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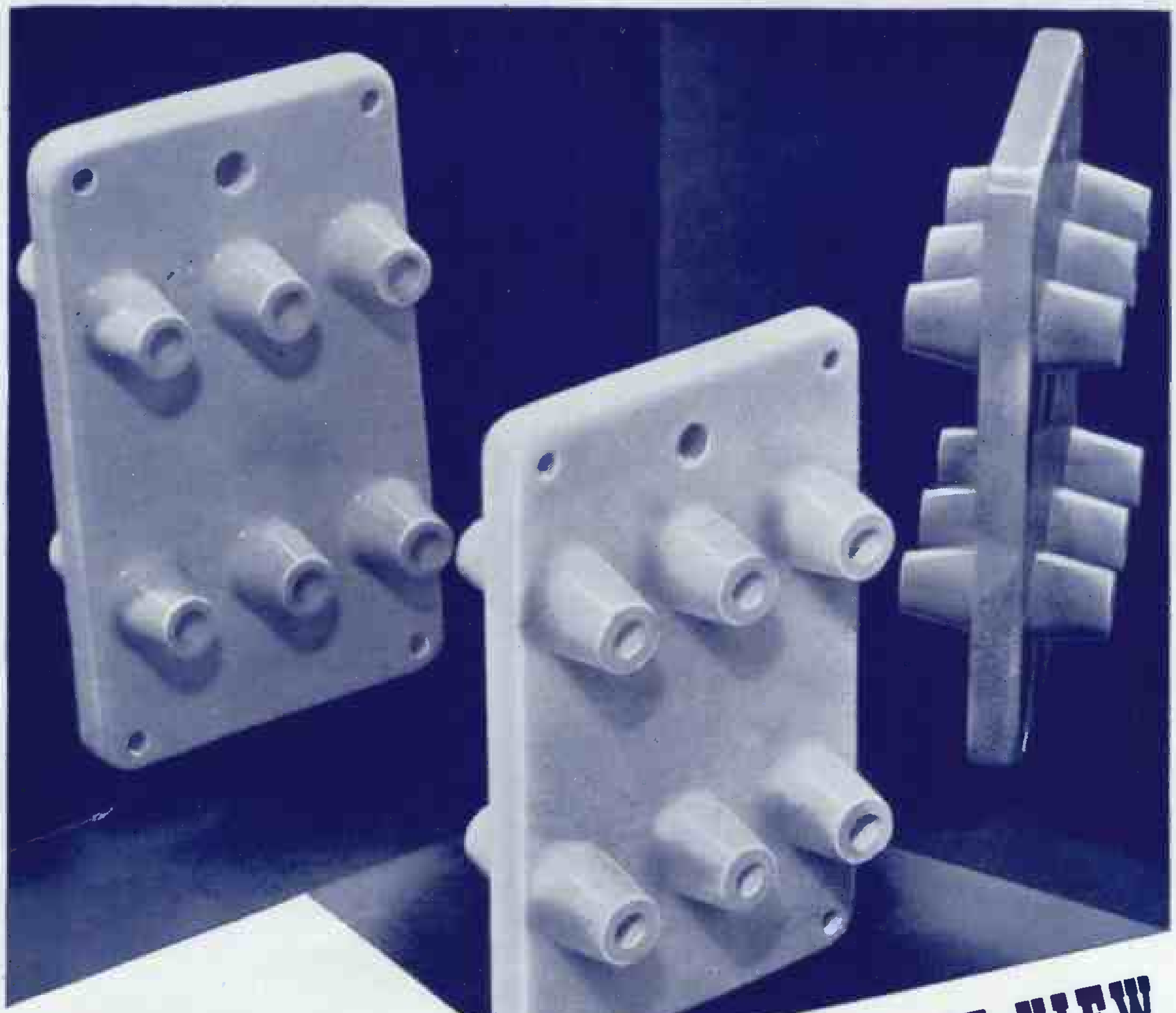

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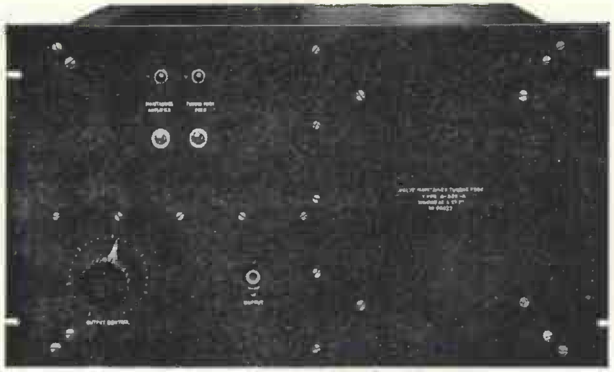

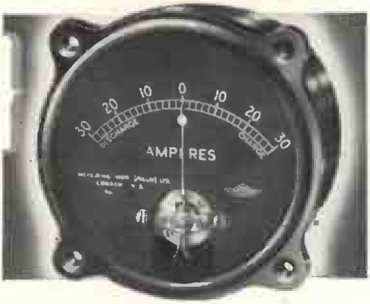
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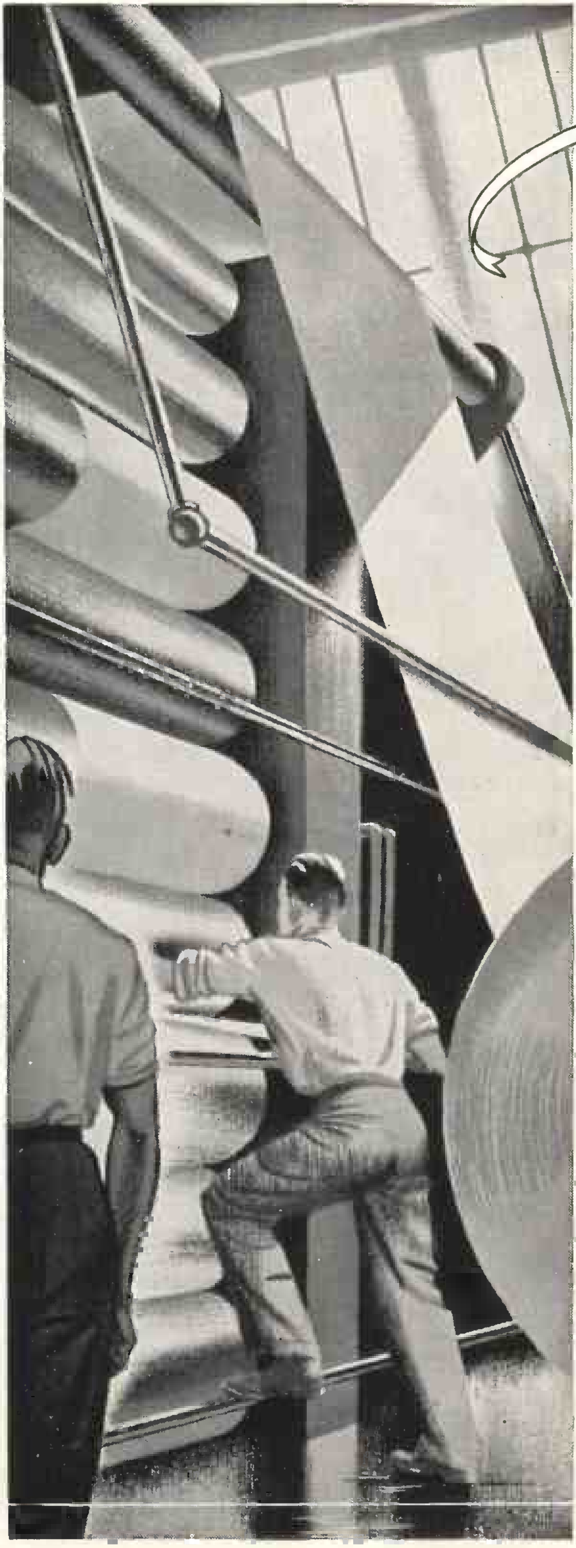

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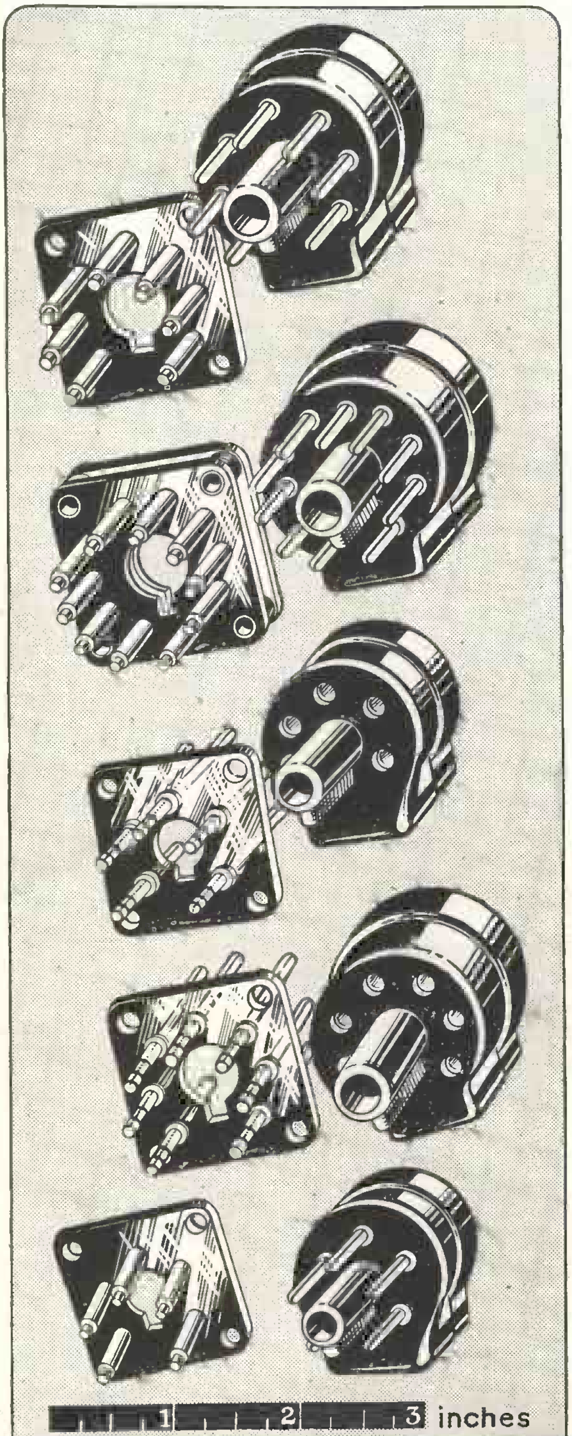
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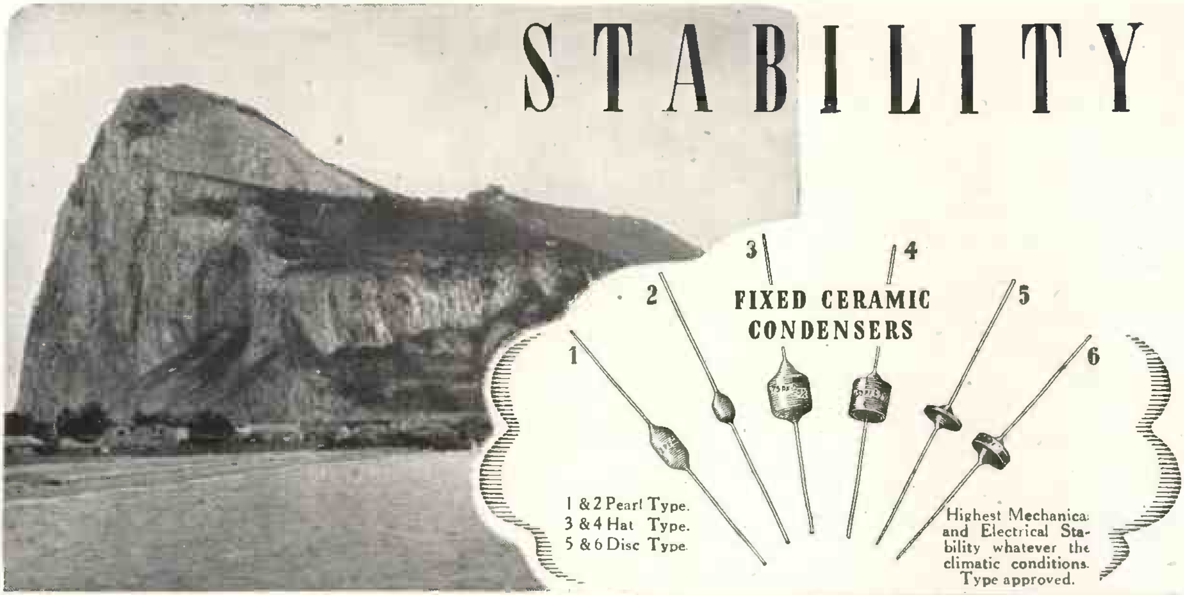

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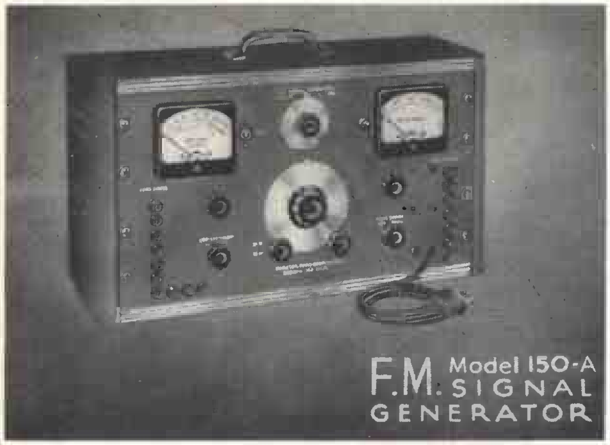

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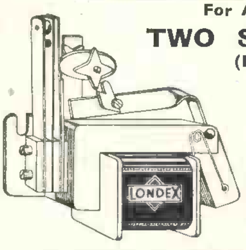

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Vol. XX JULY, 1943 No. 238

Editorial

The Make and Break Network Theorem of Helmholtz

IN the *Annalen der Physik und Chemie* of 1853 Helmholtz published a paper entitled " On some laws of the distribution of electric currents and their application to experiments in animal electricity." He was interested not only in linear networks but also, and mainly, in the distribution of current in solid bodies. This three-dimensional aspect sometimes introduces complications which do not arise in the consideration of linear network problems. He, however, fully realised this and, from time to time, gives the simpler theorems applicable to linear networks. He claims little originality, for after saying that the fundamental laws of such distribution had been given by Smaasen and Kirchhoff, he says that he begins with a law which, following du Bois-Reymond, he will call that of the superposition of electric currents, and which follows directly from Kirchhoff's general formulae. He states the law as follows :—if in any system of conductors, electromotive forces exist at various points, the potential at every point of the system is the algebraic sum of the potentials which would be produced by each of the electromotive forces acting alone.

Helmholtz then makes the following statement :—I note, moreover, that it is sometimes advantageous to picture other electromotive forces in addition to those actually present, and to regard the actual electromotive forces as the difference between the total and those added, a procedure which is obviously permissible. Then after some pages devoted to current distribution in bodies he says :—What applies to conducting bodies, applies also to the special case of a linear network. If two points of such a network are connected to other conductors, it behaves as a conductor of a certain resistance, the magnitude of which can be calculated by the ordinary rules for branched networks, and of an electromotive force equal to the potential difference that existed between the two points before they were connected by the other conductors.

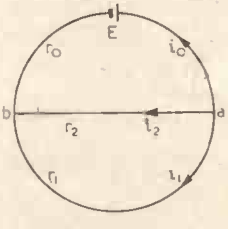

Fig. 1.

As the simplest possible example Helmholtz takes a simple circuit (Fig. 1) containing an electromotive force E and two points a and b which divide the circuit into two parts of resistances r_0 and r_1, the former part containing the source of electromotive force. The p.d. between the points a and b will be

$$V = \frac{Er_1}{r_0 + r_1}$$

This is then the e.m.f. of the equivalent system, and $R = \frac{r_0 r_1}{r_0 + r_1}$ is its resistance measured between the points a and b. A resistance r_2 is now connected between these points. Then says Helmholtz "according to our theorem"

$$i_2 = \frac{V}{R + r_2} = \frac{Er_1}{r_0r_1 + r_0r_2 + r_1r_2}$$

$$i_0 = -\frac{E}{r_0 + r_1} - \frac{Vr_1}{r_0r_1 + r_0r_2 + r_1r_2}$$

$$= -\frac{E(r_1 + r_2)}{r_0r_1 + r_0r_2 + r_1r_2}$$

and

$$i_1 = \frac{E}{r_0 + r_1} - \frac{Vr_0}{r_0r_1 + r_0r_2 + r_1r_2}$$

$$= \frac{Er_2}{r_0r_1 + r_0r_2 + r_1r_2}$$

It should be noted that the minus sign in the formula for i_0 is due to Helmholtz taking the positive direction of i_0 in opposition to E_1 so as to make $i_0 + i_1 + i_2 = 0$ at the point a.

To obtain i_0 and i_1 Helmholtz uses the device which he had mentioned of superposing fictitious electromotive forces, which is, indeed, inherent in the theorem. Two equal and opposite e.m.f.s., viz. V and $-V$ are inserted in r_2. The current due to E and $-V$ is the first term in the formulae for i_0 and i_1, since no current then flows through r_2. The second term is the current due to V acting alone.

Exit Thévenin

This clear statement and example of 1853 leave no shadow of excuse for attributing this theorem to Thévenin or any other subsequent propounder of the same.

If r_2 is made zero, that is, if the two points a and b are short-circuited, the current will obviously be equal to the open-circuit voltage divided by the resistance of the network as measured between a and b. This is sometimes very useful, because the short-circuit current and the network resistance can sometimes be calculated quite simply and the open-circuit voltage thus calculated. This is sometimes referred to as the short-circuit link theorem to distinguish it from the earlier form which is referred to as the "break" or "cutting point" theorem, but they are really slightly different statements of Helmholtz's theorem.

In the second instalment of his paper Helmholtz proved another theorem, which we may call his reciprocity theorem, viz. that in a conducting system containing no electromotive forces, if a and b are two conductor cross-sections, then an e.m.f. acting at a will produce the same current through b, as the same e.m.f. acting at b would produce through a.

Here again Helmholtz shows the same modesty in disclaiming originality, for he says that he uses a theorem which Green had discovered and used for proving a similar proposition in static electricity.

In 1883 L. Thévenin published a note of little more than a page in *Comptes Rendus*, 97, p. 159, "on a new theorem of dynamic electricity." It is just a simple and plain statement of Helmholtz's theorem, with which he was apparently unacquainted, for he says "cette regle, qui ne semble pas avoir été indiquée jusqu'à ce jour." He certainly added nothing whatever to Helmholtz's theorem, except publicity.

Application to Alternating Currents

In the *Revue Gen. de l'Élect.* of 16th April, 1919, Pomey published an article entitled "The theorem of Pleijel." Pleijel, an engineer of the Swedish Telegraphic Department, had read a paper at the International Conference of Post and Telegraphs in Paris in Sept., 1910, on the calculation of disturbances caused in telephone systems by adjacent power lines. Pomey states that concurrently with the theorem of Thévenin Pleijel employed a lemma of his own, but that his explanation was rather complicated. Pomey's object was to give a simple explanation of it. The lemma or theorem can be stated as follows. If a resistance η is inserted in a branch of a complex network, the change of current in any other branch is the same as that which would be produced by inserting an e.m.f. in the place of η equal to ηi where i was the original current at the point.

As a matter of fact even Pomey's proof is unnecessary, for this follows from Helmholtz's theorem. If the branch is opened, let the p.d. between a and b be V and let the resistance of the network excluding this branch, i.e. measured between the points a and b be R_n. When the branch is open there will be a certain distribution of current in the network upon which the current from the branch will later be superposed. When the branch is closed and the e.m.f. equal to V inserted in it—the other e.m.f.s. of the system being removed—the original current $i = V\ (R_n + R)$ will flow in the branch and be distributed throughout the network. If an additional resistance η be inserted (see Fig. 2) the current will be $i' = V/(R_n + R + \eta)$. These currents i or i' are distributed over the system in a manner depending only on the resistances of the system. Hence

$$\frac{i}{i'} = \frac{R_n + R + \eta}{R_n + R} \text{ and } \frac{i - i'}{i} = \frac{\eta}{R_n + R + \eta}$$

where $i - i'$ is the change in the current in R due to the insertion of η.

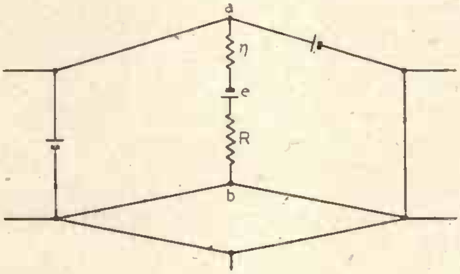

Fig. 2.

The current could be restored to i by inserting an e.m.f. e where

$$\frac{e}{R_n + R + \eta} = i - i'$$

$$\therefore \quad e = (i - i')(R_n + R + \eta) = i\eta$$

This e.m.f. exactly counteracts the effect of the added resistance η when in one direction, and has exactly the same effect as η when in the other direction.

This may be regarded as a corollary of Helmholtz's theorem. Pleijel, however, applied it also to alternating currents, which neither Helmholtz nor Thévenin had suggested.

In 1923 Dr. F. T. Chapman published a paper in *Electrical Review* (30th March) entitled "The calculation of D.C. and A.C. networks" in which he says that the purposes of the article are to draw attention to the break or cutting point theorem which is already fairly well known and to the short circuit link theorem. No references are given to earlier papers on the subject. The only extension from the work of Helmholtz is the application to alternating currents. It is all very clearly explained with a number of practical examples including unbalanced three-phase systems. Chapman says "No formal proofs of these theorems have been given, as they are quite simple, and the interested student will take pleasure in deriving them for himself."

In *Proc. Phys. Soc.* for 1927 F. Wenner published a paper, reprinted with additions from a Scientific Paper of the Bureau of Standards of U.S.A. The paper is a restatement of Helmholtz's Theorem and its application to a number of bridge problems. A large number of references are given, including Helmholtz but not Thévenin.

Dr. Hague's "A-C. Bridge Methods" also gives a number of references.

In *Revue Gen. de l'Élect.* for 1928, V. Jenkin describes the theorem, calls it the method of superposition and says that it follows from the linear equations of the circuit; he gives no references, but he discusses very fully the calculation of A.C. networks by allied methods.

In *Proc. Inst. Rad. Eng.* for 1933, J. G. Brainard states the theorem and applies it to some problems. He calls it Thévenin's theorem but adds "(Sometimes called Pollard's theorem)"; one wonders why.

