wave, and the Sommerfeld-Goubau or axial cylindrical surface wave. The significance of the Brewster angle of incidence, for which a wave suffers no reflection, is established. The parallel-plate transmission line is discussed and the transition is demonstrated from the TEM wave supported when the plates are close together to the two separate Zenneck waves when the plates are separated by a sufficient distance. The effect of bends in the line is considered and methods of reducing radiation are explained. Launching processes are surveyed with particular reference to the Brewster-angle approach.

621.372.2 : 538.566 **625**

The Types of Wave which may exist near a Guiding Surface.—J. Brown. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 363–364.) It is shown theoretically that the waves near a guiding surface can be classified as guided surface waves, evanescent fields or radiation fields. The evanescent fields differ from those in a transmission line or waveguide in that all values of attenuation constant are possible.

621.372.2.012.11 **626**

The Circle Diagram for Reflection Coefficient.—E. Thinius. (*Fernmeldetech. Z.*, Oct. 1953, Vol. 6, No. 10, pp. 468–469.) A chart is presented from which it is possible to obtain the curve for reflection coefficient as a function of frequency.

621.372.8 **627**

The Influence of Bends and Ellipticity on the Attenuation and Propagation Characteristics of the H_{01} Circular Waveguide Mode.—G. D. Sims. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 25–33.) Measurements made with a wave analyser, mainly at a wavelength of 3·2 cm, are reported. Jouguet's theory of propagation in a curved waveguide (3786 of 1947) is discussed and a brief account is given of experiments confirming it. The value of 3·4 db/km obtained for the attenuation in a long closed Cu waveguide, using a multiple-reflection technique, is about three times the theoretical figure; the difference is attributed to losses due to ellipticity and surface roughness.

621.372.9 **628**

Reflection of Electromagnetic Waves at Inhomogeneous Boundary Surfaces with a Periodic Structure Perpendicular to the Electric Vector.—R. Müller. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 492–500.) The particular cases considered mathematically include the incidence of an H_{10} wave in a rectangular waveguide on a slit diaphragm, the incidence of a plane e.m. wave on a stack of matching plates, and the incidence of an H_{10} wave on a discontinuous rectangular coupling section.

621.372.8 **629**

X-Band Rotary Joint.—H. J. Riblet & R. L. Williston. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 23–24.) A transition section for operation with high power takes the form of a tapered ridged waveguide; voltage s.w.r. is not greater than 1·02 over an 11% frequency band.

621.396.67 **630**

Some Optical Aspects of Antenna Radiation and Reception.—J. L. Salpeter. (*Philips tech. Commun., Aust.*, 1953, No. 3, pp. 3–10.) Similarities and differences between the e.m. radiations constituting light and those constituting radio waves are outlined; the former are usually noncoherent, the latter coherent. Differences in the design of radiators, reflectors and lenses for light waves and those for radio waves are explained on this basis.

621.396.67 + 621.372.8](083.74) **631**

I.R.E. Standards on Antennas and Waveguides: Definitions of Terms, 1953.—(*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1721–1728.) Standard 53 IRE 2S1.

621.396.676 632

Short Antennas for Mobile Operation.—J. S. Belrose. (*QST*, Sept. 1953, Vol. 37, No. 9, pp. 30–35, 108.) Simple numerical calculations are presented of the radiation resistance, efficiency, effective height, input reactance, etc., of unloaded and loaded vertical aerials near the ground. The results are in good agreement with those determined from field-strength measurements.

621.396.677.3 633

A High-Resolution Aerial System of a New Type.—B. Y. Mills & A. G. Little. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 272–278.) A horizontal aerial system, in the form of crossed arrays consisting of dipoles all of which are parallel to each other, is described. The experimental model, with 120-ft cross arms, operates at 97 Mc/s; the beam width is 8°. Work on a 1°-beam-width system for operation at about 80 Mc/s is in progress. The elementary theory and results of some radio-astronomy measurements are given.

621.396.677.31 634

A Simplified Calculation for Dolph-Tchebycheff Arrays.—G. J. van der Maas. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, p. 1250.) An alternative series is derived which is more suitable for the numerical calculation of the currents in individual elements than that given by Barbiere (1211 of 1952).

621.396.677.71 : 535.42 635

Babinet's Principle and the Slot Antenna.—J. L. Salpeter. (*Philips tech. Commun., Aust.*, 1953, No. 4, pp. 3–15.) Simple theory of the slot aerial is developed from optical diffraction theory. The complementary aspects of dipoles and slot aerials are discussed.

621.396.677.73 636

Calculation of the Gain of Small Horns.—E. H. Braun. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1785–1786.) A simple procedure is given for extending the range of the curves presented by Schelkunoff ('Electromagnetic Waves') to cover horns whose dimensions are small compared with λ.

621.396.677.73 : 621.396.677.8 637

Antennas Fed by Horns.—B. Berkowitz. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1761–1765.) Formulae are derived for the E- and H-plane radiation patterns as functions of illumination taper. The case of a lens or reflector associated with two contiguous horns stacked in either of the principal planes is investigated. By introducing an 'illumination factor', defined in terms of physical dimensions, the following properties are related:—(*a*) loci of half-power beam widths, nulls and side-lobe peaks; (*b*) illumination taper at edge of lens or reflector; (*c*) crossover power; (*d*) spillover power; (*e*) gain referred to the feed horn.

621.396.677.8 : 538.52 : 537.311.5 638

On the Current Induced in a Conducting Ribbon by a Current Filament Parallel to it.—Moullin. (See 704.)

621.396.677.85 639

Artificial Dielectrics having Refractive Indices less than Unity.—J. Brown. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 51–62; Summary, *ibid.*, Part III, Sept. 1953, Vol. 100, No. 67, pp. 319–320.) Two types are considered, the first comprising an array of conducting rods and the second a set of perforated parallel conducting plates. Both are designed for operation with a wave polarized so that its electric field is parallel to the conducting elements. The method of calculating the effective refractive index is indicated. The reflection occurring at the interface between the medium and free space is investigated.

AUTOMATIC COMPUTERS

681.142 640

Programme Design for the C.S.I.R.O. Mark I Computer: Part 1 — Computer Conventions.—T. Pearcey & G. W. Hill. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 316–334.) See also 1050 of 1953 (Beard & Pearcey).

681.142 641

Programme Design for the C.S.I.R.O. Mark I Computer: Part 2 — Programme Techniques.—T. Pearcey & G. W. Hill. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 335–356.) Part 1: 640 above.

681.142 642

Recent Electronic Computers and their Applications.—D. Dainelli & E. Aparo. (*Ricerca sci.*, Sept. 1953, Vol. 23, No. 9, pp. 1528–1549.) Digital computers are described and compared in respect of operating speed and structure.

681.142 643

A Mathematical Basis for an Error Analysis of Differential Analyzers.—K. S. Miller & F. J. Murray. (*J. Math. Phys.*, July/Oct. 1953, Vol. 32, Nos. 2/3, pp. 136–163.)

681.142 644

Analogue Computer for Aircraft Design.—(*Elect. J.*, 18th Sept. 1953, Vol. 151, No. 12, pp. 893–894.) A compact general-purpose instrument designed for economical quantity production.

681.142 : 531.77 645

An Analog-to-Digital Converter.—A. D. Scarbrough. (*Trans. Inst. Radio Engrs*, Sept. 1953, Vol. EC-2, No. 3, pp. 5–7.) A device for giving the angular position of a slowly rotating shaft as a binary number uses a mechanical counter which goes from zero to full capacity during one revolution of the shaft. The counter may comprise a series of cams associated with switches. On application of a reading pulse, the number registered by the counter is made available as a pattern of pulses, the arrangement being suitable as an input device for a digital computer.

681.142 : 621-526 646

Servo Systems for performing Mathematical Operations.—E. Wall. (*Product Engng*, Sept. 1953, Vol. 24, No. 9, pp. 134–140.) By combining servomechanisms with computing systems involving mechanical or electrical analogies, loading effects, which tend to introduce inaccuracies, are eliminated. An outline is given of procedures for addition and subtraction, determination of powers and roots, solution of triangles, and integration.

681.142 : 621.385 647

The Univac Tube Program.—T. D. Hinkelman & M. H. Kraus. (*Trans. Inst. Radio Engrs*, Sept. 1953, Vol. EC-2, No. 3, pp. 8–12.) Account of an integrated programme, starting with the design and initial selection, for ensuring reliable performance of valves in a large-scale computer.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.011.21.012.1 648

Rapid Parallel-Z Calculations.—L. Storch. (*Tele-Tech*, Aug. 1953, Vol. 12, No. 8, pp. 91–93 . 193.) Use of a special graph paper with both polar and rectangular coordinates facilitates the calculation. A ruler is the only instrument required in this graphical method.

621.3.012 : [621.318.42 + 621.372.4 649

The Calculation of Nonlinear Networks by means of Composite-Straight-Line Characteristics.—A. Hochrainer. (*Elektrotech. u. Maschinenb.*, 1st Sept. 1953, Vol. 70, No. 17, pp. 376–386.) Many circuit problems are simplified by substituting for an actual curved characteristic an approximation built up of rectilinear sections. Use of the method is illustrated by studying the characteristics of iron-cored coils with and without hysteresis, and with and without magnetic bias, and by analysing the free oscillations of a circuit including an iron-cored coil. Emphasis is laid on the point that the actual shape of the nonlinear characteristic is less significant than the simple fact of its deviation from linearity.

621.3.018.78 650

Harmonic and Intermodulation Distortion in "Power Law" Devices.—D. G. Lampard. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 3–7.) Explicit expressions are derived for the intermodulation components produced when two sinusoidal voltages are applied simultaneously to a device, such as a diode, whose transfer characteristic can be represented by a simple power-law formula. Results of practical importance in intermodulation-distortion testing are presented graphically.

621.315.332 + 621.316.8 + 621.319.4 651

Components for Severe Conditions of Use.—L. Podolsky. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 510–515.) A discussion of the factors to be considered in the design of capacitors and resistors for use under extreme temperature and humidity conditions, particularly when the components are required to be as small as possible. The use of ceramic-covered wire for the windings of transformers, etc., to withstand high temperatures is mentioned.

621.316.726.029.6 : 621.376.3 652

Frequency Discrimination and Stabilization of Square-Wave-Modulated Microwave Transmissions.—C. H. M. Turner. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 381–383.) The method described is a modification of that due to Aurell (M.I.T. Technical Report No. 30). The frequency of the oscillations from a reflex klystron is compared with the resonance frequency of a high-Q cavity, and a correction voltage depending on the frequency difference is fed back to the klystron reflector electrode via the modulator, where it is combined with the square-wave modulation voltage. The method of alignment of the microwave circuits is discussed in detail, and the effect of misalignment on the discriminator characteristics is shown.

621.316.86 : 537.312.6 653

Properties and Applications of Thermistors.—J. Bleuze. (*Onde élect.*, Aug./Sept. & Oct. 1953, Vol. 33, Nos. 317/318 & 319, pp. 497–509 & 578–590.)

621.316.89.029.5 654

Theory of the Boella Effect.—U. Tiberio. (*Alta Frequenza*, June/Aug. 1953, Vol. 22, Nos. 3/4, pp. 184–187.) A discussion of the mechanism causing the drop in the resistance of composition resistors at h.f. (1934 Abstracts, p. 454). A similar variation of resistance with frequency has been observed in electrolytic solutions (Debye-Falkenhagen effect). Comparative measurements were made on 30-kΩ resistors of three different types, namely (*a*) ceramic rod with helical carbon film ('low-resistance type'), (*b*) carbon/resin composition in ceramic case ('high-resistance type'), and (*c*) capillary tube containing a solution of $CuSO_4$ in water (electrolyte type). The Boella effect was most marked in case (*b*). Variation of resistance with electric field strength is also observed. The explanation given is alternative to that of Howe (3226 of 1935).

621.318.4.015.4 655

Natural Frequencies of Coils and Windings.—P. A. Abetti & F. J. Maginniss. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, p. 781.) Digest only. Calculations for an equivalent circuit consisting of reactors only were made using (*a*) punched-card equipment, (*b*) an a.c.-network analyser. The effect of neglecting the mutual inductance between elements, partly or completely, is shown graphically. Very close agreement with measured natural frequencies was obtained.

621.318.423.011 656

Air-Core Coil Design for Crossover Networks.—A. Meyer. (*Trans. Inst. Radio Engrs*, Sept./Oct. 1953, Vol. AU-1, No. 5, pp. 9–11.) Simple analysis is given for determining the correct wire gauge and optimum coil dimensions for specified values of Q and L. Results are shown in charts, and numerical examples illustrate their use.

621.318.435.3.025.3 : 621.375.3 657

Three-Phase Transductor Circuits for Magnetic Amplifiers.—A. G. Milnes. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 1–2.) Discussion on 949 of 1953.

621.318.57 : 621.314.7 658

Transistors: Theory and Application: Part 10—Switching Circuits using the Transistor.—A. Coblenz & H. L. Owens. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 186–191.) Counter circuits, relaxation oscillators, etc., using point-contact transistors are described. Part 9: 341 of February.

621.318.57 : 621.314.7 659

The Phase-Bistable Transistor Circuit.—R. H. Baker, I. L. Lebow, R. H. Rediker & I. S. Reed. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, p. 1760.) Corrections to paper noted in 3515 of 1953.

621.318.572 : 621.385.832 660

The E1T Decade Counter Tube.—(*Electronic Applic. Bull.*, May 1953, Vol. 14, No. 5, pp. 71, 76.) Corrections and addendum to paper noted in 603 of February.

621.372 661

A Note on the Network Postulates.—M. G. Arsove. (*J. Math. Phys.*, July/Oct. 1953, Vol. 32, Nos. 2/3, pp. 203–206.) Kirchhoff's law, that the sum of the potential differences about any closed path of branches is zero, is replaced by a version making no explicit references to paths of branches. The resulting law can be interpreted geometrically in terms of orthogonal subspaces of a certain vector space. The network definition given is readily shown to be invariant under changes of basis. The equivalence between the new definition and the classical one is established.

621.372 662

The Return-Difference Matrix in Linear Networks.—L. Tasny-Tschiassny. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 39–46.) Bode's concept of the 'return difference' is generalized by replacing the quantities concerned by matrices. A formula for the 'fractionated gain' is derived which is a generalization of Thévenin's theorem. Formulae are also derived for the stability of a circuit, for the variation of its output as a result of imperfections of the circuit elements, and for the input and output impedance. The method is particularly useful for analysing multiple-loop feedback circuits.

621.372 663

A Graphical Contribution to the Analysis and Synthesis of Electrical Networks.—O. P. D. Cutteridge. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 83–90. Digest, *ibid.*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 377–379.) "The contribution of the poles and zeros of a network function to the steady-state characteristics at real frequencies is considered by means of vectors, and the connection between attenuation and phase is thereby accentuated. Bode's relation between attenuation and phase in minimum-phase networks is derived by considering the contributions from individual singularities and using a known definite integral in a real variable. Details are derived for the construction of a series of templates, useful for finding pole-zero positions which yield certain attenuation, phase and delay characteristics, and vice versa." The method is illustrated by examples including the estimation of the phase and delay characteristics corresponding to the given attenuation characteristic of a minimum-phase wide-band amplifier.

621.372 664

The Relations between Circuit Pass Band and Signal-Build-up Time.—P. Poincelot. (*C. R. Acad. Sci., Paris*, 16th Nov. 1953, Vol. 237, No. 20, pp. 1217–1218.) Two pass-band criteria are discussed, namely (*a*) the bandwidth between the 3-db points and (*b*) the bandwidth defined in terms of spectral distribution of energy. It is shown that these are not uniquely related and that it is not possible to determine the time constant of a circuit solely from a knowledge of its bandwidth.

621.372 : 512.831 665

Voltage-Reference Node.—J. Shekel. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 6–10.) Description of a general method of analysing linear networks by nodal analysis without specifying the node to which all voltages are referred; the network can be represented by an indefinite admittance matrix, which can be brought to a definite form by omitting the row and column corresponding to a specified reference node. The method is useful for dealing with valve circuits with earthed-grid or earthed-anode stages or with no earthed electrodes.

621.372.2 : 534.321.9 666

Fused-Quartz Ultrasonic Delay-Line Memory.—D. A. Spaeth, T. F. Rogers & S. J. Johnson. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 151–153.) The digit-storage unit described is of the type comprising a slab of fused quartz providing a folded transmission path. Methods are indicated for eliminating spreading of the ultrasonic beam and mode conversion at the reflecting surfaces, thus reducing the intensity of spurious signals. An ultrasonic frequency of 40 Mc/s is used, and pulses with a dynamic range of 40 db can be stored at rates $>5 \times 10^6$/sec.

621.372.412 667

Some Notes on the Properties and Manufacture of Piezoelectric Quartz Crystals.—H. L. Downing. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1953, Vol. 14, No. 10, pp. 241–248.) The frequency stability, temperature coefficient and activity of quartz resonators are discussed, and the relation between these properties and the oscillation frequency of a circuit including the crystal is examined. The performance of some typical units is shown graphically.

621.372.413 668

Double Compensated Tunable Cavity.—T. S. Saad. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 25–28.) Two-frequency temperature compensation of hermetically sealed cavities filled with dry inert gas is described. A typical performance curve is shown.

621.372.5 + 621.375.23 669

Differentiating Circuits.—R. L. Ford. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 519–521.) Passive-network and feedback-amplifier types of differentiator are discussed, and the performances of two variants of the latter type are compared.

621.372.5 670

Determination of the Input Impedance of Linear Quadripoles by a Graphical Method.—M. Klobe. (*Nachr-Tech.*, Sept. 1953, Vol. 3, No. 9, pp. 421–424.) The data required are the characteristic impedance, the load or terminal impedance and the propagation constant of the quadripole. Two examples are worked out.

621.372.5 671

Build-Up Phenomena in Minimum-Phase Networks.—H. Holzwarth. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 473–477.) Wheeler's paired-echo method (3642 of 1939) is used to evaluate the network response to a single pulse and to a step voltage. The method is fundamentally a simplified application of the Fourier integral and is particularly useful for evaluating the distortion with a minimum of computation.

621.372.5 672

The Equivalent *Q* of RC Networks.—L. A. Wyatt: D. A. H. Brown: D. W. R. Wheeler. (*Electronic Engng*, Dec. 1953, Vol. 25, No 310, p. 534.) Further comments on 2919 of 1953 (Brown).

