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Editorial

The Effect of the Earth's Curvature on Ground-wave Propagation

THIS is the title of a paper published in the Proceedings* of the American Institute of Radio Engineers embodying work undertaken for the Radio Wave Propagation Committee of the Institute. The mathematical determination of the diffraction of waves around the earth is a very complex problem. The principal foundations were laid over twenty years ago by G. N. Watson, but the detailed development of his method was limited to an earth of infinite conductivity. It is only in the last three or four years that this limitation has been largely removed by the work of Wwedensky, van der Pol, Bremmer, T. L. Eckersley, Millington and others. Although it is now theoretically possible to calculate the propagation for any values of dielectric constant and conductivity, the computations are, in fact, very lengthy and involved, and the object of the paper referred to is to make the results of this recent work more readily available to the engineer. This the authors have done by plotting a series of curves from which the received field may be determined for any given constants with sufficient accuracy for practical purposes.

The method adopted is to determine the field for a plane earth of the given constants and to multiply this by a factor, which they call the shadow-factor, to allow for the earth's curvature. The earth is assumed to be smooth and free from irregularities and the atmosphere is assumed to be free from abrupt discontinuities. The effect of the gradual decrease in the dielectric constant with increasing height can be allowed for approximately by assuming the radius of the earth to be 4/3 times its actual value when determining the shadow-factor. The strength of the field is given by the formula $E = E_1 A_1 F_s G_1 G_2$ where E_1 is what the field would be with a flat earth of perfect conductivity, A_1 is the attenuation factor to allow for the actual conductivity and dielectric constant, F_s the shadow-factor to allow for the curvature, and G_1 and G_2 aerial height factors. If the aerials are both on the ground $G_1 = G_2 = 1$.

Curves are given from which the value of A_1 can be read off, but even this is not a simple matter. Each curve corresponds to a certain value of Q where $Q = \frac{\epsilon}{60\sigma\lambda}$; ϵ is the dielectric constant, σ the conductivity in mhos per metre, and λ the wavelength in metres (the M.K.S. system of units is used throughout). Instead of the actual distance d in metres the abscissae represent a numerical value $\zeta_e = \frac{d}{\lambda} \times \frac{2\pi}{\epsilon_e}$ for vertical polarisation

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* C. R. Burrows and M. C. Gray. *Proc. Inst. Rad. Eng.*, Jan. 1941.

of the electric field, and $\zeta_m = \dfrac{d}{\lambda} \times \dfrac{2\pi}{\epsilon_m}$ for horizontal polarisation, where

$$\epsilon_e = \frac{\epsilon_0{}^2}{\epsilon_0 - 1} \text{ and } \epsilon_m = \epsilon_0 - 1\,;\ \epsilon_0 = \epsilon - j60\sigma\lambda.$$

Some readers may feel uneasy about the dimensions of ϵ and $60\sigma\lambda$, but it should be pointed out that 60 is $2/10^9$ times the velocity of light, while the dimensions of $\sigma\lambda$ are the reciprocal of a velocity. The following considerations throw some light on the nature of ϵ_0 which figures so prominently in the above expressions. If a transmission line down into the earth consisted of two parallel plates of zero resistance 1 cm. apart, the magnitude and phase of the field at any depth x would be equal to that at the surface multiplied by e^{-ax} where

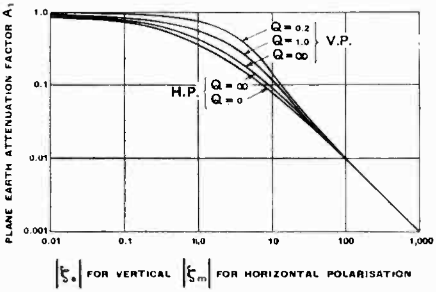

Fig. 1

$$a = \sqrt{(R + jX)(G + jB)}\,;$$

$$R = 0,\quad X = \omega L = 4\pi/10^9,\quad G = \sigma \text{ and}$$

$$B = \omega C = \frac{\omega\epsilon}{4\pi \cdot 9 \cdot 10^{11}}.$$

Substituting these values gives

$$a = \sqrt{j\omega\,\frac{4\pi}{10^9}\left(\sigma + \frac{j\omega\epsilon}{4\pi \cdot 9 \cdot 10^{11}}\right)}$$

or putting $\omega = 2\pi f = 2\pi \cdot 3.10^{10}/\lambda$

$$a = j\frac{2\pi}{\lambda}\sqrt{\epsilon - j60\sigma\lambda} = j\frac{2\pi}{\lambda}\sqrt{\epsilon_0}.$$

The actual abscissae of the curves are the magnitudes $|\zeta_e|$ and $|\zeta_m|$ which are given by the formulae

$$|\zeta_e| = \frac{d}{\lambda} \times \frac{2\pi\sqrt{(\epsilon - 1)^2 + \beta^2}}{\epsilon^2 + \beta^2}$$

$$|\zeta_m| = \frac{d}{\lambda} \times \frac{2\pi}{\sqrt{(\epsilon - 1)^2 + \beta^2}}$$

where $\beta = 60\sigma\lambda$.

It will be seen from Fig. 1 that with this numerical value as a base, the value of A_1 is represented by a single curve at great distances for all conditions, but that this desirable simplification is not possible at medium distances. For horizontally polarised waves, however, the divergence is small, the curves for all possible values of ϵ and σ lying between those for $Q = 0$, and $Q = \infty$. With vertical polarisation the divergence is greater, but even here a fairly close approximation can be made for any value of Q from the three curves shown in Fig. 1.

Two limiting shadow-factor curves were given by van der Pol and Bremmer. These are shown in Fig. 2 in which curve 1 is for vertically polarised waves over a perfectly conducting earth into which, therefore, the waves could not penetrate, ($Q = 0$), and curve 2 for similar waves over a very absorbent earth into which the waves could readily penetrate ($Q = \infty$). It is remarkable that Fig. 2 also applies to horizontally polarised waves for any condition of the earth. The abscissae of Fig. 2 represent a numerical value $\zeta_a = \dfrac{d}{\lambda} \times \dfrac{2\pi}{(2\pi r/\lambda)^{2/3}}$ in which r is the corrected radius of the earth, i.e. the actual radius multiplied by about 4/3. Putting in the value of r we have

$$\zeta_a = \frac{4{\cdot}43}{10^5} \cdot \frac{d}{\sqrt[3]{\lambda}}\,;$$

d and λ are in metres.

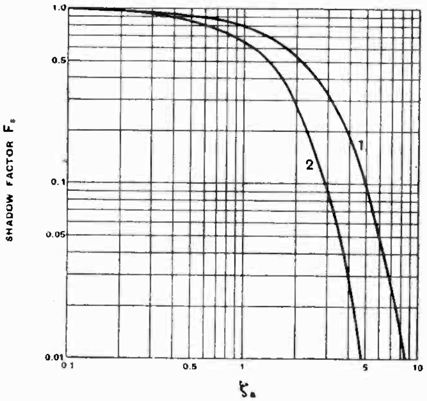

Fig. 2

For vertically polarised waves, Fig. 2 does not lend itself to accurate interpolation for given values of ϵ and σ. Burrows and Gray have tried to modify the abscissae in such a way that a single curve, viz. curve 2 in Fig. 2, will give the shadow-factor for all conditions. Instead of ζ_a the abscissae represent $\eta = \zeta_a f(\delta)$ where δ is the so-called ground-constant ;

$$\delta = \left(\frac{2\pi r}{\lambda}\right)^{2/3} \times \frac{1}{\epsilon_e}$$

They give curves from which the correcting factor $f(\delta)$ can be read for any value of δ. They also give curves from which the magnitude and phase angle of δ can be read for various values of λ, ϵ and σ, thus avoiding the calculation of the above formula. Although they did not succeed in reducing the two curves of Fig. 2, and all that lies between them, to a single curve, they greatly improved the accuracy and ease of interpolation.

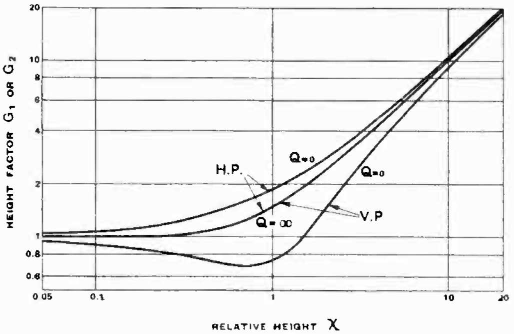

Fig. 3

If either antenna is raised above the earth the factor G_1 or G_2 is no longer unity but is given by the curves of Fig. 3, in which their values are plotted against a relative height χ. For vertical polarisation

$$\chi = \chi_e = \frac{h}{\lambda} \cdot \frac{2\pi}{\sqrt[4]{\epsilon^2 + \beta^2}} \sqrt[4]{\frac{(\epsilon - 1)^2 + \beta^2}{\epsilon^2 + \beta^2}} ;$$

for horizontal polarisation

$$\chi = \chi_m = \frac{h}{\lambda} \cdot 2\pi \sqrt[4]{(\epsilon - 1)^2 + \beta^2}.$$

This only applies to moderate heights ; at short distances to heights for which $2\pi h_1 h_2/\lambda d$ is somewhat less than unity, and at long distances to heights for which $\chi/\sqrt{\delta}$ $(=0.0167h/\lambda^{2/3})$ is less than about 0.5.

The paper referred to goes into other cases and formulae and curves are given for great heights and distances and also for the case when one or both aerials are raised until they are in the line of sight. The paper should certainly be consulted by anyone interested in the numerical calculation of such cases. G. W. O. H.

Diode as Rectifier and Frequency-Changer*

By D. A. Bell, M.A., A.M.I.E.E.

1. Introduction.
2. Effect of diode resistance in the simple rectifier.
3. Input damping of imperfect rectifier.
4. Rectifier with tuned load.
5. Signal noise ratio of diode-frequency-changer.
6. Acknowledgment.

I. Introduction.

THE diode rectifier with resistive load is a familiar part of most radio receivers, and the conditions usually allow the approximation of assuming perfect rectification : e.g. the damping imposed on the circuit feeding the rectifier is equivalent to a shunt resistance having half the value of the actual diode load resistance. But the diode is also useful as a frequency-changer in either of two circumstances : when the signal frequency is so high that transit-time effects are troublesome in multi-electrode valves, or when the output at difference frequency must be linearly proportional to the smaller of the two input voltages, but independent both of the amplitude of the other input and of valve operating potentials and of frequency. When the diode is operated as a frequency-changer, so that the useful load consists of a tuned

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circuit, the appropriate D.C. load has to be determined, and if the internal resistance of the diode becomes appreciable compared with the load impedances the effect of imperfect rectification has to be studied. Apart from frequencies too high for multi-electrode valves, the diode frequency-changer has two special applications by reason of the proportionality of its output to the smaller of the two inputs :

(*a*) as frequency-changer in measuring equipment,

(*b*) as a limiter to remove amplitude variations of the signal, the signal being in this case the larger of the two inputs.

2. Diode Resistance in the Simple Rectifier.

In the simple circuit of Fig. 1 the rectification ratio (i.e. ratio of D.C. output voltage to peak input voltage) depends both on the time-constant CR and on the internal resistance of the diode. In principle, the time-constant of the load circuit (or rather the product of this time constant and the operating frequency) controls the ratio of the maximum potential to which the condenser is charged to its mean potential ; while the internal resistance of the diode controls the difference between the maximum condenser potential and the peak input voltage. But the two effects are not independent, for increasing CR reduces the fraction of the cycle during which the diode is conducting, and if the increase is due to a larger value of C with R constant, the instantaneous current through the diode must be greater, and its internal resistance becomes more important ; increasing R, on the other hand, decreases the charge transferred per cycle as well as the conduction period, and therefore has little effect on the voltage drop across the diode.

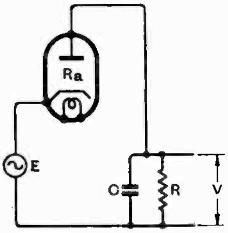


Fig. 1

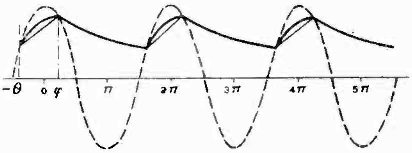


Fig. 2

Referring to Fig. 2, the input is taken to be of the form E cos pt, and the periods during which the diode is conducting are from $pt = 2n\pi - \theta$ to $pt = 2n\pi + \phi$; so that from $pt = 2n\pi + \phi$ to $pt = 2(n + 1)\pi - \theta$ the condenser discharges through the resistance, while from $2n\pi - \theta$ to $2n\pi + \phi$ it is charged through the diode. If the diode had infinite conductance, the condenser potential would follow the input E cos pt from $2n\pi = \theta$ to $2n\pi$ and fall exponentially from that point ; but owing to the voltage drop across a practical diode, the condenser potential lags behind E and continues to rise until E has fallen to meet it. The current will be small after $2n\pi$, since the values of E and the condenser potential V are rapidly approaching each other ; consequently the rate of rise of V falls away rapidly after the peak value of E has been attained, as shown by the heavy line in Fig. 2. The charge gained by the condenser during each cycle is

$$Q_{in} = \int_{t=\frac{-\theta}{p}}^{t=\frac{\phi}{p}} i_d . dt = \frac{1}{p}\int_{-\theta}^{\phi} i_d . d(pt) \quad .. \quad (1)$$

where i_d is the current through the diode. The charge lost per cycle is

$$Q_{out} = \frac{1}{p}\int_{0}^{2\pi} (V/R) . d(pt)$$

$$= \frac{1}{pR}\int_{-\theta}^{\phi} V . d(pt) + \frac{1}{pR}\int_{\phi}^{2\pi-\theta} V . d(pt) \quad (2)$$

It now remains to find expressions for V and i_d in terms of E and circuit parameters, and equate Q_{in} to Q_{out}.

The simplest case is obtained by letting the load time-constant become infinite compared with the periodicity of the applied voltage, so that the load voltage V remains constant throughout the cycle. Since V is now the same at the beginning and end of the charge, it follows that arc cos $V/E = \theta = \phi = \alpha/2$ where α is the total angle of conduction. This gives the discharge per cycle as

$$Q_{out} = \frac{2\pi}{p} . \frac{V}{R}$$

and the charge per cycle through a diode of resistance R_a as

$$Q_{in} = \frac{1}{pR_a}\int_{-\alpha/2}^{\alpha/2} (E \cos pt - V) \, . \, d(pt)$$

$$= \frac{1}{pR_a} \{2E \sin \alpha/2 - \alpha V\}$$

Putting $V = E \cos \alpha/2$ and equating Q_{in} to Q_{out},

$$\frac{2\pi}{pR} E \cos \alpha/2 = \frac{1}{pR_a} \{2E \sin \alpha/2 - \alpha E \cos \alpha/2\}$$

$$\therefore \frac{R_a}{R} = \frac{2 \sin \alpha/2 - \alpha \cos \alpha/2}{2\pi \cos \alpha/2} \quad .. \quad (3)$$

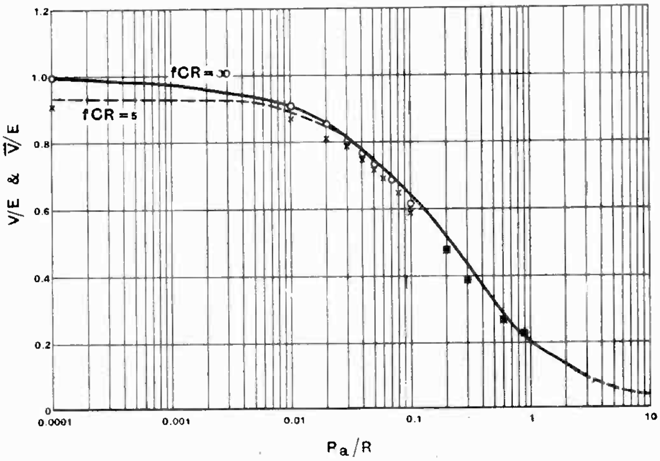


Fig. 3 (*Above*).—*Effect of diode resistance on rectification ratio.*

Fig. 4 (*Right*).—*Effect of diode resistance on conduction angle.*

For any chosen value of α, and hence of efficiency since $V/E = \cos \alpha$, a corresponding value of R_a/R can be evaluated; a graph of V/E against R_a/R derived from the equation is shown as the full-line curve, $fCR = \infty$, in Fig. 3. It may be noted that a loss of 6 db (i.e. $V/E = 0.707$) occurs when R_a is about $6\frac{1}{2}$ per cent. of R; but for the accurate measurement of peak voltage, note that to get V within 1 per cent. of E requires a ratio of R_a/R of the order of 10^{-4}. A graph of conduction angle against R_a/R is given in Fig. 4. The curves in Figs. 3 and 4 can be roughly extrapolated, as indicated by the dotted portions, from the knowledge that not until R_a/R becomes infinite does V/E become zero and α become 180°.

The next step is to consider the practical case when fCR is not infinite, but remains large enough to give good efficiency. If the maximum value of V is V_0, the value at any point in the discharge portion of the cycle is

$$V = V_0 e^{-\frac{(t-t_0)}{CR}} = V_0 e^{-\frac{(pt-pt_0)}{pCR}}$$

where t_0 is the time at which $V = V_0$, i.e. $pt_0 = \phi$. The second term of integral (2) therefore becomes

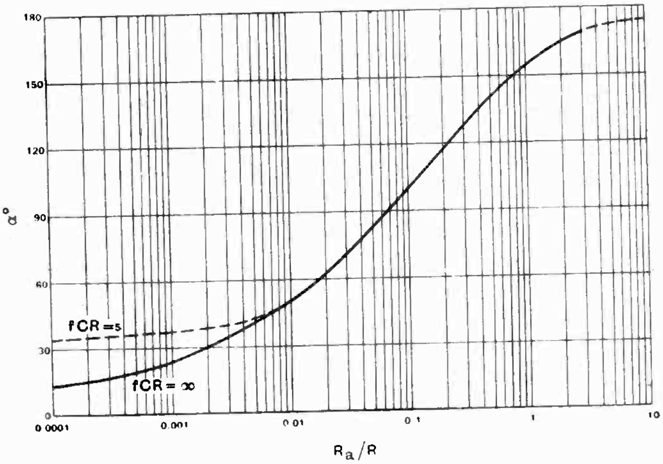
$$\frac{1}{pR}\int_{\phi}^{2\pi-\theta} V \, . \, d(pt) =$$

$$\frac{V_0}{pR}\int_{\phi}^{2\pi-\theta} e^{-\frac{(pt-\phi)}{pCR}} \cdot d(pt) =$$

$$CV_0\{1 - e^{-\frac{(2\pi-\theta-\phi)}{pCR}}\} \quad (4)$$

Let the minimum value of V be denoted by V_1:

$$V_1 = V_0 e^{-\frac{(2\pi-\theta-\phi)}{pCR}}$$



During the charging period the potential V rises from V_1 to V_0, but the exact form of the curve has not been determined; it depends upon the ratio of V_1 and V_0 to E, neither of which has yet been evaluated. However, a useful approximation can be obtained by assuming a linear variation, as shown by the thin line in Fig. 2 ; this gives an expression for V during the charging period :

$$V = V_0 - \left(\frac{V_0 - V_1}{\theta + \phi}\right)(\phi - pt)$$

The first half of the integral (2) is therefore

$$\frac{1}{pR}\int_{-\theta}^{\phi} V\,.\,d(pt) = \left(\frac{\theta + \phi}{pR}\right)\left(\frac{V_0 + V_1}{2}\right) \qquad (5)$$

Evaluating V_1 in terms of V_0 and adding (4) and (5) gives

$$Q_{out} = V_0\left\{\frac{\theta + \phi}{2pR}\left(1 + e^{-\frac{(2\pi-\theta-\phi)}{pCR}}\right) + C\left(1 - e^{-\frac{(2\pi-\theta-\phi)}{pCR}}\right)\right\} \quad .. \quad (2a)$$

To evaluate integral (1) we put

$$i_d = (E - V)/R_a$$

$$i_d = (1/R_a)\left\{E\cos pt - V_0 + \left(\frac{V_0 - V_1}{\theta + \phi}\right)(\phi - pt)\right\}$$

$$\therefore \frac{1}{p}\int_{-\theta}^{\phi} i_d\,.\,d(pt) = (1/pR_a)\left\{E(\sin\phi + \sin\theta) - \tfrac{1}{2}V_0\left(1 + e^{-\frac{(2\pi-\theta-\phi)}{pCR}}\right)(\theta + \phi)\right\} \quad .. \quad .. \quad (1a)$$

Since the discharging part of the cycle commences and ends when E is equal to V we may also write

$$V_0 = E\cos\phi \quad .. \quad .. \quad .. \quad (6)$$

$$V_1 = E\cos\theta \quad .. \quad .. \quad .. \quad (7)$$

and we shall denote the sum of θ and ϕ by α.

This enables us to divide the conduction angle α into its two constituents θ and ϕ for any given value of the product of frequency and time-constant ; substituting for V_0 and V_1 in terms of E and then eliminating E between equation (6) and (7) gives an equation for ϕ :

$$\tan\phi = \frac{e^{-(2\pi-\alpha)/pCR} - \cos\alpha}{\sin\alpha} \quad .. \quad (8)$$

This equation gives values of θ and ϕ for selected values of α, to be inserted in the equation relating R/R_a to θ and ϕ which results from equating (1a) to (2a) :—

$$\frac{R_a}{R} = \frac{1}{pCR}\cdot\frac{\sin\phi + \sin\theta - \tfrac{1}{2}\alpha\left(1 + e^{-2(\pi-\alpha)/pCR}\right)\cos\phi}{\cos\phi\left\{(\alpha/2pCR)\left(1 + e^{-(2\pi-\alpha)/pCR}\right) + 1 - e^{-(2\pi-\alpha)/pCR}\right\}} \quad .. \quad .. \quad .. \quad (9)$$

As a reasonable practical example, $pCR/2\pi$ was put equal to 5, and the ratio R_a/R evaluated for a series of values of α and hence of efficiency ; since it is the D.C. component of the output voltage which is useful, not the peak value, an approximation to the D.C. component was taken as the arithmetic mean of maximum and minimum values of V,

$$\overline{V} = \tfrac{1}{2}E\cos\phi\,.\,\left(1 + e^{-(2\pi-\alpha)/pCR}\right) \quad (10)$$

and the graph of $\overline{V}/E$ against R_a/R is shown in a dotted line in Fig. 3, with the corresponding curve for conduction angle in Fig. 4. The useful rule is found that when R_a/R is great enough to cause the rectification ratio to fall appreciably from its maximum value for the given time-constant, the loss is practically independent of time-constant. For other values of fCR, therefore, the labour of tabulating the right-hand side of (9) can be avoided by finding the value of α which gives $\phi = 0$ (this corresponds to $R_a/R = 0$) and drawing a nearly horizontal line through the corresponding value of V/E at $R_a/R = 0$ to the limiting curve $fCR = \infty$.

To obtain an experimental check on these results, the circuit of Fig. 1 was set up with $R = 10$ megohms and a steep-slope triode with grid and anode joined as diode (Cossor 41 M.H.). To approximate $fCR = \infty$, C was made 4 μF and $f = 250$ c/s, so that $fCR = 10^4$ (The idea of using a still higher frequency was rejected for fear of spurious effects due to diode self-capacitance : 20 $\mu\mu$F has a reactance of 10 megohms at just under 8 kc/s.) The circles on Fig. 1 are the experimental results under these conditions, with various values of resistance connected in series with the diode, and assuming that the resistances of the diode and the source of voltage were negligible ; this is probably not justified, but the accuracy of observation was not high since the only independent check on the true peak input voltage was by measurement on the screen of a cathode ray oscillograph. The points marked with crosses are for $fCR = 5$ obtained by putting $C = 0.01$ μF and $f = 50$ c/s, while keeping $R = 10$ megohms. Although the accuracy is rather poor, the experimental points do confirm the close agreement of the two curves for the larger values of R_a/R, and the shape of the curves.

Referring to Fig. 1, it seems evident that the internal resistance of the source of voltage E must be added to the diode internal resistance in order to get the effective value of R_a: yet applied to the common radio receiver circuit of Fig. 5 where R may be 0.1 MΩ and the rectifier be fed from a tuned circuit of dynamic resistance about 0.1 $M\Omega$, giving $R_a/R = 1$, Fig. 3 predicts an output voltage of only 20 per cent. of the peak value of E, which is absurd. The explanation is that since the resistance R_a is operating on a non-sinusoidal current, it is incorrect to include in it a dynamic resistance which is only applicable to sinusoidal currents; if α is small, we may say that at a certain point in the cycle, the diode load condenser C is connected in parallel with the tuning condenser C_0, and the resulting drop in peak voltage will be a function of C/C_0 rather than of the dynamic resistance of the circuit LC_0.

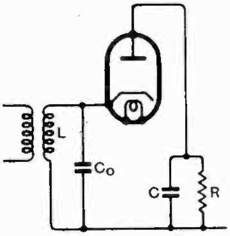


Fig. 5

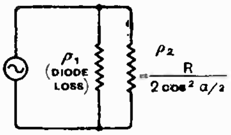


Fig. 6

3. Input Damping of Imperfect Rectifier.

If $R_a/R = 0$, the loading imposed on the source of R.F. voltage by the circuit of Fig. 1, is known to be equivalent to a resistance $R/2$; this is exact provided the R.F. voltage remains sinusoidal. When R_a/R is finite, the input loading must be determined by adding the powers dissipated in the load resistance R and in the diode resistance R_a; the former is

$$V^2/R = (E^2/R)\cos^2\alpha/2$$

and the latter is obtained from the energy dissipation per cycle. In the case of $fCR = \infty$, this is

$$\begin{aligned} W_d &= \frac{1}{p}\int_{-\alpha/2}^{\alpha/2} i^2{}_d R_a d(pt) \\ &= \frac{1}{pR_a}\int_{-\alpha/2}^{\alpha/2} E^2(\cos pt - \cos\alpha/2)^2 d(pt) \\ &= \frac{E^2}{pR_a}\int_{-\alpha/2}^{\alpha/2}\{\tfrac{1}{2}(1 + \cos 2pt) \\ &\quad - 2\cos\alpha/2 \,.\, \cos pt + \cos^2\alpha/2\}d(pt) \\ &= \frac{E^2}{pR_a}\{\alpha(\tfrac{1}{2} + \cos^2\alpha/2) \\ &\quad + \tfrac{1}{2}\sin\alpha - 4\cos\alpha/2 \,.\, \sin\alpha/2\} \\ &= \frac{E^2}{pR_a}\{\alpha(\tfrac{1}{2} + \cos^2\alpha/2) - \tfrac{3}{2}\sin\alpha\} \qquad \ldots \quad \ldots \quad (11) \end{aligned}$$

This is the energy dissipated per cycle, i.e. in time $2\pi/p$, so that the power is $W_d p/2\pi$. The power dissipation corresponding to equation (11), if E is the *peak value* of a sinusoidal voltage, is equivalent to a shunt resistance load across the input circuit of magnitude

$$\rho_1 = \frac{2\pi}{\alpha}\left\{\frac{R_a}{1 + 2\cos^2\alpha/2 - (3/\alpha)\sin\alpha}\right\} \qquad (12)$$

The power dissipated in R is equivalent to a shunt resistance

$$\rho_2 = \frac{R}{2\cos^2\alpha/2} \qquad \ldots \quad \ldots \quad \ldots \quad (13)$$

so that the equivalent circuit for input damping is as shown in Fig. 6.

If α is small, $\cos\alpha/2 \doteqdot 1$ and $(\sin\alpha)/\alpha \doteqdot 1$, so that P_1 tends to infinity. In general the equivalent resultant shunt resistance is

$$\rho_0 = \frac{R}{2}\left\{\frac{1}{\cos^2\alpha/2 + (R/R_a)(\alpha/2\pi)\{\tfrac{1}{2} + \cos^2\alpha/2 - (3\sin\alpha)/2\alpha\}}\right\} \qquad \ldots \quad \ldots \quad \ldots \quad (14)$$

It is found that for all values of α (i.e. values of R_a/R) ρ_0 is greater than $R/2$; this means that the additional dissipation in the diode is less than the reduction in dissipation in the load due to the lower output voltage. For values of α less than 35°, the diode dissipation is negligible, and $\rho_0 = R/(2\cos^2\alpha/2)$; the ratio of ρ_0 to $R/2$ is plotted against R_a/R in Fig. 7. For large values of R_a/R it is more convenient to express ρ_0 in terms of R_a, as in Fig. 8, where ρ_0/R_a is plotted against R_a/R. When the load resistance becomes small compared with R_a, the input impedance becomes asymptotic to a value of twice the diode resistance; the factor of two arises here because the diode is conducting for half the time, in the limiting case, so that the power dissipated, E^2/ρ_0, is one-half of E^2/R_a.