In *Revue Gen. de l'Élect.* for 1935, van den Meersche published "A theorem deduced from the generalised reciprocity theorem of Maxwell," which he states as follows. If in Fig. 3 we open branch 1 and place in branch 2 an e.m.f. E_2, we produce between a and b a p.d. V; then the original currents I_1 and I_2 are such that

$$\frac{I_2}{I_1} = \frac{V}{E_2}$$

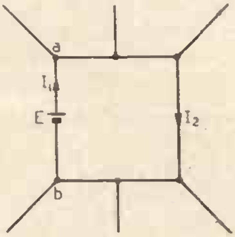

Fig. 3.

There is, however, no need to bring Maxwell into this, for the relevant portion of his reciprocity theorem is merely Helmholtz's theorem, according to which, if the e.m.f. E were transferred to the right-hand branch, it would produce the same current I_2 in the left-hand branch where $E/I_2 = R_t$ might be called the transfer resistance in either direction. If with E in the right-hand branch, the left-hand branch is opened and the p.d. V found between a and b, then on closing it again, the current I_2 is equal to V/R_n where R_n is the total network resistance as measured from a break in the left-hand branch. Hence $E/R_t = V/R_n$ and

$$\frac{V}{E} = \frac{R_n}{R_t} = \frac{E/R_t}{E/R_n} = \frac{I_2}{I_1}$$

Van Meersche also applies it to alternating current problems.

The Dual Theorem

In the *Archiv für Elektrotechnik* for 1936 H. Wigge published a paper entitled "Some Consequences of the 'Ableitungssatz' of Helmholtz (Thévenin's theorem)." After a statement of the ordinary Helmholtz theorem applied to alternating current problems, he propounds what he calls the dual theorem in which open-circuits are replaced by short-circuits, open-circuit voltages by short-circuit currents, impedances by admittances, etc. He states this theorem as follows.

If the short-circuit current that flows on joining two points a and b of a network be I_{ns} and if the admittance of the network measured between a and b be Y_{ns}, then on connecting a and b through an admittance Y, the total current will still be I_{ns} but it will flow through the Y and Y_{ns} in parallel. The potential difference V between a and b will therefore be given by the formula

$$V = \frac{I_{ns}}{Y + Y_{ns}}$$

This is the complement of Helmholtz's formula $I = \frac{V}{R + R_n}$. As Wigge says, the network acts to an admittance connected between a and b, as a constant current (I_{ns}) generator with an internal shunt of constant admittance Y_{ns}.

Wigge applies this theorem to some network problems; as he says, whether the one form or the other of the theorem is preferable depends on the nature of the network problem

In Karapetoff's "Experimental Electrical Engineering," 3rd edition, Vol. 2, p. 331, the author explains and proves what he calls Ho's theorem, quoting from a Japanese journal of 1923. This is, however, a simple A.C. application of Helmholtz's theorem. It is rather amusing that Karapetoff had published in *The Electrical World* in 1922 an article on "Finding published electrical information" and yet seemed quite unaware of the work of Helmholtz, Thévenin, Pleijel, and Pomey.

In Terman's "Fundamentals of Radio," the theorem is clearly stated and applied to some examples, but it is ascribed to Thévenin and no reference is made to Helmholtz.

In *Electrical Review* of Nov. 7th, 1941, Wall correctly ascribes the theorem to Helmholtz and draws attention to a paper by Herlitz in the *A.S.E.A. Journal* of April 1927, in which it is called the Thévenin-Pleijel theorem and in which the author, who was evidently unaware of the work of Helmholtz, says that "the theorem appears to have been generally forgotten until revived by Pleijel, who showed that it could also be applied to A.C. and to transient phenomena."

More recently still in the *Phil. Mag.* of Sept. 1942, there is a paper by Freeman on "A general superposition theorem of the 'Thévenin' type," but this is mainly a restatement of Wigge's dual theorem and its application to an interesting example.

A Question of Spelling

It will be seen from the foregoing that there is no justification whatever for attaching Thévenin's name to the theorem in any of its forms. Nor is there any justification for misspelling and thus altering the pronunciation of his name by omitting the accent, as several writers have done, or by erring in the other direction and writing Thévénin, as one author persists in doing. One culprit excused himself by pointing to "Amperes" on the dial of an instrument, apparently unaware that the name of Ampère, like that of Volta and Faraday, had been officially mutilated to form the name of an electric unit. When referring to the persons, however, we should refer to Volta, Faraday, Ampère, and Thévenin, and not to Messrs. Volt, Farad, Ampere, and Thevenin.

G. W. O. H.

Theory of Ideal Filters*

The Relation of Transient Response to an Ideally-Limited Frequency Band

By D. A. Bell, M.A.

SUMMARY.—It is shown that the conventional method of determining the transient response of an electrical system of finite band-width but unspecified structure, by taking a Fourier integral equivalent to the Heaviside unit function and limiting this infinite series of sinusoidal components to the appropriate frequency band, has two defects : (a) it corresponds to a filter in which the number of sections is a half, and (b) even this requires an unusual form of Fourier equivalent of the Heaviside function.

THE transient response of a filter with any finite number of sections can be evaluated exactly by an operational method, but the answer is found to be the integral of a Bessel function, and if the number of sections of the filter is large, it is not readily convertible into numerical form. To avoid this difficulty, the following procedure is often adopted : the steady-state response of an ideal filter is known, e.g. an ideal low-pass filter transmits uniformly all frequencies up to the cut-off frequency $\omega_c/2\pi$, and completely eliminates all frequencies above the cut-off, and it is also known that if $H(t)$ represents Heaviside's unit function, there is a mathematical equivalence

$$H(t) \equiv \tfrac{1}{2} + \frac{1}{\pi}\int_0^\infty \frac{\sin yt \, . \, dy}{y} \qquad \text{(1)}$$

It is then assumed that y in equation (1) can be interpreted as the angular velocity of a sinusoidal component, that a filter with a large number of sections behaves like an "ideal filter," and that the result of putting a signal of the form $H(t)$ through an "ideal filter" of pass band ω_1 to ω_2 can be obtained simply by writing

$$\phi(t) = \tfrac{1}{2} + \frac{1}{\pi}\int_{\omega_1}^{\omega_2} \frac{\sin \omega t \, . \, d\omega}{\omega} \qquad \text{(2)}$$

Mathematically, the justification for the form of integral used on the right-hand side of (1) is simply that it has the values 0 at $t = 0$, and $\pi/2$ for all finite values of t ; and the constant term of $\tfrac{1}{2}$ is added to satisfy the mathematical convention that at $t = 0$, $H(t) = \tfrac{1}{2}$. Neither term has any physical justification. It is true that (1) can be obtained by taking the Fourier series for a flat-topped pulse of duration T, and taking the limit as T tends to infinity ; but we shall see later that other equivalents of $H(t)$ can be similarly derived by choosing a suitable wave-form which will also produce the unit transient as a limiting case.

Physically, the objection to (1) is that it indicates an output from the ideal filter which has already reached the value of $\tfrac{1}{2}$ at $t = 0$, and since (1) is not valid for $t < 0$, there is no means of evaluating the first half of the transient ; it might of course be assumed that the fact of the output appearing to reach the value $\tfrac{1}{2}$ at $t = 0$, and therefore implying that the output transient commenced at $t < 0$, is due to the omission from the mathematical expression of the delay time of the filter. Sometimes the transient is conventionally completed by assuming that it is symmetrical about $t = 0$, which is equivalent to assuming that (1) and (2) are valid for $t < 0$; but this means that the transient in the output commenced at $t = -\infty$ (since (2) does not become constant until $t = \infty$), which is physically unsatisfactory.

Having seen the difficulties which arise from the use of equation (2), we will now examine the transient response of a real filter, and see how far it is possible to idealise

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* MS. accepted by the Editor, March, 1943.

it. The case of a low-pass filter is treated by McLachlan ("Complex Variable and Operational Calculus," pp. 224–237), who shows that if unit transient is applied to a low-pass filter having characteristic impedance $(L/C)^{\frac{1}{2}}$ and which is non-reflectively terminated, the current in the m^{th} section is

$$I_m = (C/L)^{\frac{1}{2}}\omega_c \int_0^t J_{2m}(\omega_c t)dt \quad .. \quad (3)$$

where $\omega_c/2\pi$ is the cut-off frequency and J_{2m} is the Bessel function of order $2m$. By expanding the Bessel function in the form of an integral, and then carrying out the integration with respect to time indicated in (3), McLachlan converts this into the form

$$I_m = (C/L)^{\frac{1}{2}}(2/\pi) \int_0^{\frac{\pi}{2}} \frac{\sin(\omega_c t \sin\phi)\cos 2m\phi \, . \, d\phi}{\sin\phi} \quad .. \quad .. \quad (4)$$

It will be remembered that m is the number of the section in which the current is observed, and since the filter is assumed to be non-reflectively terminated it is legitimate to regard the m^{th} section as the last section, i.e. m is the number of sections in the filter. Now as one limiting case, put $m = \frac{1}{2}$; then $\cos 2m\phi = \cos\phi$, and in (4) it is possible to make the substitution $\sin\phi = y$, $\cos 2m\phi \, . \, d\phi = \cos\phi \, . \, d\phi = dy$, giving

$$I_{\frac{1}{2}} = (C/L)^{\frac{1}{2}}(2/\pi) \int_0^1 \frac{\sin \omega_c t y}{y} dy$$

$$= (C/L)^{\frac{1}{2}}(2/\pi) \int_0^{\omega_c t} \frac{\sin z}{z} dz \quad .. \quad (5)$$

This is an expression for the current, so on multiplying it by the characteristic impedance $(L/C)^{\frac{1}{2}}$ the output voltage is

$$\phi(t) = (2/\pi) \int_0^{\omega_c} \frac{\sin z}{z} dz \quad .. \quad (6)$$

Being calculated for a real filter, this satisfies the necessary physical conditions, and gives the whole growth of the transient from zero at $t = 0$. Equations (2) and (6) are plotted in Fig. 1, against a scale of $\omega_c t$.

Now equation (6) could obviously be derived from the general identity

$$H(t) \equiv \frac{2}{\pi} \int_0^\infty \frac{\sin z}{z} dz \quad .. \quad (7)$$

which is valid for $t > 0$; this, of course, is only another way of saying $H(t) \equiv 1$ for $t > 0$. It has the objection that it would not satisfy the mathematical convention $H(t) = \frac{1}{2}$ at $t = 0$, but (a) it is only stated as valid for $t > 0$, and (b) there is no physical interpretation of the statement "$H(t) = \frac{1}{2}$ at $t = 0$," since we know that for any finite bandwidth $\phi(t) = 0$ at $t = 0$, and physically it seems more reasonable to assume that this applies also to the limiting case when the bandwidth tends to infinity. The real justification for (7) is that it has been shown in (6) that it is correct for one particular case of a real filter; but it is shown in the Appendix that (7) can be derived as the limiting case of the Fourier series for the waveform shown in Fig. 2, and therefore is consistent with the idea of resolving $H(t)$ into a continuous spectrum of sinusoidal components. Moreover, regarded as the output resulting from putting $H(t)$ through a filter of finite bandwidth, the form of Fig. 2 contains all the physically necessary characteristics, one of which is not possessed by the single flat-topped pulse corresponding to equation (2); these characteristics are as follows:

1. The output is zero for $t < 0$; this is not explicitly shown, but the expansion is not valid for $t < 0$.
2. The output rises immediately to unity at $t = 0$, and if $T \to \infty$ so also will $T/2$, so that in the limiting case the function remains constant from $t = 0$ to $t = \infty$.
3. It consists solely of alternating components, though in the limiting case extending down to zero frequency.

The third point is the most important. It has already been seen that the constant factor of $\frac{1}{2}$ in equation (2) is an embarrassment, but it is also a redundancy in form; why have this "D.C." component in addition to the zero-frequency component included in the integral with lower limit zero? Since an ideal filter consists solely of reactances, the idea of a "D.C." component in it seems less legitimate than a "zero-frequency" component, i.e. the limiting case of an alternating current. The adoption of (7) instead of (2) solves another problem; if we used (2) for a high-pass or band-pass filter, what should be done with the term ½? It is known that a D.C. component cannot be passed through such a filter, but one cannot assume that the constant term of ½ is just wiped out as soon as the lower limit of the pass-band is shifted from 0 to $\delta\omega$ where $\delta\omega$ may be a very small quantity; this is known to be incorrect, because the unit-function of Fig. 3a applied to a system with a very low frequency of cut-off does not yield an output reduced by a constant amount, as Fig. 3b, but something like Fig. 3c. It is now clear that (2) has no significance if the limits of integration are altered to finite values, while (7) represents for any limits the response of a half-section filter.

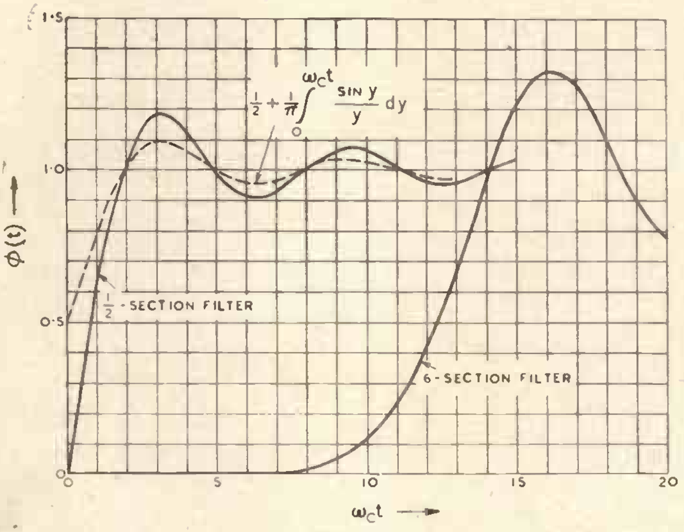

Fig. 1.

It now seems that the "ideal filter" is reduced to one of only half a section. The question still to be explored is whether there is another case of practical value, consisting of a filter with an infinite number of sections, and whether this bears any relation to the conventional procedure of assuming (2) to be valid for $t < 0$. As a first step, consider the solution of the response of a filter with a finite number of sections obtained by integration of the appropriate Bessel function. For six sections, part of the response is shown in Fig. 1; it will be noted that although this response has a gradual rise from zero (i.e. its gradient is everywhere continuous) in contrast to the curve of equation (6), yet the early part is not oscillatory, and therefore bears no similarity to the curve which would be obtained by taking equation (2) and making its curve symmetrical about $t = 0$. When the number m of sections tends to infinity, it will still be true that there are no oscillations in the part of the curve before the main rise; this is because the function plotted is the integral of a Bessel function of order m, which can be expressed as the sum of Bessel functions of order higher than m, and it is characteristic of Bessel functions that, as the order of the function is increased, there is an increasing range of values of the argument from zero upwards for which the function is of negligible magnitude. Increasing the number of filter sections therefore increases the time during which the response at the far end of the filter remains substantially zero.

When m is large, the series of sinusoidal components, to which the integral in (4) can be approximated, are not uniformly spaced over the frequency band, so they cannot be smoothed into an integral representing a continuous spectrum of sinusoidal components similar to (6); to do so would disregard the "weighting" of the frequency distribution, due to the unequal frequency intervals between components as they stand as a discrete series before one proceeds to the limit. It is therefore incorrect to represent the effect of an ideal filter of many sections as merely restricting the extent of a continuous spectrum of frequencies. Another point is that in an ideal filter, which is by hypothesis free from dissipation,

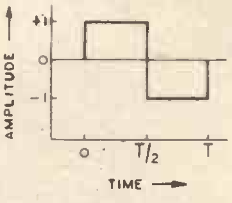

Fig. 2.

the amplitude of the oscillations in the response after the main rise increases with the number of sections, and with an infinite number of sections the oscillations would probably represent 100 per cent. modulation of the mean level. This of course is not in accordance with practical experience, if only because a real filter with an infinite number of sections would have an infinite attenuation as well as infinite delay time. Qualitatively, it may be said that dissipation within the filter will reduce the amplitude of oscillations in the response, and so make the response of a multi-section filter more like the curves of (2) and (7) for $\phi(t) > 0.5$. It may therefore be an empirical approximate solution to adopt one of these curves for $\phi(t) > 0.5$ and complete the lower half of the characteristic by any appropriate curve giving a gradual rise from zero; but this is not a unique or ideal characteristic, and must be recognised as only an empirical solution to the practical filter including a small amount of dissipation.

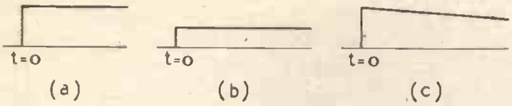

Fig. 3. (*a*) *Heaviside unit function.* (*b*) *Unit function minus* ½, *i.e. with D.C. component of equation* (1) *eliminated.* (*c*) *Actual response from a filter incapable of passing D.C. and very low frequencies.*

APPENDIX

Analogy between the integral equivalent to $H(t)$ for $t > 0$ (equation (7)) and a Fourier series.

The waveform shown in Fig. 4 performs one complete cycle of square-wave between $t = 0$, $t = T$. Although the true square-wave is discontinuous, it can be shown (by replacing the discontinuous reversal by a line of finite slope, as shown dotted, and proceeding to the limiting case) that a correct result is obtained by performing a Fourier analysis over the whole period for $t = 0$ to $t = T$, during which the square-wave function $\phi(t)$ has the following values:

$\phi(t) = 1$, from $t = 0$ to $t = T/2$.

$\phi(t) = -1$ from $t = T/2$ to $t = T$.

The form of the Fourier series is evidently

$$\phi(t) = \Sigma b_n \sin(2\pi nt/T)$$

where
$$b_n = \frac{1}{\pi}\int_0^{T/2} \sin(2\pi nt/T)dt - \frac{1}{\pi}\int_{T/2}^{T} \sin(2\pi nt/T)dt$$
$$= \frac{1}{\pi}\cdot\frac{T}{2\pi n}(1 - \cos n\pi).$$

If n is even, $b_n = 0$; if n is odd, $b_n = \frac{2}{\pi}\cdot\frac{T}{2\pi n}$.

$$\therefore \phi(t) = \frac{2}{\pi}\sum_{m=0}^{\infty}\frac{T}{2\pi(2m+1)}\cdot\sin[2\pi(2m+1)t/T] \quad \ldots \ldots \ldots \text{(i)}$$

If $T/2\pi = 1/\omega_0$,

then
$$\phi(t) = \frac{2}{\pi}\sum_{m=0}^{\infty}\frac{1}{(2m+1)\omega_0}\sin(2m+1)\omega_0 t \quad \ldots \ldots \ldots \text{(ia)}$$

Fig. 4.

Now let $T \to \infty$ so that $\omega_0 \to 0$; then the successive terms in the series (ia) become indefinitely closely spaced, and the series merges into an integral:

$$\phi(t) = \frac{2}{\pi}\int_{\omega=0}^{\omega=\infty}\frac{\sin \omega t}{\omega}d\omega \quad \ldots \ldots \text{(ii)}$$

and by the substitution $\omega t = z$, $\omega = z/t$, $d\omega = dz/t$ this is transformed to

$$\phi(t) = \frac{2}{\pi}\int_0^{\infty}\frac{\sin z dz}{z} \quad \ldots \ldots \text{(iii)}$$

which is of the desired form. Since it is a consequence of putting $T = \infty$ that $T/2$ is also infinite, it follows that $\phi(t) = 1$ for all finite positive values of t, i.e. $\phi(t) = H(t)$ for $0 < t < \infty$.

This is in no sense a "proof" of the expansion adopted for $H(t)$; it is merely a demonstration that the particular equivalent chosen out of the many possible representations of $H(t)$ is compatible with the physical concept of the limiting case of a Fourier series. As stated in the paper, the justification for selecting this form is that it represents the response of one particular physically realisable circuit.

Prize for Invention

A PRIZE of £50 is again offered by the Royal Society of Arts under the Thomas Gray Memorial Trust, for an invention which, in the opinion of the judges, is considered to be "an advancement in the science or practice of navigation," proposed or invented by a person of British or Allied nationality in the period January 1st, 1938, to December 31st, 1943. Competitors must forward their proofs of claim between October 1st and December 31st, 1943, to the Acting Secretary, Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.

Chart for Radio Noise*

By J. McG. Sowerby, B.A., Grad.I.E.E.

Introduction

In the reception of a radio signal there is inevitably some background noise or "mush" generated within the receiver itself. This noise is calculable and is due to two primary causes: (i) thermal agitation of the free electrons in the first circuits of the receiver, and (ii) shot noise in the first valve of the receiver. Ordinarily it is only the first valve and the first circuits which are of importance in this connection, since the noise produced by them is subject to the maximum amplification. It is the purpose of this note (a) to present an abac or nomogram which, it is hoped, will facilitate calculations of noise, and (b) to offer some suggestions on its use.

Notation

$\overline{e_t}$ = R.M.S. thermal noise voltage.

$\overline{i_s}$ = R.M.S. shot noise current.

$\overline{e_s}$ = R.M.S. shot noise voltage.

e_{gs} = Equivalent R.M.S. shot noise voltage at valve grid.

θ = Temperature in degrees absolute (Kelvin).

Δf = Equivalent bandwidth in c/s.

I_a = Valve anode current.

g_m = Grid-anode mutual conductance of valve in mhos.

R, R_1, etc. = Resistance.

R_a = Valve anode resistance.

R_L = Valve load resistance.

μ, M = Voltage gain of amplifier stage.

k = Boltzmann's constant = 1.37×10^{-23} joules/degree Kelvin.

ϵ = Charge of an electron = 1.6×10^{-19} coulombs.

Thermal Noise

It has been shown by Nyquist that the noise due to the thermal agitation of free electrons in a conductor of resistance R is expressed by the relation:

$$\overline{e_t} = \sqrt{4 \,.\, k \,.\, \theta \,.\, R \,.\, \Delta f} \quad \ldots \quad (1)$$

In this equation R may also represent the resistive component of any complex impedance, provided only that the resistive component is constant throughout the bandwidth considered. In general this will not be true unless the bandwidth is infinitely small; but for much radio work it may be a sufficiently close approximation. For instance, to take the dynamic resistance of the first tuned circuit as constant throughout the overall transmitted bandwidth of the ordinary receiver will not usually introduce any notable error. In cases where the effective value of R varies over the bandwidth considered, due allowance must be made.

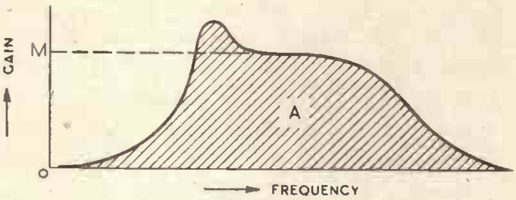

Fig. 1.

