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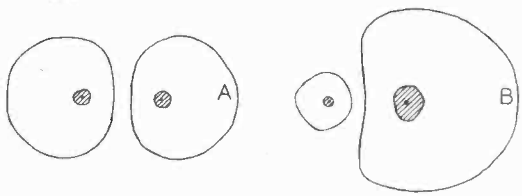
Editorial

Frequency versus Amplitude Modulation

IN the October number of *The General Electric Review*—a monthly journal issued by the General Electric Co. of America—there is a short article under the heading " High Lights and Side Lights " dealing with the relative merits of amplitude and frequency modulation. It is headed " better coverage " and makes surprising claims for frequency modulation. It is stated that, according to tests and calculations made by their radio engineers, under certain conditions, the area of good broadcast service with frequency-modulated transmission is 33 times as great as with amplitude modulation. Tests were made by installing two transmitters 15 miles apart, with transmitting antennae 300 feet high, the transmitting sets being of 1 kilowatt. The portable receiving antennae were 20 feet high. If the two transmitters were amplitude-modulated, the area around each transmitter in which its programme could be received without interference from the other transmitter was found to be very small. If the power of one transmitter was increased to 10 kilowatts, its service area was trebled, but that of the other was reduced to a third as is indicated in the figure where the shaded areas are those around each transmitter in which reception was possible with amplitude modulation, (*a*) with equal power and (*b*) with powers in the ratio of 10 to 1. It is important to note that both transmitters utilised the same frequency. A further increase of the power of the more powerful transmitter to 100 kilowatts again trebles its reception area at the expense of the 1 kilowatt station, the reception area of which is again divided by about 3.

With frequency modulation and equal transmitters of 1 kilowatt the reception area of each was 33 times that with amplitude modulation as shown by the large loops in Fig. (*a*). When the power of one station was increased to 10 kilowatts its coverage was now increased 2.35 times, and was about 25 times that with amplitude modulation, whilst that of the 1 kilowatt station, although reduced to less than a quarter, was still nearly 8 times that of the amplitude-modulated stations when both were of 1 kilowatt. Even when the other station had 100 times the power, which resulted in a further doubling of its coverage, the weaker station still had a reception area 3 times that of each of the two 1 kilowatt amplitude-modulated stations.



(*a*) (*b*)

Service areas. The inner cross-hatched areas refer to amplitude modulation, the outer limits to frequency modulation. (a) with similar 1kW transmitters, (b) with the power of one transmitter increased to 10 kW.

Although these claims may appear extravagant it must be emphasised that the article in which they are made opens with the words " under certain conditions." The aerials were 300 feet high and only 15 miles apart; the frequency employed is not stated and no details are given of the type of programme employed nor of the receiving apparatus. With two carefully controlled frequency-modulated transmitters it would be possible, with a relatively small difference between the two received signals of constant amplitude, so to adjust the limiting device that it eliminated the weaker signal entirely and still left enough of the stronger one to give satisfactory reception. According to Fig. (*a*) this was possible at a point between the stations 5.7 miles from one and 9.3 miles from the other; the most distant point *A* was 15 miles from one station and 30 miles from the other. Now, if it be assumed as an approximation that the field strength varies inversely as the square of the distance, the ratio of the wanted to the unwanted field strength was 2.66 in the first case and 4.0 in the second, which seem to be reasonable values since with weaker signals the ratio will have to be greater to provide the necessary excess of the wanted signal. When the power of one station is increased ten-fold its field strengths will be multiplied by $\sqrt{10}$. To receive the weaker station the ratios of the limiting distances were 4.4/10.6 and 6.4/21.4 miles and the field-strength ratios therefore $\frac{10.6^2}{4.4^2 \times 3.16}$ and $\frac{21.4^2}{6.4^2 \times 3.16}$, that is, 1.83 and 3.54 which again are reasonable values, agreeing as nearly as could be expected with the previous figures. Better agreement would be obtained if it were assumed that the field strength varied inversely as some higher power of the distance.

To receive the stronger station the distances were 8/7 and 21.5/36.5 miles, the upper figure referring always to the wanted station. The field strength ratios would therefore be $\frac{7^2 \times 3.16}{8^2}$ and $\frac{36.5^2 \times 3.16}{21.5^2}$, that is 2.42 and 9.1. Here again the first figure is quite reasonable but the second seems unreasonably high. On comparing Figs. (*a*) and (*b*) it will be seen that with equal powers the right-hand station could be received at *A* 15 miles from it and 30 miles from the unwanted station; on increasing the power of the nearer station ten-fold one would surely expect its working range to be extended much beyond the point *B*, which is only 21.5 miles from it, especially as the unwanted station is now 36.5 miles away. It may be, however, that the field strength fell off very rapidly at this distance of about 20 miles and that the interference from the more distant station was then a negligible factor, but if this were the case it would be difficult to account for the superiority of the frequency-modulated transmission. It would be interesting to know what were the limiting distances with the receivers employed for the two types of modulation in the absence of interference.

G. W. O. H.

The Locked-In Oscillator

Its Application to Automatic Tuning and Measurement of Modulation

By S. Byard, B.Sc., and W. H. Eccles, D.Sc., F.R.S., M.I.E.E.

Introductory

WHEN a circuit maintained in oscillation by a triode is submitted to an external electromotive force of nearly its own frequency the oscillator will "lock-in" to the external force if this be large enough, as has been well known since self-heterodyne (autodyne) receivers were first experimented with. For the purpose of our proposed application of this phenomenon to the problem of automatic tuning, we found it necessary to study experimentally the phenomenon as affected by the external force being modulated in amplitude, for on this subject little experimental information is available. The experiments of Eccles and Vincent in 1919 (1) were limited to an application of the locked-in oscillator as a receiver of waves modulated in frequency—a method employed of late years in America by

Woodyard (2). So far as we know the only writers who have touched upon amplitude modulation are U. Bab (3) and G. L. Kolber (4). But as this published work was insufficient for our purpose we undertook the measurements described in Section I of this paper.

I.—Effects of Amplitude Modulation upon Locking-In

The apparatus employed for the measurements is sketched diagrammatically in Fig. 1. T represents the triode of the oscillator to be locked-in; it was a Mullard 244V valve and was connected so that either battery bias or self bias could be used on its grid. *A* was a screened amplitude-modulated oscillator of high impedance output. *C* was a calibrated condenser of maximum capacitance about 1 $\mu\mu$F which was used to adjust

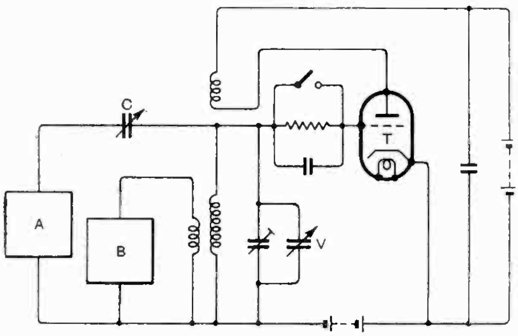


Fig. 1.—*Test circuit. A, screened modulated oscillator. B, H.F. voltmeter and modulation meter.*

as desired the input to the tuned grid circuit of the oscillator. *V* is a vernier condenser for making small changes in the natural frequency of the oscillator; an alteration of 1 $\mu\mu$F changed this frequency by 3 kc/s when it was about 1,100 kc/s. *B* was an anode bend voltmeter having a square law characteristic. It had three uses. First, it measured the voltage across the tuned grid circuit, the inductive coupling to this circuit being such that the voltmeter readings (which are plotted unaltered in the Figures) gave approximately half the volts across the tuned circuit. Secondly, it measured the input voltage when the heater of the triode was switched off and the circuit tuned to resonance with the carrier. Thirdly, it served as the H.T. detector of a modulation meter of the kind described by Cooper and Smith (5), in which the percentage modulation is deduced from the potential drop along a known resistance in its anode circuit. Such a meter cannot tell us the form of the modulation but is easily arranged to measure small modulation percentages. The depth of modulation was varied up to 90 per cent. and its measurement checked by van der Pol's crest and trough method using two diodes (6). Modulation frequencies of 50 c/s and 1,000 c/s were used in the measurements.

For making the measurements a telephone receiver was connected into the anode circuit of the valve voltmeter and then the vernier condenser was varied until the familiar rising heterodyne tone was heard. While the oscillator was locked in the modulation frequency was heard steadily and the break-away was announced as a sharp rattle, which in turn gave way to the heterodyne note, rising as distuning increased. But with the higher modulation frequencies, say 1,000 c/s, further distuning after the break-away brought another space in which only the modulation frequency was heard; caused, no doubt, by isochronism with a sideband of the input. U. Bab (3) has discussed the complementary case in which a sideband of a modulated oscillator was pulled into synchronism by an external excitation, resulting in a wholesale shift of the three oscillator frequencies In the present measurements only the first break-away each side of resonance was noted, and the alteration of capacitance from the breakaway on one side to that on the other side was taken as the isochronous range. After preliminary trials it was found convenient, for most of the measurements, to fix the carrier frequency of the input at 1,100 kc/s, the modulation frequency at 50 c/s, the anode voltage at 70 volts, and the grid bias at 4 volts negative. The feedback was also fixed at a medium value except in certain experiments mentioned below.

Results of Measurements.

The relations between the isochronous range (as measured by the change of capacitance of the vernier condenser), the percentage modulation of the input, and the percentage modulation in the locked-in triode circuits are shown by Figs. 2, 3 and 4. The curves in all these Figures indicate that the modulation was greatly reduced by passing the waves into the locked-in oscillator, the more so the smaller the input amplitude. Fig. 2 also indicates that modulation of the triode oscillation rose towards the ends of the isochronous range, doubtless because the phase differences input, or, in other words, the isochronous range is determined by the minimum input amplitude, that is, the amplitude of the trough oscillations, during a complete modulation period. The effects of varying the mean voltage of the input when this was modulated 50 per cent. are shown in Figs. 5 and 6. Both the isochronous range and the modulation in the triode circuits were nearly proportional to the mean input voltage throughout a limited variation.

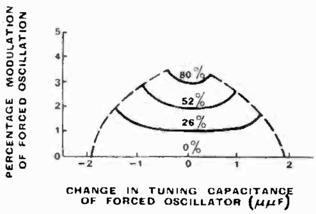


Fig. 2.—*Modulation of the forced oscillations. The figures above the curves give the percentage modulation of the input. Input amplitude = 1.2 v. Free oscillator amplitude = 1.75 v.*

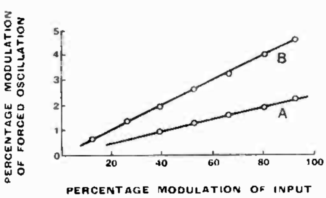


Fig. 3.—*Dependence of the forced oscillation modulation upon the input modulation. A, input amplitude = 0.8 v. B, input amplitude = 1.75 v. Free oscillator amplitude = 1.75 v.*

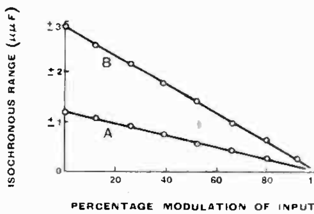


Fig. 4.—*Dependence of the isochronous range upon the input modulation. A, input amplitude = 0.8 v. B, input amplitude = 1.75 v. Free oscillator amplitude = 1.75 v.*

depend, *inter alia*, on the amplitudes. Fig. 3 indicates that the modulation in the triode circuits was proportional to the modulation of the input and nearly proportional to the amplitude of the input. Fig. 4 indicates that the isochronous range diminished linearly as the modulation of the input increased, and that the isochronous range would become zero with a fully modulated input at every amplitude within the limits of the experiments. That is to say, the isochronous range was proportional to $1 - M$, where M is the fractional modulation of the

The above results were all obtained with fixed values of oscillator grid bias and feedback. By varying the feedback the amplitude of the oscillations appearing in the triode circuits can be varied. Fig. 7 indicates the relation between the modulation in the triode circuits and the amplitude of the locked-in oscillations when the input had a fixed mean voltage and was modulated 50 per cent. When the coupling was so reduced that oscillations were just not self-maintained the mean voltage across the tunable circuit was 1.6 volts. With smaller

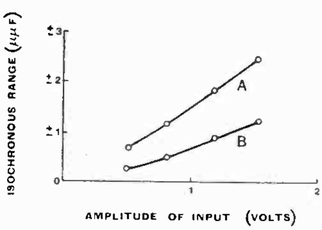


Fig. 5.—*Dependence of the isochronous range upon the input amplitude. A, input unmodulated. B, input modulated 50 per cent. Free oscillator amplitude = 1.75 v.*

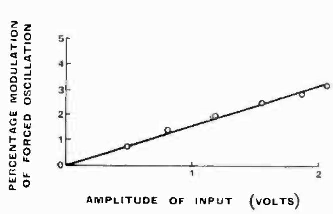


Fig. 6.—*Dependence of the forced oscillation modulation upon the input amplitude. Input modulation = 50 per cent. Free oscillator amplitude = 1.75 v.*

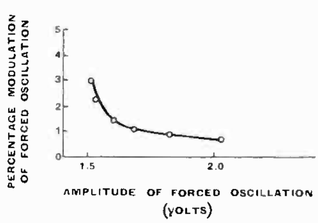


Fig. 7.—*Variation of oscillator modulation with oscillator amplitude—oscillator amplitude varied by altering feedback. Constant input of 0.67 v. Modulated 50 per cent.*

coupling still this voltage diminished and the modulation transmitted increased rapidly, as shown in the Figure.

When the fixed grid bias of the triode was replaced by the self-bias of a grid condenser and leak (300 $\mu\mu$F, 50,000 Ω) the behaviour of the circuit under a modulated input was substantially unaltered, the difference being such as would be expected with an oscillator circuit in which the grid bias depended upon the amplitude of the oscillations.

II.—Automatic Tuning of a Superheterodyne Receiver

The preceding Section demonstrates that a triode oscillator when locked in by voltages created by a modulated transmitter behaves as a very selective circuit, with the result that oscillatory energy taken from the

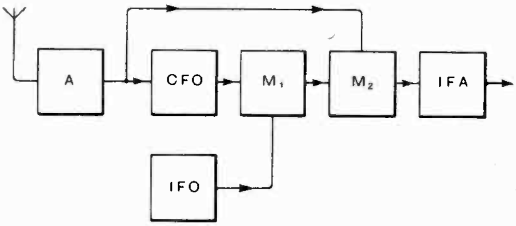


Fig. 8.—*Block schematic of a superheterodyne receiver using a locked-in oscillator for automatic tuning.*

oscillator is almost unmodulated. The transmitter may vary in frequency and the locked-in oscillator will follow the transmitter in frequency over a certain range without appreciably losing its selectivity. Its behaviour is, indeed, analogous to that of a stenode quartz plate of automatically variable thickness.

For superheterodyne reception the scheme of connections given in Fig. 8 has been tried out and found successful. The signals are amplified in A and passed to the oscillator CFO which is approximately tuned to the carrier frequency and becomes locked in to that frequency if not too different. The output from CFO is almost pure carrier. The oscillator IFO has the fixed intermediate frequency and is mixed with the carrier in M_1. The sum (or difference) frequency is then selected and mixed with the original signal oscillations in M_2. The resulting modulated current of intermediate frequency is amplified in IFA and passed on to the second detector. The locked-in oscillator CFO is ganged with the signal frequency circuits. This form of automatic tuning is not applicable to the reception of weak signals near strong ones; for when the modulation of the weak carrier is great the range of isochronism is correspondingly small and the stronger carrier may then determine the frequency of the locked-in oscillator.

III.—Application to the Measurement of Modulation

The linear decrease in the isochronous range with increase in the modulation of an input can be utilised for measuring the depth of modulation of an oscillator which is available in the modulated and also the unmodulated condition. The oscillator under test is loosely coupled to the measuring oscillator, which is provided with a vernier condenser and with a telephone receiver in its anode circuit. First the isochronous range a is determined when the first oscillator is unmodulated and, second, the range b is determined when it is modulated. From Fig. 4 it follows that the modulation depth M is given by

$$M = 1 - b/a$$

Since the ratio, not the absolute values, of the readings of the vernier condensers is involved, this condenser if of suitable form—say tubular—need not be calibrated.

REFERENCES

(1) W. H. Eccles and J. H. Vincent, Patent No. 163462.
(2) J. R. Woodyard, *Proc. Inst. Rad. Eng.*, Vol. 25, p. 612, 1937.
(3) U. Bab, *E.N.T.*, Vol. 11, p. 187, 1934.
(4) C. L. Kolker, *Arch. f. Elektrot*, Vol. 32, p. 581, 1938.
(5) A. H. Cooper and G. P. Smith, *Experimental Wireless* (now *Wireless Engineer*), Vol. 8, p. 647, 1931.
(6) B van der Pol and E. E. Posthumus, *Experimental Wireless*, Vol. 4, p. 140, 1927.

Salford Crystal Calibrator

THIS new instrument, Type BW.200, recently introduced by Salford Electrical Instruments, Ltd., Peel Works, Silk Street, Salford, 3, Lancs, provides a convenient frequency source for the calibration of R.F. oscillators and wireless receivers.

It consists of a quartz crystal-controlled oscillator giving three basic frequencies of 100 kc/s, 1 Mc/s or 5 Mc/s, and a mixing valve by means of which the beats with the unknown frequency can be compared aurally. A further oscillator operating at 25 or 50 Mc/s may be set by comparison with the 5 Mc/s controlled oscillator and frequency calibrations can be extended to 300 Mc/s with an accuracy better than 0.1 per cent.

The instrument is housed in a polished walnut case with internal copper screening, and is suitable for operation from A.C. mains 200/250 volts, 40/100 cycles.

Interference in Relation to Amplitude, Phase and Frequency Modulated Systems*

By O. E. Keall

SUMMARY.—Some characteristics of the three systems of modulation are first described, the more important being :—

(a) In amplitude modulated systems the amplitude change of the carrier is directly proportional to the depth of modulation and the signal may be resolved into a carrier of fixed amplitude together with a pair of sidebands whose (equal) amplitudes are proportional to the depth of modulation. The intelligence spectrum is twice the modulation frequency. The maximum radiated power associated with the intelligence (i.e. the sidebands) is 50% of the (constant) carrier power.

(b) In phase modulated systems the phase displacement of the carrier is directly proportional to the depth of modulation and the signal may be resolved into a carrier whose amplitude decreases on the application of modulation and a multiplicity of sidebands whose number and amplitudes vary as the depth of modulation. The intelligence spectrum varies as the depth of modulation and the modulation frequency, and for full modulation approaches 2.6 times the phase displacement times the modulation frequency (or 2.6 times the frequency deviation, or displacement, equivalent to the phase displacement). The maximum radiated power associated with the intelligence is very nearly 100% of the power of the transmitter.

(c) In frequency modulated systems the frequency deviation, or displacement, of the carrier is directly proportional to the depth of modulation and the signal may be resolved into a carrier whose amplitude decreases on the application of modulation together with a multiplicity of pairs of sidebands whose number and amplitude vary as the depth of modulation. The intelligence spectrum varies as the depth of modulation but is independent of the frequency of modulation and for full modulation approaches 2.6 times the deviation frequency. The maximum radiated power associated with the intelligence is very nearly 100% of the power of the transmitter.

(d) When two or more modulation frequencies exist simultaneously, in amplitude modulated systems the sidebands in the complex signal are the sum of those that would be produced were each frequency to modulate the carrier independently, but in phase or frequency modulated systems the sidebands in the complex signal are both as to number and amplitude derived from the product of the sidebands that would be produced were each frequency to modulate the carrier independently.

The effect of an interfering carrier is then considered assuming the wanted signal to be unmodulated. It is shown that the two carriers may be combined in such a way that they may be completely represented by a single carrier (of frequency that of the wanted signal) carrying an equivalent modulation, this equivalent modulation being dependent upon the ratio x of the amplitude of the interfering signal to that of the wanted signal $\left(x = \dfrac{\text{Interfering amplitude}}{\text{Wanted amplitude}}\right)$. It is a necessary condition for the validity of the expansions employed that x shall be less than unity. When $x > 1$, i.e. the interfering signal is greater than the wanted, the rôles of the two signals are, as far as this analysis is concerned, reversed, the interfering signal taking charge and the wanted appearing as an interference thereon. Under these conditions increasing the receiver selectivity has in general little effect and directional reception methods must be resorted to.

It is shown that the interference is much less for phase or frequency modulated systems than for amplitude modulated systems while in general a frequency modulated system is to be preferred to one phase modulated. Next the carriers are considered as being modulated by each of the three systems in turn, the reduced interference when frequency modulation is employed being maintained. In both phase and frequency modulated cases the interference decreases as the depth of modulation of either carrier is increased. It is shown that by means of a graphical representation of the spectrum, the labour of computing the equivalent modulation in phase or frequency modulated systems may be very materially reduced. Several examples are given from which the advantages to be gained by frequency modulation are made apparent. A final note stresses the conditions for which the analysis is valid.

General Considerations

A CURRENT i whose magnitude and direction are subjected to a sinusoidal change with respect to time can be represented by the projection of a constant magnitude A on the X axis if it be assumed that A rotates with constant angular velocity.

In Fig. 1 such a vector is shown and

$$i = A \sin \psi \qquad \ldots \qquad (1)$$

* MS. accepted by the Editor, June, 1940.

Now ψ is a function of time and since

$$\omega = \frac{d}{dt}\psi \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

$$\psi = \int \omega\, dt + \phi \quad \ldots \quad \ldots \quad (3)$$

Thus $i = A \sin\left(\int \omega\, dt + \phi\right) \quad \ldots \quad \ldots \quad (4)$

When A, ϕ or ω are subjected to periodic changes slow compared with the "carrier" ω, the process is termed modulation.

I.—Amplitude Modulation.

Let $A = A_0(1 + K_a \sin \mu t) \quad \ldots \quad (5)$

in which K_a indicates the degree or depth of modulation by a frequency $\frac{\mu}{2\pi} K_a$ has a maximum value of unity.

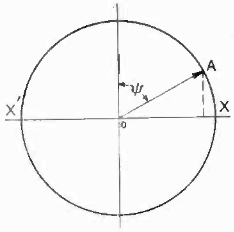


Fig. 1.

Since ω and ϕ are independent of time

$$i = A_0(1 + K_a \sin \mu t) \sin \omega_0 t \quad \ldots \quad (6)$$

where $\omega_0 t$ is written for $\omega t + \phi$.

It is convenient to refer to $(1 + K_a \sin \mu t)$ as the modulation bracket.

From (6)

$$i = A_0 \sin \omega_0 t + A_0 K_a \sin \omega_0 t \sin \mu t \quad (7)$$

$$= A_0 \sin \omega_0 t + \frac{A_0 K_a}{2} \cos (\omega_0 - \mu)t$$

$$- \frac{A_0 K_a}{2} \cos (\omega_0 + \mu)t \quad \ldots \quad (8)$$

Equation (8) which represents the radiated signal is seen to comprise a carrier frequency of amplitude independent of the modulation depth and two sidebands spaced $\frac{\mu}{2\pi}$ cycles either side of the carrier, the amplitudes of which are proportional to the modulation depth and whose maximum amplitude (corresponding to 100% modulation, i.e. $K_a = 1$), is half the carrier amplitude. The carrier and half the intelligence spectrum associated with the signal is shown for modulation frequencies of 5 and 10 kc/s for different degrees of modulation in Fig. 2. Amplitudes are shown to a logarithmic scale in the range 1 — 0.01. The intelligence spectrum is twice the modulation frequency and is independent of the modulation depth. The total radiated power associated with the sidebands is for 100% modulation ½ of the carrier power, the latter remaining constant under all conditions.

II.—Phase Modulation.

Here A and ω are constant and

$$\phi = \phi_0(1 + K_p \sin \mu t) \quad \ldots \quad \ldots \quad (9)$$

whence

$$i = A \sin \{\omega t + \phi_0(1 + K_p \sin \mu t)\} \ldots \quad (10)$$

$$= A_0 \sin (\omega_0 t + m_p \sin \mu t) \ldots \quad \ldots \quad (11)$$

$$i = A_0[\sin \omega_0 t \cos \overline{m_p \sin \mu t} + \cos \omega_0 t \sin \overline{m_p \sin \mu t}] \quad \ldots \quad (12)$$

$$= A_0[\sin \omega_0 t\{J_0(m_p) + 2J_2(m_p) \cos 2\mu t + 2J_4(m_p) \cos 4\mu t + \ldots\} + \cos \omega_0 t\{2J_1(m_p) \sin \mu t + 2J_3(m_p) \sin 3\mu t + \ldots\}] \quad \ldots \quad (13)$$

$$= A_0[J_0(m_p) \sin \omega_0 t + J_1(m_p)\{\sin(\omega_0+\mu)t - \sin(\omega_0-\mu)t\} + J_2(m_p)\{\sin(\omega_0 + 2\mu)t + \sin(\omega_0 - 2\mu)t\} + \ldots\ldots] \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

where $m_p = K_p \phi_0$ (radians), the phase displacement of the carrier. The frequency displacement or deviation frequency of the carrier corresponding to this is $m_p \frac{\mu}{2\pi}$ cycles.

$J_0(m_p) \ldots J_n(m_p)$ are the Bessel coefficients of the first kind of order 0, 1, 2 . . n with argument m_p. Tables of these coefficients are available which present no more difficulty than tables of logarithms. (Bibliography and Appendix I and III).

The radiated signal comprises a carrier frequency, the amplitude $J_0(m_p)$ of which varies in dependence upon the depth of modulation K_p and the maximum phase displacement ϕ_0, together with a multiplicity of side-band frequencies spaced in pairs $\frac{\mu}{2\pi}, \frac{2\mu}{2\pi}, \frac{3\mu}{2\pi}$,

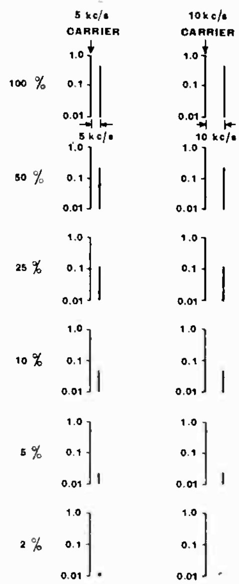


Fig. 2.—*Amplitude modulation.*

etc. cycles either side of the carrier, the amplitudes of which are also dependent upon the depth of modulation and the maximum phase displacement.