621.372.52 : 621.373.421 673

Theory of Twin-T RC Networks and their Application to Oscillators.—A. P. Bolle. (*J. Brit. Instn Radio Engrs*, Dec. 1953, Vol. 13, No. 12, pp. 571–587.) The conditions are established which the circuit elements must satisfy (*a*) for the network to produce infinite attenuation at one frequency, ω_0, and (*b*) for the output to be either in phase or in phase opposition with the input at ω_0 on varying two elements in a particular manner. The slope of the phase/frequency characteristic at $\omega = \omega_0$ is compared with that of a resonant *LC* circuit. One-valve oscillators incorporating such networks are discussed, with particular attention to distortion and stability. Results of measurements on an oscillator are compared with values calculated from theory.

621.372.542.22 : 621.372.412 674

Design Procedure for Crystal Lattice Filters.—W. C. Vergara. (*Tele-Tech*, Sept. 1953, Vol. 12, No. 9, pp. 86–87.) The technique of filter design is described and formulae for the electrical and mechanical constants of −18·5° X-cut quartz crystals are given. A bridge network of two divided-electrode crystals operating at 135 kc/s has an image impedance of 425 kΩ.

621.372.542.4.029.3 675

The Basic Design of Constant-Resistance Crossovers.—N. H. Crowhurst. (*Audio Engng*, Oct. 1953, Vol. 37, No. 10, pp. 21–22..110.) A simple mathematical analysis of the attenuation and phase characteristics for constant-resistance filters consisting of up to four elements. The frequency response is shown graphically.

621.372.543.2.029.42 676

A Band-Pass Filter for Low Frequencies.—A. H. Silcocks: G. W. Morris & P. G. M. Dawe. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 534–535.) Critical comment on 3237 of 1953 and authors' reply.

621.372.543.2.029.63 677

Duplexing Filter Design at 2000 Mc/s.—D. R. Crosby. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 31–38.) The cavity-resonator-type filters described are used in commercial communication equipment with transmitter and receiver operating with a frequency separation of 40 Mc/s; both receiving and transmitting filters have a bandwidth of 20 Mc/s.

621.372.56.029.6 **678**

A Comparison of the Properties of Certain Materials used in Low-Power Microwave Attenuators.—F. A. Benson & R. M. Pearson. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 502–505.) Results of measurements on Morganite, antistatic gutta-percha and carbon-loaded bakelite indicate that, if suitably sealed to prevent ingress of moisture, Morganite is the best from the point of view of stability.

621.372.57 : 621.3.018.75 **679**

D.C. Restoring of Variable-Width Rectangular Pulses.—J. van Bladel. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 524–525.) The well-known diode d.c. restoring circuit is discussed; the effect of deviations of source impedance, diode forward resistance and coupling capacitance from their 'ideal' values is investigated. The analysis is illustrated by a practical example.

621.372.57 : 621.385 **680**

Starvation Circuits and their Limitations.—P. J. Erdle. (*Sylvania Technologist*, Oct. 1953, Vol. 6, No. 4, pp. 85–88.) The under-running of valves is deprecated on technical grounds. The valves so operated generally tend to be unstable with variations in the supply voltage and with age.

621.373.4 : 621.316.726 **681**

A Controlled-Frequency Oscillator with Frequency 'Memory'.—J. van Bladel. (*J. sci. Instrum.*, Sept. 1953, Vol. 30, No. 9, pp. 299–301.) An arrangement is described in which a phase-comparison a.f.c. system is used to keep a first oscillator in tune with a second (pilot) oscillator. At a given instant the control loop is broken; thereafter the first oscillator continues to operate at the frequency at the cut-off instant, and subsequent frequency variations of the pilot oscillator are determined from measurements of the phase difference between the two oscillators. A practical circuit which holds frequencies in a band centered on 50 c/s is described.

621.373.4 : 621.385.3 **682**

Oscillator Characteristic Equation.—V. L. Talekar. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 3–6.) The equation for an oscillator circuit using a triode is developed in a form involving the differential coefficients of the dynamic resistance of the triode. Measurements on a Hartley oscillator are reported which are in good agreement with the theoretical results over most of the oscillation characteristic. Particular features of the oscillation characteristics are discussed, and the constants of the triode and the tank circuit are deduced from them.

621.373.4 : 621.396.822 **683**

Effect of Valve Noise on Oscillators.—A. Blaquière. (*C. R. Acad. Sci., Paris*, 23rd Nov. 1953, Vol. 237, No. 21, pp. 1316–1318.) The magnitudes of the valve shot effect and circuit thermal noise in oscillators are compared. When the oscillatory circuit is connected to the grid, the valve noise is relatively negligible; when the oscillatory circuit is connected to the anode, the valve noise preponderates.

621.373.42.029.63 **684**

Tuned Circuit Oscillators at U.H.F.—W. H. Elkin. (*Marconi Instrumentation*, Sept. 1953, Vol. 4, No. 3, pp. 50–54.) The design of a disk-seal-triode oscillator for frequencies up to 1 kMc/s is discussed. The causes of spurious resonance, and their elimination, are considered.

621.373.421 **685**

High-Frequency Resistance-Capacitance Oscillators.—G. W. Holbrook. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 509–511.) The relative merits of shunt-capacitance and shunt-resistance oscillators are discussed. The conditions of oscillation are analysed and the upper frequency limits are examined.

621.373.422/.43 **686**

Sinusoidal and Relaxation Oscillations sustained by Nonlinear Reactances.—R. S. Mackay. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1163–1167.) Descriptions are given of various combinations of nonlinear components (e.g., a saturating choke) with linear components (e.g., a capacitor) whereby negative-resistance characteristics can be obtained either of the type in which current is a single-valued function of voltage, or of the type in which voltage is a single-valued function of current. Practical applications are discussed.

621.373.52.029.4 **687**

A Transistor M.C.W. Adapter.—H. V. Braun. (*QST*, Sept. 1953, Vol. 37, No. 9, p. 51.) A miniature keyed a.f. *RC* oscillator is described.

621.375.2.024 : 621.314.58 **688**

Magnetic-Converter D.C. Amplifier.—W. A. Rote. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 170–173.) The d.c. amplifier described comprises a magnetic second-harmonic converter followed by an a.c. amplifier. D.c. signals with power as low as 2×10^{-15}W can be amplified.

621.375.2.029.4.012.3 **689**

Audio Nomographs.—J. F. Sodaro. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 200, 202.) Charts are presented for designing a pentode a.f. amplifier to have desired gain and bandwidth. The method involves the use of separate equivalent circuits for the upper, middle and lower parts of the frequency band.

621.375.232.4.029.63 **690**

Disk-Seal-Triode Amplifiers for Decimetre-Wavelength Radio Links.—A. Egger & G. Pusch. (*Fernmeldetech. Z.*, Oct. 1953, Vol. 6, No. 10, pp. 486–490.) Amplifiers for increasing the transmitter output power and receiver sensitivity in existing links are considered. Grounded-grid circuits are used; simple formulae are derived for gain and bandwidth, giving values in good agreement with experimental results obtained with Type-EC55 and Type-2C39A valves.

621.375.3 **691**

Magnetic Amplifier Circuits and Applications.—R. A. Ramey. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, pp. 791–795.) A chronological survey.

621.375.421 : 621.314.7 **692**

The Surface-Barrier Transistor: Part 3 — Circuit Applications of Surface-Barrier Transistors.—J. B. Angell & F. P. Keiper, Jr. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1709–1712.) The operating characteristics of the surface-barrier transistor are discussed and two amplifier circuits are described, namely (*a*) a wide-band low-pass amplifier, and (*b*) a band-pass amplifier for a centre frequency of 30 Mc/s. This type of transistor combines the ability to operate at v.h.f. with the low power consumption of the junction type. Part 2 : 896 below.

621.396.6.002.2 **693**

Mechanized Production of Electronic Equipment.—R. L. Henry & C. C. Rayburn. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 160–164.) An illustrated account is given of production methods developed at the National Bureau of Standards, based on modular design. A steatite wafer $\frac{7}{8}$ in. × $\frac{7}{8}$ in. × $\frac{1}{16}$ in. is used as a basic unit on which components are printed or mounted over printed wiring. Six of these wafers are automatically stacked and connected to form a plug-in unit. Automatic silver-painting, tuning, dip-soldering and testing machines are used. For other accounts see *Tech. News Bull. nat. Bur. Stand.*, Nov. 1953, Vol. 37, No. 11, pp. 161–170 and *Tele-Tech*, Nov. 1953, Vol. 12, No. 11, pp. 70–72..136.

621.396.6.002.2 **694**

Automatic Assembly of Electronic Equipment.—L. K. Lee & C. Brunetti. (*Elect. Mfg*, July 1953, Vol. 52, No. 1, pp. 97–109..308.) Description of a complete production line for a radar chassis; attaching machines fix components on a printed-circuit base plate.

621.396.6.002.2 : 621.357 : 621.315 **695**

A Flexible Plated Circuit.—E. R. Bowerman & R. F. Walton. (*Radio & Telev. News, Radio-Electronic Engng Section*, Sept. 1953, Vol. 50, No. 3, pp. 12–13.) The 'wiring', initially formed as a 0·001–0·003-in. thick, Cu electrodeposit on a stainless steel plate, is stripped off on a cloth-backed adhesive tape. The complete manufacturing process is described.

GENERAL PHYSICS

537.52 **696**

The Ignition Mechanism of an Electric Gas Discharge in a Transverse Magnetic Field at Pressures of 10^{-1}–10^{-8} Torr.—R. Haefer. (*Acta phys. austriaca*, July 1953, Vol. 7, No. 3, pp. 251–277.) Continuation of work noted in 112 of January. A nonuniform field is obtained by making the radius of the outer cylinder much greater than that of the inner. The ignition characteristic (ignition-voltage/magnetic-induction × electrode separation) obtained by calculation is compared with measurements in Ar; the agreement is good. The ionization coefficient is independent of pressure and the electron replacement coefficient is proportional to pressure. With high voltages and low magnetic fields the electrons are produced mainly by ionic bombardment of the outer cylinder and by ion collisions in the gas; with low voltages and high magnetic fields the electrons are produced mainly by ionic bombardment of the end surfaces. A formula relating the electron replacement coefficient to the ratio between the mean free path and the parameter of the cycloidal electron trajectory gives results in good agreement with those derived from the observed ignition characteristics.

537.52 + 523.72] : 621.383 **697**

Study of High-Frequency Fluctuations from Light Sources using Phototubes and Tuned Radio-Frequency Amplifiers.—K. Landecker & B. J. Robinson. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 737–742.) Observations have been made at frequencies up to 95 Mc/s, using two different amplifiers for the ranges below and above 25 Mc/s; the methods of connecting the photocell (R.C.A. Type 919) to the amplifiers are described. The spatial distribution of some types of oscillation along the axis of vapour discharges was investigated. Attempts to observe fluctuations of light from the sun have been made only during 'quiet' periods and have so far yielded negative results.

537.521.7 **698**

Calculation of the Behaviour of Sparks with Resistance and Self-Inductance in the Circuit.—W. Weizel. (*Z. Phys.*, 25th Sept. 1953, Vol. 135, No. 5, pp. 639–657.)

537.521.7 : 681.142 **699**

Analogue-Computer Solution of the Differential Equation for a Spark Gap.—A. Walther & K. J. Lesemann. (*Z. Phys.*, 25th Sept. 1953, Vol. 135, No. 5, pp. 658–664.) The differential equation derived by Weizel (698 above) is easily solved by means of the I.P.M.-Ott integrator.

537.533.8 **700**

Neutralization of Ions and Ionization of Atoms near Metal Surfaces.—L. J. Varnerin, Jr. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 859–863.) When an ion or an atom approaches a metal surface, neutralization or ionization processes are often possible. The Franck-Condon principle is applied in the determination of the probability of electron transfers. Such transfers are limited to definite ranges of separation from the surface. Most secondary-electron emission is due to an Auger-type process, the contribution due to de-excitation of metastable atoms being very small.

537.56 **701**

Ionization Phenomena in Gases.—A. von Engel & G. Francis. (*Nature, Lond.*, 31st Oct. 1953, Vol. 172, No. 4383, pp. 798–799.) A brief summary of papers presented at the conference held in Oxford in July 1953. The subjects discussed included the spark, arc, glow and h.f. discharges, G-M counters and fundamental processes.

537.562 **702**

Theory of Ionized Media with Distant Boundaries.—M. Hoyaux. (*Rev. gén. Élect.*, Sept. 1953, Vol. 62, No. 9, pp. 421–438.) Continuation of work noted in 381 of 1952. The theory is developed for a configuration in which the electrodes are relatively close while the boundaries are relatively distant. Experimental results confirm the theory. The solution of the differential equations involved, and summarized theory of the potential distribution in the mercury-vapour-rectifier arc are given in appendices.

537.564 **703**

Ionization of Gas by Electrons.—J. K. Knipp, T. Eguchi, M. Ohta & S. Nagata. (*Progr. theor. Phys., Osaka*, July 1953, Vol. 10, No. 1, pp. 24–30.) A statistical analysis is made of the ionization produced by an electron when it is absorbed in hydrogen. Linear integral equations are obtained for the average number and the mean-square fluctuations of the ion pairs. These are evaluated approximately for high values of incident energy.

538.52 : 537.311.5 : 621.396.677.8 **704**

On the Current Induced in a Conducting Ribbon by a Current Filament Parallel to it.—E. B. Moullin. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 379–381.) Digest only. The discussion presented makes use of results obtained previously [2723 of 1952 (Moullin & Phillips)] and constitutes one stage in the determination of the diffraction pattern obtained with a system of aerials in the presence of a metal reflector of arbitrary size and shape.

538.56.029.66 : 061.3 **705**

Microwave Optics.—E. Wolf. (*Nature, Lond.*, 3rd Oct. 1953, Vol. 172, No. 4379, pp. 615–616.) Account of a symposium held at McGill University, Montreal, in June 1953.

538.566 : 535.42/.43 706

Solution of Electromagnetic Scattering Problems as Power Series in the Ratio (Dimension of Scatterer)/Wavelength.—A. F. Stevenson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1134–1142.) The calculation of the successive terms in the series expressing the scattered field requires only the solution of standard problems in potential theory, together with the evaluation of certain potential integrals. The series can be calculated as far as desired if Laplace's equation can be solved, but the calculation is increasingly complex for successive terms. The special case of scattering by a perfect conductor is also considered and its relation to the problem of diffraction by an aperture in a conducting screen is indicated. Expressions for the distant field are derived.

538.566 : 535.42/.43 707

Electromagnetic Scattering by an Ellipsoid in the Third Approximation.—A. F. Stevenson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1143–1151.) The method described in 706 above is used to evaluate the first three terms of the power series in k ($= 2\pi\lambda$), viz. those in k^2, k^3 and k^4; the term in k^3 vanishes because of the symmetry of the scattering body. The result is expressed as the sum of two elliptic integrals, which are functions of the three principal axes of the ellipsoid. The special cases of the spheroid, perfectly conducting ellipsoid, perfectly conducting disk and of diffraction by an elliptical or circular hole in a perfectly conducting screen are considered.

538.566 : 535.42 708

The Vector Wave Function Solution of the Diffraction of Electromagnetic Waves by Circular Disks and Apertures: Part 1 — Oblate Spheroidal Vector Wave Functions. Part 2 — The Diffraction Problems.—C. Flammer. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1218–1231.) The vector wave functions considered are the solenoidal solutions of the vector Helmholtz equation. Oblate spheroidal vector wave functions are defined and the expansions for plane polarized waves in terms of them are obtained. A unique solution is obtained for the diffraction by an infinitely thin, perfectly conducting circular disk and by a circular aperture in a plane conducting screen. Two separate groups of these functions are combined to fulfil the condition $E_\phi = 0$ at the rims of the aperture and disk, using the spheroidal coordinate system η, ξ, ϕ.

538.566 : 535.42 709

Diffraction of Electromagnetic Waves by an Aperture in a Large Screen.—G. Bekefi. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1123–1130.) The approximate solution of the three-dimensional diffraction problem is obtained by using a single component of the Hertz vector. The results are applied to the calculation of the field in the plane of a circular aperture which is large compared with the wavelength. Experiments confirm some of the theoretical results.

538.566 : 535.42 710

Diffraction of Electromagnetic Waves by Two Parallel Half-Planes.—B. N. Harden. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 348–350.) The field of a plane wave diffracted by the edges of two parallel conducting sheets has been measured close to the diffracting edges for various spacings between the sheets. Experimental results for a spacing of one wavelength are compared with values derived from theory presented by Clemmow (1620 of 1951); the agreement is satisfactory.

537.5 711

Electronic and Ionic Impact Phenomena. [Book Review]—H. S. W. Massey & E. H. S. Burhop. Publishers: Clarendon Press, Oxford, 1952, 699 pp., 70s. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 851–853.) " . . . this work is likely to be the standard reference book on the subject for some time to come."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.5 : 621.396.969.3 712

The Radio Echo from the Head of Meteor Trails.—I. C. Browne & T. R. Kaiser. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 1–4.) Calculations based on diffraction theory give values for the intensity of head echoes in agreement with observation, and also indicate that the ratio between the intensity of the head echo and that of a specularly reflected body echo should be proportional to the radio wavelength and inversely proportional to the difference in range between these echoes. Other anomalous meteor echoes may arise from discontinuities associated with visual flares.

523.53 : 621.396.96 713

Radar Determination of the Height of Disappearance of Meteor Trails of Known Radiant.—P. Volmer. (*C. R. Acad. Sci., Paris*, 2nd Nov. 1953, Vol. 237, No. 18, pp. 1065–1067.) Observations were made during the period 11th–13th August 1952 at Meudon, using radar equipment operating on a wavelength of 4 m with a peak power of about 100 kW. Curves representing the time variation of the distance of the theoretically nearest reflection point for various values of the height h at which the trails disappear are shown together with observed nearest reflection points. From the comparison it is deduced that the mean value of h is about 85 km.

523.72 + 523.85] : 621.396.822 714

A Symposium on Radio-Astronomy at Jodrell Bank.—R. H. Brown. (*Observatory*, Oct. 1953, Vol. 73, No. 876, pp. 185–198.) Account of the proceedings at the symposium held in July 1953.

523.72 : 621.396.822 715

The Distribution of Radio Brightness over the Solar Disk at a Wavelength of 21 Centimetres: Part 2 — The Quiet Sun — One-Dimensional Observations.—W. N. Christiansen & J. A. Warburton. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 262–271.) Assuming the distribution over the solar disk to be circularly symmetrical at this wavelength, the derived radial brightness distribution shows marked limb-brightening. The observed distribution of brightness is in fair agreement with the calculations made from solar models involving a 10^4°K chromosphere and 0·3–3·0 × 10^6 K corona, provided that the coronal densities lie between 0·5 and 1·0 times the values usually quoted. Conclusive evidence of a quiet-level r.f. emission was obtained. Part 1: 3209 of 1953.