It is worth noting that the bandwidth, Δf, is not in general the frequency difference between minimum and maximum frequencies passed by a system, but an equivalent bandwidth throughout which the gain is constant. Fig. 1 shows a possible receiver response curve plotted against linear scales. If the shaded area bounded by the curve is A, and the gain in the mid-frequency region (to take a convenient reference point) is M, then $\Delta f \,.\, M = A$, or $\Delta f = A/M$. This value of Δf is the equivalent bandwidth as shown in Fig. 2 and as used in the abac.

Shot Noise

It is well known that the noise produced by a saturated diode is given by the relation

$$\overline{i_s} = \sqrt{2 \,.\, I_a \,.\, \epsilon \,.\, \Delta f} \,. \quad \ldots \quad (2)$$

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* MS. accepted by the Editor, August, 1942.

If the valve is space-charge limited, the space-charge will have a smoothing effect on $\overline{i_s}$ depending on the internal conditions of the valve, and the noise current will be less than that given by (2) by a factor F which we may call the space-charge smoothing factor; and (2) becomes:

$$\overline{i_s} = F\sqrt{2 \,.\, I_a \,.\, \epsilon \,.\, \Delta f} \qquad \ldots \quad \ldots \quad (3)$$

where $F = 1$ for a saturated diode, and less than unity for any space-charge limited valve.

In any real amplifying stage the valve will have a load R_L (which may also be the resistive component of a complex impedance with the bandwidth proviso noted above) on which the noise current will act to produce a noise voltage $\overline{e_s}$, of magnitude $\overline{i_s}R_L$. But for comparison with the incoming signal what is normally required is not $\overline{e_s}$, but the equivalent noise voltage at the grid—$\overline{e_{gs}}$. $\overline{e_{gs}}$ may be defined as that noise voltage which, applied to the grid of a perfect valve under given conditions, will produce at the anode the noise voltage actually found under the same working conditions. By definition then, $\overline{e_{gs}} = \overline{e_s}/\mu$, where μ is the gain of the valve. But

$$\mu = g_m \,.\, \frac{R_a \,.\, R_L}{R_a + R_L} \qquad \ldots \quad \ldots \quad (4)$$

And so

$$\overline{e_{gs}} = \frac{F\sqrt{2 \,.\, I_a \,.\, \epsilon \,.\, \Delta f}}{g_m} \,.\, \left(\frac{R_L}{R_a} + 1\right) \ldots \quad (5)$$

This noise voltage may be expressed in terms of a resistance of the required magnitude to produce the same noise voltage (as calculated by (1)) assuming the same bandwidth and a convenient temperature. This is known as the equivalent noise resistance of the valve.

The Addition of Noise Voltages

By means of the abac the noise due to thermal agitation and shot effect may be calculated. It remains to add them together. Consider a resistance R made up of two resistances R_1 and R_2 in series. The total noise voltage by (1) is given by $R = \overline{e_t^2}/K$ where K is a constant covering θ, Δf, etc., which are temporarily fixed. Similarly the noise voltages due to R_1 and R_2 are respectively given by

$$R_1 = \overline{e_{t_1}^2}/K \quad \text{and} \quad R_2 = \overline{e_{t_2}^2}/K$$

But

$$R = R_1 + R_2$$

Hence

$$\overline{e_t^2}/K = \overline{e_{t_1}^2}/K + \overline{e_{t_2}^2}/K$$

And so

$$\overline{e_t} = \sqrt{\overline{e_{t_1}^2} + \overline{e_{t_2}^2}} \qquad \ldots \quad \ldots \quad (6)$$

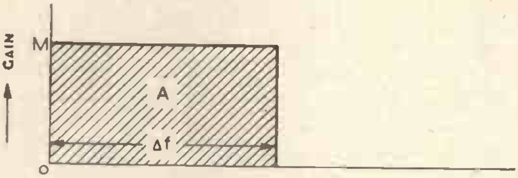


Fig. 2.

Thus noise voltages must be added in quadrature.

The Chart

The chart should be self-explanatory and its modes of operation are shown by the key. It will be noticed that no scale is included for the temperature, and in the construction of the chart a temperature of 300 degree absolute has been assumed. This represents a somewhat high room temperature but it might well be attained in the chassis of a receiver. In the calculation of thermal noise only the two outside and the centre scales are used. An example will make this clear.

Example 1

A high gain amplifier has a first grid resistance of 1 MΩ and an equivalent bandwidth of 7000 c/s; what is the thermal noise due to the first grid resistance?

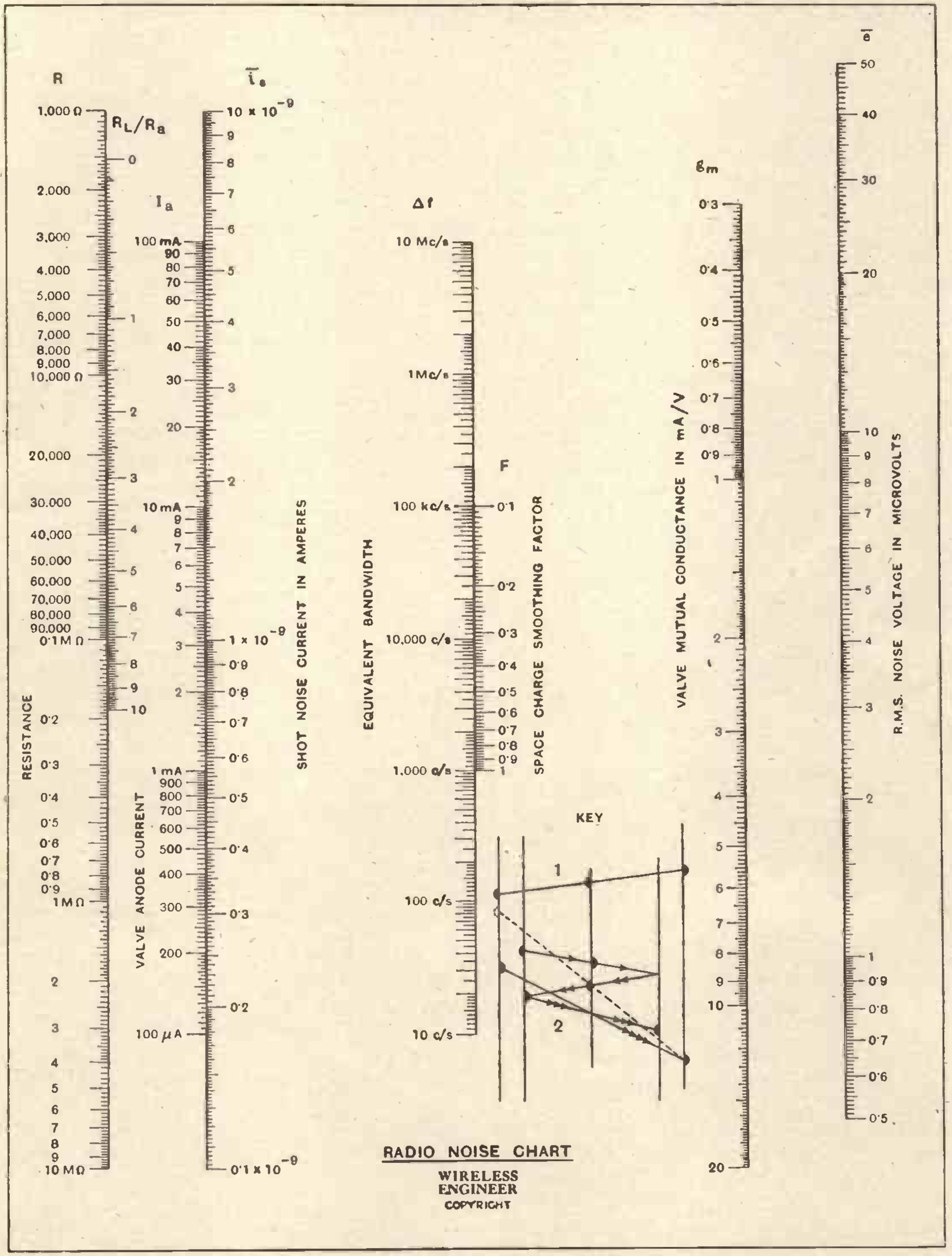
Set the ruler on 1 MΩ on the left hand resistance scale and on 7000 c/s on the centre bandwidth scale; the ruler cuts the noise voltage scale at the right at 10.72 μV and this is the required answer.

When using the chart to find the equivalent noise voltage at the grid of a valve due to the shot effect, the inner scales are used in addition to the outer. The following example brings this out.

Example 2

A variable-μ pentode has an anode current of 8 mA, a mutual conductance of

(*Concluded on page* 330.)



Nomogram for the calculation of background noise generated within a receiver.

2 mA/volt, and as used R_L/R_a is 0.1. If the valve factor is 0.6 what is the equivalent noise voltage at the grid when the equivalent bandwidth is 4,500 c/s?

Place the ruler on 8 mA on the I_a scale and 0.6 on the F scale; a point of intersection is found on the g_m scale. Join this point to 4,500 on the Δf scale and a second point of intersection is found on the I_a scale. Opposite this the noise current in amperes may be read off the $\overline{i_s}$ scale. To continue, join this point to 2 on the g_m scale and a point of intersection is found on the centre scale. Join this point to 0.1 on the R_L/R_a scale and the noise voltage is read off the right-hand scale. It is 1.12 μV. To find the equivalent noise resistance, join this point to the bandwidth (4,500 c/s) and the equivalent noise resistance is read on the left-hand R scale; it is 16,900 ohms. This last operation is shown by a dotted line in the key.

Further Notes

The calculation of F from the electrode geometry and electrode voltages is not easy. For triodes F is of the order of 0.25 or less, and this is about the value for the low-noise hexode *EF*8 whose screen current is about 1/40th of its anode current. In pentodes of more normal character where the screen current is about 1/5th of the anode current, F becomes about 0.7 or even more. Television pentodes have a value for F centring on about 0.5 or perhaps a little more. For frequency changers F may be as high as 0.8. The derivation of F from valve structure is discussed by D. A. Bell (*J.I.E.E.*, Pt. 3, Dec. 1942, p. 207) and the reader is referred to this paper for further information.

If it is thought that stages after the first in any network are sources of sensible noise, the noise produced may be calculated with the abac and referred to the first grid (say) for comparison with the signal.

It is perhaps worth noting that for first-class reception the signal voltage level should be 50 db. above the noise—a signal to noise ratio of about 300. For intelligible reception a signal to noise ratio of 30 may be tolerable.

There is some slight justification for assuming that the peak noise voltage is four times the R.M.S. value given here. V. G. Landon gives a discussion of this point in *Proc. I.R.E.*, Feb. 1941, p. 50.

The audio noise voltage produced by a given R.F. noise voltage, when applied to a linear detector in conjunction with a modulated or unmodulated signal, appears to depend to some extent on the conditions of operation. A theoretical discussion with experimental evidence on this important point is given by J. R. Ragazzini in *Proc. I.R.E.*, June 1942, p. 277.

I.E.E. Wireless Section

THE Committee of the Wireless Section of the Institution of Electrical Engineers has nominated the following to fill the vacancies which will occur on the Committee on September 30th:—Chairman, T. E. Goldup (Mullard); vice-chairman, Prof. Willis Jackson (Manchester University); Ordinary Members, Capt. C. F. Booth (Post Office Engineering Dept.); H. L. Kirke (B.B.C.); O. S. Puckle (Cossor); T. Wadsworth (B.T.H.) and Dr. R. C. G. Williams (Murphy).

The Industry

Two new test instruments manufactured by the General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2, are described in a leaflet (No. 9563) recently issued by the company. One is a "Break Locator" designed to locate faults in unscreened flexible conductors and comprises a high-frequency generator and exploring electrodes, with headphones. The other is a "Full Load Continuity Tester" for checking portable tools and appliances for faults which may not show up on light current continuity meters.

W. T. Henley's Telegraph Works Co., Ltd., has opened a new London office at 51–53, Hatton Garden, E.C.1 (telephone: Chancery 6822). The office at Denby House, Wembley, has closed down.

Glossary of Electrical Terms

THE first of eight parts of the revised "Glossary of Terms used in Electrical Engineering," which is issued by the British Standards Institution, has recently been published. This part covers the general terms used in electrical engineering, and is obtainable from the British Standards Institution, 28 Victoria Street, London, S.W.1 Price 2/-, post free.

The terms relating to telecommunications, which were given in Sections 9 and 10 of the 1936 Edition of the Glossary, will be issued separately in due course as a revision of B.S.204.

Three-point Tracking in Superheterodynes*

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(Communication from Telefunken G.m.b.H.)

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Introduction

WITH single knob tuning of receivers the problem arises of tuning the variable high-frequency circuits of the receiver to the same frequency. The obvious way to do this is by making all the high-frequency circuits identical, and in particular by providing condensers having the same shape of plates and a common spindle. In practice, in order to compensate for unavoidable stray, it is necessary at the test stage of manufacture to provide adjustable trimmers for the inductance and minimum capacitance, thus arriving at the H.F. circuit illustrated in Fig. 1. With superhet receivers there is the additional problem of tuning the oscillator resonant circuit to a frequency which is separated from the frequency of the H.F. circuits by a constant difference which is the intermediate frequency. It would be possible to satisfy this condition by making the plates of the variable condenser in the oscillator circuit a special shape; but the method now universally adopted is simpler from the point of view of manufacture. The condition of oscillator tracking is, it is true, fulfilled only approximately, e.g. with an inaccuracy of 1 per cent, by this method, which consists in providing a further trimmer or padding condenser in the oscillator circuit, as shown in Fig. 1; but on the other hand the same shape of condenser plate is retained in the oscillator circuit as in the H.F. circuits. In the past it has been a very complicated procedure to calculate the values of the five condensers from the data of the receiver range and the magnitude of the tracking error, and a simpler solution is given in the following. The results are set out in the summary in the form of an instruction for making the tracking calculation.

I. Summary

A systematic method is described for directly determining the best circuit magnitudes for the circuit of Fig. 1, the best magnitudes being those for which the maximum tracking error within the receiver range attains its minimum value. This occurs when, and only when, the maximum detuning of the H.F. circuit occurs four times with alternate sign, at the two ends of the range and twice within it.

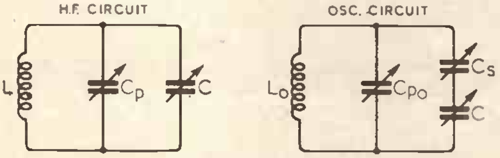

Fig. 1.—*The magnitudes of the trimmers for best tracking in this circuit are to be determined.*

The magnitude of the tracking error and the correct values of the circuit elements depend upon two fundamental parameters, e.g. the ratio of the maximum to the minimum frequency of the H.F. circuit v_h and of the oscillator circuit v_0. The family of curves in Fig. 2 shows the maximum detuning of the H.F. circuit, $Y = 2\Delta\omega/\omega$, as a function of v_0 and v_h, so that when designing a receiver it is possible to pick out the tracking error corresponding to the desired intermediate frequency without calculation.

The complicated tracking calculation [1, 2] which formerly had to be performed accurately to 7 places, can now be simplified to the point where the required L and C values

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* Translated from the original article "Determination of Circuit Magnitudes for Three-point Tracking in Superhet Receivers," which appeared in *Hochf:tech. u. Elek:akus.*, May 1942, Vol. 59, pp. 144–150.

can be calculated with fully sufficient accuracy by the use of the slide rule. For this purpose there is introduced an auxiliary magnitude B, whose value is shown in a second family of curves, again as a function of v_h and v_0, in Fig. 3. (Instead of introducing the auxiliary magnitude B, it is possible to use the auxiliary magnitude A, further defined below, which has a smaller variation and can be employed even when $v_0 \approx 1$.) The family of curves for Y (Fig. 2) is used to find the component values for the H.F. circuit by means of equations (1) and (2) below :—

$$C_p = \frac{C_e - v_h^2(1 - 2Y)C_a}{v_h^2(1 - 2Y) - 1} \quad .. \quad (1)$$

$$L = \frac{1 - Y}{(C_e + C_p)\omega_{he}^2} \quad .. \quad (2)$$

Y is negative. All the frequencies are given as angular frequencies $\omega = 2\pi f$. C_e and C_1 are respectively the final and initial capacitances of the variable condenser, C_p is the parallel capacitance of the H.F. circuit, L its inductance, and ω_{he} its nominal limit frequency. The correct magnitudes for the oscillator circuit are obtained by means of slide rule calculations using the auxiliary magnitude B found from Fig. 3 in the following equations (3) to (5) :—

$$C_s = \frac{B}{\omega_z^2 L} + C_p$$

$$= B(1 + Y)\,(C_e + C_p)\,\frac{\omega_{he}^2}{\omega_z^2} + C_p \quad .. \quad .. \quad (3)$$

$$C_{p0} = \frac{\dfrac{C_e C_s}{C_e + C_s} - v_0^2 \cdot \dfrac{C_a C_s}{C_a + C_s}}{v_0^2 - 1} \quad .. \quad (4)$$

$$L_0 = \frac{1}{\omega_{0a}^2\left(C_{p0} + \dfrac{C_a C_s}{C_a + C_s}\right)} \quad .. \quad (5)$$

in which C_s is the series capacitance of the oscillator circuit, C_{p0} its parallel capacitance and L_0 its inductance, and ω_{0a} its initial frequency. Thus all the circuit magnitudes are now found.

As a check, it would now be possible, by working backwards from these data, to find the tracking error curve. If this is correctly worked out it will be found that the two maximum errors inside the range and the errors at the ends of the range all have the same absolute value. This check calculation would, however, have to be performed with a calculating machine, as formerly, whereas, on account of the greatly simplified method of calculation, the L and C values calculated by the slide rule should fit from the outset much more frequently than formerly.

If the tracking curve has been carefully worked out, then it is possible to find from it as before the three frequencies at which the tracking error disappears, and to adjust the tracking in the test stage by the usual methods. It is, however, advantageous to use a method of tracking suited to the new method of calculation, which makes the calculation of the tracking curve superfluous and which moreover appears to economise on gauges for fixing the variable condenser settings. Since with this new method of making the calculation the nominal variation of the oscillator agrees with its actual variation, therefore by choosing the value of C_s correctly, i.e. in accordance with the calculation, it is possible to make the adjustment of L_0 and C_{p0} at the initial and final settings of the variable condenser. The adjustment of the H.F. circuit is also performed at these condenser settings, so that the H.F. circuit is tuned by means of L and C_p to its nominal limits plus or minus the tracking error known from Fig. 2.

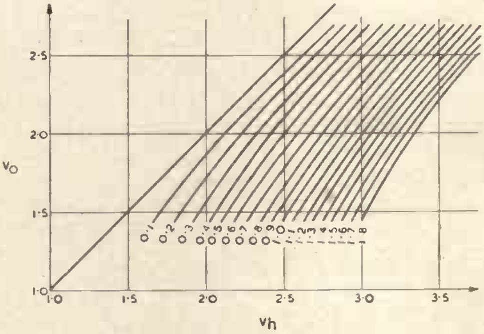

Fig. 2.—*Maximum tracking error as a function of the oscillator variation v_0 and of the H.F. variation v_h. Abscissa : H.F. variation v_h. Ordinate : Oscillator variation v_0. The curves are curves of constant maximum detuning. The parameter is the maximum detuning in per cent.*

The curves in Figs. 2 and 3 already cover a part of the technically interesting range of

v_h and v_0, but the basic calculations should be extended to enable the curves to be obtained also in the case where the oscillator frequency is lower than the H.F. (i.e. $v_h < v_0$).

II. Theory

Let us suppose that the receiver is always operated in such a way as to produce the nominal intermediate frequency. Then except at the three points where tracking is exact the H.F. circuit is detuned. The detuning y is given by :—

$$y = 2\,\frac{\omega_0 - \omega_z - \omega_h}{\omega_h} \quad .. \quad (6)$$

where ω_0 is the resonant frequency of the oscillator circuit, ω_h that of the H.F. circuit and ω_z the intermediate frequency. The two resonant frequencies may be expressed in terms of the circuit data by means of equations (7) and (8) as follows :—

$$\omega_0^2 L_0\left(C_{p0} + \frac{C_s C}{C_s + C}\right) = 1 \quad .. \quad (7)$$

$$\omega_h^2 L(C_p + C) = 1 \quad .. \quad (8)$$

C is the capacitance of the variable condenser. We find it convenient to use as our variable not the capacitance of the variable condenser but the oscillator frequency ω_0. On substituting from (7) and (8) in (6) we find :—

$$(1 + y/2)^2 = \frac{L[\omega_0^2 L_0 \alpha - (C_s - C_p)](\omega_0 - \omega_z)^2}{1 - \omega_0^2 L_0 (C_{p0} + C_s)} \quad .. \quad .. \quad (9)$$

where $\alpha = C_{p0}C_s - C_pC_{p0} - C_sC_p$. Since we are interested in detuning of the order of 10^{-2} only, we can neglect the square of the detuning. The detuning then becomes a rational function of the oscillator frequency, whose denominator is of a second degree while its numerator is of fourth degree. It will also be seen that the circuit magnitudes occur in such a way as to give rise to three fundamental parameters. Finally, let us divide all the frequencies by the intermediate frequency, and represent these frequency ratios by z. Then the intermediate frequency itself corresponds to $z = 1$; ω_{0a} corresponds to $z_1 = \omega_{0a}/\omega_z$ etc. The detuning can now also be expressed by equation (10):—

$$1 + y = \frac{(z-1)^2(z^2 - a_1^2)}{c^2z^2 - a_2^2} = \frac{g(z)}{h(z)} \quad (10)$$

where $g(z)$ is a polynomial of the fourth degree with 1 as its highest coefficient, and $h(z)$ is a polynomial of the second degree.