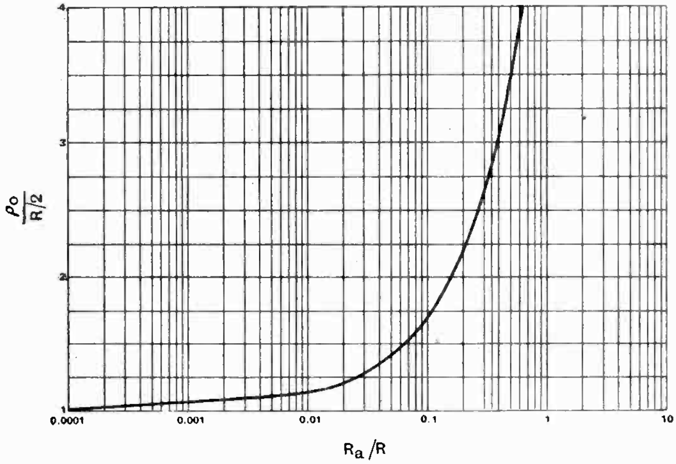


Fig. 7.—*Input resistance of imperfect rectifier.*

4. Rectifier with Tuned Load.

A simple diode frequency-changer circuit is shown in Fig. 9, where the circuit LC is tuned to the difference of the frequencies of E_1 and E_2, which is assumed to be small compared with these frequencies. The time-constant RC_1 is assumed to be very large compared with any of the frequencies involved, so that it serves as a source of bias on the diode. Let the potential difference across C_1 be v and across C be V, and let E_0 be the resultant of E_1 and E_2. Then the diode current during the conduction part of the cycle is

$$i_d = (E_0 - V - v)/R_a \quad \ldots \quad \ldots \tag{15}$$

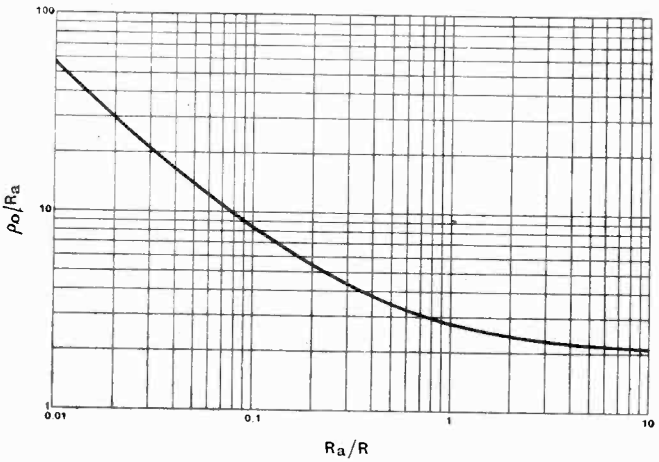


Fig. 8 (*Left*).—*Input resistance of high-resistance rectifier.*

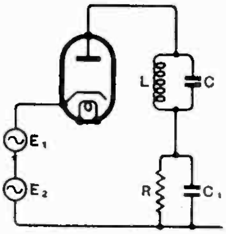


Fig. 9.

If the condenser C receives a single charge and is left to discharge from potential V_0, it will execute a damped oscillation so that

$$V = V_0 e^{-kt} \cos (t/\sqrt{LC}) \quad \ldots \quad \ldots \tag{16}$$

where the exponential factor k depends upon the losses in the circuit LC. Provided k is reasonably small, this has no D.C. component; and provided that successive charges arrive on C at regular intervals which are not related to the period $2\pi\sqrt{LC}$, the resultant of a large number of charges arriving on C will be zero, since there is no D.C. component and the A.C. components in various phases will balance out ($V = 0$). The circuit LC is still important, however, since it may control the magnitude of diode current for given values of R_a and $E_0 - v$. If L is sufficiently large, the diode current will flow entirely into the condenser C, and the charge received per cycle when the input is of the form $E_0 \cos pt$ will be

$$Q_{in} = \frac{1}{pR_a}\int_{-\theta}^{\phi} (E_0 - v)d(pt) \quad \ldots \tag{17}$$

This is derived from equation (15) remembering that $V = 0$. This charge is received from the valve anode, and must during the discharge pass through the resistance R to return to the cathode; but since RC_1 is very large the current through R remains constant throughout the cycle, so that

$$Q_{out} = \frac{1}{pR}\int_0^{2\pi} v \cdot d(pt) = \frac{2\pi}{p}\cdot\frac{v}{R} \quad .. \quad (18)$$

Equations (17) and (18) show that as far as the D.C. component resulting from an input of constant amplitude is concerned, the circuit of Fig. 6, provided both LC and RC_1 have long time-constants, behaves in the same way as Fig. 1 if the resistances R are the same in both cases. Consequently the resistance R in Fig. 6 controls α, the conduction angle of the diode, in accordance with the graph of Fig. 4; and R also controls the damping on the input circuits in accordance with Figs. 7 and 8.

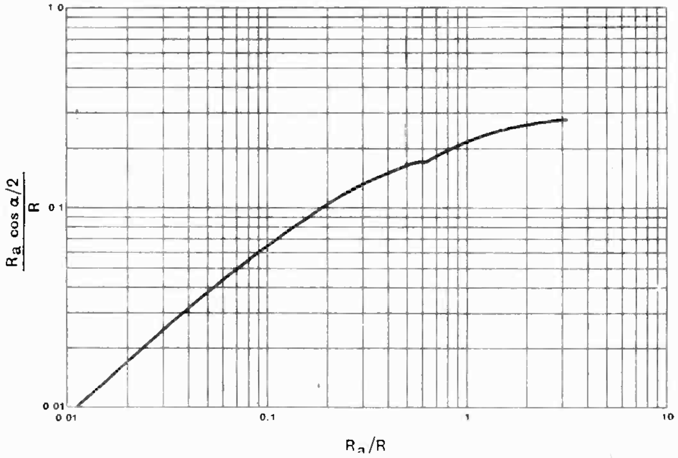


Fig. 10.—*Output factor for constant voltage input.*

Now suppose that the input consists of components at two frequencies, whose difference frequency is equal to $\omega/2\pi = 1/2\pi\sqrt{LC}$. In a frequency-changer one of the signals will normally be much smaller than the other, so that the resultant of the two can be expressed as an amplitude-modulated signal.

$$E_0 = E'(1 + x \sin \omega t) \cos p't$$

Now the steady input $E \cos pt$ produces a voltage $v = E \cos \alpha/2$ across the resistance R and therefore a rectified current of magnitude

$$I = (E/R) \cos \alpha/2$$

In most practical cases the depth of modulation is small, so that α is controlled by RC and is not appreciably affected by the depth of modulation. We may then write the rectifier current I as

$$I = (1/R)E_0(1 + x \sin \omega t) \cos \alpha/2 \quad (19)$$

The component in terms of $\sin \omega t$ will produce across the tuned circuit LC, of impedance Z, an output voltage

$$V' = (Z/R)E_0 x \sin \omega t \,.\, \cos \alpha/2 \quad .. \quad (20)$$

The diode impedance R_a will usually be fixed by the best diode available, and at high frequencies Z may be fixed by the best circuit that can be constructed; the problem then is to find the optimum value of R for given values of Z and R_a. These latter quantities being fixed, the output for constant input voltage is proportional to $R_a(\cos \alpha/2)/R$, which is plotted in Fig. 10 against R_a/R. But this is not an entirely fair representation, since the source of signal usually has an appreciable impedance; the voltage E_0 is then not a constant, but proportional to the square root of the input impedance presented by the rectifier (assuming correct matching can be achieved). If the signal source is of impedance Z_0, and has a terminal voltage E_0 when working into another impedance of the same value, the voltage applied through a matching transformer to a resistance ρ_0 will be $E_0\sqrt{\rho_0/Z_0}$ and equation (20) can now be written as

$$V' = xE_0\sqrt{\rho_0/Z_0} \cdot (Z/R) \sin \omega t \cdot \cos \alpha/2 \quad .. \quad .. \quad (21)$$

In the adjustment of the value of R the problem is therefore to find the maximum value of that part of (21) which depends upon R, namely

$$y = (1/R)\sqrt{\rho_0} \cos \alpha/2 \quad .. \quad .. \quad (22)$$

In order to use only functions already evaluated, the factor used is

$$\sqrt{\frac{\rho_0}{R/2}\cdot\frac{R_a}{R}} \cos \alpha/2 = \sqrt{2R_a} \,.\, y = y' \quad .. \quad .. \quad .. \quad .. \quad (23)$$

and this is plotted in Fig. 11*. It will be seen that even allowing for the factor $\sqrt{\rho_0/Z_0}$, the output increases as the D.C. load resistance R decreases; but this is subject to the condition that the A.C. output voltage across LC must be small compared with the D.C. voltage across R, so that the conduction angle α of the diode is independent of the modulation. This only requires a very small value of R when working as a frequency-changer on weak signals, but a much larger value in the application as a limiter where good performance is required with as deep modulation as possible (i.e. small ratio of the amplitude of the two input signals). In the application to measuring equipment, there is the further consideration that the resistance of a diode is a function of the amplitude of the applied voltage and of cathode temperature, etc.; maximum stability of calibration would then be obtained by working where the output for constant input voltage derived from a constant-impedance source does not vary rapidly with R_a. From equation (20) the requirement is seen to be minimum change of $\cos\alpha/2$ with R_a, and reference to Fig. 3 suggests that R_a/R should be either large or very small, in particular avoiding the neighbourhood of $R_a/R = 1/10$.

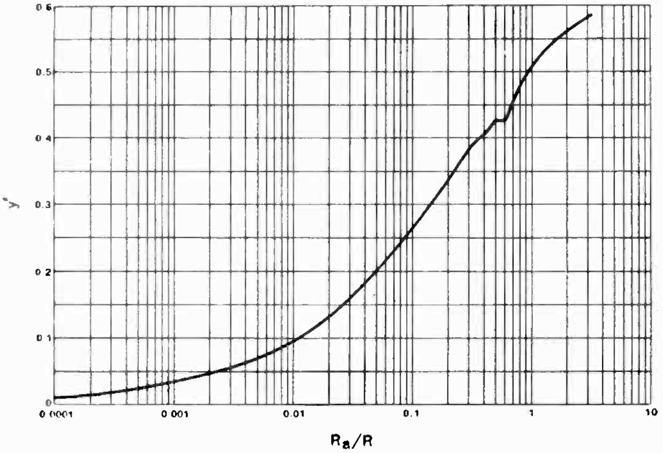


Fig. 11 (*Above*). — *Output factor for constant power input.*

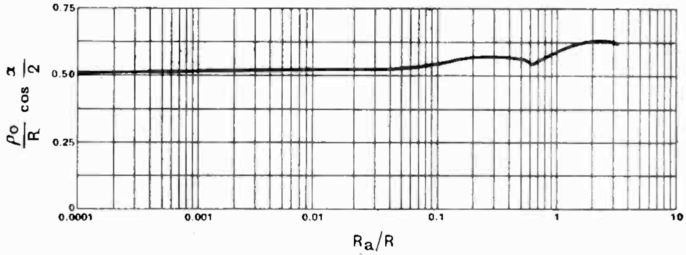


Fig. 12 (*Right*). — *Signal/noise factor of diode frequency-changer.*

5. Signal/Noise Ratio of Diode Frequency-Changer.

Equation (19) shows that the mean current through the diode is $i = (E_0/R)\cos\alpha/2$; since the diode will be operating in the space-charge limited region, the fluctuation component of this current will include a factor F^2 and will be given by

$$\bar{I}_n^{\,2} = 2F^2(E_0/R)\cos\alpha/2 \cdot edf \quad \ldots \quad (24)$$

where e is the charge on an electron and df is the band-width of the receiver or amplifier. The corresponding voltage generated in the load circuit of impedance Z will be

$$\bar{V}_n^{\,2} = Z^2\bar{I}_n^{\,2} = 2Z^2F^2(E_0/R)\cos\alpha/2\,.\,edf \qquad (25)$$

The mean square signal output can be obtained from equation (21),

$$\bar{V}_s^{\,2} = \tfrac{1}{2}V'^2 = \tfrac{1}{2}x^2E_0^{\,2}(\rho_0/Z_0)(Z^2/R^2)\cos^2\alpha/2 \quad \ldots \quad \ldots \quad (26)$$

Hence the squared signal/noise ratio is

$$\frac{\bar{V}_s^{\,2}}{\bar{V}_n^{\,2}} = \frac{x^2E^2{}_0\rho_0\cos\alpha/2}{4Z_0F^2E_0Redf} \quad \ldots \quad \ldots \quad (27)$$

In terms of R this is proportional to (ρ_0/R)

---

* Curves 10, 11, 12 have a peculiar kink in the region of $R_a/R = 0.6$; this corresponds to the reversal of curvature in Fig. 3 at this value of R_a/R a reversal which must occur to satisfy the asymptotic condition $V/E \to 0$ as $R_a/R \to \infty$. Since the basic equation (3) is transcendental, there is no algebraical expression for the various curves.

$\cos\alpha/2$, a factor which is plotted in Fig. 12. This shows very little variation and although it shows an upward trend at $R_a/R = 1.5$, it must be remembered that this corresponds to a conduction angle $\alpha = 160°$, so that the approximation of a linear charge and discharge characteristic used throughout this paper might cause an appreciable error in this region. Taking as a typical value $(\rho_0/R)\cos\alpha/2 = 0.55$, the limiting condition of signal equal to noise is given by

$$4Z_0F^2E_0e\,df = 0.55\,x^2E_0^2 \quad .. \quad (28)$$

Now $x^2E_0^2/Z_0$ is the signal power, F^2 may be about 0.1, and e is 1.59×10^{-19} coulombs so that

$$\text{minimum signal} = 1.82 \times 0.4\,E_0 \times 1.59 \times 10^{-19} df \text{ watts} \quad .. \quad .. \quad (29)$$

Suppose $E_0 = 5$ volts and $df = 4 \times 10^6$ c/s: then minimum signal is

$$1.82 \times 0.4 \times 5 \times 1.59 \times 10^{-19} \times 4 \times 10^6 = 2.32 \times 10^{-12} \text{ watts}$$

which corresponds to about 15 μV. in 80 ohms. This figure is of course only an approximation, since the diode has throughout been represented by a constant resistance, whereas in fact it follows a 3/2 law and its resistance is therefore a function of applied voltage. But the diode resistance only appears directly in the calculation of signal/noise ratio through the function plotted in Fig. 12, which varies very slowly with diode resistance. The figures given should therefore be sufficient to show the order of signal required for such purposes as television on frequencies high enough to demand a diode frequency-changer.

It is worth noting that the signal/noise ratio of a diode rectifier is expressed in terms of a power input, and is largely independent of diode characteristics (though the factor F^2 can vary between unity and less than 0.1), whereas the performance of an amplifying valve is usually expressed in terms of an equivalent noise resistance on the input side, i.e. an input voltage. This arises from the fact that an amplifying valve is nominally a voltage-operated device, and although at very high frequencies the power absorbed is substantial, there is no direct connection between power absorbed at the input and power delivered to the output circuit; a diode frequency-changer, on the other hand, is a power-operated device. This makes it difficult to compare the signal/noise performance of a diode frequency-changer with that of an amplifying valve; the only reasonable common basis is to take (mA)² output per microwatt input. For the diode, we find from equation (21) that the output current at signal frequency is

$$I^2 = \frac{x^2E_0^2}{Z_0} \cdot \frac{\rho_0\cos\alpha/2}{R} \cdot \frac{R_a}{R} \cdot \frac{1}{R_a}\cos\alpha/2 \quad .. \quad .. \quad (30)$$

Now the first factor on the r.h.s. of (30) is the power input (which will normally be measured in μW.), the second factor has been plotted in Fig. 12, from which it will be seen that in round figures it is equal to 0.5, and $(\cos\alpha/2)(R_a/R)$ should be determined from Fig. 3 for the particular value of R_a/R, but a typical value would be 0.2, so that a rough approximation for equation (30) is

$$I^2 \doteqdot 0.1 \times (1/R_a) \times (\text{watts input})$$

or if the units are reduced to mA, kΩ and μW, the diode has a performance in units of (mA)²/μW of

$$S_d = 10^{-4}/R_a \quad .. \quad .. \quad .. \quad (31)$$

For a multi-electrode valve with mutual or conversion conductance G and input resistance ρ_0 the output current squared is

$$I^2 = G^2E^2 = G^2\rho_0 \times (\text{watts input})$$

or if G is converted to mA/V, ρ_0 to kΩ and I to mA, the performance factor is in units of (mA)²/μW.,

$$S_p = 10^{-3}G^2\rho_0 \quad .. \quad .. \quad .. \quad (32)$$

Now the squared noise current is in both cases (diode and multi-electrode valve) directly proportional to the D.C. component of anode current, so that the signal/noise figure of merit is (mA)²/μW-mA (where the mA in the denominator refers to D.C. current) and is obtained by dividing S_d or S_p by the appropriate anode current i_a. For example, if a diode has an internal resistance of 500 ohms and is run at a mean rectified current of 1 mA,

$$S_d/i_a = 10^{-4}/0.5 = 2 \times 10^{-4} \text{ (mA)}^2/\mu\text{W.-mA.}$$

Now consider a multi-electrode amplifying valve with $G = 10$ mA/V. operated at a frequency where $\rho_0 = 500$ ohms, and with an anode current of 15 mA.,

$$S_p/i_a = 10^{-3} \,.\, 10^2 \,.\, 0.5/15 = 3.3 \times 10^{-3} \text{ (mA)}^2/\mu\text{W.-mA.}$$

Thus the diode frequency-changer cannot

readily compete with an amplifying valve at a frequency where the latter gives appreciable gain, provided the value of G/i of the amplifying valve is of the order or 0.5 or more ; in this case the factor appears as G/i instead of G^2/i because one factor G has already been taken in assuming $G\rho_0$ is several times greater than unity to give gain where the amplifier feeds into another similar valve. This conclusion is, however, based on the assumption that a diode for use at ultra-high frequencies cannot readily be made with an internal resistance less than 500 ohms at currents of a few milliamps ; it is for those who develop new valves to show whether it is easier to lower the resistance of a diode or to increase the factor $G^2\rho_0/i$ of a multi-electrode valve at ultra-high frequencies.

6. Acknowledgment.

The author is indebted to the Management of A. C. Cossor Ltd., for permission to publish this work.

Correspondence

Theory of Short-Wave Oscillations with the Magnetron

To the Editor, "The Wireless Engineer".

SIR,—In a series of papers in the *Quarterly Journal of Mathematics*[1] I have discussed space charges in a magnetic field and the theory of short-wave oscillations with the magnetron. This note gives an account of the papers and an observation on the tilt of a split-anode magnetron.

The first paper solves the problem of the steady motion of a saturated space charge between a thin filament and a coaxial cylinder, in a uniform magnetic field parallel to the filament. The time taken by an electron to pass from the filament to the turning point is $2.85/10^7H$, so that the wavelength in ether corresponding to oscillations whose periodic time is the time taken by an electron to traverse one orbit is 17,100/H centimetres when the current is saturated. The greatest radius of sheath that will catch the electrons is $15{,}400 I^{1/3}/H^{2/3}$, where I is the emission current per centimetre length of the filament.

In the second paper it is pointed out that the saturation current is considerably greater than that usually used in magnetrons, so that some progress can be made by neglecting the effect of space charge. The theory is given first for a single anode magnetron. In this and the following papers current is calculated by a method of great importance which seems to have been first used by Ballantine[2], and explained more fully by v. Engel and Steenbeck.[3] The latter authors show that the current due to a charge of e electromagnetic units, between two electrodes which together enclose it completely, is $e\mathbf{vE}$, where $\mathbf{vE}$ is the scalar product of the velocity and the electric force for unit difference of potential between the electrodes. This current has also been used by Bakker and de Vries[4]. Current is reckoned as the rate of increase of the charge induced in one electrode by the enclosed charges, and flows during the whole time that the charges remain between the electrodes. To reckon current by the number of electrons which fall on an electrode is wrong, and reduces to absurdity many investigations on short-wave oscillations. Ballantine's theory is correct until the wavelength of the corresponding electric oscillations has become short of the order of the distance between the electrodes, while the other process is only correct when the wavelength is very long. In my second paper I suppose that the electrons emitted by the filament just graze the anode in the steady motion, and are caught on the filament when they return. Condenser oscillations of frequency $\nu = \frac{1}{2}\omega$, where $\omega = He/m$, are shown to be maintained.

Similar methods are applied in the third paper to the split-anode magnetron. The frequency $\nu = \omega$ is selected for calculation. The current is not sinoidal, but the fundamental or first harmonic is the real part of $(a_1 - ib_1)\, I \exp i\nu t$, where the oscillatory potential is proportional to the real part of $\exp i\nu t$. Oscillations are maintained on Lecher wires of suitable length if a_1 is negative. Calculation shows that $a_1 = -0.233$, so that the condition of maintenance is satisfied.

Methods are devised in the fourth paper for calculating the effect of the filament on electrons which come near it, and the precession caused at a distance. It is curious that both depend on the same functions, which resemble the elliptic functions, the real orbit having much the same relation to a circular orbit as the finite motion of a pendulum has to an infinitely small one. The field due to a small alternating potential between the segments of the anode has hitherto been allowed for accurately, but that field is now taken to be uniform. If the oscillatory potential is of the order of 5 volts, most of the returning electrons miss the filament. The methods of this paper provide a means of finding expeditiously whether any electron is caught on the anode or filament, and when. It is common for an electron to go round five or ten times before falling on the anode.

These results are used in the fifth paper to find, in a particular case, whether oscillations are maintained with multiple orbits. The approximation of a uniform disturbing field, used in the fourth paper, yields the number $a_1 = -0.204$ instead of -0.233 for the first orbit, so that the approximation is fairly good. That number is changed to $+0.436$ for the sum of the first seven orbits, at which stage the calculations are stopped, since 95 per cent. of the electrons have by then been caught on the anode. Thus oscillations of 5-volt amplitude are not maintained in this case. At the end of the fifth paper I calculated the strength of oscillations of different frequency maintained by a single anode magnetron, for which the calculations are simple, and found (for a single orbit) an amplitude of potential proportional to $-\cos 2\nu\pi/\omega$, the condition of maintenance being that $\cos 2\nu\pi/\omega$ shall be negative.

The points brought out in these papers are that current must be correctly calculated, that orbits after the first must be considered when the oscillation is large, and that we can only properly find whether a magnetron will maintain oscillations in a circuit, without inquiring whether it has any specific frequency of its own. There has been much misunderstanding of the last point.

It is well known that strong oscillations require the magnetic field to be inclined to the filament at a certain angle called the tilt, which may be as much as 8 deg. This tilt was attributed by Kilgore[5] and Linder[6] to the reduction of space charge. The experiments of Harvey[7] show that the tilt decreases with the emission and appears to tend to zero for small emissions. The emissions recorded do not fall below 5 mA. With a CW10 magnetron adjusted to give waves of length 26 cm. in an aerial, and an emission of 0.2 mA., I have found the maximum oscillation with the magnetic field parallel to the filament, and a continuous decrease with tilt. With an emission of 0.25 mA there is still oscillation with the field parallel to the filament, but it is increased slightly by a tilt of 1 deg. on either side.

It is not easy to see what effect space charge has, so that the view of Kilgore and Linder is a pure conjecture. The true theory of the tilt for large oscillatory currents seems to have been given by Terman[8]. It is, essentially, that if the first orbit is favourable for maintaining oscillations, subsequent orbits tend to become unfavourable by precession; and we can stop at a favourable point by tilt or by end plates. Terman refers to Kilgore and Linder, so that a casual reader might suppose the theory to be theirs, whereas it is Terman's so modestly presented. Terman's theory is borne out by the calculations of my fifth paper. I have recalculated the values of a_1 for the first and subsequent orbits, with the following result:

First orbit	$a_1 = -0.204$
First two orbits ..	-0.422
First three orbits ..	-0.317
First four orbits ..	-0.048
First five orbits ..	$+0.306$
First six orbits ..	$+0.498$
First seven orbits ..	$+0.463$

The last figure is given as 0.436 in my paper: I cannot now say whether this figure is due to an error of calculation or a misprint. We see that the strength of oscillation in this numerical example is first increased by adding orbits, and subsequently reduced, so that four orbits will only just oscillate. To remove all but two or three orbits by tilt or end plates would be best in this instance.

On the other hand, oscillations are maintained by the first orbit alone, as shown in my second and fifth papers. If, therefore, there is a certain emission velocity to ensure that electrons in the steady orbit are caught when they return to the filament, a really small oscillation will always be maintained: by this we mean one so small that electrons are not deflected or retarded from the filament by the oscillatory field. This, I think, accounts for Harvey's observations.

In the paper of Harvey[9] on the magnetic cut off, various possibilities of explaining the foot of the curve are examined and excluded. It seems to me that the effect is due to a cause not there mentioned, namely the scattering of electrons by near approach to each other, whereby it becomes inadmissible to treat the field as the Coulomb field of the average charge. For information on this phenomenon reference may be made to the review of K. T. Compton and Langmuir[10]. A method of calculating the number of electrons at any point in the classical theory of a cylindrical diode (without magnetic field but with emission velocity) has been given by Wheatcroft[11].

F. B. PIDDUCK.

Corpus Christi College, Oxford.
Aug. 16th, 1941.

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Noise in Receiving Aerials

To the Editor, "The Wireless Engineer"

SIR,—It appears to be becoming customary to describe the external noise-level at a receiving site in terms of the "equivalent temperature of the radiation resistance" of an aerial situated at that point. The chief advantage is that the figure so obtained would appear to be independent of band-width of the receiver, which would not be true if the noise were expressed in μV/m.

But the whole value of this mode of expression is vitiated by the fact that in noisy sites the noise received by the aerial probably has not the characteristics of thermal noise. The definition of "fluctuation noise" is that it is the resultant of numerous components in random phase, and in consequence its mean squared voltage varies as the band-width and its peak voltage approximately as the square root of the band-width. Impulsive noise, on the other hand, consists of a series of separate impulses of more or less steep wave-front, and provided the pulse duration is short compared with the time-constant of the receiver, the peak voltage is linearly proportional to the band-width. These differences in characteristics are important in three ways:—

(1) For a given r.m.s. energy (to which the equivalent temperature corresponds) the acoustic annoyance of impulsive noise is greater than that of thermal noise.

(2) Various limiting circuits are fairly effective on impulsive noise, but not on thermal noise.

(3) In communication by frequency-modulation there is a very marked difference in the response to impulsive noise and to fluctuation noise, particularly in relation to very weak signals and the threshold of improvement of signal/noise ratio.

In view of the importance of impulsive noise (most "man-made-static" is of this type) and the marked difference of its characteristics from those of thermal noise, it would be preferable to define aerial noise-level in terms of peak μV/m. in a given band-width, with a statement of the proportion of impulsive noise if this is known.

London, N.21. D. A. BELL.
30th August, 1941.

Coupling Circuits as Band Pass Filters—Part II.*

By E. K. Sandeman

(Continued from page 367 of September issue)

The Capacity Tap Coupling Circuit

THIS circuit is shown in Fig. 1. It will be recognised as a circuit in common use for coupling the anode of a valve to its load.

The derivation of the formulae for the design of this circuit as a band pass filter is instructive because it applies the general method of solution of dissymmetrical filter sections, that is filter structures which possess a non-symmetrical arrangement of their elements so that the input and output image impedances are unequal. I am indebted to Group Captain W. P. Wilson for introducing me to this simple line of approach.

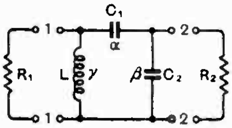

Fig. 1.

Conventions

Z_1 = image impedance at terminals 1, 1, Fig. 1
Z_2 = image impedance at terminals 2, 2, Fig. 1
SC_1 = short circuit impedance looking into terminals 1, 1 (i.e. with terminals 2, 2 shorted)
SC_2 = short circuit impedance looking into terminals 2, 2
OC_1 = open circuit impedance looking into terminals 1, 1
OC_2 = open circuit impedance looking into terminals 2, 2
P = propagation constant of the structure
R_1 and R_2 = values of Z_1 and Z_2 at geometric mid-band frequency.

Let α, β and γ be respectively the impedance of the elements C_1, C_2, and L.

The relations derived immediately below are not all essential to the present solution, but certain of these have been given on account of their intrinsic interest.

$$SC_1 = Z_1 \tanh P = \frac{\gamma\alpha}{\gamma + \alpha} \quad \ldots \quad (1)$$

$$OC_1 = Z_1 \coth P = \frac{\gamma(\alpha + \beta)}{\alpha + \beta + \gamma} \quad \ldots \quad (2)$$

$$SC_2 = Z_2 \tanh P = \frac{\alpha\beta}{\alpha + \beta} \quad \ldots \quad (3)$$

$$OC_2 = Z_2 \coth P = \frac{\beta(\alpha + \beta)}{\alpha + \beta + \gamma} \quad \ldots \quad (4)$$

Hence

$$Z_1^2 = \frac{\gamma^2\alpha\,(\alpha + \beta)}{(\alpha + \beta + \gamma)(\gamma + \alpha)} \quad \ldots \quad \ldots \quad (5)$$

$$Z_2^2 = \frac{\alpha\beta^2(\gamma + \alpha)}{(\alpha + \beta + \gamma)(\alpha + \beta)} \quad \ldots \quad \ldots \quad (6)$$

$$\tanh^2 P = \frac{\alpha(\alpha + \beta + \gamma)}{(\alpha + \beta)(\gamma + \alpha)} \quad \ldots \quad \ldots \quad (7)$$

$$\frac{Z_1}{Z_2} = \frac{\gamma}{\beta} \cdot \frac{\alpha + \beta}{\gamma + \alpha} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

$$Z_1 Z_2 = \frac{\alpha\beta\gamma}{\alpha + \beta + \gamma} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

$$\cosh^2 P = \frac{1}{1 - \tanh^2 P}$$
$$= \frac{(\alpha + \beta)(\gamma + \alpha)}{\beta\gamma} \quad \ldots \quad \ldots \quad (10)$$

Equations (1) to (10) are quite general for all π structures. For the structure shown in Fig. 1 the following substitutions are now made:

$$\alpha = \frac{1}{C_1 j\omega} = -\frac{j}{C_1\omega} = -\frac{a}{\omega} \quad \ldots \quad (11)$$

$$\text{Note that } a = \frac{j}{C_1} \quad \ldots \quad \ldots \quad (11a)$$

$$\beta = \frac{1}{C_2 j\omega} = -\frac{j}{C_2\omega} = -\frac{ma}{\omega} \quad (12)$$

$$\text{Note that } ma = \frac{j}{C_2} \quad \ldots \quad \ldots \quad (12a)$$

$$\gamma = Lj\omega = c\omega \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

$$\text{Note that } c = jL \quad \ldots \quad \ldots \quad \ldots \quad (13a)$$

Then equations (5), (6) and (8) become

$$Z_1^2 = \frac{c^2\omega^2 \cdot \dfrac{a^2}{\omega^2}(m + 1)}{\left[c\omega - \dfrac{a}{\omega}(m + 1)\right]\left[c\omega - \dfrac{a}{\omega}\right]}$$

$$= \frac{a^2c^2\omega^2(m + 1)}{(c\omega^2 - a \cdot \overline{m + 1})(c\omega^2 - a)} \quad \ldots \quad (5a)$$

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* MS. accepted by the Editor, June, 1941.

$$Z_2{}^2 = \frac{\dfrac{-m^2a^2}{\omega^2} \cdot \dfrac{a}{\omega}\left(c\omega - \dfrac{a}{\omega}\right)}{-\left[c\omega - \dfrac{a}{\omega}(m+1)\right](m+1)\dfrac{a}{\omega}}$$

$$= \frac{\dfrac{m^2a^2}{\omega^2}(c\omega^2 - a)}{[c\omega^2 - a \cdot \overline{m+1}](m+1)} \quad \ldots \quad (6a)$$

$$\frac{Z_1}{Z_2} = \frac{c\omega}{-\dfrac{ma}{\omega}} \cdot \frac{-\dfrac{a}{\omega}(m+1)}{c\omega - \dfrac{a}{\omega}} = \frac{c(m+1)\omega^2}{m(c\omega^2 - a)}$$

$$\ldots \quad \ldots \quad (8a)$$

The cut-off frequencies of this structure exist at the frequencies where Z_1 and Z_2 are respectively 0, 0 ; 0, ∞ ; ∞, 0 ; or ∞, ∞. Inspection of equations 5a and 6a shows that the cut-off frequencies $f_1 = \frac{\omega_1}{2\pi}$ and $f_2 = \frac{\omega_2}{2\pi}$ where f_1 is the lower cut-off frequency, are defined by

$$\omega_1{}^2 = \frac{a}{c} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

$$\omega_2{}^2 = \frac{a}{c}(m+1) \quad \ldots \quad \ldots \quad \ldots \quad (15)$$

ω_2 is the upper cut-off frequency because $m + 1 > 1$.