523.72 : 621.396.822 : 621.396.621 716

Two U.H.F. Radiometers (160 Mc/s and 9.350 kMc/s) and Some Radio-Astronomy Applications.—J. Arsac, E. J. Blum, J. H. Lestel & J. L. Steinberg. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 527–532.) Details are given of improved radio-noise receiving equipment used for continuing the experiments previously reported [3402 of 1953 (Steinberg)]; a power-supply unit stable to within 1 part in 10^4 for mains variations of ± 5%, a parabolic-reflector aerial for 9·35 kMc/s, and a dipole aerial array for 160 Mc/s are described. Measurements of the distribution of r.f. brightness over the sun are reported; these include observations made during the solar eclipses of 1951 and 1952.

523.746 717

Progressive Variation of the Shape of the Sunspot Curves.—A. Kiral. (*Naturwissenschaften*, Sept. 1953, Vol. 40, No. 18, pp. 477–478.) Statistical analysis of the sunspot numbers for the 30 eleven-year cycles since 1610 indicates that the asymmetry of the curves is increasing, thus giving support to Gleissberg's theory that there is another cycle with a period of the order of thousands of years.

535.325 : 551.510.52 718

Measurement of Variations in Atmospheric Refractive Index with an Airborne Microwave Refractometer.—H. E. Bussey & G. Birnbaum. (*J. Res. nat. Bur. Stand.*, Oct. 1953, Vol. 51, No. 4, pp. 171–178.) The cavity-resonator refractometer described is essentially the same as that used for previous measurements [2176 of 1951 (Birnbaum)]. Observations were made at heights up to 10 000 ft; examples of strip records obtained are reproduced. The variations were negligible for distances <5 m. Large increases of refractive index were observed on entering cumulus clouds, and intense fluctuations were noted within the clouds.

538.71 719

Airborne Magnetometer for determining All Magnetic Components.—E. O. Schonstedt & H. R. Irons. (*Trans. Amer. geophys. Union*, June 1953, Vol. 34, No. 3, pp. 363–378.) Description of the airborne vector magnetometer Type-1A, an enlarged and modified form of the instrument previously described by Felch et al. (220 of 1948).

550.38 : 551.510.535 : 621.396.11 720

Measurements of the Terrestrial Magnetic Field in the E Layer.—M. Cutolo. (*Nature, Lond.*, 24th Oct. 1953, Vol. 172, No. 4382, pp. 774–775.) Two methods are outlined, both based on determination of the gyro-frequency, which is related by a simple formula to the intensity H of the geomagnetic field in the lower part of the E layer. The first method is based on the double-hump resonance curve (2617 of 1950) and the second is based on the self-demodulation of radio waves at carrier frequencies near gyrofrequency (1758 of 1951). A table is given of values of H determined by these methods in Italy.

550.384 721

A Universal Time Component in Geomagnetic Disturbance.—R. P. W. Lewis & D. H. McIntosh. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 78–80.) Evidence of a universal time component in the diurnal variation of the geomagnetic disturbance is obtained from an analysis of K-index figures.

550.384 : 621.396.822.029.42 722

Low-Frequency Noise in the Range 0·5–20 c/s.—J. Aarons & M. Henissart. (*Nature, Lond.*, 10th Oct. 1953, Vol. 172, No. 4380, pp. 682–683.) Continuation of previously noted investigations [1628 of 1948 (Menzel & Salisbury) and 3408 of 1948 (Willis)] of the correlation between l.f. e.m. fluctuations and geomagnetic and solar phenomena. A pickup loop with an effective area of 257 m² was used with an amplifier having a gain of 160 db and a recorder with chart speed of 1 mm/s. An operating site with low-noise characteristics was chosen. Evidence was obtained of frequent storms in the noise-frequency range studied. A diurnal variation similar to that of the Cheltenham K indices was observed. Analysis indicates significant correlation between the l.f. noise and the 200-Mc/s solar noise observed 29 days earlier.

551.510.53 : 546.214 723

Daily Variation of Amount of Ozone in the Atmosphere.—K. R. Ramanathan & B. V. R. Murthy. (*Nature, Lond.*, 3rd Oct. 1953, Vol. 172, No. 4379, pp. 633–634.) Observations made at Mount Abu and Ahmedabad from Nov. 1952 to April 1953 showed a substantial increase of ozone during night hours, with rapid change-over from day to night values after sunset.

551.510.535 724

An Interpretation of Vertical-Incidence Equivalent-Height versus Time Recordings on 150 kc/s.—R. Lindquist. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 10–27.) The results of observations made in Pennsylvania, U.S.A., between January 1950 and April 1952 are shown graphically and discussed. One form of echo regularly observed during magnetically disturbed nights is due to one type of sporadic-E stratum. Recorded group and phase heights are compared and the differences compared with those predicted from theory. Results are also given of a preliminary investigation of the effects of solar flares.

551.510.535 725

Investigation of Travelling Disturbances in the Ionosphere by Continuous-Wave Radio.—Y. V. Somayajulu: B. R. Rao & E. B. Rao. (*Nature, Lond.*, 31st Oct. 1953, Vol. 172, No. 4383, pp. 818–820.) Continuous records of the signal intensity of c.w. transmissions over a 640-km path at 9·59 Mc/s and 4·92 Mc/s indicate an F-layer-disturbance velocity of 200–400 m/s. Transmission modes up to $2 \times$ F and $5 \times$ F, respectively, were observed. Simultaneous signal-intensity records of two in-line transmitters 240 km apart, operating at $\sim$ 7·5 Mc/s, showed a constant 8·5-min interval between the corresponding maxima, indicating a disturbance velocity of $\sim$ 230 m/s.

551.510.535 726

The Effect of Soft X-rays from the Solar Corona on the Formation of the Normal Ionospheric E layer.—G. Elwert. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 68–77. In German.) A calculation has been made previously of the soft X-rays from the solar corona (*Z. Naturf.*, 1952, Vol. 7a, No. 2, pp. 202–204). The results are used to determine the height at which the radiation is absorbed and the number of electrons present at this height under equilibrium conditions. The results agree well with observations of the normal E layer.

551.510.535 727

The Structure of the F Region of the Ionosphere.—A. A. Weiss. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 291–303.) The effects of temperature cycles, of a decay coefficient which is nonuniform with height, and of vertical tidal drifts are considered. The diurnal and seasonal height variations of the F_2 region are explained qualitatively by postulating, in addition to the vertical tides acting on an isothermal Chapman region, a diurnal temperature cycle. This requires a decay coefficient which does not change rapidly with height. On an alternative hypothesis involving discontinuities in the height gradient of the decay coefficient, tidal drifts are still necessary, but a diurnal temperature cycle is not of major importance.

551.510.535 728

World-wide Diurnal Variations in the F_2 Region.—C. W. Allen. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 53–67.) The chief characteristics of the f_0F_2 variations are described in terms of (*a*) the sunspot-minimum anomaly, (*b*) the sunrise anomaly and (*c*) the diurnal-range anomaly. These anomalies are evaluated quantitatively and extracted from the observations to determine the normal curves. The world distribution of these anomalies is studied and explanations are suggested. Variations of $h'F_2$ do not appear to be related either to the sunspot cycle or to the f_0F_2 variations.

551.510.535 **729**

The Electron Content of the F_2 Layer above Singapore.—B. W. Osborne. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 82–84.) A comparison of the estimated total ionization present in a unit column below the level of maximum ionization density of the F_2 layer in 1949 and in 1952.

551.510.535 : 550.386 **730**

Geomagnetic and Ionospheric Relationships.—R. P. W. Lewis & D. H. McIntosh. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 44–52.) The effect of a magnetic 'disturbance' on various geomagnetic and ionospheric parameters is investigated by choosing days on which the K_p sum is markedly different from that of the adjacent days. Most of the parameters show a peak or trough corresponding to that of the disturbance, following it with a delay of 0–18 hours. Particular attention is called to some peculiar seasonal effects, to features of the sporadic E layer at Slough and the vertical movement of the F_2 layer at Huancayo.

551.510.535 : 550.389 **731**

The Effect of the Magnetic Equator on the Ionization of the E_s Layer.—K. Rawer. (*C. R. Acad. Sci., Paris*, 2nd Nov. 1953, Vol. 237, No. 18, pp. 1102–1104.) Observations made at stations at different latitudes in Africa and Europe are analysed. Daytime values of fE_s show a pronounced maximum at the magnetic equator. Observations of the E_s blanketing frequency indicate that the E_s minimum-ionization ceiling is not subject to the effect, which exists only for the ionization clouds.

551.510.535 : 551.55 **732**

Winds in the Ionospheric Regions.—S. Deb. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 28–43.) A model for the region between 100 and 400 km height is constructed from considerations of the temperature gradients and the observed wind velocities. According to this model, the wind is south-west in the E and F_1 regions and north-east or east in the F_2 region; its velocity increases from 50 m.p.h. at 100 km to 200 m.p.h. at 200 km. There is a seasonal variation in the magnitude of the velocity, but the model does not involve any diurnal or seasonal changes of direction such as have been reported by observers.

551.510.535 : 621.396.11 **733**

Results relating to the Critical Frequency and the Transmission Factor of the Ionosphere F_1 Layer.—Theissen. (See 831.)

551.594.4 : 621.396.11 **734**

A Note on Auroral Interaction.—N. C. Gerson. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 81–82.) The modulation of a radio wave due to a moving auroral reflecting screen is discussed.

LOCATION AND AIDS TO NAVIGATION

621.396.93 **735**

H.F. Direction Finding.—S. B. Smith & H. G. Hopkins. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 11–14.) A comparison is made of the error components with (*a*) pulse transmissions and (*b*) c.w. transmissions, with particular reference to the performance of Adcock c.r. direction finders operating at frequencies near 8 Mc/s and in the absence of a ground ray. The results presented refer to transmission distances from about 400 to 2 000 km and indicate that pulse operation will normally be at least as accurate as c.w. operation; in the most favourable circumstances for pulse operation (i.e. when a direct first-order echo via the E or E_s layer can be used) the expected ratio of pulse variance to c.w. variance is about 1/3 for single snap bearings.

621.396.93 **736**

An Analysis of Errors in Long-Range Radio Direction-Finder Systems.—J. G. Holbrook. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1747–1749.) A rigorous mathematical analysis is made of errors usually encountered with a newly installed fixed Adcock d.f. station. The effect of variations in the aerial spacing is discussed particularly.

621.396.96 **737**

A Theory of Target Glint or Angular Scintillation in Radar Tracking.—R. H. Delano. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1778–1784.) "A theory is presented to describe the statistical aspects of tracking a complex isolated structure, such as an aircraft or naval vessel, by radar. The results are expressible in simplest form when the target subtends an angle small compared with the beamwidth. Other situations require special consideration and treatment, but can be attacked by the same general methods. However, when the angle subtended by the target is small, a single description applies to all radar tracking systems. An apparent and an effective radar center are defined and their statistical properties derived. Special treatment is given to additional noise arising in conical scanning due to amplitude fluctuations as such. The theory provides information relating to the spectra as well as to the probability densities and r.m.s. values of the pertinent quantities. It must be understood that the theory is approximate, is based on a particular model of the target, and leaves the determination of certain critical parameters to experiment in the case of any particular target."

621.396.96 **738**

The Effective Number of Pulses per Beamwidth for a Scanning Radar.—L. V. Blake. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, p. 1785.) Addendum to paper noted in 2671 of 1953.

621.396.96 : 551.578 **739**

Radar Displays of Atmospheric Precipitation.—B. Birardi. (*Alta Frequenza*, June/Aug. 1953, Vol. 22, Nos. 3/4, pp. 146–160.) Theory of the reflection of radio waves by precipitation is presented and an illustrated description is given of results obtained at the Research Centre for Microwave Physics at Florence. The future research programme is outlined.

621.396.96 : 621.39.001.11 **740**

Radar Detection and Information Theory.—U. Tiberio. (*Alta Frequenza*, June/Aug. 1953, Vol. 22, Nos. 3/4, pp. 161–183.) Radar operation is analysed by a statistical method; errors in range and direction are considered. The common ground between the theory of radar and communication is demonstrated by a discussion of automatic and Doppler-effect radar systems.

621.396.962.3 : 621.396.812.3 **741**

Interpretation of the Fluctuating Echo from Randomly Distributed Scatterers: Part 1.—J. S. Marshall & W. Hitschfeld. (*Canad. J. Phys.*, Sept. 1953, Vol. 31, No. 6, pp. 962–994.) The random fluctuations in the radar echo are investigated statistically and by analogue computation. The results are interpreted in terms of physical methods of reducing their effect. Thus, continuous averaging and limited averaging by the receiver or the A-scope display tube (by superposition of traces) is considered. The precision and the method of measurement of the intensity of the echo from steady and moving targets against a fluctuating noise background are also discussed.

621.396.962.3 : 621.396.812.3 : 551.578 **742**

Interpretation of the Fluctuating Echo from Randomly Distributed Scatterers: Part 2.—P. R. Wallace. (*Canad. J. Phys.*, Sept. 1953, Vol. 31, No. 6, pp. 995–1009.) Echoes from atmospheric precipitation are considered. The method of averaging independent signals is compared with that of continuous averaging. With frequency variation, effectively independent observations from a given region can be obtained. The variation of the signal as the reflection region recedes continuously or as the beam sweeps laterally, is studied. The Markoff method is used throughout. Part 1: 741 above.

621.396.963.3 **743**

Information Cells on Intensity-Modulated C.R.T. Screens.—D. Levine. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1766–1768.) Analysis of screen excitation is based on the assumption that the distribution of the electrons across the beam is Gaussian. It is assumed that two identical radar pulses are just resolvable when they are spaced on the screen so that the crossover of their charge distributions occurs at 40% of the peak intensity; the distance between the 40% points defines the size of the 'information cell'. A specific number of information cells is associated with each type of c.r. tube for a given pulse length and maximum beam current.

621.396.963.8 **744**

Passive Radar Responder.—L. de Magondeaux & R. de Magondeaux. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 533–539.) The arrangement described consists essentially of a resonator associated with a crystal which, when excited by incident pulses of radiation at a resonance frequency, re-radiates between these pulses the energy abstracted from them. In its simplest form the resonator comprises a $\lambda/2$ dipole with the crystal at its midpoint. Using a quartz crystal with a fundamental frequency of 40 Mc/s, the highest practical operating frequency is the harmonic at 200 Mc/s. Possible applications are discussed under three headings, namely (*a*) those based on the individual character of the response, (*b*) those making use of the time delay of the response, and (*c*) those involving modulation of the response.

621.369.969.11 **745**

Doppler-Effect Omnirange.—P. G. Hansel. (*Proc. Inst. Radio Engrs.*, Dec. 1953, Vol. 41, No. 12, pp. 1750–1756.) An omnirange is described in which the transmitting aerial is caused either to move or to appear to move along a circular path, thus producing low-deviation f.m. by Doppler effect. Deviation expansion and selective degeneration in an a.f.c. circuit are used at the receiver to detect the directional signal in the presence of f.m. noise. Advantages claimed for the system include improved resolution, accuracy and ease of multiplexing.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.787.6/.7 **746**

High-Resolution Micromanometer.—(*Tech. News Bull. nat. Bur. Stand.*, Sept. 1953, Vol. 37, No. 9, pp. 140–142.) An instrument designed by Perls, Kaechale & Goalwin, and capable of measuring differential pressures down to $0\cdot03\ \mu$ of Hg, uses a capacitance-type pickup with a thin diaphragm and a capacitance bridge driven by a 500-kc/s oscillator.

533.56 **747**

A Portable High-Vacuum System.—V. C. DeMaria. (*Sylvania Technologist*, Oct. 1953, Vol. 6, No. 4, pp. 96–97.) Outline description of a portable diffusion pump suitable for maintaining pressures down to $\sim 10^{-6}$ mm Hg.

535.215.3 : 538.639 : 546.289 **748**

Photoelectromagnetic and Photodiffusion Effects in Germanium.—T. S. Moss, L. Pincherle & A. M. Woodward. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 743–752.) When a slab of Ge is illuminated, a potential gradient is created in the direction of illumination, due to the difference between the electron and hole mobilities (photodiffusion effect). If a magnetic field is applied perpendicular to the direction of illumination, a potential gradient is created in the direction perpendicular to both field and illumination (photoelectromagnetic effect); voltages as great as 0·5 V have been obtained. The saturation value of the photoelectromagnetic voltage provides a convenient measure of the surface recombination velocity. Theory and experimental details are given.

535.37 **749**

Studies on the Concept of Large Activator Centers in Crystal Phosphors.—J. Ewles & N. Lee. (*J. electrochem. Soc.*, Sept. 1953, Vol. 100, No. 9, pp. 392–407.) A study in three parts, under the headings (*a*) dependence of luminescence efficiency on concentration of activator; size of luminescent centres; (*b*) effects of concentration of activator, of temperature, and of flux on the excitation and emission of CaO:Bi phosphors; (*c*) preparation and properties of CaO phosphors with eleven different activators.

535.37 **750**

The Luminescence of Alkaline-Earth Polysulphides.—H. Gobrecht & D. Hahn. (*Z. Phys.*, 25th Sept. 1953, Vol. 135, No. 5, pp. 523–530.)

537.226 : 546.431.82 **751**

The Dielectric Properties of Barium-Titanate Single Crystals in the Region of their Upper Transition Temperature.—L. E. Cross. (*Phil. Mag.*, Oct. 1953, Vol. 44, No. 357, pp. 1161–1170.) A determination was made of the ferroelectric hysteresis and the dielectric constant over the temperature range 20°–150°C. The ferroelectric transition in untwinned crystals, at $\sim$ 120°C, is a thermodynamically first order transition; in twinned crystals different regions transform at different temperatures. In untwinned crystals hysteresis is re-introduced at temperatures in a small range above the transition temperature by application of a sufficient electric field. The forms of the hysteresis figures are explained in terms of Devonshire's theory (663 of 1950).

537.226.2 : 537.29 : 621.315.616 **752**

Variations of the Dielectric Constant of some Plastics as a Function of the Electric Field.—G. Mesnard & L. Eyraud. (*C. R. Acad. Sci., Paris*, 30th Nov. 1953, Vol. 237, No. 22, pp. 1406–1407.) Measurements made using a double-heterodyne method are outlined; the material under test constituted the dielectric of a capacitor in a Hartley oscillator circuit, and was subjected to a unidirectional electric field of variable strength. Relative variations of the order of 5×10^{-6} in the value of the dielectric constant could be detected. Results obtained with vinyl chloride, polyethylene, cellophane and other plastics are reported.