The points of zero tracking error are given by the fourth degree equation :—

$$g(z) - h(z) \equiv z^4 - 2z^3 + z^2(1 - a_1^2 - c^2) + 2za_1^2 + a_2^2 - a_1^2 = 0 \quad .. \quad (11)$$

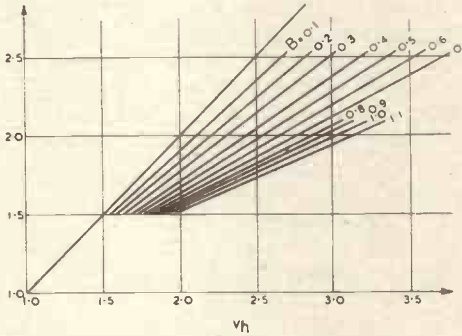

Fig. 3.—*Auxiliary magnitude B for calculating the series capacitance of the oscillator circuit as a function of the oscillator variation* v_o *and of the H.F. variation* v_h. *Abscissa : H.F. variation* v_h. *Ordinate : Oscillator variation* v_o. *The curves are for B = const. The parameter is the value of B.*

It is known that with this circuit three-point tracking can always be attained, i.e. three zero values for equation (11) can be found within the receiver range (z_a, z_e). If a real equation of the fourth degree has three real roots, then it must also have a fourth real root, but it is obvious that the fourth root cannot also lie within the receiver range ; for the sum of the roots is equal to 2, corresponding to the coefficient of z^3. If these three roots be z'_1, z'_2 and z'_3, then obviously $1 < z_e < z'_3 < z'_2 < z'_1 < z_a$, so that the fourth root $z'_4 = 2 - z'_1 - z'_2 - z'_2$ and must be negative. It is thus proved that four-point tracking is not possible with the usual circuit.

It is clear that the three independent parameters in (9) and (10) make it possible to locate three zero error points within the receiver range, and the hitherto universal tracking calculation consists in distributing these three zero points according to empirical rules so that the four maximum errors are of about the same magnitude. For this purpose the zero points are assumed and the corresponding tracking curve is calculated ; the actual distribution of the error is then observed, and is corrected by shifting the zero points until a satisfactory result is obtained. With this method, unfortunately, the numerical calculation must be accurate to a great number of places.

It will be shown below that the problem of minimising the maximum error within the receiver range is identical with the other problem of equalising the values of the four extreme errors, as might be expected. It will be observed that three equations result, which can be used to determine the three fundamental parameters, where formerly the three zero error points were found empirically. Let $|Y|$ be the maximum detuning, occurring four times, and let z_1 and z_2 be those two frequencies at which this error occurs within the receiver range. Let them satisfy the inequalities $1<z_e<z_2<z_1<z_a$. Then clearly

$$g(z_a) - (1 + Y)h(z_a) \equiv F(z_a) = 0 \qquad (12)$$

Further,

$$F(z_2) = 0 \quad .. \quad .. \quad (13)$$

The error has opposite sign at the two ends of the range, and therefore

$$g(z_e) - (1 - Y)h(z_e) \equiv G(z_e) = 0 \qquad (14)$$

and

$$G(z_1) = 0 \quad .. \quad .. \quad (15)$$

G and F are again polynomials of the fourth degree with 1 as the high coefficient, while the coefficient of z^3 is again -2. The sum of the four roots of G or F is therefore also 2. At the maximum values of the error y inside the range the derivative dy/dz also vanishes, therefore $d(y - Y)/dz$ also vanishes, and also, from equation (13), $F'(z_2)$, so that $F(z)$ has the four roots z_a, z_2, z_2, $2 - z_a - 2z_2$ or

$$F(z) \equiv (z - z_a)(z - z_2)^2(z - 2 + z_a + 2z_2) \quad .. \quad .. \quad (16)$$

$$G(z) \equiv (z - z_e)(z - z_1)^2(z - 2 + z_e + 2z_1) \quad .. \quad .. \quad (17)$$

The previously usual tracking calculation would become precise if the three frequencies z'_1, z'_2 and z'_3 could be so chosen that the four maximum errors were of equal magnitude. It is, however, not easy to do this. But it is easy to choose the two points z_1 and z_2 so that this condition is fulfilled. The two equations needed for determining z_1 and z_2 are built up in the following way :—By definition we have

$$\left.\begin{aligned} g - h(1 + Y) &= F \\ g - h(1 - Y) &= G \end{aligned}\right\} \qquad (18)$$

and since

$$h'(0) = 0 \quad .. \quad .. \quad (19)$$

it follows that

$$F'(0) = G'(0) \quad .. \quad (20)$$

This is the first equation for z_1 and z_2. From

$$g(1) = 0 \quad .. \quad .. \quad (21)$$

and (18) it follows further that

$$\frac{1 + Y}{1 - Y} = \frac{F(1)}{G(1)} \quad .. \quad .. \quad (22)$$

and from

$$g'(1) = 0 \quad .. \quad .. \quad (22)$$

that

$$\frac{1 + Y}{1 - Y} = \frac{F'(1)}{G'(1)} \quad .. \quad .. \quad (24)$$

From (22) and (24) we obtain the second equation for determining z_1 and z_2, viz. :—

$$\frac{F'(1)}{F(1)} = \frac{G'(1)}{G(1)} \quad .. \quad .. \quad (25)$$

The two equations (20) and (25) give z_1 and z_2 as functions of $z_a = \omega_{0a}/\omega_z$ and $z_e = \omega_{0e}/\omega_z$, i.e. as functions of known magnitudes. Now suppose the two equations solved ; we could then calculate the constants occurring in (10) or (9) as functions of z_a and z_e also, and easily obtain from equation (9) the circuit magnitudes according to equations (1) to (5). For example, comparison of (11), (18), and (19) gives

$$F'(0) = 2a_1^2 \quad .. \quad (26)$$

while comparison of (10), (11), and (18) gives

$$F(0) = - a_1^2 + (1 + Y)a_2^2 \quad .. \quad (27)$$

From (10), (18), and (21) we find the last of the fundamental parameters

$$(1 - Y)F(1) = a_2^2 - c^2 \quad .. \quad (28)$$

with the three equations (26) to (28) we can express the tracking error y as a function of the oscillator frequency and of the three magnitudes ω_{0a}, ω_{0e}, and ω_z. The maximum tracking error Y is found from (22) to be

$$Y = \frac{F(1) - G(1)}{F(1) + G(1)} \quad .. \quad (29)$$

It becomes obvious how, by comparing (10) with (9), we arrive at the final circuit magnitudes according to (1) to (5). We find for example that the magnitude B which serves to determine the series capacitance is given by

$$B = - a_1^2/a_2^2 \quad .. \quad .. \quad (30)$$

Instead of B we may introduce the auxiliary magnitude A, given by

$$A = \frac{v_0 - 1)^2}{v_0(v_h - v_0)} B \qquad \ldots (30a)$$

Equation (1) expresses the fact that the actual variation of the high frequency circuit differs from the nominal variation by twice the tracking error, this error being positive at one end of the range and negative at the other. Equation (4) expresses the fact that the nominal variation of the oscillator agrees with its actual variation, and equations (2) and (5) give the corresponding inductances.

III. Solution of the simultaneous equations for the frequencies z_1 and z_2 at which the maximum error within the receiver range occurs.

Written out in full equation (20) becomes

$$z_1^3 - z_1^2 + 2z_1^2 z_e - 2z_1 z_e + z_1 z_e^2 - z_2^3 + z_2^2 - 2z_2^2 z_a + 2z_2 z_a - z_2 z_a^2 = 0 \qquad \ldots \ldots (20a)$$

Similarly for (25) we have

$$\frac{1}{1 - z_a} + \frac{2}{1 - z_2} + \frac{1}{z_a + 2z_2 - 1} - \frac{1}{1 - z_e} - \frac{2}{1 - z_1} - \frac{1}{z_e + 2z_1 - 1} = 0 \qquad \ldots \ldots (25a)$$

Thus (20) is an equation of the third degree in z_1 and z_2, (25) is an equation of the second degree in z_1 or z_2. The sum of the powers of the unknowns in (20) is not more than three. (25) on the other hand is a form of fourth degree. The elimination of one of the two unknowns would thus lead to an equation of twelfth degree, with one unknown, which would not be exactly pleasant to handle numerically, and which would moreover be very long. A simpler way is, by means of (25), to find z_2 as a function of z_1 and z_a and z_e, which involves the solution of a quadratic equation. This solution is inserted in (20), so that it can be checked whether in fact $F'(0) - G'(0)$ vanishes. The method is to estimate the higher of the two frequencies at which the maximum error occurs inside the range, i.e. z_1; it will naturally be found that for this estimated value $F' - G'$ vanishes only approximately and it can be easily checked that z_1 has been assumed too high if the sum of the positive terms S_+ in (20*a*) exceeds the sum of the negative terms S_-. A new value of z_1 is now estimated, which is found by multiplying the previous value by the factor S_-/S_+, and a better solution for the simultaneous equations is found. If the first estimate for z_1 was not too far out, linear interpolation will give a third value for z_1 which should be sufficiently accurate. All these calculations can be performed quite simply with a calculating machine, and it is sufficient to work to six places, and to solve the equation (25) accurately to one unit of the 5th place of a summand, and the equation (20) to one unit of the 5th place of S_+. It should be pointed out that in solving the quadratic (25) the root must always be given the negative sign. In Table I are set forth a large number of calculated values for z_1 and z_2. Starting from these values it is easy to make the first estimate of z_1 correct to within 1 per cent. The second step generally brings the accuracy to 10^{-3}, and the final step brings it to appreciably better than 10^{-4}. With practice, the whole calculation for the receiver range, including the evaluation of (10) and (1) to (5), can be done in half a day.

It will naturally be desired to substitute curves for these calculations, so that the complicated part of the work involved in determining the receiver component magnitudes can be performed once for all. When drawing the curves it is advisable to plot the magnitudes Y and B, since the other magnitudes of interest can be derived from these with sufficient accuracy with the slide rule. For this purpose curves $Y = \text{const.}$ and $B = \text{const.}$ are drawn in a $(v_h \,.\, v_0)$ plane. These are obtained by working out sections with $v_0 = \text{const.}$ Representation in the $(v_0 \,.\, v_h)$ plane is convenient because the

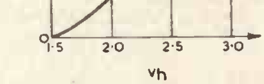

Fig. 4.—*Detuning Y as a function of the H.F. variation v_h at constant oscillator variation $v_o = 1.5$.*

desired curves have only slight curvature, so that a few points suffice to establish them with sufficient accuracy. For example, the straight line $v_0 = v_h$ is obviously one such curve of constant tracking error, since the tracking error vanishes along this line. Hence in drawing a cross section $v_0 =$ const. in a $(v_h Y)$ plane, the curve $Y = Y(v_h)$ must pass through the point v_0, 0. Three more points at equal distances are needed to fix the Y-curve. In order to obtain the family of Y curves as in Fig. 2 three such cross sections would be worked out, of which one is shown in Fig. 4. If the magnitudes z_1 and z_2 have already been calculated as functions of z_a and z_e when preparing the curves for Y, then it involves only a little trouble, using the formulae given, to work out the curves of Fig. 3 for B. We naturally obtain for the magnitude B the same cross sections $v_0 =$ const. as for the error Y; one such is shown in Fig. 5. With the scale chosen for Fig. 2, the absolute value of the tracking error can be read, to 10^{-4}, i.e. an accuracy considerably in excess of technical requirements. With the scale chosen, the magnitude B can be found with an accuracy varying from 1 per cent. to 10 per cent. of its value. The series capacitance C_s is also obtained with an accuracy in general not much better. As an accuracy of 1 per cent. is desirable here, individual portions of the curves may be drawn to an enlarged scale, and a greater number of cross sections may be worked out.

In order to facilitate the performance of the calculation, the numerical data on which Figs. 2 and 3 are based are given in the following table. It is definitely desirable to prepare a larger scale representation for the curves shown in Fig. 3, and this can easily be done with the help of the numerical values of B.

IV. Numerical Example

We will now work through a numerical example, taken from the broadcasting field. The medium wave range of a broadcast superhet has the end frequencies $\omega_{ha}/2\pi = 1530$ kc/s and $\omega_{he}/2\pi = 510$ kc/s, i.e., a variation $v_h = 3$. The intermediate frequency chosen is $\omega_z/2\pi = 468$ kc/s, so that the oscillator range must extend from $\omega_{0a}/2\pi = 1998$ kc/s to $\omega_{0e}/2\pi = 978$ kc/s, an oscillator variation $v_0 = 2.04294$, yielding initial and final ratios $z_a = 4.26923$ and $z_e = 2.08974$. We shall see later that for $v_h = 3$ and $v_0 = 2$ our two sets of curves 2 and 3 enable the whole circuit to be worked out by means of the slide rule with quite sufficient accuracy. But first, as an example, we will perform the full calculation up to the determination of the frequency ratios z_1 and z_2 and of the tracking curve.

We have first to estimate a value z_1, and we may usefully start from the nearest figure in Table 1. This is the figure for the point $v_0 = 2$, $v_h = 3$. The first estimate of z_1 thus gives

$$z_1 = \frac{3.27445 \times 4.26923}{4} = 3.49485$$

TABLE I.

z_e	z_2	z_1	z_a	v_h	$-Y$	B
$v_0 = 1.5$						
1.3	1.39448	1.71694	1.95	3.166	2.04%	3.70849
1.5	1.62294	1.99510	2.25	2.5	0.959%	2.26093
2	2.18300	2.67957	3	2.0	0.337%	1.13099
$v_0 = 2$						
1.8	2.05382	2.93554	3.6	3.25	1.59%	1.14712
2	2.29424	3.27445	4	3	1.19%	0.930612
2.2	2.53305	3.61100	4.4	2.833	0.913%	0.783190
2.5	2.89074	4.11712	5	2.666	0.711%	0.632151
3	3.48402	4.9562	6	2.5	0.493%	0.478618
3.5	4.0757	5.7935	7	2.4	0.377%	0.385064
4	4.6673	6.6313	8	2.33	0.30%	0.327020
4.5	5.25803	7.46783	9	2.28571	0.252%	0.276760
$v_0 = 2.5$						
2	2.37202	3.82063	5	4	2.16%	0.823823
2.5	3.00084	4.81404	6,25	3.5	1.32%	0.566013
4	4.86948	7.77546	10	3	0.582%	0.292210

Inserting this value in (25a) we find the first approximation for z_2, viz. $z_0 = 2.41531$. The sum of the positive terms in (20a) amounts to 135.4528, and exceeds the sum of the negative terms by 0.7087. We therefore estimate a new value z_1 which must be smaller, viz.

$$z_1 = \frac{134.7441 \times 49485}{135.4528} = 3.47656$$

(25a) now gives a new value z_2, viz. $z_2 = 2.40981$. The sum of the positive terms in (20a) now amounts to 134.1002, which is 0.0170 smaller than the sum of the negative terms. By linear interpolation we find a new value z_1, viz.

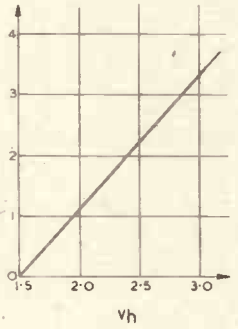

Fig. 5.—*Auxiliary magnitude B for calculating the series capacitance of the oscillator circuit as a function of the H.F. variation v_h at the fixed oscillator variation $v_o = 1.5$.*

$$z_1 = 3.47656 + \frac{0.0170}{0.7257} \times 0.01829 = 3.47699$$

Repeating the insertion in (20a) we now obtain agreement between the sum of the positive and the sum of the negative terms, both sums having the value 134.1320. We obtain immediately $a_1^2 = 81.1256$, $F(1) = -52.5711$, $G(1) = -53.7810$, and $Y = -1.137$ per cent. From the curves of Fig. 2 we find, for $v_h = 3$ and $v_0 = 2.04$, a value of 1.15 per cent., which agrees with the above exact value within the technically interesting limits. We determine further $a_2^2 = -95.7246$, $c^2 = -42.5558$ and $B = 0.847489$. In Fig. 3 we read the value of B as 0.86, so that in this case also the agreement between the value read from the curve and the exact value is within the technically interesting limits. For the tracking error as a function of z we find

$$y = \frac{(z-1)^2 (1.90633 - 0.0234986\, z^2)}{z^2 - 2.24939}$$

The tracking curve is illustrated in Fig. 6. It is possible to check by this example whether in a special case the empirical rules for the location of the three zero error points give the correct values.

Proof that the maximum detuning in the receiver range must occur four times.

We have already seen that, formulated mathematically, the problem of determining the circuit magnitudes depends on fixing the three parameters a_1^2, a_2^2, and c^2 of equation (10) in such a way that the greatest deviation Y in the receiver range is a minimum. This method of approximating to zero by means of a function of prescribed form with selectable parameters is known as Tschebyscheff's Approximation. It is known that a necessary condition for the correctly chosen parameters is that the following system of equations cannot be solved for λ :—

$$\frac{\partial y\ (z_\nu)}{\partial a_1^2}\lambda_0 + \frac{\partial y\ (z_\nu)}{\partial a_2^2}\lambda_1 + \frac{\partial y\ (z_\nu)}{\partial c^2}\lambda_2 = s_\nu$$

This system of equations is to be interpreted thus :—The partial derivatives with respect to the parameters are to be formed at all points z_ν at which the maximum error Y occurs. The magnitudes s_ν are fixed only as regards sign, which must agree with that of the error Y at the point z_ν. We will now show that if an error occurs only three times with alternate sign, then this system of equations can always be solved for λ, hence the error must occur at least four times with alternate sign. We will also show that the system of equations cannot be solved for λ if the error occurs four times or more. If it occurs at least four times then, as we have seen, it is completely determined by our method of solving. If we now form from (10) the partial derivatives, we find

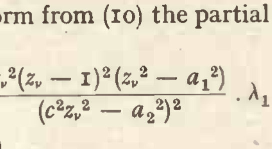

Fig. 6.—*Example of tracking curve for the medium-wave range of a broadcast superhet. Abscissa : Frequency of reception. Ordinate : Detuning. The nominal limit frequencies are 1530 and 510 kc/s, and the intermediate frequency is 468 kc/s.*

$$-\frac{(z_\nu - 1)^2}{c^2 z_\nu^2 - a_2^2}\,.\,\lambda_0 - \frac{z_\nu^2 (z_\nu - 1)^2 (z_\nu^2 - a_1^2)}{(c^2 z_\nu^2 - a_2^2)^2}\,.\,\lambda_1$$
$$+ \frac{(z_\nu - 1)^2 (z_\nu^2 - a_1^2)}{(c^2 z_\nu^2 - a_2^2)^2}\,.\,\lambda_2 = s_\nu$$

We may multiply the left-hand side of this equation by the positive magnitude $(c^2 z_v^2 - a_2^2)^2$, since the right-hand side s_v is in any case only fixed as regards its sign. We then have on the left-hand side an ordinary equation of the sixth degree in z_v. This equation has, firstly, two roots equal to 1, and secondly, four further roots whose absolute values are in pairs, since the equation, after division by $(z_v + 1)^2$ becomes a quadratic in z_v^2. Thus in the interval z_e, z_a, there can be two and not more than two roots, and the same number of changes to sign. Hence, with three values of z^2 it is always possible to find a system of values of λ which fits, and the error must occur at least four times with alternate sign. With four changes of sign and hence four values of z_v the system of equations for λ is necessarily insoluble. This proves the proposition.

Bibliography

[1] A. L. M. Sowerby, *Wireless Engineer*, Vol. 9 (1932), p. 70.

[2] W. Kautter, *E.N.T.*, Vol. 12 (1935), p. 31. See also V. D. Landon and E. A. Sveen, *Electronics*, Vol. 5 (1932), p. 250. R. C. Couppez, *L'onde électrique*, Vol. 15 (1936), p. 804. M. Wald, *Wireless Engineer*, Vol. 17, (1940), p. 105. O. Meisinger, *Funk.* (1941) p. 23. Kj. Prytz, *Ingeniörvidenskabelige Skrifter*, Copenhagen (1941), No. 3.

[3] Kirchberger, Dissertation Gottingen 1902.

[4] W. Cauer, "Theorie der linearen Wechselstromschaltungen," Leipzig : Akad. Verl.-Ges. 1941, p. 548.

[The subject has also been recently discussed in the following articles in *Wireless Engineer*: M. Wald, April 1941, p. 146. Editorial, April 1942. A. L. Green, June 1942, p. 243. Ruby Payne-Scott and A. L. Green, June 1942, p. 290. D. Riach, April 1943, p. 159.]

I.E.E. Councillors

Col. Sir A. Stanley Angwin, D.S.O., Engineer-in-Chief G.P.O., has been nominated president and Dr. E. B. Moullin, M.A., Sc.D., Oxford University, a vice-president of the I.E.E. for the 1943/44 Session. Among the seven nominees to fill the vacancies which will occur on the Council on September 30th are Brig. F. T. Chapman, C.B.E., D.Sc., Deputy Director of Military Training (Technical); J. S. Forrest, M.A., B.Sc., of the Research Staff of the Central Electricity Board and E. C. S. Megaw, M.B.E., B.Sc., G.E.C. Research Laboratory.

"The Signal Converter"

It is regretted that the following errors occurred in the article "The Signal Converter," which appeared in the June issue :—

In Fig. 4, the potential V should be placed on the accelerating electrodes F and G and not on the grid.

In the inscription to Fig. 12, for "$i_o = 0.2$ mA" read "$i_b = 0.2$ mA."

The last line on page 288 should read "and during the respective fly-back and scan."

Book Reviews

Experimental Radio Engineering

By E. T. A. Rapson, assisted by E. G. Ackermann. Pp. 159+viii., with 170 Figs. Sir Isaac Pitman & Sons, Ltd., 39 Parker Street, Kingsway, London, W.C.2. Price 8s. 6d.

This is the second edition of this excellent little laboratory handbook. The experiments described are suitable for a three or four year (years if you like, but not years' as the author has it in his preface)* course in radio engineering at a technical college. There are eighty experiments and a student might reasonably be expected to do about twenty in each year. The author is the head of the department of radio engineering at Southall Technical College, and the book is evidently a record of his experience in developing and working out the details of suitable laboratory classes. Diagrams of connections are given and sample results and curves indicating how the results are to be set out. An excellent point is that each experiment concludes with a number of questions as to the conclusions to be drawn from the experimental results, but one cannot help wondering how many students will have the strength of will not to turn to the end of the book to see what conclusions he is supposed to draw. The book is divided into 13 sections; two of them deal with series, parallel, and coupled circuits, two with audio- and radio-frequency measurements, two with valve characteristics, three with amplifiers, detectors, and oscillators, one with attenuators and filters, one with testing radio receivers, one with electro-acoustic tests and one with cathode-ray tubes and their applications. The multi-vibrator is apparently not included, but some difficult acoustical experiments such as the determination of the reverberation characteristics of a room are included; the latter due probably to the proximity of the college to the Gramophone Co.'s Works at Hayes. Great care has been taken with the nomenclature and symbols, but it is a pity that the diagrams of the third experiment have got mixed up with the text of the second one.

There is a great demand for such a book as this at the present time, and one can recommend it unreservedly.

G. W. O. H.

High Frequency Thermionic Tubes

By A. F. Harvey, B.Sc., D.Phil. Pp. 222+XIII; 99 figures. Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C.2. Price 18s.