Note also that

$$m + 1 = \frac{\omega_2{}^2}{\omega_1{}^2} \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

Determination of the value of L.

Eliminate a and m between 5a, 14 and 15,

$$\therefore \quad Z_1{}^2 = \frac{\omega^2\omega_1{}^2\omega_2{}^2c^2}{(\omega^2 - \omega_2{}^2)(\omega^2 - \omega_1{}^2)}$$

Putting $c = jL$ and $\omega^2 = \omega_1\omega_2$

$$R_1{}^2 = \frac{\omega_1{}^3\omega_2{}^3L^2}{(\omega_2{}^2 - \omega_1\omega_2)(\omega_1\omega_2 - \omega_1{}^2)}$$

$$= \frac{\omega_1{}^2\omega_2{}^2L^2}{(\omega_2 - \omega_1)^2}$$

$$\therefore \quad L = \frac{\omega_2 - \omega_1}{\omega_1\omega_2} \cdot R_1 = \frac{f_2 - f_1}{2\pi f_1 f_2} \cdot R_1$$

$$\ldots \quad \ldots \quad (17)$$

Determination of C_1 and C_2

Eliminate m and c between 5a, 14 and 15.

$$\therefore \quad Z_1{}^2 = \frac{a^2\omega^2\dfrac{\omega_2{}^2}{\omega_1{}^2}}{(\omega^2 - \omega_2{}^2)(\omega^2 - \omega_1{}^2)}$$

Putting $a = \frac{j}{C_1}$ and $\omega^2 = \omega_1\omega_2$

$$R_1{}^2 = -\frac{\dfrac{\omega_2{}^3}{\omega_1} \cdot \dfrac{1}{C_1{}^2}}{(\omega_1\omega_2 - \omega_2{}^2)(\omega_1\omega_2 - \omega_1{}^2)}$$

$$= \frac{\dfrac{\omega_2{}^2}{\omega_1{}^2} \cdot \dfrac{1}{C_1{}^2}}{(\omega_2 - \omega_1)^2}$$

$$\therefore \quad C_1 = \frac{\dfrac{f_2}{f_1}}{2\pi(f_2 - f_1)R_1} \quad \ldots \quad \ldots \quad (18)$$

From 11 and 12

$C_1 = mC_2$, and from 16

$$m = \frac{f_2{}^2}{f_1{}^2} - 1 = \frac{f_2{}^2 - f_1{}^2}{f_1{}^2}$$

$$\therefore \quad C_2 = \frac{C_1}{m} = \frac{\dfrac{f_2}{f_1}}{2\pi(f_2 - f_1)R_1} \cdot \frac{f_1{}^2}{(f_2{}^2 - f_1{}^2)}$$

$$= \frac{f_1 f_2}{2\pi(f_1 + f_2)(f_2 - f_1)^2 R_1}$$

$$\ldots \quad \ldots \quad (19)$$

From 8a, 14 and 15, putting $\omega^2 = \omega_1\omega_2$,

$$\frac{R_1}{R_2} = \frac{\dfrac{\omega_2{}^2}{\omega_1{}^2} \cdot \omega_1\omega_2}{\left(\dfrac{\omega_2{}^2}{\omega_1{}^2} - 1\right)(\omega_1\omega_2 - \omega_1{}^2)}$$

$$= \frac{w_2{}^3}{(\omega_2{}^2 - \omega_1{}^2)(\omega_2 - \omega_1)} = \frac{f_2{}^3}{(f_1 + f_2)(f_2 - f_1)^2}$$

$$\ldots \quad \ldots \quad (20)$$

From (19) and (20) an alternative solution for C_2 can be found in terms of R_2.

$$C_2 = \frac{\dfrac{f_1}{f_2}}{2\pi f_2 R_2} = \frac{f_1}{2\pi f_2{}^2 R_2} \quad \ldots \quad \ldots \quad (19a)$$

Summary.

$$L = \frac{(f_2 - f_1)R_1}{2\pi f_1 f_2} \qquad C_1 = \frac{f_2}{2\pi f_1(f_2 - f_1)R_1}$$

$$\frac{R_1}{R_2} = \frac{f_2{}^3}{(f_1 + f_2)(f_2 - f_1)^2}$$

$$C_2 = \frac{f_1 f_2}{2\pi(f_1 + f_2)(f_2 - f_1)^2 R_1} = \frac{f_1}{2\pi f_2{}^2 R_2}$$

The Inductance Tap Circuit

The circuit is shown in Fig. 2, there being no mutual inductance between L_a and L_b.

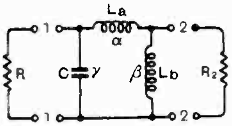


Fig. 2.

Equations 1-10 are still applicable, but in Fig. 2

$$\alpha = L_a j\omega = a\omega \quad \ldots \quad \ldots \quad (21)$$

Note that $a = jL_a$ .. .. (21a)

$$\beta = L_b j\omega = ma\omega \quad \ldots \quad \ldots \quad \ldots \quad (22)$$

Note that $ma = jL_b$ .. .. (22a)

$$\gamma = -\frac{j}{C\omega} = -\frac{c}{\omega} \quad \ldots \quad \ldots \quad (23)$$

Note that $c = \dfrac{j}{C}$ .. .. (23a)

Substituting these in equations 5, 6, and 8

$$Z_1^2 = \frac{\dfrac{c^2}{\omega^2} \cdot a\omega(a\omega + ma\omega)}{(a\omega\overline{1+m} - \dfrac{c}{\omega})\,(a\omega - \dfrac{c}{\omega})}$$

$$= \frac{\omega^2 c^2 a^2(1 + m)}{(a^2\omega^2\overline{1 + m} - c)(a\omega^2 - c)} \qquad (25)$$

$$Z_2^2 = \frac{a^3\omega^3 m^2(a\omega - \dfrac{c}{\omega})}{(a\omega\overline{1 + m} - \dfrac{c}{\omega})(a\omega + ma\omega)} \qquad (26)$$

$$\frac{Z_1}{Z_2} = \frac{ca(1 + m)}{ma(c - a\omega^2)} \quad \ldots \quad \ldots \quad (27)$$

Cut-off frequencies : f_1 and f_2 corresponding to ω_1 and ω_2.

These occur when Z_1 and Z_2 are 0, 0 ; ∞, ∞ ; 0, ∞ ; or ∞, 0.

Hence $a\omega_2 - \dfrac{a}{\omega_2} = 0$

$$\therefore \quad \omega_2^2 = \frac{c}{a} \quad \ldots \quad \ldots \quad \ldots \quad (28)$$

and $a\omega_1(1 + m) = \dfrac{c}{\omega_1}$

$$\therefore \quad \omega_1^2 = \frac{1}{1+m} \cdot \frac{c}{a} \quad \ldots \quad \ldots \quad (29)$$

Comparison of 28 and 29 shows $\omega_2 > \omega_1$ since m is positive, and also that

$$\frac{\omega_2^2}{\omega_1^2} = m + 1 \quad \ldots \quad \ldots \quad \ldots \quad (30)$$

Determination of L_a.

Eliminate c and m between 25, 28, and 30.

$$\therefore \quad Z_1^2 = \frac{\omega^2 a^4 \omega_2^2 \dfrac{\omega_2^2}{\omega_1^2}}{(a\omega^2 \dfrac{\omega_2^2}{\omega_1^2} - a\omega_2^2)(a\omega^2 - a\omega_2^2)}$$

$$= \frac{\omega^2 a^2 \omega_2^2}{(\omega^2 - \omega_1^2)\,(\omega^2 - \omega_2^2)} \quad \ldots \quad (31)$$

Now put $\omega^2 = \omega_1\omega_2$ so that $Z_1 = R_1$.

$$\text{Then } R_1^2 = \frac{\omega_1\omega_2 a^2 \omega_2^4}{(\omega_1\omega_2 - \omega_1^2)(\omega_1\omega_2 - \omega_2^2)}$$

$$= \frac{-a^2\omega_2^4}{(\omega_2 - \omega_1)^2}$$

But $a = jL_a$

$$\therefore \quad R_1^2 = \frac{L_a^2 \omega_2^4}{(\omega_2 - \omega_1)^2}$$

$$\text{Hence } L_a = \frac{(f_2 - f_1)R_1}{2\pi f_2^2} \quad \ldots \quad \ldots \quad (32)$$

Determination of L_b.

From 21a and 22a, $L_b = mL_a$ and from 30, $m = \dfrac{\omega_2^2}{\omega_1^2} - 1$

Hence

$$L_b = (\frac{f_2^2}{f_1^2} - 1)\, L_a = \frac{(f_2^2 - f_1^2)(f_2 - f_1)R_1}{2\pi f_1^2 f_2^2} \quad \ldots \quad \ldots \quad (33)$$

Determination of C.

Eliminate a and m between 25, 28, and 30.

$$\therefore \quad Z_1^2 = \frac{\omega^2 c^2 \dfrac{c^2}{\omega_2^4} \cdot \dfrac{\omega_2^2}{\omega_1^2}}{(\dfrac{c}{\omega_2^2} \cdot \omega^2 \cdot \dfrac{\omega_2^2}{\omega_1^2} - c)\,(\dfrac{c}{\omega_2^2}\omega^2 - c)}$$

and putting $\omega = \omega_1\omega_2$

$$R_1^2 = \frac{\omega_1\omega_2 c^2}{(\omega_1\omega_2 - \omega_1^2)(\omega_1\omega_2 - \omega_2^2)} = \frac{-c^2}{(\omega_2 - \omega_1)^2} \quad \ldots \quad \ldots \quad (34)$$

But $c = \dfrac{j}{C}$

$$\therefore \quad R_1^2 = \frac{1}{C^2(\omega_2 - \omega_1)^2}$$

$$\therefore \quad C = \frac{1}{2\pi(f_2 - f_1)R_1} \quad \cdots \quad \cdots \quad (35)$$

Impedance Ratio : $\dfrac{R_1}{R_2}$

Eliminating c and m between 27, 28 and 30.

$$\frac{Z_1}{Z_2} = \frac{\omega_2{}^2 a^2 \dfrac{\omega_2{}^2}{\omega_1{}^2}}{\left(\dfrac{\omega_2{}^2}{\omega_1{}^2} - 1\right) a(\omega_2{}^2 a - a\omega^2)}$$

Putting $\omega^2 = \omega_1\omega_2$

$$\frac{R_1}{R_2} = \frac{\omega_2{}^4}{(\omega_2{}^2 - \omega_1{}^2)(\omega_2{}^2 - \omega_1\omega_2)}$$

$$= \frac{f_2{}^3}{(f_1 + f_2)(f_2 - f_1)^2} \quad \cdots \quad \cdots \quad (36)$$

Alternative expression for L_b.

Substituting the value of R_1, obtained from 36, in 33 :

$$L_b = \frac{(f_2{}^2 - f_1{}^2)(f_2 - f_1)}{2\pi f_1{}^2 f_2{}^2} \cdot \frac{f_2{}^3 R_2}{(f_2{}^2 - f_1{}^2)(f_2 - f_1)}$$

$$= \frac{f_2 R_2}{2\pi f_1{}^2}$$

Summary.

$$L_a = \frac{(f_2 - f_1)R_1}{2\pi f_2{}^2}$$

$$L_b = \frac{(f_2{}^2 - f_1{}^2)(f_2 - f_1)R_1}{2\pi f_1{}^2 f_2{}^2} = \frac{f_2 R_2}{2\pi f_1{}^2}$$

$$C = \frac{1}{2\pi(f_2 - f_1)R_1}$$

$$\frac{R_1}{R_2} = \frac{f_2{}^3}{(f_1+f_2)(f_2-f_1)^2}$$

The Single Parallel Tuned Mutual Coupling

The circuit is shown in Fig. 3(a), and one equivalent circuit, obtained by replacing the mutual coupling by its equivalent circuit is shown at 3(b). (The equivalent circuit for the mutual coupling could have been drawn as in Fig. 3(c), in which case a solution appears in terms of a Shea Type III$_3$ half-filter section. Neither this solution nor the one shown here is to be preferred on grounds of simplicity).

In 3(b), the circuit of 3(a) has been replaced by an inductance tap circuit plus an ideal transformer : the solution of the inductance tap circuit appears in the preceding summary.

From this solution, and inspection of Fig. 3(b) it is evident that

$$(1 - k^2)L_1 \, (= L_a) = \frac{f_2 - f_1}{2\pi f_2{}^2} R_1 \cdots \quad (37)$$

$$k^2 L_1 (= L_b) = \frac{f_2}{2\pi f_1{}^2} \cdot \frac{k^2 L_1}{L_2} \cdot R_2 \cdots \quad (38)$$

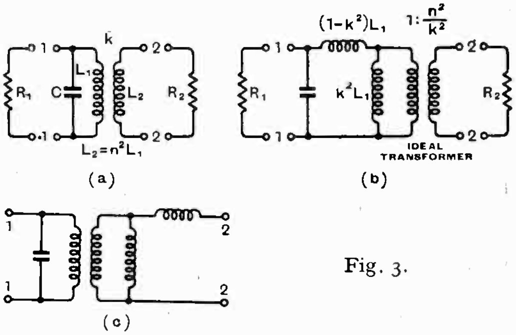
(Since the impedance facing the shunt inductance is $\dfrac{k^2}{n^2} R_2 = \dfrac{k^2 L_1}{L_2} R_2$)

$$\therefore \quad L_2 = \frac{f_2}{2\pi f_1{}^2} R_2 \quad \cdots \quad \cdots \quad \cdots \quad (39)$$

From 37 and 38

$$\frac{1}{1 - k^2} = \frac{f_2}{2\pi f_1{}^2} \cdot \frac{2\pi f_2{}^2}{f_2 - f_1} \cdot \frac{L_1 R_2}{L_2 R_1}$$

$$\therefore \quad \frac{R_1 L_2}{R_2 L_1} = \frac{f_2{}^3}{f_1{}^2(f_2 - f_1)} \cdot (1 - k^2) \qquad (40)$$



(a) (b) (c)

Fig. 3.

Also from the formula for the impedance ratio in the inductance tap case :

$$\frac{n^2 R_1}{k^2 R_2} \cdot = \frac{R_1 L_2}{R_2 k^2 L_1} = \frac{f_2{}^3}{(f_1 + f_2)(f_2 - f_1)^2} \quad \cdots \quad \cdots \quad (41)$$

From 40 and 41

$$\frac{1 - k^2}{f_1{}^2(f_2 - f_1)} = \frac{k^2}{(f_1 + f_2)(f_2 - f_1)^2}$$

$$\therefore \quad k^2 f_1{}^2 = (1 - k^2)(f_2{}^2 - f_1{}^2)$$

$$\therefore \quad k^2 f_2{}^2 = f_2{}^2 - f_1{}^2$$

$$\therefore \quad k = \sqrt{1 - f_1{}^2/f_2{}^2} \quad \cdots \quad \cdots \quad (42)$$

Substituting 42 in 41

$$\therefore \frac{R_1 L_2}{R_2 L_1} = \frac{f_2{}^2 - f_1{}^2) f_2{}^3}{f_2{}^2(f_1 + f_2)(f_2 - f_1)^2} = \frac{f_2}{f_2 - f_1}$$

$$\therefore L_1 = \frac{f_2 - f_1}{f_2} \cdot \frac{R_1}{R_2} L_2$$

$$= \frac{f_2 - f_1}{f_2} \cdot \frac{R_1}{R_2} \cdot \frac{f_2}{2\pi f_1^2} R_2$$

$$= \frac{f_2 - f_1}{2\pi f_1^2} R_1 \qquad \ldots \qquad \ldots \qquad (43)$$

Summary.

$$L_1 = \frac{f_2 - f_1}{2\pi f_1^2} R_1 \qquad L_2 = \frac{f_2}{2\pi f_1^2} R_2$$

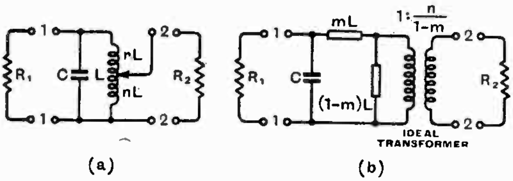
$$k = \sqrt{1 - f_1^2/f_2^2} \qquad C = \frac{1}{2\pi(f_2 - f_1)R_1}$$

$$\frac{R_1}{R_2} = \frac{k^2 f_2^3}{n^2(f_1 + f_2)(f_2 - f_1)^2}$$

(The formula for C has not been derived, but is evidently the same as in the inductance tap circuit).

The Tapped Inductance Circuit

This is shown in Fig. 4(a). The inductance is tapped at a point such that the fraction of the total inductance L between the tap and the lower end of the inductance is nL, the remainder of the inductance is rL.



(a) (b)

Fig. 4.—*In (b) $m = r\,(1 - k^2)$; k = coupling factor between rL and nL in (a).*

The equivalent circuit obtained by replacing the tapped inductance by its equivalent network is shown in Fig. 4(b). The derivation of this equivalent network is given later.

The circuit of Fig. 4(b) consists of an inductance tap circuit plus an ideal transformer such that the inductance tap circuit works between impedance R_1 and $\frac{1 - m}{n} R_2$ where $m = (1 - k^2)r$ and k is the coupling between the two parts of the inductance L in Fig. 4(a) lying respectively each side of the tapping point.

Referring to the summary of the solution for the inductance tap circuit it is evidently possible to write

$$mL = L_a = \frac{f_2 - f_1}{2\pi f_2^2} R_1$$

$$\therefore \; L = \frac{R_1}{m} \cdot \frac{f_2 - f_1}{2\pi f_2^2} \qquad \ldots \qquad \ldots \qquad (44)$$

Also

$$(1 - m)L = L_b = \frac{f_2}{2\pi f_1^2} \cdot \frac{1 - m}{n} \cdot R_2$$

$$\therefore \; L = \frac{R_2}{n} \cdot \frac{f_2}{2\pi f_1^2} \qquad \ldots \qquad \ldots \qquad (45)$$

From equation 36, and inspection of Fig. 4(b),

$$\frac{R_1}{R_2} \cdot \frac{n}{1 - m} = \frac{f_2^3}{(f_1 + f_2)(f_2 - f_1)^2}$$

$$\therefore \; n = \frac{(1 - m) f_2^3}{(f_1 + f_2)(f_2 - f_1)^2} \cdot \frac{R_2}{R_1} \qquad \ldots \qquad (46)$$

From 44 and 45

$$n = \frac{R_2 f_2}{2\pi f_1^2} \cdot \frac{2\pi f_2^2}{f_2 - f_1} \cdot \frac{m}{R_1} = \frac{f_2^3}{f_1^2(f_2 - f_1)} \cdot \frac{mR_2}{R_1}$$

$$\ldots \qquad \ldots \qquad (47)$$

From 46 and 47

$$\frac{(1 - m) f_2^3}{(f_1 + f_2)(f_2 - f_1)^2} \cdot \frac{R_2}{R_1} = \frac{f_2^3}{f_1^2(f_2 - f_1)} \cdot \frac{mR_2}{R_1}$$

$$\therefore \; \frac{1 - m}{f_2^2 - f_1^2} = \frac{m}{f_1^2} \qquad \therefore m = \frac{f_1^2}{f_2^2} \qquad \ldots \qquad (48)$$

Determination of n

From 47 and 48

$$n = \frac{f_2}{f_2 - f_1} \cdot \frac{R_2}{R_1} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (49)$$

Determination of L

From 48 and 44

$$L = \frac{f_2 - f_1}{2\pi f_1^2} R_1 \qquad \ldots \qquad \ldots \qquad \ldots \qquad (50)$$

Determination of r

$$m = r\,(1 - k^2) = \frac{f_1^2}{f_2^2}$$

$$\therefore \; r = \frac{f_1^2}{(1 - k^2)\, f_2^2} \qquad \ldots \qquad \ldots \qquad (51)$$

In the derivation of the equivalent circuit for the tapped inductance given below, it is shown that

$$k^2 = \frac{(1 - n - r)^2}{4nr} \qquad \text{(see equation 68).}$$

Substituting this in 51, and solving for r it can be shown that

$$r = 1 + n \pm 2\sqrt{n\left(1 - \frac{f_1^2}{f_2^2}\right)} \quad .. \quad (52)$$

The negative signs of the roots apply when k is positive and the positive signs when k is negative.

Substituting in 51 the value of n from 49

$$r = 1 + \frac{f_2}{f_2 - f_1} \cdot \frac{R_2}{R_1} \pm 2\sqrt{\frac{f_2}{f_2 - f_1} \cdot \frac{f_2^2 - f_1^2}{f_2^2} \cdot \frac{R_2}{R_1}}$$

$$= 1 + \frac{f_2}{f_2 - f_1} \cdot \frac{R_2}{R_1} \pm 2\sqrt{\frac{f_1 + f_2}{f_2} \cdot \frac{R_2}{R_1}} \quad .. \quad .. \quad (52)$$

Determination of C.

This is evidently the same as in the inductance tap circuit, i.e.

$$C = \frac{1}{2\pi(f_2 - f_1)R_1}$$

Summary.

$$L = \frac{f_2 - f_1}{2\pi f_1^2} \cdot R_1 \qquad C = \frac{1}{2\pi(f_2 - f_1)R_1}$$

$$n = \frac{f_2}{f_2 - f_1} \cdot \frac{R_2}{R_1} \qquad k = \frac{1 - n - r}{2\sqrt{nr}}$$

$$r = 1 + \frac{f_2}{f_2 - f_1} \cdot \frac{R_2}{R_1} \pm 2\sqrt{\frac{f_1 + f_2}{f_2} \cdot \frac{R_2}{R_1}}$$

The negative sign of the root applies when k is positive and vice versa.

$$\frac{r}{n} = 1 + \frac{f_2 - f_1}{f_2} \cdot \frac{R_1}{R_2} \cdot \left[1 + 2\sqrt{\frac{f_1 + f_2}{f_2} \cdot \frac{R_1}{R_2}}\right]$$

My thanks are due to Mr. D. Maurice and Mr. P. Nirodi for working out the detailed algebra of the last solution and for plotting the design curves.

Equivalent Circuit for Auto-transformer or Tapped Inductance

The circuit is shown in Fig. 5(a), and it will be shown that it is equivalent to the circuit in Fig. 5(b).

where $D = r(1 - k^2)L$,

$$F = [1 + r(k^2 - 1)]L$$

and $\quad t^2 = \dfrac{n}{1 - m} \quad$ where $m = r(1 - k^2)$

Open and short circuit impedances.

Let OC_1 and OC_2 be the open circuit impedances respectively looking into 1, 1 and 2, 2; and let SC_1 and SC_2 be the corresponding short circuit impedances.

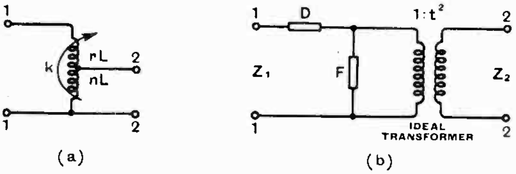


Fig. 5.—t = *turns ratio of ideal transformer.*

Then $OC_1 = Lj\omega$ and $OC_2 = nLj\omega$

Determination of SC_1.

With an e.m.f. "e" applied at 1, 1, let i_1 be the current entering terminals 1, 1, and i_2 the current flowing through 2, 2, the senses being in accordance with the equations:

$$e = rLj\omega i_1 - Mj\omega i_2 \quad .. \quad .. \quad (53)$$

$$0 = Mj\omega i_1 - nLj\omega i_2 \quad .. \quad .. \quad (54)$$

From 54

$$i_2 = \frac{M}{nL} i_1 \quad .. \quad .. \quad .. \quad (55)$$

From 53 and 54

$$SC_1 = \frac{e}{i_1} = j\omega\left(rL - \frac{M^2}{nL}\right) = j\omega L\left(r - \frac{k^2 nr}{n}\right)$$

$$= j\omega Lr(1 - k^2) \quad .. \quad .. \quad (56)$$

Determination of SC_2.

Choose convention such that i_1 and i_2 enter at 2, 2, i_1 flowing through rL and i_2 through nL.

$$\text{Then } e = rLj\omega i_1 - Mj\omega i_2$$

$$= nLj\omega i_2 - Mj\omega i_1 \quad .. \quad .. \quad (57)$$

$$\therefore \quad i_1 = \frac{nL + M}{rL + M} i_2 \quad .. \quad .. \quad (58)$$

$$\therefore \quad i_1 + i_2 = \left(1 + \frac{nL + M}{rL + M}\right) i_2$$

$$= \frac{rL + nL + 2M}{rL + M} i_2 = \frac{L}{rL + M} i_2$$

$$= (1 + \frac{rL + M}{nL + M})i_1$$

$$= \frac{rL + nL + 2M}{nL + M} = \frac{L}{nL + M}i_1$$

$$\therefore \quad i_2 = \frac{rL + M}{L}(i_1 + i_2)$$

and $$i_1 = \frac{nL + M}{L}(i_1 + i_2)$$

$$\therefore \quad S_2C_2 = \frac{e}{i_1 + i_2} = rLj\omega \cdot \frac{nL + M}{L}$$

$$- Mj\omega \cdot \frac{rL + M}{L}$$

$$= j\omega(rnL + rM - rM - M^2)$$

$$= j\omega(rnL - k^2rnL)$$

$$= j\omega rnL(1 - k^2) \quad \ldots \quad \ldots \quad (59)$$

By inspection, from Figs. 5(a) and 5(b).

$$OC_1 = D + F = Lj\omega \quad \ldots \quad \ldots \quad (60)$$

$$SC_1 = D = r(1 - k^2)Lj\omega \quad \ldots \quad (61)$$

$$OC_2 = t^2F = nLj\omega \quad \ldots \quad \ldots \quad (62)$$

$$SC_2 = t^2\,\frac{DF}{D+F} = rnLj\omega(1 - k^2) \quad (63)$$

From 61

$$D = r(1 - k^2)Lj\omega = mLj\omega \text{ say,} \quad (64)$$

where $m = r(1 - k^2)$

From 60 and 64

$$F = (1 - m)jL\omega \quad \ldots \quad \ldots \quad (65)$$

From 62 and 65

$$t^2 = \frac{nLj\omega}{F} = \frac{n}{1 - m} \quad \ldots \quad \ldots \quad (66)$$

Relation between r, n and k.

Since in two series connected coupled inductances, L_1 and L_2, with mutual M between them, the total series inductance

$$L = L_1 + L_2 \pm 2M$$

In Fig. 5(a) $L_1 = nL$, $L_2 = rL$ and $M = k\sqrt{L_1L_2} = k\sqrt{nLrL} = kL\sqrt{nr}$,

Hence $L = nL + rL \pm 2kL\sqrt{nr}$

$$\therefore \quad k = \pm\frac{1 - n - r}{2\sqrt{nr}} \quad \ldots \quad \ldots \quad (67)$$

and $$k^2 = \frac{(1 - n - r)^2}{4nr} \quad \ldots \quad \ldots \quad (68)$$

Design Charts

Single Parallel Tuned Mutual Coupling.

The design chart for this is given in Fig. 6 and its method of use is the same as that of the charts for the double parallel tuned and series parallel tuned circuits previously discussed (see *Wireless Engineer*, September, 1941.)