537.311.33 **753**

A More Exact Treatment of the Equations describing Dielectric Relaxation and Carrier Motion in Semiconductors.—J. Keilson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1198–1200.) An exact treatment of the linearized equations of hole and electron flow in a homogeneous semiconductor leads to an expression for the polarization attributable to local variations in conductivity. The corrections to the previously obtained values for the effective mobility and the diffusion coefficient are of the order of τ_r/τ where τ_r is the relaxation time and τ is the lifetime. These corrections are negligible for semiconductors.

537.311.33 : 546.281.26 754

The Infrared Absorption Spectrum of Silicon Carbide.—A. K. Ramdas. (*Proc. Indian Acad. Sci. A*, April 1953, Vol. 37, No. 4, pp. 571–577.) The transmission spectra of 12 specimens were studied over the range 1–20 μ. The results are discussed in relation to X-ray determinations of the structure.

537.311.33 : 546.289 755

Thermal Acceptors in Vacuum-Heat-Treated Germanium.—S. Mayburg & L. Rotondi. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1015–1016.) The Ge single-crystal specimen was heated by passing a current directly through it, and was cooled by radiation. The value found for the concentration of acceptors differed by as much as a factor of 80 from results reported by workers using other methods of vacuum heat treatment. Reasons are advanced for concluding that the observed acceptors are lattice vacancies and not impurity atoms.

537.311.33 : 546.289 756

Infrared Absorption of *p*-type Germanium.—W. Kaiser, R. C. Collins & H. Y. Fan. (*Naturwissenschaften*, Sept. 1953, Vol. 40, No. 18, p. 479.) Measurements were made over the wavelength range 1·5–35μ, using specimens with resistivities from 0·04 to about 10 Ω.cm. The characteristic absorption spectrum obtained at room temperature is much more complex than for *n*-type Ge. Weak absorption bands were found at about 2·9μ and 4·5μ, and a strong wide band centred at about 20μ. Modified curves obtained at 5° and 77°K are also shown and discussed.

537.311.33 : 546.824-31 757

Electrical Properties of Titanium Dioxide Semiconductors.—R. G. Breckenridge & W. R. Hosler. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 793–802.) Measurements of resistivity and Hall coefficient in the temperature range − 190°C to + 500°Cwere made on ceramic and single-crystal rutile specimens with resistivities between 0·1 and 100 Ω.cm. From these measurements, which were made for two different crystal orientations, the variations of electron mobility and charge-carrier concentration with temperature were deduced. The mobility data can be explained in terms of scattering, with the effect of lattice vibration predominant at high temperatures, and that of ionized impurities predominant at lower temperatures. A large effective electron mass is deduced from the mobility values, indicating that the specimens were not degenerate in the temperature range studied, in spite of the large number of charge carriers. The charge-concentration variation found suggests that two types of donor centres, possibly oxygen ion vacancies are present.

537.311.33 : 548.55 : 546.682.86 758

Hall Effect and Conductivity of InSb Single Crystals.—M. Tanenbaum & J. P. Maita. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1009–1010.) Measurements on three samples over a range of temperatures are reported, a reversal in sign of the Hall coefficient occurring in two cases, at 155° and 182°K respectively. The deduced value of the energy gap at room temperature is 0·18 eV; this is in agreement with that obtained from infrared-absorption measurements.

537.311.33 : 621.314.7 759

The Surface-Barrier Transistor: Part 5 — The Properties of Metal-to-Semiconductor Contacts.—Schwarz & Walsh. (See 895.)

537.312.8 760

Galvano-Magnetic Effects at High Frequencies.—B. Donovan & E. H. Sondheimer. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 849–851.) A theoretical investigation of the variation of resistivity of a semi-infinite metal with the frequency of an electric field parallel to the surface, in the presence of a magnetic field perpendicular to the surface.

537.533 : 546.78 761

Crystallographic Variations of Field Emission from Tungsten.—M. K. Wilkinson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1203–1209.) Emission from a tungsten single crystal was investigated photometrically at pressures around 10^{-12} mm Hg. The experimental method and, in particular, the vacuum technique, are described and the results are tabulated and shown graphically.

537.533.8 : 537.311.33 762

Secondary Electron Emission from Impurity Semiconductors.—H. Gobrecht & F. Speer. (*Z. Phys.*, 25th Sept. 1953, Vol. 135, No. 5, pp. 602–614.) Measurements were made on four Ge crystals with different impurities and electrical properties. A monotonic increase up to 7% in the secondary-emission factor was observed to accompany an increase up to $1·5 \times 10^3$ in conductivity. This increase is attributed to the increase of impurity concentration accompanying the increased conductivity. The decrease in secondary emission, to be expected as a result of the increased number of charge carriers, is masked. The type of conduction and the nature of the impurity do not affect the secondary emission. Measurements made on Ge and Se evaporated layers with and without impurities confirmed the above results. Secondary-emission curves were also obtained for evaporated layers of the four impurity metals used, namely Ga, Sb, Tl and Bi.

538.221 763

On the Nature of Ferromagnetism in Pyrrhotite.—K. Alexopoulos & A. Theodossiou. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 753–759.)

538.221 764

A Study of Bitter Figures on the (110) Plane of a Single Crystal of Nickel.—L. F. Bates & G. W. Wilson. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 819–822.)

538.221 765

A Proposed Structure for Certain Domain Configurations on a Single Crystal of Nickel.—G. W. Wilson. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 840–841.)

538.221 766

Microwave Resonance Absorption in some Ferromagnetic Manganese Compounds.—G. D. Adam & K. J. Standley. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 823–835.)

538.221 767

Magnetic Viscosity in Platinum Cobalt.—A. W. Simpson & R. H. Tredgold. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 805–807.) Experimental results indicate that this alloy obeys the general relation for ferromagnetic materials found by Barbier (1661 of 1950).

538.221 768

Magnets and Magnetism — Recent Developments.—W. Sucksmith. (*Brit. J. appl. Phys.*, Sept. 1953, Vol. 4, No. 9, pp. 257–262.) Ferromagnetic materials, including oxides, are discussed.

538.221 769

Measurement of Permeability Tensor in Ferrites.—J. O. Artman & P. E. Tannenwald. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1014–1015.) Preliminary report on an experimental method of determining the off-diagonal tensor components of permeability which involves the splitting of degenerate cavity modes in a magnetic field.

538.221 770

A Comparison of the Powder Patterns on a Sample of Grain-Orientated Silicon-Iron with those obtained on a Single Crystal.—L. F. Bates & A. Hart. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 813–818.)

538.221 771

The Permeability of Silicon-Iron.—E. Both. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, p. 797.) Digest only. The Si/Fe alloy described has an initial permeability of 1 500 and an incremental permeability value ~0·5% per millioersted; the corresponding values for Ni/Fe alloys are 2 000 and 0·2%.

538.247 : 621.318.2 772

Investigations of Aging Processes in Permanent Magnets.—K. J. Kronenberg. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 321–329.) The changes in remanence due to the application of direct and alternating magnetic fields and a variation in the form factor by short-circuiting with a soft iron bar, were investigated experimentally and the results are presented graphically. The magnets investigated were made of tungsten steels, cast and sintered alnic, alnico and iron dust. The remanence of alnic alloys, the most stable magnets, decreased with increase in the number of demagnetizations and with increase in the storage time in the magnetized state. An increase in remanence with storage times was observed in certain cases.

539.23 : 546.87 : 535.215.1 773

The Photoelectric Effect of Thin Bi Films.—D. J. Fourie. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, p. 803.) The variation of photoelectric current observed when d.c. is passed through the film depends on the direction and magnitude of the current but is not a pure heating effect since the passage of a.c. does not cause the same variation.

539.23 : 546.46-31 : 537.533.8 774

The Mechanism of Self-Sustained Electron Emission from Magnesium Oxide.—D. Dobischek, H. Jacobs & J. Freely. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 804–812.) Continuation of work reported in 998 of 1953 (Jacobs et al.). When higher fields are applied, the secondary-emission current becomes very much larger and increasingly independent of the bombarding current, and, under certain conditions, persists for many hours after the bombarding current has been switched off. This enhanced emission has two components. The first is a true field-enhanced secondary-emission effect similar to that previously described. The second component is a self-sustained electron emission produced by the same type of avalanche effect, except that the internal ionization of the dielectric is initiated by electrons produced from within the material.

546.26 775

The Formation of Black Carbon.—R. O. Grisdale. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1082–1091.) Electron-microscope evidence is presented in support of the hypothesis that black carbon resulting from pyrolysis of gaseous hydrocarbons is produced through the intermediate formation of droplets of complex hydrocarbons. It appears that the process is fundamentally similar to that for obtaining carbon by the carbonization of solids.

546.321.85 : 537.226 776

The Properties of Colloidal Ferroelectric Materials: Part 1 — Potassium Phosphate (KH_2PO_4).—C. Jaccard, W. Känzig & M. Peter. (*Helv. phys. Acta*, 15th Sept. 1953, Vol. 26, No. 5, pp. 521–544. In German.) An isolated and nonconducting ferroelectric crystal of approximately spherical shape cannot become polarized spontaneously, if forced to form a single domain, since the energy of the surface charges would exceed the polarization energy. For small crystals, the wall energy prevents splitting into domains; hence a critical size exists, below which spontaneous polarization cannot occur. This was observed in KH_2PO_4 crystals of diameter $<1\,500$ Å embedded in insulating media of dielectric constant $\epsilon \leqslant 5$; crystals of diameter $>4\,000$ Å showed normal ferroelectric properties. The critical diameter decreases with increasing ϵ; in a conducting medium even 500 Å crystals showed normal spontaneous polarization. The anomaly in the dielectric constant of crystals smaller than the critical size at $1{\cdot}0 \pm 0{\cdot}5$°C below the Curie temperature, is probably not due to an antiferroelectric transition.

546.817.231 : 537.312.5 777

"Phosphorescent" Effect in Lead Selenide.—P. A. Lee. (*Canad. J. Phys.*, Sept. 1953, Vol. 31, No. 6, pp. 1023–1024.) Brief report of measurements of the conductivity of a thin layer of PbSe on illumination, at 90°K, by tungsten light. The effect observed is similar to that noted in PbS by Chasmar & Gibson (3156 of 1951).

621.314.634.012.6 778

Contribution to the Knowledge of Dynamic Phenomena in the Selenium Rectifier.—H. Lauckner. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 341–349.) Current creep was investigated experimentally in Se rectifiers with, and without, a lacquer intermediate layer. The results are in agreement with the mobile charge-carrier hypothesis on the assumption that small field changes due to slow ion movements result in large inverse-current changes. The rapid current response to a step voltage in the lacquer-layer type is due to the inhibition of ion movement at the Se grain boundaries.

621.315.6 779

Recent Progress in Dielectrics.—(*Nature, Lond.*, 26th Sept. 1953, Vol. 172, No. 4378, pp. 563–564.) Brief account of the discussions at the meeting of the British Association, Section A, in Liverpool, September 1953.

621.315.61.029.4/.53 780

Maxwell-Wagner Loss and Absorption Currents in Dielectrics.—B. V. Hamon. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 304–315.) The dielectric loss factor of mixtures consisting of a nonpolar base material and a small amount of a slightly conducting solid or liquid 'impurity', was measured at frequencies up to 3 Mc/s. 'Impurities' in the form of small spheres and in the form of a fine powder covering the surfaces of the grains of the base material were studied. The effect of direct and alternating potential gradients on the conductivity and loss factor of the mixtures was also investigated. The results are shown graphically, compared with theoretical results and with published data for practical dielectrics.

621.315.611 **781**

Experimental Contribution to the Study of the Dielectric Strength of Solid Insulators.—P. Dubois & R. Hérou. (*Rev. gén. Élect.*, Sept. 1953, Vol. 62, No. 9, pp. 438–441.) Report of experiments carried out at the Laboratoire central des Industries électriques to determine the influence of electrode shape and insulator thickness.

621.315.612 **782**

Phase Transitions in Antiferroelectric $PbHfO_3$.—G. Shirane & R. Pepinsky. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 812–815.) $PbHfO_3$ is antiferroelectric below 163°C and has an intermediate phase between 163°C and 215°C which is also antiferroelectric, with a different type of dipole arrangement from that of the lowest phase. At 215°C $PbHfO_3$ becomes paraelectric, and its structure changes from the tetragonal to the cubic type.

621.315.612.4 : 621.317.733 **783**

Some Dielectric Properties of Barium-Strontium Titanate Ceramics at 3 000 Mc/s.—L. Davis, Jr, & L. G. Rubin. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1194–1197.) Measurements at 10 kc/s, 500 kc/s and 3 kMc/s indicate that the dielectric constant is independent of frequency at temperatures above the Curie temperature. The effects of electric field strength and temperature on the dielectric constant and the loss tangent were also investigated. The results are shown graphically. The 3-kMc/s bridge is described.

621.315.613.1 **784**

Synthetic Mica Investigations: Part 1 — A Hot-Pressed Machinable Ceramic Dielectric.—J. E. Comeforo, R. A. Hatch, R. A. Humphrey & W. Eitel. (*J. Amer. ceram. Soc.*, 1st Sept. 1953, Vol. 36, No. 9, pp. 286–294.) The properties and the manufacture of a new ceramic composed entirely of synthetic fluorine-mica are described. Extensive ionic-replacement possibilities permit a large range of variation in the properties, and tables and graphs for the electrical and mechanical characteristics of several types are given. Thus, $BaMg_3Al_2Si_2O_{10}F_2$ has a water absorption $< 0.1\%$, density 3·51 g/cm³, power factor 0·0003, dielectric constant 7·6 and loss factor 0·0022 at 1 Mc/s. The effect of an increase of temperature up to 250°C is small. The transverse strength is $> 8\,000$ lb/in².

621.315.616 **785**

Dielectric Properties of Teflon from Room Temperature to 314°C and from Frequencies of 10^2 to 10^5 c/s.—P. Ehrlich. (*J. Res. nat. Bur. Stand.*, Oct. 1953, Vol. 51, No. 4, pp. 185–188.) Measurements indicate that the dielectric constant decreases slightly with increasing temperature and is independent of frequency at all temperatures.

621.318.22 : 538.221 **786**

The Coercive Force of Magnets moulded from Very Fine Co-Fe Powders.—F. Lihl. (*Acta. phys. austriaca*, July 1953, Vol. 7, No. 3, pp. 239–247.) Continuation of work noted previously (1935 of 1952). Coercive force, remanence and *BH* product increase with Co content; the practically attainable optimum values are not yet reached for 36·4% Co. The positions of the maxima of coercive force and *BH* product, with respect to variations of reduction time and degree depend on the composition; for a given composition the positions of these maxima depend on the powder preparation and moulding processes. Extrapolation to the case of infinitely low density gives lower values of the coercive force than would be expected from Néel's theory, but indicates the highest practically attainable values.

621.791 : 546.621 **787**

Joining Aluminum to Other Materials.—M. A. Miller. (*Mater. & Meth.*, Sept. 1953, Vol. 38, No. 3, pp. 96–99.) Methods appropriate to various materials, component designs and service requirements are described.

621.92 : 549.514.51 : 621.372.412 **788**

The Production of Very Thin Quartz Oscillator Plates.—J. E. Thwaites & C. F. Sayers. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 105–107.) Account of the construction and operation of a machine for lapping plates to a thickness of about 0·055 mm.

666.1 **789**

Glass in the Electronic Industry.—M. Manners. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 512–516.) The various types of glass available are reviewed and their particular applications indicated, with special reference to problems of sealing. Tables show the composition and properties of some of the most common glasses and some combinations of glass and metal for making seals.

MATHEMATICS

511 : 53 : 621.39 **790**

Radio Technology and the Theory of Numbers.—B. van der Pol. (*J. Franklin Inst.*, Sept. 1953, Vol. 256, No. 3, p. 265.) Correction to paper noted in 3346 of 1953.

513.761.22 : 621.372 **791**

Geometric Construction of the Homographic Transformation.—P. Mourmant. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 540–542.) A discussion of the geometric properties of the homographic transformation $Z = \alpha(\beta + z)/(\gamma + z)$, giving generalized impedance in terms of the complex coefficients α, β and γ and elementary impedance z.

517.6 **792**

Evaluation of the Integral $\int_0^\infty e^{-u^2-x/u}.du$.—M. Abramowitz. (*J. Math. Phys.*, July/Oct. 1953, Vol. 32, Nos. 2/3, pp. 188–192.) The integral studied appears in various physical problems involving particles with Maxwellian distribution of velocities.

518.2 : 517.564 **793**

Radix Table for obtaining Hyperbolic and Inverse Hyperbolic Functions to Many Places.—H. E. Salzer. (*J. Math. Phys.*, July/Oct. 1953, Vol. 32, Nos. 2/3, pp. 197–202.)

MEASUREMENTS AND TEST GEAR

53.08 : 621.39.001.11 **794**

The Negentropy Principle of Information.—L. Brillouin. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1152–1163.) The statistical definition of information is compared with Boltzmann's formula for entropy. The relations between the information obtained and the cost in entropy (or money) in the measurement of very small quantities are derived and applied to a consideration of the accuracy and efficiency of measurements.

621.317 : 621.396.82 **795**

Radio Interference.—(*Elect. Rev., Lond.*, 11th Sept. 1953, Vol. 153, No. 11, p. 563.) A note of British Standards on interference measurements and of Electrical Research Association Reports Ref. M/T 116 and 117 describing appropriate measurement equipment.

621.317.089.6 796

Practical Calibration Adjustments for Apparatus which Obeys a Theoretical Law Imperfectly.—J. W. Head. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 499–501.) Description of a method devised for calibrating a tone source for which the dial angle ϕ was theoretically related to the frequency f by the formula $\phi = A + B \log_{10} f$. The object was to obtain easily a calibration curve sufficiently smooth and accurate for practical purposes, rather than to find the unique curve satisfying some mathematical criterion of goodness of fit.

621.317.3 : 621.396.822 797

Valve and Receiver Noise Measurement at V.H.F.—N. Houlding. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 15–26.) Techniques for the measurement of noise factor, valve noise and other parameters involved in the investigation of receiver noise performance are described. Sources of error, and precautions required to minimize errors, are discussed. Equipment giving improved accuracy is described. Some measurements on noise generators and valve noise are reported.

621.317.32 : 621.385.832 798

Measurement of Voltage using a Simple Electron-Beam Valve.—A. Lieb. (*Funk u. Ton*, Sept. 1953, Vol. 7, No. 9, pp. 463–471.) A detailed description is given of a valve of magic-eye type adapted to indicate the adjustment of a variable voltage to a desired setting. Two luminescent streaks, produced by independent beam-forming electrode systems, are brought into coincidence when the adjustment is correct.