Everyone will recognise that to issue a book on ultra-high-frequency valves in the fourth year of scientific warfare is to omit many of the subjects on which expert readers most desire enlightenment, since the really exciting developments naturally remain the private property of government servants in every belligerent country. But that is no reason for ignoring Dr. Harvey's first edition and refusing to make use of his wide research experience until the book is drastically rewritten in the first post-

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* One never measures the height of a six feet's wall with a three-pennies' tape measure.

war year. For the subject which he treats in greatest detail, the extraordinary varieties of Magnetron behaviour, depends upon fundamental relationships between complicated electron orbits in a magnetic field; these orbits are executed in the fluctuating electric fields to which the flow of charge itself contributes. If the mutual consequences were completely analysed we would be at once many years ahead in our knowledge. Dr. Harvey's book does carry such possibility much further than the standard German monographs available in 1939, and must be read by everyone who uses such electrodynamic principles. A defect is the wealth of pictures of valve exteriors: internal diagrams would give less of the air of a manufacturer's catalogue and convey more scientific information. Treatments of positive ion emission, in connection with Ratcliffe's important method of scale-models, and also of vacuum technique, are too brief and seem oddly selected. Discussion of closed resonators is also brief and requires the original papers or Lamont's recent "Wave Guides."

Perhaps the feature making the book indispensable to the valve laboratory is the thoroughly detailed account of many test-bench experiments on impedance, etc., to which Dr. Harvey has himself been a contributor. M. J.

Books Received

High Vacuum Technique. By J. Yarwood, B.Sc. (Hons.). This handbook contains, in concise form, much practical and up-to-date information regarding the production and measurement of high vacua. The author, who was at one time in the research laboratories of Electric and Musical Industries, states in the preface, however, that it is not intended to compete with the classics on the subject, but rather to introduce the latest developments in apparatus, to describe important industrial processes hitherto discussed only in scientific periodicals, and to bring together in one volume the diverse facts regarding the relevant properties and uses of materials encountered in all types of vacuum work. Pp. 106. Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C.2. Price 10*s*. 6*d*.

Radio Goes to War. By Charles J. Rolo. The author, who has worked for the Princeton Listening Centre in America, has made a close study of propaganda by radio and presents in this book a dramatic story of the part it is playing in the present crisis. Pp. 245. Faber and Faber, Ltd., 24, Russell Square, London, W.C.1. 8*s*. 6*d*.

Solderless Wire Jointing

THE more serious of the risks inherent in the traditional manner of joining wires by soldering, namely, that of corrosion due to the use of a fluxing material, may be avoided by a method recently patented by Technotherm Ltd., of St. Albans, Herts.

The uniting of single wires, or of one strand to several finer wires, is effected by means of a device which somewhat resembles a miniature spot welder. This Rakos process, as it is called, is not a true welding operation, since it does not involve arc formation or pressure-contact heating of the junction being made.

The wires to be jointed, having been lightly twisted together, are laid in a groove cut in the blunt tip of a carbon electrode. A suitable jointing medium, such as phosphor-bronze, copper or silver, is applied and a second similarly grooved carbon electrode is moved down upon the lower one, thereby simultaneously closing the energising circuit. Butt contact of the electrodes causes them quickly to become red hot; a temperature of the order of 3,000 deg. C. being generated in the grooved depression. The minute furnace enclosure minimises the risk of oxide growth by the exclusion of air. At the same time any varnish on the wires is burned off without damaging the metal core, thereby obviating the necessity of laboriously removing it by hand.

It is understood that Technotherm Ltd. does not propose to manufacture or distribute wire-jointing equipment made according to this system, preferring to arrange for it to be undertaken by manufacturers who have the necessary facilities to do so.

I.E.E. Premiums

THE Council of the Institution of Electrical Engineers has awarded the following premiums for papers read before the Wireless Section during the 1942-43 Session:—Duddell Premium (£20) to Dr. R. L. Smith-Rose, D.Sc., Ph.D., and Miss A. C. Stickland, M.Sc., for their paper "A Study of Propagation over the Ultra-Short-Wave Radio Link between Guernsey and England on Wavelengths of 5 and 8 Metres"; Ambrose Fleming Premium (£10) to G. Parr and W. Grey Walter, M.A., for their paper "Amplifying and Recording Technique in Electro-Biology, with special reference to the Electrical Activity of the Human Brain"; and an Extra Premium (£5) to Prof. Willis Jackson, D.Sc., D.Phil., for his paper, "The University Education and Industrial Training of Telecommunication Engineers."

Wireless Patents

A Summary of Recently Accepted Specifications

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

ACOUSTICS AND AUDIO-FREQUENCY CIRCUITS AND APPARATUS

550 756.—Piezo-electric microphone for mechanical operation by the muscles of the throat.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 29th July, 1941.

550 907.—Push-pull amplifier with means for eliminating the effects of any fluctuation in the voltage of the mains supply.

Philips Lamps (communicated by Philips' N. V. Gloeilampenfabrieken). Application date, 13th January, 1942.

551 000.—Piezo-electric transducer element designed to respond to a wide range of frequencies, particularly for a loudspeaker.

The Brush Development (assignees of A. L. W. Williams). Convention date (U.S.A.), 2nd August, 1940.

551 069. Push-pull amplifier in which the cathode of each stage is connected to a common load-circuit for minimising undesirable input capacitances.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 9th January, 1942.

551 364.—Stereophonic sound reproduction with means for compensating distortion due to the microphone mounting.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 14th January, 1942.

551 809.—Minimising harmonic components in a push-pull amplifier comprising a driver stage and a phase inverter.

Western Electric Co., Inc. Convention date (U.S.A.), 4th December, 1940.

AERIALS AND AERIAL SYSTEMS

551 243.—Preventing undesired reaction effects between an elevated aerial of the Adcock type and associated metallic parts, such as the earthed supporting structure.

Marconi's W. T. Co.; S. B. Smith; and I. S. Forbes. Application date 12th January, 1940.

551 546.—Frame aerial provided with a powdered-iron core or mass which is symmetrically arranged with respect to the axis of rotation of the aerial windings. [Addition to 522 492.]

Standard Telephones and Cables (communicated by W. J. Polydoroff). Application date, 21st March, 1940.

551 585.—Electromagnetic horn radiators and means for coupling them to wave-guides.

Marconi's W.T. Co. (assignees of M. Katzin). Convention date (U.S.A.), 31st August, 1940.

DIRECTIONAL WIRELESS

550 611.—Indicating device for a radio direction-finder adapted also to give a true or compass bearing and to compensate for quadrantal and other inherent errors.

Marconi's W. T. Co.; C. S. Cockerell; and J. H. Moon. Application date, 9th June, 1941.

550 633.—Radio beacon or navigational overlapping-beam system in which the signals are so modulated as to prevent casual "shifting" of the course-line.

Standard Telephones and Cables (assignees of A. Alford). Convention date (U.S.A.), 1st March, 1941.

550 660.—Aircraft receiver for use with blind-landing beams modulated at different frequencies to ensure the most favourable glide path.

Sperry Gyroscope Co., Inc. (assignees of W. T. Cooke and A. S. Maeder). Convention date (U.S.A.), 28th August, 1940.

551 376.—Radio direction-finding system in which the position of a beacon transmitter is visibly pinpointed on a map.

J. Thorley. Application date 18th August, 1941.

551 773.—Dipole array with a dividing screen for a radio-navigational beacon of the overlapping-beam type.

Aga-Baltic Akt. Convention date (Sweden), 13th January, 1941.

551 947.—Feed-line arrangement for resolving the 180° ambiguity in a direction-finding system using two spaced dipoles.

A. C. Cossor and F. R. W. Strafford. Application date, 13th September, 1941.

RECEIVING CIRCUITS AND APPARATUS

(See also under Television)

550 770.—Variable condenser comprising two dielectric members, one a tapering plug and the other a tapering socket.

United Insulator Co.; T. J. Rehfisch; and T. R. Amschwand. Application date, 11th June, 1941.

550 899.—Modulation system giving complete or partial suppression of one of the sidebands

and undistorted reproduction with linear detection.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 7th October, 1941.

550 958.—Single-span superhet receiver in which selectivity is increased by the use of a diode as mixer valve.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 29th July, 1941.

551 045.—Receiver in which high fidelity is secured partly by the use of permeability tuning to give constant coupling and partly by using separate valve stages for amplification and regeneration, respectively.

Johnson Laboratories, Inc. (assignees of W. A. Schaper). Convention date (U.S.A.), 10th June, 1940.

551 064.—Receiver which is tuned continuously over a wide range of short waves with band-spread control over certain parts of the tuning range.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 18th December, 1941.

551 209.—Crystal rectifiers and mixers for ultra-short-wave receivers.

Standard Telephones and Cables (communicated by Western Electric Co., Inc.). Application date, 4th February, 1941.

551 231.—Tuning system in which the overall resonance of two pre-tuned circuits is varied over a range of frequencies by suitably adjusting an inter-coupling link.

H. Fletcher. Application date, 26th November, 1941.

551 234.—Safeguarding device for the electrolytic smoothing condensers used for driving a wireless set from a direct-current mains supply.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 11th December, 1941.

551 320.—Tuning-indicator scale with a fixed cursor-line which is curved in order to compensate for known " tolerance " errors.

Marconi's W. T. Co. and C. S. Cockerell. Application date, 12th August, 1941.

551 472.—Means for varying the operating wavelength of a combined transmitter and receiver for phase- or frequency-modulated signals.

J. W. Dalgeish and Pye. Application date, 20th August, 1941.

551 678.—Automatic volume control in which both the carrier wave and the side-bands are utilised to offset selective fading.

Standard Telephones and Cables (assignees of C. B. H. Feldman). Convention date (U.S.A.), 4th October, 1940.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

551 665.—Limiting the radial velocity of the electrons forming the stream in a cathode-ray tube in order to improve the magnetic focusing of the scanning spot.

Marconi's W.T. Co. (assignees of H. B. de Vore). Convention date (U.S.A.), 23rd August, 1940.

TRANSMITTING CIRCUITS AND APPARATUS

(See also under Television)

551 034.—Transmission of picture telegraphy and like facsimile signals by frequency modulation.

Marconi's W. T. Co. (assignees of J. W. Cox). Convention date (U.S.A.), 7th November, 1940.

551 277.—Arrangement for automatically maintaining a source of carrier-waves in the event of the failure of one of two parallel oscillators.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 8th August, 1941.

551 282.—Phase-modulated system in which the signal voltages are utilised to produce time-phased pulses of carrier-wave energy.

Standard Telephones and Cables. Application date, 15th August, 1941.

551 764.—Frequency- or phase-modulating system in which part of the phase-shifting network is the grid-cathode space of a control valve.

Marconi's W.T. Co. (assignees of C. N. Kimball). Convention date (U.S.A.), 2nd October, 1940.

551 843.—Automatic gain-control system utilising a pilot current for live-wire repeaters.

Standard Telephones and Cables (assignees of J. G. Kreer, Junr.). Convention date (U.S.A.), 25th February, 1941.

551 890.—Piezo-electric control for stabilising the mean frequency in a frequency-modulating system.

Marconi's W.T. Co. (assignees of M. G. Crosby). Convention date (U.S.A.), 6th September, 1940.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

550 655.—Cathode-ray tube with a ring electrode for suppressing the so-called " standing current " which normally flows even when the modulating voltage is at cut-off.

Cinema-Television and K. A. R. Samson. Application date, 15th July, 1941.

550 728.—Method of coating the anode and screening grid of a pentode valve with secondary-emission material in order to allow the suppressor grid to be wound with a wide pitch to secure a desired valve characteristic.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 23rd August, 1941.

550 733.—Method of constructing and mounting the indirectly-heated cathode of a valve in order to secure a desired distribution of heat.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 19th September, 1941.

550 972.—Squirrel-cage electrode structure for a valve in which two or more groups of flat-wire loops are arranged so as to minimise undesirable capacitance effects.

Standard Telephones and Cables (communicated by International Standard Electrical Corporation). Application date, 23rd January, 1942.

551 014.—Means for eliminating undesirable patches of light due to space-charge effects in the vicinity of the mosaic screens of iconoscope and like cathode-ray tubes.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 8th August, 1941.

551 096.—Means for preventing cracking or splitting of the ceramic discs commonly used to support valve electrodes.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 18th December, 1941.

SUBSIDIARY APPARATUS AND MATERIALS

550 451.—Flexible control circuit for A.C./D.C. converter valves.

The British Thomson-Houston Co. Convention date, (U.S.A.), 5th July, 1940.

550 473.—Filter circuit for separating carrier-wave, voice-frequency, and direct-current signals in a line-wire Multiplex system.

Standard Telephones and Cables (assignees of T. O'Leary). Convention date (U.S.A.), 24th October, 1940.

550 570.—Scanning-head for a telegraphic picture or facsimile transmitter.

Finch Telecommunications Inc. (assignees of W. G. H. Finch and L. M. Cockaday). Convention date (U.S.A.), 16th August, 1940.

550 591.—Self-quenched single-valve oscillation generator comprising resistance and capacitance, time-constant components, and Lecherwire or coaxial-line tuning.

Marconi's W. T. Co. and T. D. Parkin. Application date, 13th June, 1941.

550 610.—Construction of condenser for measuring a small steady voltage by first converting it into an alternating voltage.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 6th February, 1942.

550 607.—Indicating device, of the "magic eye" type, for synchronising two frequencies.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 9th January, 1942.

550 716.—Minimising the distorting or modulating effect of the screw propeller of an aeroplane on incoming or outgoing radio fields.

Standard Telephones and Cables (assignees of A. Alford.) Convention date (U.S.A.), 11th October, 1939.

550 743.—Voltage-regulating circuit for stabilising the voltage taken from a source liable to fluctuations.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 19th November, 1941.

550 808.—Radio altimeter or distance-indicator depending upon the phase adjustment of an outgoing signal and its reflected echo.

E. T. J. Tapp; F. J. G. van den Bosch; and Vacuum-Science Products. Application date, 22nd July, 1941.

550 814.—Multiplex signalling system of the kind in which the different signals are distributed or interleaved over repeated cycles of time.

Hazeltine Corporation (assignees of J. C. Wilson). Convention date (U.S.A.), 28th May, 1940.

550 826.—Construction of dry-contact rectifiers of the barrier-layer type.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 6th March, 1942.

550 922.—Valve holder comprising a metal plate mounted between two layers of insulation and provided with curled-over contact clips.

J. D. Cockcroft and R. E. Ridsdale. Application date, 15th July, 1941.

551 087.—Synchronising system for picture telegraphy and like facsimile signals.

Marconi's W. T. Co. (assignees of M. Artzt). Convention date (U.S.A.), 3rd August, 1940.

551 139.—Damp-proof and heat-proof housing for the elements of a fixed condenser.

Sir H. Ingram (Bart). Application date, 8th December, 1941.

551 176.—Controlling the fluorescent and phosphorescent characteristics of a luminescent screen for a cathode-ray tube by subjecting the screen to an exciting beam and a de-activating beam simultaneously.

The Fairey Aviation Co.; J. L. Hills; and P. B. Hovell. Application date, 20th December, 1939.

551 194.—Arrangements for calculating and measuring the impedance characteristics of an electric network.

Westinghouse Electric International Co. Convention date (U.S.A.), 13th November, 1940.

551 197.—Automatic switching system for a transmission line carrying power currents and carrier-wave signals.

Radio Gramophone Development Co. and H. F. Duffell. Application date, 21st November, 1941.

551 230.—Constant-impedance attenuator network for coupling a carrier-wave transmission line to a receiving set.

Radio Gramophone Development Co. and H. F. Duffell. Application date, 21st November, 1941.

551 293.—Automatic gain-control system in which a transmission line is divided into sections by blocking means, each section being subject to a pilot or control current.

Standard Telephones and Cables (assignees of B. J. Kinsburg). Convention date (U.S.A.), 19th October, 1940.

551 344.—Oscillation generator in which the output frequency is controlled by a reactance valve, and in which power losses in the phase-shifting network are minimised.

A. C. Cossor; D. A. Bell; and A. H. A. Wynn. Application date, 16th August, 1941.

551 485.—Construction and processing of indirectly-heated resistances having a positive or negative temperature characteristic.

Standard Telephones and Cables; H. Wolfson; and S. C. Shepard. Application date, 22nd August, 1941.

551 539.—Means for alternately generating two time-base sweeps at different speeds for a cathode-ray indicating tube.

Marconi's W. T. Co. (assignees of W. D. Hershberger). Convention date (U.S.A.), 26th September, 1940.

551 588.—Method of comparing or measuring high frequencies involving a preliminary stage of heterodyning or frequency conversion.

British Insulated Cables and H. R. F. Carsten. Application date, 16th October, 1941.

551 638.—Vacuum condenser with electrode surfaces of oxidised nickel for high-power radio frequencies.

Standard Telephones and Cables; and W. T. Gibson. Application date, 29th August, 1941.

551 664.—Gas-filled relay adapted to be triggered by the bodily movement, say, under magnetic attraction, of one of its electrodes.

Standard Telephones and Cables (assignees of R. H. Badgley). Convention date (U.S.A.), 29th August, 1940.

551 686.—Automatic code signalling device with means for varying the code sequence.

Westinghouse Brake and Signal Co. and R. M. MacGregor. Application date, 3rd March, 1941.

551 698.—Composition of electrode for a contact rectifier of the selenium type. [Addition to 534 043.]

Westinghouse Brake and Signal Co.; L. E. Thompson; and A. Jenkins. Application date, 2nd September, 1941.

551 732.—Construction of a magnetic circuit comprising a laminated coil core and a laminated bridging yoke, with a toothed engagement between each element.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 24th October, 1941.

551 767.—Coupling a light-sensitive device to a gas-filled relay of the shield-grid type.

The British Thomson-Houston Co. (communicated by General Electric Co.). Application date, 15th December, 1941.

551 772.—Spark-measuring device for testing the load on high-tension coils and the like.

Crypton Equipment and E. T. L. Helme. Application date, 10th January, 1942.

551 775.—Means for maintaining constant power consumption in an A.C. circuit subject to voltage variations.

E. G. Budd Manufacturing Co. Convention date (U.S.A.), 31st December, 1940.

551 818.—Cathode-ray indicator for locating and measuring impedance faults or irregularities in a transmission line.

Standard Telephones and Cables (assignees of K. E. Gold). Convention date (U.S.A.), 26th March, 1941.

551 844.—Circuit for generating electric pulses of constant shape and amplitude and of fixed repetition frequency.

Standard Telephones and Cables (assignees of A. W. Horton, Jr., and M. E. Mohr). Convention date (U.S.A.), 21st January, 1941.

551 877.—Electromagnetic timing device or switch for producing a periodic output which is independent of the frequency of the A.C. supply.

Igranic Electric Co. (assignees of E. W. Seeger and C. Stansbury). Convention date (U.S.A.), 28th June, 1941.

Waste Paper Salvage

THE wireless industry is co-operating with the electrical industry in organising schemes to ensure more effective collection and disposal of waste paper. Although support from many important wireless firms has already been received, an appeal for further economy in the use of paper and increased effort in the recovery of waste, is made by the Electrical Industry Waste Paper Recovery Committee.

Information on the work of the Committee can be obtained from the Secretary, 2, Savoy Hill, London, W.C.2.

GOODS FOR EXPORT

The fact that goods made of raw materials in short supply owing to war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

Abstracts and References

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For the information of new readers it is pointed out that the length of an abstract is not necessarily an indication of the importance attached to 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.

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PROPAGATION OF WAVES

1818. THE MAGNETIC FUNDAMENTAL OSCILLATION OF THE CYLINDRICAL CAVITY WITH CIRCULAR CROSS SECTION.—F. Borgnis. (*Hochf:tech. u. Elek:akus.*, Dec. 1942, Vol. 60, No. 6, pp. 151–155.)

"The propagation of electromagnetic waves in the interior of a metallic tube is, as is well known, only possible when the exciting wavelength lies below a definite limit given by the internal radius of the tube; longer waves cannot be propagated through the tube. The limiting wavelength depends in each case on the special oscillation-type excited in the wave-guide. A particular importance attaches to the oscillation-type which gives the longest limiting wavelength for a given tube-radius: this is a magnetic type, *i.e.* one in which a magnetic field, but no electric field, exists in the direction of propagation (axis of tube). Limiting wavelength and tube-radius bear the relation $\lambda = 3.41R$. The oscillation-type is represented by the term H_{11}-wave (or H_{10}-wave).

"If such a circular-sectioned cylindrical tube is closed at both ends by plane surfaces, a cavity resonator is formed. By exciting this to the oscillation-type discussed above, standing waves are now formed in the closed space by reflection at the walls, and the oscillation régime is obtained which we call the 'magnetic fundamental oscillation' (H_{111} type). This is of special importance in that it represents, for a given circular-sectioned cylindrical cavity, the oscillation régime with the longest possible resonance wavelength, on the assumption that the ratio of the tube-length l to the tube-radius R does not fall below a certain fixed value. If l is less than $2R$ [more accurately, $2.02R$] another type of oscillation, the 'electrical fundamental oscillation,' takes over the rôle of the oscillation mode with the longest possible resonance wavelength.

"The electrical fundamental oscillation has already been dealt with thoroughly elsewhere (Borgnis, 905 of 1940). In the present paper the properties of the magnetic fundamental oscillation will be described, and in addition the point of contact between the electrical and magnetic fundamental oscillations will be investigated." The expressions for the electric and magnetic field components of the magnetic fundamental oscillation (eqns. 1 & 2), are taken, as a starting point, from the writer's paper dealt with in 3874 of 1939, and its resonance wavelength is found to be $\lambda = 2/\sqrt{0.343/R^2 + 1/l^2}$. Hence the natural wavelength of an infinitely long cylinder is $\lambda = 3.41R$ (identical with the limiting wavelength for progressive waves of this oscillation-type): R must always be greater than $\lambda/3.41 = 0.293\lambda$. With decreasing l and a constant R the natural wavelength decreases, but never falls below $\lambda/2$: for the limiting case $l = \lambda/2$ the equation gives R = infinity. For a given cylinder-surface the natural wavelength λ has a maximum for $l/R = 2.33$: this maximum wavelength is $\lambda = 2.75\ R = 1.18\ l$.

Equation (11) is found (for the actual derivation *see* the appendix, section v) for the damping d in the case of a copper/air combination. For a given resonance wavelength λ, d has a minimum for $R/l = 0.66$ (corresponding to the condition $\lambda = 2.25R = 1.49\ l$). It also has a weakly defined relative maximum for $R/l = 4.24$. The damping minimum becomes increasingly marked as the wavelength decreases, so that for very short waves (of the order of a few cms) it is advantageous to keep R/l equal to 0.66 if it is desired to reduce the damping as much as possible.