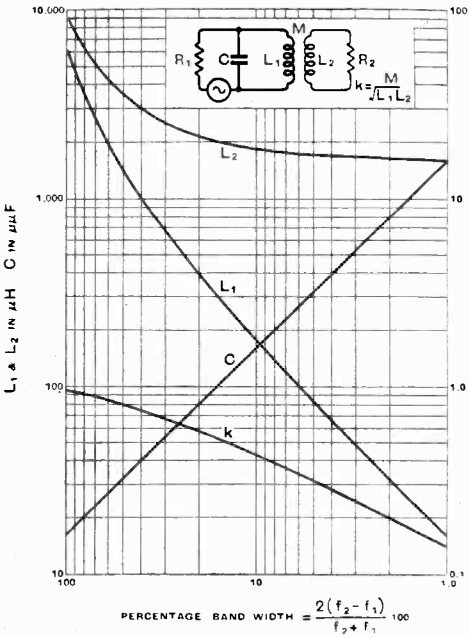


Fig. 6.—*Mutual coupling circuit. Single parallel tuned. k, C, L_1 and L_2 against per cent. band width for $R_1 = R_2 = 10{,}000\ \Omega$ and $\bar{f} = \frac{1}{2}(f_1 + f_2) = 10^6$ c/s.* $k = \sqrt{1 - f_1^2/f_2^2}$;

$$C = \frac{1}{2\pi(f_2 - f_1)R_1}; \qquad L_1 = \frac{f_2 - f_1}{2\pi f_1^2}\,.\,R_1;$$

$$L_2 = \frac{f_2}{2\pi f_1^2}\,.\,R_2.$$

Capacitance Tap and Inductance Tap Circuits.

The design charts for these are given in Figs. 7 and 8. In these filters the impedance ratio and band width are interdependent, so that if the impedance ratio is chosen, the percentage band width is fixed by the curve given for the relation between R_1/R_2 and percentage band width.

The other curves give the values of the filter elements plotted against percentage band width for a structure having a value of $\bar{f} = \frac{1}{2}(f_1 + f_2) = 10^6$ c/s. and designed to work from one impedance of 10,000 ohms connected on the same side as the inductance in the case of the capacitance tap circuit (Fig. 7), and on the same side as the capacitance in the case of the inductance tap circuit (Fig. 8). The second impedance, facing the other side of the coupling is then determined by the impedance ratio of the coupling.

Example :

(1) Given impedance ratio 5,000 : 100 then $\frac{R_1}{R_2} = 50$ and from curve between R_1/R_2 and band width, the band width = 11 per cent.

(2) Given $R_1 = 5{,}000$, $f_1 = 472{,}500$, $f_2 = 527{,}500$.

Percentage band width

$$= 100\,\frac{2(f_2 - f_1)}{f_2 + f_1} = 11 \text{ per cent.}$$

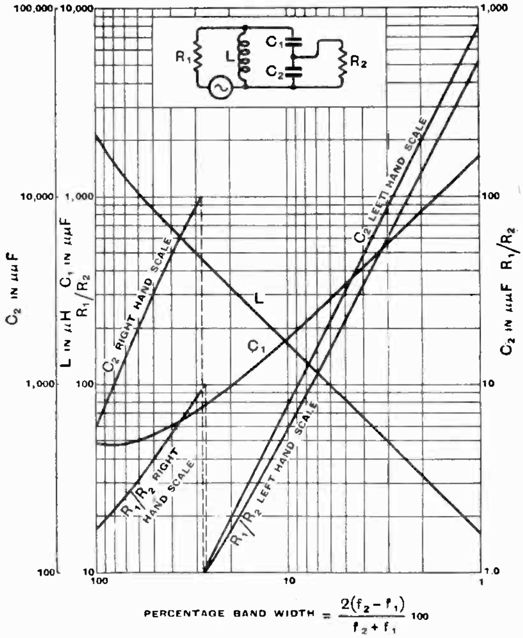


Fig. 7.—*Capacity tap coupling circuit.* R_1/R_2, *L*, C_1 *and* C_2 *against per cent. band width for* $R_1 = 10{,}000\ \Omega$ *and* $\bar{f} = \frac{1}{2}(f_1 + f_2) = 10^6$ *c/s.*

$$R_1/R_2 = \frac{f_2^3}{(f_1 + f_2)(f_2 - f_1)^2}; \quad L = \frac{(f_2 - f_1)R_1}{2\pi f_1 f_2};$$

$$C_1 = \frac{f_2}{2\pi f_1(f_2 - f_1)R_1}; \quad C_2 = \frac{f_1 f_2}{2\pi(f_1 + f_2)(f_2 - f_1)^2 R_1}.$$

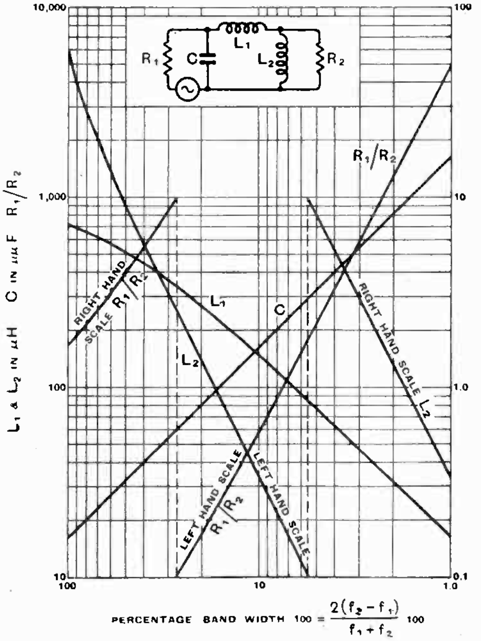


Fig. 8.—*Inductance tap coupling circuit without mutual.* R_1/R_2, *C*, L_1 *and* L_2 *against per cent. band width for* $R_1 = 10{,}000\ \Omega$, *and*

$$\bar{f} = \tfrac{1}{2}(f_1 + f_2) = 10^6 \text{ c/s.}$$

$$R_1/R_2 = \frac{f_2^3}{(f_1 + f_2)(f_2 - f_1)^2};$$

$$C = \frac{1}{2\pi(f_2 - f_1)R_1};$$

$$L_1 = \frac{(f_2 - f_1)R_1}{2\pi f_2^2};$$

$$L_2 = \frac{(f_2^2 - f_1^2)(f_2 - f_1)R_1}{2\pi f_1^2 f_2^2} = \frac{f_2 R_2}{2\pi f_1^2}.$$

From curve between R_1/R_2 and band width

$$\frac{R_1}{R_2} = 50. \quad \text{Hence } R_2 = \frac{5{,}000}{50} = 100.$$

It will be clear that the above two examples specify the same network in different ways. The remainder of the design is then the same for both specifications. It may be noted also that since the R_1/R_2 curve is the same for both capacitance tap and inductance tap circuits, the design may now proceed in terms of either.

Capacitance tap (Fig. 7).

From chart ; corresponding to 11 per cent. band width.

$L = 180$ μH. $C_1 = 160$ μμF.

$C_2 = 660$ μμF.

Transformation for impedance.

Multiply the capacitance and divide the inductances by $\dfrac{10{,}000}{R_1} = \dfrac{10{,}000}{5{,}000}$

Transformation for frequency.

Multiply all elements by $\dfrac{10^6}{f} = \dfrac{10^6}{500{,}000}$

Inductance tap (Fig. 8).

$C = 145\ \mu\mu\text{F}.\ L_1 = 150\ \mu\text{H}.\ L_2 = 38.5\ \mu\text{H}$

Transform for impedance and frequency as above.

Tapped Inductance Circuit.

Two design charts are required for this circuit and are shown in Figs. 9 and 10.

Fig. 9 shows values of L, C and n, plotted against band width for a filter structure having a value of $\bar{f} = \frac{1}{2}(f_1 + f_2) = 10^6$ c/s. and designed to work between impedances $R_1 = R_2 = 10{,}000$ ohms. n is the fraction of L observed between terminals 2 and 3 with terminal 1 open circuited, (see circuit on Fig. 9). f_1 and f_2 are the cut-off frequencies.

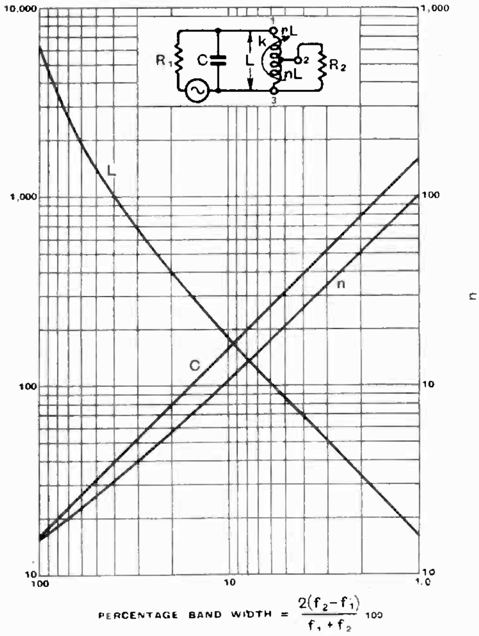


Fig. 9.—*Inductance tap coupling circuit with mutual. L, C and n against per cent. band width for* $R_1 = R_2 = 10{,}000\ \Omega$ *and*

$$\bar{f} = \tfrac{1}{2}(f_1+f_2) = 10^6\ c/s.$$

$$L = \frac{f_2 - f_1}{2\pi f_1^2} R_1\,;\quad C = \frac{1}{2\pi(f_2-f_1)R_1}\,;$$

$$n = \frac{f_2}{f_2 - f_1}\cdot\frac{R_2}{R_1}.$$

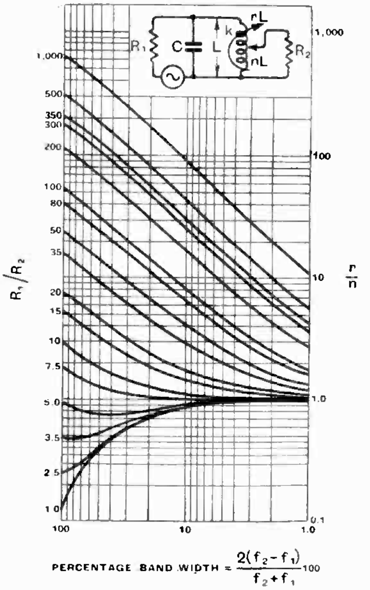


Fig. 10.—*Inductance tap coupling circuit with mutual. r/n against per cent. band width for various values of* R_1/R_2.

$$r/n = 1 + \frac{f_2 - f_1}{f_2}\cdot\frac{R_1}{R_2}\left[1 + 2\sqrt{\frac{f_1 + f_2}{f_2}\cdot\frac{R_1}{R_2}}\right];$$

$$k = \frac{1 - n - r}{2\sqrt{nr}}.$$

Fig. 10 shows values of $\dfrac{r}{n}$ plotted against band width for various values of $\dfrac{R_1}{R_2}$, r is the fraction of inductance L observed between terminals 1 and 2 and 3 open circuited: (see circuit on Fig. 9).

By means of these charts it is possible to design rapidly filters operating between any impedances, and for any band width for which the required value of coupling is realisable.

Example :

To design an inductance tap circuit to pass the frequency range 400-600 kc/s. and to work from $5{,}000\Omega$ to 100Ω:

Make the higher impedance $= R_1$ and the lower impedance $= R_2$, i.e., $R_1 = 5{,}000\Omega$, $R_2 = 100\Omega$.

Then per cent. band width

$$= 100\frac{2(f_2 - f_1)}{f_1 + f_2} = 100\frac{2 \times 200}{1{,}000} = 40\ \%$$

$$f = \tfrac{1}{2}(f_1 + f_2) = 500\ \text{kc/s.}$$

From Fig. 9, corresponding to a band width of 40 per cent. : $L = 1{,}000\ \mu\text{H}$. $C = 40\ \mu\mu\text{F}$.

Transforming for frequency :

$$\text{from } \bar{f} = 1{,}000\ \text{kc/s. to } \bar{f} = 500\ \text{kc/s.}$$

$$L = 2{,}000\ \mu\text{H.} \qquad C = 80\ \mu\mu\text{F.}$$

Transforming for impedance :

$$\text{from } R_1 = 10{,}000 \text{ to } R_1 = 5{,}000$$

$$\underline{\underline{L = 1{,}000\ \mu\text{H.}}} \qquad \underline{\underline{C = 160\ \mu\mu\text{F.}}}$$

These are the final values of L and C.

Again from Fig. 9, corresponding to 40 per cent. band width, n for case where $R_1 = R_2$ is 3.1 ; hence for case where $\frac{R_2}{R_1} = \frac{100}{5{,}000}$,

$$\underline{\underline{n = 3.1 \times \frac{100}{5{,}000} = 0.062,}}$$

so that

$$\underline{\underline{nL = 0.062 \times 1{,}000 = 62\ \mu\text{H.}}}$$

From Fig. 10, corresponding to case where $\frac{R_1}{R_2} = \frac{5{,}000}{100} = 50$

and 40 per cent. band width, $\frac{r}{n} = 12$

whence $r = 12n = 0.744$ and $\underline{\underline{rL = 744\ \mu\text{H.}}}$

The coupling factor k between the two inductances is then given by

$$\underline{\underline{k}} = \frac{1 - n - r}{2\sqrt{nr}} = \frac{1 - 0.062 - 0.744}{2\sqrt{0.062 \times 0.744}}$$

$$= \frac{0.194}{0.43} = \underline{\underline{0.45}}$$

If k is found to be too large to be realised in practice, then either the band width or the impedance ratio must be reduced. This applies equally whether the value of k calculated by the above method is found to be less than unity or (absurdly) greater than unity, as may happen.

(*To be continued*).

Errata to Part I.

In the summary of equations for the Series Parallel Tuned Mutual Coupling on page 363 the equation for k should read $\frac{\phi - 1}{(\phi^2 - \phi + 1)^{\frac{1}{2}}}$. Equation 18, on page 366, should read $= \frac{\phi - 1}{\sqrt{\phi^2 - \phi + 1}}$.

Two E.R.A. Reports

The High Frequency Properties of Various Forms of Wire Specimens. Report M/T69. By G. G. Sutton, B.Sc. Pp. 32. Price 6s.

This is an account of some skin-effect measurements on fine iron wires (20 to 40 S.W.G.) at very high frequencies (20 to 400 Mc/s) by two different methods. In the first method the wire was under tension and its increase of length due to the heating was measured with a microscope ; in the second the wire was enclosed in the bulb of an air-thermometer. In each case a calibrated Eureka wire was used as a comparison standard. The skin-effect in iron depends on the permeability and this varies in a most complicated way with the current, temperature and frequency, falling off very rapidly at very high frequencies. The high-frequency resistance does not lend itself therefore to accurate calculation and measurements at 100 Mc/s bristle with difficulties. The results obtained indicated an effective permeability of about 60 at 20 Mc/s falling to less than 10 at 250 Mc/s.

Tests were made to find the effect of applying a steady longitudinal magnetic field. It was found that the high-frequency resistances fell with increasing field strength, indicating a reduced effective permeability.

The apparatus is stated to be "shown in the photograph," but the photograph does not appear. For high frequencies such as were employed, the skin-effect formula should be $0.25 + (x/2\sqrt{2})$; Arnold used 0.26 instead of 0.25 in order to extend the formula to lower frequencies without a large error. It is stated that potentiometers were used in the arms of a bridge, which sounds rather formidable, but the diagram shows merely that variable resistances were used of a type sometimes employed in potentiometers. In Fig. 4 the ordinates are stated to represent contraction in Cm^{-3}, whatever that may be. The reference to Fig. 14 on p. 8 is presumably intended for Fig. 12. On p. 18 there is a reference to the arc impedance of mumetal but no explanation of the term is given. Much of the work was anticipated by Möhring in the *Hochf : tech. u. Elek : akus.* of June 1939. The report takes us very little, if any, further.

Radio Interference from Thermostats in Refrigerators and Irons. Report M/T67. By S. F. Pearce and S. Whitehead. Pp. 23. Price 4s.

British Standard Specifications set limits to the amount of radio interference that is permissible from the thermostats in refrigerators and irons. The report deals with a statistical survey of the loudness of the clicks produced both on make and on break. If a large number of observations are made it is found that the loudness readings are dispersed over a considerable range. Four refrigerators and one iron were tested. The order of the standard deviation was found to be from 3 to 9 db. The distribution approximated closely to the normal Gaussian—the authors spell it Guassian-type. Various methods of applying the limits of B.S. No. 800 are considered. G. W. O. H.

Both of these reports are obtainable from the British Electrical and Allied Industries Research Association, 15, Savoy Street, London, W.C.2.

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

AERIALS AND AERIAL SYSTEMS

535 396.—Multi-aerial arrangement and method of feeding it with phase-displaced currents to ensure that the power radiated is at all times equal to the average power.

G. Longo. Convention date (France) 11th October, 1938.

535 425.—Aerial in which a column of mercury provides a convenient method of varying the effective length for tuning purposes.

A. C. Ducati. Convention dates (Italy) 15th October, 1938 *and 30th August,* 1939.

535 707.—Short-wave aerial comprising a plurality of in-phase dipoles coaxially arranged.

Marconi's W.T. Co. (assignees of N. E. Lindenblad). Convention date (U.S.A.), 15th October, 1938.

536 259.—Aerial and counterpoise arrangement for giving a zero indication or "artificial horizon" when located in a zone of vertically-polarised waves.

Marconi's W.T. Co. and J. Stewart. Application date 3rd November, 1939.

DIRECTIONAL WIRELESS

535 193.—Cam and link arrangement for automatically correcting quadrantal error in direction finding.

Marconi's W.T. Co. and J. H. Moon. Application date 12th January, 1940.

535 908.—Directional navigation indicator associated with "reversed" detectors to show visually the different strengths of the "complementary" signals in an overlapping beam system.

Standard Telephones and Cables; C. W. Earp; and G. I. A. Bywaters. Application date 24th October, 1939.

536 178.—Direction-finding system or radio compass in which the pick-up currents from two crossed aerials are first separately modulated before being fed to the indicator.

Standard Telephones and Cables; C. W. Earp; and R. V. Coles. Application date 3rd November, 1939.

536 377.—Direction-finding system in which a rotating radio beam is used to give visible indications by time-modulated pulses on a C.R. tube.

Standard Telephones and Cables; W. A. Beatty; and P. K. Chatterjea. Application date 10th November, 1939.

RECEIVING CIRCUITS AND APPARATUS

535 672.—Method of applying automatic volume control to a "differential" receiver, i.e., one which indicates relative changes in strength of signals originating from separate points.

Marconi's W.T. Co. (assignees of R. A. Braden). Convention date (U.S.A.) 30th December, 1938.

535 904.—Arrangement for indicating accurate tuning, in a set fitted with A.V.C., by the cessation of a slight mechanical vibration imparted automatically to the control knob.

Standard Telephones and Cables and C. N. Smyth. Application date 24th October, 1939.

535 907.—Automatic gain control system in which a resistance, variable with temperature, is used to regulate negative feed-back.

Standard Telephones and Cables and D. H. Black. Application date 24th October, 1939.

535 952.—Aerial-coupling circuit with a double resonance characteristic for eliminating the image frequency in a superhet.

Johnson Laboratories Inc. (assignees of D. V. Sinninger). Convention date (U.S.A.) 19th January, 1939.

TRANSMITTING CIRCUITS AND APPARATUS

536 351.—Means for deriving auxiliary signalling currents on a carrier-wave system utilising at least two stages of modulation.

Siemens Bros & Co. and M. Reed. Application date 23rd February, 1940.

536 454.—Means for automatically switching over in the case of failure, from one amplifier to a stand-by, by utilising the variable G.B. of a control valve.

Standard Telephones and Cables; B. B. Jacobsen; and R. A. Martin. Application date 14th November, 1939.

536 500.—Short-wave oscillation-generator in which the effective back coupling is automatically varied, to ensure stability, at different tuning frequencies.

Marconi's W.T. Co.; C. S. Cockerell; J. D. Brailsford; and M. H. Cufflin. Application date 23rd February, 1940.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

534 946.—Electron-discharge tube in which a steady magnetic field is used to control the harmonic modulation of the output.

Standard Telephones and Cables (assignees of I. G. Wilson). Convention date (U.S.A.) 16th November, 1938.

535 002.—Frequency changer of the type in which energy is taken from a beam of electrons by induction instead of by impact against an output electrode.

Marconi's W.T. Co. and G. B. Banks. Application date 30th January, 1940.

535 277.—Arrangement of the lead-in connections to the electrode of a valve for minimising inter-capacity effects and to facilitate screening.

G. H. Taylor. Application date 8th February, 1940.

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

2620. A Reflection Method of measuring Optical and Electrical Constants at Ultra-High Radio Frequencies [using a Straight Vertical Aerial variable in Millimetre Steps up to Several Wavelengths: Measurements on Various Soils, with 73.7 cm Wave: Effect of Moisture: Comparison with McPetrie's Values (16 of 1935)].—L. S. Palmer & G. R. Forrester. (*Proc. Phys. Soc.*, 1st July 1941, Vol. 53, Part 4, pp. 479–489.)

Based on the work dealt with in 4340 of 1938 and back reference. " It is believed that the values of the phase change ϕ were measured to within 1% and that the amplitude reduction factor ρ was measured to within 3%."

2621. Investigations on the Absorption and Ray-Concentration of [Ultra-] Short Electromagnetic Waves in Electrolytes and Biological Tissues, as a Basis for a Medical Application of the Radiation Field.—J. Pätzold. (*Wiss. Veröff. a. d. Siemens-Werken*, 14th March 1940, Vol. 19, No. 2, pp. 1–31.)

The paper referred to in 2580 of September. Application of the Drude and Debye theories to the problem of the calculation of the energy absorption due to ionic conductivity of the electrolyte and to the dipole structure of the water molecule. Preliminary experiments: absorption measurements on (air) wavelengths of 430 and 58 cm: on the latter wavelength the measured values of the " half-strength " layer of electrolyte are much smaller than the calculated, which may be because at the distances in question the energy drop occurs according to a higher-power law than on the 430 cm wave, or because the reflector action is less on the shorter wave on account of the stronger dipole absorption of the water. Whether, in addition, the Debye theory, with its simplifying assumptions, is no longer quantitatively correct at such short wavelengths " cannot be decided by these tests."

Investigations, with reflectors under water, on the near zone of the radiating dipole: the poor behaviour of reflectors designed on the lines of " open air " reflectors used for the parallel beams required in communications technique: improvement on using much smaller types, with apertures only of the order of a single wavelength (*e.g.* hemispherical and " skull-cap " reflectors with aperture diameters 3–40 cm, for air wavelengths around 107 cm, corresponding to water wavelengths around 12 cm: energy maximum about 5–7 cm in front of the aperture plane: no appreciable advantages given by elliptical shape): experiments with dipole embedded in hemispherical reflector of Condensa N instead of in distilled water—high gain but, on the 107 cm air wavelength, no " focusing " action, which however appeared on a 58 cm wave and would no doubt improve on still shorter wavelengths, though these would be of little practical use because of the higher absorption in the electrolyte or tissue. Finally, section 7 deals with temperature-distribution measurements on biological " phantoms ", using first the water-immersed reflector and then the Condensa reflector, on a 107 cm air wavelength.

Among many and various results arrived at by these investigations are :—for the air wavelengths 25–430 cm the half-strength layers come out at 1–4 cm for substances similar to muscular tissue and at considerably higher values for those representing fatty tissue, so that for the fat/muscle layering important in therapy a good thermal action on the muscle, without over-heating of the fat, can be expected. The adverse, rather than favourable, effect of adding a reflector dipole indicates that it gives no true quasi-optical focusing but merely an interference effect. The ceramic reflector appears to have valuable properties. As regards penetration in fat/muscle layers, a 1 m wave is much better than a 25 cm wave. On the whole, results quite unobtainable with the usual condenser-field or coil-field technique are possible.

2622. The Propagational Characteristics of High-Frequency Waves around 30 Mc/s and Their Applications.—K. Ohno & S. Arima. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], pp. 47–63.)

Tokyo observations (1935/39) on reception of 24–43 Mc/s frequencies: propagation to & beyond 2500 km depends chiefly on F_2 layer: up to 2000 km, on F_2 layer but also on irregular or stratified distribution in F_2 or E layer: uselessness of scattered propagation: useful 1000–2000 km service (*e.g.* during Dellinger effect and for time-modulated facsimile, thanks to comparative absence of multiple paths) given by "quasi-regular" reflection (4284 of 1939) which, unlike the regular reflection of the same waves, was little affected by the variation of solar activity during the period mentioned. These waves undergo far less attenuation than ordinary short waves in passing through the E layer, and do not undergo strong attenuation on being reflected from the F_2 layer until the max. usable frequency is approached: properly used, therefore, they can economise in operating cost (2151 of 1940).

2623. Penetration of Thin Ionospheric Layers.—A.C. Deb. (*Indian Journ. of Phys.*, Dec. 1940, Vol. 14, Part 6, pp. 451–457.)

Saha & Rai have adapted Gamow's treatment of the transparency of the potential barrier surrounding an atomic nucleus to the problem of the propagation of electromagnetic waves through an ionospheric "electron barrier", assuming, for their numerical calculations, a linear gradient and an isosceles-triangle outline of the barrier: they find that "the amount of energy transmitted falls to half its value, for the assumed form of barrier and for a gradient of electron density characteristic of the F layer, if the half-breadth of the barrier is about 1.5 km": for the reference here given *see* 2624, below.

"Recent observations show that, though the complete form of the electron barrier may not have any simple geometric form, the portion of it near the max. electron density (which is determinative of the penetration frequency) has the simple form of a parabola. The transparency coefficient of a potential barrier of this form has already been calculated in quantum mechanics by the well-known B.W.K. [Brillouin - Wentzel - Kramers] method, and in the present paper this method has been adapted for determining the reflection coefficients of ionospheric regions having distribution of electron density of similar form. . . . From the curves in Fig. 2 it is seen that the reflection coefficient is not zero [but 0.5] for the so-called critical frequency. For the two cases considered it becomes so only when the frequency has been increased above the critical value by about 50 and 30 times the square roots of the critical frequencies. This shows that the reading of critical frequency from the P'–f curve in the usual way, *i.e.* by noting the frequency at which reflection from the ionised region ceases, entails a certain percentage of error. A comparison of the two curves, for $H = 11.4$ km and for $H = 50$ km, representing the E and F regions respectively, shows that for a region which is more diffuse a smaller percentage departure from f_0 is needed for complete penetration: in other words, for a diffuse region the transition from complete reflection to complete transmission is sharper."

2624. Paper on the Penetration of the Ionosphere at Frequencies near the Critical Frequency, treated by Wave Optics [Adaptation of Gamow's Treatment].—Saha & Rai. (*Proc. Nat. Inst. Sci. India*, Vol. 3, 1937, p. 359 onwards.) Referred to in 2623, above. For a later paper *see* 1754 of 1940.

2625. On the Mechanism of the Nitrogen Afterglow [Rejection of Cario-Kaplan Theory: New Theory (Modification of Triple-Collision Hypothesis)].—H. Hebb & H. Sponer. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 925: summary only.)

2626. Equivalent Thickness of the Atmospheric Nitrous Oxide Layer [presumably at a High Level & of Photochemical Origin: Lower Limit of 3 mm at NTP as Equivalent Thickness].—A. Adel. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 944–945: summary only.)

2627. A Grating Map of the Infra-Red Solar Spectrum: 14 mu to 2 mu [Resolution of Atmospheric Bands of Carbon Dioxide, Ozone, Nitrous Oxide, & Water Vapour: etc.].—A. Adel. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 915: summary only.)

2628. The Solar Radiation Constant and the Active Region on the Sun.—F. Sanford: Abbot. (*Science*, 4th July 1941, Vol. 94, p. 18.)

Prompted by Abbot's paper (1827 of July). "The present writer undertook to find a relation between the solar constant and the permanently disturbed region on the sun several years ago, but without success. The limits of this region seem to be very sharply defined. However, Abbot's results seem to indicate that the intensity of solar radiation may be related to the solar rotation period, but that its variation occurs a few days before the sunspot-disturbance region is facing the earth."

2629. Birth Distribution of Sunspots [Frequency Curve of Observed First Appearances].—G. H. A. Archenhold. (*Nature*, 12th July 1941, Vol. 148, p. 57: summary only.)

2630. Geomagnetic Character and Cosmic-Ray Intensity Pulses: Additional Note.—J. W. Broxon: Forbush. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 909.) *See* 2062 of August: the writer inadvertently omitted reference to Forbush's paper (1608 of June) "in which he arrived at about the same conclusions by a different method".

2631. Summaries of Papers on Cosmic-Ray Research, American Physical Society Meeting (South-Eastern Section).—(*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 929–932.)

2632. A New Algebraic Method for the Determination of Unknown Periods.—K. Stumpff. (*Gerlands Beiträge zur Geophysik*, No. 1, Vol. 57, 1940, pp. 1–19.)

Author's summary :—" In addition to other methods for the analysis, into its elementary periodic components, of a series of values which constitutes a number of sine waves, there are the so-called algebraic methods, which allow the frequencies of the unknown periods to be derived together from the roots of an algebraic equation. These methods, although of great mathematical elegance, have never made headway in practice because—particularly in problems of this type occurring in geophysics—they are all too sensitive to observational errors and other influences, which cause deviations of the series from the assumed mathematical form.

" The method here described, which is based on a preliminary harmonic analysis of the series under investigation, avoids these disadvantages as much as possible and leads to useful results even when those waves which are near a certain part of the curve spectrum are taken as unknown and the other waves present are neglected. The method solves, also, the problem of how to determine directly, without the use of the often extremely complicated periodogram analysis (with its calculation of phase-diagrams, etc.), the waves represented by a series of observations from the course of the Fourier coefficients of that series. The use of the method is illustrated by the working out of several examples " : it is successful even when the empirical series has strongly aperiodic components. The basis of the method is the fact that in the results of harmonic analysis, the Fourier coefficients, there occur linear combinations of the observational values in which the action of the periodic elements of the curve are brought strongly to the fore, while the aperiodic disturbances are suppressed. These Fourier coefficients have, also, the property that they are derived, whatever their order, in a completely homogeneous way from the whole of the observational values. If, therefore, the algebraic method of differences can be so modified that the differences are replaced by the far more favourable Fourier coefficients, the object is attained. This is found to be possible on the condition that Fourier coefficients of the series to be analysed are actually present, at any rate in a limited region of the spectrum.