621.317.33 : 621.372.413 799

Measurement of Resonant-Cavity Characteristics.—G. L. Hall & P. Parzen. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1769–1773.) The system considered is a re-entrant cavity terminating a coaxial line. A method of determining the loaded and unloaded Q and the shunt resistance of the cavity is described, involving measurements of frequency shifts caused by introducing a small obstacle into the cavity. A high-stability high-resolution a.f.c. system for controlling the klystron oscillator is described.

621.317.333.6 : 621.372.8 800

A Standard Waveguide Spark Gap.—D. Dettinger & R. D. Wengenroth. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 39–48.) Description and comparison of four types of spark gap used for testing the power-handling capacity of waveguides, namely (*a*) resonant-section, (*b*) swayback, (*c*) cylindrical-bump, (*d*) hemispherical-bump types.

621.317.335.3 + 621.317.411 801

Optical Methods for Measurement of Complex Dielectric and Magnetic Constants at Centimetre and Millimetre Wavelengths.—T. E. Talpey. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 561–569.) Modifications necessary to take account of loss factors in basic formulae relating to transmission and reflection of a plane wave incident on a reflecting plate are discussed. Using formulae derived, permittivity k_e, permeability k_m and loss angles δ_e, δ_m can be determined, when losses are small, from (*a*) Brewster angle and transmission and reflection coefficients at this angle of incidence, when the plane of polarization is parallel to the plane of incidence, (*b*) the ratio of the moduli of the reflection coefficients with polarization parallel to and normal to the plane of incidence, (*c*) plate thickness and wavelength. Equipment for measuring these quantities comprises a klystron oscillator with associated wavemeter, attenuator and horn radiator, a receiver with horn attenuator and detector, and a rotatable support for the sample. Experimental results for bakelite, glass, polystyrene and paraffin at λ 8·36 mm are quoted.

621.317.34 : 621.372.8 802

Precision Measurement of Waveguide Attenuation.—J. H. Vogelman. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 196–199.) A method of determining attenuation values between 0·01 and 0·5 db, and down to 0·001 db with lower accuracy, is based on standing-wave measurements. The technique is useful for investigating the influence of the waveguide surface condition on the attenuation.

621.317.341.029.62/.65 803

Audio Modulation Substitution System for Microwave Attenuation Measurements.—J. Korewick. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 14–21.) An arrangement for measuring attenuations up to 40 db over the frequency range 240 Mc/s–40 kMc/s uses an audio-modulated klystron oscillator as a stable r.f. source and a barretter as a square-law detector. Attenuation produced in the microwave section by the system under test is compensated by adjustment of a standard attenuator in the audio section, the output level being held constant.

621.317.361.029.64 804

Techniques of Frequency Measurement in the Centimetre-Wave Region.—E. G. Hope. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 144–153. Digest, *ibid.*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 383–384.) Methods developed at the National Physical Laboratory and based on the 100-kc/s quartz-crystal standard are discussed. Frequencies up to 50 kMc/s can be measured with an error $<$ 1 part in 10^8. For producing the required standard frequencies in the centimetre-wave range, crystal diodes are used as harmonic generators. The properties of a number of types of crystal diode have been investigated and the optimum values of input power and bias voltage determined. Most types of Si diode and several types of Ge diode are suitable, the Ge types in general requiring less input power for the same harmonic output. On the basis of measurements, an approximate formula is derived for predicting the power in a given harmonic.

621.317.7 : 621.395.822 805

A Mains-Operated Psophometer.—F. H. Goldsmith & J. A. Widdicks. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 112–114.) The psophometer is essentially a valve voltmeter measuring the r.m.s. voltage of a complex a.f. signal and incorporating a frequency-weighting network. An experimental model is described in which the overall error is $< 3\%$.

621.317.723 806

Portable Quadrant Electrometer of High Sensitivity.—G. F. Schilling & P. Kreager. (*Rev. sci. Instrum.*, Sept. 1953, Vol. 24, No. 9, pp. 877–878.) Description of an instrument developed in connection with the study of atmospheric electricity.

621.317.73 : 546.28 + 546.289 807

Four-Probe Instrument for Resistivity Measurements of Germanium and Silicon.—A. L. MacDonald, J. Soled & C. A. Stearns. (*Rev. sci. Instrum.*, Sept. 1953, Vol. 24, No. 9, pp. 884–885.) A brief description of the construction of the instrument is given.

621.317.733 : 621.315.612.4 808

Some Dielectric Properties of Barium-Strontium Titanate Ceramics at 3 000 Mc/s.—Davis & Rubin. (See 783.)

621.317.763.029.64/.65 **809**

A Microwave Fabry-Perot Interferometer.—J. O. Artman. (*Rev. sci. Instrum.*, Sept. 1953, Vol. 24, No. 9, pp. 873–875.) Details are given of an interferometer for measurements in the wavelength range 5 mm–4 cm, using a movable totally reflecting surface parallel to a fixed partially reflecting surface composed of elements (e.g., metal balls) whose dimensions are much smaller than λ. A magic-T waveguide junction takes the place of the beam-splitting plate of the optical system.

621.317.78.029.6 : 536.62 **810**

Accurate R.F. Power Measurements.—R. M. Soria & J. G. Krisilas. (*Radio & Telev. News, Radio-Electronic Engng Section*, Sept. 1953, Vol. 50, No. 3, pp. 3–6, 29.) Continuous-flow calorimetric methods are used for r.f. power output measurements, in the range 2 W–5 kW, and for the calibration of input-power indicators. The power-indicator component calibrated is isolated electrically from the thermocouple inserted in it by means of a quarter-wave transformer. Constructional details of the equipment used and performance curves are given.

621.397.621.2.001.4 **811**

Simple Linearity-Measuring Instrument.—K. G. Beauchamp. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 36–37.) A device on the lines of a travelling microscope is described for measuring the distance between pairs of parallel bars of a test pattern at different parts of the screen face.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.77 : 621.383 **812**

A Photoelectric Decimal-Coded Shaft Digitizer.—W. H. Libaw & L. J. Craig. (*Trans. Inst. Radio Engrs*, Sept. 1953, Vol. EC-2, No. 3, pp. 1–4.) A device is described for giving an indication of the position of a rotating shaft. Lamps illuminate photocells arranged round the shaft, in accordance with the position of slits in a screen attached to the shaft. Details are given of a decade system.

538.569.2.047 **813**

Capacity and Conductivity of Body Tissues at Ultrahigh Frequencies.—H. P. Schwan & Kam Li. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1735–1740.) Results of measurements over the frequency range 200–1 000 Mc/s are analysed, and the variations are explained on a biological basis. Temperature variations are also investigated. Measuring technique is described.

621.316.729 **814**

Cathode-Ray Synchroscope and Automatic Synchronizer.—M. A. H. Ahmed. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, p. 808.) Summary only. Two voltages are compared for synchronism by applying them to a c.r. tube so that one produces a circular trace while the other produces radial pips. Automatic synchronization is obtained by using a c.r. tube with a two-electrode target in conjunction with a relay system.

621.317.083.7 : 621.396.91 **815**

Automatic Radio Equipment for Long-Period Operation for Long-Range Transmissions of Weather Data.—E. Plötze, K. Rawer & E. Stoebe. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 351–359.) Equipment for short-wave meteorological stations for use on sea or land is described. Operational experience with equipment used in the Arctic and the Atlantic regions is discussed.

621.319.339 **816**

The Design of the Electric Field in a Van de Graaff Generator.—J. W. Boag. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 63–82.)

621.319.339 : [621.398 + 621.317.083.7 **817**

A Remote Control and Telemetering System for a Van de Graaff Generator.—B. Millar. (*Electronic Engng*, Nov. & Dec. 1953, Vol. 25, Nos. 309 & 310, pp. 446–450 & 506–508.) A system using modulated light beams is described.

621.384.611 **818**

Vertical Focusing in the Microtron.—J. S. Bell. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 802–804.) A theoretical study is made of the vertical focusing oscillations. See also 2090 of 1953 (Henderson et al.).

621.384.612 **819**

Stability of Orbits in a Strong-Focusing Synchrotron.—S. Lundquist. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 981–983.)

621.384.612 **820**

Proton Synchrotron of the University of Birmingham.—(*Nature, Lond.*, 17th Oct. 1953, Vol. 172, No. 4381, pp. 704–706.) Preliminary tests of the machine are reported. See also 700 of 1951 (Hibbard).

621.384.612 **821**

The Cosmotron — a Review.—M. H. Blewett (Ed.). (*Rev. sci. Instrum.*, Sept. 1953, Vol. 24, No. 9, pp. 725–870.) A series of papers covering all aspects of the Brookhaven proton synchrotron.

621.385.83 : 621.317.329 + 517.944 **822**

Electrostatic Potential Plotting for Use in Electron-Optical Systems.—Kuo-Chu Ho & Moon. (See 912.)

621.385.833 **823**

A Method for the Direct Measurement of the Caustic Surfaces of Electron Lenses.—W. Scheffels, M. Hahn & F. Lenz. (*Optik, Stuttgart*, 1953, Vol. 10, No. 9, pp. 455–458.)

621.385.833 **824**

Correction of Electrostatic Lenses by Departure from Rotational Symmetry.—J. C. Burfoot. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 775–792.)

621.385.833 **825**

Determination of Focal Lengths of Unipotential Lenses by the Rotating-Beam Method.—R. V. Jordan, D. W. Shipley & M. Krawitz. (*Sylvania Technologist*, Oct. 1953, Vol. 6, No. 4, pp. 92–95.) Measurements were made on a three-cylinder unipotential lens modified by inserting apertured diaphragms, by varying the length of the focusing (middle) cylinder, and by varying the spacing between the cylinders. The results are shown graphically.

621.387.424 : 550.8 **826**

Electronic Equipment used for Geological Research at Depth by Radioactivity Methods.—J. Berbezier. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 553–560.) The equipment comprises a G-M-counter probe lowered down the bore-hole on a cable, an automatic depth recorder, pulse integrator and recorder. Records reproduced show the natural and the neutron-induced gamma radiation from different strata at depths down to 680 m.

621.387.424 : 550.8 **827**

Radioactivity Method of Prospecting for Uranium Ores.—C. Lallemant. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 547–552.) Review of the technique, including descriptions and circuit details of French equipment for the detection and measurement of radioactivity.

PROPAGATION OF WAVES

538.566 : 535.42 **828**

Diffraction of Electromagnetic Waves near the Earth's Surface in an Optically Inhomogeneous Medium.—R. Schachenmeier. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, p. 491.) Correction to paper abstracted in 238 of 1952.

621.396.11 : 550.38 : 551.510.535 **829**

Measurements of the Terrestrial Magnetic Field in the E-Layer.—Cutolo. (See 720.)

621.396.11 : 551.510.535 **830**

Prediction of Ionospheric Propagation for Distances greater than 10 000 km.—E. Harnischmacher. (*C. R. Acad. Sci., Paris*, 2nd Nov. 1953, Vol. 237, No. 18, pp. 1071–1073.) The method discussed is developed from that previously described by Rawer (199 of 1953) and is based on the assumption that in very-long-distance propagation reflections occur at both F and E layers; the total number of hops is greater than for pure F-layer propagation and the absorption is therefore higher, but the blanketing effect of the E and E_s layers is eliminated. The values of the different possible angles of departure are close together for very-long-distance circuits, and the wave in effect adapts its path to the ionospheric conditions along the route. Experimental results obtained on a 17 000-km path confirm predictions made on this basis.

621.396.11 : 551.510.535 **831**

Results relating to the Critical Frequency and the Transmission Factor of the Ionosphere F_1 Layer.—E. Theissen. (*C. R. Acad. Sci., Paris*, 2nd Nov. 1953, Vol. 237, No. 18, pp. 1104–1106.) Using values measured at Freiburg in the formula $f_0F_1 = k \cos^n z$ (z is the zenithal angle of the sun, k is the critical frequency for $z = 0$) the mean value of n for the months March–September was found to be 0·22. No seasonal or eleven-yearly variation of its value was found. The value of k depends on the sunspot number. The F_1 transmission factor (M3000) has a diurnal and seasonal variation represented by $M_0\cos^m z$, the value of m being $0{\cdot}08 \pm 0{\cdot}02$. The observations also indicate that the F_1 layer rises as solar activity increases.

621.396.11 : 551.594.5 **832**

A Note on Auroral Interaction.—N. C. Gerson. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 81–82.) The modulation of a radio wave due to a moving auroral reflecting screen is discussed.

621.396.81.029.62 : 551.593 **833**

The Increase of U.S.W. Field Strength due to a Refracting Tropospheric Layer (Inversion).—R. Schachenmeier. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 485–491.) Expressions are derived for the effect of an inversion layer on the field strength at points beyond the horizon. A practical example is worked out. When the receiving aerial is far beyond the horizon and the inversion layer lies below the transmitting aerial, the field strength is increased.

621.396.812.029.62/.63 **834**

Investigation of the Influence of the Troposphere on the Propagation of Ultra-short Waves.—R. Schachenmeier. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, p. 491.) Correction to paper abstracted in 2524 of 1951.

RECEPTION

621.376.233 : 621.314.632 **835**

Crystal-Mixer Design at Frequencies from 20 000 to 60 000 Mc/s.—Ditchfield. (See 890.)

621.396.621 : 621.314.7 **836**

Experimental Transistor Receiver.—B. R. Bettridge. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 2–5.) Two two-transistor circuits for local-station reception are described. The total consumption is 6 mA at 18 V; acceptable volume is obtained with an input of about 20 mW to a sensitive loudspeaker. Reflexing is used to improve sensitivity in the more elaborate circuit.

621.396.621 : 621.396.822 **837**

First Probability Densities for Receivers with Square-Law Detectors.—R. C. Emerson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1168–1176.) A procedure is indicated for using the Kac-Siegert method (3645 of 1947) in its widest generality without the necessity of finding eigenvalues and without dealing with the characteristic function at all; it involves expanding the density function in an orthonormal series, the coefficients of which are expressed in terms of cumulants, which in turn are obtained from the system kernel. A receiver with Gaussian i.f. and Gaussian a.f. pass characteristics is treated in detail.

621.396.621.57 : 621.376.3 : 631.314.7 **838**

A Portable Transistor F.M.-Receiver.—R. C. Ballard. (*Tele-Tech*, Aug. 1953, Vol. 12, No. 8, pp. 79, 206–207.) Eleven point-contact Ge transistors and four Ge diodes are used in an experimental receiver giving an overall amplification of 67 db and an undistorted output of 75 mW. The collector-current drain is 60 mA. Circuit details are given.

621.396.812.3 **839**

Evaluation of Polarization Diversity Performance.—J. L. Glaser & L. P. Faber, Jr. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1774–1778.) Experiments on the reduction of fading effects are reported. Measurements were made on unmodulated signals of frequencies 6·985 and 11·66 Mc/s transmitted from Red Bank, N.J., and received near St. Louis, Mo., separate aerials being used to receive the vertically and horizontally polarized components. The results on 11·66 Mc/s were nearly equal to those which would be produced by independent Rayleigh distributions of signal amplitude for the two components. On 6·985 Mc/s the improvement due to the diversity reception was not so great.

621.396.82 : 621.317 **840**

Radio Interference.—(See 795.)

621.396.828 : 621.327.43 **841**

Present Position as regards Suppression of Radio Interference from Fluorescent Lamps.—W. Rüegg. (*Bull. schweiz. elektrotech. Ver.*, 5th Sept. 1953, Vol. 44, No. 18, pp. 804–805. Discussion, pp. 805–807.)

551.594.6 : 621.396.822 **842**

Radio Research Special Report No. 26. Measurements of Atmospheric Noise at High Frequencies during the years 1945-51. [Book Notice]—F. Horner. Publishers: H.M. Stationery Office, London, 1953, 1s. 9d. (*Govt Publ., Lond.*, Sept. 1953, p. 21.)

STATIONS AND COMMUNICATION SYSTEMS

621.39 : 621.376 **843**

Applications of Polyphase Modulation in Telecommunications.—S. Silleni. (*Poste e Telecomunicazioni*, Sept. 1953, Vol. 21, No. 9, pp. 403–415.) Some particularly difficult filtering problems can be solved by use of polyphase modulation. The basis of the method is explained and applications are described, including a frequency-shift radiotelegraphy system and transmitters and receivers for s.s.b. radiotelephony. Phase changers, modulators and mixers are described. The usefulness of the system for economizing on bandwidth is indicated. 45 references.

621.39.001.11 **844**

Introduction to Communication Theory.—E. H. Harwood. (*Trans. S. Afr. Inst. elect. Engrs*, Aug. 1953, Vol. 44, Part 8, pp. 241–250.)

621.39.001.11 **845**

Bits, Language Efficiency and Information Theory.—R. L. Shuey. (*Gen. Elect. Rev.*, Sept. 1953, Vol. 56, No. 5, pp. 15–19.) The basic concepts of communication theory are simply explained.

621.39.001.11 : 519.272 **846**

Correlation and Autocorrelation in Communication Engineering.—W. Meyer-Eppler. (*Arch. elekt. Übertragung*, Oct. & Nov. 1953, Vol. 7, Nos. 10 & 11, pp. 501–504 & 531–536.) The common correlation functions and coefficients are defined and their meanings are explained in physical terms. Numerous applications are noted to problems in physics (e.g., interference) and, in particular, to problems in communication and acoustic engineering, e.g., recognition of signals in noise, objective determination of the acoustic quality of a room, etc. Correlatographs are also discussed. Special devices such as a reading apparatus for the blind and a device for the automatic recognition of the spoken word are mentioned. 46 references.

621.395.43/.44 **847**

Interchannel Interference in Multichannel Carrier Telephone Systems.—S. Dossing. (*Telecommun. J. Aust.*, Oct. 1952, Vol. 9, No. 2, pp. 101–108.) Various forms of interchannel interference are described, and methods of measurement are discussed.

621.395.63 : 621.396.5 **848**

Selective Calling for Radio-Telephone Systems.—J. R. Pollard. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 490–496.) R/T systems consisting of a master station and a number of subsidiary stations are considered, and three alternative circuit arrangements are described for use at subsidiary stations to enable individual, group or general calls to be made. Each arrangement includes a pulse-counting section and a discriminator section; dekatrons and/or cold-cathode trigger triodes are used.