Section IV deals with the conditions for equality of the resonance wavelengths of the electric and magnetic fundamental oscillations: equating the expression for the former ($\lambda = 2.61R$) with that for the latter (*see* above), it is found that $R/l = 0.494$ and $l/\lambda = 0.775$. Hence along the straight line $l = 0.755\lambda$ in Fig. 5 the two types of oscillation occur simultaneously and independently.

1819. "Microwave Transmission" [Book Review].—J. C. Slater. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, p. 120.) For another review *see* 1661 of June.

1820. The Making Visible and Photographing of the Field of Hertzian Waves [Method of "Spark Styctography"].—W. K. Arkadiew & D. I. Penner. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 10th Aug. 1940, Vol. 28, No. 4, pp. 315–317: in German).

Arkadiew's method using "styctographic coherers" was dealt with in 25, 26, & 372 of 1935, 2664 of 1938, and 461 of 1940: *see* also references at end of paper. He also suggested a simpler method which Penner has now developed into practical form. It employs a thin layer of metallic particles (the metals tried were aluminium, copper, and nickel) scattered on a photographic plate or paper which is kept vibrating with sufficient intensity to make the particles vary in their spacing so that the optimum distances for spark formation (under the influence of the ultra-short-wave field) occur. A dark-adapted eye can actually see the resulting figures directly, apart from the possibility of the photographic recording. "It is too soon to estimate the practical importance of the method, but since it renders the Hertzian waves visible in a way similar to that in which, for instance, a fluorescent screen makes X-rays visible," it should be capable of important applications. The wavelengths used were around 3.5 cm. A full description of the new method is promised.

1821. The Dielectric Constant and Loss Angle of Dry and Wet Sand for Centimetric Waves.—E. Löb. (*Hochf:tech. u. Elek:akus.*, Feb. 1943, Vol. 61, No. 2, pp. 35–38.)

"A description was recently given in this journal (3643 of 1942) of an apparatus evolved by W. Küsters for measuring the dielectric constants and loss angles of ceramic materials at centimetric wavelengths: the usefulness of the apparatus was illustrated by measurements on various materials. As a supplement to these measurements, the same apparatus, with suitable modifications, has been used for similar measurements on dry and wet sand." In the original work the concentric tubes were themselves composed of the material under test, the inner and outer conductors being formed of sintered-on silver coatings. The materials involved were dielectrics with comparatively low damping, whereas the present measurements, especially those on the wet sand, dealt with such large values of damping that the plotting of resonance curves became difficult. The complete resonance curve was therefore plotted only for dry sand: in the case of the wet sand only the resonance points corresponding to the various degrees of wetness were taken, and these were referred to the maximum galvanometer deflections obtained with the dry sand. Measurements were all made around a wavelength of 8.652 cm: the sand was introduced into a concentric line both of whose conductors were of brass. The great practical difficulties in damping the sand uniformly and at the same time only slightly are described on p. 36 (r–h column), together with the technique finally evolved.

The resonance curves were plotted by keeping a constant generator voltage at the input end of the line and measuring the currents at the end of the line as the test frequency was varied. The thermo-converter coupled to the line for measuring the line current was so designed that the line could be interchanged without altering the coupling between generator or converter and the line. The dampings involved were such that the resonance curves were fairly broad, and the thermo-converter itself was therefore made in the form of a tunable circuit which at every measurement was adjusted to give the maximum galvanometer deflection: but as the sensitivity of the arrangement varied with the adjustment, each value had to be corrected from a calibration curve. The formula given by Küsters (*loc. cit.*) was used for the calculation of $\tan\delta$. More difficulties were encountered in the measurement of wavelengths (for the determination of ϵ): the existing wavemeter had to be modified, and p. 36, l-h column, describes the re-design of the tungsten-silicon detector (so as to obtain a sensitivity which would allow the wavemeter/line coupling to be made loose enough to avoid various difficulties encountered with a tight coupling) and of the spring contact between the wavemeter piston and the inner conductor.

Fig. 4 shows the variation of ϵ and $\tan\delta$ for Rhine sand plotted against percentage water content: $\tan\delta$ ranges from 134.8×10^{-4} for "dry" sand (less than 0.05%) to nearly 500×10^{-4} for 0.5%: ϵ remains approximately constant at about 2.7, or about 2.5 for sea sand (Fig. 5). On p. 37, r-h column, the conductivities here found are compared with Strutt's results for other frequencies: the centimetric-wave values are seen to be of the same order as those for metric waves (Strutt's figure for a 1.42 m wave was 4×10^{-14} e.m.u., compared with the present writer's value of 4.3×10^{-14} for an 8.6 cm wave; but the former value was presumably for dry sand, whereas the latter was for a 0.52% water content) and about ten times larger than for low frequencies. It was also found that with very dry sand the loss angle decreases sharply with increase of temperature, probably owing to the disappearance of moisture films between the particles. The apparatus and technique were found suitable for sands with a water content up to 0.5%: for higher percentages it was impossible to obtain reliable resonance curves.

1822. The Determination of the Electrical Properties of Soil at a Wavelength of 5 Metres (Frequency 60 Mc/s).—J. S. McPetrie & J. A. Saxton. (*Journ. I.E.E.*, Part III, March 1943, Vol. 90, No. 9, pp. 33–35.)

Authors' summary :—" The paper describes experiments made to determine the electrical properties of various ground surfaces from the reflection-coefficient obtained for radiation incident normally on them. The subsoil on the sites investigated varied from wet clay to gravel ; the corresponding values of dielectric constant ranged from about 5 to 60 and the conductivity values from less than 10^8 up to not greater than 10^9 e.s.u. The lowest values in each case refer to a site at which the soil had been dug out to a depth of 7 ft, and the new surface consisted of pure gravel. The results obtained for both electrical properties and reflection-coefficient are in general agreement with previous experiments conducted at longer and shorter wavelengths by the same and other methods."

1823. A Study of Propagation over the Ultra-Short-Wave Radio Link between Guernsey and England on Wavelengths of 5 and 8 metres (60 and 37.5 Mc/s).—R. L. Smith-Rose & A. Christine Stickland. (*Journ. I.E.E.*, Part III, March 1943, Vol. 90, No. 9, pp. 12–19 : Discussion pp. 20–25.)

Authors' summary :—" The paper presents a survey and analysis of field intensity measurements obtained during the years 1937–1939, over the Post Office radio-telephone link between Guernsey and Chaldon, England, on wavelengths of 5 and 8 m (frequencies 60 and 37.5 Mc/s). The path between the stations was almost entirely over sea and about 85 miles in length, of which some 36 miles was outside the optical range. The data recorded have been analysed in such a way as to illustrate the general and detailed variations in received signal strength, and the manner in which these are dependent on various atmospheric conditions.

" The results of the analysis have shown that while the fading of the signals was similar in type on the two wavelengths, there was a difference in the secular variation of the amount of fading on 5 and 8 m. No diurnal or seasonal variation of signal intensity was noted, nor was there any definite diurnal variation in the amount of fading. The fading observed took various forms, ranging from a rapid type in which the changes occurred more or less periodically every three or four minutes, to a slow type of variation extending over one or more hours. The latter type was usually accompanied by a high level of signal intensity interrupted at long intervals by rapid and deep fading lasting from 10 to 30 minutes. The field strength records show a marked correlation between periods of negligible fading and the existence of low atmospheric pressure conditions generally, including lack of appreciable temperature inversion. The occurrence of fog and snow has a similar effect to that due to the prevalence of low pressure.

" A consideration of these results and of similar data obtained by other workers leads to the conclusion that abrupt changes in temperature and water vapour gradients in the atmosphere give rise to signal variations in good weather, while the absence of these discontinuities in bad weather allows of steadier signal conditions."

1824. The Speed of Travel of Wireless Waves [Part of Wireless Section Chairman's Address]. — R. L. Smith-Rose. (*Journ. I.E.E.*, Part III, March 1943, Vol. 90, No. 9, pp. 2–11.)

The first and second sections of the address deal with the history of the development of the Wireless Section of the Institution of Electrical Engineers and the work of the Radio Research Board respectively, while the third section deals with present knowledge of the speed of travel of wireless waves. The need is stressed for an accurate knowledge of this speed, for example in the study of the properties of the ionosphere and in the evaluation of the distance between two points on the earth's surface by radio methods. A brief résumé is given of the most accurate determinations of the speeds of light and radio waves. The experimental evidence indicates that these speeds are very nearly the same in free space but that the speed of wireless waves may be modified when transmission takes place close to the earth. *See* also 3495 and 3803 of 1942.

1825. Electromagnetic Fields in Radio : V—Stationary Waves and Velocities of Travel.—M. Johnson. (*Wireless World*, May 1943, Vol. 49, No. 5, pp. 144–147.) *See* also 1621 of June.

1826. U.H.F. Circuit Contours.—C. D. Haigis. (*Communications*, Feb. 1943, pp. 17, 20, 21, 71 and 72.)

A study of systems in operation on frequencies in the region of 30 Mc/s. The ground-contours of the transmission path are shown for some twenty cases, including mountainous country in which there is no optical path between sender and receiver.

1827. Refractive Indices of Gases at High Radio Frequencies.—Kerr. (*See* 1740 of June.)

1828. Reciprocity of Wave Propagation through Magnetically Doubly-Refracting Media.—Goubau. (*See* 1885.)

1829. The Specular Reflection of Plane Wave Pulses in Media of Continuously Variable Refractive Properties.—M. E. Rose. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, pp. 111–120.)

1830. Suggestions for a Theory of the Coastal Refraction.—G. Grünberg. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, pp. 185–189.)

" Although the problem of the propagation of electromagnetic waves along a plane separating two dissimilar isotropic homogeneous media can be at present considered completely solved through the work of Sommerfeld and his followers, the more difficult case of three or more different media seems not yet to have been successfully attacked. Such an investigation would, however, be of considerable interest, both theoretical and practical.

In particular, the theory of the coastal refraction, *i.e.* of the peculiar way in which electromagnetic waves are reflected and refracted when passing from the sea to the shore, relates to the case of three different media (air, water, soil). . . . We appreciate the difficulty of the last problem when we recall that even the much simpler problem of the diffraction of electromagnetic waves by a simple wedge of finite conductivity has not yet been solved exactly. We cannot therefore expect that the much more difficult problem of the coastal refraction, which in its simplest form (when the boundaries of the different media are planes) corresponds to the case of two such wedges with different properties, can be solved exactly. . . . In such circumstances it seems to be advisable to seek for some approximate method of approach to the problem under consideration. Such a method can be based on the well-known fact that an electromagnetic field varying with the time can penetrate but little into a sufficiently good conductor. This leads to the possibility of formulating a certain approximate boundary condition at the surface of separation of two media, one of which has much higher conductivity than the other."

A detailed investigation of the solution of the final equation is to be given in a paper which is to appear in the *Journal of Physics of the U.S.S.R.* under the same title as above.

1831. CHALMERS IONOSPHERIC OBSERVATORY (11° 59′ E, 57° 41′ N), GÖTEBORG, SWEDEN.—O. E. H. Rydbeck. (*Hochf:tech. u. Elek: akus.*, Dec. 1942, Vol. 60, No. 6, pp. 149–151.)

In service since November 1941 for regular automatic recordings: one fixed-frequency transmitter at present on 2927 kc/s with a max. power of about 500 W, and one frequency-sweep transmitter (at present, 1–14 Mc/s sweep in about 6 minutes once an hour) with a max. steady output of about 750 W. Day and night unattended operation, with fire-alarm and protective system. Fifteen horizontal half-wave L aerials each with a separate matching stage on the building roof. Receiving equipment 2 km away. Recorder uses the German point-glow lamp PL12 (with quartz window) having about ten times as large a max. permissible current as the American RCA 901: for the fixed-frequency records the lamp current is about 1 mA (paper speed 37 mm/h) while for the frequency-sweep records the lamp current rises to about 20 times this value for a speed 20 times greater. An English version of this paper was referred to in 6 of January.

1832. THE SUN AS AN ENTITY AND THE ELEVEN-YEAR CYCLE OF ITS ACTIVITY [Examination of the Discrepancy between "the Constancy of the General Energy Régime of the Sun and the Cyclicity of Its Visible Activity": an Explanatory Hypothesis].—M. S. Eigenson. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, 30th Aug. 1940, Vol. 28, No. 6, pp. 494–496: in English.)

"The cyclicity of solar phenomena, that is, the dependence of their total power on the 11-year solar rhythm, is not a process becoming manifest in the whole totality of the phenomena of a given type, but refers only to phenomena of a definite power; the amplitude of the 11-year cycle depends upon the power (or duration of phenomena, which varies directly as the power) in such a way that the more powerful or long-lived a given phenomenon, the greater is the amplitude of the 11-year cycle." The writer establishes this hypothesis by a special treatment of Greenwich data on the recurrence of sunspot groups. He ends: "Thus, the Schwabe-Wolf law (*i.e.*, the 11-year cycle of changes in the total *power* of solar phenomena) is on the whole limited to more noticeable details localised within the observable peripheral layers of the Sun in its active regions. This must not be taken to mean, however, that the *source* of 11-year cyclicity is necessarily localised in the same peripheral layers; it may in fact be deep-seated, too. The above-mentioned shows only that the particular form of manifestation of solar cyclicity which is expressed in the form of Schwabe-Wolf's law is a purely peripheral phenomenon, which fails to encompass the whole of the Sun's periphery and comprises only its separate portions, namely the active regions."

1833. WHY CERTAIN GEOPHYSICAL PHENOMENA HAVE THE EPOCHS OF MAXIMA IN THEIR ELEVEN-YEAR RHYTHMS SHIFTED WITH RESPECT TO THE EPOCHS OF MAXIMA OF SOLAR ACTIVITY.—M. S. Eigenson. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, 30th Aug. 1940, Vol. 28, No. 6, pp. 497–499: in English.)

"As has lately been shown by the author [refs. 1, 2], solar spots reach their greatest life-time 1 to 2 years after the epoch of maximum solar activity. It was found that the life-time of spots represents a stochastic function of their heliographic latitude; it increases with decrease of the latter [refs. 3, 4]. At the same time the mean latitude of the 'royal zone' has proved to be the lowest precisely upon the lapse of a certain time after the epoch of maximum solar activity; later on, *i.e.*, already close to the epoch of the next minimum of solar activity, there appear high-latitude spots on a new solar cycle which again produce an increase in the mean latitude of the 'royal zone'. Accordingly, in the course of a given cycle, a short time after its maximum, there appears a year with the least mean latitude of the spot-generating zone, this year being simultaneously distinguished by the greatest life-time of spots." Moreover, for the three reasons given on p. 499, "groups of spots with a greater life-length will have a relatively more intensive effect" on the troposphere and other envelopes of our planet, and this would explain the shift (of + 1.4 years for the last five cycles) of the curve of geomagnetic activity with respect to the curve of Wolf's numbers, and the shifts of certain "atmospheric megaprocesses" (heavy Nile floods, relative activity of polar and tropical airs, great microseismic disturbances due to enhanced cyclonic activity, thunderstorm frequency, etc.).

1834. The Nature of the Primary Particles Responsible for Cosmic-Ray Phenomena.—W. F. G. Swann. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, pp. 210–211.)

The writer continues his examination of the cosmic-ray latitude effect (*see* 12 of 1942) and, as a result of comparing experimental data with his theoretical formulae, concludes that "there may be two types of primaries—protons which are responsible for the generation of the mesotrons observable at sea level and at semi-high altitudes, and in addition, heavier particles, possibly singly ionised helium atoms which, through their offspring electrons, result in the special features pertinent to the broad intensity/zenith-angle curves for high altitudes."

1835. Cloud-Chamber and Counter Studies of Cosmic Rays Underground.—V. C. Wilson & D. J. Hughes. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, pp. 161–171.)

Authors' abstract :—" A counter-controlled cloud chamber and two counter-coincidence sets were used to study the nature of the cosmic rays observable underground. The experiments were performed in a copper mine at depths of 71, 141, 582 and 657 metres water equivalent. The data are easily interpreted, if one assumes that, underground, the primary rays are mesotrons and that the soft rays and showers are electronic secondaries produced by the penetrating mesotrons."

1836. The Origin of Cosmic Rays.—R. Millikan, H. Neher, & W. Pickering. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, p. 140 : abstract only.)

1837. Preliminary Energy Distribution Curve of Cosmic Rays.—L. Katz, R. V. Adams, & W. Deeds. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, p. 140 : abstract only.)

1838. The Specific Primary Ionisation of Cosmic Rays in Helium.—W. E. Hazen. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, pp. 107–110).

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

1839. Lightning Risks [Discussion at I.E.E. of Paper on New Recommendations by B.S.I. for Protection of Steel-Framed and Ferro-Concrete Buildings].—J. F. Shipley. (*Elec. Review*, 14th May 1943, Vol. 132, pp. 659–660.)

1840. Thunderstorm Experiences and Lightning-Protector Problems in Electricity Supply Systems [Symposium].—Th. Zambetti & others. (*Bull. de l'Assoc. Suisse des Élec.*, 24th March 1943, Vol. 34, No. 6, pp. 129–138 : in German.)

1841. The Coordination of the Insulation in High-Voltage Installations [with Data from Various Sources on Switching & Lightning (Indirect & Direct) Surges, Flash-Over Potentials of Insulators in Air, etc.].—S. Rump. (*Bull. de l'Assoc. Suisse des Élec.*, 10th Feb. 1943, Vol. 34, No. 3, pp. 61–75 : in German.) With 83 literature references.

1842. An Improved Cosmic-Ray Radio Sonde.—W. H. Pickering. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, p. 140.) Abstract only.

PROPERTIES OF CIRCUITS

1843. The Magnetic Fundamental Oscillation of the Cylindrical Cavity with Circular Cross Section.—Borgnis. (*See* 1818.)

1844. Transformation Elements [Quarter-Wavelength Parallel-Wire or Concentric Lines] with Lowest " Ballast " on the Oscillating Field Energy.—W. Dällenbach. (*Hochf:tech. u. Elek:akus.*, Feb. 1943, Vol. 61, No. 2, pp. 53–56.)

From the Julius Pintsch laboratories. " In the following communication a characteristic impedance W_a is matched with a characteristic impedance W_e through n transformation elements of wavelength $\lambda/4$, and the characteristic impedances $W_1, W_2 \ldots W_n$ of the n elements are so chosen that a number q representing the ballast action on the oscillating field energy assumes a minimum value $q_{\min}$. That is the case when the characteristic impedances $W_1, W_2 \ldots W_n$ form a geometrical series. The value $q_{\min}$ depends not only on the ratio W_a/W_e but also on the number n ; in the region $W_a/W_e = 1$ to about 25 it takes on the absolute smallest value when n is unity (that is, with only one transformation element), while in the range $W_a/W_e =$ about 25 to about 360 this occurs when $n = 2$, that is with only two elements."

The general expression for $q_{\min}$ is given in eqn. 48 or in a more convenient form in eqn. 50, namely $q_{\min} = (n/4) . \mathfrak{Cof}\, [(1/2n) . \log_e(W_a/W_e)]$, where the German lettering represents the hyperbolic cosine. Fig. 3 shows $q_{\min}$ as a function of W_a/W_e (this ratio is plotted on a logarithmic scale, from 1 to 10^6) for $n = 1 \ldots 6$. The derivation of q, the figure representing the " ballast " on the oscillating field energy along a homogeneous, loss-free line, is given on pp. 54–55 : for a finite length of line $\xi - \xi_1$ ($\xi = 2\pi . x/\lambda$, where x, in centimetres, is the space coordinate along the line) q is given by eqn. 28, namely

$$q = \{(\xi - \xi_1)/2\pi\} . \{(Z_1/W + W/\bar{Z}_1)/(1 + Z_1/\bar{Z}_1)\}.$$

1845. An Analysis of Radio-Frequency Transmission Lines.—G. B. Hoadley. (*Communications*, Feb. 1943, pp. 22, 24–26, 28, 50 and 52.)

The fundamental concept developed can be described in two basic theories : A—Any load on a loss-less transmission line may be replaced by a pure-resistance load on the end of an extension of the line, the virtual load : and B—The equivalent parallel resistance looking into a loss-less line towards the load varies sinusoidally as the distance from the load, and is biased so that it is always positive.

1846. NOMOGRAM FOR THE INDUCTANCE OF A CIRCULAR RING.—T. S. E. Thomas. (*Communications*, Jan. 1943, Vol. 23, No. 1, p. 55.)

1847. "THE INDUCTANCE AUTHORITY" [Book Review].—E. M. Shiepe. (*Communications*, Feb. 1943, Vol. 23, No. 2, p. 42.) With 38 inductance charts, etc.

1848. DESIGN OF ELECTRONIC REACTANCE NETWORKS.—H. A. Ross & B. Sandel. (*A.W.A. Tech. Review*, Feb. 1943, Vol. 6, No. 2, pp. 59–71.)

The importance of reactance valves in the control of oscillator-frequency in the fields of frequency-modulation, automatic frequency-control, etc., is indicated and reactance-valve design is discussed in relation to such problems. Expressions are derived to determine the value of resistance and reactance associated with a reactance valve, in terms of mutual-conductance change in that valve with respect to frequency-variation. Special features in relation to circuit design are pointed out, and limitations of the method are examined. Experimental verification of derived equations is supplied.

1849. REACTANCES WITH NEGATIVE INDUCTIVE OR CAPACITIVE RESISTANCE CHARACTERISTICS: NEGATIVE INDUCTANCES AND CAPACITANCES. —F. Vilbig. (*Bull. de l'Assoc. Suisse des Élec.*, 24th Feb. 1943, Vol. 34, No. 4, pp. 101–103: in German.) Long summary of paper dealt with in 2928 of 1940.

1850. GRAPHICAL TREATMENT OF NON-LINEAR CIRCUITS.—P. I. Wold. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, p. 218.)

Abstract of paper to American Physical Society. "Graphical methods of treatment will be presented which avoid approximations and permit the ready plotting of the current characteristics of any branch in simple networks."

1851. A METHOD OF DEMONSTRATING THE ACTION OF THE MULTIVIBRATOR [Circuit made to Oscillate at so Low a Frequency that Normal D.C. Meters can be used in Anode & Grid Circuits to indicate Variations of Voltage & Current].—B. Hallett. (*Electronic Eng:g*, April 1943, Vol. 15, No. 182, pp. 476–479.)

1852. ALARM AND COMPARISON CIRCUITS FOR REFERENCE - FREQUENCY EQUIPMENT. — Dennis. (*See* 1925.)

1853. THE SYNCHRONISATION OF OSCILLATORS: PART I [the Direct Synchronisation of Feedback Oscillators].—D. G. Tucker. (*Electronic Eng:g*, March 1943, pp. 412–418.)