2633. Study on the Resultant Amplitude of Multi-Vibrations whose Phases and Amplitudes are at Random [for Statistical Research on Fading : the Cases when Phase is Constant & Amplitude varies, *vice versa*, & when Both vary irregularly Simultaneously].—M. Nakagami. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], Abstracts pp. 1–2.) For previous papers *see* 2883 of 1940.

2634. The Accuracy of Field-Strength Measurements [and a Field-Strength Meter & Its Calibration].—Veegens & van Zelts. (*See* 2783.)

2635. A Contribution on the Refraction of Electric Waves at the Earth's Surface [with Particular Reference to Propagation from Below Ground to the Open Air, as in Communication or Radio Prospecting from Mines, etc.].—R. M. Wundt. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 352–357.)

Author's summary :—" In the passage of plane electric waves from the earth into the air, inhomogeneous plane waves emerge into the air, having their planes of equal amplitude perpendicular to the plane of incidence in the direction of propagation. The attenuation transverse to the propagation direction is caused by the differences in the paths traversed in the first medium. The propagation velocity and the penetration velocity [*see* section 2] of the waves in the air can be greater or smaller than the corresponding velocities in the earth. Similarly the angle of refraction is greater or less than the angle of incidence, and for every conducting material there is an angle of incidence for which the angle of refraction is of the same value. The max. angle of refraction is always smaller than 90°, and reaches the value of 45° for very large values of m_1 [m_1 is a quantity selected as a parameter for the curves given : it is equal to $6 \times 10^3 \times \sigma_1\lambda_0/\epsilon_1$, and values for it are given in a table (p. 354) for the two extreme wavelengths 10 m and 20 000 m and for values of ϵ_1 of 5 and 80 : in the curves, a dielectric constant of 5 is chosen as representing normal conditions, and for this the value of m_1 is seen to range from 0.012 to 2400 according to the wavelength and the value of σ_1 (badly, highly, and very highly conducting soils)].

" Total reflection does not occur. For the limiting angle of total reflection there is a maximum, dependent on m_1, for the amount of the emerging energy : at this maximum a considerable proportion of the incident energy passes out into the air " [this maximum lies in the region $m_1 = 10^{-2}$ to $m_1 = 1$, and for vertical polarisation nearly attains unity ; so that here, at the same angle of incidence at which total reflection begins in an insulator, almost the whole of the energy emerges into the air ; while for horizontal polarisation the maximum energy emerging is slightly less. The falling off as m_1 is decreased is proportional to $\sqrt{m_1}$; as m_1 is increased it is proportional to m_1]. A fuller treatment is to appear in *Lorenz-Berichte*.

2636. Acoustic Refraction and Total Reflection : Experiments with Gases with Continuous Transition of Boundary Layers [Production of " Acoustic Head Wave " : " Transversely Damped Wave " as Cause of Total Reflection : Close Analogy to Optics.]—O. van Schmidt & A. Kling. (*Physik. Zeitschr.*, 1st/15th Sept. 1940, Vol. 41, No. 17/18, pp. 407–409.)

Further development of the work dealt with in 1368 of 1939.

2637. Lloyd's Single-Mirror Interference Fringes [Clearing-Up of Discrepancies, and the Nature of the Interference System produced by Reflection from an Optically Less Dense Medium: Phase Change in Region of π for Grazing Incidence: Possibility of obtaining Photographic Evidence of Change differing from π].—P. F. Titchmarsh. (*Proc. Phys. Soc.*, 1st July 1941, Vol. 53, Part 4, pp. 391–402.)

2638. Measurements of Some Optical Properties of Atmospheric Haze, *and* Angular Distribution of Light scattered in Liquids.—E. O. Hulburt: L. H. Dawson & E. O. Hulburt. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 914: p. 914: summaries only.)

2639. The Stabilisation of Electromagnetic Waves on a Line which has a Source of Current at the Receiving End.—V. I. Kovalenkov. (*Automatics & Telemechanics* [in Russian], No. 5, 1940, pp. 67–76.)

The electromagnetic processes occurring on a telegraph line when the key is operated at the sending end are considered for the cases when the receiving end has (a) a battery only (Fig. 1), and (b) a battery and a relay in series (Fig. 6). Formulae are derived for (a) to determine the current and voltage distribution along the line, and curves are plotted (Figs. 2–5) for the case of a 5 mm iron line 400 km long. Similar formulae are derived for (b), and a curve is plotted (Fig. 8) showing the building-up of the relay current when the reflection of the waves from the receiving end, subsequent to the first wave, can be neglected.

2640. The Interpretation of Amplitude and Phase Distortions in Transmission Lines by the Echo Spectrum.—Someya. (*See* 2761.)

2641. Conditions for Minimum Attenuation in Coaxial Cables at High Frequencies, *and* The Distortions of Signals in Non-Uniform Cables.—Malatesta: Zin. (*See* 2762 & 2763.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

2642. Geoelectric Constitution of the Subsoil and Protection against Lightning [Survey, including Description of the Absroth Lightning Research Area].—V. Fritsch. (*Naturwiss.*, 4th July 1941, Vol. 29, No. 27, pp. 397–403.) For a long paper on the same subject see *Gerlands Beiträge zur Geophysik*, No. 1, Vol. 57, 1940, pp. 65–108. *Cf.* also 2367 of September.

2643. Influence of Azimuthal Error on the Ballistic Wind in the Electrical Tracking of Radiosondes.—Kihm & Sänger. (*See* 2732.)

2644. A. Overbeck's Papers on the General Circulation of the Atmosphere [and a Simplification & Further Development].—H. Arakawa. (*Gerlands Beiträge zur Geophysik*, No. 1, Vol. 57, 1940, pp. 20–28.)

2645. Criticism of H. R. Neumann's Work "Measurements of the Aerosol over the North Sea": Reply.—W. Findeisen: H. R. Neumann. (*Gerlands Beiträge zur Geophysik*, No. 1, Vol. 57, 1940, pp. 34–37.)

2646. On the Variation with Time and Height of the Interchange Coefficient in the Course of the Day, in the Ground-Layer Region [Theory: Observations & Their Analysis].—H. Lettau. (*Gerlands Beiträge zur Geophysik*, No. 2, Vol. 57, 1941, pp. 171–192.)

PROPERTIES OF CIRCUITS

2647. Properties of an Isotropic Dielectric in the Electric Fields of Ultra-High Frequencies ["Bone Effect"—Tendency to flow More Densely through Centre: Mathematical Analysis: Effect on Losses: Equivalent Admittance & Effective Impedance].—H. Ataka. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], Abstracts pp. 8–9.)

2648. The Electrostatic Problems of Two Equal Parallel Circular Plates [Resultant Potential expressed as Series of Integrals involving Bessel Functions, with Tables of Constants: Capacity, & Forces between the Plates, calculated & plotted].—Y. Nomura. (*Proc. Phys.-Math. Soc. Japan*, March 1941, Vol. 23, No. 3, pp. 168–180: in English.)

2649. Papers on the Multivibrator.—Vecchiacchi: Kobayasi. (*See* 2772 & 2773.)

2650. "Elektrische Kippschwingungen" [Relaxation Oscillations: Book Review].—H. Richter. (*Alta Frequenza*, April 1941, Vol. 10, No. 4, p. 256.)

2651. The Image-Termination of the Vectorial Multi-Terminal Linear Modulation Networks: Parts I & II [Double-Sideband Modulators & Demodulators, Linear Inverters & Rectifiers, Frequency Multipliers, etc.].—M. Akiyama. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 245–246: summary only.) Extension of the work referred to in 1036 of April.

2652. On the Solution of Certain Differential Equations of the Second Order [occurring in Problems on Oscillations in Circuits].—L. Roth. (*Phil. Mag.*, Aug. 1941, Vol. 32, No. 211, pp. 155–164.)

2653. On Matrix Calculus applied to Linear Quadripoles Simplified and Generalised [in Connection with Filters in Parallel and Separating Filters: a New Type ("Orthoverse") Matrix].—A. Ferrari-Toniolo. (*Alta Frequenza*, Aug./Sept. 1940, Vol. 9, No. 8/9, pp. 566–567: summary only.)

2654. Expansion Theorem and Design of Two-Terminal Relay Networks: Part I.—A. Nakasima & M. Hanzawa. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 203–210.)

2655. REPRESENTATION OF TWO-TERMINAL NETWORKS BY FOUR-TERMINAL NETWORKS MADE UP OF PURE REACTANCES AND TERMINATED BY RESISTANCES.—G. Cocci. (*Alta Frequenza*, Nov. 1940, Vol. 9, No. 11, pp. 685–698.)

Author's summary :—" The canonical representation of a dipole circuit given by Brune (1932 Abstracts, p. 280), though presenting a notable theoretical interest, lends itself badly to the systematic study of dipoles. It is here shown that any dipole can be represented as a quadripole made up of pure reactances and closed by a resistance, and a method is given for determining unequivocally the characteristics of such a quadripole, starting from the impedance function $Z(p)$: an arbitrary phase-changing section can always be inserted between quadripole and resistance, without changing the impedance at the junction. A numerical example makes the process clear.

" The new method of representation, besides being useful for the systematic study of dipole circuits, can be employed in the study of wave-separators, in the design of dipoles with special characteristics, and in the solution of various problems concerning dipoles. As an example, the application is shown to the calculation of the imaginary component of an impedance whose real component is given."

2656. A CONTRIBUTION TO THE TWO-TERMINAL NETWORK THEORY [particularly with Reference to Kamiya's Method of Filter Synthesis for a Given Input Impedance (958 of 1940), and to Constant-Resistance Networks (especially Piloty's Wave-Separating Filters, 2477 & 3623 of 1937 and 46 of 1940)].—Y. Watanabe, T. Isikawa, & Kiyasu-Zen'iti. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 211–219.)

For the papers of Brune, Darlington, and of Fenyves, here referred to, *see* 1932 Abstracts, p. 280 ; 1361 of 1940 ; and 2657, below. For Piloty's later work *see* 2226 of 1938, 959 of 1940, & 1035 of April.

2657. CONTRIBUTION TO THE DESIGN OF TWO-TERMINAL NETWORKS WITH PREDETERMINED CHARACTERISTICS.—F. Fenyves. (Referred to in 2656, above.)

2658. ON NEW PHASE NETWORKS FOR MEASURING PURPOSES, WITH FREQUENCY AND TEMPERATURE COMPENSATION.—Poleck. (*See* 2779.)

2659. UNIVERSAL CURVES OF RESONANCE FOR CIRCUITS WITH LOSSES.—A. Ferrari-Toniolo. (*Alta Frequenza*, Oct. 1940, Vol. 9, No. 10, pp. 626–636.)

" It is shown how, with only four universal curves, it is possible to represent the course of the impedance and admittance (both in modulus and phase, in real and imaginary parts) and thus of the voltage and current, in any resonant circuit, series or parallel, with resonance obtained by variation of frequency, inductance, or capacitance. The four given curves, which cover all possible cases, must be used each time with the correct choice, systematically guided by the tables given, of the right variable to be employed as abscissa, namely $\omega_0/\omega - \omega/\omega_0$, $(C - C_0)/C_0$, $(C - C_0)/C$, $(L - L_0)/L_0$, or $(L - L_0)/L$."

2660. ON THE DESIGN OF A LOW-PASS FILTER [for Carrier Currents on Power Lines].—A. R. Livshits. (*Automatics & Telemechanics* [in Russian], No. 5, 1940, pp. 89–96.)

The object of the design is to obtain the " power " coil, *i.e.* the coil connected in series with the line, of the lowest possible impedance, and to ensure that the impedance (active component) offered by the filter to h.f. currents is not less than 800 ohms throughout the whole frequency range used in practice (67–200 kc/s). The following types of circuit are considered : (1) simple parallel-resonance circuits (Fig. 5), (2) half-pi section of a constant-*k* type filter (Fig. 6), (3) multi-resonant circuits, and (4) circuits with a negative inductance on a certain frequency range. It appears from this investigation that (2) is more advantageous than the other types.

2661. CURRENT UNBALANCE IN A PARALLEL-LINE FEEDER DIRECTLY COUPLED TO A PI-TYPE TUNED CIRCUIT.—Kono. (*See* 2703.)

2662. CALCULATION OF CURRENT DISTRIBUTION AND LOSS RESISTANCE IN CONDUCTOR SYSTEMS [Theoretical Study of Problem hitherto treated only for Pairs of Conductors : including Application to Four Conductors in a Star Quad], *and* CALCULATION OF THE CAPACITY OF STAR QUADS HAVING CYLINDRICAL SHIELDING.—A. Matsumoto & T. Sakurai : S. Yoh. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 242–244 : p. 248—summary only.)

2663. ON THE DISTRIBUTION OF NON-LINEAR DISTORTION IN MULTI-CHANNEL CARRIER TELEPHONE SYSTEM.—Y. Degawa. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 238–241.)

2664. GEOMETRICAL THEORY OF THE KRARUP [Continuously Loaded] CABLE : PARTS I & II [Longitudinal Component of Induction & Its Elimination].—O. von Auwers. (*Wiss. Veröff. a.d. Siemens-Werken*, 14th March 1940, Vol. 19, No. 2, pp. 32–56.)

2665. PAPER ON INVERTED AND OTHER AMPLIFIERS, *and* HIGH-EFFICIENCY AMPLIFIER OF VARYING LOAD, AND A STUDY OF LINEAR AMPLIFICATION.—Tanaka. (*See* 2675 & 2676.)

2666. AN ANALYSIS OF THE AMPLIFICATION OF EXPONENTIAL PULSES [primarily in Counter-Pulse Amplifier with Self-Biased Stage to obviate Change in Gain as Valves & Batteries grow Old : Advantages of an Unconventional Cathode Network].—C. H. Page. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 920–921 : summary only.)

2667. REMARKS ON THE WRITER'S PAPER " ON THE THEORY OF RADIO-FREQUENCY AMPLIFICATION."—A. Marino. (*Alta Frequenza*, Aug./Sept. 1940, Vol. 9, No. 8/9, pp. 553–555.) Pointing out the difference between his treatment (1788 of 1940) and that of the Galileo Ferraris Institute paper (2724 of 1939) to which his attention has been drawn.

2668. On the Stable Negative Resistance [Defect of Instability in Negative-Resistance Amplifiers removed by Differential Feedback : Steep Negative Resistance obtained by combining Parallel Regenerative & Series Suppressive Feedbacks : etc.].—H. Tanaka. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, p. 247 : summary only.)

2669. On the Equivalent Circuit of the Double-Feedback Amplifier [with Positive & Negative Feedback].—K. Kobayashi. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, p. 246 : summary only.)

TRANSMISSION

2670. Dielectric Constant of a Space Charge rotating in a Magnetic Field [Magnetrons, etc.].—J. P. Blewett & S. Ramo. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 922 : summary only.)

"The solutions of the field and force equations [in a previous work, 2953 of 1940] were found to be somewhat similar to the free-space wave-guide solutions. In particular, it was noted that the space charge behaves towards an E_0-type wave as though it were a medium whose dielectric constant is less than unity by an amount depending on magnetic field and frequency. For convenient values of magnetic field and frequency, this dielectric constant may easily become zero, or even attain negative values. An experimental study of this phenomenon for a frequency of 470 Mc/s and magnetic fields of a few hundred gauss gives results in agreement with the theoretical predictions."

2671. Discussion on "On Ultra-High-Frequency Oscillations generated by means of a Demountable Thermionic Tube having Electrodes of Plane Form" [including Prediction of Optimum Value of d_1/d_2].—W. E. Benham : Leyshon. (*Proc. Phys. Soc.*, 1st July 1941, Vol. 53, Part 4, pp. 490–491.) *See* Leyshon's paper, 1636 of June.

2672. Ultra-Short-Wave Group Transmitter [Row of Self-Excited Oscillators inside Reflector : Radiation Coupling between Them has to be Reduced to Optimum Value by Partitions with Suitable Apertures : Alternative Coupling by Reflector or Secondary Radiator in Common Field].—J. Pintsch Company. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 121.) German Pat. 696 986.

2673. An Inexpensive 56-Mc/s Exciter or Transmitter : Ten Watts of Crystal-Controlled Output from Receiving Valves [Type 6A6].—V. Chambers. (*QST*, June 1941, Vol. 25, No. 6, pp. 13–15 and 76, 78.)

2674. Balanced Inductive Coupling for Ultra-High Frequency Transmitters [Flat Spiral for Coupling to Push-Pull Windings in place of Cylindrical Coil with Electrically Asymmetrical Ends].—M. Mix. (*QST*, June 1941, Vol. 25, No. 6, p. 56.)

2675. Short-Wave High-Power Amplifiers : Part I—Neutralised Push-Pull Type : Part II—Inverted Amplifiers [Causes of Instability, and Their Cure : Theory & Advantages of Inverted Amplifier].—N. Tanaka. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], pp. 21–46.) For the "inverted" amplifier *see* Strong, 4230 of 1940 and back reference.

2676. High-Efficiency Amplifier of Varying Load, and a Study of Linear Amplification [Analysis of Grid-Excitation Conditions necessary for Linear Amplification with the Doherty Amplifier, selected as the Most Practical of the "High-Efficiency" Systems (Floating Carrier, etc.)].—N. Tanaka. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 223–229.)

2677. A New Interpretation of the Internal Resistance of Vacuum Tube in Oscillator Stability.—S. Uemura. (Reference only in *Nippon Elec. Comm. Eng.*, April 1941, No. 24, p. 248.)

2678. A Transmitter Frequency-Control Unit with Three-Band Output [Electron-Coupled Variable-Frequency Oscillator with Outputs on 80, 40, & 20 m Bands by changing Coils only].—G. W. Shuart. (*QST*, June 1941, Vol. 25, No. 6, pp. 45–48.)

2679. An Automatic Frequency Control for Cyclotron R.F. Power Supply [correcting for Drift due to Changes resulting from Load Heating Effects].—R. B. Jacques. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 918–919 : summary only.)

2680. The Fourier Integral, *and* An Extension of the Fourier Integral.—R. Sartori : K. W. Wagner. (*Alta Frequenza*, Aug./Sept. 1940, Vol. 9, No. 8/9, pp. 531–552 : April 1941, Vol. 10, No. 4, pp. 195–214.)

(1) Fourier series : Fourier integral : properties of the Fourier spectra : applications of the Fourier transformation : Fourier spectrum of complex functions : of sinusoidal functions : conclusions.

(2) Prompted by (1). "It is shown how simple unit functions, represented by the Fourier integral, can be resolved into continuous spectra of different kinds by varying the integration path. According to the choice of this path, spectra of continuous, damped, increasing, or otherwise modulated oscillations can be obtained. In the case of damping (positive or negative) the character of this can be chosen either as constant or as an arbitrary function of the frequency.

"The extension of this procedure to arbitrary time functions is made possible by the use of the 'spectral function', defined by a Laplace integral. The inversion of this functional relation leads to the representation of the time function by a complex integral ; from this, as in the case of the unit function, the desired spectra of the time function can be derived. The process is illustrated by a series of simple examples, in some of which the ordinary Fourier integrals are divergent.

"The importance is shown of the singular points of the function lying on the imaginary axis and in the positive half-plane of the complex pulsation $p = \rho + j\omega$. These points are considered because here the additional terms may be separated from the continuous spectrum; the remaining spectrum can then be represented by a convergent Fourier integral. Odd and even functions can be resolved directly into a spectrum of oscillations respectively sinusoidal and cosinusoidal. The possibility of solving time functions having any course for values of time whether positive or negative is thus deduced".

2681. THE IMAGE-TERMINATION OF THE VECTORIAL MULTI-TERMINAL LINEAR MODULATION NETWORKS.—Akiyama. (*See* 2651.)

2682. ON THE DOUBLE BALANCED MODULATOR AND ITS VARIOUS NEW TYPES [Jaumann, Riegger, & Other Circuits].—Y. Degawa. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 220–222.)

2683. TUBE KEYING [Valve Device for "Clickless" Transmission: with Oscillograms]. — B. Goodman. (*QST*, June 1941, Vol. 25, No. 6, pp. 30–33.)

2684. MULTIVIBRATOR AS A SINUSOIDAL OSCILLATION GENERATOR [by Insertion of Resistances in Cathode Circuits, and Other Measures: One Cycle to Several Kilocycles per Second].—K. Kobayasi. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], Abstracts p. 6.)

2685. ON ELECTRON MOVEMENTS IN PLASMAS, AND SOME APPLICATIONS [Preliminary Communication].—W. O. Schumann. (*Naturwiss.*, 27th June 1941, Vol. 29, No. 26, pp. 389–390.)

Mathematical analysis of the case of a plasma with a constant positive stationary density of charges (p coulombs/cm^3) through which electrons are moving, their motion governed by the equation $eE = m.dv/dt + rv$, where r is a frictional coefficient e/b, b being the mobility of the electrons. The final velocity i/p will be attained aperiodically or periodically according to whether $r^2/4m^2$ is greater or less than $ep/m\Delta$ (for i and Δ see eqn. 1): $\sqrt{ep/m\Delta}$ is Langmuir's natural frequency λ of the plasma, and for ordinary mercury-vapour plasmas is of the order of 10^{10} per sec. The oscillatory condition occurs particularly at low pressures, when b is large and r consequently small: the electrons are subject to damped "swings" of velocity during their motion. An investigation of relations at the point of entry of the electrons shows that anomalous conditions may occur there which also are capable of setting up oscillations: "a long positive column acts, moreover, as a stabilising resistance in series".

It is found that fast electrons are retarded with extreme rapidity. Neglecting the friction, if the velocity of entry v_0 is equal to $2i/p$, the velocity sinks to zero; if v_0 is larger still, the velocity becomes negative, and eqn. 1 no longer holds. In certain conditions the distance of penetration is independent of the entrance velocity: the faster the electrons on entrance, the more quickly are they brought to a halt, "since for fast electrons (v_0 much greater than i/p) the stopping distance becomes smaller and smaller compared with π/λ. The path s_τ is practically determined by $i/p \,.\, \pi/\lambda$: for the usual mercury-vapour plasma it is about one-tenth to one millimetre, but it may be considerably more than this for low positive densities p and high current densities i.

The case is also considered where p is less than zero, *e.g.* when the electrons enter a cloud of bound electrons (negative ions): no velocity oscillations are now possible (eqn. 3), the velocity increases exponentially with increasing time, the more quickly the larger $ep/m\Delta$ is compared with r/m. The increase is limited by energy loss in excitation and ionisation. So many positive ions may thus be produced that the negative space charge is counteracted or reversed in sign, so that once again a process with positive p ensues, in which velocity and field are reduced, until electron capture again produces a region of negative density. "This mechanism should be of importance in the formation of striated positive columns".

In conclusion, it is pointed out that the assumption $p =$ const. is not essential to the phenomena. These will also occur with ions in motion, "though the formulae will then be more complicated. The ions will always be at their slowest where the electrons are fastest, and *vice versa*".

RECEPTION

2686. NEGATIVE-TRANSCONDUCTANCE OSCILLATORS OF RETARDING-FIELD TYPE AS FREQUENCY CONVERTERS.—A. Pinciroli. (*Alta Frequenza*, Oct. 1940, Vol. 9, No. 10, pp. 581–593.)

This type of oscillator (Herold, 77 of 1936: Pinciroli, 1363 of 1938: the "voltage-controlled" variety only is considered now) has the merits of simplicity, good wave-form, and high stability of frequency which are shared by dynatron oscillators, but in addition has a high permanency of characteristic, secondary emission not being involved. These advantages make it desirable to examine the possibilities of this oscillator as applied to the mixing stage of receivers. The investigation begins with a consideration of various ways of measuring conversion transconductance (Kammerloher, 1934 Abstracts, p. 503: Wey, 1458 of 1935): and a third, direct method (Fig. 3) which gives results agreeing quite well with those of the other two methods. The applicability of these methods to the retarding-field negative-transconductance oscillator is then considered, and a series of results discussed.

The value of the differential resistance of the plate in the region of high oscillator-stability is found to be too low to allow the type of valve investigated (Philips pentode EF6) to be considered as a frequency-changer in cases where f_m ($= f_{osc} \pm f_{sig}$) lies in the r.f. region, as in a receiver. It might however be so used when f_m is in the a.f. region, for example in a beat-note generator. The use of a special valve with five grids, three of which would have the functions of the three grids of the pentode used, while the other two would form an efficient electrostatic screen, might get over the difficulty as regards the application to receivers: experiments on these lines are in progress.

2687. TESTS ON BROADCAST RECEIVERS: GENERAL DETERMINATIONS AND MEASUREMENTS ON THE LOW-FREQUENCY COMPLEX [Systematic

Comparative Tests at Galileo Ferraris Institute on Receivers built in Italy: including Measurement of Impedance of Moving Coil, Matching of Output Valve to Loudspeaker, Overload & Distortion, including the Owen Harries "Two Signal" Procedure (analogous to Selectivity Method): etc.].—C. Egidi. (*Alta Frequenza*, Aug./Sept. 1940, Vol. 9, No. 8/9, pp. 453–493.)

2688. The Sensitivity of Radio Receivers and the Methods of Measuring It [Importance of Background Noise].—R. Koch. (*Alta Frequenza*, Nov. 1940, Vol. 9, No. 11, pp. 644–684.)

Part I—Sensitivity and background noise (definition of sensitivity in different receiving conditions: inadequacy of I.R.E. Standards and others definitions omitting the effect of background noise: a new definition taking account of this background noise and its influence on the quality of reception: expressions for the fluctuations of voltage in circuits and of current in valves—shot and flicker effects: equivalent voltage of background noise in a receiver, noise modulation). Part II—Determination of the sensitivity (previous methods and their imperfections, including British R.M.A. 1937 recommendations and German methods: method developed and practised at Guidonia—*see* also French proposals, 2300 of 1938 and 972 of 1939, for a method based on the same principle—taking background noise into account: criteria for the choice of signal/background-noise ratios in the measurement of sensitivity: variation of sensitivity with output power and with the value of the signal/noise ratio). Part III—Limits of sensitivity in modern receivers (and the conditions for obtaining the highest possible sensitivity: experimental investigation with results in good agreement with those predicted by theory).

2689. Noise and Sensitivity of Amplifier Circuits.—W. Kleen. (*Arch. f. Techn. Messen*, 1939, J 8333.) Referred to in Kleen's paper, 2708, below.

2690. On the Interdependency of Radio Receiver Characteristics [Analysis of Frequency Characteristics as Function of Stability: Interdependence of Amplification, Set Noise, & Frequency Characteristics: Conclusions affecting Receiver Design].—H. Seki. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], pp. 11–19.)

2691. Minimising Selective Fading: an Experimental Attack on the Problem [Preliminary Report].—L. A. Moxon. (*Wireless World*, Aug. 1941, Vol. 47, No. 8, pp. 200–202.) From the Murphy laboratories. For a small correction *see* Sept. issue, p. 245.

2692. The Selectable Single-Sideband Receiving System [New Semi-Automatic Heterodyne-Rejection Circuit for Telephone Reception].—J. L. A. McLaughlin. (*QST*, June 1941, Vol. 25, No. 6, pp. 16–17 and 74.)

2693. More Makeshifts: Receiver Maintenance in the Face of Shortages.—W. H. Cazaly. (*Wireless World*, Aug. 1941, Vol. 47, No. 8, pp. 208–210.) *See* also 2116 of August.

2694. The "Personal" Receiver: Commercial Development of the Type in America.—(*Wireless World*, Aug. 1941, Vol. 47, No. 8, pp. 203–204.) *See* also 1062 of April.

2695. Designing Small Portables: Use of High-Inductance Tuning Circuits in Simple Headphone Sets.—S. W. Amos. (*Wireless World*, Aug. 1941, Vol. 47, No. 8, pp. 206–207.) For correspondence on this paper *see* Sept. issue, No. 9, p. 243.

2696. Learning the Code: Combination Radio Receiver provides Practice [Communications-Type Receiver with Self-Contained Facilities for Keying & Code-Reading Practice].—(*Scient. American*, July 1941, Vol. 165, No. 1, p. 30.) For a Morse practice oscillator, see *Wireless World*, Sept. 1941, No. 9, p. 243.

AERIALS AND AERIAL SYSTEMS

2697. Improving the Transmitting Loop: Side Loading for Increased Radiating Properties [Advantages of Loops for 5–10 m Bands, particularly for Portable Transmitters: the Reinartz Unidirectional Loop (969 of 1938) with Gain still below That of Simple Dipole: Williams's Side-Loaded Loop with Gain 1.4 db over Dipole].—J. H. Green, Jr: E. M. Williams. (*QST*, June 1941, Vol. 25, No. 6, pp. 24–26.) *See* also 759 of March.

2698. On the Use of Tuned and Aperiodic Frame Receiving Aerials with Few Turns.—R. Koch. (*Alta Frequenza*, Oct. 1940, Vol. 9, No. 10, pp. 621–622: summary only.)

From *Atti di Guidonia*, 1940: the work appears to cover much the same ground as the U.R.S.I. paper dealt with in 4426 of 1939, but includes as well an experimental investigation on aperiodic frames with inductive coupling to the secondary circuit, to confirm the theoretical results (variation of secondary voltage with the coupling parameters, etc.): the effect of screening is also considered briefly.

2699. The Improvement of the Transmission Efficiency by Directive Aerials.—K. Fränz. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 117: summary, from *Telefunken-Hausmitt.*, May 1940.)

This is presumably the paper mentioned at the end of 761 of March. "The general equations for the energy gain produced by replacing a single dipole by a directive array are collected [in the full paper] in their simplest possible forms [for their mathematical derivation *see* 2249 of 1940]. As an example, the absorption surface of a Telefunken fir-tree array is equal to its geometrical surface, or the gain of a directive array of vertical dipoles arranged abreast in a vertical plane is proportional to the number of dipoles, the proportionality function being a known function of the spacing between the dipoles. The following mistake [in the full paper] is to be corrected: if these dipoles are spaced $\lambda/2$, their gain is only half as great with alternating counter-phase excitation as with in-phase excitation, whereas through an error in calculation the gain in the two cases was stated to be equal.