621.396.41 : 621.376.3 **849**

Some Recent Developments in the Multiplexed Transmission of Frequency Modulated Broadcast Signals.—E. H. Armstrong & H. J. Bose. (*Proc. Radio Cl. Amer.*, 1953, Vol. 30, No. 3, pp. 3–13.) An account of the two-channel system operated at Alpine, New Jersey (KE2XCC). The main carrier is frequency-modulated by a subcarrier of frequency 27·5 kc/s; both main carrier and subcarrier are individually frequency-modulated with programme material, the maximum deviation of the former being about 50 kc/s and of the latter 5 kc/s. The maximum modulation frequency is 15 kc/s for the main channel and 7·5 kc/s for the second channel. Cross modulation at the transmitter is avoided by keeping the channels separate up to a stage where the normal circuit requirements call for a bandwidth sufficient to ensure good phase linearity. At the receiver, the first discriminator must be carefully designed to avoid introduction of cross modulation. Performance tests are reported; signals received at a level of $< 10\,\mu$V are intelligible.

621.396.65 : 621.396.41.029.63 **850**

Portable Microwave for Allied Forces in Europe.—M. G. Staton. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 130–134.) The radio relay system described comprises 7 terminal stations and 18 repeater stations, and provides 24 voice channels. The equipment is truck mounted and includes a 58-ft telescoping aerial tower. A f.m. system is used which makes interception difficult.

621.396.65.029.62 **851**

Design Considerations for V.H.F. Link Radio Equipment.—B. Wilson. (*G.E.C. Telecommun.*, Sept. 1953, No. 17, pp. 16–26.) General design of 54–330-Mc/s point-to-point R/T equipment is discussed. Both a.m. and f.m. equipments are considered.

621.396.712 : 621.396.61 **852**

The R.T.F. Transmitting Stations at Sélestat and Allouis L.W.—Gaillard. (See 886.)

621.396.712.029.62 **853**

Radio and Television in [Western] Germany.—(*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 497–499.) Operating frequency and power of the 90 or so v.h.f. stations are tabulated.

621.396.712.3 **854**

The Technical Equipment of the B.B.C. Swansea Studios.—W. J. Stentiford. (*B.B.C. Quart.*, Autumn 1952, Vol. 7, No. 3, pp. 169–173; *Proc. Instn Radio Engrs, Aust.*, Nov. 1953, Vol. 14, No. 11, pp. 270–273.)

621.396.7 **855**

Construction of a Mountain-Top Remote Base Station.—H. V. Church. (*Commun. Engng*, Sept./Oct. 1953, Vol. 13, No. 5, pp. 22–25..38.) An account of the 250-W station of the Central Vermont Public Service Corporation, installed on Pico Peak, altitude 4 000 ft. The station is remotely controlled by land-line from headquarters 12 miles away. Installation and maintenance problems peculiar to such a location are discussed in detail.

621.396.721 **856**

Two-Band Transmitter-Receiver.—G. P. Anderson. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, p. 37.) Correction to paper noted in 530 of February.

621.396.97 : 621.396.66 **857**

The Automatic Monitoring of Broadcast Programmes.—H. B. Rantzen, F. A. Peachey & C. Gunn-Russell. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 372–373.) Discussion on 269 of 1952.

SUBSIDIARY APPARATUS

621-526 **858**

A Nonlinear Servomechanism with Several Independent Variables.—D. Mitrovic. (*C. R. Acad. Sci., Paris*, 16th Nov. 1953, Vol. 237, No. 20, pp. 1209–1211.)

621.311.6 : 539.16 **859**

Radioactive Charging Effects with a Dielectric Medium.—P. Rappaport & E. G. Linder. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1110–1114.) The characteristics of a cell consisting of a Sr^{90}-Y^{90} β-ray source, a polystyrene dielectric separator and a collector made of carbon or metal, were investigated. Radioactive current and voltage sources similar to this cell are feasible. The arrangement offers a simple way of studying the effects of radiation on electrical processes in solids.

621.314.634 **860**

The Problem of Heating in the Selenium Rectifier.—W. Stiassny. (*Elektrotech. u. Maschinenb.*, 15th Sept.–15th Oct. 1953, Nos. 18–20, pp. 409–413, 437–441 & 455–

460.) Formulae for the calculation of heat losses are derived. Design for good efficiency and low-temperature rise is discussed in detail, with reference to the operational demands of various applications in power rectification. Typical characteristics curves are given.

621.314.65 861
Recent Developments in Ignitrons.—G. M. Zins. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 135–137.)

621.316.722 862
Stabilization Problems in Physics.—P. Goudal. (*Cah. Phys.*, Sept. 1953, No. 45, pp. 40–55.) A review of voltage, current, and magnetic-field regulators. The performances of various stabilizing valve circuits and primary regulators are compared, and the importance of good control of filament heating voltages is emphasized. Special problems of stabilization in nuclear physics are mentioned.

621.316.722 : 621.311.6 863
A Stabilized D.C. Supply Unit for Output Voltages of 0 to 300 V.—D. J. H. Admiraal. (*Electronic Applic. Bull.*, May 1953, Vol. 14, No. 5, pp. 61–71.) A circuit is described in which the whole of the output-voltage variation is available for controlling the amplifying valve, so that the gain is the same for any output voltage down to zero. The control valve is a pentode whose screen-grid voltage is stabilized by means of a stabilizer tube; the filaments of the amplifying valves, which are also fed from this source, have low consumption. Variation of the output voltage is < 2 mV for mains fluctuations up to 10%.

621.316.722 : 621.387 864
Relaxation Oscillations in Voltage-Regulator Tubes.—P. L. Edwards. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1756–1760.) Relaxation oscillations may occur if the regulator tube is shunted by a capacitor and the load line intersects the tube characteristic on the low-current side of the minimum. Methods of modifying the circuit to prevent these oscillations are indicated.

621.316.722.1 : 621.311.6 865
An Alternating-Current Stabilizer.—P. A. V. Thomas. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 522–523.) A stabilizer for a valve-heater power supply uses a diode operating with low heater voltage as the error detector and a transductor as the control element. The output voltage can be maintained constant to within $\pm$ 1%.

621.373.4 866
Industrial Tube Generator for Low Frequencies.—H. Hertwig & F. N. Wissing. (*Electronic Applic. Bull.*, May 1953, Vol. 14, No. 5, pp. 72–75.) A detailed description is given of a three-phase valve generator suitable for supplying an asynchronous motor at frequencies from 1 to 2 kc/s.

TELEVISION AND PHOTOTELEGRAPHY

621.397.2(41) 867
Television Service to Belfast.—T. Kilvington. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 130–133.) "Vision signals for the B.B.C. temporary television transmitter at Belfast are picked up direct from Kirk o' Shotts on 56·75 Mc/s at a receiving site on Black Mountain and passed on a carrier of 6·12 Mc/s over about a mile of coaxial cable to the temporary transmitter site in Glencairn, whence they are re-broadcast on a carrier of 45 Mc/s."

621.397.26 : 621.385.029.63 : 621.376.3 868
A 50-Watt F.M. Magnetron for Relay Service.—Kennedy. (See 904.)

621.397.5 : 535.623 869
The American Television Scene.—M. J. L. Pulling. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 13–15.) Impressions reported by a visiting British engineer, particularly of the colour-television demonstration staged on 15th October 1953.

621.397.5 : 535.623 870
Compatible Colour Television.—D. A. Bell. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, p. 31.) Sideband interference problems involved in using the N.T.S.C. colour-subcarrier system with the British television system are discussed; the narrower video-frequency band is the most serious difficulty.

621.397.5 : 535.623 871
The N.T.S.C. Color-Television Standards.—D. G. Fink. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 138–150.) The final N.T.S.C. compatible-colour signal specifications, presented in July 1953, are discussed in detail.

621.397.5 : 621.39.001.11 872
The Impact of Information Theory on Television.—D. A. Bell. (*J. Brit. Instn Radio Engrs*, Dec. 1953, Vol. 13, No. 12, pp. 590–591.) Discussion on 3731 of 1953.

621.397.5 (41) 873
An Outline of the British Television System: Part 2 — Transmitting the Picture Waveform.—D. Wray. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 123–128.) The five-channel vestigial-sideband broadcasting system is outlined; operating frequency and power are tabulated for the ten stations. The transmitters are connected to the London studios by cable and radio links. Outside-broadcast material is transmitted over short distances either by coaxial or balanced-pair cable, portable radio links, or ordinary telephone pairs. Part 1: 271 of January.

621.397.611 : 621.375.232 874
Modified Preamplifier improves Movie Telecasts.—K. B. Benson. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 166–169.) A preamplifier circuit for use with an iconoscope combines a cascode arrangement with negative feedback. Advantages claimed are reduction of noise, of beam-current requirements and of spurious signals, and improvement in the rendering of the grey scale.

621.397.611.2 : 621.385.832 875
A Television Camera with an Image Iconoscope.—C. J. Seur. (*Commun. News*, Sept. 1953, Vol. 14, No. 1, pp. 29–34.) The equipment used in the Bussum studio for experimental transmissions is described.

621.397.621.2.001.4 876
Simple Linearity-Measuring Instrument.—Beauchamp. (See 811.)

621.397.7 877
Studio Equipment used for Television Broadcasting in the Netherlands.—J. M. Olthuis. (*Commun. News*, Sept. 1953, Vol. 14, No. 1, pp. 19–28.) Description of the equipment of the studios at Bussum, near Amsterdam.

621.397.7 : 534.86 878
The Sound Equipment in the Television Studio at Bussum.—A. Cramwinckel. (*Commun. News*, Sept. 1953, Vol. 14, No. 1, pp. 34–39.)

621.397.82 **879**

A Level Compensator for Telephotograph Systems.—T. A. Jones & W. A. Phelps. (*Elect. Engng, N.Y.*, Sept. 1953, Vol 72, No. 9, pp. 787–791.) The interference modulation in picture transmission via wide-band carrier equipment is effectively cancelled out by introducing an equal and opposite interference signal obtained by detecting a single-frequency pilot current transmitted simultaneously with the picture. Block diagrams and performance characteristics are given.

621.397.621.2 : 621.316.729 **880**

Flywheel Synchronization of Sawtooth Generators. [Book Review]—P. A. Neeteson. Publishers: Cleaver-Hume Press, London, 156 pp., 21s. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 27–28.) " . . . a necessary book for the designer."

TRANSMISSION

621.376.223 **881**

Balanced Crystal-Diode Modulator.—W. F. Byers. (*Radio & Telev. News, Radio-Electronic Engng Section*, Sept. 1953, Vol. 50, No. 3, pp. 10–11, 27.) Description of the low-power Si-diode modulator Type 1000-P7, giving linear operation over the range 0–20 Mc/s at carrier frequencies from 60 Mc/s to 2·5 kMc/s. Circuit diagram and performance figures are given.

621.396.61.029.58 : 621.396.65 **882**

Single-Sideband Multi-Channel Operation of Short-Wave Point-to-Point Radio Links: Part 4(a)—An Independent-Sideband High-Power Short-Wave Transmitter—The Radio and Power Units.—H. E. Sturgess & F. W. Newson. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 140–143.) The transmitter can provide peak power up to 70 kW in the frequency range 4–22 Mc/s. By using the two-channel drive unit described in part 2 (2175 of 1953 (Owen & Ewen)) the transmitter can also be used for d.s.b. telephony and c.w. and m.c.w. telegraphy.

621.396.61.029.62 **883**

A New V.H.F. Transmitter for Frequency Modulation.—W. Grimbaldeston. (*G.E.C. Telecommun.*, Sept. 1953, No. 17, pp. 27–33.) Description of the BRT-108 250-W transmitter, for 71·5–100 Mc/s. Ph.m. corrected to f.m. over the required audio range is used. The nominal frequency deviation is ±15 kc/s for 0·5 mV across the 15-Ω input, at 1 kc/s modulation frequency.

621.396.662 : 621.316.7 **884**

Automatic Control System with Provision for Scanning and Memory.—N. H. Young. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, pp. 782–784.) The control element (e.g. a tuning capacitor) is scanned through its entire range of adjustment and the input voltage is fed, via a diode, to the 'memory' capacitor, causing it to charge up to the maximum peak value. On re-scanning, the input voltage is compared with this peak value; the control element is stopped when they are equal. A simplified circuit diagram is given, and a radio transmitter embodying the system is briefly described.

621.396.665 **885**

Circuits for Limiting Peak Voltages.—E. G. Beard. (*Philips tech. Commun., Aust.*, 1953, No. 3, pp. 11–15.) A system of amplified a.g.c. for preventing overmodulation of a transmitter is described. The peak signal voltages trigger a quiescent 1-Mc/s oscillator which then oscillates in a series of pulses. The length of the pulse sequence is a function of the signal amplitude. The rectified and integrated pulses are used for the a.g.c. bias.

621.396.712 : 621.396.61 **886**

The R.T.F. Transmitting Stations at Sélestat and Allouis L.W.—A. Gaillard. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 489–496.) The long-wave transmitter at Allouis, which was destroyed in 1944, was re-started in October 1952. The power is 250 kW; it is planned to add a second transmitter to bring the total power up to 450 kW. Anode modulation is used, with two Type-E3056 valves in push-pull in the r.f. stage. The aerial is a folded unipole designed to handle a bandwidth 12·4% of the carrier frequency; its total height is 308 m. The new Sélestat station, intended to serve the whole of Alsace, also came into full operation in October 1952. It has two 150-kW transmitters, each comprising two units. There are two widely spaced aerials, one 115 m and the other 90 m high. The heat developed at the anodes of the power valves is recovered and used for heating the buildings. See also 1735 of 1952.

VALVES AND THERMIONICS

621.314.632 **887**

Post-Injection Barrier Electromotive Force of *p-n* Junctions.—B. R. Gossick. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1012–1013.) By injecting carriers across a *p-n* junction with a high-back-voltage point-contact diode in series, the post-injection barrier e.m.f. may be observed under approximately open-circuit conditions. From measurements using a CK708 diode, the calculated e.m.f. is ~ 0·2 V at room temperature.

621.314.632 : 546.289 **888**

Effect of Transit Time on Ge-Rectifier Behavior.—R. Bray & B. R. Gossick. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1011–1012.) The forward characteristics of Ge point-contact rectifiers were measured using 0·4-μs pulses. Resistance was very much higher at the beginning of the pulse than at the end, when it reached the d.c. value. Thus transit times <0·4 μs are involved. In *p-n*-junction rectifiers, the resistance takes longer to change, and is still much higher than the d.c. value at the end of a 3·6-μs pulse.

621.314.632 : 546.289 **889**

The Manufacturing and Testing of Germanium Rectifiers.—C. Peters & H. Strong. (*G.E.C. Telecommun.*, Sept. 1953, No. 17, pp. 34–39.) An illustrated account dealing with point-contact Ge diodes.

621.314.632 : 621.376.233 **890**

Crystal-Mixer Design at Frequencies from 20 000 to 60 000 Mc/s.—C. R. Ditchfield. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 365–371.) Crystal valves designed during the war are reviewed. A new design of plug-in waveguide type is described and some performance figures are given. With a minor modification to the holder, this type can be used as a harmonic generator.

621.314.7 **891**

A Germanium *N-P-N* Alloy Junction Transistor.—D. A. Jenny. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1728–1734.) The transistor discussed is the counterpart of the *p-n-p* type described by Law et al. (876 of 1953). It is made by fusing Pb-Sb alloy into both faces of a thin wafer of *p*-type single-crystal Ge. Compared with the *p-n-p* type, the penetration of the alloy is more uniform, giving flatter junctions and better control of junction spacing. Test figures for a typical lot of 100 units are given; the best values obtained are 45 db for the power gain, 0·997 for α and 3 db for the 1-kc/s noise factor. The h.f. performance is better than that of the *p-n-p* type, but the improvement is not so great as would be expected from the electron/hole mobility ratio.

621.314.7 **892**

Home-Made Transistors.—P. B. Helsdon. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 20–23.) Practical details are given for converting selected Ge diodes into point-contact transistors.

621.314.7 **893**

The Surface-Barrier Transistor: Part 1 — Principles of the Surface-Barrier Transistor.—W. E. Bradley. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1702–1706.) The 'surface-barrier' transistor comprises a plate of *n*-type single-crystal Ge with the thickness at a central region reduced to a few microns, and emitter and collector electrodes plated respectively on to the two faces at the thinned region. A method of production is used which permits accurate control of the geometry. An explanation is given of the hole-emission, conduction and collection mechanisms involved in the operation; this depends on the formation of a layer about 0·0001 in. thick just below the Ge surface, within which there are practically no free charge carriers. Efficient operation at frequencies $>$ 60 Mc/s has been achieved with a supply voltage of 3 V.

621.314.7 **894**

The Surface-Barrier Transistor: Part 4 — On the High-Frequency Performance of Transistors.—R. Kansas. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1712–1714.) A theoretical determination of the α-cut-off frequency for the surface-barrier transistor is given, based on analysis presented by Steele (881 of 1953) for junction transistors. Values found from the theory are compared with experimental values. The effect of nonuniformity of the thickness of the Ge is demonstrated. Part 3: 692 above.

621.314.7 : 537.311.33 **895**

The Surface-Barrier Transistor: Part 5 — The Properties of Metal-to-Semiconductor Contacts.—R. F. Schwarz & J. F. Walsh. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1715–1720.) An investigation is made of the properties of the plated In-Ge junctions formed by the technique used in the production of the surface-barrier transistor (see 896 below). Measured *I/V* characteristics are only slightly different from those for alloyed junctions. The shape and capacitance of the barrier are discussed; from a comparison of measured capacitance values with theoretically derived values it is inferred that the effective area of the barrier is of the same order of magnitude as the actual area of the plated electrode. Expressions are derived for the hole and electron currents across the barrier, and it is shown that enhanced hole current is obtained in the transistor as a result of the relatively small distance between the emitter and collector electrodes. Part 4: 894 above.

621.314.7.002.2 **896**

The Surface-Barrier Transistor: Part 2 — Electrochemical Techniques for Fabrication of Surface-Barrier Transistors.—J. W. Tiley & R. A. Williams. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1706–1708.) Details are given of the method used to reduce the thickness of the Ge plate (see 893 above). Two glass nozzles of diameter about 0·005 in. are mounted so as to direct jets of electrolyte on to the two faces of the plate, the latter being connected as anode. An even etch is obtained. The influence of illumination and of the high resistivity of the surface barriers on the passage of the etching current is discussed. When the etching is completed, the polarity of the system is reversed and the transistor electrodes are plated on using the same arrangement of equipment. Experiments indicate that In is a suitable metal for the electrodes. In typical units the diameter of the etched pit is 0·015 in., that of the emitter is 0·003 in., and that of the collector 0·006 in. The unit is provided with a Ni base tab by which it is mounted on a glass stem. Part 1: 893 above.

621.38.002.2 : 53 **897**

Physics in the Electronic Valve Industry.—J. Thomson. (*Brit. J. appl. Phys.*, Sept. 1953, Vol. 4, No. 9, pp. 262–267.) The importance of physics in the development and manufacturing stages of production of various electronic devices is indicated.