1854. THE SYNCHRONISATION OF OSCILLATORS: PART II [the "Phase-Shift" R.C.-Tuned Oscillator: R.C. Oscillator of the Muirhead-Wigan type: the Beat-Tone Oscillator: the Bridge-Stabilised Oscillator].—D. G. Tucker. (*Electronic Eng:g*, April 1943, Vol. 15, No.182, pp. 457–461.)

1855. PHASE-SHIFT GENERATORS [Theory of the C.W. Amplifier with Retroaction: Derivation of Conditions for Generation of Sinusoidal Oscillations: Design of a Phase-Shift Note-Frequency Oscillator of High Frequency-Stability and Freedom from Harmonics].—G. Willoner & F. Tihelka. (*Hochf:tech. u. Elek:akus.*, Feb. 1943, Vol. 61, No. 2, pp. 48–51.)

For a previous paper *see* 2026 of 1942. The actual oscillator constructed on the basis of the theory given in section II 1–4 covers a frequency band of 20 c/s to 20 kc/s: it has a maximum output of 700 mw, with a non-linear-distortion factor not exceeding 1% over that part of the range from 30 c/s to 15 kc/s. Over the whole range the departure of the output voltage never exceeds ±1 db, referred to the value at 800 c/s. The output impedance is designed for 20 or 200 ohms, its fluctuation remaining always within ±10%. As a test of frequency stability the frequency was measured at 20 c/s and the mains voltage then changed by 30%: the resulting frequency variation was less than 0.1 c/s.

The oscillator was made up of three parts—the generator, the "control organ" (*see* later), and the output amplifier. The generator consisted of a two-stage amplifier back-coupled through a four-terminal network according to the theory of section II 4. Since a phase-pure amplification independent of frequency and free from harmonics was required, the only possible circuit for such a wide band of frequencies was that of a negative-feedback amplifier (Fig. 6). Pentodes were used in both stages, and the negative-feedback voltage taken off the amplifier output was led back to the cathode circuit of the input stage. The retroaction network was of the resistance–capacitance type seen in Fig. 5, with three separate resistances controlled by a range switch for the three frequency ranges 20–200 c/s, 200–2000 c/s, and 2000–20 000 c/s: the fine adjustment was carried out by a rotating condenser. Since, by eqn. 9, the capacitance bears a reciprocal linear relation to the frequency, a double rotating condenser of ordinary design could cover a frequency band of 1 : 10 with suitable overlapping.

The "control organ" was based on the theory of section II 4, which showed that a special control of the amplification is necessary in order to pass from the building-up régime to a stationary régime. The currents and voltages in the generator are linked only by linear relations, so that the self-excited oscillations would keep on increasing exponentially: to prevent this, an amplitude-limiting device is necessary, such as would be provided by a non-linearity of the amplification. Since the generator takes the form of a negative-feedback amplifier, the only available way of controlling its amplification is by varying the degree of negative feedback: the dividing-ratio of the voltage-feedback potentiometer must be made dependent on amplitude. This is accomplished with the help of a limiter valve, whose internal resistance lies in parallel with the resistance of the lower branch of the voltage-divider and is controlled by the rectified output voltage: in its unbiased state this valve must have a very low internal resistance, and therefore takes the form of an "impedance" valve, preferably a pentode connected in the negative (voltage) feedback mode.

The circuit is arranged so that the regulation during the building-up process continues until the amplification reaches the value 3, which is the condition for the stationary régime (eqn. 10).

The requirements of the output amplifier are merely those of a high-quality output stage—linear frequency-characteristic, freedom from harmonics, and an output impedance independent of frequency: how these properties are obtained in the actual design, by the use of strong negative feedback, is described in section III 3.

1856. STABILISED OSCILLATOR [derived from Shunt-Feed Tuned-Plate Oscillator with Several Additional Features including Use of Feed-back Stabilising Circuit: includes Diode Rectifier with Delayed Biasing Voltage for Amplitude Limitation].—(*Electronics*, Feb. 1943, Vol. 16, No. 2, pp. 130–132.) Due to F. E. Terman.

1857. TRANSITRON OSCILLATORS.—E. A. Dedman. (*Wireless World*, May 1943, Vol. 49, No. 5, p. 152.) *See* 1400 of May.

1858. TUNED CIRCUITS AT AUDIO-FREQUENCIES [Radio Data Charts: No. 7].—J. McG. Sowerby. (*Wireless World*, May 1943, Vol. 49, No. 5, pp. 132–133.)

1859. "ELECTROMECHANICAL TRANSDUCERS AND WAVE FILTERS" [Book Review].—W. P. Mason. (*Communications*, Jan. 1943, Vol. 23, No. 1, p. 48.) For a previous review *see* 353 of February.

1860. APPLICATION OF THE LAPLACIAN TRANSFORM TO THE STUDY OF ELECTRICAL CIRCUITS [such as the Problem of the Stability of a Negative-Feedback Amplifier: Relation to the Nyquist Criterion; etc.].—A. G. Clavier. (*Rev. Gén. de l'Élec.*, Oct. 1942, Vol. 51, No. 10, p. 447 onwards.)

1861. THE COMPENSATION OF RANDOM FLUCTUATIONS IN A D.C. BRIDGE AMPLIFIER [Abstract of Paper to American Physical Society].—J. C. M. Brentano & E. R. Schleiger. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, p. 218.)

Authors' abstract:—"In measuring small potential differences or currents it is sometimes necessary to use d.c. amplification. Instances are the measurement of weak ionisation currents of photoelectric phenomena involving delay actions where a.c. amplification cannot readily be adopted. A compensated symmetrical bridge using two thermionic tubes has the advantage over single-tube circuits that it is easy to control; with it all disturbances and fluctuations can be eliminated very effectively, except fluctuations due to random changes of filament emission which actually set the limit to the ultimate amplification obtainable. In a bridge (Brit. Pat. 526 869) comprising two vacuum tubes, essentially of tetrode type, the intermediate grids acting as control grids, compensation for such fluctuations can be obtained by a system of cross connections between the inner grids and plates by which an emission fluctuation of one filament produces similar changes in the symmetrical halves of the bridge. The unsteadiness level can thus be reduced by a factor of thirty."

1862. HIGH-FREQUENCY RESPONSE OF VIDEO AMPLIFIERS.—Preisman. (*See* 1912.)

1863. PERFORMANCE OF RESISTANCE-CAPACITY COUPLED AMPLIFIERS [Data Sheets 45 & 46].—(*Electronic Eng:g*, March 1943, pp. 421–424.)

1864. CHOKE-COUPLED AMPLIFIERS AT AUDIO-FREQUENCIES [Data Sheets 47, 48, & 49].—(*Electronic Eng:g*, April 1943, Vol. 15, No. 182, pp. 465–468.)

TRANSMISSION

1865. ON THE PRINCIPLES OF VELOCITY-MODULATED VALVES, GENERATORS OF ULTRA-HIGH-FREQUENCY ELECTROMAGNETIC OSCILLATIONS [Survey, with 16 Diagrams].—R. Warnecke. (*Bull. de la Soc. Franç. des Élec.*, June 1942, Series 6, Vol. 2, No. 16, p. 237 onwards.)

1866. THE CYLINDRICAL RETARDING FIELD [as in the "Resotank" Oscillator].—W. Kleinsteuber. (*Hochf:tech. u. Elek:akus.*, Feb. 1943, Vol. 61, No. 2, pp. 38–47.)

From the Julius Pintsch laboratories. "Experiment shows that for wavelengths of the order of 10 to 20 cm the oscillation condition in a cylindrical retarding field is much more favourable than in a plane retarding field. An explanation of this fact has not been provided until now, although we have already made use of the results to be obtained in the present paper, in several previous publications (2258 of 1938: 1374 of 1940: 2389 of 1941). The present paper completes the series of investigations on the retarding-field Resotank covered in the above publications in conjunction with Kleinsteuber's paper dealt with in 1861 of 1941.

"Among many attempts to obtain a general explanation of oscillation excitation in the retarding field, the work of Bakker & de Vries (1390 of 1935) is to be mentioned. In this paper the writers derive the relation between the alternating current of a plane 'retarding-field diode' and the alternating voltage. Their result cannot be applied without modification to the cylindrical field. A first approximation is given on p. 5 of the present writer's paper last referred to above: the general extension to the cylindrical field follows in the present paper. The difficulty consists in obtaining not only a solution for any selection of voltages and geometrical dimensions but also a picture of the complete field, without allowing the work of calculation to become impossibly laborious."

The treatment assumes a small amplitude of oscillation, and other simplifying assumptions (pp. 38–39) are made which are justified by the good agreement between the calculated results and experiment and by the determination of the electron paths as given in the Gundlach–Kleinsteuber paper cited above. The results for the plane field are to a large extent reproduced, but a difference exists in the dependence of the excitation value on a second parameter M (eqns. 11 and 8^4) which does not occur for the plane field. "This dependence is not very great, so that for the cylindrical field a simple approximate formula can be given which has already been used in the earlier papers and is here determined accurately for the first time. On the assumption of this approximation the case of a finite amplitude can also be dealt with roughly [section VI]. The results of this extension to a finite amplitude in the cylindrical field have already been given in the Allerding–Dällenbach–Kleinsteuber paper already referred to."

1867. F.M. COMMUNICATION SYSTEMS [Definitions of Frequency Modulation and Phase Modulation: Signal/Interference Characteristics: Propagation Characteristics and Applications].—D. A. Bell. (*Wireless Engineer*, May 1943, Vol. 20, pp. 233–242.)

The paper is a summary of the known data on the subject, with a restricted bibliography containing references likely to be most useful for the reader who has not specialised in this subject.

1868. A CRYSTAL-CONTROLLED TRANSMITTER FOR WERS [War Emergency Radio Service: Simple Exciter Circuit also used as Frequency Standard].—F. E. Brooks. (*QST*, April 1943, Vol. 27, No. 4, pp. 36–38.)

An account of the functions of WERS is given in the same number of this journal (*see* also, for example, 222 of January, 593/4 of February, and 905/8 of March: also 1993, below).

1869. MODES OF VIBRATION AND DESIGN OF V-CUT QUARTZ PLATES FOR MEDIUM BROADCAST FREQUENCIES.—Benson. (*See* 1930.)

1870. THE SYNCHRONISATION OF OSCILLATORS.—Tucker. (*See* 1853 & 1854.)

RECEPTION

1871. TUNING INDICATORS AND CIRCUITS FOR FREQUENCY-MODULATION RECEIVERS.—J. A. Rodgers. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, pp. 89–93.)

"Frequency modulation provides good reception, but requires operation at resonance. The circuits described in these pages are applicable to standard receivers and provide effective means for accurate tuning. Some of these circuits include additional diodes, triodes, and combinations of diodes and triodes to produce sharp determination of the discriminator cross-over point. A novel tuning eye employing two grids is suggested for a simplified tuning indicator."

1872. HETERODYNING PHENOMENA IN THE RECEPTION OF FREQUENCY-MODULATED WAVES [Calculation of L.F. Current at Receiver Output: Vectorial Representation of Superposition of F.M. Oscillation and Unmodulated Oscillation of Adjacent Frequency & Arbitrary Phase Relation: etc.].—R. M. Wundt & E. G. Hoffmann. (*Lorenz-Berichte*, Dec. 1941, No. 3/4, p. 63 onwards.) With 16 diagrams.

1873. FREQUENCY MODULATION: V—DEMODULATION: THEORY OF THE DISCRIMINATOR.—C. Tibbs. (*Wireless World*, May 1943, Vol. 49, No. 5, pp. 140–143.)

In the fifth article of the series a graphical method of demonstrating the effect of circuit constants is used to explain the principles underlying the design of the discriminator circuit now in general use. *See* also 1061 of April, 1412 of May, and 1676 of June.

1874. F. M. COMMUNICATION SYSTEMS [Definitions of Frequency Modulation and Phase Modulation: Signal/Interference Characteristics: Propagation Characteristics and Applications].—Bell. (*See* 1867.)

1875. AIRCRAFT-ENGINE RADIO SHIELDING [to prevent Interference].—Randolph. (*See* 1817 of June.)

1876. INTERFERENCE FROM POWER LINES [Its Nature and Extent].—J. S. Forrest. (*Wireless World*, May 1943, Vol. 49, No. 5, pp. 128–131.)

1877. SUPERHETERODYNE TRACKING CHARTS: III.—A. L. Green. (*A.W.A. Tech. Review*, Feb. 1943, Vol. 6, No. 2, pp. 97–124.)

Author's summary:—"In communication receivers and in bandspread broadcast receivers the problem sometimes arises of reducing the frequency ratio of the signal circuits to a value less than that for which the ganged tuning condenser was originally designed. It is common practice to achieve this result by inserting a fixed padding capacity in series with the tuning condenser, that is to say by converting the signal circuit to the type customarily used in a superheterodyne oscillator. The present paper introduces the analytical conception of a virtual pilot circuit, with which are tracked both the padded signal circuit and the padded oscillator circuit in a superheterodyne receiver. An advantage of this method of approach to the problem is that the components in both the signal and the oscillator circuits can readily be designed according to superheterodyne tracking charts of the type previously described." *See* also 87 & 1669 of 1942.

1878. FIRE PREVENTION REQUIREMENTS FOR ELECTRIC RADIOS REVISED [Reprint from American Standards Association].—H. B. Smith. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, pp. liv, lvi, lviii, & lx.)

1879. A SIPHON TAPE RECORDER FOR RADIO-TELEGRAPH SIGNALS [Home-Made Unit with Play-Back System].—J. P. Gilliam. (*QST*, April 1943, Vol. 27, No. 4, pp. 18–23 and 82..94.)

AERIALS AND AERIAL SYSTEMS

1880. A CIRCULAR AERIAL FOR U.H.F. [Uniform Radiation in All Horizontal Directions].—M. W. Scheldorf. (*Electronic Eng:g*, March 1943, pp. 432–433.) Based on the article in *QST* dealt with in 762 of March.

1881. FREQUENCY-MODULATION CIRCULAR ANTENNA.—M. W. Scheldorf. (*Gen. Elec. Review*, March 1943, Vol. 46, No. 3, pp. 163–170.)

A short description is given of various types of aerial arrays giving a roughly circular polar diagram with horizontal polarisation. The final design arrived at may be termed a "folded loop aerial." It consists of a single-turn loop, tuned by a parallel-plate condenser at the end of the loop remote from the input terminals, the "folded" short-circuited turn being coaxial with the primary turn and connected to the plates of the condenser. The end of the folded turn furthest from the condenser (*i.e.* nearest the input terminals of the aerial) is at earth potential, so that the aerial can be supported directly on a metal mast at this point. In an experimental set-up for the frequency-modulation band 42–50 Mc/s the radiating elements consisted of standard steel tubing formed into circles 33 inches in diameter. The rates of change of resistance and reactance with frequency are too great for the design to be useful for television but the author suggests its suitability in frequency-modulation systems. The polar diagram is essentially the same as that of a horizontal loop, that is a circle in the horizontal and a figure of eight in the vertical planes. The polar diagram in the vertical plane results in low mutual impedance between elements mounted vertically above one another to form an array, also the design lends itself to use on sites where the aerial has to be mounted above metal surfaces such as a locomotive or metal-roofed car. For earlier papers *see* 762 of March and 1091 of April.

1882. TRANSMITTING ANTENNA DE-ICER [Electric Heat used to Prevent Formation of Ice on Transmitting Antenna high up on Top of Building: Antenna consists of Two Sets of Hollow Cross Arms in "Turnstile" Fashion, with Electric Heating Unit built into Each].—(*Electronics*, Feb. 1943, p. 116.) *Cf.* 414 of February.

1883. TRANSFORMATION ELEMENTS [Quarter-Wavelength Parallel-Wire or Concentric Lines] WITH LOWEST "BALLAST" ON THE OSCILLATING FIELD ENERGY.—Dällenbach. (*See* 1844.)

1884. REFLECTIONS FROM UNMATCHED FEEDER TERMINALS [Editorial].—G.W.O.H. (*Wireless Engineer*, May 1943, Vol. 20, pp. 215–218.)

In view of the increasing interest of this subject a simple graphical method is given for representing the conditions that exist under various circumstances and for solving the design problems that arise.

1885. RECIPROCITY OF WAVE PROPAGATION THROUGH MAGNETICALLY DOUBLY-REFRACTING MEDIA.—G. Goubau. (*Hochf:tech. u. Elek:akus.*, Dec. 1942, Vol. 60, No. 6, pp. 155–160.)

"All hitherto known reciprocity theorems (Lorentz, in 1895–1896: Sommerfeld & Pfrang, 1925 & 1931: Carson, 1924 & 1929) fail when applied to the ionosphere, since they assume media which are isotropic or whose material constants are represented by symmetrical tensors; whereas the ionosphere, being a magnetically doubly-refracting medium, possesses an asymmetrical tensor of the dielectric constant. In the following work it will now be investigated whether, and under what conditions, a reciprocity exists in the wave propagation through magnetically doubly-refracting media."

It is shown that whether reciprocity does or does not occur depends on the nature of the radiators, and further, that to every radiator there is a reciprocal radiator—that is, a radiator such that its field together with the field of the other radiator fulfils the Lorentz reciprocity theorem in its integral representation (that is,

$$\int_F \{[\mathfrak{E}_1 \cdot \mathfrak{H}_2] - [\mathfrak{E}_2 \cdot \mathfrak{H}_1]\}\, dF = 0).$$

Two such aerials behave as a normal four-terminal network (*cf.* Dällenbach's derivation of the reciprocity law for $2n$-pole networks, 3260 of 1942). In certain circumstances the reciprocal condition may be such that no mutual interchange takes place ("null-reciprocity"), but this is not generally the case, as is seen in the example discussed in section III.

1886. REMARKS ON THE ABSORPTION SURFACES OF DIRECTIVE AERIALS [including Adcock-Type Transmitting Aerials].—K. Fränz. (*Hochf:tech. u. Elek:akus.*, Feb. 1943, Vol. 61, No. 2, pp. 51–53.)

From the Telefunken laboratories. "It has often been attempted to formulate a law of some kind stating that the absorption surface of an otherwise arbitrary aerial cannot be appreciably greater than its geometrical surface, unless its absorption surface is large compared with the square of the wavelength. The aerials hitherto used in practice no doubt satisfy this assertion, and quite analogous relations are known in other branches of Physics, for example in the theory of the resolving power of optical instruments and the closely associated considerations of the Heisenberg uncertainty relations. In contradiction to the above opinion, I have shown that an arbitrarily small aerial can have an arbitrarily large absorption surface (2249 of 1940 and 2699 of 1941: a note at the end mentions that in both these earlier papers the gain of a row of $\lambda/2$ spaced dipoles, alternately fed in opposed phase, was erroneously given twice as large as it should have been); if, for a given aerial surface, the sharpness of beaming is increased more and more, the production of heat in the aerial and its tuning components makes the efficiency decrease more rapidly than the gain increases. This, as I see it, is the reason why no use is made in practice of the theoretically existing possibility of obtaining an arbitrarily sharp beam effect with small aerials. Thus the question whether aerials can be realised with large absorption surfaces and small geometrical dimensions depends on the accident of the technically attainable values of the ohmic resistance of the conductor and the loss angle of the dielectric, and not on a fundamental and easily comprehended law. The question is often raised, in discussing the subject, whether hitherto unrecognised relations may not exist which would exclude the unacceptable possibility of the large absorption surface; and in particular whether the current distributions hitherto taken as examples, which lead to high gains with arbitrarily small aerials, can actually be obtained in practice. That they can be so translated into fact will be shown in the present note; we shall show, further, that the energetic efficiency must decrease more quickly than the gain increases. Finally we shall deal with the question of the energy dispersed by an aerial, and show that in general, that is with the exception of the elementary dipole, the power dispersed by a receiving aerial has no connection with the power apparently consumed in the active resistance of the aerial. It follows from this that a receiving aerial cannot have assigned to it a dispersion surface, in analogy to its absorption surface, as is sometimes attempted.

"The diagrams given by me are derived from the repeatedly counter-phase combination of dipoles somewhat after the following fashion: if, as in Fig. 1, two parallel closely adjacent dipoles are connected in counter-phase, there is formed from the circular diagrams a figure-of-eight diagram in the equatorial plane: this represents an increase of the absorption surface compared with that of a dipole. The new diagram $\sin^2\delta \cos\phi$ occurs independently of how close together the dipoles are brought; and the gain, and consequently the increase in absorption surface, is given by $g^{-1} = (3/8\pi)\int \sin^4\delta \, \cos^2\phi \, d\Omega = 2/5$. Since this aerial is much employed in practice—it is the Adcock d.f. aerial—it must be admitted that the corresponding current distribution is a possible one to obtain. Now I have no possible doubt that it is also practicable to connect two Adcock aerials in counter-phase at a distance small compared with the wavelength, and to enforce the desired counter-phase current distribution. By an n-times repetition of the process the diagram $\cos^n \phi$ occurs in the equatorial plane, possessing an absorption surface increasing to any extent with n."

The writer then argues that with aerials of sufficient symmetry it is possible to calculate strictly the conditions of feed and the necessary current distributions without explicitly calculating the radiation coupling, and takes as an example the case of the Adcock transmitting aerial. He then deals with a system of $2n$ dipoles disposed at the corners of a regular figure with that number of corners, the polarisation being perpendicular to the plane of the figure. All the dipoles have equally long feeders, connected at their common point with alternating polarity: for $n = 1$ the system becomes the Adcock transmitting aerial just considered. He thus obtains (p. 52, r-h column) the feeding conditions, current distribution, and gain for an aerial arbitrarily small compared with the wavelength, and shows that the gain, and consequently the absorption surface, can be made arbitrarily large. "Radiators of the symmetry in question are often considered in Physics as multipoles. For example it is known that atoms can emit not only the usual dipole radiation but also multipole radiation; for instance the green auroral line is a quadripole radiation. To the extremely small radiation resistance of the multipole in wireless telegraphy there corresponds in atomic theory the extremely small emission-probability of multipole radiation. In any case, the appropriate current distributions also occur of their own accord in nature."

The writer then proceeds to show that for an arbitrarily augmented beam-action of an aerial of finite length the efficiency must decrease more rapidly than the gain increases: for this purpose he first calculates that current distribution along a straight wire of length $2l$ which, for a given amount of heat produced in the wire, will generate a maximum field strength at a receiving point in the equatorial plane of the wire. "The solution of our maximum problem is that for a given heat production in the aerial wire a uniform current distribution gives the greatest received power"; if not merely the heat in the wire is given but the sum of the heat and the radiated power, the received power can only be smaller, so that although for a given size of aerial an arbitrarily large gain can be obtained, it is only possible to reach a finite value of the product of gain and efficiency: this proves the point in question.