Fig. 3 shows the intelligence spectrum of a phase modulated signal for modulation frequencies of 5 and 10 kc/s for different modulation depths, ϕ_0 being taken as 10

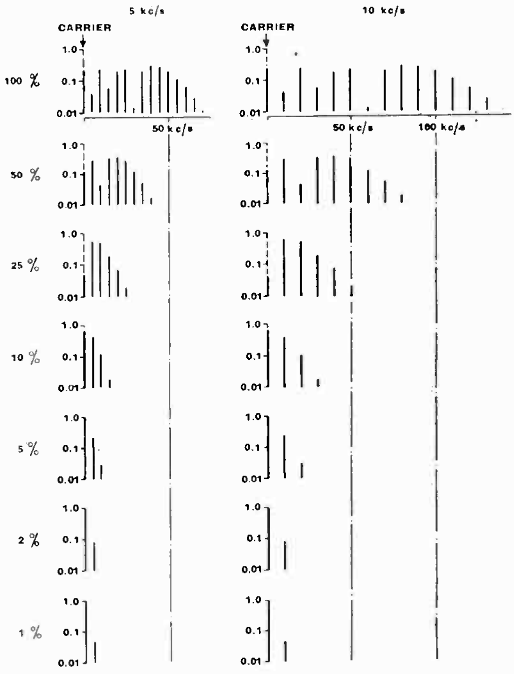


Fig. 3.—*Phase modulation ;* $\phi_0 = 10$ *radians.*

radians. Sidebands of amplitude less than 0.01 of the unmodulated carrier are not shown. The intelligence spectrum is seen to be dependent upon the depth of modulation K_p, the modulation frequency (and also it may be shown, upon the maximum phase displacement ϕ_0). No simple relation exists between these quantities and the intelligence spectrum, but the latter may be determined to a fair degree of accuracy by $2n\dfrac{\mu}{2\pi}$ where n is the highest order of the Bessel coefficient for which $J_n(m_p) = J_n(K_p\phi_0)$ is approximately 0.01 ; this may be rapidly determined from an inspection of tables. As an approximation when $m_p > 5$ the intelligence spectrum is $2.6\, m_p \dfrac{\mu}{2\pi}$ (i.e. 2.6 times the deviation frequency) and when $m_p < 0.2$ the intelligence spectrum is twice the modulation frequency as in amplitude modulated systems. $2n$ represents the number of sidebands which effectively constitute the signal. For a given transmitter this number is dependent upon depth of modulation only and is independent of the modulation frequency. The radiated power associated with the sidebands is for 100% modulation the total transmitter power (with the exception of the relatively small power associated with the carrier) as may be determined by summing the squares of the amplitudes of all the sidebands.

III.—Frequency Modulation.

Here A and ϕ are constant and

$$\omega = \omega_0(1 - K' \cos \mu t) \quad \ldots \quad \ldots \quad (15)$$

Substituting this in (3)

$$\psi = \int \omega_0(1 + K' \cos \mu t)dt + \phi \quad \ldots \quad (16)$$

$$= \omega_0 t + \phi + \frac{K'\omega_0}{\mu} \sin \mu t \quad \ldots \quad (17)$$

Substituting in (1) and neglecting ϕ,

$$i = A \sin\left(\omega_0 t + \frac{K'\omega_0}{\mu} \sin \mu t\right) \quad \ldots \quad (18)$$

At full modulation $\dfrac{K'\omega_0}{2\pi}$ is the maximum deviation frequency (frequency displacement of the carrier). In practice $K' \ll 1$, and in order that the modulation coefficient K_f may be unity for 100% modulation as in former cases it is convenient to write $K'\omega_0 = K_f\omega_D$ where $\dfrac{\omega_D}{2\pi}$ is the deviation frequency at full modulation.

Then

$$i = A \sin\left(\omega_0 t + K_f \frac{\omega_D}{\mu} \sin \mu t\right) \quad \ldots \quad (19)$$

$$= A[\sin \omega_0 t \cos \overline{m_f \sin \mu t} + \cos \omega_0 t \sin \overline{m_f \sin \mu t}] \quad \ldots \quad (20)$$

$$= A[\sin \omega_0 t\{J_0(m_f) + 2J_2(m_f) \cos 2\mu t + 2J_4(m_f) \cos 4\mu t + \ldots\} + \cos \omega_0 t\{2J_1(m_f) \sin \mu t + 2J_3(m_f) \sin 3\mu t + \ldots\}] \quad \ldots \quad \ldots \quad \ldots \quad (21)$$

$$= A[J_0(m_f) \sin \omega_0 t + J_1(m_f)\{\sin(\omega_0 + \mu)t - \sin(\omega_0 - \mu)t\} + J_2(m_f)\{\sin(\omega_0 + 2\mu)t + \sin(\omega_0 - 2\mu)t\} + \ldots\ldots] \quad \ldots \quad \ldots \quad \ldots \quad (22)$$

where $m_f = K_f \frac{\omega_D}{\mu}$ (radians)

and $J_0(m_f) \ldots J_n(m_f)$ are the Bessel coefficients of the first kind of order, 0, 1, 2 . . . n and argument m_f.

The radiated signal comprises a carrier and a multiplicity of sidebands spaced in pairs $\frac{\mu}{2\pi}, \frac{2\mu}{2\pi}, \frac{3\mu}{2\pi}$ . . . cycles on either side thereof, the amplitudes of all of which are dependent upon the depth of modulation, the

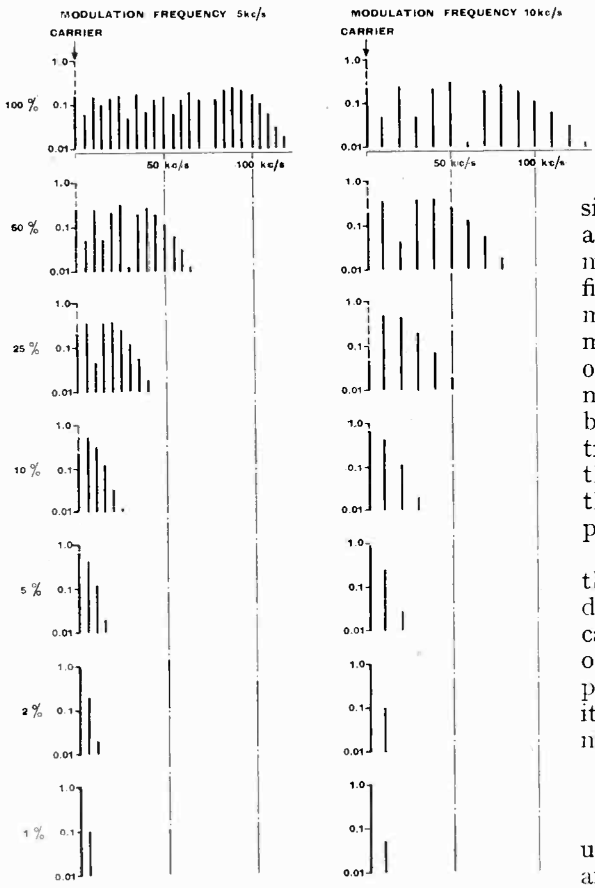


Fig. 4.—*Frequency modulation* : $\omega_D = 100$ *kc/s.*

maximum deviation frequency and the modulation frequency itself.

Fig. 4 shows the intelligence spectra for modulation frequencies of 5 and 10 kc/s for different modulation depths, ω'_D being taken as 100 kc/s $\left(\omega'_D = \frac{\omega_D}{2\pi}\right)$. The maximum intelligence spectrum corresponding to 100% modulation is proportional to the deviation frequency and is practically independent of the modulation frequency, its value being given approximately by 2.6 ω'_D or 2.6 times the deviation frequency. For lower depths of modulation, the intelligence spectrum is dependent upon the modulation frequency and may be approximately determined by $2n \frac{\mu}{2\pi}$ where n is the highest order of the Bessel coefficient for which

$$J_n(m_f) = J_n\left(K_f \frac{\omega_D}{\mu}\right)$$

is approximately 0.01. As before this may be conveniently determined by an inspection of tables. For values of $m_f > 5.0$, $2n$ represents the number of sidebands which effectively constitute the signal ; for constant modulation depth, $2n$ is approximately inversely proportional to the modulation frequency, i.e. there are about five times as many sidebands in a signal modulated by 1 kc/s as there are in one modulated by 5 kc/s. When m_f is less than 0.2, the intelligence spectrum is twice the modulation frequency and only two sidebands are present as in amplitude modulation. The radiated power associated with the sidebands for 100% modulation is nearly the whole of the transmitter power as for phase modulation.

In frequency modulation it will be noted that it is the rate of change of the phase displacement (i.e. the frequency) of the carrier that is proportional to the amplitude of the modulation frequency whereas for phase modulation the phase displacement itself is proportional to the amplitude of the modulation frequency.

Comparison of the Systems

An inspection of Figs. 3 and 4 shows that under certain conditions the spectra for phase and frequency modulation are identical, e.g. for 10 kc/s modulation frequency. The spectra will in fact be identical when $K_p\phi_0 = K_f \frac{\omega_D}{\mu}$; there is then no means of telling at a receiver whether the transmission be phase or frequency modulated unless a change in the modulation frequency be made, when an examination of the new spectrum will show which system is being employed.

For values of $m < 0.2$ it is also seen that in Figs. 2, 3 and 4 the sidebands for all three systems may be of the same amplitude and the intelligence spectra equal, e.g. for 10 kc/s modulation frequency the spectra are equivalent for a 10% amplitude modulated signal and 1% phase and frequency modulated signals. Here the similarity between the signals ends for the diagrams do not show the phase relations between the carrier and sidebands which distinguish amplitude from phase or frequency modulation. In the former the sidebands are displaced in phase by equal amounts in opposite directions with respect to the carrier their resultant being in phase with the carrier, while in phase or frequency modulation the resultant of the two sidebands is in phase quadrature with the carrier, the sidebands themselves also being in phase quadrature with those of the corresponding sidebands due to amplitude modulation. These conditions are shown vectorially in Fig. 5 in which (a) shows the carrier and sidebands of an amplitude modulated wave in which the resultant of the two sidebands is either in phase or reversed phase with respect to the carrier,

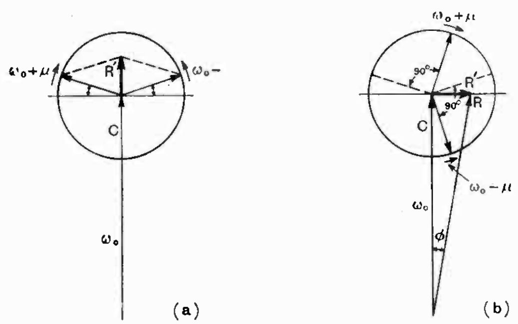


Fig. 5.

while (b) shows the same sidebands both displaced 90° in the same direction with respect to (a) now giving a resultant R^1 in quadrature with the carrier while the resultant R of the carrier and sidebands makes an angle ϕ with the carrier vector corresponding to the instantaneous phase displacement. In (a) the resultant is from (8) equal to $\sin \omega_0 t(1 + K_a \sin \mu t)$ whilst in (b) assuming m_p small and therefore neglecting orders of the Bessel coefficients greater than one, the resultant is from (13) approximately

$$\sin \omega_0 t + \cos \omega_0 t(2\, J_1(m_p) \sin \mu t).$$

Before dealing with vector representation generally, it is important to notice another distinction between amplitude and phase or frequency modulated signals. Suppose the carriers associated with the three systems be modulated by two frequencies $\frac{\mu_1}{2\pi}$ and $\frac{\mu_2}{2\pi}$. For amplitude modulation we have from eqn. (6)

$$i = A(1 + K_1 \sin \mu_1 t + K_2 \sin \mu_2 t)\sin \omega_0 t \quad \ldots \quad \ldots \quad (23)$$

$$= A \sin \omega_0 t + \frac{AK_1}{2}\cos(\omega_0 - \mu_1)t - \frac{AK_1}{2}\cos(\omega_0 + \mu_1)t + \frac{AK_2}{2}\cos(\omega_0 - \mu_2)t - \frac{AK_2}{2}\cos(\omega_0 + \mu_2)t \quad \ldots (24)$$

showing that the intelligence spectrum comprises a carrier together with two pairs of sidebands, these being spaced $\frac{\mu_1}{2\pi}$ and $\frac{\mu_2}{2\pi}$ cycles on either side of the carrier. Thus in an amplitude modulated system modulated simultaneously by two or more tones or frequencies, the complex signal is constituted by the sum of the sidebands that would be obtained were the carrier to be modulated by each tone independently. Now for phase or frequency modulation by two frequencies and treating the two cases as one we may write according to equation (11) or equation (19).

$$i = A \sin(\omega_0 t + m_1 \sin \mu_1 t + m_2 \sin \mu_2 t) \ldots (25)$$

$$= A\,[\sin \omega_0 t \cos \overline{m_1 \sin \mu_1 t} \cos \overline{m_2 \sin \mu_2 t} + \cos \omega_0 t \sin \overline{m_1 \sin \mu_1 t} \cos \overline{m_2 \sin \mu_2 t} + \cos \omega_0 t \cos \overline{m_1 \sin \mu_1 t} \sin \overline{m_2 \sin \mu_2 t} - \sin \omega_0 t \sin \overline{m_1 \sin \mu_1 t} \sin \overline{m_2 \sin \mu_0 t}] \quad \ldots \quad \ldots \quad (26)$$

The expansion of these expressions is tedious and it is sufficient to state that the respective terms of equation (26) give rise to sidebands as follows:—

(a) pairs displaced $\left(2p\frac{\mu_1}{2\pi} \pm 2q\frac{\mu_2}{2\pi}\right)$ either side of the carrier of amplitudes

$$J_{2p}(m_1)J_{2q}(m_2)$$

(b) pairs displaced $\left(\overline{2p+1}\,\frac{\mu_1}{2\pi} \pm 2q\frac{\mu_2}{2\pi}\right)$

either side of the carrier of amplitudes

$$J_{2p+1}(m_1)\,J_{2q}(m_2)$$

(c) pairs displaced $\left(2p\,\frac{\mu_1}{2\pi} \pm \overline{2q+1}\,\frac{\mu_2}{2\pi}\right)$

either side of the carrier of amplitudes

$$J_{2p}(m_1)J_{2q+1}(m_2)$$

(d) pairs displaced $\left(\overline{2p+1}\,\frac{\mu_1}{2\pi} \pm \overline{2q+1}\,\frac{\mu_2}{2\pi}\right)$

either side of the carrier of amplitudes

$$J_{2p+1}m_1)J_{2q+1}(m_2)$$

in which $\pm$ indicates both sum and difference frequencies and p and q have values 0, 1, 2 . . . ∞ independently.

In (a) when both p and q are zero the carrier amplitude is obtained.

Thus not only are the sidebands due to one of the signals when applied alone changed in amplitude, but also new combination sidebands are produced.

In contrast with an amplitude modulated system, the complex signal resulting from simultaneous modulation by two or more tones is thus derived from the product (both in number and amplitude) of the sidebands that would be obtained if the carrier were to be modulated by each tone independently.

The possible sidebands are shown in Fig. 6 (a), those above and to the side of the frame being those due to the two signals applied separately, while those inside the frame result when the two signals are applied together. The amplitudes of the signals are shown in a similar chart in (b), the amplitude of a particular sideband occupying the same position on the chart (b) as the sidebands occupy in (a). The amplitudes inside the frame are obtained by multiplication of the Bessel coefficients at the ends of the row and column concerned. The amplitudes shown correspond to a particular case for which $m_1 = 2.0$ and

	Carrier	f_1	$2f_1$	$3f_1$	$4f_1$	$5f_1$
Carrier	Carrier	f_1	$2f_1$	$3f_1$	$4f_1$	$5f_1$
f_2	f_2	$f_2 \pm f_1$	$f_2 \pm 2f_1$	$f_2 \pm 3f_1$	$f_2 \pm 4f_1$	$f_2 \pm 5f_1$
$2f_2$	$2f_2$	$2f_2 \pm f_1$	$2f_2 \pm 2f_1$	$2f_2 \pm 3f_1$	$2f_2 \pm 4f_1$	$2f_2 \pm 5f_1$
$3f_2$	$3f_2$	$3f_2 \pm f_1$	$3f_2 \pm 2f_1$	$3f_2 \pm 3f_1$	$3f_2 \pm 4f_1$	$3f_2 \pm 5f_1$
$4f_2$	$4f_2$	$4f_2 \pm f_1$	$4f_2 \pm 2f_1$	$4f_2 \pm 3f_1$	$4f_2 \pm 4f_1$	$4f_2 \pm 5f_1$
$5f_2$	$5f_2$	$5f_2 \pm f_1$	$5f_2 \pm 2f_1$	$5f_2 \pm 3f_1$	$5f_2 \pm 4f_1$	$5f_2 \pm 5f_1$

(*a*)

	$J_0(m_1)$ 0.224	$J_1(m_1)$ 0.577	$J_2(m_1)$ 0.353	$J_3(m_1)$ 0.129	$J_4(m_1)$ 0.034	$J_5(m_1)$ 0.011
$J_0(m_2)$ 0.55	0.123	0.317	0.194	0.071	0.0187	—
$J_1(m_2)$ 0.547	0.122	0.316	0.193	0.071	0.0186	—
$J_2(m_2)$ 0.215	0.048	0.124	0.076	0.0278	—	—
$J_3(m_2)$ 0.054	0.012	0.0312	0.019	—	—	—
$J_4(m_2)$ 0.01	—	—	—	—	—	—
$J_5(m_2)$	—	—	—	—	—	—

(*b*)

FIG. 6

$m_2 = 1.43$. These modulation indices are those applicable to a signal, frequency modulated to a depth of 10% in each case by frequencies of 5 and 7 kc/s respectively. A dot in the chart (b) indicates that the side-band concerned is less than 0.01 of the unmodulated carrier. This distinction is of course quite arbitrary. In Fig. 7 are shown the corresponding intelligence spectra (a) representing modulation by 5 kc/s only,

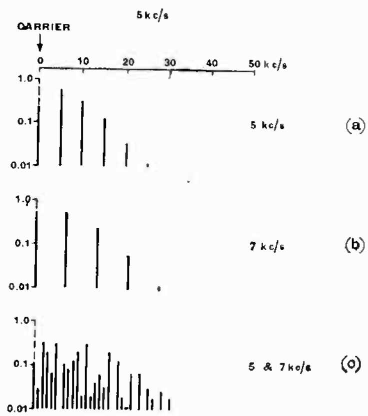


Fig. 7.—*Frequency modulation* : ω_D = 100 *kc/s*.

(b) by 7 kc/s only, while (c) is that for 5 and 7 kc/s together. In the latter it is seen that a large number of new sidebands exist, some of appreciable amplitude whilst the original sidebands are reduced in amplitude. There is also a slight increase in the intelligence spectrum consistent with the increased effective modulation depth.

Owing to the increasing complication that is inevitable with more than two modulation frequencies, detailed consideration of such cases is omitted. The general effect will be as for the two frequencies, but with a correspondingly larger number of new sidebands.

Vector Representation

The vector representation of modulated signals has been dealt with by Roder and is only briefly dealt with here. The amplitude modulated signal has already been depicted in Fig. 5 (a) where it was seen that the instantaneous length of the vector was $A(1 + K \sin \mu t)$ which is the coefficient of $\sin \omega_0 t$ in eqn. (6). Similarly the vector representation of phase or frequency modulated signals is obtained from the coefficients of the terms involving $\omega_0 t$ in equations (13) and (21) respectively. These coefficients are $(J_0(m) + 2J_2(m) \cos 2\mu t + 2J_4(m) \cos 4\mu t + \ldots)$ associated with $\sin \omega_0 t$ and $(2J_1(m) \sin \mu t + 2J_3(m) \sin 3\mu t + \ldots)$ associated with $\cos \omega_0 t$. After evaluation, the former is measured vertically and the latter horizontally their resultant being the instantaneous amplitude of the signal. In Fig. 8 (c), AB is the coefficient of $\sin \omega_0 t$, BC that of $\cos \omega_0 t$, and their resultant is AC for $\mu t = 30°$. The vector traces out the arc of a circle of radius unity (i.e. the amplitude of the unmodulated carrier) and the maximum displacement from the initial position (0°) is m radians in either direction. According as the carrier be phase or frequency modulated the diagrams in order from a–d represent phase modulation at increasing modulation depths ($m = K_p \phi_0$ radians) or frequency modulation, either at constant modulation frequency and increasing modulation depth, or at constant modulation depth and decreasing modulation frequency $\left(m = K_f \dfrac{\omega_D}{\mu} \text{ radians}\right)$. When m is sufficiently large the vector will of course

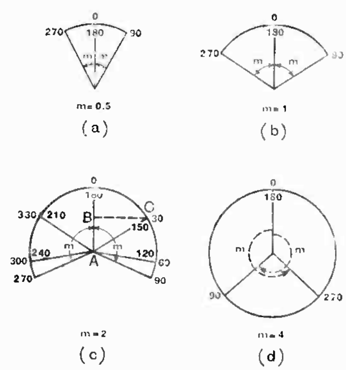


Fig. 8.

make several revolutions in one direction before reversing. In these diagrams the instantaneous displacement of the vector in terms of the modulation frequency $\dfrac{\mu}{2\pi}$ is $m \sin \mu t$ radians. Since the vector is of constant length over the modulation cycle the "envelope" of the signal is a straight line, i.e. the amplitude of the carrier remains constant when modulation is applied only its phase or frequency varying.

Effect of an Interfering Signal

In investigating the effects produced by an interfering signal in the presence of a wanted signal (however it may be proposed to modulate the latter), it will first be assumed that both signals are unmodulated. Since the interfering signal will in general give rise to an audible (or visual) output it may be regarded as causing an equivalent modulation of the wanted carrier. It is necessary then to find an equivalent expression for the sum of two signals which indicates the nature of such modulation. An inspection of equations 5, 9 and 15 shows that modulation results in the appearance of a bracketed factor (which will be termed the modulation bracket) of the form $(1 + K \sin \mu t)$ which can be derived from the expression representing the sidebands by reversing the analytical processes. Since an interfering signal may be regarded as a single sideband associated with the wanted carrier, then by representing the wanted carrier by $A \sin \omega_0 t$ and the interfering signal by $B \sin \omega t$

$$i = A \sin \omega_0 t + B \sin \omega t \quad \ldots \quad (27)$$

$$= A(\sin \omega_0 t + x \sin (\omega_0 + b)t) \quad \ldots \quad (28)$$

where $\omega = \omega_0 + b$, i.e. b' is the beat frequency $\left(= \frac{b}{2\pi}\right)$ and $x = \frac{B}{A}$ the ratio of interfering to wanted signals.

Then omitting A

$$i = \sin \omega_0 t + x \sin \omega_0 t \cos bt + x \cos \omega_0 t \sin bt \quad \ldots \quad (29)$$

$$= \sin \omega_0 t(1 + x \cos bt) + \cos \omega_0 t(x \sin bt) \quad \ldots \quad (30)$$

$$= P \sin \omega_0 t + Q \cos \omega_0 t \quad \ldots \quad (31)$$

$$= \sqrt{P^2 + Q^2} \sin (\omega_0 t + \phi) \quad \ldots \quad (32)$$

where

$$\phi = \tan^{-1} \frac{Q}{P} = \tan^{-1} \frac{x \sin bt}{1 + x \cos bt} \quad \ldots \quad (33)$$

$$\therefore i = (1 + x^2 + 2x \cos bt)^{\frac{1}{2}} \sin (\omega_0 t + \phi) \quad \ldots \quad (34)$$

This equation indicates that the two signals may be expressed in terms of one of them (the wanted carrier), the equivalent signal so obtained being subjected to amplitude changes as represented by

$$(1 + x^2 + 2x \cos bt)^{\frac{1}{2}}$$

and phase changes as represented by

$$\phi = \tan^{-1} \frac{x \sin bt}{1 + x \cos bt}$$

these two expressions representing the equivalent amplitude and phase modulations respectively. (See Appendix II). They are dealt with separately.

Equivalent Amplitude Modulation

In a receiver of amplitude modulated signals the detector is able to discriminate changes of amplitude in the signal but cannot discriminate changes of phase or frequency. To obtain the equivalent modulation bracket we have

$$(1 + x^2 + 2x \cos bt)^{\frac{1}{2}}$$

$$= (1 + x^2)^{\frac{1}{2}} \left(1 + \frac{2x}{1 + x^2} \cos bt\right)^{\frac{1}{2}} \quad \ldots \quad (35)$$

$$= (1 + x^2)^{\frac{1}{2}} (1 + 2X \cos bt)^{\frac{1}{2}} \quad \ldots \quad (36)$$

where $X = \frac{x}{1 + x^2}$. Since x is to be taken as less than unity, $X < 0.5$ and hence the second bracket which is the modulation bracket may be expanded by the Binomial Theorem. The first bracket represents a steady increase in carrier amplitude due to the presence of the interfering signal and may from this point be disregarded. Expanding the second bracket we have

$$\text{M.B.} = \left(1 + X \cos bt - \frac{X^2}{2} \cos^2 bt + \frac{X^3}{2} \cos^3 bt - \frac{5X^4}{8} \cos^4 bt + \ldots\right) \ldots \quad (37)$$

Transforming powers of cos bt into multiple angles

$$\text{M.B.} = \left(1 - \frac{X^2}{4} - \frac{15}{64} X^4 - \ldots \right.$$
$$+ (X + \tfrac{3}{8}X^3 + \ldots) \cos bt \ldots$$
$$- \left(\frac{X^2}{4} + \frac{5}{16} X^4 + \ldots\right) \cos 2bt$$
$$+ \left(\frac{X^3}{8} + \ldots\right) \cos 3bt$$
$$\left. - \left(\frac{5}{64} X^4 + \ldots\right) \cos 4bt + \ldots\right) \ldots \quad (38)$$

when $x < 0.5$ the above may be written with sufficient accuracy as

$$\text{M.B.} = \left(1 + X \cos bt - \frac{X^2}{4} \cos 2bt\right.$$

$$+\frac{X^3}{8}\cos 3bt - \ldots\Big) \quad \ldots \quad (39)$$

or when X is sufficiently small as

$$\text{M.B.} = (1 + X\cos bt) \quad \ldots \quad \ldots \quad (39a)$$

X is given in terms of x in Fig. 9 (b).