"This simple form of law has proved strictly true as a limiting law for large directive arrays measured in wavelengths. It applies with excellent approximation to fairly small aerials. It is indeed possible to devise arrays for which there is no simple relation between geometrical dimensions and absorption surfaces, while on the other hand the absorption surface of a geometrically small aerial can be made arbitrarily large; but such aerials have no technical interest since their radiation resistance is extremely small, so that the aerial efficiency (ratio between radiated power and the heat produced in the aerial-tuning system) is extremely bad.

"Special importance is laid on the proof that the gain of an array is the same in transmitting and receiving: the application of two-wire circuit theory to aerials does not bring this out sufficiently clearly. For the equality in the two cases there is a well-known proof based on Carson's version of the reciprocity theorem, and also a thermodynamic proof using Kirchhoff's law of the equality of the emitting and absorbing powers of all bodies. To look into this, an aerial is imagined to be closed by an ohmic load resistance equal to its radiation resistance and brought into a room filled with "black" radiation: then the energy reaching the ohmic resistance from all angles in the space must correspond to an exactly opposed energy flux coming from the ohmic resistance, if that resistance and the "black" radiation have the same temperature. This follows from the second law of thermodynamics. The equilibrium condition for radiated and received energies applies even to an arbitrarily small part of the whole space-angle 4π, from which follows at once the equality of the transmitting and receiving diagrams of the aerial and, almost directly, the equality also of gain. Remembering that the intensity of the "black" radiation at a wavelength λ and temperature T is equal to kT/λ^2, it is easy to calculate, for a dipole as aerial, the square of the induced e.m.f. as $E^2 = 4kTR\Delta\nu$, where k is the Boltzmann constant, R the radiation resistance, and $\Delta\nu$ the band-width. This is the well-known Nyquist formula for the noise in an ohmic resistance, which he derived in a similar way."

2700. THE "G" RECEIVING AERIAL FOR SHORT WAVES [Gori's Progressive-Wave Type].—A. Niutta: Gori. (*Alta Frequenza*, April 1941, Vol. 10, No. 4, pp. 215–235.)

Preliminary papers on this aerial have already been dealt with in 4437 of 1939. Examples have now been erected at the Malnome (Rome) receiving station, for reception from Rio de Janeiro and Buenos Aires, and some results are given at the end of the present paper, together with a horizontal radiation diagram obtained by transmissions from an aeroplane circling at a radius of 6 km: this agrees well with the calculated diagram of Fig. 8. The frequency response characteristic is such that the variation of gain is within 1 db when the ratio of the extreme frequencies is 1.68 : 1.

2701. ONE TYPE OF THE HORIZONTAL SHORT-WAVE DIRECTIVE ANTENNA [Array of $\lambda/2$ Square Elements, with Missing Side at Each End: Methods of Feeding].—K. Umeda. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], Abstracts p. 10.)

Very successfully employed for transmission and receiving. "This paper shows that the currents in each element become of equal amplitude and of the same phase when the two centre points of the phasing parts are shortened so that they are always at the same potential".

2702. ACOUSTIC MODELS OF RADIO ANTENNAS.—E. C. Jordan. (*Ohio State University Studies, Engineering Series*, May 1941, Vol. 10, No. 3, 58 pp.)

A summary of a joint paper by Jordan & Everitt was dealt with in 582 of 1940, and another paper by the same writers is contained in *Proc. I.R.E.* for April 1941, pp. 186–194. The present bulletin described the whole course of the researches. A major problem in the operation of aerial arrays is the reaction of one aerial on another: this can be given quantitatively by the mutual impedances between each pair, and Chapter 4 describes an acoustic method for determining these impedances which is much quicker than previous analyses using mechanical integration. Chapter 5 describes the considerable amount of directive sound equipment, microphones, "sound guns," adjustable acoustic impedances, etc., developed for the work, and ends with a section on the direct measurement of sound-absorption coefficients by a new method using a sound gun and a directional microphone equally inclined to the reflecting surface.

2703. CURRENT UNBALANCE IN A PARALLEL-LINE FEEDER DIRECTLY COUPLED TO A PI-TYPE TUNED CIRCUIT [consists of Unbalance between the Two Wires (Small, merely results in Increase of Useless Radiation) and Unbalance between Sending & Receiving Ends (may have Serious Consequences), particularly Large when Line Length is an Odd Quarter of Wavelength].—M. Kono. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 247–248: summary only.)

2704. CONDITIONS FOR MINIMUM ATTENUATION IN COAXIAL CABLES AT HIGH FREQUENCIES, *and* THE DISTORTIONS OF SIGNALS IN NON-UNIFORM CABLES.—Malatesta: Zin. (*See* 2762 & 2763.)

2705. GROUNDING ELECTRIC CIRCUITS EFFECTIVELY: PART I—CHARACTERISTICS OF GROUNDS [including Resistivities of Different Soils, Effect of Moisture & Salt Contents, Temperatures, etc.].—J. R. Eaton. (*Gen. Elec. Review*, June 1941, Vol. 44, No. 6, pp. 323–327.)

VALVES AND THERMIONICS

2706. DIELECTRIC CONSTANT OF A SPACE CHARGE ROTATING IN A MAGNETIC FIELD [Magnetrons, etc.].—Blewett & Ramo. (*See* 2670.)

2707. Negative-Transconductance Oscillators of Retarding-Field Type as Frequency Converters [including Methods of measuring Conversion Transconductance]. — Pinciroli. (*See* 2686.)

2708. Position of Ultra-Short-Wave Valve Technique.—W. Kleen. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 357–367.)

Survey of Telefunken development work during the past few years and of some of the researches, German and otherwise, on which it has been based : 15 literature references are given. Glass, ceramics, and metal were all tried : for quantity production the glass container with pressed-glass " platter " replacing the pinch (Fig. 3 c-g) is the most satisfactory. Here the following data are given : the resistance of a lead-in wire of 0.1 cm diameter and 1 cm length, at 50 cm wavelength, is 0.02 ohm for copper and 0.03 ohm for tungsten : the inductance is about 10^{-8} henry. Between two such connections, spaced 1 cm, the measured value of resistance on the same wave, as a result of dielectric loss, was from $1-3 \times 10^5$ ohms according to the type of glass : this was at room temperatures, at 300° C the values were about halved. Fig. 4 shows several complete valves of this type : electrode spacings of 0.2 mm are not unusual, especially between grid and cathode.

Subsequent sections deal with the systematic investigation of the input admittance, slope, output admittance, retroaction admittance, and lastly the important equivalent grid-noise resistance, which combined with the input admittance provides a reliable measure of the sensitivity of an input stage (Fränz, 3126 of 1939 : Kleen, 2689, above) : since in u.s.w. working the input admittance of a circuit depends chiefly on that of the valve itself, the product of valve input admittance and equivalent grid-noise resistance decides the optimum sensitivity, so that this resistance becomes the fifth important characteristic of such valves (*see* table 3).

2709. Complex Probe Measurements on Models, for determining the Field Distribution in the Flow of the Ultra-Short-Wave Condenser Field through Multi-Layered Dielectrics [primarily in connection with Therapy Research : a New Electrolytic Trough].—H. Schaefer & R. Stachowiack. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 367–372.)

The various layers are represented by different liquid electrolytes of suitable dielectric constant and conductivity, separated by thin separating walls of very high transverse and very low longitudinal conductivity (*see* also 2710, below). The impossibility of a direct use of ultra-short waves (the 6 m wave was of chief interest, as being the most usual in therapy) because the capacity of even the smallest probe and its lead would disturb the field, made it essential to represent the u.s. wave by a 100 m working wave, by employing a method of design based on the following principle.

Fig. 1a shows a two-layered dielectric. The potential distribution in an elementary domain of the surface of separation (Fig. 1b) is based on the operator diagram of Fig. 1c, and the combination of all the volume elements of the whole arrangement gives the total resistance distribution and hence also the field distribution. Now nothing will change in this field distribution if the system is replaced by one which is geometrically similar but in which the impedance operators are represented in magnitude and phase by Fig. 1d. This principle of the rotation of the whole system of partial operators through a fixed angle, with a simultaneous proportional reduction in the absolute values, can be applied to the present problem as shown in Fig. 2, since the field distribution in such a system is determined by the geometry of the arrangement, by the dielectric constants and conductivities of the liquids, and by the frequency. In the equivalent 100 m system (r-h side) the air-gap in the 6 m system has been replaced by an aqueous solution of electrolyte, since in this medium of high dielectric constant the capacity of the probe-lead has a smaller disturbing effect, and the true field distribution can be plotted point by point with a valve voltmeter. The trough equipment described and illustrated is for two-dimensional field-distributions only, but Fig. 7 represents a possible three-dimensional arrangement : here the separating barriers must naturally be of " dot " instead of " strip " design. Results with this arrangement will be reported later.

2710. Non-Distorting Separating Partition for Complex Electrolyte Models [in New Electrolytic Trough]. — R. Stachowiack. (*E.T.Z.*, 8th May 1941, Vol. 62, No. 19, pp. 441–443.) Description of the special barrier mentioned in 2709, above.

2711. On the Thermodynamic Interpretation of Certain Thermionic and Thermoelectric Phenomena [Derivation of Relationship between Steady-State Thermionic Phenomena and Thermoelectric Properties of the Metal : Application to Interpretation of Experiments on Cooling Effect, etc.].—C. Herring. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 889–896.)

2712. Average Thermionic Constants for Single-Crystal Tungsten Wire [Theory & Experiment], *and* Work Function and Double Layer.—M. H. Nichols : R. Smoluchowski. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 944 : p. 944 : summaries only.) Both dealing with the experimental fact that different crystal faces of the same metal have different work functions.

2713. Electron Emission from Surfaces subject to Periodic Fluctuations in Work Function.—Waterman. (*See* 2767.)

2714. Electron Emission of Metals in Electric Fields : II—Field Dependence of the Surface Photo-Effect.—Guth & Mullin. (*See* 2766.)

2715. Remarks on Energy Losses attending Thermionic Emission of Electrons from Metals [and the Question whether Electrical Conduction in a Metal can occur at Levels lower than μ, the Fermi Parameter].—W. B. Nottingham : Fleming & Henderson.

(*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 906–908.) Criticism of the paper dealt with in 2139 of August: the authors reply.

2716. ON THE THEORY OF SECONDARY EMISSION [Number of Secondaries per Primary about 1/10th to 1/4th of Ratio of Rates of Energy Loss of Primary Particle & Secondary Electron: Application to Insulators, Alkalis, etc.].—H. A. Bethe. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 940: summary only.)

2717. A HITHERTO UNUSED METHOD FOR MEASURING THE ENERGY DISTRIBUTION OF SECONDARY ELECTRONS [Longitudinal Magnetic Field Method, and Some Results].—R. Kollath. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 328–331.) *See* also 2135 of August.

2718. THE PROPERTIES OF SECONDARY-EMISSION FILMS OF MAGNESIUM DIOXIDE.—H. Schnitger. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 376–380.)

The films usually employed for electron multipliers are activated by caesium or some other alkali metal, and though satisfactory in their secondary emission are not similarly satisfactory in the way they stand rises in temperature. A caesium-activated silver-oxide layer, for instance, is quickly destroyed at a little over 180°. Jonker & Overbeek showed that satisfactory multipliers could be made from magnesium-oxide films (2334 of 1938) from which a considerably better resistance to temperature can be expected. The good s.e. properties of magnesium combinations have long been known from development work on the dynatron, and the ready occurrence of s.e. at the grids of transmitting valves where magnesium has been used is also a recognised fact: it must be due to magnesium oxide, since it cannot be eliminated by making the grid incandescent. The present paper describes experiments to determine some characteristic properties of magnesium-oxide layers with the object of gaining knowledge of their structure.

It is found that the high s.e. outputs only occur when the layers contain free magnesium: it is not necessary that free metal should be present also at the surface. The s.e. output is at a maximum for a definite concentration of the magnesium, but at this concentration the thermal stability is comparatively low, presumably because the free magnesium is not sufficiently tightly bound. A much better stability is obtained at lower concentrations, when however the s.e. output is distinctly lower. The minimum satisfactory thickness for the film is 3×10^{-6} cm. At room temperatures the films are fairly insensitive to oxygen but are quickly destroyed by water vapour. The nature of the metal base (nickel, preoxidised or otherwise, platinum, or aluminium) has no influence on the secondary emission.

2719. THE CONTAMINATION OF INCANDESCENT MOLYBDENUM FILAMENTS IN A VACUUM OBTAINED BY AN OIL DIFFUSION PUMP.—F. T. Worrell & S. S. Sidhu. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 944: summary only.)

2720. GRID-MAKER: AUTOMATIC MACHINE MAKES VACUUM TUBE PARTS [including Valve-Controlled Welding].—R. C. A. (*Scient. American*, June 1941, Vol. 164, No. 6, pp. 336–337.)

2721. "GRUNDLAGEN UND KENNLINIEN DER ELEKTRONENRÖHREN" [Fundamentals & Characteristics of Valves: Book Review].—H. Rothe & W. Kleen. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 124.) Vol. 2 of Zenneck's series (*see* 2339 of September).

DIRECTIONAL WIRELESS

2722. DOUBLE-FRAME ARRANGEMENT FOR DIRECTION-FINDING ON SHORT AND ULTRA-SHORT WAVES [Second Frame, disconnected from Receiver, coupled to First Frame to eliminate Abnormally Polarised Field Component].—E. Hüttmann. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 122.) German Patent 696 140, assigned to R. Hell.

2723. METHOD OF PRODUCTION OF GLIDING-PATH SURFACES [for Blind Landing: Distortion of Path close to End of Ferroconcrete Runway avoided by Buried Conductor].—W. M. Hahnemann. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 122.) German Patent 696 684, assigned to Lorenz Company.

2724. BLIND LANDING SYSTEM [Two Horizontal Dipoles, First in Landing Direction, Second at Right Angles: Energy supplied at One Moment alternately to Each at Supersonic Switching Rate, at Next Moment to Second only].—(*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, pp. 122–123.)

German Patent 697 074, assigned to the State. The aircraft carries a frame rotatable (by Cardan shafts) about horizontal and vertical axes, giving (first) direction of approach and (second) angle of elevation.

2725. SIMULTANEOUS AURAL AND VISUAL INDICATION IN INTERLOCKED SIGNAL SYSTEM WITH TWO NOTE FREQUENCIES [by Heterodyning the Two Frequencies to give Common Note in Telephones].—J. Goldmann. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 123.) German Patent 696 681, assigned to Lorenz Company.

2726. HARVEY DIRECTIONAL CONTROL [for Fully Automatic Maintenance of Straight-Line Course passing through Two Wireless Stations: Combination of Two Opposed Homing Devices and Servo Motor].—(*Journ. Roy. Aeronaut. Soc.*, July 1941, Vol. 45, No. 367, Abstracts pp. 181–182.)

2727. A CATHODE-RAY DIRECTION FINDER FOR LONG WAVES [primarily for Marine Application: Description: Results, including Tests with Signals from Aeroplane, using Loop and Adcock Aerials].—J. T. Henderson, H. R. Smyth, & J. W. Bell. (*Nat. Res. Council of Canada, Pub. No.* 928, Feb. 1941, 6 pp.) Presented at U.R.S.I.-I.R.E. Meeting, Washington, 1939. *See* also 2280 of 1940.

2728. U-Type Adcock System with Aerials connected to Earth or Counterpoise [Transmission Line raised so that Fields due to Horizontally Polarised Rays, between Line & Earth and Line & Aerials, cancel out], *and* U-Type Adcock System with Aerials raised above Ground, Transmission Line screened up to Bases of Aerials.—K. Koschmieder. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 122 : p. 122.) German Patents 696 683 & 696 988, assigned to Lorenz Company.

2729. Arrangement for the Automatic Clearing of the Minimum in a Rotating Direction-Finder [by Equalising the Amplitudes of the Two Component Oscillations by Automatic Control].—F. Johnske & others. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 123.) German Patent 697 223, assigned to Telefunken.

2730. Arrangement for the Compensation of Periodic Errors in D.F. [Field Coils of Goniometer automatically displaced with respect to Search Coil, by Eccentric or Contoured Discs].—E. Müller. (*Hochf:tech. u. Elek:akus.*, April 1941, Vol. 57, No. 4, p. 122.) German Patent 696 682, assigned to Lorenz Company.

2731. On the Use of Tuned and Aperiodic Frame Receiving Aerials with Few Turns.—Koch. (*See* 2698.)

2732. Influence of Azimuthal Error on the Ballistic Wind in the Electrical Tracking of Radiosondes.—O. Kihm & R. Sänger. (*Schweizer Arch. f. angewändte Wiss. u. Tech.*, March 1941, Vol. 7, No. 3, pp. 61–68.)

The writers set themselves the problem of calculating the accuracy with which the d.f. on the radiosonde must be carried out in order that the wind may be determined with a precision sufficient for the requirements of ballistics. They assume a d.f. system of three stations disposed for simplicity's sake in an equilateral triangle of sides $2l$ (two stations are insufficient, because of the inaccuracy when the sonde happens to reach a position whose horizontal projection lies close to the line joining the two stations). The ballistic wind is given by eqn. 1, involving the mean velocity of the wind in the layer between heights h_i and h_{i+1}, the time of stay of the projectile in that layer, and the total trajectory time.

The centre formula of eqn. 25 (which is based on an average total trajectory time of 50 secs.) assumes a mean rate of ascent for the sonde of 100 m/min. and an interval of 1 min. between the d.f. readings, and gives the mean error of the ballistic wind as 1/300th of the "maximum mean point error" (in the locating of a point by the assumed triangulation—*see* section 3) which, in section 5, is found to be equal to $15\,sl/h$, where h is a constant representing accuracy—*see* eqn. 9 and subsequent text. Thus with the above assumptions the mean error of the ballistic wind is $15sl/300h$. But assuming that the ballistic wind has to be determined within 1 metre per second, and remembering that (with the Gaussian error-distribution which is postulated throughout) the maximum error may be 3 times the mean error, the latter must not exceed one-third of a metre per second. Hence in the limit $15sl/300h = \frac{1}{3}$. Jordan (*see* footnotes 4 & 1) has shown that the relation between the accuracy h of the azimuth measurement and its mean error m is given by $h^2 = 1/2m^2$, and for the "mean error ellipse" s^2 must be put equal to $\frac{1}{2}$ (*see* p. 65, l-h column). Inserting these values for s and h in the equation $15sl/300h = \frac{1}{3}$, it is found that $m = 20/3l$.

Experience shows that with the rate of ascent assumed, 100 m/min., the total sonde drift which has to be considered is not likely to exceed 10 km. In estimating the "maximum mean point error" in section 5, mentioned above, it was pointed out that this error must be limited by assuming that the greatest distance from the centre of the triangle which would require dealing with would not exceed $4l$, twice the length of base. Putting, therefore, $4l = 10$ km, l becomes 2500 m, and the permissible mean error of azimuth determination is thus given as $m = 20/3l = 0.0027 = 10'$. Thus to determine the ballistic wind within 1 m/sec. in the conditions assumed above, the individual azimuths must be measured to within $\pm \frac{1}{2}$ degree. The final section deals with errors due to lack of simultaneity in the working of the three stations. Practice shows that such errors are of small importance compared with the maximum mean azimuthal error.

2733. Distance Signals [Distance Determination by Optical Phenomenon of Double Grating].—E. Lau. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 296–298.) *See* also 2282 of 1940.

ACOUSTICS AND AUDIO-FREQUENCIES

2734. The Rochelle Salt Crystal and Its Application in the Field of Telephony [including Descriptions of Table Telephone Set without Any Current Supply, & the "Electric Speaking-Tube", particularly for Ships].—L. Sengewitz. (*E.T.Z.*, 15th May 1941, Vol. 62, No. 20, pp. 463–465.)

2735. Effect of Temperature Variation and Electric Field on X-Ray Intensity reflected from Rochelle Salt Crystal : Part I—Temperature Effect.—S. Miyake. (*Proc. Phys.-Math. Soc. Japan*, May 1941, Vol. 23, No. 5, pp. 377–395 : in English).

The existence of a definite temperature effect on the reflecting intensity is established and attributed to a variation of the secondary structure of the crystal in the neighbourhood of its Curie point, and not to the change in the structure factor suggested by Staub.

2736. Acoustic Models of Radio Antennas [and Some Directional Microphones & Sound Guns, etc., including Application to the Direct Measurement of Absorption Coefficients].—Jordan. (*See* 2702.)

2737. The Fundamental Theory of the Electro-acoustic Transformer [Microphones, Loudspeakers, etc : General Equation obtained by Solution of Maxwell-Lagrange Equation of Motion, with Aid of Tensor Analysis].—S. Okada & K. Fukusima. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, p. 245: summary only.)

2738. THE STRUCTURE OF BLACK CARBON [Carbon Films deposited on Silica by Decomposition of Methane, important because of Microphonic Properties: Electron-Diffraction Studies].—A. H. White & L. H. Germer. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 926: summary only.)

2739. AN IMPROVED "MAGNETTON" PROCESS [of Sound Recording on Film carrying Magnetic Particles: Greatly Improved Performance by H.F. Treatment during Recording: Signal/Noise Ratio over 1000/1: Linear Characteristic up to 10 kc/s].—H. J. von Braunmühl & W. Weber. (*Zeitschr. V.D.I.*, 12th July 1941, Vol. 85, No. 28, p. 628: paragraph only.) Used in German broadcasting.

2740. ON THE THEORY OF MODULATION OF A HIGH-PRESSURE ARC BY AN ALTERNATING COMPONENT SUPERPOSED ON THE DIRECT CURRENT.—Weizel, Rompe, & Schulze. (*See* 2954.)

2741. PLASTIC SOUND REPRODUCTION.—K. de Boer. (*E.T.Z.*, 8th May 1941, Vol. 62, No. 19, pp. 446–447: summary from *Philips techn. Rundschau*, Vol. 5, 1940, p. 108 onwards.)

The factors involved in the localisation of a sound-source: frequency-dependence of the diffracting effect of the head (resulting in differences in quality which may contribute to the power of direction discrimination): binaural stereophonic reception, with earphones: stereophonic reception from loudspeakers (two spaced loudspeakers for frequencies above 300 c/s, a third for lower frequencies, suitably situated): etc.

2742. APPLICATIONS OF OUR DIRECT-READING PITCH AND INTENSITY RECORDER: PARTS III AND IV [Studies of Acoustical Properties of "Chansons" & Jazz Songs, and Precision of Pitch Intonation by Famous Sopranos].—J. Obata & R. Kobayashi. (*Proc. Phys.-Math. Soc. Japan*, March 1941, Vol. 23, No. 3, pp. 239–251: in English.) For previous parts *see* 4324 of 1940.

2743. DYNAMICS OF THE PIANOFORTE STRING AND THE HAMMER: PART IV—STUDY OF DURATION OF IMPACT: PART V—SOME SPECIAL THEORIES.—M. Ghosh. (*Indian Journ. of Phys.*, Dec. 1940, Vol. 14, Part 6, pp. 475–488 & 489–497.) For previous parts *see* 2291 of 1940.

2744. THE ABSORPTION OF SOUND BY MEANS OF RESONATING SYSTEMS [Theoretical Treatment, with Experimental Confirmation by Series of Tests on Stationary Waves in a Kundt's Tube: Pre-Calculation of Resonance Frequency, Max. Value & Frequency-Characteristic of Absorption Coefficient: etc.].—A. Gigli. (*Alta Frequenza*, Dec. 1940, Vol. 9, No. 12, pp. 717–744.)

2745. A NEW SOUND-ABSORBING ARRANGEMENT OF HIGH EFFICIENCY, AND THE CONSTRUCTION OF A SOUND-DAMPED ROOM [at Technical College, Berlin: Coating of Metre-High Pyramids made of a Gauze Shell filled with Slag-Wool].—E. Meyer, G. Buchmann, & A. Schoch. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 372–375.)

2746. ON THE SPACE ATTENUATION OF IMPACT SOUNDS IN A BRICK BUILDING.—A. E. Knowler. (*Phil. Mag.*, March 1941, Vol. 31, No. 206, pp. 240–246.)

2747. LOGARITHMIC CHARACTERISTICS OF DRY-PLATE RECTIFIERS, AND THEIR APPLICATION TO MEASURING INSTRUMENTS.—R. Manfrino. (*Alta Frequenza*, Aug./Sept. 1940, Vol. 9, No. 8/9, pp. 494–517.)

An investigation showing how a critical study of the behaviour of the copper-oxide "linear decibel meter" proposed by Akazawa & Uno (4530 of 1939) has led to a distinct improvement in the performance of such an instrument. Characteristics of dry-plate rectifier elements are given, for temperatures between 15° and 50° C. By suitable matching of the circuit elements the useful voltage range can be increased and shifted. Two elements in series enable the range to be extended from 40 db to at least 54 db. The optimum internal resistance of the indicating instrument (at least 5 kilohms) and series resistance (about 10 kilohms) are determined.

2748. THE ESTIMATION OF THE QUALITY OF TRANSMISSION IN TELEPHONIC SYSTEMS, *and* THE SIGNIFICANCE AND DETERMINATION OF THE QUALITY OF TRANSMISSION IN TELEPHONY.—H. Bornemann: K. Braun. (*Alta Frequenza*) Dec. 1940, Vol. 9, No. 12, pp. 766–775., Based on papers in *Europ. Fernsp. Dienst* of March 1939 and *T.F.T.* of May 1940.

2749. ON THE DISTRIBUTION OF NON-LINEAR DISTORTION IN MULTI-CHANNEL CARRIER TELEPHONE SYSTEM.—Y. Degawa. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 238–241.)

2750. SOUND RADIATION PRESSURE IN LIQUIDS AND GASES IN RELATION TO THE EQUATION OF STATE.—G. Hertz. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 298–301.)

2751. VELOCITY OF SOUND IN SOME BINARY ALLOYS [and Its Variation with the Composition].—G. E. Allan. (*Phil. Mag.*, Aug. 1941, Vol. 32, No. 211, pp. 165–170.)

2752. A MATERIAL WITH EXTREMELY HIGH VELOCITY OF SOUND PROPAGATION ["Degussit" (essentially Aluminium Oxide) with Velocity 9600 m/s].—H. Thiede. (*Alta Frequenza*, April 1941, Vol. 10, No. 4, p. 252: summary only.) From *Akust. Zeitschr.*, Jan. 1941.

2753. ACOUSTIC REFRACTION AND TOTAL REFLECTION: EXPERIMENTS WITH GASES WITH CONTINUOUS TRANSITION OF BOUNDARY LAYERS.—von Schmidt & Kling. (*See* 2636.)

2754. ON THE DISPERSION OF SOUND WAVE CONSIDERING THE EFFECTS OF HEAT CONDUCTION AND VISCOSITY.—Z. Sakadi. (*Proc. Phys.-Math. Soc. Japan*, March 1941, Vol. 23, No. 3, pp. 208–213 : in English.)

2755. ON THE MECHANICAL BEHAVIOUR OF LIQUIDS UNDER HIGH-FREQUENCY OSCILLATIONS.—I. Osida. (*Proc. Phys.-Math. Soc. Japan*, Jan. 1941, Vol. 23, No. 1, pp. 18–27 : in English.) For Russian work on the same problem *see* 3085 of 1940.

2756. THE SENSITIVE FLAME [Guthrie Lecture].—E. N. da C. Andrade. (*Proc. Phys. Soc.*, 1st July 1941, Vol. 53, Part 4, pp. 329–355.)

2757. THE CORRELATION BETWEEN COCHLEAR MICROPHONICS AND STAPES MOTION.—O. Stuhlman, Jr. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 911 : short summary only.)

PHOTOTELEGRAPHY AND TELEVISION

2758. A NEW SYSTEM FOR MOTION-PICTURE PHOTOGRAPHY [or Television where Lighting Conditions are under Control : Equal Sharpness for Distant & Near-By Objects.]—A. N. Goldsmith & others. (*Science*, 20th June 1941, Vol. 93, Supp. p. 8.)

2759. TELEVISION FLOODLIGHT [giving 195 000 Lumens without Excessive Heat.]—(*Gen. Elec. Review*, June 1941, Vol. 44, No. 6, p. 352.)

2760. THE RECENT DEVELOPMENT OF TELEVISION PICK-UP AND STUDIO TECHNIQUE IN GERMANY.—J. G. Weiss. (*E.T.Z.*, 30th April 1941, Vol. 62, No. 18, pp. 432–433 : long summary.)

2761. THE INTERPRETATION OF AMPLITUDE AND PHASE DISTORTIONS IN TRANSMISSION LINES BY THE ECHO SPECTRUM.—I. Someya. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 232–237.)

" The use of similar and time-derivative paired echoes in graphical methods has already been developed by Wheeler [3641 of 1939] and Strecker [447 of February]. However, [these] methods are applicable only when the phase distortion is very small, and therefore a transmission line with large phase distortion must be divided into many tandem networks of small phase distortion, in which case the graphical calculation becomes very complicated . . ." The present mathematical method is applicable to the design of low-pass filters giving smooth response to a unit impulse, and of networks for the aperture compensation of cathode-ray spots : to the determination of the characteristics of networks from the response to a unit impulse, and of the permissible limits of amplitude and phase distortions of television transmission lines, etc.

2762. CONDITIONS FOR MINIMUM ATTENUATION IN COAXIAL CABLES AT HIGH FREQUENCIES.—S. Malatesta. (*Alta Frequenza*, Dec. 1940, Vol. 9, No. 12, pp. 755–762.)