621.385 : 621.372.57 **898**

Starvation Circuits and their Limitations.—Erdle. (See 680.)

621.385 : 621.396.662 **899**

Tuning-Indicator Valves.—F. Malsch. (*Elektrotech. Z., Edn A*, 1st Sept. 1953, Vol. 74, No. 17, pp. 497–500.) Description of the construction and operation of various types of indicator valve, including some relatively little used ones.

621.385 : 681.142 **900**

The Univac Tube Program.—Hinkelman & Kraus. (See 647.)

621.385.029.6 **901**

Some Recent Work in France on New Types of Valves for the Highest Radio Frequencies.—R. Warnecke & P. Guénard. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 351–362.) The valves reviewed include reflex klystrons, multicavity klystrons, velocity-modulation valves with distributed buncher, travelling-wave valves, magnetrons, magnetron-type travelling-wave valves, and backward-wave valves (called carcinotrons). Theory is given, design aspects are discussed, and some performance figures are presented. References to papers dealing with these valves in greater detail are included.

621.385.029.6 : 621.372.2 **902**

Analysis of a Transmission-Line Type of Thermionic-Amplifier Valve.—I. A. D. Lewis. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 16–24.) Analysis is presented for a line comprising two helices in proximity to an earthed straight conductor. Two waves in each direction, with different phase velocities, can co-exist. The design of a valve is discussed with a cylindrical cathode and coaxial helical grid and anode. Waves in the slower mode, in which anode and grid voltages are out of phase, are amplified according to an exponential law; waves in the faster mode, in which anode and grid voltages are in phase, are attenuated by a similar amount. For perfect matching at the ends of the line, the two helices must be wound in opposite senses and the coefficients of inductive and capacitive coupling must be equal. With a valve of this type a balanced output could be obtained with an unbalanced input.

621.385.029.63/.64 **903**

Electron Flow through Small Tubes with Magnetic Focusing.—J. L. Stewart. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1236–1240.) A calculation is made of the beam current flowing through a narrow tube or between a pair of parallel plates, taking account of the helical electron motion due to the magnetic focusing. The results are presented graphically. Expressions are also given for the current intercepted and for an equivalent beam conductance relating the power associated with the rotational motion of the beam to the intensity of an applied transverse electric field. The theory is applicable to travelling-wave valves.

621.385.029.63 : 621.376.3 : 621.397.26 **904**

A 50-Watt F.M. Magnetron for Relay Service.—D. P. Kennedy. (*Tele-Tech*, Aug. 1953, Vol. 12, No. 8, pp. 66–68.) Outline descriptions are given of the QK-174C magnetron oscillator, which is continuously tunable over the frequency range 1·99–2.11 kMc/s, and of a television relay transmitter incorporating it. The associated wide-band f.m. receiver is also briefly described.

621.385.029.64 **905**

Low-Noise Traveling-Wave Tubes for X-Band.—D. A. Watkins. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1741–1746.) Tests on valves using velocity jumps for noise reduction (1470 of 1952) show that best results are obtained with a single-jump arrangement in which the electrodes are shaped so as to make the transition from the low-voltage to the high-voltage space relatively gradual. A valve with a noise figure of 11·3 db and a gain of 18 db at 9 kMc/s is described The variation of noise figure with magnetic field, operating voltage and cathode temperature is shown graphically.

621.385.032.216 **906**

The Life of Oxide Cathodes in Modern Receiving Valves.—G. H. Metson, S. Wagener, M. F. Holmes & M. R. Child. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 371–372.) Discussion on 1781 of 1952.

621.385.032.216 : 621.317.332 **907**

The Dependence of Mutual Conductance on Frequency of Aged Oxide-Cathode Valves and its Influence on their Transient Response.—J. R. Tillman, J. Butterworth & R. E. Warren. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 8–15.) Full paper. See 2838 of 1953.

621.385.1 **908**

Valve Codes.—M. H. N. Potok. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 38–40.) An examination of the possibility of devising a method of designation which will serve not only to distinguish valves which are not interchangeable but also to give information about the properties of the valve designated.

621.385.2 **909**

The Space-Charge Smoothing Factor: Part 3.—C. S. Bull. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 47–50.) In a previous paper (2383 of 1950), thirty partial differential coefficients were enumerated which together express the characteristics of a diode. A study of the effect of fluctuations on one of these coefficients brings to light a serious error in all prior work on the subject. As a result, it may be assumed that the total emission fluctuates according to the law derived by Schottky in 1918, and estimates of the fluctuations can hence be obtained in closer agreement with values observed experimentally. Part 2: 291 of 1953.

621.385.3.029.63 **910**

A Disc-Seal Triode as a U.H.F. Amplifier.—S. C. Peek. (*Sylvania Technologist*, Oct. 1953, Vol. 6, No. 4, pp. 81–85.) The construction of the Type-6BA4 planar triode is described, and the results of performance tests in a 450–900-Mc/s grounded-grid coaxial amplifier are given. At 890 Mc/s a power gain of 14 db and a noise figure of 10 db were obtained.

621.385.83 **911**

Spatially Alternating Magnetic Fields for Focusing Low-Voltage Electron Beams.—J. R. Pierce. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, p. 1247.) A note referring to the work of Courant et al. (1454 of 1953). The solution of the equations of motion of an electron in axially symmetrical, converging, periodic magnetic fields shows that dense beams can be stable in such fields. Periodic focusing is discussed briefly.

621.385.83 : [621.317.329 + 517.944 **912**

Electrostatic Potential Plotting for Use in Electron-Optical Systems.—Kuo-Chu Ho & R. J. Moon. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1186–1193.) A noniterative numerical method is developed for solving a partial differential equation, the boundary conditions of which are not known over the entire closed boundary. This method is used to calculate the shapes of beam-forming electrodes for a rectilinear flow. Complete agreement is obtained with Pierce's experimental results (4275 of 1940) and with the results of electrolyte-trough determinations.

621.385.832 : 621.317.32 **913**

Measurement of Voltage using a Simple Electron-Beam Valve.—Lieb. (See 798.)

621.385.832 : 621.318.572 **914**

The E1T Decade Counter Tube.—(*Electronic Applic. Bull.*, May 1953, Vol. 14, No. 5, pp. 71, 76.) Corrections and addendum to paper noted in 603 of February.

621.385.832.002.2 **915**

The Production of Emiscope Cathode-Ray Tube Gun-Assemblies.—(*Machinery, Lond.*, 18th Sept. & 23rd Oct. 1953, Vol. 83, Nos. 2131 & 2136, pp. 555–563 & 795–800.)

621.385.832.002.2 : 681.142 **916**

Cementing Metal Screens to Cathode Ray Tubes.—R. W. Holmes. (*Mater. & Meth.*, Sept. 1953, Vol. 38, No. 3, pp. 184, 186.) The method described was used for fixing fine mesh screens externally to the screens of c.r.-tube storage units for the AVIDAC digital computer.

621.385.832.012 **917**

Experimental Determination of the Characteristic-Curve Index in Cathode Ray Tubes.—E. Gundert. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 340–341.) The cathode current J_k in a triode gun is related to the control grid voltage U_g by the equation $J_k = K(U_g - U_{sp})^n$ where U_{sp} is the value of U_g for $J_k = 0$. Logarithmic plotting presupposes a knowledge of U_{sp}, which, owing to the Maxwell electron velocity distribution, is not easily determined. A formula is derived from which n can be calculated by substituting the values of U_g corresponding to three values of J_k in geometrical progression. For cathode currents up to about 100 μA, $n \approx 2{\cdot}5$.

621.387.032.212 : 621.396.665 **918**

Gas-Discharge Tubes for Control of Microwave Attenuation.—D. H. Pringle & E. J. Whitmore. (*J. sci. Instrum.*, Sept. 1953, Vol. 30, No. 9, pp. 320–323.) Details are given of the construction and operation of cold-cathode tubes as attenuators for the 3-cm waveband. Operation depends on the interaction between the microwave field and the electron gas supported by the discharge plasma. Construction is based on that of conventional t.r. switches; a high-Q narrow-band type and a low-Q wide-band type are described. Applications to a.g.c. and modulator circuits are discussed.

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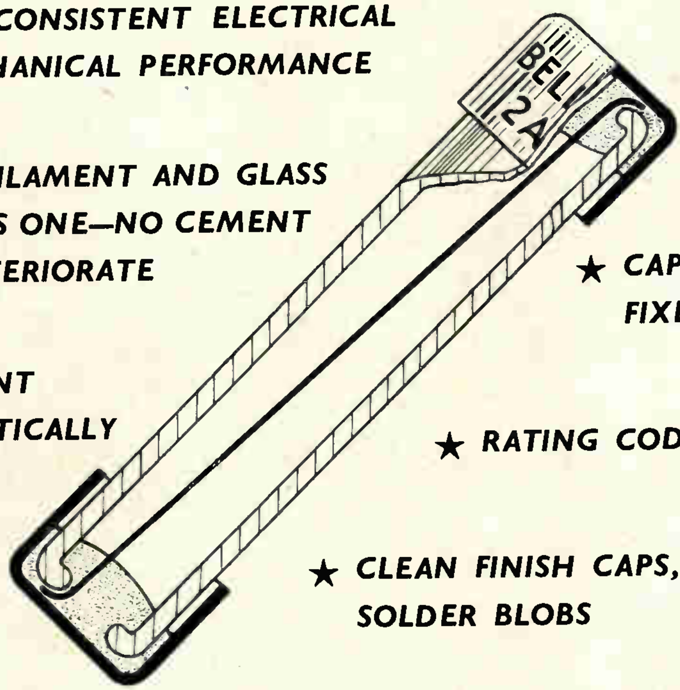

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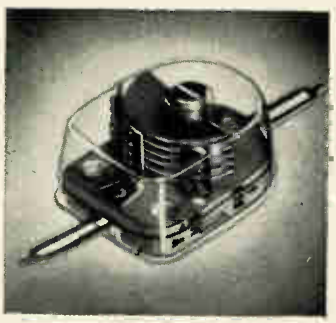

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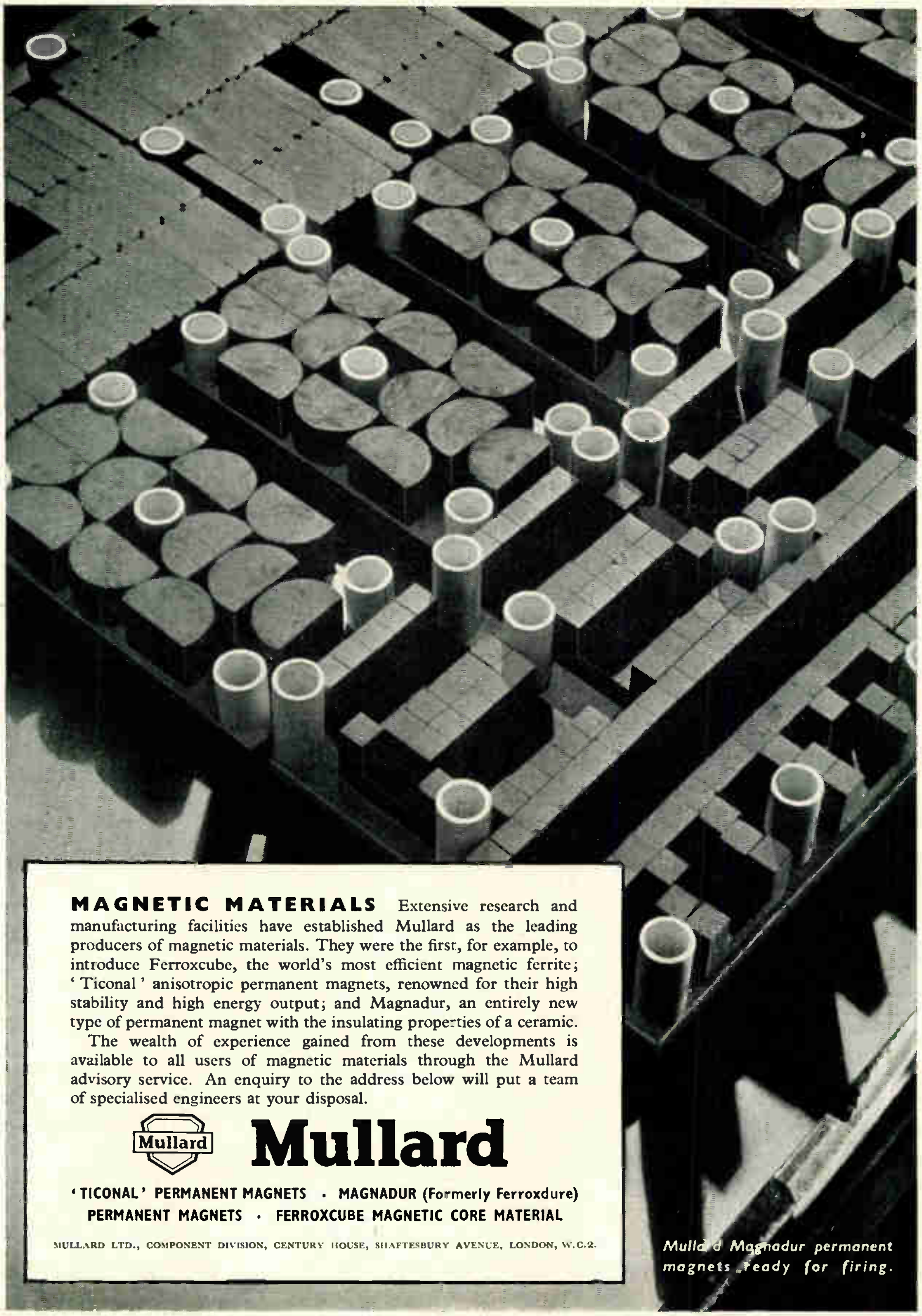

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APPOINTMENTS—The engagement of persons answering these advertisements must be made through the local office of the Ministry of Labour and National Service, etc., if the applicant is a man aged 18-64 or a woman 18-59 inclusive, unless he or she or the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

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Index to Advertisers

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INDEX

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INDEX TO AUTHORS

INDEX TO WIRELESS ENGINEER
ABSTRACTS AND REFERENCES

VOL. 30. 1953

This index to the Abstracts and References, published monthly in "Wireless Engineer" during 1953, is compiled on the same plan as for 1952, there being both Author and Subject Indexes. A list of the principal journals scanned for abstracting is included with the publishers' addresses.

CONTENTS

SYMBOLS (A) Abstract, (B) Book Review, (C) Note of Correction, (D) Discussion

AUTHOR INDEX A name followed by "and" is that of the first author of a jointly written paper, while the word "with" indicates that the name indexed is that of the second author.

Abbreviations used in the Abstracts and Index

a.c.	= alternating current
d.c.	= direct current
h.v.	= high voltage
l.v.	= low voltage
a.f.	= audio frequency
i.f.	= intermediate frequency
r.f.	= radio frequency, including:—
l.f.	= low frequency, <300 kc/s
m.f.	= medium frequency, 300–3000 kc/s
h.f.	= high frequency, 3–30 Mc/s
v.h.f.	= very high frequency, 30–300 Mc/s
u.h.f.	= ultra high frequency, >300 Mc/s
a.m.	= amplitude modulation
f.m.	= frequency modulation
p.m.	= pulse modulation, including:—
p.a.m.	= pulse amplitude modulation
p.c.m.	= pulse code modulation
p.f.m.	= pulse frequency modulation
p.ph.m.	= pulse phase modulation *or*
p.p.m.	= pulse position modulation
p.w.m.	= pulse width modulation
ph.m.	= phase modulation
v.m.	= velocity modulation
c.w.	= continuous wave
i.c.w., m.c.w.	= modulated c.w.
s.w.*	= short wave
u.s.w.*	= ultra short wave
λ	= wavelength
c.r.	= cathode ray
c.r.o.	= cathode ray oscilloscope
d.f.	= direction finding
e.m.	= electromagnetic, *but*
e.m.f.	= electromotive force
a.f.c.	= automatic frequency control
a.g.c.	= automatic gain control
a.ph.c.	= automatic phase control
a.v.c.	= automatic volume control
m.u.f.	= maximum usable frequency
p.p.i.	= plan position indicator
s.s.b.	= single sideband
d.s.b.	= double sideband
s.w.r.	= standing wave ratio
v.f.o.	= variable frequency oscillator
R/T	= radiotelephony
W/T	= wireless telegraphy
TV	= television

*No clearly defined limits

AUTHOR INDEX

G

SUBJECT INDEX

J

ERRATA

In "Abstracts and References" throughout the year

Abstract No.	41	Cancel the dagger in the U.D.C. number.
,, ,,	121	In line 4, for 'larger' read 'large'.
,, ,,	384	For '537.533.8' read '537.534.8'.
,, ,,	454	For '621.385.5' read '621.383.5'.
,, ,,	763	In line 9, for '(f)t' read 'f(t)'.
,, ,,	1377	For 'S. T. Kalashnikov' read 'S. G. Kalashnikov'.
,, ,,	1547	For '621.38(061.4)' read '621.38 : 061.4'.
,, ,,	2328	For 'R. Freymann' read 'R. Freymann, R. Rohmer & B. Hagene'.
,, ,,	2576	In line 9, for 'required' read 'described'.
,, ,,	2894	For 'S. K. Dike' read 'S. H. Dike'.
,, ,,	3015	For '537.311.35' read '537.311.33'.
,, ,,	3095	For '3905' read '3095'.
,, ,,	3408	For '621.018.78' read '621.3.018.78'.

U.D.C. Changes

Cyclotron 621 384.611
Getters 621.3.032.461
Pulse 621.3.018.75

LIST OF JOURNALS

A selection of the journals which are regularly scanned is given below, together with the addresses of their publishers or editorial offices and the abbreviations of their titles as used in the Abstracts and References. Applications for copies of any journal should be made to the addresses given.

The full title of each journal is given in bold type and is followed by the address, the abbreviated title being shown within brackets. In a few cases the nature of a journal is indicated, where neither the title nor the address shows it clearly.