The coefficients X, $\frac{X^2}{4}$ etc., represent the "equivalent modulation depth" (E.M.D.) at the beat frequency or its harmonics, produced by the interfering signal. This is not the same as the distortion since the latter must depend upon the depth to which the wanted signal is modulated (K). Distortion is then $\frac{E.M.D.}{K} \times 100\%$ and is only equal to the E.M.D. ($\times$ 100) when $K = 1$ or the wanted signal is fully modulated. In Fig. 9 (a) the E.M.D. is expressed as a percentage for frequencies up to the third harmonic as estimated from 38.

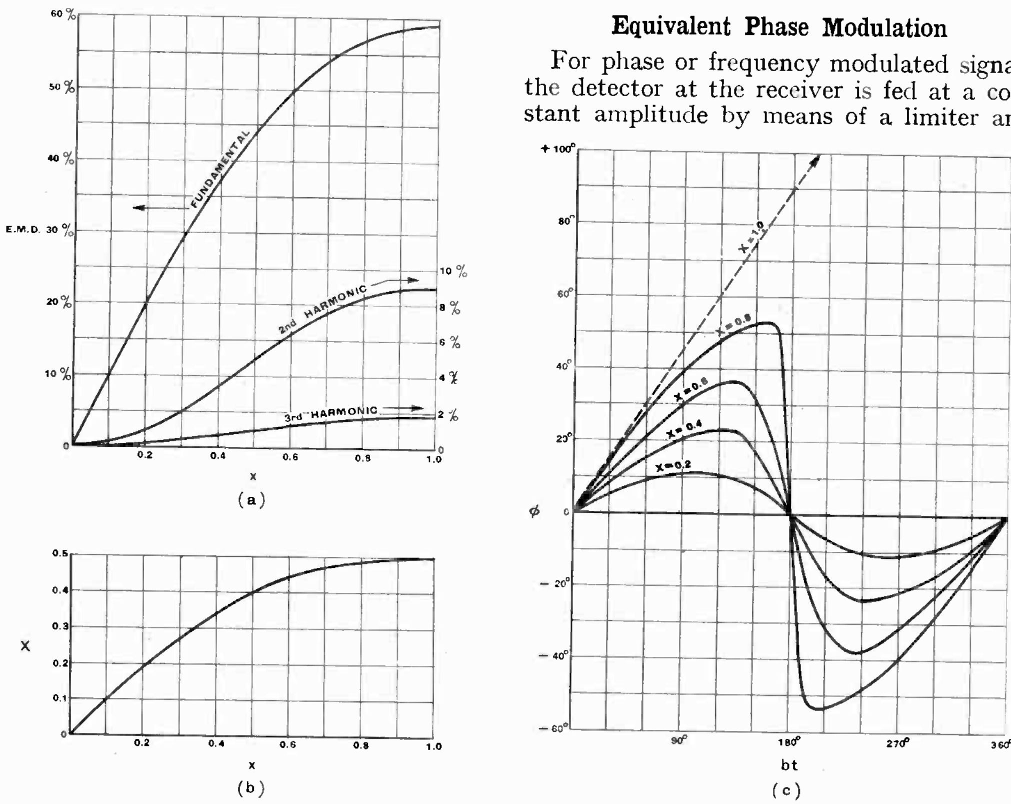


Fig. 9.

(The term distortion herein refers to electrical distortion. In assessing "nuisance value" of any distortion component the loudness value may be derived from loudness level contours corresponding to the frequency of the component.)

This case corresponds in practice to the interference due to a single frequency, as for instance an atmospheric or unmodulated carrier, situated within the intelligence spectrum of the wanted signal.

Equivalent Phase Modulation

For phase or frequency modulated signals the detector at the receiver is fed at a constant amplitude by means of a limiter and is then only responsive to changes of phase or frequency. These are represented by ϕ in equation 34.

Now

$$\phi = \tan^{-1}\frac{x\sin bt}{1 + x\cos bt} \quad \ldots \quad (40)$$

$$\tan\phi = \frac{x\sin bt}{1 + x\cos bt} \quad \ldots \quad \ldots \quad (41)$$

$$\frac{e^{j\phi} - e^{-j\phi}}{e^{j\phi} + e^{-j\phi}} = \frac{j\,x\sin bt}{1 + x\cos bt} \quad \ldots \quad \ldots \quad (42)$$

$$e^{j\phi}(1 + x \cos bt - jx \sin bt) = e^{-j\phi}(1 + x \cos bt + jx \sin bt) \quad \ldots \quad \ldots \quad (43)$$

$$e^{j2\phi} = \frac{1 + x e^{jbt}}{1 + x e^{-jbt}} \quad \ldots \quad \ldots \quad (44)$$

$$j2\phi = \log(1 + x e^{jbt}) - \log(1 + x e^{-jbt}) \quad \ldots \quad \ldots \quad (45)$$

$$= x(e^{jbt} - e^{-jbt}) - \tfrac{1}{2}x^2(e^{j2bt} - e^{-j2bt}) + \tfrac{1}{3}x^3(e^{j3bt} - e^{-j3bt}) - \ldots \quad (46)$$

Whence

$$\phi = x \sin bt - \frac{x^2}{2} \sin 2bt + \frac{x^3}{3} \sin 3bt - \ldots \quad \ldots \quad \ldots \quad (47)$$

A graph of this function with x as parameter is shown in Fig. 9 (c). Equations 46, 47 are valid so long as $x < 1$, as is confirmed by the graph.

The detector has to deal with

$$\sin\left(\omega_0 t + \phi_0 + x \sin bt - \frac{x^2}{2} \sin 2bt + \frac{x^3}{3} \sin 3bt - \ldots\right) \ldots \quad \ldots \quad (48)$$

where ϕ_0 is the phase displacement (radians) employed for the transmission concerned (c.f. equations 9, 10 and 11).

Dividing terms other than $\omega_0 t$ by ϕ_0 as in equation 9 we obtain the equivalent modulation bracket

$$\text{M.B.} = \left(1 + \frac{x}{\phi_0} \sin bt - \frac{x^2}{2\phi_0} \sin 2bt + \frac{x^3}{3\phi_0} \sin 3bt \ldots\right) \quad \ldots \quad (49)$$

from which

$$d_1 = \frac{x}{\phi_0} \times 100\,\%, \; d_2 = \frac{x^2}{2\phi_0} \times 100\,\%,$$

$$d_3 = \frac{x^3}{3\phi_0} \times 100\%, \ldots$$

where the subscripts of d, the percentage E.M.D., indicate the harmonic of the beat frequency concerned. The distortion which can only be determined from a knowledge of the modulation depth K_p of the wanted signal is given approximately by $D = \frac{d_1}{K_p}$ or more accurately by

$$D = \frac{1}{K_p}(d_1^2 + d_2^2 + d_3^2 + \ldots)^{\frac{1}{2}}$$

It will be observed that x represents to a first approximation the displacement in radians due to the interfering signal. Fig. 10 is the vector representation of the two signals in which A represents the wanted carrier, B the interfering signal, the latter rotating at a rate dependent on the beat frequency. $\frac{B}{A} = x = 0.4$ radians. OD represents the extreme displacement of the vector A as given by $\theta_2 = \sin^{-1} x = 0.412$ radians. The smaller is x the more nearly is this equal to x radians, this condition holding so long as $\sin^{-1} x$ is nearly equal to $\tan^{-1} x$ which is indicated by θ_1. For this $x < \frac{1}{3}$. When $x > \frac{1}{3}$ the coefficient $\frac{x^2}{2}$ of the second harmonic becomes appreciable so that departure of the angle θ_2 from x radians is an indication of modulation by harmonics of the beat frequency.

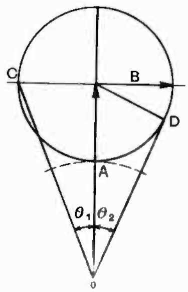


Fig. 10.—$x = \frac{B}{A} = 0.4$ *radians* $= 22.9°$. $\theta_1 = \tan^{-1}x = 21.8° = 0.381$ r. $\theta_2 = \sin^{-1}x = 23.6° = 0.412$ r.

The dotted arc represents the signal applied to the detector, i.e. after the limiter has performed its function in eliminating amplitude changes. It will be appreciated that as B approaches A in amplitude, the amplitude of the signal approaches zero at one point of the cycle. The limiter is then unable to fulfil its function and an amplitude change is passed on to the detector. This will result in considerable distortion and equation 49 will not then hold. The point at which the limiter action fails will of course be dependent on the receiver design.

Equivalent Frequency Modulation

From equations 15–18 it is seen that when the wanted carrier is to be frequency modulated the modulation bracket is obtained by differentiation. Thus

$$\psi = \left(\omega_0 t + x \sin bt - \frac{x^2}{2} \sin 2bt + \frac{x^3}{3} \sin 3bt - \ldots\right) \ldots \quad (50)$$

$$\text{M.B.} = \frac{1}{\omega_0}\frac{d}{dt}\psi = \left(1 + \frac{xb}{\omega_0}\cos bt - x^2\frac{b}{\omega_0}\cos 2bt + x^3\frac{b}{\omega_0}\cos 3bt - \ldots\right) \quad (51)$$

In accordance with the convention previously adopted ($K_f = 1$ for 100% modulation), the E.M.D. is then given by

$$d_1 = x\frac{b}{\omega_D} \times 100\%,\quad d_2 = x^2\frac{b}{\omega_D} \times 100\%,$$

$$d_3 = x^3\frac{b}{\omega_D} \times 100\%$$

the subscripts of d indicating the harmonic of the beat frequency concerned. Thus the E.M.D. is not only dependent upon x, the ratio of interfering to wanted carriers, but is also directly proportional to the ratio of the beat frequency to the maximum deviation frequency. This is in contra-distinction to phase modulation in which the distortion is independent of the beat frequency.

It is of course common to all systems operating with audio signals that beat frequencies falling outside the audio range (say exceeding 15 kc/s) will produce no audible output of themselves though they might give rise to combination tones falling inside the audio spectrum. In the table above the three systems are compared for E.M.D. due to an interfering signal, appropriate receivers being used in each case. In the phase modulated system ϕ_0 has been assumed as 10 radians giving a spectrum of $\pm$ 100 kc/s at 10 kc/s modulation frequency (Fig. 3), while in the frequency modulated system the deviation frequency ω'_D is also taken as 100 kc/s. As already stated, in amplitude and phase modulated systems the E.M.D., and hence distortion, is independent of the beat frequency.

There is thus considerable advantage to be gained by employing a frequency modu-

TABLE

EQUIVALENT MODULATION DEPTH (PER CENT.)

x	Amp. Mod.	Phase Mod.	Frequency Mod.				
	All frequencies		Kilocycles				
			1	3	5	10	15
0.1	10	1.0	0.1	0.3	0.5	1.0	1.5
0.2	19.5	2.0	0.2	—	—	2.0	—
0.3	29	3.0	0.3	—	—	3.0	—
0.4	37	4.1	0.42	—	—	4.2	—
0.5	44	5.15	0.57	1.71	2.85	5.7	8.5
0.6	—	6.25	0.73	—	—	7.3	—
0.7	—	7.45	0.92	—	—	9.2	—
0.8	—	8.7	1.14	3.42	5.70	11.4	17

APPENDIX No. I

A SHORT TABLE OF BESSEL COEFFICIENTS

m	$J_0(m)$	$J_1(m)$	$J_2(m)$	$J_3(m)$	$J_4(m)$	$J_5(m)$	$J_6(m)$	$J_7(m)$	$J_8(m)$	$J_9(m)$	$J_{10}(m)$
0	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2	0.99	0.10	0.00_5	—	—	—	—	—	—	—	—
0.4	0.96	0.20	0.02	—	—	—	—	—	—	—	—
0.6	0.91	0.29	0.04	0.00_5	—	—	—	—	—	—	—
0.8	0.85	0.37	0.08	0.01	—	—	—	—	—	—	—
1.0	0.77	0.44	0.11	0.02	—	—	—	—	—	—	—
1.5	0.51	0.56	0.23	0.06	0.01	—	—	—	—	—	—
2.0	0.22	0.58	0.35	0.13	0.03	0.00_7	—	—	—	—	—
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01	—	—	—	—
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	0.00_5	—
7.0	0.30	-0.00_5	−0.30	−0.17	0.16	0.35	0.34	0.23	0.13	0.06	0.02
10.0	−0.25	0.04	0.25	0.06	−0.21	−0.23	−0.01	0.22	0.32	0.29	0.21
15.0	−0.01	0.20	0.04	−0.19	−0.12	0.13	0.21	0.03	−0.17	−0.22	−0.09
20.0	0.17	0.07	−0.16	−0.10	0.13	0.15	−0.05	−0.18	−0.07	0.12	0.19

Table (*contd.*)

m	$J_{11}(m)$	$J_{12}(m)$	$J_{13}(m)$	$J_{14}(m)$	$J_{15}(m)$	$J_{16}(m)$	$J_{17}(m)$	$J_{18}(m)$	$J_{19}(m)$	$J_{20}(m)$	$J_{21}(m)$
10.0	0.12	0.06	0.03	0.01	—	—	—	—	—	—	—
15.0	0.1	0.24	0.28	0.25	0.18	0.12	0.07	0.03	0.02	0.01	—
20.0	0.06	−0.12	−0.20	−0.15	—	0.15	0.23	0.25	0.22	0.16	0.11

A dash indicates a value less than 0.01.

lated system, particularly as the distortion is graded over the audio spectrum, being low where the ear is most sensitive. This advantage is only maintained, however, when the modulation index $m > 1$. For $m = 1$ the E.M.D. or distortion in the three systems is the same unless $x > \frac{1}{3}$ (except that for frequency modulation the distortion is graded over the spectrum). For $m < 1$ amplitude modulation has the advantage. This distinction is important, for it is implicit in frequency modulated systems in which the modulation frequency may exceed the deviation frequency that interfering signals outside the deviation range produce equivalent modulation to a depth greater than 100%. This may be very damaging to the intelligence even though the bulk of the latter be at frequencies lower than the deviation frequency.

APPENDIX No. II

Colebrook in "High Selectivity Tone Corrected Receiving Circuits" (Radio Research Special Report No. 12 D.S.I.R.) expands the sum of two signals in a different manner, viz. :—

$\sin \omega_0 t + x \sin \omega_1 t$

$$= \{1 + x^2 + 2x\cos(\omega_0 - \omega_1)t\}^{\frac{1}{2}} \sin\left(\frac{\omega_0 + \omega_1}{2} t + \alpha\right)$$

$$= \{1 + x^2 + 2x \cos bt\}^{\frac{1}{2}} \sin\left(\frac{\omega_0 + \omega_1}{2} t + \alpha\right)$$

where

$$\alpha = \tan^{-1}\frac{1 - x}{1 + x}\tan\frac{b}{2}t$$

Although the amplitude change thus derived is the same as that in equation 34 (and therefore as far as amplitude modulation is concerned it is immaterial which expansion be employed), this amplitude change is associated with the mean frequency $\frac{1}{2\pi}\frac{\omega_0 + \omega_1}{2}$ of the two signals, the phase of which is changed periodically by the value α which is here a function of half the beat frequency. The objections to this form of expansion are (1) that the mean frequency has no physical existence, the only physically real frequencies being ω_0' and ω_1', (2) the reference point of the detector characteristic for phase or frequency modulation is the frequency of the wanted signal ω_0', and it is inconvenient to assume new reference points, as determined by the mean frequency, for each interfering signal that may be encountered.

APPENDIX No. III

The following expansions are useful :

1.—$\sin(A + B + C) = \cos A \cos B \cos C (\tan A + \tan B + \tan C - \tan A \tan B \tan C)$

2.—$\cos \overline{m \sin \mu t} = J_0(m) + 2J_2(m) \cos 2\mu t + 2J_4(m) \cos 4\mu t + \ldots$

3.—$\sin \overline{m \sin \mu t} = 2J_1(m) \sin \mu t + 2J_3(m) \sin 3\mu t + \ldots$

4.—$\tan^{-1}\frac{x \sin A}{1 + x \cos A} = x \sin A - \frac{x^2}{2}\sin 2A + \frac{x^3}{3}\sin 3A - \ldots$

5.—$\tan^{-1}\frac{\sin B + x \sin A}{\cos B + x \cos A} = B + x\sin(A - B) - \frac{x^2}{2}\sin 2(A - B) + \frac{x^3}{3}\sin 3(A - B) - \ldots$

(*To be concluded.*)

Geomagnetism

By SYDNEY CHAPMAN and JULIUS BARTELS. 2 vols. Pp. 1049 + xxviii + x. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 63s. net.

This great work by two leading authorities, one Professor of Mathematics at the Imperial College, London, the other Director of the Potsdam Geophysical Institute, will be welcomed by everyone who is in any way interested in the subject of geomagnetism. The size of the work gives some indication of the vast amount of research that has been devoted to this subject and of its importance as a branch of modern physics. In 1927 the subject set for the Adams Prize Essay by Cambridge University was the theoretical interpretation of the phenomena of the earth's magnetism, and in 1929 the prize was awarded to Professor Chapman for an essay which formed the basis of the present work, and in the same year he invited Professor Bartels to co-operate with him in its preparation.

Vol. I deals with geomagnetic and related phenomena and the methods by which the observed facts are found and recorded. Vol. II consists of two parts; the first deals with the analysis and synthesis of the data, and the second with physical theories of the phenomena.

The opening chapters discuss magnetic principles and magnetic measurements, then follow chapters on the earth's field and its secular variation, magnetism and geology and magnetic prospecting, solar and lunar data, various magnetic variations, transient, solar and lunar, storms, etc., earth currents, auroræ, and the earth's atmosphere.

Vol. II opens with chapters on harmonic analysis and spherical harmonics, and their application to the various magnetic variables. This section of the book is naturally of a very mathematical character. The final 250 pages will probably prove most attractive to the non-specialist reader, for they contain a masterly discussion of the various physical theories that have been propounded from time to time to explain the complex geomagnetic phenomena. There is also an absorbingly interesting historical chapter in which portions of Gilbert's "*De Magnete*" are reproduced. On p. 930 it is stated that "at Greenwich Observatory the magnetic declination was read thrice daily, using a Dollond magnet, from June, 1818, to December, 1920." I wonder if this is a misprint for 1820 ?

The completeness of the classified bibliography may be judged from the fact that it occupies 70 pages. There is the same thoroughness about the classified index. The plates and diagrams, of which there are a great number, are excellent.

The publication of these volumes is surely an outstanding event in the history of geomagnetism.

G. W. O. H.

Abstracts and References

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For the information of new readers it is pointed out that the length of an abstract is generally no indication of the importance of the work concerned. An important paper in English, in a journal likely to be readily accessible, may be dealt with by a square-bracketed addition to the title, while a paper of similar importance in German or Russian may be given a long abstract. In addition to these factors of difficulty of language and accessibility, the nature of the work has, of course, a great influence on the useful length of its abstract.

PROPAGATION OF WAVES

1. Calculation of the Radiation Properties of Hollow Pipes and Horns [Analysis using Vector Kirchhoff Formula].—Chu. (*See* 84.)

2. Physics and Technique of the Hollow-Space Conductor [Wave Guide].—O. Schriever. (*E.T.Z.*, 15th Aug. 1940, Vol. 61, No. 33, pp. 749–753.)

(1) History (from Rayleigh's 1897 paper on the passage of electric waves through tubes and the oscillations of dielectric cylinders—which "would not have been so quickly forgotten if decimetric-wave generators had then been available"—through Hondros & Debye's work in 1909/10 and that of Zahn, Rüter, & Schriever, 1915/1920; and through Bergmann & Krügel's use of open cylindrical resonators—*see* long abstract, 429 of 1935—to the recent work in America). (2) Physical nature of the internal waves and their differences from external waves on wires: the various types of internal waves, and the damping due to the tube walls in the corresponding types of guide; the rôle of the dielectric: dielectric losses. (3) Technical applications: the German work of the writer (the earlier work already cited; the long recent paper dealt with in 4276 of 1939 is not mentioned) and of Borgnis (*see* 61, below: for later work *see* 3 below) is cited, together with Reber's use of a resonance chamber at the focus of a parabolic reflector and his measurements of the screening powers of various materials (*see* 1340 & 1889 of 1939) and Southworth & King's metal norns as receivers (1888 of 1939). Practical difficulties in the use of wave-guides for the carrying of energy are discussed in the last paragraph, such as those due to irregularities and bends in the guides, particularly over long lengths. For short lengths, as in aerial feeders, the theoretical promises should be realised closely, except that it is difficult to generate truly circular waves (such as are required in order to gain the vanishingly low damping of the H_0-type wave) in the decimetric band.

3. The Concentric Line as Resonator [Analysis applicable also to Propagation along Concentric Lines].—Borgnis. (*See* 50.)

4. The Troposphere and Radio Waves [Effect of Tropospheric Reflections on Broadcast-Band and Ultra-Short Waves explained by assuming Fairly Strong Reflection from Inversion Layers at 1–10 km Height: Changing Cyclones & Anticyclones vary Height & Reflecting Power of Inversion Discontinuities: Occasional Great Increases in Reflecting Power].—R. C. Colwell. (*Proc. I.R.E.*, July 1940, Vol. 28, No. 7, pp. 299–302.)

For previous work *see* 401 of 1938, 3034 & 3428 of 1939, and 7, 3725, & 3730 of 1940. Tilton's u.s.w. results at his station on top of a mountain are included. "It seems that at certain times something takes place in the troposphere which greatly increases the reflecting power of the inversion layer": very strong inversion reflections in America during the eclipse of 19th June 1936 (which was accompanied by an intense magnetic storm) and the simultaneous "strange observation" of Pierucci in Italy (43, below) "lend weight to the assumption that certain magnetic storms on the sun send out a radiation which can penetrate the atmosphere even to the surface of the earth (or at least cause electrical effects at the earth's surface)."

5. Ultra-Short-Wave Transmission over a 39-Mile "Optical" Path [and the Diurnal & Seasonal Variations: Effects of Changes in Dielectric-Constant Gradient and of Air-Mass-Boundary Reflections: etc.].—England, Crawford, & Mumford. (*Proc. I.R.E.*, Aug. 1940, Vol. 28, No. 8, pp. 360–369.) A summary, under a different title, was dealt with in 2864 of 1940.

6. **The Transmission of Ultra-Short Waves through Ionospheric Action.**—E. Fendler. (*Hochf:tech. u. Elek:akus*, Aug. 1940, Vol. 56, No. 2, pp. 41–47.)

By "ultra-short" waves the writer here indicates waves below 12 m. The irregular transmission of these waves over distances of 300–2000 km, and sometimes (for the waves over 5 m) much more, is of great importance for ionospheric research. But it is also very important in connection with interference (thanks to the high field strengths attained owing to the very low absorption) with regular u.s.w. communication over quasi-optical paths, such as in television and aircraft-beacon working (a scale showing the 1938 Cairo allocations is given in Fig. 1). The writer therefore sets himself to investigate the whole question of the connection between these long-distance transmissions and the time of day and year, sunspot, auroral, & meteoric activity, and power used. His treatment is based on German and U.S.A. results, chiefly on wavelengths between 10.7 m and 5 m, given in papers up to 1939, many under his own name.

He begins by considering the curves of Fig. 2 showing the E, F_1, & F_2 reflecting heights for vertical incidence (left-hand set) and oblique (right-hand set), for various frequencies: unlike the former, each of the latter curves is re-entrant at its point of maximum usable frequency, "from which it follows that extremely high frequencies can often enjoy unweakened propagation to great distances."

Fig. 2 brings together, for 1933/8, the afternoon means of the F_2 limiting frequencies for vertical incidence (Bureau of Standards), the sunspot numbers, and the times of day at which 10 m (shaded areas) and 7 m (black areas) waves could be used on the Germany/U.S.A. service; it is deduced that the 10 m wave was only serviceable when the sunspot number exceeded 50, and the 7 m wave only when the number exceeded 100: the paper by Stoye & the writer (446 of 1937) is here referred to, the year of publication being wrongly given as 1939. Stoye's provisional solution postulating "M" and "E" solar regions (*Gerlands Beitr.*, 1937: *see* also 1696 & 1697 of 1936 and 1737 of 1938) is linked to Waldmeier's work on the 5303 AU coronal line, which led him to identify the long-sought-for sources of corpuscular radiation with these regions of intense line-emission (*see* 2167 of 1940). The period covered by Fig. 2 is the ascending portion of the sunspot cycle; in the early part (1933/4) no 10 m or 7 m reception appears. Nor were any such signals received (from overseas) in Germany during those years, whereas Fig. 5 shows reception there from the southern hemisphere in 1935/8 (*see* 3451 of 1938): here the absorption during the southern summer (December, January) comes in, so that the best conditions are in spring and autumn. Fig. 6 shows (curve *a*) the average course of the lower wavelength limit for long-distance propagation throughout the period 1933/8, ranging from 13 m to 7 m. Curve *b* represents results due to abnormal-E ionisation, and leads to section IV on this subject.