Author's summary :—" When, for reasons of space or cost, the diameter of the outer conductor of a cable is fixed, there exists a value of the diameter of the inner conductor which will give the minimum attenuation : the value of the ratio, between the internal diameter of the outer conductor and the external diameter of the inner, which will give this minimum depends on the nature and structure of the conductors. If the cable is designed with this ratio between the diameters, the attenuation is inversely proportional to the internal diameter of the outer conductor. If the cable is designed in the optimum way, it is possible to replace the copper of the outer conductor by other metals " [aluminium, or if the cable can be flexible, the actual lead sheathing which usually covers such cables. " Such observations show how it is possible, in this field also, to make a modest contribution to the autarchy of our country "].

2763. THE DISTORTIONS OF SIGNALS IN NON-UNIFORM CABLES [Wide-Band Television Cables].—G. Zin. (*Alta Frequenza*, Aug./Sept. 1940, Vol. 9, No. 8/9, pp. 569–570 : summary only.) For other work *see* 1131 of 1940 and 2075 of August.

2764. A SEALED-OFF HIGH-VACUUM PHOTOCELL FOR ULTRA-VIOLET LIGHT [for Measurement of Emission from Metal Surfaces : Objections (including Impossibility of obtaining Saturation Values) of System in Air : Fluctuating Results with Continuously Evacuated Tube : Special Design of Sealed-Off Tube].—C. Brinkmann. (*Zeitschr. f. Instr:kunde*, Dec. 1940, Vol. 60, No. 12, pp. 369–371.)

2765. A NEW PHOTOCELL WITH SECONDARY-EMISSION AMPLIFICATION [of Reduced Size, with No Magnetic Field, Max. Anode Potential only 600 V].—M. C. Teves. (*Alta Frequenza*, April 1941, Vol. 10, No. 4, pp. 251–252.) From *Rev. techn. Philips*, Sept. 1940.

2766. ELECTRON EMISSION OF METALS IN ELECTRIC FIELDS : II—FIELD DEPENDENCE OF THE SURFACE PHOTO-EFFECT [Expression for Photocurrent contains Periodic Term, Fractional Magnitude being even Larger than with Thermionic Emission : etc.].—E. Guth & C. J. Mullin. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 867–873.) For I *see* 1909 of July.

2767. ELECTRON EMISSION FROM SURFACES SUBJECT TO PERIODIC FLUCTUATIONS IN WORK FUNCTION [Calculations with Possible Application to Thermionic and Photoelectric Emission and the Temperature Dependence of Work Function].—A. T. Waterman. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 943 : summary only.)

2768. RELAXATION TIME OF COLLOIDAL PARTICLES FROM MEASUREMENTS OF THE ELECTRO-OPTICAL EFFECT [and the Two Components of the Double Refraction at Frequencies below the Relaxation Frequency].—B. W. Sakmann. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 935 : summary only.)

MEASUREMENTS AND STANDARDS

2769. A Reflection Method of Measuring Optical and Electrical Constants at Ultra-High Radio Frequencies.—Palmer & Forrester. (*See* 2620.)

2770. Method for Measuring High-Frequency Electric Fields and Its Use for Local Short-Wave Dosimetry.—K. S. Lion. (*Helvet. Phys. Acta*, 20th Feb. 1941, Vol. 14, pp. 21–50: reference only in *Review Scient. Instr.*, May 1941, p. 296.)

2771. The Conductivity and Dielectric Constant of a Normal Aqueous Solution of Potassium Chloride in Ultra-High-Frequency Fields.—M. A. Divilkovski & D. I. Mash. (*Journ. of Exper. & Theoret. Phys.* [in Russian], No. 11, Vol. 10, 1940, pp. 1257–1262.)

The thermometric method (*see* 1958 of 1940 and back references), based on observing the warming-up of a liquid in a h.f. field, was used for determining σ and ϵ on wavelengths of 443 and 23.6 cm and at a temperature of about 22° C: the results are shown separately for magnetic and electric fields. The l.f. value of σ decreases at 443 and 23.6 cm by 5% and 30% respectively. On 23.6 cm the value of ϵ was 100. Results by other investigators are discussed briefly.

2772. Mechanism of Action and Frequency of the Multivibrator.—F. Vecchiacchi. (*Alta Frequenza*, Dec. 1940, Vol. 9, No. 12, pp. 745–754.)

Author's summary:—"A simple analysis of the mechanism of action of the classic Abraham-Bloch multivibrator has been made, principally with the object of obtaining a sufficiently precise expression for the oscillation frequency. Experiment shows that in normal cases the agreement between the frequency values calculated from a knowledge of the statically determined characteristic quantities, and the oscillation frequencies actually obtained, easily comes within 2–3%." The formula employed is that given by eqn. 4, which reduces to eqn. 5 if both valves have the same characteristics, and to eqn. 6 or 6′ if the three capacities and resistances are equal among themselves. A further simplification, eqn. 7 ($T = 2RC \log_e \mu_0$ approx.) is considerably less accurate. The approximation $T = R_2C_1 + R_1C_2$, given by other workers, is condemned.

2773. Multivibrator as a Sinusoidal Oscillation Generator.—Kobayasi. (*See* 2684.)

2774. Optical Refraction Patterns: Part I—Theory [Mathematical Theory of Formation of Refraction Patterns applied to Study of Quartz].—R. S. Rivlin. (*Proc. Phys. Soc.*, 1st July 1941, Vol. 53, Part 4, pp. 409–417.) Supplementary to the work dealt with in 830 of March.

2775. Effect of Temperature Variation and Electric Field on X-Ray Intensity reflected from Rochelle Salt Crystal: Part I—Temperature Effect.—Miyake. (*See* 2735.)

2776. The Broadcasting of Standard Frequency in Japan [from 5 kW Tokyo Transmitter giving 4, 7, 9, & 13 Mc/s, C.W. and with 1 kc/s Modulation: Accuracy about 1×10^{-6}: Times & Code, etc.].—T. Amisima & M. Yoneyama. (*Nippon Elec. Comm. Eng.*, April 1941, No. 24, pp. 230–231.) Accuracy to be improved to 1×10^{-8}.

2777. A New Short-Interval Chronoscope [Thyratrons & Indicating Device on Magnetic Surge-Crest-Ammeter Principle (1934 Abstracts, p. 555)].—H. P. Kuehni. (*Gen. Elec. Review*, June 1941, Vol. 44, No. 6, pp. 337–339.) "A speed-indicating instrument for 10^{-4} or even 10^{-5} sec. should therefore not present insurmountable difficulties." *Cf.* 2497 of September.

2778. On a Certain Problem of Kelvin relating to the Theory of Clocks.—N. Butenin. (*Journ. of Exper. & Theoret. Phys.* [in Russian], No. 11, Vol. 10, 1940, pp. 1283–1292.)

By analogy with the processes taking place in auto-oscillating electrical systems with two degrees of freedom, the theory of non-linear oscillations is applied to the phenomena observed by Kelvin (in the rate of clocks and chronometers as determined by the method of suspension), and simple formulae interpreting these are derived.

2779. On New Phase Networks for Measuring Purposes, with Frequency and Temperature Compensation [for Precision Working].—H. Poleck. (*Wiss. Veröff. a.d. Siemens-Werken*, 5th Nov. 1940, Vol. 19, No. 3, pp. 48–57.) In addition to the networks for 90° displacement with which the paper is concerned, a compensated 0° circuit for very high voltage tests is given.

2780. Designing Resistances: Abac for Estimating Eureka Wire Windings.—R. F. Blackwell. (*Wireless World*, July 1941, Vol. 47, No. 7, pp. 189–191.)

2781. Technique of Resistance Measurements on Alumina at High Temperatures.—A. Walter & B. Gorelik. (*Journ. of Tech. Phys.* [in Russian], No. 2, Vol. 10, 1940, pp. 85–90.)

2782. Balance Conditions and Sensitivity of Bridges for the Measurement of Impedances.—P. Lombardi. (*Alta Frequenza*, Aug./Sept. 1940, Vol. 9, No. 8/9, pp. 518–530.)

Author's summary:—"The property of being easily and quickly balanced is a valuable characteristic of an impedance bridge. The study of this property, with the help of the locus diagrams of the impedances of the arms, suitably combined, allows the balancing operation to be followed so as to provide criteria for the estimation and improvement of the 'convergence' of the bridge.

"The sensitivity is another factor of importance in the comparison of measuring instruments. For a bridge, it can be expressed in a simple form as the product of a factor depending on the type and construction of the bridge ["bridge factor"] and a factor depending on the composition of the branch in which the unbalancing occurs ["unbalance factor "]: this form lends itself to discussion and instructive conclusions." The simplification, in itself, is merely formal since each factor is a ratio of complex quantities; but its advantage lies in the fact that in a certain number of practical cases both of them can be calculated in advance. A simple example is given for a Wheatstone bridge for pure resistances.

2783. The Accuracy of Field-Strength Measurements.—J. D. Veegens & J. J. Z. van Zelst. (*E.T.Z.*, 30th April 1941, Vol. 62, No. 18, p. 431: summary from *Philips techn. Rundschau*, Vol. 5, 1940, p. 141 onwards.)

The accuracy of the usual measuring equipment depends above all on the accuracy of calibration of the valve voltmeter. For the recording field-strength meter here described, calibration is performed by putting a calibrating voltage from a signal generator across a resistance of about 0.1 ohm connected in the frame-aerial circuit. This resistance consists of 15 chrome-nickel wires of 25μ thickness and 1 mm length, connected in parallel, so that it is free from inductance and its resistance at 50 Mc/s differs from its d.c. value by less than 1%. Harmonics from the signal generator affect the calibration accuracy practically not at all if the generator current is checked by a thermo-ammeter. Frame-circuit asymmetry due to calibrating resistance, and resulting in a "vertical-aerial" effect, causes an error of at most 1%. Errors due to the capacitances of the leads between frame and valve voltmeter, to each other and to the casing, can be compensated to 1% or less. Taking the remaining sources of error into account, the over-all inaccuracy of the equipment is estimated at 4%, which is good enough for most purposes. The frequency range is wide—150 kc/s to 25 Mc/s.

2784. The Sensitivity of Radio Receivers and the Methods of Measuring It.—Koch. (*See* 2688.)

2785. Tests on Broadcast Receivers: General Determinations and Measurements on the Low-Frequency Complex.—Egidi. (*See* 2687.)

2786. Logarithmic Characteristics of Dry-Plate Rectifiers, and Their Application to Measuring Instruments.—Manfrino. (*See* 2747.)

2787. Inexpensive Thermionic Voltmeter [D.C. Voltmeter, usually needed for Slide-Back Peak-Voltmeter Circuit, eliminated by Use of Calibrated Potentiometer (Receiver Volume Control)].—T. B. Rymer. (*Journ. of Scient. Instr.*, Aug. 1941, Vol. 18, No. 8, p. 166.)

2788. Determination of the Correction of the Instrument under Test in D.C. Compensation Measurements [directly from the Galvanometer Reading].—W. Zschaage. (*E.T.Z.*, 24th April 1941, Vol. 62, No. 17, pp. 405–408.) Using, in particular, the Schmidt compensator dealt with in 2196 of August.

2789. Note on the D.C. Characteristics of the String Galvanometer [including Equation useful in Study of Departures from Strict Linearity].—F. T. Rogers, Jr. (*Review Scient. Instr.*, July 1941, Vol. 12, No. 7, pp. 351–354.)

2790. Improvements in the String Galvanometer.—C. W. Lutz. (*Zeitschr. f. Instr:kunde*, Aug. 1940, Vol. 60, No. 8, pp. 252–254.)

2791. Radiant Energy Measurements with Thermopiles [Explanation of 20–40% Discrepancy between Evacuated & Air-Filled Junctions used for Ultra-Violet Measurements].—N. C. Beese. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 922: summary.)

2792. Foundations of the Magnetic Amplifier for Measuring and Control Technique.—Geyger. (*See* 2857.)

2793. A New [Ballistic] Method of Measuring the True Remanence of Permanent Magnets.—H. Neumann & W. Zumbusch. (*Wiss. Veröff. a.d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials," pp. 21–36.)

2794. Cushioned Instruments [Use of "Vibro-Insulators"].—Goodrich Company. (*Review Scient. Instr.*, April 1941, Vol. 12, p. 238.)

2795. Insulation Test Set: Another Use for the Cathode-Ray Tuning Indicator.—J. S. Forrest. (*Wireless World*, July 1941, Vol. 47, No. 7, pp. 178–179.)

2796. A Timer for Spark Breakdown Studies [Device for Application & Measurement of 1–5000 μsec. Rectangular Voltage Waves: Technique for obtaining Truly Rectangular Waves].—J. D. Cobine & E. C. Easton. (*Review Scient. Instr.*, June 1941, Vol. 12, No. 6, pp. 301–305.)

2797. Internal Electro-Analysis [for Rapid Measurement (*e.g.*) of Copper & Bismuth Impurities in Lead Sheath].—C. L. Luke. (*Bell Lab. Record*, May 1941, Vol. 19, p. 294.)

2798. Engineering Problems in Dimensions and Tolerances.—W. W. Werring. (*Bell S. Tech. Journ.*, April 1941, Vol. 20, No. 2, pp. 179–198.)

SUBSIDIARY APPARATUS AND MATERIALS

2799. Cathode-Ray Tubes with Post-Acceleration [Type DN9-5: Comparison with Ordinary Type DN9-3: Recording Speed 24 km/s compared with 850 m/s].—de Gier. (*Alta Frequenza*, April 1941, Vol. 10, No. 4, pp. 253–254: summary only.) From *Rev. techn. Philips*, Sept. 1940.

2800. The Excitation of Crystal Phosphors by Corpuscular Rays.—Möglich & Rompe. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 304–307.)

Authors' summary:—"The transfer of energy from the impacting corpuscles to the crystal phosphor takes place directly through the electron gas of the crystal. The electrons take up the energy and give it up as radiation, in accordance with the ideas of Schön & Riehl (1580 of 1940). The incident particles produce in the electron gas a cascade of excited electrons. An electron incident with high velocity produces a cascade of electrons with progressively decreasing energy. An alpha particle, on the other hand, produces a large number of comparatively slow electrons, each of which forms the origin of an electron cascade. The life of an excited electron is very much longer in the first case than in the second, since it increases with $V^{3/2}$. Thus the electrons excited by electron collision are more exposed to multiple impacts with the lattice than the electrons whose cascades are produced by heavy particles. This explains why the quantum output at the excitation of a crystal phosphor by heavy particles is, as has been observed, incomparably more favourable than the output at excitation by electrons."

2801. Lifetime of Fluorescence by an Electronic Method [Decay Curve given Directly on C-R-Tube Screen: Present Form of Apparatus measures Lifetimes longer than 1 μsec.].—Rawcliffe. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 915: summary only.) *See* also *Science*, 23rd May 1941, Vol. 93, Supp. p. 8.

2802. On the Number of Quanta required for the Developability of a Silver Halide Grain.—Silberstein: Webb. (*Journ. Opt. Soc. Am.*, May 1941, Vol. 31, No. 5, pp. 343–348.) Challenging the correctness of Webb's conclusions (*see* 1173 of 1940): for reply, and another paper, *see* pp. 348–357.

2803. The Formation of Negative Halide Ions at the Interaction between Alkali-Halides and the Surface of Incandescent Tungsten.—Dukelski & Ionov. (*Journ. of Exper. & Theoret. Phys.* [in Russian], No. 11, Vol. 10, 1940, pp. 1248–1256.)

2804. A New Electrolytic Trough for the Investigation of Ultra-Short-Wave Fields in Multi-Layered Dielectrics.—Schaefer & Stachowiack. (*See* 2709.)

2805. "Elektrische Kippschwingungen" [Relaxation Oscillations: Book Review].—Richter. (*Alta Frequenza*, April 1941 Vol. 10, No. 4, p. 256.)

2806. The Mechanism of the Electrical Dissipation of Gas at Pressures below 10^{-4} mm Hg ["Clean-Up" Effect, with Consequent Further Decrease in Pressure].—Schwarz. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 381–384.) A more complete treatment was dealt with in 1671 of June.

2807. A Recording Sensitive Differential Manometer [responding to Pressure Differences as Small as 0.00003 cm Hg and as Rapid as 80 c/s].—Hurst. (*Review Scient. Instr.*, May 1941, Vol. 12, No. 5, pp. 265–268.)

2808. A New Low-Pressure Gauge [Simple & Cheap: depending on Rate of Sublimation of Solid CO_2].—Coffin & Dingle. (*Canadian Journ. of Res.*, May 1941, Vol. 19, No. 5, Sec. B, pp. 129–131.)

2809. The Measurement of Pressures by Thermoelectric Methods [Short Survey, leading to an Improved Thermo-Junction Manometer].—Bartholomeyczyk. (*Zeitschr. f. tech. Phys.*, No. 2, Vol. 22, 1941, pp. 25–27.)

2810. Molybdenite as a New Lubricant [for Bearings in a Vacuum, & Others].—Bell & Findlay. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 922: summary only.) *Cf.* 171 of January.

2811. A Mouth-Controlled Valve for Compressed Air in Glass Blowing.—Allison. (*Review Scient. Instr.*, April 1941, Vol. 12, No. 4, pp. 212–213.)

2812. A Magnetic Electron Microscope [Two-Stage, at M.I.T.].—Harvey & Sullivan. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 929: summary only.)

2813. Use of the Term "Resolving Power" in Spectroscopy [Suggestion of "Resolving Limit" (Instrumental Line Width in cm^{-1} at a Particular Wavelength) as Practical Measure].—Tolansky. (*Nature*, 12th July 1941, Vol. 148, p. 54.)

2814. On the Focusing of Ion Beams in the Cyclotron [and the Avoidance of Electrical Defocusing: Change of Phase by "Feeler" with Edge inclined to Dee Edge: etc.].—Yamaguchi. (*Proc. Phys.-Math. Soc. Japan*, May 1941, Vol. 23, No. 5, pp. 396–397: in English.)

2815. Preliminary Results on Two New Ion Sources [Vigdorchick's Gasomagnetron & a "Doughnut" H.F. Ring Discharge Tube].—Getting. (*Phys. Review*, 1st March 1941, Vol. 59, No. 5, p. 467: summary only.) For the gasomagnetron *see* also 783 of 1940 and back reference.

2816. Transmission of an Electron Density Disturbance along a Positive Column in a Longitudinal Field [Theory].—Tonks. (*Phys. Review*, 15th March 1941, Vol. 59, No. 6, pp. 522–527.)

2817. On Electron Movements in Plasmas, and Some Applications.—Schumann. (*See* 2685.)

2818. Influence of a Longitudinal Magnetic Field on an Electrical Discharge in Mercury Vapour at Low Pressure [Experimental Investigation of Tonks's Theory].—Cummings & Tonks. (*Phys. Review*, 15th March 1941, Vol. 59, No. 6, pp. 514–522.)

2819. Electrostatic Arc-Extinction on the "Starvation" Principle [Interruption of Mercury-Vapour Discharges by Electrostatic Suppression (by Grids) of Positive Ions: Extinction Times under 10^{-5} Second].—Meinhardt. (*Arch. f. Elektrot.*, 20th Feb. 1941, Vol. 35, No. 2, pp. 85–98.)

2820. Gap Recovery Strength of A.C. Arcs at High Pressure.—Bauer & Cobine. (*Gen. Elec. Review*, June 1941, Vol. 44, No. 6, pp. 315–321.)

2821. An Effect of Light in Gases under Electrical Discharge [Instantaneous Diminution of Discharge Current in Chlorine on Irradiation—Extension of Experiments to Other Gases].—Joshi & Deshmukh. (*Nature*, 28th June 1941, Vol. 147, p. 806.)

2822. A New Loss-Law for the A.C. Corona [for Commercial Frequencies].—Prinz. (*Wiss. Veröff. a. d. Siemens-Werken*, 5th Nov. 1940, Vol. 19, No. 3, pp. 88–135.)

2823. Forms of Discharge in Micro-Gaps [of Order of 10^{-4} cm, at Atmospheric Pressure].—Jones & Huxford. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 932–933: summary only.)

2824. High-Frequency Discharges through Gases [Survey, based chiefly on Writer's Researches, 1929/1939].—Asami. (*See* 2947).

2825. Alterations to Dielectric Liquids produced by Electric Gaseous Discharges [Systematic Investigation of the "Voltol" Process producing (1914/18) the Lubricating Oil "Electrion": New Developments (Lower Working Voltage & Frequency, Greatly Increased Activation) by Use of Results, particularly the Employment of Aluminium-Oxide Films as Stabilising Layers].—Rummel. (*Wiss. Veröff. a. d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials," pp. 278–317.) The work on the development of the oxide layers would seem to have an interest in connection with electrolytic condensers.

2826. On the Mechanism of the Oxide-Layer Formation on the Aluminium Anodes of Electrolytic Condensers.—Herrmann. (*Wiss. Veröff. a. d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials," pp. 188–212.)

Author's summary:—"The oxide layers formed on aluminium surfaces may be divided according to the conditions of their formation into atmospheric-oxide and anodic-oxide layers. The former type, which occurs from oxidation in the air, consists strictly of two layers, of which only one (the denser) acts as a dielectric. This follows from a comparison of the results of various types of investigating procedure. The structure of the modifications of the aluminium oxide, especially the γ-modification, makes it probable that the atmospheric-oxide layer is formed by the migration of aluminium ions and electrons [and as a dielectric it is only useful for very low voltages—under 2 v: it is of greater importance, however, in that "poled" electrolytic condensers generally have their cathodes in the form of an untreated aluminium foil, which is naturally covered with an atmospheric oxide layer, so that the properties of this layer enter into the behaviour of all "poled" electrolytics].

"The anodic layers are divided into dielectrically effective dense layers and dielectrically ineffective layers. The dense layers occur for forming-field strengths of over 10^8 v/cm. They consist chiefly of γ-Al$_2$O$_3$ and are presumably formed by migration of aluminium ions and chemical reaction at the boundary between aluminium oxide and electrolyte. If the forming field sinks below 10^8 v/cm, in electrolytes which readily dissolve aluminium oxide (sulphuric acid, oxalic acid) there is formed a further oxide layer which is dielectrically ineffective and allows current to pass. On the other hand if the electrolyte attacks aluminium oxide only feebly (boric acid, for example), no dielectrically ineffective oxide layer forms, as a rule, when the forming-field strength falls below 10^8 v/cm. In this potential region and with such electrolytes, the dielectric layers produced have low residual current and high specific capacitance, which are very important properties for electrolytic condensers. On a certain thickness being reached, corresponding, according to the nature and amount of the anions in the electrolyte, to a potential of the order of from 100 to 1500 v, a direct electron passage through the oxide layer occurs, with spark production, which limits any further growth of the oxide layer." There is a bibliography of 58 items. For further development *see* 2827, below.

2827. Researches on the Influence of Halogens in Electrolytes on the Electrolytic Valve-Action of Aluminium.—Herrmann & Prang. (*Wiss. Veröff. a. d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials," pp. 262–270.) Carrying on the work dealt with in 2826, above.

2828. Deviations of Semiconductors from Ohm's Law [including the Difference between Behaviour of Selenium & Copper-Oxide Rectifiers].—Schottky. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 322–325.) For a fuller treatment see *Schweizer Arch. f. angew. Wiss. u. Tech.*, Jan. & March 1941, Vol. 7, Nos. 1 & 3, pp. 20–29 & 82–86.

2829. The Use of the Selenium Cell in Rectifiers [and Its Limiting Values: Useful Surface of 90 cm^2, with Cooling Plates, gives Admissible Current 4–6 A, with Max. Loss (in Pass Direction) of about 12 W: Experimental Investigation].—Duinker. (*Alta Frequenza*, April 1941, Vol. 10, No. 4, pp. 239–240: summary only.) From *Rev. techn. Philips*, July 1940, Vol. 5, No. 7, pp. 196–205.

2830. "Keystone" Resistors with Negative Resistance Coefficient [for Temperature Range 0–150° C].—(*Review Scient. Instr.*, May 1941, Vol. 12, No. 5, p. 288.)

2831. The Evaporation of Molten Metals from Hot Filaments [for Production of Thermocouples, High Resistances, etc: Investigation of Best Filament for Each Metal].—Caldwell. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 940: summary only.)

2832. Properties of an Isotropic Dielectric in the Electric Fields of Ultra-High Frequencies ["Bone Effect"].—Ataka. (*See* 2647.)

2833. Dispersion and Absorption in Dielectrics [with Empirical Formula for Liquids & Solids: Result is Not satisfactorily described by Existing Dispersion Theories].—Cole & Cole. (*Phys. Review*, 1st March 1941, Vol. 59, No. 5, p. 474: summary only.)

2834. TRANSIENT CURRENT IN DIELECTRICS.—Cole & Cole. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 935–936: summary only.)

2835. DIELECTRIC CONSTANTS OF ALIPHATIC KETONES [and the Importance of the Dipole/Dipole Coupling].—Cole. (*Phys. Review*, 15th April 1941, Vol. 59, No. 8, p. 689: summary only.)

2836. "DIELECTRIC LOSS IN DIPOLAR SOLIDS: I—SOLUTIONS OF DIPOLAR MOLECULES IN SOLID PARAFFINS" [Book Review].—Fröhlich. (*Electrician*, 1st Aug. 1941, Vol. 127, p. 65.) An E.R.A. Technical Report.

2837. DIELECTRIC PROPERTIES OF EXPERIMENTAL RESIN-PAPER BOARDS.—Hartshorn, Rushton, & Megson. (*BEAMA Journal*, July 1941, Vol. 48, No. 49, pp. 112–115.) E.R.A. Report Ref. L/T100.

2838. THE CHARACTERISATION OF INSULATING-MATERIAL MIXTURES BY LOSS-ANGLE MEASUREMENTS.—Schupp. (*Wiss. Veröff. a.d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials," pp. 230–242.)

Measurements are reported here on commercial organic dielectrics consisting of mixtures of isomers whose exact chemical composition is hard to determine, namely chlornaphthaline (largely used for impregnation in condenser manufacture) and chlordiphenyl. It was found that the differences in the various molecule-types could be recognised from the dielectric behaviour, provided that sufficiently wide ranges of frequency and temperature were employed. "Some special results which thus came to notice are reported: they lead to an extension of the Debye theory. It can be assumed that a systematic development of the method will bring new knowledge not only to the physicist but also to the chemist." In the following paper (pp. 243–261) the method is applied to researches on the ageing condition and dielectric properties of mineral oils.

2839. KINETICS OF DEGRADATION AND SIZE DISTRIBUTION OF LONG-CHAIN POLYMERS.—Simha. (*Journ. Applied Phys.*, July 1941, Vol. 12, No. 7, pp. 569–578.)

2840. ON THE PHYSICS OF STYROFLEX: TECHNICALLY IMPORTANT PROPERTIES OF THE POLYSTYROL IN THE "STRETCHED" STATE.—Müller. (*Wiss. Veröff. a.d. Siemens-Werken*, 16th Jan. 1940, Vol. 19, No. 1, pp. 110–133.)

Author's summary:—"A simple treating process, thermal 'stretching,' allows a very flexible material, Styroflex, to be prepared from the essentially brittle Polystyrol. The great technical importance of this Styroflex makes an exact investigation into its physical properties seem desirable. The behaviour of Polystyrol and Styroflex can be understood from molecular-physical considerations. Styroflex is seen as a Polystyrol whose molecules are oriented in a particular manner. The straightening of the thread-like molecules permits all the properties of this material to be explained. After it was found that its double refraction forms a suitable measure of the condition of Styroflex [pp. 117–122], this method has been employed to investigate, in particular, the thermal effects such as the shrinking at high temperatures and the internal elastic strains, and also the alteration, with time, of the Styroflex condition at various high temperatures. Since the hardening is seen to be a 'freezing-in' process, Styroflex below its 'freezing-in point' is quite constant in time [no signs of deterioration over several years have been found, and a 1½ years' test at 70° actually showed an improved response to the "folding" test within the first month, and this persisted throughout the period: *see* footnotes 3, p. 130, and 2, p. 132. The "freezing-in" point ranges from about 70° for a medium-quality material to over 85°]. The more important data are collected into tables and curves." *Cf.* Keutner, 391 of February.

2841. ELECTRICAL PROPERTIES OF SOLIDS [Measurements over Wide Temperature Range at 60–10 000 c/s on Polar Polymers such as Polyvinyl Chloride, including Mixtures].—Fuoss. (*Nature*, 7th June 1941, Vol. 147, p. 714: summary only.)

2842. SOME RELATIONS OF FLOW AND PHYSICAL PROPERTIES WITH FORMULATION IN CELLULOSE ACETATE PLASTICS.—Gloor. (*Journ. Applied Phys.*, May 1941, Vol. 12, No. 5, pp. 420–425.)

2843. THE PLASTICS INDUSTRY: SOME RECENT DEVELOPMENTS IN MOULDING MATERIALS [including Luminous Plastics].—Yarsley. (*Electrician*, 8th Aug. 1941, Vol. 127, p. 73.)

2844. THE ELECTRICAL PROPERTIES OF ZINC OXIDE, *and* THE ELECTRICAL CONDUCTIVITY OF TITANIUM DIOXIDE [Rutile & Anatase Modifications: Reduction Semiconductor of Same Type as Zinc Oxide].—Miller: Earle. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 942: p. 942: summaries only.)

2845. ELECTRICAL CONDUCTIVITY IN COMPOSITE ALKALINE BORIC GLASSES.—Markin. (*Journ. of Tech. Phys.* [in Russian], No. 1, Vol. 10, 1940, pp. 66–78.)

2846. THE CONDUCTIVITY OF GLASS AS A FUNCTION OF FIELD STRENGTH [Measurements between 0° & 110° C agree with Seitz's Theory of Electrolytic Conductivity of Solids].—Maurer: Seitz. (*Phys. Review*, 15th April 1941, Vol. 59, No. 8, p. 691: summary only.)