Acta physica austriaca, Springer Verlag, Wien I, Mölkerbastei 5, Austria. (*Acta phys. austriaca*)

Acta Polytechnica, Royal Swedish Academy of Engineering Sciences, Stockholm, Sweden. (*Acta polyt., Stockholm*)

Acustica, S. Hirzel Verlag, Gotthardstrasse 6, Zürich, Switzerland. (*Acustica*)

Advances in Physics, Taylor & Francis Ltd, Red Lion Court, Fleet Street, London, E.C.4, England. (*Advances Phys.*)

Akustische Beihefte, S. Hirzel Verlag, Gotthardstrasse 6, Zürich, Switzerland. (*Akust. Beihefte*)

Alta Frequenza, Associazione Elettrotecnica Italiana, Milano (202), Via S. Paolo 10, Italy. (*Alta Frequenza*)

Annalen der Physik, J. A. Barth, Leipzig C1, Salomonstrasse 18B, Germany. (*Ann. Phys. Lpz.*)

Annales de Géophysique, Service des Publications du C.N.R.S., 45 rue d'Ulm, Paris 5e, France. (*Ann. Géophys.*)

Annales de Physique, Masson & Cie, 120 Boulevard Saint-Germain, Paris 6e, France. (*Ann. Phys., Paris*)

Annales de Radioélectricité, 10 rue Carducci, Paris 19e, France. (*Ann. Radioélect.*)

Annales des Télécommunications, 3 & 5 Boulevard Pasteur, Paris 15e, France. (*Ann. Télécommun.*)

Annali di Geofisica, Istituto Nazionale di Geofisica, Città universitaria, Roma, Italy. (*Ann. Geofis.*)

Applied Scientific Research, Martinus Nijhoff, Lange Voorhout 9, The Hague, Netherlands. (*Appl. sci. Res.*)

Archiv der elektrischen Übertragung, S. Hirzel Verlag, Stuttgart, Germany. (*Arch. elekt. Übertragung*)

Archiv für Elektrotechnik, Springer Verlag, Heidelberg, Neuenheimer Landstrasse 24, Germany. (*Arch. Elektrotech.*)

Archiv für Meteorologie Geophysik und Bioklimatologie, Series A, Springer Verlag, Wien I, Mölkerbastei 5, Austria. (*Arch. Met., Wien*)

Archiv für technisches Messen, R. Oldenbourg Verlag, München, Lotzbeckstrasse 2b, Germany (*Arch. tech. Messen*)

Arkiv for Fysik, published for Royal Swedish Academy of Sciences by Almqvist & Wiksells Boktryckeri A.B., Stockholm, Sweden. (*Ark. Fys.*)

A.T.E. Journal (incorporating Strowger Journal), Automatic Telephone & Electric Co., Strowger Works, Liverpool 7, England. (*A.T.E. J.*)

Audio Engineering, Radio Magazines Inc., 10 McGovern Avenue, Lancaster, Pa., U.S.A (*Audio Engng, N.Y.*)

Australian Journal of Applied Science, Commonwealth Scientific and Industrial Research Organization, 314 Albert Street, East Melbourne C2, Australia. (*Aust. J. appl. Sci.*)

Australian Journal of Physics (formerly **Australian Journal of Scientific Research Series A**), Commonwealth Scientific and Industrial Research Organization, 314 Albert Street, East Melbourne C2, Australia. (*Aust. J. Phys.*)

A.W.A. Technical Review, Amalgamated Wireless (Australasia) Ltd, Sydney, Australia. (*A.W.A. tech. Rev.*)

B.B.C. Quarterly, British Broadcasting Corporation, 35 Marylebone High Street, London, W.1, England. (*B.B.C. Quart.*)

Beama Journal, British Electrical and Allied Manufacturers' Association, 36 Kingsway, London, W.C.2, England. (*Beama J.*)

Bell Laboratories Record, 463 West Street, New York 14, N.Y., U.S.A. (*Bell Lab. Rec.*)

Bell System Technical Journal, American Telephone and Telegraph Company, 195 Broadway, New York 7, N.Y., U.S.A. (*Bell Syst. tech. J.*)

British Journal of Applied Physics, 47 Belgrave Square, London, S.W.1, England. (*Brit. J. appl. Phys.*)

Brown Boveri Review, Baden, Switzerland. (*Brown Boveri Rev.*)

Bulletin de l'Académie des Sciences de l'U.R.S.S., (*a*) série physique, (*b*) série géophysique, (*c*) classe sciences techniques, Academy of Sciences, Moscow, U.S.S.R. (In Russian.) (*Bull. Acad. Sci., U.R.S.S.,* (*a*) *sér. phys.,* (*b*) *sér. géophys.* (*c*) *tech. Sci.*)

Bulletin de l'Association suisse des Électriciens, S.A. Fachschriften-Verlag and Buchdruckerei, Stauffacherquai 36–40, Zürich 4, Switzerland. (*Bull. schweiz. elektrotech. Ver.*)

Bulletin de la Société française des Électriciens, 55 Quai des Grands-Augustins, Paris 6e, France. (*Bull. Soc. franç. Élect.*)

Câbles et Transmission, Sotelec, 16 rue de la Baume, Paris 8e, France. (*Câbles & Transm.*)

Canadian Journal of Physics, National Research Council, Ottawa, Canada. (*Canad. J. Phys.*)

Chalmers tekniska Högskolas Handlingar, N. J. Gumperts Förlag, Göteborg, Sweden. (*Chalmers tek. Högsk. Handl.*)

Communication Engineering, The Publishing House, Great Barrington, Mass., U.S.A. (*Commun. Engng*)

Communication News, Philips Telecommunications Industries, Hilversum, Netherlands. (*Commun. News*)

Communications on Pure and Applied Mathematics, Interscience Publishers Inc., 250 Fifth Avenue, New York 1, N.Y., U.S.A. (*Commun. pure appl. Math.*)

Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, Gauthier-Villars, 55 Quai des Grands-Augustins, Paris 6e, France. (*C.R. Acad. Sci., Paris*)

Comptes Rendus (Doklady) de l'Académie des Sciences de l'U.R.S.S., Academy of Sciences, Moscow, U.S.S.R. (In Russian.) (*C.R. Acad. Sci. U.R.S.S.*)

Electrical Communication, International Telephone and Telegraph Corporation, 67 Broad Street, New York 4, N.Y., U.S.A. (*Elect. Commun.*)

Electrical Engineering, Journal of the American Institute of Electrical Engineers, 500 Fifth Avenue, New York 36, N.Y., U.S.A. (*Elect. Engng, N.Y.*)

Electrical Journal (formerly **Electrician**), Bouverie House, 154 Fleet Street, London, E.C.4, England. (*Elect. J.*)

Electrical Manufacturing, 1250 Sixth Avenue, New York 20, N.Y., U.S.A. (*Elect. Mfg*)

Electrical Times, Sardinia House, Sardinia Street, London, W.C.2, England. (*Elect. Times*)

Electronic Application Bulletin, N.V. Philips Gloeilampenfabrieken, Eindhoven, Netherlands. (*Electronic Applic. Bull.*)

Electronic Engineering, 28 Essex Street, London, W.C.2, England. (*Electronic Engng*)

Electronics, 99–129 North Broadway, Albany 1, N.Y., U.S.A. (*Electronics*)

Elektrotechnik und Maschinenbau, Journal of the Elektrotechnischer Verein Österreichs, Springer Verlag, Wien I, Mölkerbastei 5, Austria. (*Elektrotech. u. Maschinenb.*)

Elektrotechnische Zeitschrift, Edition A & B, VDE-Verlag G.m.b.H., Frankfurt/Main, Osthafenplatz 6, Germany. (*Elektrotech. Z.*)

Endeavour, Imperial Chemical Industries, Millbank, London, S.W.1, England. (*Endeavour*)

Engineer, 28 Essex Street, London, W.C.2, England. (*Engineer, Lond.*)

Engineering, 35 & 36 Bedford Street, London, W.C.2, England. (*Engineering, Lond.*)

Ericsson Review, Stockholm 32, Sweden. (*Ericsson Rev.*)

Fernmeldetechnische Zeitschrift, Vieweg & Sohn, Braunschweig, Burgplatz 1, Germany. (*Fernmeldetech. Z.*)

Frequenz, Schiele & Schön, Berlin, S.W.29, Boppstrasse 10, Germany. (*Frequenz*)

Funk und Ton, Verlag für Radio-Foto-Kinotechnik G.m.b.H., Berlin-Borsigwalde, Eichborndamm 141–167, Germany. (*Funk u. Ton*)

G.E.C. Journal, General Electric Company, Magnet House, Kingsway, London, W.C.2, England. (*G.E.C. J.*)

G.E.C. Telecommunications, General Electric Company Ltd, Coventry, England. (*G.E.C. Telecommun.*)

General Electric Review, General Electric Company, 1 River Road, Schenectady 5, N.Y., U.S.A. (*Gen. Elect. Rev.*)

General Radio Experimenter, General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass., U.S.A. (*Gen. Radio Exp.*)

Helvetica Physica Acta, Journal of the Société suisse de Physique, Éditions Birkhäuser, Bâle, Switzerland. (*Helv. phys. Acta*)

HF, 55 rue Defacqz, Brussels, Belgium. (*HF, Brussels*)

Indian Journal of Physics (and Proceedings of the Indian Association for the Cultivation of Science), 210 Bowbazer Street, Calcutta, India. (*Indian J. Phys.*)

Journal of the Acoustical Society of America, American Institute of Physics, 57 East 55th Street, New York 22, N.Y., U.S.A. (*J. acoust. Soc. Amer.*)

Journal of Applied Physics, American Institute of Physics, 57 East 55th Street, New York 22, N.Y., U.S.A. (*J. appl. Phys.*)

Journal of Atmospheric and Terrestrial Physics, Pergamon Press Ltd, 242 Marylebone Road, London, N.W.1, England. (*J. atmos. terr. Phys.*)

Journal of the Audio Engineering Society, P.O. Box 12, Old Chelsea Station, New York 11, N.Y., U.S.A. (*J. audio Engng Soc.*)

Journal of the British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1, England. (*J. Brit. Instn Radio Engrs*)

Journal of the Franklin Institute, Prince and Lemon Streets, Lancaster, Pa, U.S.A. (*J. Franklin Inst.*)

Journal of Geophysical Research, 5241 Broad Branch Road, N.W., Washington 15, D.C., U.S.A. (*J. geophys. Res.*)

Journal of the Indian Institute of Science, Indian Institute of Science, Bangalore 3, India. (*J. Indian Inst. Sci.*)

Journal of the Institute of Navigation, John Murray Ltd, 50 Albemarle Street, London, W.1, England. (*J. Inst. Nav.*)

Journal of the Institution of Engineers, Australia, Science House, Gloucester & Essex Streets, Sydney, Australia. (*J. Instn Engrs, Aust.*)

Journal of Mathematics and Physics, Massachusetts Institute of Technology, Cambridge 39, Mass., U.S.A. (*J. Math. Phys.*)

Journal of the Optical Society of America, American Institute of Physics, 57 East 55th Street, New York 22, N.Y., U.S.A. (*J. opt. Soc. Amer.*)

Journal of the Physical Society of Japan, Maruzen Publishing Co., P.O. Box 605 Central, Tokyo, Japan. (*J. phys. Soc. Japan*)

Journal de Physique et le Radium, 12 place Henri-Bergson, Paris 8e, France. (*J. Phys. Radium*)

Journal of Research of the National Bureau of Standards, U.S. Government Printing Office, Washington, D.C., U.S.A. (*J. Res. nat. Bur. Stand.*)

Journal of Scientific Instruments, 47 Belgrave Square, London, S.W.1, England. (*J. sci. Instrum.*)

Journal of the Society of Motion Picture and Television Engineers, 40 West 40th Street, New York 18, N.Y., U.S.A. (*J. Soc. Mot. Pict. Televis. Engrs*)

Journal of the Television Society, 164 Shaftesbury Avenue, London, W.C.2, England. (*J. Televis. Soc.*)

Marconi Review, Marconi House, Chelmsford, England. (*Marconi Rev.*)

Materials and Methods, Reinhold Publishing Corporation, 330 West 42nd Street, New York 36, N.Y., U.S.A. (*Mater. & Meth.*)

Metal Industry, Louis Cassier Company Ltd, Dorset House, Stamford Street, London, S.E.1, England. (*Metal Ind., Lond.*)

Metal Treatment, 49 Wellington Street, London, W.C.2, England. (*Metal Treatm.*)

Metallurgia, 31 King Street West, Manchester 3, England. (*Metallurgia, Manchr*)

Meteorological Magazine, His Majesty's Stationery Office, York House, Kingsway, London, W.C.2, England. (*Met. Mag., Lond.*)

Microtecnic, 23 Avenue de la Gare, Lausanne, Switzerland. (*Microtecnic*)

Modern Plastics, Breskin Publications, Emmett Street, Bristol, Conn., U.S.A. (*Mod. Plast.*)

Monthly Notices of the Royal Astronomical Society, Burlington House, London, W.1, England. (*Mon. Not. R. astr. Soc.*)

Nachrichten Technik, V.E.B. Verlag Technik, Berlin N.W.7, Unter den Linden 12, Germany. (*NachrTech.*)

Nature, Macmillan & Co. Ltd, St. Martin's Street, London, W.C.2, England. (*Nature, Lond.*)

Naturwissenschaften, Springer Verlag, Heidelberg, Neuenheimer Landstrasse 24, Germany. (*Naturwissenschaften*)

Nucleonics, 330 West 42nd Street, New York 36, N.Y., U.S.A. (*Nucleonics*)

Nuovo Cimento, Editore Nicola Zanichelli, Bologna, Via Irnerio 34, Italy. (*Nuovo Cim.*)

Observatory, Royal Observatory, Herstmonceux Castle, Hailsham, Sussex England. (*Observatory*)

Onde électrique, 40 rue de Seine, Paris 6e, France. (*Onde élect.*)

Optik, Wissenschaftliche Verlagsgesellschaft, Stuttgart 1, Postfach 40, Germany. (*Optik, Stuttgart*)

Österreichische Zeitschrift für Telegraphen- Telephon- Funk- und Fernsehtechnik, Springer Verlag, Wien I, Mölkerbastei 5, Austria. (*Öst. Z. Telegr. Teleph. Funk Fernsehtech.*)

Philips Research Reports, N.V. Philips Gloeilampenfabrieken, Eindhoven, Netherlands. (*Philips Res. Rep.*)

Philips Technical Review (as for **Philips Research Reports**) (*Philips tech. Rev.*)

Philosophical Magazine, Taylor and Francis Ltd, Red Lion Court, Fleet Street, London, E.C.4, England. (*Phil. Mag.*)

Philosophical Transactions of the Royal Society, Cambridge University Press, Bentley House, London, N.W.1, England. (*Phil. Trans.*)

Physica, Journal of the Dutch Physical Society, Bijlhouwerstraat 6, Utrecht, Netherlands. (*Physica*)

Physical Review, 57 East 55th Street, New York 22, N.Y., U.S.A. (*Phys. Rev.*)

Post Office Electrical Engineers' Journal, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1, England. (*P.O. elect. Engrs' J.*)

Poste e Telecomunicazioni, Ministero P.T., Viale Trastevere 189, Roma, Italy. (*Poste e Telecomunicazioni*)

Proceedings of the Cambridge Philosophical Society, Cambridge University Press, Bentley House, London, N.W.1. England. (*Proc. Camb. phil. Soc.*)
Proceedings of the Institute of Radio Engineers, 1 East 79th Street, New York 21, N.Y., U.S.A. (*Proc. Inst. Radio Engrs*)
Proceedings of the Institution of Electrical Engineers, Parts I, II, III and IV, Savoy Place, London, W.C.2, England. (*Proc. Instn elect. Engrs*)
Proceedings of the Institution of Radio Engineers, Australia, Science House, Gloucester Street, Sydney, N.S.W., Australia. (*Proc. Instn Radio Engrs Aust.*)
Proceedings of the National Electronics Conference, 852 East 83rd Street, Chicago 19, Illinois, U.S.A. (*Proc. nat. Electronics Conf., Chicago*)
Proceedings of the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7, England. (*Proc. phys. Soc.*)
Proceedings of the Radio Club of America, 11 West 42nd Street, New York, N.Y., U.S.A. (*Proc. Radio Cl. Amer.*)
Proceedings of the Royal Society, Cambridge University Press, Bentley House, London, N.W.1, England. (*Proc. roy. Soc.*)

QST, American Radio Relay League Inc., 38 La Salle Road, West Hartford, 7, Conn., U.S.A. (*QST*)
Quarterly of Applied Mathematics, Brown University, Providence 12, R.I., U.S.A. (*Quart. appl. Math.*)
Quarterly Journal of Mathematics, Oxford University Press, Amen House, London, E.C.4, England. (*Quart. J. Math.*)

Radio Technical Digest (Édition française), 122 Boulevard Murat, Paris 16e, France. (*Radio tech. Dig., Édn franç.*)
Radio Technik, Wien VI, Mariahilferstrasse 71, Austria. (*Radio Tech., Vienna*)
Radio & Television News, Ziff Davis Publishing Company, 366 Madison Avenue, New York, N.Y., U.S.A. (*Radio & Televis. News*)
RCA Review, RCA Laboratories Division, Princeton, N.J., U.S.A. (*RCA Rev.*)
Report on Ionosphere Research in Japan, Maruzen Publishing Co., P.O. Box 605 Central, Tokyo, Japan. (*Rep. Ionosphere Res. Japan*)
Reports on Progress in Physics, The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7. England. (*Rep. Progr. Phys.*)
Research, Butterworth's Scientific Publications Ltd, 88 Kingsway, London W.C.2, England. (*Research, Lond.*)
Review of Scientific Instruments, 57 East 55th Street, New York 22, N.Y., U.S.A. (*Rev. sci. Instrum.*)
Reviews of Modern Physics, 57 East 55th Street, New York 22, N.Y., U.S.A. (*Rev. mod. Phys.*)
Revista de Telecomunicación, Palacio de Comunicaciones, Madrid, Spain. (*Rev. Telecomunicación, Madrid*)
Revista Telegrafica Electronica, Arbó Editores, Buenos Aires, Argentina. (*Rev. telegr. Electronica, Buenos Aires*)
Revue générale de l'Électricité, 12 place Henri Bergson, Paris 8e, France. (*Rev. gén. Élect.*)
Revue d'Optique, 3 & 5 Boulevard Pasteur, Paris 15e, France. (*Rev. d'Optique*)
Revue scientifique, 4 rue Pomereu, Paris 16e, France. (*Rev. sci., Paris*)
Revue technique Compagnie française Thomson-Houston, 173 Boulevard Haussmann, Paris, France. (*Rev. tech. Comp. franç. Thomson-Houston*)
Ricerca scientifica, Roma, Piazza della Libertà 10, Italy. (*Ricerca sci.*)
R.S.G.B. Bulletin, New Ruskin House, Little Russell Street, London, W.C.1, England. (*R.S.G.B. Bull.*)

Schweizer Archiv für angewandte Wissenschaft und Technik, Buchdruckerei Vogt-Schild, Solothurn, Switzerland. (*Schweiz. Arch. angew. Wiss. Tech.*)
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