This section discusses the occasional strong long-distance signals obtained when the critical frequency of the E layer becomes, in places, greater than that of the F_2 layer, owing presumably to the formation of ion clouds: usually in daytime in summer, but sometimes at night and in winter. Thus Fig. 7 shows good 10 m signals up to distances of 2600 km over Europe even in 1933, a year of low solar activity when no overseas 10 m signals were received (see above); Fig. 8 shows 5 m communication over 500–2000 km in America in 1938, and Fig. 9 gives the relative behaviours of the 5 m wave in America in 1938 (Pierce, 4214 of 1938) and the 10 m wave in Europe in 1933, the ordinates representing the number of contacts established on a June day over the distances represented by the abscissae. "The absolute dead zone [skip distance] is, in this example (which can be taken as a very good average), about 300 km less for the 5 m wave, and so is the maximum range; probably as a result of greater general refraction of the 5 m wave in the troposphere." Up to the present no range over 2000 km has been observed with a 5 m wave; this suggests that long-distance working of this wave is due to an ion cloud whose diameter does not in general exceed 2000 km. The possible meteoric contribution to the formation of such clouds is discussed; thus Hess has found a striking connection between favourable u.s.w. working on 8–15th August in 1935/7 and the passage of the Perseid showers: *see* also Skellett, Leithäuser, 1752/3 of 1938. Other writers have found a correlation factor of 0.5 with thunderclouds. Altogether, the abnormal-E layer "seems to be produced by the combination of several layers due to different types of radiation"; whether it reflects the waves directly, or disperses them so that they fall on the F layer very obliquely and are then thrown back again through the ion clouds, is not yet certain.

Section V deals with the relation between aurora and u.s.w. propagation. Brilliant auroral displays occurred in medium latitudes on 25th Jan. 1938 and on 24th Feb. 1939; on both occasions the records show u.s.w. results typical of abnormal-E ionisation, and not otherwise observable during winter, but the relations were different on the two occasions. Thus Fig. 10 shows the sudden appearance of 5 m signals in Germany on 23rd Jan. 1938, about 24 hours before the appearance of the aurora; this may be interpreted by supposing that a violent solar eruption (unobserved by astrophysical observation) produced by its ultra-violet radiation a strong concentration in the E layer on 22nd/23rd January, and that its slower corpuscular radiation reached the earth's ring current on the 25th, produced the aurora, and caused immediate disturbances in the cosmic-ray curve and magnetic curves (shown below in the figure). On the other hand, the Feb. 1939 aurora and the effect on u.s.w. working occurred *simultaneously*. The behaviour of 10 m and 5 m waves on this occasion is illustrated in Fig. 11 (10 m, in Germany) and Fig. 12 (5 m, in North America, *occurring 6 hours later*) and is discussed in the adjacent text. One interpretation is that the localised zone of high ionisation took no part in the earth's rotation and was thus given an apparent velocity from east to west so that it would reach America in 6 hours. The section ends with the admission that the cause of the abnormal-E ionisation cannot yet be considered as decided: the most hopeful method of investigation is the measurement of cosmic rays, but unluckily such systematic observations have only recently been undertaken. They have already established a correlation with magnetic disturbances and with solar activity; the former correlation does not necessarily imply the latter, since the cosmic-ray corpuscles are influenced (like the auroral corpuscles) by the magnetic field; but the records have established a close correlation with the solar eruptions which can only be explained by supposing that certain important components of the cosmic rays, whose origin is not yet known, must also produce effects on the sun.

Section VI deals briefly with transmitter powers and aerials. Amateur and experimental stations, whose results form the chief basis of the paper, work on powers from 10 to 100 watts (50 in Germany) and often establish extremely satisfactory long-distance contacts; there is, however, a critical value at about 30 w below which the number of good contacts falls off rapidly (Fig. 13). Commercial services may use 1 kw, for greater certainty, but a 100-fold increase above this brings only a 10-fold increase and is therefore of little advantage. For overseas traffic a h.f. power of about 50 w is quite satisfactory.

Although ultra-short waves lend themselves so well to use with directive aerial systems, the advantages are rather illusory for long-distance communication, for the reason that the waves follow the most strongly ionised path and not necessarily the shortest. Most of the stations here concerned obtained their radiation sloping upwards at about 20° by means of L-aerials of length 5–8λ. If the angle is made much less than 20°, good overseas propagation may still be obtained and simultaneously a slight audibility in the skip region, becoming stronger as the radiation is made flatter: this is due to partially scattered and thrown-back radiation (*see* Fendler, 2857 of 1937).

7. Field-Strength Survey, 52.75 Megacycles from Empire State Building [Sound Channel of N.B.C. Television Transmitter: Horizontal Polarisation].—G. S. Wickizer. (*Proc. I.R.E.*, July 1940, Vol. 28, No. 7, pp. 291–296.) For previous work *see* 4281 of 1939 and 3285 of 1940.

8. A Note on the Origin of the D Layer [Objections to O_2-Photoionisation and Ozone Hypotheses: the High Stability produced by Forces of Inversion: D Layer as a Result of the Settling of Dust-like Metallic Particles of Meteoric Origin on Inversion Level at 55–60 km: Support from Night-Sky Spectrum, Magnetic, & Other Results: Explanation of Dellinger Effect].—S. Deb. (*Indian Journ. of Phys.*, April 1940, Vol. 14, Part 2, pp. 89–92.)

9. Radio Fade-Outs and Their Origin [Survey, leading to Comparison of Various Proposed Mechanisms for Production, by Solar Eruptions, of Fade-Outs and the Accompanying Increase of F-Region Height and Decrease in Its Ionic Density].—J. N. Bhar. (*Sci. & Culture*, Calcutta, Sept. 1940, Vol. 6, No. 3, pp. 150–157.)

The picture given of the ionosphere shows, as the chief constituents, thoroughly mixed O_2 and N_2 up to about 100 km, with a transition region $O_2 \rightarrow O + O$ (the splitting being due to radiation at and below 1750 AU) between 80 and 130 km, and from there upwards a region of diffusive equilibrium with chiefly N_2 and O. In the transition region the E layer is formed at about 100 km by the absorption of radiation at and below 774 AU by molecular oxygen; lower, at about 55–60 km, the oxygen molecules absorb, rather weakly, radiation at and below 1010 AU and give rise to the D layer (Mitra, Bhar, & Ghosh, 3429 of 1939). The F region is formed in the region of diffusive equilibrium by the atomic oxygen there absorbing radiation at and below 660 AU.

"It is evident that below the region E, between 60 and 100 km, both O_2 and O are present," and it has been suggested that the increase in D-layer ionisation produced by the solar eruption, and causing the fade-out, is due to L-α absorption by the atomic oxygen (*see* Martyn & others, 6 of 1938: in the present paper there would appear to be a mix-up in the footnote references). The writer, however, thinks that in the relatively cool atmosphere of region D the collisions between excited atoms would not have the violence necessary for the proposed mechanism, and also that atomic oxygen cannot be sufficiently abundant in that region. He considers it almost certain that the constituent affected is O_2 and not O, and therefore that the Lyman radiation responsible for the increase in ionisation must be L-γ (973 AU), since L-β is just greater than 1010 AU. He adopts, however, the idea that the L-α radiation is responsible for the decrease in the ionic density of the F region and the increase in the height of that region, through its dissociation of water-vapour molecules and the consequent raising of the equilibrium temperature.

In the course of his survey the writer discusses the difference between the ionised molecules resulting from the absorption, by oxygen molecules, of the two radiations 1010 AU and 774 AU, taken as responsible for the D and E layers respectively: the strong evidence in favour of the dynamo theory, as against the drift-current and diamagnetic theories, furnished by the combined observations of magnetic and wireless effects during a fade-out: and the explanation of the difficulties raised by the fact that not all observed solar flares are accompanied by fade-outs and that fade-outs have been reported which have had no corresponding solar flares: "all radio fade-outs reported as such may not be really so." So far as the F region is concerned, "the decrease in ionisation occurs almost simultaneously with every solar eruption" (whereas fade-outs usually occur after the beginning of the eruption—sometimes by as much as two hours).

10. Wireless Transmission at Its Best Four Days before Auroral Display; Bad for about One Week after Display, at Its Worst (for Short & Broadcast Wavelengths) Two Days after].—Stetson. (*Sci. News Letter*, 28th Sept. 1940, Vol. 38, No. 13, pp. 199 and 204.) *See* also 2886 of 1940.

11. Physical and Astronomical Information concerning Particles of the Order of Magnitude of the Wavelength of Light [with Experimental Work and Deductions concerning Electro- & Magnetophotophoresis, Polar Light & Magnetic-Storm Effects, etc.].—F. Ehrenhaft. (*Journ. Franklin Inst.*, Sept. 1940, Vol. 230, No. 3, pp. 381–393.) See also 3623 of 1940, and 222, below.

12. Solar Radiation and Geomagnetism [Intensity-Variations of Wave & Corpuscular Radiations estimated by Their Geomagnetic Effects: Ideas regarding Corpuscular Radiation lead to Hypothetical Division of Magnetic Storms into "Nascent-Stream" & "Mature-Stream" Types: etc.].—J. Bartels. (*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 339–343.)

13. Periodicities in Solar Variation reflected in the Weather [and Results in Long-Range Forecasting].—C. G. Abbot. (*Nature*, 26th Oct. 1940, Vol. 146, pp. 564–565.) *Cf.* 4200 & 4201 of 1940.

14. The Theory of the First Phase of a Geomagnetic Storm [based on Neutral Ionised Stream of Ions and Electrons from Sun].—S. Chapman & V. C. A. Ferraro. (*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 245–268.)

15. The Magnetic Storm of March 24th, 1940 [and the Disturbance of North American Power Circuits, Wireless & Wire Communication: Earth Potential Gradients of about 10 Volts/Mile: etc.].—A. G. McNish. (*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 359–364.)

16. Geomagnetic Tides in Horizontal Intensity at Huancayo: Part I.—J. Bartels & H. F. Johnston. (*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 269–308.)

17. Geomagnetic Three-Hour-Range Indices for the Years 1938 and 1939.—Bartels, Heck, & Johnston. (*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 309–337.)

18. Magnetic Storms [Popular Lecture].—S. K. Mitra. (*Sci. & Culture*, Calcutta, Aug. 1940, Vol. 6, No. 2, pp. 70–74.)

19. "Canadian Polar Year Expeditions, 1932/33: Terrestrial Magnetism, Earth-Currents, Aurora Borealis: Vol. 2" [Book Review].—(*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 368–370.)

20. Final Relative Sunspot-Numbers for 1939 and Monthly Means of Prominence Areas for 1931/1939.—W. Brunner. (*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 365–367.)

21. The Active Region of the Sun's Surface [has persisted for more than Seventy-Five Years: Implications regarding Constitution of Sun].—F. Sanford. (*Science*, 4th Oct. 1940, Vol. 92, pp. 309–310.)

22. On the Dielectric Constant of an Electronic Medium [Anode/Screen-Grid Space] at Medium Radio-Frequency.—Khastgir & Choudhury. (*See* 92.)

23. The Propagation of Electromagnetic Waves in an Ionised Medium and the Calculation of the True Heights of the Ionised Layers of the Atmosphere.—O. Rydbeck. (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, pp. 282–293.)

"The mechanical interpretation is only valid when eqn. 3 [obtained from the wave-equation for propagation in absence of a magnetic field, eqn. 1] is reducible to the Hamilton-Jacobi equation for the action function of a particle of energy $hf/2$ travelling in a force field with a potential energy V. . . . Usually the energies of the exploring signals used in ionospheric measurements are so high, however, and the wavelengths become so small, that one is quite justified in assuming the mechanical interpretation to hold up to the classical level of reflection at vertical incidence, *i.e.* where $V = hf/2$": the error made by this assumption is examined on p. 288 and found to be of the order of only $\lambda/8$, and therefore negligible here.

When the potential energy is a function of the electronic density only, and a single-valued function of the height, the relation of virtual height to true height of reflection is given by eqn. 8, from which (taking the case of the ordinary component when the magnetic field is perpendicular to the direction of propagation) is obtained the Abelian-type integral equation 9, and finally eqn. 11a: *the true height is thus given in the simple form of the Schlömilch integral*, where only the virtual height as a function of the frequency is required to be known. The true height is easily obtained with a planimeter from the virtual-height curve projected on an angular-frequency scale. The specimen curves of Fig. 1 (F region in evening) show how the rapid increase of the measured virtual height near the critical frequency contributes very little to the integral, the computed true height increasing by hardly 10%: even when the recorded virtual-height line is a broad band (diffuse F region) the true-height variation computed is only 8–15%.

The solution can be used with an error less than the experimental error for angles of the magnetic field down to 75° instead of the 90° assumed above. A similar solution is found for observatories where the angle is up to 20°, such as Cambridge, Mass. (Figs. 1–4: these curves show that at around 370 km the magnetic field has dropped to about 0.49 oersted; that in spite of the enormous rise in virtual height of the F_2 layer near the critical frequency, the maximum increase in true height is only 105 km; and they confirm the belief that the F_2 layer generally is parabolic in nature). At other geographical locations the errors introduced should be susceptible of estimation.

24. Early Morning Variation of Ionisation and the True Height of Region F of the Ionosphere [Calcutta Observations: Shift of Hour of Pre-Sunrise Increase in Ionisation towards Earlier Part of Night, in Winter, and Absence of Increase with Approach of Summer Solstice, explained as Effects of

Cooling: Ionisation Minimum always after F-Layer Sunrise (Lag greatest in Summer, when Heating Effect predominates more over Electron-Detachment Effect): True Heights of F Region (from P', f Curves) average about 100 km less than Virtual Heights].—S. P. Ghosh. (*Indian Journ. of Phys.*, April 1940, Vol. 14, Part 2, pp. 101–107.)

25. MULTI-FREQUENCY RECORDINGS OF RADIO-WAVE POLARISATION NEAR THE GEO-MAGNETIC EQUATOR [at Huancayo, Peru, where Propagation with Wave-Normal perpendicular to Magnetic Field & to Iso-Ionic Surfaces of Ionosphere is possible throughout Wave-Path: 1935 Results (2902 of 1936) confirmed and extended to E Region].—H. W. Wells. (*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 353–358.)

26. PAPERS AT THE JOINT MEETING, I.R.E. AND U.R.S.I. (AMERICAN SECTION), APRIL 1940.—(*Nature*, 5th Oct. 1940, Vol. 146, pp. 450–451.)

27. CHARACTERISTICS OF THE IONOSPHERE AT WASHINGTON, D.C., MAY & JUNE 1940, WITH PREDICTIONS FOR AUG. & SEPT. 1940.—Gilliland & others. (*Proc. I.R.E.*, July 1940, Vol. 28, No. 7, pp. 332–335.)

This monthly feature appears in the August issue under a slightly different title, and prepared by Kirby, Smith, & Gracely.

28. SHORT-WAVE RECEIVING CONDITIONS [and Prospects for the Current Month].—Cable & Wireless, Ltd. (*Wireless World*, Oct. & Nov. 1940, Vol. 46, Nos. 12 & 13, pp. 436 & 472.)

29. AMATEUR COOPERATION IN IONOSPHERIC AND OTHER RESEARCH IN PHILADELPHIA.—American Philosophical Society's Committee. (*Science*, 11th Oct. 1940, Vol. 92, pp. 331–333.)

30. REFLECTION [of Light] AT ABSORBING MEDIA.—H. Littmann. (*Ann. der Physik*, Ser. 5, No. 2, Vol. 38, 1940, pp. 139–152.)

"Observations with an Abbe refractometer show that the light reflected by absorbing liquids no longer conforms with the Fresnel formulae. A strictly valid reflection formula is derived for arbitrary angle of incidence, index of refraction, and absorption, and its connection with other formulae is shown. The calculated course of intensity is verified qualitatively by experiment." Westerdijk's work on inhomogeneous plane waves (2177 of 1940) is mentioned.

31. THE TRANSMISSION OF INFRA-RED LIGHT BY FOG.—J. A. Sanderson. (*Journ. Opt. Soc. Am.*, Sept. 1940, Vol. 30, No. 9, pp. 405–409.)

A summary was dealt with in 3661 of 1940: contrast Smith & Hayes, 4519 of 1940.

32. ON THE THEORY OF PLANE DISTURBANCES IN FRICTIONLESS GASES [and Liquids: Difference of Propagation from that of Electromagnetic Waves: Formation of Stationary Waves—Position of Nodes independent of Distortion & Wave-Amplitude: etc.]: PARTS I & II.—K. Bechert. (*Ann. der Physik*, Ser. 5, No. 2, Vol. 37, 1940, pp. 89–123: No. 1, Vol. 38, 1940, pp. 1–25.)

33. THE PROPAGATION OF ELECTROMAGNETIC WAVES ALONG OPEN WIRE LINES.—V. I. Kovalenkov. (*Automatics & Telemechanics* [in Russian], No. 1, 1940, pp. 3–26.)

In a previous paper (3744 of 1940) equations were derived determining the propagation of a wave along an infinite line. Using these equations and the laws of the reflection of waves at the ends of the line, the following particular cases of a finite line are discussed:—(1) The wave is totally reflected at the end of the line; (2) the wave is partially reflected at the end of the line; (3) the distant end of the line is short circuited (earthed); and (4) the distant end of the line is isolated. For each of the above cases (with the exception of case 2, which will be considered in detail in a separate paper) curves are plotted showing the propagation and reflection of the wave and the building up of the current and voltage at various points of the line. A comparison with experimental results shows that the method proposed by the author gives an accurate picture of the processes taking place on a line.

34. CERTAIN CONSEQUENCES ARISING FROM AN ANALYSIS OF THE PROPAGATION OF ELECTROMAGNETIC ENERGY ALONG THREE-PHASE SYMMETRICAL LINES.—V. A. Dyakov. (*Automatics & Telemechanics* [in Russian], No. 1, 1940, pp. 39–46.)

The conclusions reached in a previous paper (3745 of 1940) regarding the propagation of a h.f. electromagnetic wave along a 3-phase symmetrical line are applied to the case of a line having n symmetrically arranged conductors.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

35. THE WAVE FORM OF ATMOSPHERICS AT NIGHT [Johannesburg & Durban Observations with C-R-Oscillographs provided with Automatic Brilliancy Control and Anticipatory Leader Triggering: Sources located and marked automatically on Wave-Form Record: Results & Conclusions].—Schonland, Elder, Hodges, Philips, & van Wyk. (*Proc. Roy. Soc.*, Ser. A, 9th Oct. 1940, Vol. 176, No. 965, pp. 180–202.)

"It is here shown that the forms taken by all atmospherics at night arise from a simple direct pulse followed by a series of ionospheric reflections" [30 being frequently recorded, and the height of the reflecting layer being determinable within ± 1 km: it ranged from 85.5 to 90.5 km (winter): reflection coefficient over 0.80 for wave-forms around 200 μsec., 0.50 for pulses of shorter period]. "More recent work indicates that similar night forms can be obtained in summer." "Before our night observations were analysed it was thought from our day observations that the apparent increase in the day value of h with distance was real and it was suggested that it arose from a reduction of h in the neighbourhood of the parent thunderstorm [3063 of 1939]. The discovery of the merging of G and S_1 at night makes this hypothesis unnecessary, and our day observations when analysed anew give a value for h of about 60 km irrespective of the distance travelled by the atmospheric." The velocities of ground and sky pulses are discussed, among other points.

36. General Meteorological Aspects of Thunderstorm Electricity [Discussion of Simpson's & Wilson's Theories, and Their Defects: the "Danger Zone" in Vicinity of − 10° C Isotherm, and Bergeron's Theory of Precipitation: Ice Crystals play Essential Rôle also in Generation of Thunderstorm Electricity: New Picture of Idealised Thundercloud].—H. R. Byers. (*Terr. Mag. & Atmos. Elec.*, Sept. 1940, Vol. 45, No. 3, pp. 345–350.)

37. Lightning Storms: IV [Evidence supporting Writer's Picture of Turbulence, and Deductions].—J. F. Shipley. (*Distribution of Electricity*, Oct. 1940, Vol. 13, No. 140, pp. 409–414.) For previous parts *see* 3337 of 1940.

38. Changes of Atmospheric Electric Potential Gradient during Monsoon Rains in Bombay [Data suggesting that Monsoon Clouds have Distribution of Charges similar to That of Thunderstorm Clouds, with Preponderance of Negative Charge near Base].—A. R. Pillai. (*Current Science*, Bangalore, Aug. 1940, Vol. 9, No. 8, pp. 363–366.)

39. The Variation of Sparking Potential with Initial Photoelectric Current: Part II [More Rigorous Solution: Breakdown probably initiated by Mid-Gap Streamers, for the Larger Photoelectric Currents].—J. M. Meek. (*Proc. Phys. Soc.*, 1st Nov. 1940, Vol. 52, Part 6, pp. 822–827.) Further development of the work dealt with in 3339 of 1940.

40. "Einiges über die Beziehungen der Funkgeologie zur Blitzforschung" [Some Points on the Relations of Radio-Geological Prospecting to Lightning Research: Book Review].—V. Fritsch. (*E.T.Z.*, 25th July 1940, Vol. 61, No. 30, p. 704.) The book is a special expanded reprint from *Gerlands Beiträge*.

41. The Problem of the Resistance of Lightning-Conductor Earths [including the Desirability of testing Existing Earths by the High-Frequency Method].—V. Fritsch. (*E.T.Z.*, 8th Aug. 1940, Vol. 61, No. 32, pp. 739–741.) Thus "an important fraction of the German harvest is stored in granaries whose conductors do not nearly conform to modern requirements." *See* also 42, below.

42. The Measurement of [Lightning-Conductor] Earth Resistances with High-Frequency Test Currents.—Fritsch. (*See* 158.)

43. A Strange Observation during a Partial Eclipse of the Sun [Enormous Increase in Atmospheric Conductivity].—M. Pierucci. (*Nuovo Cimento*, May 1939, Vol. 16, Fasc. 5, pp. 225–228.)

The original observation was during the partial (0.8 at Modena) eclipse of 19th June 1936, when an electroscope discharged itself rapidly and had to be continually re-charged, the time of discharge falling, at the maximum of the eclipse, to under 12 seconds instead of the normal time (to which it returned when the eclipse had passed) of many minutes. The eclipse of 19th April 1939 was much less complete (only 0.1 at the same locality) and the results were correspondingly small, the electroscope having to be charged only once: but the sudden change in the discharge curve at the beginning of the eclipse (Fig. 2) shows the reappearance of the phenomenon. The first eclipse was at sunrise, the other at sunset, so that in both cases the path through the atmosphere was at its longest, and close to the ground. "It would be very premature to suggest an interpretation" of the phenomenon: *see* Colwell, 4, above.

44. Measurement of Cosmic Rays at Agra and Kodaikanal [including Negative Result of Attempted Correlation between Mean Daily Intensity and Sunspot Numbers & Flocculi Figures].—A. K. Das & M. Salaruddin. (*Indian Journ. of Phys.*, June 1940, Vol. 14, Part 3, pp. 191–205.) But the data are "very meagre for drawing any definite conclusion" [*cf.* Fendler, 6, above].

45. Cosmic Rays at High Altitudes [University of Chicago's Recent Investigations: a True Seasonal Effect ?].—W. P. Jesse. (*Nature*, 19th Oct. 1940, Vol. 146, p. 527.) *See* also 4206 of 1940.

46. Further Investigations of the Air Mass Effect on Cosmic-Ray Intensity.—Loughridge & Gast. (*Phys. Review*, 1st Oct. 1940, Vol. 58, No. 7, pp. 583–585.)

47. On the Fine Structure Pattern of Cosmic Rays at Mexico City.—E. J. Schremp & A. Baños, Jr. (*Phys. Review*, 1st Oct. 1940, Vol. 58, No. 7, pp. 662–663.) Using the "cosmic-ray telescope" described in a previous paper.

48. Cosmic-Ray Showers in the Stratosphere [Pilot-Balloon Results with Quadruple Coincidence Recorder: Difference between Curves measures Magnitude of Hard Component].—E. Regener & A. Ehmert. (*E.T.Z.*, 1st Aug. 1940, Vol. 61, No. 31, pp. 723–724: summary only.)

49. "The Meteorological Glossary" [Book Review].—Meteorological Office. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, pp. 568–569.)

PROPERTIES OF CIRCUITS

50. The Concentric Line as Resonator.—F. Borgnis. (*Hochf:tech. u. Elek:akus.*, Aug. 1940, Vol. 56, No. 2, pp. 47–54.)

"A dielectric space completely shut in by a metallic wrapping and containing, it may be, a number of arbitrarily shaped conductors, represents in the most general sense an electromagnetic cavity. Such a cavity possesses a discrete infinite series of electromagnetic resonance modes. The lower limit of this series of resonance frequencies (*i.e.* the resonance mode with the lowest natural frequency or longest natural wavelength) is entitled the fundamental oscillation.

"From this standpoint, a concentric tubular line closed at each end by a flat surface represents a cavity which will possess the above attributes. Such coaxial conductors, having an axial length equal to a half-wavelength or a multiple of this, have been used extensively as resonators for decimetric waves. The mode of oscillation employed in such a half-wave line short-circuited at both ends has been the Lecher-wire type; the radial electric field E_r and the circular magnetic field H_ϕ are distributed sinusoidally along the axis (Fig. 1). These oscillations, however, represent only one among the infinitely many possible oscillation modes of this special cavity. The outstanding prominence attained hitherto by the Lecher-wire mode is due to the fact that the corresponding resonance frequency is determined only by the axial length of the system and not by its radial dimensions. In all other possible oscillation modes the radial dimensions play their part in determining the resonance wavelengths; but these modes only make their appearance when the resonance wavelengths are comparable with the radial dimensions. In the decimetric-wave region the radial dimensions were generally much smaller than the longitudinal, so that no oscillation modes other than the Lecher-wire type presented themselves.