2847. ELECTRIC BREAKDOWN OF GLASSES AND CRYSTALS AS A FUNCTION OF TEMPERATURE, *and* SCATTERING, TRAPPING, AND RELEASE OF ELECTRONS IN NaCl AND IN MIXED CRYSTALS OF NaCl AND AgCl.—von Hippel, Maurer, Lee. (*Phys. Review*, 15th May 1941, Vol. 59, No. 10, pp. 820–823: pp. 824–826.)

2848. ELECTRICAL CONDUCTION IN THE GLASS INSULATION OF RESISTANCE THERMOMETERS [Soft-Glass Seals subjected to about 0.1 Volt: Phenomenon also observed in Leyden Jars].—Hoge. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 921: summary only.)

2849. THE EFFECT OF X-RAYS ON THE BREAKDOWN STRENGTH AND FLASHOVER VOLTAGE OF CERTAIN DIELECTRICS [Reduction in Strength influenced by Gap Length & Quantity of X-Rays: Flashover Voltage increased by Exposure of Solid/Air Boundary to X-Rays].—Walker. (*Journ. Applied Phys.*, March 1941, Vol. 12, No. 3, pp. 215–218.)

2850. SURGE POTENTIALS OF GREAT STEEPNESS [Secondary Discharges occurring (*e.g.*) in the Shock-Testing of Insulators].—Kläy. (*Bull. Assoc. suisse des Élec.*, 6th June 1941, Vol. 32, No. 11, pp. 242–245.)

2851. INTRODUCTION TO VDE 0360/XII.40 "RULES FOR THE TESTING OF INSULATING VARNISHES".—Husse & Pfestorf. (*E.T.Z.*, 30th April 1941, Vol. 62, No. 18, pp. 423–427.)

2852. SPECIFIC HEAT OF LAC AND LAC CONSTITUENTS [of Interest in connection with Storage].—Bhattacharya. (*Indian Journ. of Phys.*, Dec. 1940, Vol. 14, Part 6, pp. 415–422.)

2853. HEAT OF ADSORPTION OF WATER BY PAPERS [in Connection with the Commercial Drying of Insulating Papers].—Houtz & McLean. (*Bell Tel. System Tech. Pub.*, Monograph B-1272, 16 pp.)

2854. THE DIELECTRIC PROPERTIES OF RESIN-OIL MIXTURES.—Whitehead & Chapman. (*Journ. Franklin Inst.*, March 1941, Vol. 231, No. 3, pp. 245–268.)

2855. ASBESTOS-COVERED CABLES: INVESTIGATIONS RESPECTING INSULATION RESISTANCE AND ELECTRIC STRENGTH.—Lethersich. (*Electrician*, 15th Aug. 1941, Vol. 127, pp. 87–88.) E.R.A. Report No. F/T.123a.

2856. PAPERS ON THE PENETRABILITY TO MOISTURE OF SYNTHETIC-MATERIAL CABLE SHEATHS [replacing Lead].—Schulze: Schupp. (*E.T.Z.*, 30th April 1941, Vol. 62, No. 18, p. 427: p. 433: summaries only.)

2857. FOUNDATIONS OF THE MAGNETIC AMPLIFIER [on the Principle of the Polarised Iron-Cored Choke] FOR MEASURING AND CONTROL TECHNIQUE [including Latest Developments in Single-Stage & Two-Stage Types (Magnification 10^7) and Their Applications as Contact-less Relay, for driving Recorders, etc.].—Geyger. (*Wiss. Veröff a.d. Siemens-Werken*, 5th Nov. 1940, Vol. 19, No. 3, pp. 4–47.) *Cf.* 4235 of 1940, also 3149 & 4285 of 1938.

2858. MAGNETIC INCREASE OF RESISTANCE AND TYPES OF CONDUCTION IN METALS [with Measurements of the Galvano-Magnetic Effect].—Justi. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 315–322.)

2859. THE SCREENING OF MAGNETIC FIELDS: SURVEY OF LITERATURE.—Maschke. (*Zeitschr. f. Instr:kunde*, Dec. 1940, Vol. 60, No. 12, p. 378: summary only.) Particularly the work of Gustafson, 4414 of 1938 and 1244 of 1939. For Moeller's recent paper *see* 2237 of August.

2860. THE HYSTERESIS CYCLE AND ITS INTERPRETATION.—Bates. (*Proc. Phys. Soc.*, 1st July 1941, Vol. 53, Part 4, pp. 468–479.)

2861. CALCULATION OF THE TORQUE ON A FERROMAGNETIC SINGLE CRYSTAL IN A MAGNETIC FIELD.—Bozorth & Williams. (*Phys. Review*, 15th May 1941, Vol. 59, No. 10, pp. 827–833.)

2862. STATISTICS OF THE TWO-DIMENSIONAL FERROMAGNET [Study of Curie Transition].—Wannier. (*Phys. Review*, 15th April 1941, Vol. 59, No. 8, p. 683: summary only.)

2863. STATISTICAL THEORY OF BINARY ALLOYS: I.—Takagi. (*Proc. Phys.-Math. Soc. Japan*, Jan. 1941, Vol. 23, No. 1, pp. 44–65: in English.) Part II (not in the Feb. or March issues) will deal in detail with the application to ferromagnetism.

2864. MAGNETIC PERMEABILITY AND RESISTANCE OF IRON WIRES OF VARIOUS STRUCTURES AT FREQUENCIES ABOUT 10^8 C/S IN RELATION TO THE SIZE OF THE WEISS ELEMENTARY REGIONS.—Strutt & Knol. (*Review Scient. Instr.*, April 1941, p. 246: reference only, to paper in *Physica*, July 1940, Vol. 7, pp. 635–654.) For previous work *see* 1526 of 1940.

2865. SOME EXPERIMENTS ON THE INFLUENCE OF THE NATURAL STRAINS ON THE COERCIVE FORCE AND CRITICAL FIELD STRENGTH OF THE BARKHAUSEN JUMPS [leading to an Estimate of the Thickness of the Weiss Domains].—Kersten & Gottschalt. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 345–352.)

2866. DISPERSION OF INITIAL PERMEABILITY, *and* EFFECTIVE LENGTH OF A SMALL BARKHAUSEN DISCONTINUITY.—Snoek. (*Review Scient. Instr.*, April 1941, p. 246: references only, to papers in *Physica*, June & July 1940, Vol. 7, pp. 515–518 & pp. 609–624.)

2867. ON THE MECHANISM OF THE DISCONTINUOUS MAGNETISATION OF THE SINGLE CRYSTAL OF MAGNETIC PYRITES, PYRRHOTIN [Investigation of Barkhausen Jumps in Ferromagnetic Semiconductor, to avoid Disturbance by Eddy-Current Effects], *and* ON THE MAGNETIC BEHAVIOUR OF MAGNETITE AT LOW TEMPERATURES.—Okamura & others. (*Proc. Phys.-Math. Soc. Japan*, Feb. 1941, Vol. 23, No. 2, pp. 132–142: May, No. 5, pp. 363–369: in German.)

2868. ELEMENTARY PROCESSES OF MAGNETISATION IN THE REGION OF INITIAL SUSCEPTIBILITY: CORRECTIONS.—Thiessen. (*Ann. der Physik*, 13th Jan. 1941, Vol. 39, No. 1, p. 30.) *See* 217 of January.

2869. THE TEMPERATURE DEPENDENCE OF THE INITIAL SUSCEPTIBILITY AND THE COERCIVE FORCE IN FERROMAGNETIC CRYSTALS.—Dekhtjar & Andrjushin. (*Journ. of Exper. & Theoret. Phys.* [in Russian], No. 12, Vol. 10, 1940, pp. 1402–1407.)

2870. Dislocations and Magnetisation [in connection with Empirical Formula for Magnetisation Curve of Nickel at High Fields].—Brown. (*Phys. Review*, 15th March 1941, Vol. 59, No. 6, p. 528.)

2871. Discontinuities of Magnetostriction and Magnetisation in Nickel [Simultaneous Records of Sounds & of Magnetisation Jumps: Results & Deductions].—Heaps. (*Phys. Review*, 1st April 1941, Vol. 59, No. 7, pp. 585–587.)

2872. Anomalous Recrystallisation in Surface-Centred Iron-Nickel-Copper Alloys.—Müller. (*Wiss. Veröff. a. d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials," pp. 1–20.)

2873. Outlook for Use of Neutron Scattering in studying Ferromagnetic Substances, *and* Neutron Studies of Order in Fe-Ni Alloys.—Bloch: Nix & others. (*Journ. Applied Phys.*, April 1941, Vol. 12, No. 4, p. 305: p. 305: summaries only.) For the second paper see *Bell Tel. System Tech. Pub.*, Monograph B-1267, 9 pp.

2874. Saturation Magnetisation of Nickel-Antimony and Nickel-Tantalum Alloys, *and* Magnetisation of Copper-Nickel Alloys.—Rado, Kaufmann, Starr. (*Phys. Review*, 15th April 1941, Vol. 59, No. 8, p. 690: p. 690.)

2875. A New Method of Measuring the True Remanence of Permanent Magnets.—Neumann & Zumbusch. (*See* 2793.)

2876. On the Standardisation of Permanent-Magnet Materials.—Zumbusch. (*E.T.Z.*, 8th May 1941, Vol. 62, No. 19, p. 448: summary only.)

2877. Single Casting Magnet Cores [for Mass Spectrograph].—Jordan. (*Review Scient. Instr.*, May 1941, Vol. 12, No. 5, pp. 261–264.)

2878. Sinter Magnets of Iron-Nickel-Aluminium [Advantages offered by the Sintering Method of Alloy Formation over the Fusing Method: Practical Considerations].—Ritzau. (*Wiss. Veröff. a. d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials", pp. 37–43.)

2879. The Development and Technical Significance of the Hard Metals [Survey, including the Sintering Process (*see* Ritzau, 2878, above)].—Amman. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 332–335.)

2880. Theory of the Plastic Properties of Solids: IV.—Seitz & Read. (*Journ. Applied Phys.*, July 1941, Vol. 12, No. 7, pp. 538–554.) For this series *see* 2235 of August.

2881. "Handbuch der Werkstoffprüfung" [Testing of Materials: Book Review].—(*Schweizer Arch. f. angewändte Wiss. u. Tech.*, March 1941, Vol. 7, No. 3, pp. 91–92.) Produced by collaboration between the German State Establishment for Testing Materials and other authorities.

2882. Effect of Prolonged Heating at 80° C on Copper Wire.—Voce. (*Engineering*, 2nd May 1941, Vol. 151, pp. 359–360.)

2883. Wires with a Zinc Basis, for Electric Lines and Cables.—Deisinger & Reinbach. (*Wiss. Veröff. a.d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials", pp. 88–102.)

2884. "Silver in Industry" [including Many New Applications developed by Recent Research: Book Review].—Addicks (Edited by). (*Review Scient. Instr.*, June 1941, Vol. 12, No. 6, pp. 339–341.)

2885. Electro-Tinning of Parts to be Soldered [Thickness of Deposit is Decisive Factor].—Homer & Watkins. (*Engineering*, 13th June 1941, Vol. 151, p. 470: summary only.)

2886. Substitute Materials for Optical Apparatus.—Sporkert. (*Zeitschr. V.D.I.*, 31st May 1941, Vol. 85, No. 22, pp. 501–504.)

2887. Electrical Contact Resistance [Survey].—Windred. (*Journ. Franklin Inst.*, June 1941, Vol. 231, No. 6, pp. 547–585.)

2888. On the Suppression of Hunting in "Electrical Shafting" [Electrically Synchronised Motors] by Inductive and Ohmic Resistances in the Rotor Circuit.—Jordan & Schmitt. (*AEG-Mitteilungen*, March/April 1941, No. 3/4, pp. 102–106.)

STATIONS, DESIGN AND OPERATION

2889. Radio-Communication between Fixed Posts and Moving Trains [Experiments with Telephony on Various Italian Electric Railways: Necessity for Carrier System, to overcome Interference: Successful Results (800 m Wave) with 40 W Transmitter over 40 km].—(*Alta Frequenza*, Nov. 1940, Vol. 9, No. 11, pp. 706–707: summary only.)

2890. "Report on the Progress of Broadcasting in India" [Book Review].—(*Indian Journ. of Phys.*, Dec. 1940, Vol. 14, Part 6, pp. 499–503.) Including criticisms and recommendations. *See* also 920 of March.

2891. The Broadcasting of Standard Frequency in Japan.—Amisima & Yoneyama. (*See* 2776.)

GENERAL PHYSICAL ARTICLES

2892. Biot-Savart Law and Newton's Third Law of Motion [Apparent Failure of Former in Certain Electrical Calculations is due to General Inapplicability of Latter to Mutual Forces between Current Elements.]—Mathur. (*Phil. Mag.*, Aug. 1941, Vol. 32, No. 211, pp. 171–176.)

2893. A New Treatment of the Theory of Dimensions [Dimensions of Physical Quantities in terms of Symbols representing Length & Time Measurements only, and New Use for Dimensional Equations in checking

Physical Theories, not merely Equations of Physical Terms].—Burmiston Brown. (*Proc. Phys. Soc.*, 1st July 1941, Vol. 53, Part 4, pp. 418–432.) *See* also 2894, below.

2894. The Dimensions of Physical Quantities [and Their Dependence on Definition & on Choice of "Indefinables"].—Duncanson (*Proc. Phys. Soc.*, 1st July 1941, Vol. 5 Part 4, pp. 432–448.)

For an Editorial by G.W.O.H. on this paper, and the one referred to in 2893, above, see *Wireless Engineer*, Sept. 1941, pp. 351–352.

2895. Electron Theory of Thermoelectric Effects [including the Distinction between "Driving" & "Working" Electromotive Forces].—Houston. (*Journ. Applied Phys.*, July 1941, Vol. 12, No. 7, pp. 519–529.)

2896. How do the Conduction Electrons of a Metal dispose themselves in Layers under the Action of Gravity ?—Wolf. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 325–327.) *See* also 2563 of September.

MISCELLANEOUS

2897. A New Algebraic Method for the Determination of Unknown Periods.—Stumpff. (*See* 2632.)

2898. On the Solution of Certain Differential Equations of the Second Order.—Roth. (*See* 2652.)

2899. The Matrix Theory of Differential Equations.—Luzin. (*Automatics & Telemechanics* [in Russian], No. 5, 1940, pp. 4–66.)

A theoretical treatise at the end of which are indicated possible practical applications of the theory in studying the operation of a mechanism : for a prefatory note by Kulebakin *see* pp. 3–4.

2900. The Fourier Integral, *and* An Extension of the Fourier Integral.—Sartori : Wagner. (*See* 2680.)

2901. "Gap and Density Theorems", *and* "Fourier Series and Boundary Value Problems" [Book Reviews].—Levinson : Churchill. (*Science*, 11th July 1941, Vol. 94, pp. 41–42 : p. 42.)

2902. Partial Derivatives of Derivatives : Part II—Partial Derivatives of a Line Integral in the Calculus of Variations having a Curved Path of Integration.—Kimball. (*Phil. Mag.*, Aug. 1941, Vol. 32, No. 211, pp. 137–154.) For Part I *see* 4486 of 1940.

2903. Statistical Methods [Reviews of Three Books].—(*Science*, 23rd May 1941, Vol. 93, pp. 497–498.)

2904. The Standard Error of the Mean Vector : The Normal Law of Frequency for Vector Quantities : *and* The Characteristic Values of the Correlation Tensor and a New Measure of Correlation between Vector Quantities.—Masuyama. (*Proc. Phys.-Math. Soc. Japan*, March 1941, Vol. 23, No. 3, pp. 194–204 : in English.)

2905. The Totally Orthonormalised Vector Set and the Normal Form of Correlation Tensor, *and* The Mean Angle between Two Vector Sets.—Masuyama. (*Proc. Phys.-Math. Soc. Japan*, April 1941, Vol. 23, No. 4, pp. 346–351 : pp. 351–355 : in English.)

2906. Some Formulae for the E-Function [in connection with Evaluation of Integrals involving Hypergeometric & Legendre Functions].—MacRobert. (*Phil. Mag.*, March 1941, Vol. 31, No. 206, pp. 254–260.)

2907. Numerical Integration by Tchebycheff's *q*-Functions, with an Application to a Hydrodynamical Problem.—Okaya. (*Proc. Phys.-Math. Soc. Japan*, April 1941, Vol. 23, No. 4, pp. 273–282 : in English.)

2908. "The Stereographic Projection" [Method of Representing a Solid Body on a Plane : Circles remain Circles, Angles are retained : Book Review].—Sohon. (*Nature*, 12th July 1941, Vol. 148, p. 37.) Applicable to seismology, astronomy, etc.

2909. The Eötvös Effect and Its Applications [to East/West Differences, in Aircraft & Projectile Velocities, Movements of Air Masses, etc.].—Szolnoki. (*Naturwiss.*, 9th May 1941, Vol. 29, No. 19, pp. 273–277.)

2910. Distance Signals [Distance Determination by Optical Phenomenon of Double Grating].—Lau. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 296–298.) *See* also 2282 of 1940.

2911. An Analysis of the Amplification of Exponential Pulses [primarily in Counter-Pulse Amplifier].—Page. (*See* 2666.)

2912. An Investigation [Theoretical & Experimental] of the Properties of Proportional Counters : I.—Rose & Korff. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, pp. 850–859.)

2913. New Circuit for a Thyratron-Driven Counter [for Use with Counter-Tube or Ionisation Chamber : High-Vacuum "Blocking" Valve in Series with Thyratron], *and* A Coincidence Amplifier with High Resolving Power.—Schintlmeister & Czulius : Weber. (*Physik. Zeitschr.*, 10th May 1940, Vol. 41, No. 9/10, pp. 269–271 : 1st/15th July 1940, No. 13/14, pp. 338–339.)

2914. Counter Circuits using Gas-Filled Valves, *and* On the Estimation of the Resolving Power of Geiger-Müller Counters.—Piccioni : Cocconi & Tongiorgi. (*La Ricerca Scient.*, June 1940, Vol. 11, No. 6, pp. 409–412 : July/Aug. 1940, No. 7/8, pp. 518–525.)

2915. Geiger-Mueller Counters [Review of Methods of Construction and Application in the light of the Writers' Picture of Counter Mechanism].—Montgomery & Montgomery. (*Journ. Franklin Inst.*, May & June 1941, Vol. 231, Nos. 5 & 6, pp. 447–467 & 509–545.)

2916. Technical Counter-Tube Apparatus for Coarse- and Fine-Structure Investigations [with X-Rays: using Special Counter Tubes].—Trost. (*E.T.Z.*, 27th June 1940, Vol. 61, No. 26, p. 596: summary only.) *See* also 2301 of August.

2917. Quantum Efficiency of Geiger-Müller Counters for X-Ray Intensity Measurements.—Sullivan. (*Review Scient. Instr.*, Nov. 1940, Vol. 11, No. 11, pp. 356–362.)

2918. X-Ray Analysis in Industry: Part II—Technique of X-Ray Analysis Methods and Some Recent Developments [Thirteen Papers, by Various Authors, on Study of Alloys, Crystal Orientation, Particle-Size Measurements, etc.].—(*Journ. of Scient. Instr.*, July 1941, Vol. 18, No. 7, pp. 126–158.) Part I was referred to in 2303 of August.

2919. X-Ray Physics and X-Ray Tubes: X-Ray Diffraction Methods: Determination of Constitution Diagrams with X-Rays: Evaluation of the Avogadro Number N and the Charge on the Electron e, by X-Rays: *and* X-Rays in Medicine.—Hicks & others. (*Journ. Applied Phys.*, May 1941, Vol. 12, No. 5, pp. 364–413.)

2920. "Applied X-Rays: Third Edition" [Book Reviews].—Clark. (*Engineering*, 13th June 1941, Vol. 151, p. 463: *Nature*, 12th July 1941, Vol. 148, p. 36.)

2921. Electrical Breakdown of Anodically Oxidised Coatings on Aluminium: a Means of Checking Thickness of Anodised Finishes.—Compton & Mendizza. (*Bell S. Tech. Journ.*, April 1941, Vol. 20, No. 2, p. 251: summary only.)

2922. The Use of Radioactive Materials in Measuring the Thickness of Enamel Coatings [avoiding Limitations of Electrical & Magnetic Methods].—Miller & Cohee. (*Phys. Review*, 1st March 1941, Vol. 59, No. 5, p. 468: summary only.)

2923. The Detection of Flaws in Non-Magnetic Metals by Eddy Currents.—Gunn. (*Engineering*, 27th June 1941, Vol. 151, pp. 518–519.)

2924. The Outgassing of Aluminium and Its Alloys by means of Acoustic Vibrations.—Esmarch & others. (*Wiss. Veröff. a. d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials," pp. 78–87.)

2925. Properties and Use of a High-Frequency Spark Discharge for Local Micro-Analysis [of Metallic Surfaces].—Murray & others. (*Journ. Opt. Soc. Am.*, June 1941, Vol. 31, No. 6, pp. 433–438.) "Potentially a very powerful tool . . ."

2926. High Rotational Speed with Small Rotors [with "Inductance Control" of Vertical Stabilisation: Ball-Bearing Ball (with Ground Faces to act as Mirror) at over 100 000 r.p.s.].—MacHattie. (*Phys. Review*, 1st March 1941, Vol. 59, No. 5, p. 468: summary only.) *Cf.* 2013 of July.

2927. Measurement of Amplitude and Acceleration of Vibrations by means of a Special Rochelle-Salt Pick-Up.—Schilling. (*Sci. Abstracts*, Sec. B, June 1941, Vol. 44, No. 522, p. 100.)

2928. A Piezoelectric Acceleration Meter [for I.C. Engines].—Frölich. (*Zeitschr. f. Instr: kunde*, July 1940, Vol. 60, No. 7, pp. 226–227: summary only.)

2929. "Practical Solution of Torsional Vibration Problems" [Book Review].—Ker Wilson. (*Electrician*, 25th July 1941, Vol. 127, p. 47.) Including list of patents on elimination of vibration.

2930. "Teoria e Technica delle Vibrazioni Meccaniche" [Book Review].—Tessarotto. (*Alta Frequenza*, April 1941, Vol. 10, No. 4, pp. 255–256.)

2931. Electron-Microscopical Determination of Object Thicknesses.—Marton. (*Phys. Review*, 1st June 1941, Vol. 59, No. 11, p. 929: summary only.)

2932. Papers on the Electron-Microscope in the Testing of Materials, including the Obtaining of Electron-Diffraction Diagrams by the Electron-Microscope.—von Borries, Ruska, & others. (*Wiss. Veröff. a. d. Siemens-Werken*, 18th Sept. 1940, Vol. 19, Special Issue on "Materials," pp. 334–379.)

2933. The Plastic-Impression Method for the Electron-Microscopic Examination of Surfaces [of Corroded Aluminium, etc.].—Mahl. (*Zeitschr. f. tech. Phys.*, No. 2, Vol. 22, 1941, pp. 33–38.) This method was first mentioned in the paper dealt with in 2102 of 1940.

2934. The Electron Microscope in Bacteriology and Virus Study.—Mudd. (*Journ. Franklin Inst.*, May 1941, Vol. 231, No. 5, pp. 496–498.)

2935. The Fine Structure of Erythrocyte Membranes [with Electron-Microscopic Photographs, Magnifications up to 17 000, increased in Reproduction to 51 000].—Wolpers. (*Naturwiss.*, 11th July 1941, Vol. 29, No. 28, pp. 416–420.)

2936. Investigations on the Absorption and Ray-Concentration of Ultra-Short Waves in Electrolytes and Biological Tissues, as a Basis for a Medical Application of the Radiation Field.—Patzöld. (*See* 2621.)

2937. A New Electrolytic Trough for the Investigation of Ultra-Short-Wave Fields in Multi-Layered Dielectrics [representing Biological Tissues].—Schaefer & Stachowiack. (*See* 2709.)

2938. On the Problems of Ultra-Short [and Micro-] Waves [Researches since 1936 of Radio Research Committee: Generation, Action on Human Body, Measurement].—Shibusawa. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], Abstracts p. 4.)

"During the last year [1938] tubes capable of generating 17 kw output at 3 m, and 20 w at 20 cm, were produced. . . ." Methods of measuring wavelength are satisfactory, but measurement of current and power is not accurate, and greater effort is to be concentrated on this research.

2939. ACCIDENTS DUE TO ELECTRICITY IN SWITZERLAND DURING 1940.—(*Bull. Assoc. suisse des Élec.*, 6th June 1941, Vol. 32, No. 11, pp. 237–242.)

2940. VARIABLE-FREQUENCY STIMULATOR [Repetition Rate 0.5 to 1500 per Second].—DuMont Laboratories. (*Review Scient. Instr.*, April 1941, Vol. 12, No. 4, p. 232.)

2941. HAZARD OF MERCURY VAPOUR IN SCIENTIFIC LABORATORIES.—Shepherd & others. (*Journ. of Res. of Nat. Bur. of Stds.*, May 1941, Vol. 26, No. 5, pp. 357–375.) *See* also Giese, 3250 of 1940.

2942. THE PRODUCTION OF WAVES BY THE SUDDEN RELEASE OF A SPHERICAL DISTRIBUTION OF COMPRESSED AIR IN THE ATMOSPHERE.—Unwin. (*Proc. Roy. Soc.*, Ser. A, 12th June 1941, Vol. 178, No. 973, pp. 153–170.) A summary was dealt with in 1255 of April.

2943. DAMPING OF WAVES BY SURFACE-ACTIVE SUBSTANCES [Oil on Water: Mathematical Analysis].—Levich. (*Journ. of Exper. & Theoret. Phys.* [in Russian], No. 11, Vol. 10, 1940, pp. 1296–1304.)

2944. THE REFRACTION OF ELECTRIC WAVES AT THE EARTH'S SURFACE [in Propagation from Below Ground to the Open Air, as in Communication or Radio-Prospecting Tests from Mines, etc.].—Wundt. (*See* 2635.)

2945. GEOELECTRIC CONSTITUTION OF THE SUBSOIL AND PROTECTION AGAINST LIGHTNING.—Fritsch. (*See* 2642.)

2946. "GEOPHYSICAL EXPLORATION" [Book Review].—Heiland. (*Review Scient. Instr.*, April 1941, Vol. 12, No. 4, pp. 227–228.)

2947. HIGH-FREQUENCY DISCHARGES THROUGH GASES [Survey, based chiefly on Writer's Researches, 1929/1939].—Asami. (*Rep. Rad. Res. in Japan*, Nov. 1940, Vol. 10 [only issue], pp. 1–10.)

"H.F. engineering calls for this study for the protection of the apparatus used at h.f. and high voltage. . . Moreover, the interest of some investigators [Swiss & Russian references are given] has been recently directed towards the chemical aspect of h.f. discharges, and it has been reported that the yield per kWh of the discharge energy of some chemical reactions has increased considerably when the frequency was greater than 10 Mc/s." For some of the writer's previous papers *see* 1229 of 1935 and 1196 & 4033 of 1940.

2948. ALTERATIONS TO DIELECTRIC LIQUIDS PRODUCED BY ELECTRIC GASEOUS DISCHARGES ["Voltol" Process].—Rummel. (*See* 2825.)

2949. A MATERIAL WITH EXTREMELY HIGH VELOCITY OF SOUND PROPAGATION.—Thiede. (*See* 2752.)

2950. FOUNDATIONS OF THE MAGNETIC AMPLIFIER FOR MEASURING AND CONTROL TECHNIQUE.—Geyger. (*See* 2857.)

2951. ON THE THEORY OF AUTOMATIC CONTROLLING SYSTEMS.—Koshcheev. (*Automatics & Telemechanics* [in Russian], No. 5, 1940, pp. 77–88.)

The theory of servo-mechanisms in which the output torque is determined by the input/output deviation is discussed. Conditions are established under which self-oscillations of the system are generated, and the operation of a stabilised system is considered.

2952. PAPERS ON IGNITRON-TYPE ["Ignition-Pin Controlled"] RECTIFIER TUBES AS APPLIED TO WELDING CONTROL.—Arends & others. (*AEG-Mitteilungen*, March/April 1941, No. 3/4, pp. 81–101.)

2953. RESULTS OF FIELD TESTS OF THE AUTOMATIC SPEED REGULATOR OF FAST PAPER-MAKING MACHINES.—Kogan. (*Automatics & Telemechanics* [in Russian], No. 5, 1940, pp. 111–122.)

The theory and advantages of the static method of speed regulation making use of ion and electron devices are discussed, and a report is given on tests with a speed regulator using thyratrons (Fig. 1). The relative speed deviation of a machine controlled by this regulator does not exceed ± 0.15% under any load conditions.

2954. ON THE THEORY OF MODULATION OF A HIGH-PRESSURE ARC BY AN ALTERNATING COMPONENT SUPERPOSED ON THE DIRECT CURRENT.—Weizel, Rompe, & Schulze. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 21, 1940, pp. 387–391.) Including a comparison with Mangold's experimental results (1537 of May) on the modulation of the high-pressure mercury-vapour lamp.

2955. ENERGY AT THE THRESHOLD OF VISION [New Tests give 2.2–5.7 × 10^{-10} Ergs at Cornea (58–148 Quanta of Blue-Green Light): Estimation of Quanta absorbed by Retina: etc.].—Hecht, Shlaer, & Pirenne. (*Science*, 20th June 1941, Vol. 93, pp. 585–587.)

2956. A NEW SHORT-INTERVAL CHRONOSCOPE.—Kuehni. (*See* 2777.)

2957. A TURBULENCE ANALYSER [for Wind Tunnels at the Aeronautical Laboratory, Turin: with Special Amplifier].—Dilda. (*Alta Frequenza*, Oct. 1940, Vol. 9, No. 10, pp. 594–620.)

The four-stage amplifier has to have an over-all amplification of about one million, because the circuit which compensates for the thermal inertia of the hot-wire-anemometer wire makes use of only a fraction of the available voltage. This amplification has to extend to the lowest frequencies, since these contain the greater part of the energy corresponding to the turbulence phenomena.