"Now, however, that still shorter waves are worked with, the remaining possible modes of oscillation must be considered, not only in order that their unwanted appearance may be suppressed by suitable precautions, but also so that use may be made of them in place of the Lecher-wire-type oscillations. The following investigations give information on the possible free oscillation modes of the special cavity resonator formed by a coaxial line closed at both ends by flat conducting plates; see also Buchholz [1301 of 1940]." The Lecher-wire mode is assumed as being known in detail: the damping d, taking into account the losses in the end-plates, for the case of copper/air is given by eqn. 1. For $r_2/r_1 = 3.61$ the term

$$(1 + r_2/r_1)/\log_e r_2/r_1$$

is a minimum, and so long as the value $2l\,(= 4/\lambda)$ can be neglected in comparison with the first term in the brackets of eqn. 1, this ratio of radii represents the one for minimum damping.

The whole series of possible oscillation modes of the cavity with cylindrical symmetry can be divided into two groups: the group of the electric (E) type which has, in the direction of the cylinder axis, an electric field component only, and the magnetic (H) type which has in the axial direction only a magnetic component. The Lecher-wire type stands outside both groups, having in the axial direction neither an electric nor a magnetic component; also its existence, unlike that of any of the other modes, is bound up with the presence of a finite inner conductor (r_1 not equal to zero).

The general solution of the cylindrically symmetrical oscillation régimes is taken from the writer's previous paper (3874 of 1939). Of the various roots of the equations 12 & 13, those of most practical importance are the two corresponding to the fundamental electric type (E_{001}) and the fundamental magnetic type (H_{111}). The first of these (corresponding to $m = 0$, $n = 0$ in eqn. 2) is dealt with in section 3; this mode has already been investigated in detail, for the special case of a vanishing inner conductor ($r_1 = 0$), in a previous paper (*see* 905 of 1940); the more general case is here considered. Fig. 2 shows the course of the natural wavelength for a fixed outer radius r_2 as a function of $a = r_1/r_2$, as the radius of the internal conductor is increased from 0 to r_2: actually what is plotted is not λ but λ/r_2. The resonance wavelength decreases steadily as r_1 increases, tending towards zero as r_1 approaches r_2, when in the limiting case the oscillation mode approximates to that between two parallel infinite planes. When $a \rightarrow 1$, eqn. 21 is obtained, namely $\lambda/r_2 = 2(1 - a)$; actually, as Fig. 2 shows, for values of $a > 0.5$ the half wavelength may be taken in practice as about equal to the gap between the conductors, $r_2 - r_1$. The behaviour when $a \rightarrow 0$ is interesting, for the solution of eqn. 17 shows that then the natural wave of the cavity without any internal conductor is not altered by the introduction of an infinitely thin internal conductor, although such an introduction would presumably bring down the electric field along the axis, hitherto (in the "empty" cavity) at its maximum, to zero, and would thus alter the distribution of the electric field. The physical explanation of this apparent anomaly is that the infinitely thin conductor would affect the field distribution only in its very nearest neighbourhood, its introduction producing only an infinitely small disturbance of energy. Results of a more exact examination of the solutions of eqn. 17 are discussed and illustrated (Figs. 3–5); it is found that even when a is as small as 0.02 the introduction of the inner conductor reduces the wavelength of the previously "empty" cavity by about 18%. Section 3 ends with an analysis of the damping of the cylindrical cavity, without and with an internal conductor, for the fundamental electric oscillation, and with a comparison of this damping with that of the Lecher-wire type of oscillation.

Section 4 deals similarly with the fundamental oscillation of the magnetic type (H_{111}, with $m = 1$, $n = 1$). It is the longest natural wave, next to the Lecher-wire type, of which the concentric line is capable: its length is given by eqn. 33. For a fixed outer radius r_2 and an increasing ratio of r_1/r_2 this wavelength increases steadily (top curve of Fig. 8) and in the limit, when the gap between the two conductors disappears, it reaches the value of the circumference of the outer conductor (on the assumption of an infinite length for the concentric line: the influence of the finite length of the line in reducing the wavelength is seen in eqn. 33). It is obvious, therefore, that the Lecher-wire oscillation is the only one to which the cavity is capable of resonating, so long as the wavelength exceeds the circumference of the outer conductor.

Section 5 deals briefly with waves of the magnetic type H_{011} and the electric type E_{111}, both given by eqn. 37 and Fig. 12, and both shorter than the two types just considered. Finally, section 6 in a few lines points out that "the results thus obtained for the cavity formed by two concentric tubular conductors can be suitably applied to the propagation of electromagnetic waves along concentric-tube lines. Thus Figs. 2, 8, & 12 also represent the ratio between limiting wavelength and outer-conductor radius, as a function of the radii-ratio $a = r_1/r_2$, for the corresponding wave-types in such concentric lines."

51. On the Nature of Negative Resistances and Negative-Resistance Sections [Experimental Studies of Stability, Value & Character of Impedance, Linearity, and Phase-Distortion in Negative Resistances of Dynatron, Transitron, & Feedback Types (Frequency Range 0.5 kc/s to 1.0 Mc/s): Properties of Symmetrical Sections formed from Positive & Negative Resistances or Negative Resistances only].—S. P. Chakravarti. (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, pp. 294–311.) For an erratum on p. 299 *see* November issue, inside back cover.

52. Electric Oscillations and Surges in Subdivided Windings [Analysis].—R. Rüdenberg. (*Journ. Applied Phys.*, Oct. 1940, Vol. 11, No. 10, pp. 665–680.)

53. The Mutual Inductance of Two Circles: a Problem in Approximation [Determination of Dominant Part in Function when Difference between Radii is Small].—E. H. Neville. (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, p. 340.)

54. Inductance of Hollow Rectangular Conductors [Complete Expression for Inductance per Unit Length of Two Parallel Conductors, One the Return for the Other, Cross Sections being Hollow Rectangles symmetrically placed with respect to One Another].—T. J. Higgins. (*Journ. Franklin Inst.*, Sept. 1940, Vol. 230, No. 3, pp. 375–380.) As used in bus-bars, etc.

55. Transversal Filters [differing from Conventional Resonance Filter as a Grating Spectroscope differs from a Prism Spectroscope: particularly suitable for Television, owing to Absence of Distortion: Series of Matched Delay Cable Sections with Terminating Resistance, Signals being derived as Sums or Differences (obtained by Special External-Electrode or Cathode-Ray Type Devices) of Voltages tapped off at Points along Cable].—H. E. Kallmann. (*Proc. I.R.E.*, July 1940, Vol. 28, No. 7, pp. 302–310.)

In the "multiple echo" type, corresponding to a single or a few pairs of tappings, no special electronic devices are required. The paper includes the design of "condensed cables" avoiding the use of cumbersome coiled-up sections of actual cables.

56. New Voice-Frequency Electrical Delay Network.—H. M. Thomson. (*Bell Lab. Record*, Sept. 1940, Vol. 19, No. 1, pp. 15–18.)

57. The Matrix Theory of Four-Terminal Networks [including Application to General Artificial Line, Smooth Line, & General Ladder Structure: replacing More Complex Usual Methods of Differential & Difference Equations, Continued Fractions, & Continuants].—L. A. Pipes. (*Phil. Mag.*, Nov. 1940, Vol. 30, No. 202, pp. 370–395.)

58. A Matrix Generalisation of Heaviside's Expansion Theorem [Derivation of General Expression for Currents in *n*-Mesh Linear Bilateral Network, taking into account Initial Charges & Currents and Application of Arbitrary E.M.Fs. at $t = 0$ (unlike Conventional Form)].—L. A. Pipes. (*Journ. Franklin Inst.*, Oct. 1940, Vol. 230, No. 4, pp. 483–499.)

59. Properties of the Witch of Agnesi: Application to Fitting the Shapes of Spectral Lines [Plane Curve $y = ha^2/(a^2 + x^2)$, approximating also to Power dissipated in Sharply-Tuned Resonant Circuits].—R. C. Spencer. (*Journ. Opt. Soc. Am.*, Sept. 1940, Vol. 30, No. 9, pp. 415–419.)

60. Method of Calculating the Current Harmonics in Rectifier or Converter Circuits [Failure of Usual Differential-Equation Procedure to give Nature & Strength of Harmonics: Method based on "Fictive E.M.F.", and independent of Lags due to Grid Control, etc.].—P. Werners. (*Arch. f. Elektrotech.*, June 1940, Vol. 34, No. 6, pp. 383–396: *E.T.Z.*, 8th Aug. 1940, Vol. 61, No. 32, p. 745—summary only.)

TRANSMISSION

61. Electromagnetic Hollow-Space [Cavity] Resonators in Short-Wave Technique [in Transmitting & Receiving Circuits, etc.].—F. Borgnis. (*E.T.Z.*, Vol. 61, 1940, p. 461 onwards.) Mentioned in Schriever's paper (2, above): for previous work *see* 905 of 1940 and back reference, and for a later paper *see* 50, above.

62. The Ultra-Short-Wave Generator with Phase-Focusing (Klystron).—Lüdi. (*Hochf: tech. u. Elek:akus.*, Aug. 1940, Vol. 56, No. 2, pp. 60–62.) Long illustrated summary of the paper dealt with in 3777 of 1940.

63. Low-Loss Hollow-Space Circuits for Oscillation Generation in the Decimetric-Wave Region by Velocity Modulation.—R. H. Varian. (*E.T.Z.*, 1st Aug. 1940, Vol. 61, No. 31, p. 722.) Summary of the second paper dealt with in 2773 of 1939.

64. Production of Ultra-High-Frequency Radio Waves by Electronic Oscillations [in Positive-Grid Triodes].—S. S. Banerjee & A. S. Rao. (*Indian Journ. of Phys.*, April 1940, Vol. 14, Part 2, pp. 93–100.) A preliminary account was dealt with in 4356 of 1939.

65. Parasitic Electronic Oscillations and Coupling Frequencies in a Power Tube [Type RK-38 Triode].—King. (*See* 91.)

66. A Frequency-Modulation Monitoring System [with Analytical Discussion & Computed Charts of Spectra produced by F.M. Waves].—Pieracci. (*See* 220.)

67. Better Coverage [Tests of Comparative Effectiveness of Frequency-Modulated and Amplitude-Modulated Transmitters].—Weir. (*See* 219.)

68. Synchronised Frequency - Modulation Transmitter [Western Electric Type 503A-1 1000-Watt].—W. H. Doherty. (*Bell Lab. Record*, Sept. 1940, Vol. 19, No. 1, pp. 21–25.) *See* also 4246 of 1940.

69. Foundations of [Amplitude] Modulation by Variable Load Circuit (Absorption Modulation) and Its Application to Decimetric Waves.—K. Lamberts. (*Hochf:tech. u. Elek:akus.*, July 1940, Vol. 56, No. 1, pp. 1–13.)

Author's summary :—" The work deals with a modulation method by which the modulation of the h.f. amplitude is obtained by a variable load circuit. The method is suitable for the modulation of h.f. generators of all types so long as they produce sinusoidal alternating voltages. With the help of a simple resistance equivalent-circuit the conditions to be observed in the modulating resistance are determined. Diodes are employed as the modulating element, their resistance being variable by the modulating voltage over the necessary range without the expenditure of power. The variable h.f. resistance which the diode represents for the oscillatory circuit is calculated, with the aid of the current-flow angle, under simplifying assumptions, and the course of the modulation characteristic is determined by the use of an equivalent circuit for the oscillatory circuit. The modulation method is investigated experimentally on a transmitter in the broadcast band, and good agreement is obtained between the calculated and measured values.

" In the decimetric-wave region a Lecher-wire [or concentric-tube] system takes the place of the quasi-stationary circuit. The use of the line equations shows that a modulation of the radiated energy, for constant generator voltage, is possible if the modulating resistance is arranged at the voltage nodes of the line. To detect the frequency variations introduced by the modulation, a measuring method [Fig. 16] is developed on the heterodyne principle. The influence of temperature on the frequency of a back-coupled decimetric-wave transmitter is treated briefly. The practical development of load modulation in the decimetric-wave region is gone into thoroughly. The comparison of load modulation with other known modulation methods, on a back-coupled transmitter, a magnetron, and a Barkhausen-Kurz generator, shows the superiority of the load-modulation method as regards linearity of characteristic, depth of modulation, and frequency changes.

" During the carrying-out of these researches, a paper by Parker [4447 of 1938] appeared on a modulation method for television transmitters which in its fundamentals agrees with the modulation method here described with simple load circuit in a non-quasi-stationary system. The results established in Parker's paper for the power relationships correspond to the curves given by me in Fig. 4 for the general case."

Fig. 18 shows the application of the " load modulation " method to a decimetric-wave transmitter with a parallel-wire (telescopic) system whose ends carry a dipole. The absorbing resistance is given an infinitely high value by a suitable bias and is slid along the parallel wires until it reaches its optimum position near a potential node : owing to the capacity of the absorbing organ the resonance length of the parallel-wire system is slightly below $\lambda/2$. The distance between the dipole and the modulation resistance, and the coupling between generator and Lecher-wire system, are adjusted till maximum signals are obtained in a local crystal-receiver circuit. For reasons of symmetry the modulating resistance is formed from two diodes in series, each taking half the voltage between the tapping-points on the Lecher system. Filament and modulating voltages are brought in over choking coils. The whole apparatus is mounted on an aluminium plate which serves as a reference plane as regards capacity effects, and screening is provided so that the test receiver is affected only by the dipole radiation ; otherwise erroneous results on the modulation range would be obtained. In plotting the modulation characteristic the necessary changes in the d.c. modulating voltage are carried out through a relay to avoid capacitive effects by the operator's body.

Figs. 19 & 20 show comparisons between anode-voltage modulation and load-modulation for a back-coupled transmitter, Figs. 21, 22 & 23, 24 similar comparisons for a magnetron, the first pair showing the limitations of anode-voltage modulation ; Fig. 25 shows the same for magnetic-field modulation of a magnetron compared with load-modulation (at full modulation by the latter method marked effects on the frequency are, however, liable to occur under certain conditions of magnetic field). The final figures compare load-modulation with anode-voltage and grid-voltage modulation for a B-K generator. It is mentioned that simultaneous modulation of grid and retarding-field voltages will give an approximately frequency-stable modulation over a limited range.

70. The Numans Oscillator : New Style [Advantages of Mazda AC/SP1 for Transitron Circuit, including Wide Frequency Range up to & over 12 Mc/s].—T. J. Rehfish : Cocking. (*Wireless World*, Oct. 1940, Vol. 46, No. 12, p. 442.) Prompted by Cocking's article (3792 of 1940.)

71. Thickness Vibrations of Piezoelectrically Excited Crystal Plates.—Bechmann. (*See* 150.)

RECEPTION

72. Electromagnetic Cavity Resonators in Short-Wave Technique [in Transmitting & Receiving Circuits, etc.].—Borgnis. (*See* 61.)

73. An Ultra-High-Frequency Superheterodyne Receiver for Direction Finding [on 1.67 m Waves from Radio Sonde].—L. C. L. Yuan & C. E. Miller. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 273–276.)

Primarily for the work dealt with in 3752 of 1940 and back reference. Super-regenerative receivers are not suitable for this purpose owing to their automatic-volume-control action, and the ordinary superheterodyne receiver has a band-width in the i.f. amplifier which is too narrow to allow for the slight changes in the signal or heterodyne-oscillator resulting from temperature variations, etc. The present receiver has an i.f. circuit with a constant gain of 110 000 over a 110 kc/s band. The overall input/output curve of the receiver can be made very steep (Fig. 4, curve "D"), which is very desirable for d.f. by a null-point method.

74. THE INVERSION PHENOMENA IN CRYSTAL DETECTORS AT ULTRA-HIGH FREQUENCIES [in Lecher-Wire Measurements].—Shinyanski. (*See* 147.)

75. SHORT-WAVE INTERVALVE COUPLINGS: ADVANTAGES OF A MODIFIED TUNED-ANODE CIRCUIT [Difficulties due to Unwanted Circuit-Capacities: Use of Circuit equivalent to Auto-Transformer with Capacitive instead of Inductive Tapping-Point].—W. T. Cocking. (*Wireless World*, Oct. 1940, Vol. 46, No. 12, pp. 424–426.)

76. SHORT-WAVE RECEIVING CONDITIONS [and Prospects for the Current Month].—Cable & Wireless, Ltd. (*Wireless World*, Oct. & Nov. 1940, Vol. 46, Nos. 12 & 13, pp. 436 & 472.)

77. REDUCING INTERFERENCE: METHODS APPLICABLE TO THE RECEIVER [Investigation of Course of Transient through Receiver, and the Limitations of Simple "Hole-Punching" Devices: Use of Auxiliary Parallel Amplifier to provide Correctly-Timed Blocking Pulses: Successful Modification of the de Monge Auxiliary-Aerial System].—R. I. Kinross. (*Wireless World*, Oct. & Nov. 1940, Vol. 46, Nos. 12 & 13, pp. 432–436 & 469–470.)

Continued from 3816 of 1940. For de Monge's arrangement *see* 99 & 1857 of 1938.

78. NOISE LIMITER: SATURATING DETECTOR CIRCUIT [Triode used as Detector, with Grid controlled by Signal and Anode/Cathode Path operating as Diode].—R.C.A. Laboratories. (*Wireless World*, Oct. 1940, Vol. 46, No. 12, p. 427).

79. REGULATIONS FOR THE HIGH-FREQUENCY [Interference] SUPPRESSION OF ELECTRICAL MACHINERY AND APPARATUS OF NOMINAL POWERS UP TO 500 WATTS [with Table of Minimum Values for Various Types of Machine, etc.].—Verband Deutscher Elektrotechniker. (*E.T.Z.*, 15th Aug. 1940, Vol. 61, No. 33, pp. 759–760.) *See* also p. 767.

80. COMPULSORY INTERFERENCE SUPPRESSION [Editorial Comment].—(*Wireless World*, Oct. 1940, Vol. 46, No. 12, p. 415.)

"If a law covering this matter had been already in force, it is likely that the present restrictions would have been unnecessary, or at least that they would have imposed very much less hardship on private users of h.f. apparatus. . . ."

81. "DIE WARTUNG DER ELEKTRISCHEN FLUGZEUGAUSRÜSTUNG" [Care of Electrical Installation on Aircraft, including Interference-Suppression: Book Review].—Klinker. (*E.T.Z.*, 25th July 1940, Vol. 61, No. 30, pp. 703–704.)

82. TEST REPORT: ARMSTRONG MODEL EXP48 [for Export & Home Markets].—(*Wireless World*, Oct. 1940, Vol. 46, No. 12, pp. 430–431.)

83. "ACTIVE SERVICE" TRANSPORTABLE [Car Radio Receiver in Wooden Case carrying Car Battery & Telescopic Aerial].—Delco-Philco. (*Wireless World*, Oct. 1940, Vol. 46, No. 12, p. 439.) *Cf.* 1004 of 1940.

AERIALS AND AERIAL SYSTEMS

84. CALCULATION OF THE RADIATION PROPERTIES OF HOLLOW PIPES AND HORNS [Analysis using Vector Kirchhoff Formula].—L. J. Chu. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, pp. 603–610.) Supplying the mathematical discussion of the curves given in the Chu & Barrow paper (3944 of 1939). For the sectoral horn *see* 1446 of 1939.

85. AERIAL REFLECTORS: SOME MEASUREMENTS ON THEIR EFFECTS [particularly in Reception of Ultra-Short-Wave Transmissions].—E. L. Gardiner. (*Wireless World*, Oct. 1940, Vol. 46, No. 12, pp. 419–423.)

86. PRINCIPLE OF THE PAPER-TUBE "TICKLER" (UNCURLING WHEN BLOWN OUT) APPLIED TO COLLAPSIBLE AERIAL FOR CARS, ETC.—(*Sci. News Letter*, 28th Sept. 1940, Vol. 38, No. 13, p. 201.)

87. THE MEASUREMENT OF [Lightning-Conductor] EARTH RESISTANCES WITH HIGH-FREQUENCY TEST CURRENTS.—Fritsch. (*See* 158.)

VALVES AND THERMIONICS

88. VELOCITY-MODULATED TRANSIT-TIME VALVES [Survey].—H. Döring & L. Mayer. (*E.T.Z.*, 25th July & 1st Aug. 1940, Vol. 61, Nos. 30 & 31, pp. 685–690 & 713–715.)

The concept of velocity modulation: conversion of velocity modulation into an electron-density modulation (phase-focusing: mathematical relations). Theoretical design of a velocity-modulated valve, and energy considerations: difference between maximum theoretical efficiency of the "Heil chamber" device, where the voltage at the modulating organ is necessarily identical with that at the "coupling-out" ("catcher") organ and the two fields are opposed in phase, and those devices where the choice of voltage and phase relations is free: the respective figures are 35% and 58% (Geiger's paper—2950 of 1940—is cited here). Practical forms: the Klystron and the Hahn-Metcalf amplifier: advantages and applications of the new devices (including aircraft landing beams, replacement of coaxial-cable links for television by horn-radiation automatic relay stations, and medical uses: Hollmann's article—2222 of 1940—is quoted in this last connection). Present difficulties (such as the necessity, in the blind-landing system mentioned, of having to keep the Klystron continually on the vacuum pump) will no doubt be gradually eliminated.

89. The Ultra-Short-Wave Generator with Phase-Focusing (Kystron).—Lüdi. (*See* 62.)

90. The Operation of Electron Tubes at High Frequencies [1–300 Mc/s: Survey of Previous Literature, and Experimental Checking of Theoretical Results with Diodes, Triodes, Pentodes, & Hexodes: Production of Negative Resistance by the Induced Current: "Current-Distribution" Control: Disappearance of Virtual Cathode at Certain Plate Current, & Its Results: etc.].—H. Rothe. (*Proc. I.R.E.*, July 1940, Vol. 28, No. 7, pp. 324–331.)

The German version was dealt with in 2574 of 1937: for allied papers *see* 2575/7 and (for later work) 4023/4 of same year.

91. Parasitic Electronic Oscillations and Coupling Frequencies in a Power Tube [Type RK-38 Triode with 100 Watts Plate Dissipation & Four-Wire Filament: Curves show Two Distinct Simultaneous Primary Frequencies, Each of which may be replaced (near Resonance) by Two Coupling Frequencies: Interpretation in Terms of Doubly-Resonant Space-Charge Region and of Coupled-Circuit Theory: Wavelengths 50–250 cm, Great Intensities].—R. King. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, pp. 615–620.)

92. On the Dielectric Constant of an Electronic Medium [Anode/Screen-Grid Space] at Medium Radio-Frequency.—S. R. Khastgir & C. Choudhury. (*Indian Journ. of Phys.*, June 1940, Vol. 14, Part 3, pp. 213–229.)

Extension of the ultra-high-frequency investigations dealt with in 2055 of 1937 and 456 of 1940 to much lower frequencies: Prasad & Verma's results at such frequencies (408 of 1938 & back reference) "were vitiated by the fact that in determining the d.c. of the electronic medium the effect of the conductivity of the medium was not considered at all." A multiplying factor $\mu = A/\lambda \,.\, f(t)$ was introduced into the Lorentz formula to obtain the effect of the time of stay of the electrons in the inter-electrode space. Keeping current and transit-time constant and changing the wavelength, "the effective d.c. was found to decrease strictly proportionately with the [increasing] square of the wavelength. In order to fit in with the Lorentz formula (after introducing the factor μ) it was concluded that the transit-time factor μ must be independent of the wavelength. The constant A should therefore vary directly as the wavelength." With fixed thermionic current and wavelength, the change of capacity on filling the inter-electrode space with electrons increased steadily with the increase of the transit-time of the electrons. "This meant that the effective dielectric constant . . . decreased steadily with the increase of the transit-time. It is therefore concluded that the multiplying factor μ depends only on the transit-time."

93. High-Frequency Measurements of the Amplification Factor and Internal Resistance of a Thermionic Valve.—M. K. Rao. (*Indian Journ. of Phys.*, June 1940, Vol. 14, Part 3, pp. 247–252.)

Joshi & Saxena (2776 of 1938: the date given in the present footnote is incorrect) and Mitra & Sil (1932 Abstracts, p. 463) have already dealt with the subject: the present paper gives results with a Telefunken RE 134 and a Philips B 406 (the latter for R_i only, without any voltage on the plate). For the former valve, μ increased steadily up to about 1600 kc/s and then decreased, perhaps because at the higher frequencies the "non-inductive" resistance used in the modified Miller bridge could not be considered non-inductive. The internal resistances (by the detuning method) of both valves diminished at first with increasing frequency and then increased steadily. For the Telefunken valve the minimum was at about 1600 kc/s (mis-printed as 600 kc/s), that is at the frequency where μ has been found to be greatest.

94. The Proper Algebraic Sign for the Transconductance of Valves [Proposal to alter Definition so that Transconductance of Conventional Triode would become Negative: Denunciation].—H. A. Wheeler: B. J. Thompson. (*Proc. I.R.E.*, Aug. 1940, Vol. 28, No. 8, pp. 385–386.) Further opinions are invited.

95. Secondary Emission from Films of Platinum on Aluminium [Direct Proportionality between Primary Energy (up to 800 eV) and Max. Depth from which the Secondary Electrons come: etc.].—P. L. Copeland. (*Phys. Review*, 1st Oct. 1940, Vol. 58, No. 7, pp. 604–607.) Comparison with Hasting's results (2595 of 1940); Wooldridge's picture (147 of 1940) is also discussed.

96. The Relative Secondary Electron Emission due to He, Ne, and A Ions bombarding a Hot Nickel Target.—M. Healea & C. Houtermans. (*Phys. Review*, 1st Oct. 1940, Vol. 58, No. 7, pp. 608–610.)

97. Secondary Emission and Electron Diffraction on the Glass Surface [Difficulty due to Charging-Up of Surface obviated by projecting Second Beam (of Low-Velocity Electrons) and adjusting till Resultant S.E. Factor is Zero].—H. Kamogawa. (*Phys. Review*, 1st Oct. 1940, Vol. 58, No. 7, p. 660.) *See* Salow, 1881 of 1940: the present letter wrongly refers to *Zeitschr. f. Phys.*

98. Design and Performance of an Electron-Diffraction Camera [for Study of Photo- and Secondary-Electron Emissive Surfaces].—J. E. Ruedy. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 292–295.) A summary was referred to in 3429 of 1940.

99. Temperature Dependence of the Work Function of Tungsten from Measurement of Contact Potentials by the Kelvin Method.—J. G. Potter. (*Phys. Review*, 1st Oct. 1940, Vol. 58, No. 7, pp. 623–632.)

"The coefficient obtained resolves the discrepancy between the experimental value of *A* in the Richardson equation and the theoretical factor of 120 without the introduction of a reflection coefficient."

100. THE EFFECT OF ABSORBED GASES ON THE THERMIONIC EMISSION FROM TUNGSTEN AND PLATINUM AT LOW TEMPERATURES.—M. N. Dyachenko & M. I. Allenbach. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 10, 1940, pp. 58–62.)

The Geiger-Müller method of counting separate electrons was adapted for this investigation (*cf.* 2982 of 1937) and the thermionic emission measured under the following conditions: W in hydrogen at 700 to 850° C, Pt in nitrogen at 850 to 1030° C, and Pt in hydrogen at 1000 to 1600° C. The apparatus used is described and a number of experimental curves are shown. It is pointed out that this investigation is the first so far recorded in technical literature to give quantitative data on the subject under discussion.

101. THE DISTRIBUTION OF AUTELECTRONIC EMISSION FROM SINGLE-CRYSTAL METAL POINTS: I.—TUNGSTEN, MOLYBDENUM, NICKEL IN THE CLEAN STATE [including Changes in Pattern with Temperature & Applied Field and the Geometrical Shape of the Point (Explanation of Flash-Arc Phenomena in High-Vacuum Devices: Highest Safety given by Tungsten: Effect of Gas Traces): etc.].—M. Benjamin & R. O. Jenkins. (*Proc. Roy. Soc.*, Ser. A, 9th Oct. 1940, Vol. 176, No. 965, pp. 262–279.) Müller's equation (1428 of 1940) is criticised in a footnote.

102. CRYSTAL-STRUCTURE MODELS FOR CLOSE-PACKED SYSTEMS.—D. B. Langmuir & R. B. Nelson. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 295–297.) Modification of the method used by Martin (619 of 1940).

DIRECTIONAL WIRELESS

103. AN ULTRA-HIGH-FREQUENCY SUPERHETERODYNE RECEIVER FOR DIRECTION FINDING [on 1.67 m Waves from Radio Sonde].—Yuan & Miller. (*See* 73.)

104. DIRECT-READING D.F. [particularly for Aircraft: Suggestions of Neon Lamp revolving with Goniometer Search Coil, and Cathode-Ray Tube with Pointer formed by Solid "Figure-of-Eight" Image, produced by feeding Search-Coil-Amplifier I.F. Output into Second, Synchronised Search Coil].—J. A. McGillivray. (*Wireless World*, Oct. 1940, Vol. 46, No. 12, pp. 428–429.)

For previous work by the writer *see* 562 & 1013 of 1939; for Marique's neon-tube indicator *see* 550 of 1937 and 2370 of 1939. For a survey of aircraft compasses *see* 3044 of 1940.

105. A METHOD FOR DETERMINING THE ACOUSTIC REFLECTION COEFFICIENTS OF THE EARTH'S SURFACE.—Ernsthausen & von Wittern. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 310–311.) Long summary of the German paper dealt with in 1095 (*see* also 3442) of 1940.

ACOUSTICS AND AUDIO-FREQUENCIES

106. SIX-WAY DIRECTIONAL MICROPHONE [Type 639B, and Its Applications].—W. R. Harry. (*Bell Lab. Record*, Sept. 1940, Vol. 19, No. 1, pp. 10–14.)

107. A METHOD FOR PRODUCING EXTREMELY STRONG STANDING SOUND WAVES IN AIR.—Oberst. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 308–309.) Long summary of the German paper dealt with in 1898 of 1940.

108. PUBLIC ADDRESS EQUIPMENT [Recent B.T-H. Designs: including Speech-Amplifying Device without Valve Amplifier (Special Push-Pull Carbon Microphone with Specially Designed Loudspeaker)].—(*B.T-H. Activities*, Oct. 1940, Vol. 16, No. 5, pp. 183–184.)

109. PROPERTIES OF ROCHELLE SALT: III.—H. Mueller. (*Phys. Review*, 15th Sept. 1940, Vol. 58, No. 6, pp. 565–573.) Extension of the "interaction" theory dealt with in 3052 of 1940.

110. A PHYSICAL ANALYSIS OF DISTORTION PRODUCED BY THE NON-LINEARITY OF THE MEDIUM [in High-Output Loudspeakers: Treatment (by following the Career of Plane Progressive Wave) gives Correct Quantitative Results and Straightforward Interpretation of Them].—L. J. Black. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 266–267.)

111. OLD PHONOGRAPH RECORDS REJUVENATED [Re-Recording on Discs, using the Philco Photoelectric Pick-Up].—Philco. (*Science*, 4th Oct. 1940, Vol. 92, Supp. p. 8.) For this pick-up *see* 3449 & 3906 of 1940.

112. A NEW OPTICAL METHOD OF MEASUREMENT FOR GRAMOPHONE RECORDINGS [for Investigation of Characteristics of Cutting Head, etc.].—Buchmann & Meyer. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 303–306.) Long summary of the German paper dealt with in 1930 abstracts, p. 458: *see* also 3245 of 1938.

113. SYMMETRICAL SAND FIGURES ON CIRCULAR PLATES.—Colwell, Stewart, & Arnett. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 260–265.)

"The conclusion of Kirchhoff's theory, that two modes cannot exist simultaneously on a vibrating plate, is inherent in his hypothesis": if his solution is generalised, "the very intricate figures actually found upon circular plates may be calculated. . ."

114. INVESTIGATIONS ON "RECORDERS" [with Description of Method of Analysis].—von Lüpke. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 307–308.) Long summary of the German paper referred to in 1908 of 1940.

115. THE "SOLOVOX" [Electronic Musical Instrument clipped to Under-Side of Piano Keyboard].—Hammond. (*Science*, 4th Oct. 1940, Vol. 92, Supp. p. 12.)

116. TRANSMISSION OF SOUND THROUGH PARALLEL CONDUITS [and Low-Pass Filters formed from Series of Parallel-Tube Sections].—L. W. Labaw. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 232–240.)

"By varying the cross sections and the lengths, practically as many or as few frequencies as desired, from 0 to 10 000 c/s, can be attenuated."

117. NEW VOICE-FREQUENCY ELECTRICAL DELAY NETWORK.—H. M. Thomson. (*Bell Lab. Record*, Sept. 1940, Vol. 19, No. 1, pp. 15–18.)

118. THE RECORDING OF SMALL PITCH-VARIATIONS.—Grützmacher & Lottermoser. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 309–310.) Long summary of the German paper dealt with in 1912 of 1940.

119. A METHOD FOR DETERMINING THE ACOUSTIC REFLECTION COEFFICIENTS OF THE EARTH'S SURFACE.—Ernsthausen & von Wittern. (*See* 105.)

120. ACOUSTIC IMPEDANCE AND SOUND ABSORPTION [Agreement of Theoretical Curves (Acoustic-Impedance/Frequency) with Measured Values of Impedance shows that these Curves will yield Values for Effective Porosity, etc., as well as Reasonably Accurate Values of Absorption Coefficient: etc.].—Morse, Bolt, & Brown. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 217–227.)

121. SOUND ABSORPTION IN RECTANGULAR DUCTS [Newer Concept of Specific Normal Acoustic Impedance of Lining is a More Satisfactory Designation for Absorbing Properties of Lining than the Reverberation-Chamber Absorption Coefficient].—L. L. Beranek. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 228–231.)

122. ACOUSTICS IN STUDIOS [Disadvantages of Rooms with Parallel Walls (Harmonically Related Eigentones, Coincident Regions of Max. & Min. Sound Pressure, Excessive "Deadness"): a Scoring Stage at Hollywood].—M. Rettinger. (*Proc. I.R.E.*, July 1940, Vol. 28, No. 7, pp. 296–299.)

123. "SCHALLABWEHR IN BAU- UND MASCHINENWESEN" [Protection against Noise in Building & Machinery Technique: Book Review].—E. Lübcke. (*Hochf:tech. u. Elek:akus.*, Aug. 1940, Vol. 56, No. 2, p. 64.)

124. "ELEMENTS OF ACOUSTICAL ENGINEERING" [Book Review].—H. F. Olson. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, p. 312.) "Very definitely needed."

125. THREE MECHANISMS OF HEARING BY ELECTRICAL STIMULATION [Electrophonic Perception: Normal Ear, through Electrostatic Action in Cavity of Middle Ear (Square-Law Response): Ear lacking Tympanic Membrane (Linear Response) perhaps through Inverse of "Cochlear Microphonic" (Hair Cells): Buzzing Noise through Direct Stimulation of Auditory Nerve].—Clark Jones, Stevens, & Lurie. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 281–290.) Further development of the work dealt with in 3119 of 1939.

126. THE INTERFERENCE OF TONES IN THE COCHLEA [New Type of Effect (in addition to Beats, Combination Tones, & Masking): "Tonal Interference," revealed by Electrical Responses of Cochlea, occurs between Tones of Any Frequency: etc.].—Wever, Bray, & Lawrence. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 268–280.)

127. RESULTS OF THE WORLD'S FAIR HEARING TESTS [New York & San Francisco: Relation of Hearing Acuity to Place of Residence, Economic Status, etc.].—Steinberg, Montgomery, & Gardner. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 291–301.) *See* also 1055, 1480, & 3468 of 1940.

128. INVESTIGATIONS OF VOCAL-CORD VIBRATION [by Recordings by Condenser-Microphone or Photographic Method].—Trendelenburg & Wullstein. (*Journ. Acous. Soc. Am.*, Oct. 1940, Vol. 12, No. 2, pp. 306–307.) Summary of a 1935 paper.

129. A RELATION BETWEEN VELOCITY OF SOUND IN LIQUIDS AND MOLECULAR VOLUME.—M. R. Rao. (*Indian Journ. of Phys.*, April 1940, Vol. 14, Part 2, pp. 109–116.)

130. A NEW TECHNIQUE FOR DETERMINING ULTRASONIC VELOCITIES IN LIQUIDS [More Precise Method using Diffraction Pattern for Number of Wavelengths simultaneously].—Narasimhaiya & Doraiswami. (*Indian Journ. of Phys.*, June 1940, Vol. 14, Part 3, pp. 187–189 and Plate.)

PHOTOTELEGRAPHY AND TELEVISION

131. QUALITY IN TELEVISION PICTURES [Investigations to determine Best Quality obtainable within American R.M.A. Standards: including Photographic Method of producing Artificial Television Pictures permitting Variation of Contrast, Brilliance, Spot-Shape, etc.].—P. C. Goldmark & J. N. Dyer. (*Proc. I.R.E.*, Aug. 1940, Vol. 28, No. 8, pp. 343–350.)

132. PORTABLE EQUIPMENT FOR OBSERVING TRANSIENT RESPONSE OF TELEVISION APPARATUS [Oscillator, Modulator, & Attenuator (Carbon-Disc Type suitable for Ultra-High Frequencies), Square-Wave Generator, Synchronised Oscilloscope, etc: Some Results on British (1938) Receivers, & Comparison with Owners' Satisfaction: etc.].—H. E. Kallmann. (*Proc. I.R.E.*, Aug. 1940, Vol. 28, No. 8, pp. 351–360.)

133. ROTATING COLOUR FILTER IS HEART OF COLUMBIA BROADCASTING SYSTEM TELEVISION [in Colours, using only One Communication Channel].—Goldmark. (*Sci. News Letter*, 21st Sept. 1940, Vol. 38, No. 12, p. 191.) *Cf.* Lorenzen, 3944 of 1940.

134. MULTIPLE INTERLACED SCANNING [including Colour Television].—Reichel. (*E.T.Z.*, 15th Aug. 1940, Vol. 61, No. 33, p. 765.) Summary of the paper dealt with in 1513 of 1940.

135. The Spherical Aberration of Magnetic Focusing Coils.—H. Marschall. (*Telefunken-Röhre*, No. 16, 1939, pp. 190–197: *E.T.Z.*, 22nd Aug. 1940, Vol. 61, No. 34, p. 785—summary only.)

The writer replaces the air-cored concentrating coil by an ideal circular conductor and calculates the spherical aberration (aperture error) for this. By combining the result with Glaser's spherical-aberration formula he obtains a simple formula, given in the summary, in which all the values are easily measured directly. The calculated results agree within about 8% with experimental measurements.

136. Space-Charge Limitations on the Focus of Electron Beams [Derivation of Equations for Beams of Circular & Rectangular Cross Sections: Curves calculated for Direct-Viewing & Projection Kinescopes: Advantage of High Second-Anode Voltages for Television: etc.].—B. J. Thompson & L. B. Headrick. (*Proc. I.R.E.*, July 1940, Vol. 28, No. 7, pp. 318–324.)

A summary of the original Rochester Fall Meeting paper was referred to in 1153 of 1938. For the work of von Borries & Dosse *see* 2947 of 1938.

137. Transversal Filters [primarily for Television].—Kallmann. (*See* 55.)

138. Some Factors affecting the Choice of Lenses for Television Cameras [Derivation of Equations & Charts for Selection of Lens to meet Requirements of Pick-Up Tube employed].—H. B. De Vore & H. Iams. (*Proc. I.R.E.*, Aug. 1940, Vol. 28, No. 8, pp. 369–374.) "Leading to conclusions reasonably close to the observer's judgment of picture quality."

139. Investigation of Thin Evaporated Silver Films on Glass.—Strong & Dibble. (*Journ. Opt. Soc. Am.*, Sept. 1940, Vol. 30, No. 9, pp. 431–438.) A summary was dealt with in 2337 of 1940.

140. Interpretation of Ferromagnetic Colloid Patterns on Ferromagnetic Crystal Surfaces [Bodily Motion responsible more than Magneto-Optic Effect: Simple Relation between Colloid Concentration & Magnetic Field Intensity near Crystal Surface: Chain Formation to be expected in Suspensions but Not in Colloids whose Particle Size is 100 mμ or Less].—W. C. Elmore. (*Phys. Review*, 1st Oct. 1940, Vol. 58, No. 7, pp. 640–642.) For previous work *see* 3101 of 1940.

141. The Optical Properties of Colloidal Suspensions in Relation to the Measurement of Particle-Size Frequency.—Richardson. (*Journ. Applied Phys.*, Oct. 1940, Vol. 11, No. 10, pp. 653–657.)

142. Design and Performance of an Electron-Diffraction Camera [for Study of Photo- and Secondary-Electron Emissive Surfaces].—J. E. Ruedy. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 292–295.) A summary was referred to in 3429 of 1940.

143. On the Possibilities of using Photocells for Automatic Control.—N. S. Khlebnikov. (*Automatics & Telemechanics* [in Russian], No. 1, 1940, pp. 107–116.)

The properties of existing types of photocells, including the sulphur-thallium barrier-layer cell developed in Russia (*see* back references in 716 of 1940) are discussed from the point of view of their use in automatic controlling devices.

144. Note on the Barrier-Layer Resistance of Selenium Photoelements.—A. E. Sandström. (*Phil. Mag.*, Nov. 1940, Vol. 30, No. 202, pp. 428–429.)

Supplement to the paper dealt with in 2349 of 1940. "Tiring" effect occurs only if the external resistance is high enough: no simple relation between this effect and the change in barrier-layer resistance (Elvegård & others, 1984 of 1938): effects of electric shock (Schweikert, 4047 of 1938): element without apparent barrier layer develops this after shocks: dark resistance of element increased by shock treatment from 6700 to 11 800 ohms, falling to 150 ohms when exposed to very intense flood of light: etc.

145. Cuprous-Cupric Oxide Films on Copper [Electrolytic Reduction Method applied to study Influence of Film-Thickness on Composition].—C. G. Cruzan & H. A. Miley. (*Journ. Applied Phys.*, Oct. 1940, Vol. 11, No. 10, pp. 631–634.)

146. Photovoltage at the Element Metal/Semiconductor/Metal: VII—The Normal Semiconductor Photovoltage at the Element Metal/Cuprous-Oxide/Metal.—W. Rohde. (*Ann. der Physik*, Ser. 5, No. 1, Vol. 38, 1940, pp. 46–58.) Continuing Monch's work (1116 of 1940).

MEASUREMENTS AND STANDARDS

147. The Inversion Phenomena in Crystal Detectors at Ultra-High Frequencies (Preliminary Communication). — L. A. Shinyanski. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 10, 1940, p. 126.)

Cases have been recorded (*see* Hollmann, 1929 Abstracts, p. 647, and Kopilowitch & Tschernez, 107 of 1935) of changes in the direction of the current through a crystal detector when either the frequency or the applied e.m.f. is varied. In this communication a brief report is made on yet another case of inversion of the detector current, observed by the writer while measuring the wavelength (of the order of 60 cm) of an oscillator with a Lecher system. It appears that if the detector (galena-steel) is connected at certain points to the input of the Lecher system (Fig. 1), then (depending on the distance of the condenser bridge from the detector) the inversion effect will take place, as can be seen from Fig. 2. If, however, the position of the detector is altered a normal resonance curve is obtained (Fig. 3). A further investigation of this phenomenon is being carried out.

148. THE TWIN-T: A NEW TYPE OF NULL INSTRUMENT FOR MEASURING IMPEDANCE AT FREQUENCIES UP TO 30 MEGACYCLES [Advantages: Design Features: Examination of Residual Parameters causing Error: Their Reduction & Correction].—D. B. Sinclair. (*Proc. I.R.E.*, July 1940, Vol. 28, No. 7, pp. 310–318.) Commercial instrument based on one of the circuits dealt with by Tuttle (1549 of 1940).

149. HIGH-FREQUENCY MEASUREMENTS OF THE AMPLIFICATION FACTOR AND INTERNAL RESISTANCE OF A THERMIONIC VALVE.—Rao. (*See* 93.)

150. THICKNESS VIBRATIONS OF PIEZOELECTRICALLY EXCITED CRYSTAL PLATES [Strict Solution based on Hamiltonian Energy Principle].—R. Bechmann. (*Hochf:tech. u. Elek:akus.*, July 1940, Vol. 56, No. 1, pp. 14–21.)

The treatment applies to plates of any material and any orientation and is based on the introduction, into the Hamiltonian principle, of the piezoelectric potential in addition to the kinetic, potential, and frictional energies of the plate. "Since this contains the whole electrical field working on the plate, the solution leads also to a representation of the purely electrical behaviour of the piezoelectric resonator. For the derivation of the natural vibrations we consider the plate as infinitely large and assume [in an earlier paper: *see* 503 of 1935] plane processes. The assumption of infinitely large plates eliminates the effects of transverse contraction [interactions with degrees of freedom depending on the transverse dimensions] and the elasticity moduli determining the natural vibrations are obtained as the roots of a secular equation of the third order, which we have already calculated numerically for quartz as a function of the orientation [1556 of 1936]. So long as mechanical considerations are concerned, as in the determination of the natural vibrations, the assumption of infinitely large plates is allowable. On the other hand, in considering the oscillating plate as an electrical system, electrode surfaces of finite dimensions must be introduced in order to arrive at finite current strengths: in the representation of an electrical equivalent circuit the exciting electrodes are a determining factor. Herein lies a serious difficulty for the solution of the electrical problem; for if the surface of the exciting electrode is considered as finite, the assumption of plane waves in the crystal plate, whether the latter is infinite or finite, is no longer fulfilled, and a correction becomes necessary.

"In the following work we assume that the crystal surface is large enough to justify the assumption of plane waves, and that the surfaces of the electrodes are smaller than, or equal to, the crystal surfaces. The areas of plate and electrodes are in any case taken as large compared with the thickness of the plate."

Taking the Hamiltonian energy equation 26, the writer introduces expressions for T (the total kinetic energy of the plate, eqn. 27), for U_m (the total potential energy of the mechanical motion, eqn. 28), for Ue (the potential energy of the total piezoelectric interaction, eqn. 29, taken in conjunction with eqns. 22a and 23a), and for $\delta' A$ (the work of the internal frictional forces, eqn. 25): he thus obtains the double integral eqn. 30. From this, after partial integration and other processes, he arrives at the equation for the natural frequencies of the free undamped vibrating plate (eqn. 44).

"The natural frequencies of the free thickness vibrations of crystalline plates are thus modified in a dual manner by the piezoelectric effect: first by a piezoelectric supplementary force acting on the volume unit and increasing the modulus of elasticity by $8\pi e^2/\epsilon$ [eqns. 32, 32a], and secondly by a surface force which diminishes the frequency to a degree dependent on the arrangement of the electrodes, their size and spacing from the crystal plate. The natural frequencies of the piezoelectric plate are, as a result of the supplementary factor $(1-\gamma_n)$ due to the piezoelectric effect, no longer purely harmonic. The strict expression 44 differs in two ways from that given by Cady for the same problem [3890 of 1936]. According to Cady the modulus of elasticity is submitted to two corrections, one of the value $4\pi e^2/\epsilon$, only the half of that appearing in eqn. 32a, and the second corresponding to the supplementary factor in eqn. 44 arising from the boundary conditions. In this way the elasticity modulus (and also the propagation velocity) is dependent, according to Cady's assumption, on the order of the vibrations: a result which cannot be reconciled with the assumption of plane waves. However, this has little significance in Cady's work, which considers only the fundamental vibration."

Forced oscillations are next considered (eqns. 45–52): "thus the amplitude and phase of the vibration have been determined for every plane, and the mechanical problems of free and forced vibrations solved. We turn now to the electrical problem," and eqn. 53 gives the current flowing between plates 1 & 4 (Fig. 1) of the condenser containing the crystal: this yields eqn. 54 which, in the neighbourhood of resonance, reduces to the simpler eqn. 55: "with this expression the electrical problem of the vibrating piezoelectric resonator is solved." A later paper will deal with the numerical working-out of the relations here obtained, and with experimental results with quartz and tourmalin plates.

151. PROPERTIES OF ROCHELLE SALT: III.—H. Mueller. (*Phys. Review*, 15th Sept. 1940, Vol. 58, No. 6, pp. 565–573.) Extension of the "interaction" theory dealt with in 3052 of 1940.

152. THE DEATH OF PROF. E. GIEBE.—(*E.T.Z.*, 18th July 1940, Vol. 61, No. 29, p. 683.)

153. STANDARD-FREQUENCY [1000 c/s] TRANSMISSION OF THE P.T.R. OVER THE DEUTSCHLANDSENDER, ON WORKDAYS AT 10 h 50 MIN. [Table giving Daily Deviations for April 1940].—Scheibe & Adelsberger. (*Hochf:tech. u. Elek:akus.*, July 1940, Vol. 56, No. 1, p. 21.) *See* also 3523 of 1940. There was an outstanding deviation on 6th April (+ 22 compared with the usual 1–7). A reading is given for 31st April.

154. PRECISION SHORT-INTERVAL TIMING EQUIPMENT [up to 100 Sec. with Accuracy better than 0.1 %].—Fry & Baldeschwieler. (*Journ. of Scient. Instr.*, Oct. 1940, Vol. 17, No. 10, p. 252: summary only.) It had been found that mains-driven clocks were liable to errors as great as 0.3% for such measurements: *cf.* Tritschler, 1151 of 1940.

155. THE MUTUAL INDUCTANCE OF TWO CIRCLES: A PROBLEM IN APPROXIMATION [Determination of Dominant Part of Function when Difference in Radii is Small].—E. H. Neville. (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, p. 340.)

156. INDUCTANCE OF HOLLOW RECTANGULAR CONDUCTORS [One the Return for the Other].—Higgins. (*See* 54.)

157. "M.K.S. UNITS AND DIMENSIONS" [Book Notice].—Jauncey & Langsdorf. (*Journ. of Scient. Instr.*, Oct. 1940, Vol. 17, No. 10, p. 250.) *See* also next page, under "Pondors."

158. THE MEASUREMENT OF EARTH RESISTANCES WITH HIGH-FREQUENCY TEST CURRENTS.—V. Fritsch. (*Hochf:tech. u. Elek:akus.*, Aug. 1940, Vol. 56, No. 2, pp. 54–59.)

See also 41, above. Earths are generally tested by methods employing low- or medium-frequency currents. So long as only power or communication systems are concerned, such methods are satisfactory as a rule, though there are exceptions; but when lightning-conductor earths are to be dealt with the case is very different. Although a lightning stroke is considered a direct-current surge, it is known to behave just like a h.f. alternating current to the conductor; and since current conduction, particularly in geological conductors, is very dependent on the frequency, a test of the earthing by l.f. currents may lead to a completely false picture of its powers. This has often been confirmed disastrously in actual practice, and the writer urges that all such earths should in future be tested by a h.f. method.

He elaborates this point, with the help of various equivalent circuits which he derives for different practical conditions, in sections 1, 2 & 3. The argument frequently used, that l.f. measurements are good enough in most cases, is dismissed as unsound: in loamy soil, for instance, there may not usually be much difference between h.f. and l.f. results, but even the most apparently homogeneous ground may contain slight discontinuities capable of affecting the properties of an earth connection which, as a rule, is of small area. Section 4 deals with the h.f. method recommended. The choice of frequency is first discussed by considering the shape of a normal lightning-current characteristic: the front duration is taken as half a microsecond, and it is assumed that if the over-voltage is led away successfully in that time, the conductor system is working satisfactorily. An equivalent test current, if sinusoidal, would have a period of about 2 microseconds, or a frequency of 500 kc/s. For various reasons it is necessary to reduce this frequency slightly, using about 300 kc/s or in certain circumstances 100 kc/s: "the 300 kc/s should never be exceeded, except in determining the corrosion layer" [Fig. 5 and adjacent text: the meaning of this dictum on frequency is partly explained below].

In practice what is measured is the sum of the earth-plate, bedding-material, and surrounding-ground ("propagation") resistances, "though for various reasons it would be desirable to keep the last separated from the two others." To measure this sum, the exploring electrode or probe must be driven in at a certain minimum distance from the earth plate, determined by the "voltage funnel" of Fig. 11: the procedure described in the adjacent text is that of d.c. methods. For the h.f. method the probe must be arranged differently from usual: thus if connection is made to a metallic conductor (*e.g.* a water-pipe to a well, as in Fig. 11b), the characteristic impedance of this must be calculated roughly and an estimate made of what length can be considered as involved in the carrying-away process: the probe must then be driven in at a distance somewhat exceeding this. Apparatus used in wireless technique is employed; in practice the potentiometer method has proved to be the best, and Fig. 13 shows the arrangement. Modulated h.f. is supplied to the circuit, which includes the earth element E, the auxiliary earth-point H, and the probe S. The resistance R' is adjusted so that the voltage drops in R_1 and R_2 are equal; there is then no p.d. between the points 1 and 2. If R_1 and R_2 are equal, the currents in the upper and lower branches are also equal. Contact 3 on the resistance R is then so adjusted that there is no p.d. between the points 3 and 4. Then the total earth resistance is equal to $R.a/(a + b)$. A "magic eye" indicator with amplifier and detector is used.

Fig. 15 shows how the effect of a corrosion layer can be estimated by raising the test frequency. If R is the ohmic and X_c the capacitive component of the corrosion resistance, the diagram is obtained: "if the frequency is increased, X_c will diminish. This will make the resultant resistance approach nearer and nearer to the only practically important sum of R_p (resistance of earth plate), R_B (of bedding material), and of R_g (resistance in the surrounding ground). By high frequency it is thus possible to decide whether a change in the total resistance is due to deterioration in the geological conductors or to plain corrosion" [*see* also pp. 55–56]. Finally, measurements by the Siemens-bridge method and by the h.f. method, on an installation (Fig. 16) which had led to disaster, show that the former method gave 27 & 31 ohms for the resistances measured at the two points A & B respectively, whereas at 300 kc/s the figures were 20 & 80. When the apparatus used for the h.f. method was worked at only 1000 c/s, the results differed only slightly from those given by the Siemens bridge.

159. A SCREENED WHEATSTONE BRIDGE FOR MEASUREMENTS ON H.F. IRON-CORED COILS AT FREQUENCIES UP TO 10 Mc/s.—Zimmermann. (*See* 211.)

160. MERCURY-CONTACT RHEOSTATS FOR CONTINUOUS FINE ADJUSTMENT.—C. R. Barber. (*Journ. of Scient. Instr.*, Oct. 1940, Vol. 17, No. 10, pp. 245–247.)

161. SCREENED MERCURY-ELECTRODE CLAMPS FOR DIELECTRIC MEASUREMENTS [at Frequencies from Zero up to 1 Mc/s].—E. Rushton & E. J. Pratt. (*Journ. of Scient. Instr.*, Oct. 1940, Vol. 17, No. 10 pp. 247–248.)

162. Electrostatic High-Voltage Meters [Survey of Types for Absolute and Relative Measurements, including Designs for High Frequencies].—H. Böcker. (*E.T.Z.*, 8th Aug. 1940, Vol. 61, No. 32, pp. 729–733.) The h.f. instruments are of the Starke & Schroeder type (Abstracts, 1928, p. 585, and 1929, pp. 220–221).

163. Coordinated Power Supply and Control Equipment for Instrument and Meter Testing.—Weller & Giroux. (*Gen. Elec. Review*, Oct. 1940, Vol. 43, No. 10, pp. 420–424.)

164. On the Construction of Very Sensitive Vacuum Thermoelectric Cells [primarily for Astrophysical Research].—Rogers. (*See* 286.)

SUBSIDIARY APPARATUS AND MATERIALS

165. A Portable Cathode-Ray Oscillograph [using the 2½" "Monitor" Tube, Type 4081: Design for Compactness, Simplicity of Operation, & Versatility: Provision for Green Celluloid Screen for Use in Well-Lit Room].—Macfadyen. (*Journ. of Scient. Instr.*, Oct. 1940, Vol. 17, No. 10, pp. 249–250.) The author's abstract is confused by the introduction of a superfluous "and."

166. A Multi-Channel Delay Unit [for Use with Cathode-Ray Oscillograph: primarily for Research on Action Potentials], *and* A Multiple-Sweep System for Cathode-Ray Oscillography [giving Several Successive Lines on Screen: Trigger Unit shifts Trace and brightens It during Transit].—Marshall & Talbot: Talbot. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 287–289: pp. 289–291.)

167. The Super-Microscope with Electrostatic Lenses [A.E.G. Model, with Semi-Automatic Locks for Changing of Object and Plate, Provision for Dark-Field & Stereoscopic Working, and Other Facilities].—Henneberg. (*E.T.Z.*, 22nd Aug. 1940, Vol. 61, No. 34, pp. 773–776.)

168. The Spherical Aberration of Magnetic Focusing Coils.—Marschall. (*See* 135.)

169. Space-Charge Limitations on the Focus of Electron Beams.—Thompson & Headrick. (*See* 136.)

170. The Prism and the Theory of Optical Resolution [especially the Use of the Interferential Method, More Precise than Method of Geometrical Optics, Less Intricate than Method of Diffraction].—Ramsay, Koppius, & Cleveland. (*Journ. Opt. Soc. Am.*, Sept. 1940, Vol. 30, No. 9, pp. 439–444.)

171. Lubrication in Vacuum by Vaporised Thin Metallic Films [primarily for Rotating Anodes in X-Ray Tubes].—Atlee, Wilson, & Filmer. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, pp. 611–615.) *See* also *Gen. Elec. Review*, Nov. 1940, p. 471.

172. The Effect of an Activator on the Absorption Spectrum of Zinc-Sulphide Powders [Long-Wave Limit of Absorption Band at 3800 AU, moving to Longer Wavelengths with Increasing Concentration of Ag Activator: etc.].—Brasefield. (*Phys. Review*, 1st Sept. 1940, Vol. 58, No. 5, pp. 436–438.)

173. A Theory on Cathode Luminescence [Examination of Large Difference in Order of Magnitude of Efficiencies of Alpha Rays & Cathode Rays whose Velocities are nearly the Same, leading to Theory that Efficiency of Production of Luminescence is proportional to Average Depth of Production of "Excitons" (*i.e.* of Energy Loss by Electrons)].—Fano. (*Phys. Review*, 15th Sept. 1940, Vol. 58, No. 6, pp. 544–553.)

174. Apparent Splitting of Light from Fluorescent Lamps by Reflection from Thin Films [and Application to Estimation of Thickness and Optical Regularity of Reflecting Surfaces of Thin Plates].—Scull. (*Science*, 13th Sept. 1940, Vol. 92, pp. 236–237.) For previous work *see* 3157 of 1940.

175. Baffles for Oil Diffusion Pumps [Relative Advantages of Charcoal Traps, Cold Traps, Hot Baffles, Electrical & Mechanical Baffles: Designs for High-Speed Baffles].—Morse. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 277–281.)

176. A Comparative Study of Water Aspirators.—Little & Pond. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 285–286.)

177. New Lamp using Tellurium Vapour [giving Light very close to Daylight].—Westinghouse. (*Science*, 4th Oct. 1940, Vol. 92, Supp. pp. 9–10.)

178. The Characteristics and Function of Anode Spots in Glow Discharges [Important Rôle in Gaseous-Discharge Devices employing Thermionic or Cathode-Spot Emitters, where Discharge Currents may become Large].—Rubens & Henderson. (*Phys. Review*, 1st Sept. 1940, Vol. 58, No. 5, pp. 446–457.)

179. Developments and Improvements in the Construction of Iron-Cased Rectifiers.—Dällenbach & Gerecke. (*E.T.Z.*, 1st & 8th Aug. 1940, Vol. 61, Nos. 31 & 32, pp. 705–709 & 734–738.)

180. Method of Calculating the Current Harmonics in Rectifier or Converter Circuits.—Werners. (*See* 60.)

181. Thermostatic Control [Simple Completely A.C.-Operated Circuit using Dual Triode as Half-Wave Grid-Controlled Rectifier].—Butt. (*Science*, 11th Oct. 1940, Vol. 92, pp. 339–340.)

182. Cuprous-Cupric Oxide Films on Copper.—Cruzan & Miley. (*See* 145.)

183. Electrical and Optical Behaviour of Semiconductors: XV—Electrical Measurements on Lead Selenide [including Large Unexplained Temperature-Dependence of Resistance of Certain Samples (exceeding That of Iron)]: XVI—Electrical Measurements on Lead Sulphide.—Bauer: Eisenmann. (*Ann. der Physik*, Ser. 5, Nos. 1 & 2, Vol. 38, 1940, pp. 84–96 & 121–138.)

184. The Molecular Basis of Resin Behaviour [Critical Survey].—Kraemer. (*Journ. Franklin Inst.*, Sept. 1940, Vol. 230, No. 3, pp. 405–410.) Continued in the October issue.

185. The Dielectric Properties of Some Thermoplastics [mainly determined by Rotation of OH Groups], *and* Molecular Relaxation and the Elastic and Dielectric Properties of Plastics [Comparison with Kühn's Theory regarding Elastic Behaviour].—Hartshorn, Megson, & Rushton. (*Proc. Phys. Soc.*, 1st Nov. 1940, Vol. 52, Part 6, pp. 796–816: pp. 817–821.)

186. The Measurement of Solid Friction of Plastics [including Measurements on Polystyrene & Paraffin Wax].—Gemant. (*Journ. Applied Phys.*, Oct. 1940, Vol. 11, No. 10, pp. 647–653.)

187. Absorption of Water by Plastics.—A.S.T.M: Kline, Martin, & Crouse. (*Tech. News Bull. of Nat. Bur. of Stds.*, Sept. 1940, No. 281, pp. 74–75: summaries only.)

188. "Industrial Plastics" [Book Review].—Simonds. (*Engineering*, 1st Nov. 1940, Vol. 150, pp. 342–343.)

189. The Nature of Organic Insulating Materials [and Recent Progress in Synthesis of High-Molecular Substances].—Fuller. (*Bell Lab. Record*, Sept. 1940, Vol. 19, No. 1, pp. 7–9.)

190. Blending of Natural Rubber [with Synthetic] improves Its Qualities [including Insulating Properties].—Longman. (*Sci. News Letter*, 28th Sept. 1940, Vol. 38, No. 13, p. 206.)

191. Increasing the Uses of Lac [including Promising Development of Shellac Injection Moulding as distinct from Compression Moulding].—(*Sci. & Culture*, Calcutta, Sept. 1940, Vol. 6, No. 3, p. 168.)

192. A Note on the Refractive Index of Shellac [measured by Simple Refractometer Method: Some Results: Importance as a Test of Properties of Resins in General].—Bhattacharya. (*Indian Journ. of Phys.*, June 1940, Vol. 14, Part 3, pp. 237–246.)

193. The Dielectric Properties of the Rutile Form of TiO_2.—Berberich & Bell. (*Journ. Applied Phys.*, Oct. 1940, Vol. 11, No. 10, pp. 681–692.) A summary was dealt with in 2726 of 1940.

194. Compressed Magnesia as Electrical Insulator [in the Search for a Plastic Homogeneous Inorganic Dielectric].—Gemant & Glassow. (*Journ. Franklin Inst.*, Oct. 1940, Vol. 230, No. 4, pp. 471–481.)

Prompted by the advantages of inorganic insulators (as illustrated by fibrous glass—4149 of 1939) and by Bethenod's paper (2546 of 1938) on Pyrotenax cable with magnesia behaving like a plastic material.

195. The Conductivity of Insulating Oils under Alternating [60 c/s] Stress [Dielectric Losses are due entirely to Electric Conduction: etc.].—Whitehead & Kang. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, pp. 596–603.)

196. "Properties of Ordinary Water-Substance" [Book Review].—Dorsey. (*Current Science*, Bangalore, Aug. 1940, Vol. 9, No. 8, pp. 385–386.)

197. Breakdown Potentials of Gases under Alternating Voltages [up to 1 Mc/s].—Fox & McCoy. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, pp. 592–595.)

198. The Variation of Sparking Potential with Initial Photoelectric Current.—Meek. (*See* 39.)

199. Electrostatic Generator with Concentric Electrodes [Voltages up to 4.5 Megavolts].—Herb & others. (*Phys. Review*, 15th Sept. 1940, Vol. 58, No. 6, pp. 579–580.)

200. A Low-Frequency Alternator [Frequency continuously Variable from Zero up to (*e.g.*) 10 c/s, Amplitude independent of Frequency: D.C. (Motor-Car) Generator with Brushes rotating].—Roberds. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, p. 299.)

201. Cathode Sputtering in a Magnetic Field.—Penning & Moubis. (*Proc. Koninklijke Nederlandsche Akademie van Wetenschappen*, Jan. 1940, Vol. 43, No. 1, pp. 41–56: in English.) Issued also as Reprint 1486 of the Philips' Company.

202. Papers on Cathode Sputtering, especially since 1932.—(*Sci. Library Bibliographical Series* No. 537, 1940, 3 pp.)

203. Platinised Glass as a Laboratory Substitute for Massive Platinum.—Coffin. (*Canadian Journ. of Res.*, Oct. 1940, Vol. 18, No. 10, Sec. B, pp. 318–321.)

204. Investigation of Thin Evaporated Silver Films on Glass.—Strong & Dibble. (*Journ. Opt. Soc. Am.*, Sept. 1940, Vol. 30, No. 9, pp. 431–438.) A summary was dealt with in 2337 of 1940.

205. Catalytic Activity, Crystal Structure, and Adsorptive Properties of Evaporated Metal Films [Oriented & Unoriented Films obtained by Control of Gas Pressure: Former have Fivefold Activity of Latter: etc.].—Beeck, Smith, & Wheeler. (*Proc. Roy. Soc.*, Ser. A, 9th Oct. 1940, Vol. 176, No. 965, pp. S 57–58.)

206. SLIDING ELECTRICAL CONTACTS [Short Survey].—Windred. (*BEAMA Journal*, Sept. 1940, Vol. 47, No. 39, pp. 42–44.)

207. INVESTIGATIONS ON PURE CHROMIUM IN THE ANOMALOUS REGION [Bridgman's Anomaly of a Marked Resistance-Minimum at about Room Temperatures].—Söchtig. (*Ann. der Physik*, Ser. 5, No. 2, Vol. 38, 1940, pp. 97–120.)

208. THE HIGH-FREQUENCY RESISTANCE OF SUPER-CONDUCTING TIN [measured by Calorimetric Method at 20.5 cm Wavelength: Gradual Decrease, as Temperature falls below Transition Point, in Contrast to Sudden Drop with D.C.: Explanation: Normal-State Conductivity at Liquid-Helium Temperature considerably Lower for H.F. than for L.F.].—London. (*Proc. Roy. Soc.*, Ser. A, 9th Oct. 1940, Vol. 176, No. 965, p. S 64.)

209. MODIFIED CENCO IMPULSE COUNTER [made Direct-Reading and Sources of Error eliminated].—Petrauskas & Northrup. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, p. 298.)

210. A DIALLING CIRCUIT OF INCREASED RANGE.—Low. (*Bell Lab. Record*, Sept. 1940, Vol. 19, No. 1, pp. 32–36.)

211. MEASUREMENTS ON HIGH-FREQUENCY IRON-CORED COILS WITH A SCREENED WHEATSTONE BRIDGE AT FREQUENCIES UP TO 10 Mc/s [also on Air-Cored Coils and on Solid & Litz Wires]. — Zimmermann. (*Hochf:tech. u. Elek:akus.*, Aug. 1940, Vol. 56, No. 2, pp. 33–41.)

In section I the special precautions taken to make the screened bridge accurate over the high-frequency range of 2.5–10 Mc/s are described: thus Siemens & Halske short-wave carbon resistances are used for the fixed arms R_1 and R_2, since these components remain constant up to very high frequencies: the adjustable resistance R_N is a spring-stretched bifilar nickel-chromium wire with a continuously displaceable short-circuiting contact (with vernier): resistance variations due to skin effect are negligible. The very complete screening (double at certain points) and its connections are described. For the sake of obtaining the highest possible sensitivity, the null indicator, a compensated audion, is matched to the bridge by a transformer whose secondary inductance can be tuned by a condenser. The over-all accuracy is estimated at 1% ± 0.03 ohm.

The coils investigated were Siemens & Halske commercial types (and some special forms cut by the writer) with "Sirufer 5" as core material. "Sirufer 4" and "Sirufer 6" were also tested for comparison: all these types differ in effective permeability, owing to their different "filling factors." The preliminary measurements confirmed the square-law variation of inductance with number of turns, for various shapes of coil, with and without iron cores (Fig. 6); they also showed that the inductance (and therefore the permeability) remained practically constant over the range of frequencies. This result was to be expected; a significant change in the effective permeability would only occur if the frequency were so high that the eddy currents could no longer flow over the whole section of the individual particles (diameter 3–5μ) and could only penetrate into a skin on the surface, when the magnetic flux also would suffer a skin effect: this would occur at about 1000 Mc/s. The slight rise in the curves of Fig. 6 at a small number of turns is explained by a small change in the magnetic path length which only becomes noticeable when the turns are few. Fig. 8 shows the influence of the number of turns on the coil quality $\omega L/R$: the pot coils tested, both with and without iron cores, show different optimum values for the number of turns at the different frequencies, but these optima move, with increasing frequency, only slightly towards the lower winding numbers. This behaviour is investigated further (Fig. 9 and text): the displacement of the quality maxima is traced to the fact that with increasing frequency the straight portion of the curves $R = f(n^2)$ becomes shorter and moves towards lower turn-numbers, because the "coil-field" resistance (that component of the total resistance which is due to eddy-current loss from the winding of the wire into a coil) increases with the square of the frequency. For the later investigations on iron-cored coils, 18 and 28 turns were employed, these being approximately the optimum values for the 30 and 80 m waves respectively. Finally, Fig. 10 shows the comparison, as regards resistance, between solid wire and Litz of the same d.c. resistance; the abscissae represent the squares of the frequency. At first the dissipative resistance of the solid wire exceeds that of the Litz, but then, instead of increasing with f^2 like the Litz, it increases only as the square root of f (Fig. 11) "so that at the highest frequencies the resistance of the solid wire is less than that of the Litz" [it does not, however, appear from the curves of Fig. 10 that this statement applies literally to the finer Litz wire of 25 strands of 0.04 mm diameter]. These tests also show that the turns should be wound "loosely," so that the resistance component due to copper losses may not increase too much.

The exploratory tests being now completed, section III describes the measurements on the various types of coil. The results are summed up in section IV as follows:—"All the tests show that that shape of iron core is the most favourable for which the least possible number of lines of leakage flow through the copper of the winding. This can be attained in two ways. First, the effective permeability of the iron can be increased. . . . This can only be done by raising the 'filling factor' of the core; that is, by increasing the proportion of the iron particles to the insulating material; but since the added resistance due to the core is chiefly dependent on the eddy currents in the iron particles, such an increase of the factor will make the loss resistance of the coil larger." That this is the case is seen in Fig. 16, where the "Q" values of coils with cores of Sirufer 4, 5, & 6 are compared with a similar air-cored coil. The core with the highest permeability, Sirufer 6, gave the lowest "Q," although it gave the highest inductance. "The best core material for the short-wave range is Sirufer 5."

"The second possibility of raising the quality of the iron-cored coil is to choose the best shape of core, taking into consideration the permeability of the material. As the measurements show, the best shape is that for which all leakage lines through the copper are avoided, and this is most nearly fulfilled, for the material employed, by the 'pulley' design [Fig. 3 b].

"At what frequencies the use of iron cores presents no advantage as regards coil quality, compared with an air core, depends according to these investigations on (1) the construction of the coil, (2) the core material, and (3) the shaping of the core. The application of the winding to the most low-loss former possible must, for short waves, be carried out in the form of a single-layer 'loose' winding; too close a winding increases the loss resistance. As has been pointed out earlier [Fig. 13], at 10 Mc/s the 'Q'-value of a pulley-type coil with thick solid wire equals that of a coil with the finest Litz wire used. The value is there about 200, but falls as the frequency is increased; this is because the number of turns chosen was the optimum for about 5 Mc/s (Fig. 6). With fewer turns about the same figure of merit can be obtained at the higher frequencies.

"The great advantage, however, of the iron-cored coil lies in the simplicity with which its inductance can be adjusted by altering the magnetic resistance; thus with a pulley-type coil an inductance variation of some 10% can be obtained by drawing out the iron. When an iron core is used for trimming purposes only, account must be taken of the field distribution of the core thus introduced." The advantage in smaller size is mentioned only at the beginning of the paper.

212. Circuit Arrangements for Quick-Action Magnets [using Condensers to shorten the Delay].—Blankenburg. (*E.T.Z.*, 25th July 1940, Vol. 61, No. 30, pp. 693–696.)

213. An Analysis of the Laws governing the Distribution of the Magnetic Flux in the Magnetic Circuits of Neutral Electromagnetic Devices, taking into Account the Non-Linearity of the Magnetisation Curves.—Livshits. (*Automatics & Telemechanics* [in Russian], No. 1, 1940, pp. 27–38.)

The method proposed in a previous paper (4431 of 1940, where the year should read "1939") for determining $\phi = f(x)$ was based on the assumption that the impedance of a magnetic circuit is independent of its inductance. In this paper a more accurate method is discussed, in which the non-linearity of the magnetisation curves and the effect of inductance on the impedance of the circuit are taken into account.

214. Armature Reaction in an A.C. Generator excited by a Ring-Shaped Permanent Magnet [produces No Series Weakening of the Modern-Alloy Magnet].—Pohlmann. (*Arch. f. Elektrotech.*, July 1940, Vol. 34, No. 7, pp. 363–381: *E.T.Z.*, 8th Aug. 1940, Vol. 61, No. 32, p. 744—summary only.)

215. An Important New Magnetic Alloy ["Vicalloy"].—Nesbitt & Kelsall. (*Bell Lab. Record*, Sept. 1940, Vol. 19, No. 1, p. 36.) *See* also 4057 of 1940.

216. Template for measuring Curved Arcs [Path-Lengths in Magnetic Design, etc.].—Hague. (*Engineering*, 4th Oct. 1940, Vol. 150, pp. 263–264.)

217. Elementary Processes of Magnetisation in the Region of Initial Susceptibility [with Experimental Confirmation of Becker's Theory: the Great Importance of Internal Strain Conditions: etc.].—Thiessen. (*Ann. der Physik*, Ser. 5, No. 2, Vol. 38, 1940, pp. 153–176.)

218. Crystal-Structure Models for Close-Packed Systems.—Langmuir & Nelson. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 295–297.) Modification of the method used by Martin (619 of 1940).

STATIONS, DESIGN AND OPERATION

219. Better Coverage [Tests of Comparative Effectiveness of Frequency-Modulated and Amplitude-Modulated Transmitters of Equal Power: Service Area may be 33 Times greater: etc.].—Weir. (*Gen. Elec. Review*, Oct. 1940, Vol. 43, No. 10, p. 425.) *See* also p. 426, for frequency modulation in a utility industry and in a police system.

220. A Frequency-Modulation Monitoring System [to prevent Adjacent-Channel Interference & Distortion in Receiver: Analytical Discussion & Computed Charts of Spectra produced by F.M. Waves: Monitor plotting Amplitude & Frequency Distribution of Spectrum, on Oscilloscope Screen: Comparison of Results with Calculated Charts].—Pieracci. (*Proc. I.R.E.*, Aug. 1940, Vol. 28, No. 8, pp. 374–378.)

GENERAL PHYSICAL ARTICLES

221. Physical and Astronomical Information concerning Particles of the Order of Magnitude of the Wavelength of Light.—Ehrenhaft. (*See* 11, above, and 222, below.)

222. Production of Single Magnetic Poles by Light: a Hypothesis of Magnetic Ions and Magnetic Currents.—Ehrenhaft. (Unpublished paper referred to in the work dealt with above.)

223. Luminescence excited by Exposure to Neutrons.—Wick & Vincent. (*Phys. Review*, 15th Sept. 1940, Vol. 58, No. 6, p. 578.)

224. Note on Interaction Energies in Radiation Theory [Energies calculated for Photon & Electron, Mesotron & Photon, Two Electrons, and Two Mesotrons].—Hurwitz. (*Phys. Review*, 1st Sept. 1940, Vol. 58, No. 5, pp. 467–471.)

225. The Lateral Diffusion of a Stream of Ions [or Electrons] in a Gas [under Action of Uniform Electric Field: Alternative & More Convenient Analysis: Effects of Added Magnetic Field].—Huxley. (*Phil. Mag.*, Nov. 1940, Vol. 30, No. 202, pp. 396–413.)

The advantages of this treatment were discussed by Green (1931 Abstracts, p. 632) in an investigation of heat conduction in terms of wave-trains.

226. RANDOM PATHS IN TWO AND THREE DIMENSIONS.—McCrea & Whipple. (*Proc. Roy. Soc. Edinburgh*, Session 1939/40, Vol. 60, Part 3, pp. 281–298.)

227. "ELECTRODYNAMICS" [Book Review].—Leigh Page & Adams. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, pp. 572–573.) The last chapter deals with special problems, including the magnetron and cosmic-ray trajectories.

228. ON THE ELECTROMAGNETIC TWO-BODY PROBLEM [on Assumption of Small Mass Ratio].—Synge. (*Proc. Roy. Soc.*, Ser. A, 9th Oct. 1940, Vol. 176, No. 965, p. S 65.)

"If the orbit of the light particle is initially approximately circular it remains so, but its radius decreases steadily to an ultimate collision. This agrees with the classical conclusion that an accelerated charge radiates energy, but the rate is much smaller than that given by the Larmor formula."

229. A COMPLETE ISOMETRIC CONSISTENCY CHART FOR THE NATURAL CONSTANTS *e*, *m*, AND *h*.—DuMond. (*Phys. Review*, 1st Sept. 1940, Vol. 58, No. 5, pp. 457–466.)

230. ON THE RADIO-FREQUENCY SPECTRA OF SODIUM, RUBIDIUM, AND CAESIUM.—Millman & Kusch. (*Phys. Review*, 1st Sept. 1940, Vol. 58, No. 5, pp. 438–445.) For previous work *see* 3219 of 1940.

231. QUATERNION ANALOGY OF WAVE-TENSOR CALCULUS [Quaternion Algebra used in place of Eddington's E-Number Algebra].—McCrea. (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, pp. 261–281.)

232. RECIPROCITY: PARTS 2–4: SCALAR WAVE FUNCTIONS, RECIPROCAL WAVE FUNCTIONS, SPINOR WAVE FUNCTIONS.—Born, Fuchs. (*Proc. Roy. Soc. Edinburgh*, Session 1939/40, Vol. 60, Part 1, pp. 100–116: Part 2, pp. 141–146 & 147–163.)

233. GENERALISED BOLTZMANN'S FORMULA AND PLANCK'S LAW.—Mathur & Singh. (*Sci. & Culture*, Calcutta, Sept. 1940, Vol. 6, No. 3, pp. 189–190.)

234. "REPORTS ON PROGRESS IN PHYSICS: VOL. VI" [Book Review].—Awbery (Edited by). (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, p. 348.)

235. "AN INTRODUCTION TO THE KINETIC THEORY OF GASES" [Book Review].—Jeans. (*Nature*, 26th Oct. 1940, Vol. 146, pp. 535–536.)

236. "ELECTROCAPILLARITY: THE CHEMISTRY AND PHYSICS OF ELECTRODES AND OTHER CHARGED SURFACES" [Book Review].—Butler. (*Nature*, 26th Oct. 1940, Vol. 146, p. 536.)

237. THE THERMAL AND ELECTRICAL CONDUCTIVITIES OF METALS AND ALLOYS [and the Anomalies in Their Relationships].—Chubb. (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, pp. 323–330.)

MISCELLANEOUS

238. THE MATRIX THEORY OF FOUR-TERMINAL NETWORKS.—Pipes. (*See* 57.)

239. A MATRIX GENERALISATION OF HEAVISIDE'S EXPANSION THEOREM.—Pipes. (*See* 58.)

240. NOTES ON MATHIEU FUNCTIONS: I—A CLASS OF HYPERBOLIC MATHIEU FUNCTIONS.—Bickley. (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, pp. 312–322.)

241. THE PERIODIC LAMÉ FUNCTIONS, *and* FURTHER INVESTIGATIONS INTO THE PERIODIC LAMÉ FUNCTIONS.—Ince. (*Proc. Roy. Soc. Edinburgh*, Session 1939/40, Vol. 60, Part 1, pp. 47–63 and 83–99.)

242. PROPERTIES OF THE WITCH OF AGNESI: APPLICATION TO FITTING THE SHAPES OF SPECTRAL LINES.—Spencer. (*See* 59.)

243. SOME CONFLUENT HYPERGEOMETRIC FUNCTIONS OF TWO VARIABLES.—Erdélyi. (*Proc. Roy. Soc. Edinburgh*, Session 1939/40, Vol. 60, Part 3, pp. 344–352.)

244. INTERPOLATED DERIVATIVES.—Spain. (*Proc. Roy. Soc. Edinburgh*, Session 1939–40, Vol. 60, Part 2, pp. 134–140.)

245. "DEVELOPMENT OF THE MINKOWSKI GEOMETRY OF NUMBERS" [Book Review].—Hancock. (*Phil. Mag.*, Oct. 1940, Vol. 30, No. 201, p. 347.)

246. "THE PRINCIPLE OF STATISTICAL MECHANICS" [Book Review].—Tolman. (*Science*, 27th Sept. 1940, Vol. 92, pp. 287–288.)

247. "BRITISH ASSOCIATION MATHEMATICAL TABLES: VOL. VIII—NUMBER-DIVISOR TABLES" [Book Review].—(*Phil. Mag.*, Nov. 1940, Vol. 30, No. 202, pp. 435–436.)

248. ELECTRICAL MEASURING METHOD FOR THE DETERMINATION OF INTEGRAL AND AVERAGE VALUES [Ordinates (representing Pressures, Velocities, etc.) converted into Conductivities which control the Speed of Discharge of Condenser in Relaxation-Oscillation Circuit].—Schemmrich. (*Arch. f. Elektrotech.*, July 1940, Vol. 34, No. 7, pp. 415–422: *E.T.Z.*, 8th Aug. 1940, Vol. 61, No. 32, p. 744—summary only.)

249. NATIONAL DEFENCE AND THE PHYSICIST [and the Need for Speeding-Up Research as well as Material Output: Editorial].—(*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, p. 567.)

250. BOARD OF SCIENTIFIC AND INDUSTRIAL RESEARCH AT WORK.—(*Sci. & Culture*, Calcutta, Aug. 1940, Vol. 6, No. 3, pp. 103–105.)

251. THE SYDNEY-MELBOURNE TYPE J CARRIER TELEPHONE SYSTEM.—O'Leary & others. (*Elec. Communication*, July 1940, Vol. 19, No. 1, pp. 3–17.) For a transportable testing equipment for 12-channel systems see *ibid.*, pp. 66–67.

252. Preparation of High-Melting Alloys with the Aid of Electron Bombardment.—Hultgren & Pakkala. (*Journ. Applied Phys.*, Oct. 1940, Vol. 11, No. 10, pp. 643–646.)

253. The Detection of Defects in Magnetic Materials by Magnetic Methods [Survey], *and* The Sperry Rail-Defect Detecting Car.—Armour: Sperry. (*Sci. Abstracts*, Sec. B, 25th Aug. 1940, Vol. 43, No. 512, pp. 340–341: *Engineering*, 20th Sept. 1940, Vol. 150, pp. 223–225.) For earlier work on the Sperry system *see* 1929 Abstracts, p. 406.

254. Alternating Current Source for Resistance Welding [and the Use of a Series Condenser to Stabilise the Voltage against Load Fluctuations].—Matano. (*Electrotech. Journ.*, Tokyo, July 1940, Vol. 4, No. 7, pp. 150–152.)

255. Non-Existent Difficulties in Welding [" Arc Welding has Too Many Doctors "].—Lincoln. (*Elec. Engineering*, Aug. 1940, Vol. 59, No. 8, p. 330.)

256. Continuous Testing of Copper-Coated Iron Wire for Thickness of Coat [Electro-Magnetic Probe with Split Tip: Valve-Amplified Indication].—(*E.T.Z.*, 1st Aug. 1940, Vol. 61, No. 31, p. 715.) Summary of an *Electrical World* article.

257. Magnetic Ultra-Micrometer [particularly for Measurement of Metallic, Paint, or Other Deposit on Magnetic Material].—Ellwood. (*Bell Lab. Record*, Sept. 1940, Vol. 19, No. 1, pp. 37–38.)

258. Precision Short-Interval Timing Equipment.—Fry & Baldeschwieler. (*See* 154.)

259. The Automatic Obtainment of Stationary Images of Internal Sections of Moving Objects.—Ivanov. (*Automatics & Telemechanics* [in Russian], No. 1, 1940, pp. 67–74.)

General discussion of the principles underlying "tomography," *i.e.* the technique of obtaining stationary sections of moving details of machines by synchronising the movements of the X-ray tube, the moving object, and the screen or film.

260. The " Ripplay " [Metrovick Ripple-Relay System for Remote Control, A.R.P. Signalling, etc.].—Smith. (*Met. Vickers Gazette*, Oct. 1940, Vol. 19, No. 330, pp. 76–80.)

261. Rythmatic Control [and the Development of the System for Remote Switching by Currents superposed on Power Mains].—Mackenzie. (*Strowger Journ.*, Aug. 1940, Vol. 5, No. 2, pp. 42–61.)

262. On the Damping of Oscillations determined by a Linear Differential Equation of the Third Order with Constant Coefficients.—Ayzermann. (*Automatics & Telemechanics* [in Russian], No. 1, 1940, pp. 55–65.)

Periodic oscillations may appear in the moving part of an automatic mechanical regulator during the process of regulation. Taking into account the mass of the moving part, these oscillations can usually be represented by eqn. 1. It is pointed out that no general method has been proposed for determining the damping coefficient of these oscillations without integrating this equation, and it is shown that approximate formulae (7) and (9) derived by previous investigators are very inaccurate and can only be used in a limited number of cases. Accordingly a conception is introduced of the " periodicity coefficients " of a system, X and Y (top of page 59), and an equation (13) is derived from which a family of curves representing the percentage damping j can be plotted (Fig. 2). Knowing X and Y, whose values depend on the coefficients of eqn. 1, the percentage damping of the system can be determined immediately from Fig. 2.

263. The Propagation of Electromagnetic Waves along Open Wire Lines, *and* Certain Consequences arising from an Analysis of the Propagation of Electromagnetic Energy along Three-Phase Symmetrical Lines [in Connection with Telemechanics].—Kovalenkov: Dyakov. (*See* 33 & 34, above.)

264. Control Mechanism: Device stops a Machine Error before It Happens [High-Speed Regulator and Gyroscopic Stability Control sensitive to Acceleration rather than to Velocity].—Westinghouse. (*Scient. American*, Oct. 1940, Vol. 163, No. 4, pp. 199–200.)

265. Paper on Photocells and Their Suitability for Automatic Control Systems.—Khlebnikov. (*See* 143.)

266. Photoelectric Regulation of Revolving Furnaces in Manufacture of Cement.—Rogers. (*E.T.Z.*, 11th July 1940, Vol. 61, No. 28, pp. 660–661: summary only.)

267. A Photoelectric Colorimeter-Fluorimeter.—Froman & McFarlane. (*Canadian Journ. of Res.*, Aug. 1940, Vol. 18, No. 8, Sec. B, pp. 240–245.)

268. Optical Smoothness-Meter [Correspondence].—Guild. (*Journ. of Scient. Instr.*, Sept. 1940, Vol. 17, No. 9, pp. 231–232.) *See* 4161 of 1940.

269. Photocell Applications [Sorting Rice: Sugars: Distillation: Calorimeter for Chemical Analysis: Spectrum: Rate-of-Feed Control (in Printing): Air-Brush: Control of Cultivators].—Seymour. (*Sci. Abstracts*, Sec. B, 25th Aug. 1940, Vol. 43, No. 512, p. 340.)

270. Paper on Photographic Exposure and Photoelectric Exposure Meters [Influence of Varying Tonal Characteristics on the Readings: etc.].—Harrison. (*E. & Television & S-W.W.*, June 1940, Vol. 13, No. 148, p. 266: summary only.)

271. " Electric Eye " measures Protein in Wheat Flour.—Zeleny. (*Journ. Franklin Inst.*, Aug. 1940, Vol. 230, No. 2, p. 280.)

272. PHOTOELECTRIC CONTROL OF PAPER REGISTRATION IN THE PRINTING INDUSTRY.—Forster. (*E. & Television & S-W.W.*, Aug. 1940, Vol. 13, No. 150, pp. 353–355 and 357.) From the B.T-H. laboratories.

273. AERIAL PHOTOGRAPHS BY NIGHT [U.S. Army's Explosive Light Bomb of 1000 Million Candle-Power: Photocell opens Camera Shutter at Moment of Greatest Illumination].—(*The Times*, 12th Oct. 1940, p. 3.)

274. TYPICAL COLOUR CURVES [taken with Photoelectric Photometer] AND THEIR APPLICATION FOR PURITY TESTS IN PHYSIOLOGICAL RESEARCHES.—Singh & Rao. (*Current Science*, Bangalore, Aug. 1940, Vol. 9, No. 8, pp. 368–369.)

275. VITAMIN A METER [using Special Photocells & Circuit for measuring Ultra-Violet Radiation remaining after Passage through Fish Oil].—G-M Laboratories. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, p. iv.)

276. BIOLOGICAL EFFECTS OF HIGH-FREQUENCY AND MAGNETIC FIELDS [Experience with "Inductotherm" Short-Wave Diathermy shows Definite Part played by Magnetically-Produced Currents].—Nagelschmidt. (*Nature*, 2nd Nov. 1940, Vol. 146, p. 590.) These currents "probably account for the immediate relief of pain in some cases, long before any measurable rise of temperature in the tissue occurs." For Summers & Hughes's results with h.f. magnetic fields acting on microorganisms *see* 4134 of 1940.

277. RADIO-THERAPY: WIRELESS IN THE SERVICE OF MEDICINE.—Dalton. (*Wireless World*, Oct. 1940, Vol. 46, No. 12, pp. 416–418.) *See* also 1284 of 1940.

278. AN ELECTRICAL INTEGRATOR FOR "ACTION CURRENTS" [Amplified Currents charge Condenser till This is discharged by Gas-Filled Tube to activate Impulse Counter].—Freeman & Hoffman. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 283–284.)

279. PAPERS ON MULTI-CHANNEL DELAY UNIT AND MULTIPLE-SWEEP SYSTEM FOR C-R OSCILLOGRAPHS [primarily for Action-Potential Research].—Marshall, Talbot. (*See* 166.)

280. "SOME POINTS ON THE RELATIONS OF RADIO-GEOLOGICAL PROSPECTING TO LIGHTNING RESEARCH" [Book Review].—Fritsch. (*See* 40.)

281. ELECTROMETRIC p_H MEASUREMENTS IN INDUSTRIAL TECHNIQUE [Recent Developments, including Valve-Amplifier Equipment].—Lieneweg & Naumann. (*E.T.Z.*, 25th July 1940, Vol. 61, Nos. 29 & 30, pp. 665–668 & 690–692.)

282. "PROCEEDINGS OF THE SEVENTH SUMMER CONFERENCE ON SPECTROSCOPY AND ITS APPLICATIONS" [Book Review].—Harrison (Edited by).—(*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, p. 570.)

283. THE OPTICAL PROPERTIES OF COLLOIDAL SUSPENSIONS IN RELATION TO THE MEASUREMENT OF PARTICLE-SIZE FREQUENCY.—Richardson. (*Journ. Applied Phys.*, Oct. 1940, Vol. 11, No. 10, pp. 653–657.)

284. THE TRANSMISSION OF INFRA-RED LIGHT BY FOG.—Sanderson. (*Journ. Opt. Soc. Am.*, Sept. 1940, Vol. 30, No. 9, pp. 405–409.) A summary was dealt with in 3661 of 1940: contrast Smith & Hayes, 4519 of 1940.

285. OPTICAL TELEGRAPHY AND TELEPHONY [Summary of Lecture to VDE Meeting].—Schwenkhagen. (*E.T.Z.*, 22nd Aug. 1940, Vol. 61, No. 34, p. 785.)

286. ON THE CONSTRUCTION OF VERY SENSITIVE VACUUM THERMOELECTRIC CELLS [primarily for Astrophysical Research].—Rogers. (*Review Scient. Instr.*, Sept. 1940, Vol. 11, No. 9, pp. 281–282.)

"Almost as convenient to handle as commercial radio tubes": the light from Betelgeuse, through a 24-inch reflecting telescope, produced a double deflection of 12 cm at a scale distance of 2 m with a Paschen galvanometer.

287. CHEMICAL TREATMENT [as opposed to Applied-Film Method] TO INCREASE THE TRANSPARENCY OF GLASS.—Jones & Homer. (*Science*, 4th Oct. 1940, Vol. 92, Supp. p. 8.) For the previous methods *see*, for example, 3656/8 of 1940.

288. SYMPOSIUM ON OPTICAL METHODS FOR STUDY OF MOLECULAR STRUCTURE [X-Ray-Diffraction, Electron-Diffraction, & Raman-Spectra Methods].—Warren & others. (*Journ. Opt. Soc. Am.*, Sept. 1940, Vol. 30, No. 9, pp. 369–404.)

289. "THE RAMAN EFFECT AND ITS CHEMICAL APPLICATIONS" [Book Review].—Hibben. (*Journ. Applied Phys.*, Sept. 1940, Vol. 11, No. 9, p. 569.)

290. DEVICES FOR MEASUREMENT OF AIR TURBULENCE [for Design of Aerofoils] AND PROPELLER VIBRATION [causing Crystallisation of Metal].—Weske: Kearns. (*Proc. I.R.E.*, Aug. 1940, Vol. 28, No. 8, p. 383: summaries only.) *See* also 2808 of 1940.

291. UTILISING SUN RAYS [including Recent Developments using "Alcoa" Metal Mirrors and "Aroclor" Liquid in Thermos Bottles].—Abbot. (*Scientific Monthly*, Sept. 1940, Vol. 51, No. 3, pp. 195–200.)

292. THE UTILISATION OF WIND POWER [Data relating to Design of "Wind Turbines": Necessity for Increased Diameters (to 60 m) & Higher Wind Velocities (as at 200 m above Ground): Need for Prolonged Tests].—van Heys. (*E.T.Z.*, 22nd Aug. 1940, Vol. 61, No. 34, pp. 787–790.)

293. ORIGINS OF ELECTRIC TRANSMISSION BY RESONANCE [Letter prompted by Death of Sir Oliver Lodge].—Larmor. (*Nature*, 5th Oct. 1940, Vol. 146, p. 459.)

Wireless Patents

A Summary of Recently Accepted Specifications

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each

ACOUSTICS AND AUDIO-FREQUENCY CIRCUITS AND APPARATUS

527 026.—Loud-speaker diaphragm fitted with a dust-excluding element so arranged as not to introduce any undesirable resonance effects within the signal range of frequencies.

Standard Telephones and Cables (communicated by P. A. J. Visschers). Application date 28th March, 1939.

527 395.—Simplified magnetic system for a gramophone pick-up of the moving-iron type.

Cosmocord and A. Schumann. Application date 11th April, 1939.

DIRECTIONAL WIRELESS

526 036.—Short-wave direction finder based on the use of two crossed pairs of spaced dipoles with feed-lines of constant length.

Soc. Francaise Radio-Electrique. Convention date (France) 4th March, 1938.

526 055.—Means for accentuating the relative strengths of the "complementary" signals used to mark out a radio-navigational course.

Standard Telephones and Cables and C. W. Earp. Application date 7th March, 1939.

526 114.—Removing the D.C. component of the "complementary" signals used to mark out a radio-navigational course or "blind-landing" system.

Standard Telephones and Cables and C. W. Earp. Application date 7th March, 1939.

526 182.—Direction-finding system in which the "complementary" signals are also used to charge two condensers for the purpose of applying automatic volume control.

J. R. Steinhoff. Convention date (U.S.A.) 19th March, 1938.

526 318.—Arrangement of a number of radio beacons for defining a clear-cut navigational route.

Standard Telephones and Cables (assignees of Le Matériel Téléphonique Soc. Anon.). Convention date (France) 12th March, 1938.

RECEIVING CIRCUITS AND APPARATUS

(*See also under Television*)

525 405.—Switch-tuned receiver in which the station-selecting device is arranged to operate the tuning condenser without the use of intermediate gearing.

N. Hansen. Convention date (Denmark) 25th July, 1938.

525 470.—Amplifier with positive reaction in which the feed-back circuit includes a non-linear impedance to reduce the gain of stronger relatively to the weaker signals.

L. E. Ryall. Application date 18th February, 1939.

525 606.—Controlling the band width accepted by a radio receiver or gramophone amplifier, automatically and solely by means of the low and intermediate sound frequencies.

Philips' Lamps. Convention date (Germany) 22nd July, 1938.

525 611.—Switch-tuned wireless set in which the press-buttons or selectors can also be utilised, in one position, to allow of continuous manual control of the tuning.

E. K. Cole and R. Kemp. Application date 17th February, 1939.

525 613.—Remote tuning and volume control for a wireless set through an impulse transmitter at the distant point.

A. R. Fokerd. Application date 23rd February, 1939.

525 722.—Remote tuning system for a set fitted with A.V.C. and allowing for an additional manual control of volume.

Philco Radio and Television Corporation (assignees of W. E. Gilbert). Convention date 14th March, 1938.

525 829.—Push-button control for the wave-band settings of a wireless receiver, and also for changing over to gramophone reproduction or to television reception.

The General Electric Co. and F. R. Jones. Application date 1st March, 1939.

525 869.—Arrangement of the band-pass filter circuits and associated automatic selectivity control in a superhet receiver.

Philips' Lamps. Convention date (Germany) 27th May, 1938.

525 951.—Amplifier circuit for very high frequencies in which means are provided to prevent damping of the grid circuit due to the "transit time" of the electrons.

Telefunken Co. Convention date (Germany) 3rd March, 1938.

525 953.—Negative feed-back amplifier with means for reducing the so-called Johnson and other "valve noise," relatively to the signal level.

Standard Telephones and Cables; K. G. Hodgson; and A. H. Roche. Application date 3rd March, 1939.

526 087.—Wired-wireless receiver with a volume control safeguarded against the effects of a short-circuit in the loud speaker or its leads.

Philips' Lamp Co. Convention date (Netherlands) 25th February, 1939.

526 153.—Cam-control mechanism for a push-button receiver designed to give a graduated control as the critical tuning point is approached.

Philco Radio and Television Corporation (assignees of L. H. Zepp). Convention date (U.S.A.) 10th March, 1938.

526 173.—Amplifying circuit including a non-linear impedance in the feed-back circuit whereby the effective reaction is automatically made greater for

weak than for strong signals. (Addition to 525 470.)

L. E. Ryall. Application date 8th March, 1939.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

525 608.—Discharge tube in which a picture projected on to a caesium-coated screen is focused and reproduced on a fluorescent screen arranged at right-angles to the first screen.

The Mullard Radio Valve Co. Convention date (Netherlands) 13th October, 1938.

525 616.—Cathode-ray television receiver in which the picture is reproduced on an enlarged scale by scanning a crystalline screen of an alkali-halide, so as to vary its transparency.

Marconi's W.T. Co.; L. M. Myers; and A. T. Starr. Application date 23rd February, 1939.

525 628.—Television system in which the sound signals are transmitted by frequency modulation and the picture signals by amplitude modulation.

H. E. Kallmann. Application date 24th February, 1939.

525 629.—Automatic gain control for television based upon first bringing the average picture brightness, and then a datum level, to a substantially constant value.

Telefunken Co. Convention date (Germany) 25th February, 1938.

525 791.—Means for producing "fade-outs," "rolling-cuts" and similar effects in a television programme.

Baird Television and G. A. R. Tomes. Application date 1st March, 1939.

525 826.—Superhet receiver, for combined sound and picture signals, using a common intermediate-frequency amplifier covering a range of from 500 kc/s to 10 Mc/s.

Kolster Brandes and D. S. B. Shannon. Application date 28th February, 1939.

525 967.—Arrangement for showing a "close-up" of a television picture, and for controlling the brightness or "contrast" values accordingly. (Addition to 520 235.)

Kolster-Brandes; R. E. Prichard; and C. N. Smyth. Application date 3rd March, 1939.

525 968.—Sound and picture receiver in which an oscillator valve, of the electron-coupled type, is used as a mixer for both sets of signals.

Kolster-Brandes and C. N. Smyth. Application date 3rd March, 1939.

526 032.—Saw-toothed oscillation generator designed to avoid key-stone distortion, when receiving television signals. (Addition to 483 999.)

Telefunken Co. Convention date (Germany) 3rd March, 1938.

TRANSMITTING CIRCUITS AND APPARATUS

(See also under Television)

525 183.—Signalling system in which a modulated oscillating valve serves either as a means for volume compression or expansion according to the operating conditions.

Kolster-Brandes and W. A. Beatty. Application date 17th February, 1939.

525 343.—Valve oscillator back-coupled through a piezo-electric crystal in which frequency stability is ensured by the inclusion in the feed-back circuit of an in-phase impedance combination.

"Fides" Ges. (assignees of Siemens and Halske Akt.). Convention date (Germany) 17th February, 1938.

525 934.—Electron-amplifier circuit for the modulation of ultra-short waves.

Magyar Wolf Ramlampa Co. Convention date (Hungary) 3rd March, 1938.

526 418.—Resistive coupling arrangements particularly for the modulator and sub-modulator stages of a wireless transmitter.

Marconi's W.T. Co. and N. H. Clough. Application date 16th February, 1939.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

525 243.—Electrode arrangement for an electron-multiplier used as a carrier-wave modulating device.

Farnsworth Television, Inc. Convention date (U.S.A.) 21st February, 1938.

525 344.—Photo-electric cell in which a luminescent coating is combined with a light-sensitive cathode to produce electron-emission.

"Fides" Ges. (assignees of Siemens and Halske Akt.). Convention date (Germany) 17th February, 1938.

525 378.—Construction and arrangement of the electrodes of a valve for handling very-high frequencies wherein a cathode of large surface surrounds the anode.

The M-O. Valve Co. and M. R. Gavin. Application dates 20th February, 1939 and 24th January, 1940.

525 601.—Arrangement of the focusing electrodes in a cathode-ray television receiver designed to reduce the number of voltage-supply of lead-in connections.

The Mullard Radio Valve Co. Convention date (Germany) 13th June, 1938.

SUBSIDIARY APPARATUS AND MATERIALS

525 758.—Electron-multiplier circuit arranged to include the use of controlled positive or negative reaction.

Kolster-Brandes; W. A. Beatty; and P. K. Chatterjea. Application date 28th February, 1939.

525 882.—High-frequency resonant line of the coaxial type, with means for stabilising its inherent frequency against temperature variations.

Marconi's W.T. Co. (assignees of H. E. Goldstine). Convention date (U.S.A.) 2nd February, 1938.

525 938.—Perforated metallic shield for screening the ignition system of a motor car and preventing high-frequency radiation.

R. H. Stone and M. F. Peters. Convention date (U.S.A.) 16th March, 1938.

526 377.—Valve-oscillator circuit for generating square-topped wave-forms, rich in harmonics.

Telefunken Co. Convention date (Germany) 14th March, 1938.