The final section deals with the view occasionally encountered that a given receiving aerial can attain an "efficiency" only of 50%, in the following sense: the secondary field due to the currents flowing in a receiving aerial transports a power which, in the case of the highest removal of energy from the aerial (namely in the case of perfect matching), is exactly equal to this maximum received power. For elementary dipoles this has actually been demonstrated by Rüdenberg (in 1918). Accordingly there is a disposition to attribute to every aerial an active surface twice as large as the absorption surface and made up equally of an absorption surface and a dispersing surface. It is true that, for an ordinary dipole with ohmic internal resistance, with perfect matching as much heat is produced in the internal resistance as is taken up by the load: for a receiving aerial, on the other hand, the power consumed in its internal resistance has no connection with the power dispersed by the aerial (Heilmann, 3333 of 1941). The writer illustrates this by the example of a load resistance connected in the middle of a twice-$\lambda/2$ dipole in free space: if the load resistance is made infinitely great, the aerial becomes broken at its mid-point, no current flows in its internal resistance of some thousands of ohms, and the power apparently consumed in it is zero. But the dispersed power is by no means zero, for along the two separated halves currents still flow, with current antinodes at their mid-points. Thus considerations of "efficiencies" of 50% are fallacious: for an aerial either transmitting or receiving the efficiency should be derived uniformly from a comparison of the power converted into heat with the power derived from the e.m.f. The same figure is naturally arrived at, whether the e.m.f. is induced in the aerial circuit by a transmitting valve or by a distant field. It is known that this figure, and not one derived from the dispersed power, is the determining factor for the optimum design of receiving circuits (Fränz, 3126 of 1939).

1887. AERIAL CHARACTERISTICS: DISCUSSION [Addition to Author's Reply: Direct-Reading Curves of Aerial Impedance of Vertical Antennas].—N. Wells. (*Journ. I.E.E.*, Part III, March 1943, Vol. 90, No. 9, pp. 24–25.) For the original paper *see* 3585 of 1942.

1888. SHORT-WAVE DIPOLE AERIALS.—N. Wells. (*Wireless Engineer*, May 1943, Vol. 20, pp. 219–232.)

The paper consists of a series of notes on the use of dipole aerials for short-wave radio communication, based partly on theory and partly on experiment. The dimensions and coupling for a single dipole and the use of twin dipoles in line to obtain greater directivity than is given by a single horizontal dipole are discussed. Diagrams are given showing the field strength in the vertical plane for different heights of a horizontal dipole for two different conditions of earth. Similar diagrams are also given for two-tier stacked dipoles. The respective advantages of horizontal and vertical dipoles and the arrangement and dimensions of balanced feeder lines, both for transmission and reception, are discussed. Line termination is examined in some detail and a practical technique is given for obtaining a satisfactory termination, using a stub. Appendices deal with the limits of multi-wave aerials and the effects of ground upon horizontal and upon vertical polarisation. In connection with the former *see* the author's paper on "Aerial Characteristics", 3585 of 1942 and 1887, above.

1889. THE INPUT RESISTANCE OF DIPOLE AERIALS. —H. Kaufmann. (*Hochf:tech. u. Elek:akus.*, Dec. 1942, Vol. 60, No. 6, pp. 160–168.)

"The application of line theory to aerials allows the input resistance and the current distribution to be described much more accurately than might be expected in view of the somewhat unreliable assumptions as to the existence of a uniform characteristic impedance and of a damping due to the radiation. Apart from the fact that by the line theory it is at present impossible to explain the 'shortening' effect quite satisfactorily [*see* also bottom of p. 161], it is only in the determination of the damping that certain difficulties arise. For practical application it is true that a similar difficulty may present itself in connection with the characteristic impedance (*cf.* section 2a), but this need not affect the development of the theory if only the length of the aerial (more accurately, its length referred to its working wavelength) and its characteristic impedance are taken as its characterising magnitudes. A linear aerial is thus fully determined as to its dimensions, and only the damping to be attributed to this aerial remains to be found. Fundamentally what one does is to calculate by line theory the power consumed by the equivalent line with the (at present) unknown damping, and then to equate this with the radiated power, thus obtaining an equation to yield the equivalent-line damping. If one uses, for the radiated power, the expression obtained by van der Pol on the assumption of a sinusoidal distribution of current along the aerial (*i.e.* an undamped line), then one is employing for this method two mutually contradictory assumptions. Since, however, in general one has to deal with aerials with such large characteristic impedances that their damping can be regarded as small, the difference between the current distributions along the damped and the undamped lines is not actually serious: the current-minimum for longer aerials merely shows a finite value differing from zero.

"With large values of line damping, occurring with small characteristic impedances, the van der Pol radiation resistance obviously cannot, however, be employed directly for the calculation of damping. Brückmann has therefore suggested (*Telefunken-Mitteilungen*, No. 83, 1940, p. 20) that van der Pol's expression for the radiation resistance should be regarded only as the first approximation of an iterative process in which the radiation resistance would be repeatedly calculated, taking into account the damping (and therewith the current distribution) obtained by each preceding approximation. In the present paper the writer uses, in place of this suggested process, another, semi-graphical method: the radiation resistance R_s is calculated once and for all as a function of the quantities which determine the current distribution, namely $a = \alpha l$ and $b = \beta l$, where α is the impedance-angle constant, β the damping factor, and l the length of the equivalent line. On the other hand the equating of the radiated power of the aerial with the power consumption of the radiation-damped equivalent line yields the radiation resistance as a function of the characteristic impedance Z and the damping b. The graphical representation of the two above-named functions gives the desired relation between the damping b on the one hand and Z and αl (based on dimensions and wavelength) on the other". A footnote mentions that such a method has already been used by Wiechowski (2339 of 1939) but that he gives the calculated radiation resistance in a difficult form for working out, and without showing its derivation: moreover, his diagrams do not cover the case of the small characteristic impedances which have recently assumed such importance.

The writer begins by calculating in section 11 the transmission constants of the line of length l equivalent to the symmetrical linear aerial of length $2l$. Brückmann (*loc. cit.*) has discussed the question whether the total radiation damping should be described as resistance damping (as, for instance, Siegel & Labus have done) or whether it should be divided equally into resistance damping and leakance loss, which would imply an equally large radiation damping for the electric and magnetic fields. This latter plausible hypothesis (which is supported by Brückmann's measurements) is adopted in the present treatment, and simplifies the subsequent calculations.

Author's summary :—" The treatment of the input resistance of aerials with the help of line theory requires a knowledge of the transmission constants, and here the calculation of the damping, in particular, presents a certain difficulty. This calculation is carried through for dipole aerials and presented in the form of diagrams : the serviceability of approximations is tested. By these means the input resistance is first calculated at the resonance points, and then its behaviour in the neighbourhood of these points is considered, whereby in particular the differences between simple [half wave] and double dipoles are brought out." A specially important difference (p. 165, l-h column) is that the double dipole is particularly suitable for the design of an aerial to show a pre-determined input resistance ; for the input resistance of a double dipole can be influenced very strongly (in practice from 200 to 10 000 ohms) by the choice of its characteristic impedance (thickness of conductor), whereas that of a simple dipole can be varied only within comparatively narrow limits—in the case considered between about 73 and 60 ohms : *see* Figs. 5 and 6. For wide-band aerials the behaviour of the input resistance in the neighbourhood of the resonance point is of special importance (pp. 165–166) : here the double dipole displays its full superiority over the simple dipole only at low values of characteristic impedance, although even at comparatively high values, *e.g.* well above 600 ohms, it still shows a " relative deviation " p for a given de-tuning (*see* eqn. 24) which is 0.74 times smaller than that given by a simple dipole.

1890. A MATHEMATICAL THEORY OF LINEAR ARRAYS. — S. A. Schelkunoff. (*Bell S. Tech. Journ.*, Jan. 1943, Vol. 22, No. 1, pp. 80–107.)

A mathematical theory of linear antenna-arrays can be based upon a simple modification of the usual expression for the radiation-intensity of a system of radiating sources. The first step in this modification is closely analogous to the passage from the representation of instantaneous values of harmonically varying quantities by real numbers, to a symbolic representation of these quantities by complex numbers. The second step consists in a substitution which identifies the radiation-intensity with the norm of a polynomial in a complex variable. This mathematical device leads to a pictorial representation of the radiation-intensity.

The following theorems are established :—I. Every linear array with commensurable separations between the elements can be represented by a polynomial (of a complex variable) and every polynomial can be interpreted as a linear array. II. There exists a linear array with a space-factor equal to the product of the space-factors of any two linear arrays.

If the minimum separation between the elements does not exceed $\lambda/2$, it is theoretically possible to design a linear array with a space-factor given by an arbitrary function of the direction of radiation.

1891. A REPORT OF THE 1943 I.R.E. WINTER CONFERENCE [including C. E. Smith's Electromechanical Calculator for Aerial Patterns].—Winner. (*See* 2018.)

VALVES AND THERMIONICS

1892. THEORY OF THE MAGNETRON : PART III.—L. Brillouin. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, pp. 127–136.)

" The general theory of the magnetron tubes, as developed in a former paper (107 of 1942), showed that the magnetron should sustain oscillations in an outer circuit, when the frequency was nearly $\sqrt{2}$ times the Larmor's frequency ω_H. The present paper contains a more detailed study of the behaviour of a magnetron with one cylindrical anode when the radius a of the filament and the radius b of the anode are both taken into account. It is shown that the magnetron is able to sustain oscillations on the frequency $\omega = \omega_H (2 + 2a^4/b^4)^{\frac{1}{2}}$ which lies between $\sqrt{2}\,\omega_H$ and $2\omega_H$, according to the dimensions of the electrodes. The agreement of this theory with some interesting results obtained by Blewett & Ramo (676 of 1942) is shown, and the limiting case of the plane magnetron discussed." *See* also 1354 & 1681 of 1942.

1893. WATER-COOLED TRANSMITTING TUBES [Installation and Operation : with Particular Reference to Ultra-Short-Wave Valves].—K. C. Dewalt & W. J. Walker. (*Communications*, Jan. 1943, Vol. 23, No. 1, pp. 20–24.)

1894. FLUCTUATIONS IN SPACE-CHARGE-LIMITED CURRENTS.—D. A. Bell. (*Journ. I.E.E.*, Part III, Dec. 1942, Vol. 89, No. 8, pp. 207–212 : Discussion in Part III, March 1943, Vol. 90, No. 9, p. 36.)

Author's summary :—" The paper shows that the fluctuations in the anode-current of a space-charge-limited valve can be calculated, in a manner exactly similar to the calculation of the thermal-agitation noise in a metallic conductor, in terms of the electron transits. Corresponding values of the noise-ratio or smoothing-factor are derived ; they are found to be in agreement with experimental data from a variety of sources. The ratio is a function of $eV/k\theta$ (V is the anode voltage, θ the cathode temperature) and is only slightly dependent upon the ratio of anode diameter to cathode diameter of the valve."

1895. " PRINCIPLES OF ELECTRON TUBES " [Book Review].—H. J. Reich. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, p. 120.) For a previous review *see* 2569 of 1942.

DIRECTIONAL WIRELESS

1896. SUGGESTIONS FOR A THEORY OF THE COASTAL REFRACTION.—Grünberg. (*See* 1830.)

1897. REMARKS ON THE ABSORPTION SURFACES OF DIRECTIVE AERIALS [including Adcock-Type Transmitting Aerials].—Fränz. (*See* 1886.)

1898. AN ANALYSIS OF THE BELLINI–TOSI FIXED DIRECTION FINDER.—H. Pollack. (*Communications*, Jan. 1943, Vol. 23, No. 1, pp. 33–34 and 51.)

1899. "Principles of Aeronautical Radio Engineering."—P. C. Sandretto. (*Communications*, Feb. 1943, Vol. 23, No. 2, p. 42.)

ACOUSTICS AND AUDIO-FREQUENCIES

1900. Applications of the Throat Microphone [of Special Value at High Noise Levels].—J. Shawn. (*Communications*, Jan. 1943, Vol. 23, No. 1, pp. 11–12 and 26, 46.)

1901. Music in the Factory [Large Installation with Remote Control of One Section: Six Amplifiers each serving 30 Speakers].—(*Elec. Review*, 14th May 1943, Vol. 132, pp. 637–642.)

1902. The Comprehensive Assessment of Telephone Communication Efficiency.—J. R. Hughes. (*Journ. I.E.E.*, Part III, Dec. 1942, Vol. 89, No. 8, pp. 195–207.)

Author's summary :—" The introduction defines the problem under discussion and distinguishes between subjective, objective, and semi-objective tests. The author then considers subjective telephone tests in greater detail, and emphasises the importance of testing for 'fitness for purpose' under conditions similar to those of practical use. There follows a discussion of the application of the results of subjective tests to practical cases, in the course of which the arguments are put forward foi the statistical extension of the results of immediate-appreciation tests. An account is then given of the application of the statistical technique to immediate-appreciation tests, and the author concludes with some suggestions as to how the effects of speaking-end room-noise may be included in the statistical technique. A short bibliography is appended."

1903. Electro-Acoustics and Audiometry [Threshold of Audibility: Perception by the Aerotympanic Path: Bone Conduction: etc.].—P. Chavasse. (*Bull. de la Soc. Franç. des Élec.*, Sept. 1942, Series 6, Vol. 2, No. 19, p. 341 onwards.) With 17 diagrams.

1904. Method for the Microscopic Viewing of Magnetic Sound-Recordings.—H. Heidenwolf. (*Lorenz-Berichte*, Dec. 1941, No. 3/4, p. 119 onwards.) With 9 diagrams.

1905. Needle-Armature Pick-Up [Design giving Good Frequency Response and Low Amplitude Distortion].—G. A. Hay. (*Wireless World*, May 1943, Vol. 49, No. 5, pp. 137–139.)

1906. Choke-Coupled Amplifiers at Audio-Frequencies [Data Sheets 47–49].—(*Electronic Eng'g*, April 1943, Vol. 15, No. 182, pp. 465–468.)

1907. 4.5 Watt Amplifier with Tone Control [Two-Valve Amplifier with Selective-Feedback Tone Control].—(*Sci. Abstracts*, Sec. B, Jan. 1942, Vol. 45, No. 529, p. 25: from a *Radiotronics* article.)

1908. Frequency Compensation in Audio-Amplifiers [a 6J7-G Tone-Control Stage giving Bass Boost & Cut and Treble Boost & Cut, in Anode Circuit].—(*Sci. Abstracts*, Sec. B, Jan. 1942, Vol. 45, No. 529, pp. 25–26: from a *Radiotronics* article.)

1909. Tuned Circuits at Audio-Frequencies [Radio Data Charts: No. 7].—J. McG. Sowerby. (*Wireless World*, May 1943, Vol. 49, No. 5, pp. 132–133.)

1910. A Note on the Design of Iron-Cored Coils at Audio-Frequencies.—Ruby Payne-Scott. (*A.W.A. Tech. Review*, Feb. 1943, Vol. 6, No. 2, pp. 91–96.)

Author's summary :—It is shown that at any specified value of frequency and flux-density, the Q of a coil wound on a given core is a function only of the mass of copper in the winding, whatever the number of turns and gauge of wire used, and may hence be calculated from measurements made on any other coil wound on a similar core, provided the relative masses of copper used in the two coils are known. Also the frequency at which Q is a maximum is, for a given core and flux density, a function only of the mass of copper, and can similarly be derived from a knowledge of the position of Q_{max} for any other coil.

1911. A Note-Frequency Oscillator for a Range 20 c/s to 20 kc/s and a Maximum Output of 700 mW, on the Phase-Shift Generator Principle.—Willoner & Tihelka. (*See* 1855.)

PHOTOTELEGRAPHY AND TELEVISION

1912. High-Frequency Response of Video Amplifiers [Tellegen–Verbeck Method of determining Circuit Constants].—A. Preisman. (*Communications*, Jan. 1943, pp. 29, 32, and 49.) *See* also 1677 of June for previous instalment.

1913. The Focusing View-Finder Problem in Television Cameras.—G. L. Beers. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, pp. 100–106.) A summary was referred to in 825 of March.

1914. Mercury Lighting for Television Studios.—H. A. Breeding. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, pp. 106–112.) Summaries were dealt with in 827 of March and 1167 of April. The present paper gives the author's first initial correctly.

1915. "Television Standards and Practice" [Book Review].—D. G. Fink. (*Communications*, Feb. 1943, Vol. 23, No. 2, p. 42.)

1916. PHOTOELECTRIC ALLOYS OF ALKALI METALS.—Sommer. (*See* 1752 of June.)

MEASUREMENTS AND STANDARDS

1917. THE DIELECTRIC CONSTANT AND LOSS ANGLE OF DRY AND WET SAND FOR CENTIMETRIC WAVES [and the Special Measuring Technique].—Löb. (*See* 1821.)

1918. THE DESIGN OF ULTRA-SHORT-WAVE FIELD-STRENGTH MEASURING EQUIPMENT.—F. M. Colebrook & A. C. Gordon-Smith. (*Journ. I.E.E.*, Part III, March 1943, Vol. 90, No. 9, pp. 28–32.)

The paper describes the essential features of design and construction of field-strength measuring equipment for use at frequencies up to about 600 Mc/s, *i.e.* wavelengths down to about 50 cm. The equipment is of relatively narrow band-width (about 20 kc/s) and is primarily intended for the measurement of continuous-wave fields of the order of tens or hundreds of microvolts per metre. The paper is supplementary to a previous paper on the same subject (2029 of 1939) and is intended to bring the information in the previous paper up to date in respect of recent practical and theoretical developments. The main new features introduced at the highest frequencies are the use of a dipole aerial instead of a closed loop, and a tuned line for the signal-frequency closed circuit.

An appendix to the paper briefly outlines the theory of the transference of received radio-frequency energy from an aerial to a diode detector or other load by way of a closed tuned circuit.

1919. THE MEASUREMENT OF THE CHARACTERISTICS OF CONCENTRIC CABLES AT FREQUENCIES BETWEEN 1 AND 100 MEGACYCLES PER SECOND.—T. I. Jones. (*Journ. I.E.E.*, Part III, Dec. 1942, Vol. 89, No. 8, pp. 213–220.)

The paper discusses in detail the technique of the familiar open-end and closed-end method. It is illustrated by reference to the use of the N.P.L. dielectric test-set for these measurements, but is applicable to all measurements based on the connection of the cable as a shunt-circuit to a closed tuned circuit, with reactance - variation as the basis of the measurement.

The chief quantities to be measured are the characteristic impedance (Z_0), the attenuation constant (α) and the velocity constant ($\sqrt{LC}$ or β/ω). Z_0 can be measured in three ways, the simplest and most accurate of which is measurement of the effective capacitance of the cable at a frequency well below resonance, or of a short length at the lowest frequency in the range covered, and the deduction of the capacitance per unit length. Dividing this into the average value found for $\sqrt{LC}$ gives Z_0. The attenuation constant should be measured either at frequencies corresponding to an odd number of one-eighth wavelengths or with the cable in resonant conditions corresponding to a whole number of one-quarter wavelengths. The former gives the value directly. The latter requires a knowledge of Z_0. The velocity constant can be determined directly from the frequencies corresponding to the various multiple-quarter-wave resonances.

The paper is based on practical experience on this work and is intended as a guide for any who have occasion to make this type of measurement.

1920. ACCURACY CONSIDERATIONS IN STANDARD SIGNAL GENERATORS.—T. B. Minter. (*Communications*, Jan. 1943, Vol. 23, No. 1, pp. 7–10, 43–45, and 50.)

1921. THE MEASUREMENT OF "Q."—F. E. Planer. (*Electronic Eng:g*, April 1943, Vol. 15, No. 182, pp. 452–456.)

1922. A REPORT ON THE 1943 I.R.E. WINTER CONFERENCE [including G. H. Brown's Paper on Direct-Reading Wattmeters for Radio Frequencies].—Winner. (*See* 2018.)

1922 *bis*. THE USE OF COUNTER CIRCUITS IN FREQUENCY DIVIDERS: CORRECTION TO ABSTRACT 1725 OF JUNE, 1943.—E. L. Kent. (The 1940 abstract quoted should read 3961, not 3061: it deals with the paper by Bedford & Smith to which Kent refers.)

1923. A METHOD OF DEMONSTRATING THE ACTION OF THE MULTIVIBRATOR.—Hallett. (*See* 1851.)

1924. A FREQUENCY SYNTHESISER [Frequencies Harmonically Related to Sub-Multiple of Standard generated by Decade System: Short Abstract of Paper submitted to Institution of Electrical Engineers].—H. J. Finden. (*Elec. Review*, 14th May 1943, Vol. 132, p. 646.)

1925. ALARM AND COMPARISON CIRCUITS FOR REFERENCE-FREQUENCY EQUIPMENT.—F. R. Dennis. (*Bell Lab. Record*, Feb. 1943, Vol. 21, No. 6, pp. 149–152.)

Paper contains description of an alarm system which gives an indication when the difference between two basic 100 kc/s frequencies rises to 2 parts in ten million.

1926. A NEW FREQUENCY-COMPARISON CIRCUIT FOR THE CATHODE-RAY TUBE.—G. H. Rawcliffe. (*Journ. I.E.E.*, Part III, Dec. 1942, Vol. 89, No. 8, pp. 191–194.)

The paper describes a modification of Dye's original method in which, by a combination of electromagnetic and electrostatic deflection, the frequencies to be compared are made to trace a circle having a number of peripheral loops. The main feature of the modification is that, by means of a double phase-splitting circuit, the same pattern can be produced by electric deflection only. This makes the method applicable to the normal type of oscillograph and to circuits of very low power.

1927. A DIFFERENTIAL STABILISER FOR ALTERNATING VOLTAGES, AND SOME APPLICATIONS.—Glynne. (*See* 1957.)

1928. Stabilised Oscillator [derived from Shunt-Feed Tuned-Plate Type].—Terman. (*See* 1856.)

1929. Quartz Crystals Oriented by X-Ray Diffraction Method [used for Location of *X* & *Y* Axes, Checking of Critical Angles, & Compliance with Temperature-Coefficient Requirements]. — (*Electronics*, Feb. 1943, Vol. 16, No. 2, pp. 98 and 100.) From the Philips Metalix Corporation.

1930. Modes of Vibration and Design of V-Cut Quartz Plates for Medium Broadcast Frequencies.—J. E. Benson. (*A.W.A. Tech. Review*, Feb. 1943, Vol. 6, No. 2, pp. 73–90.)

The manufacture, for frequency-control purposes, of high-quality quartz crystals operating in the region of 500 to 3000 kc/s has, in the past, been complicated by the occurrence of abrupt changes in frequency and activity with variation in temperature. The paper briefly discusses the nature of contour modes of vibration in V-cut quartz plates, with special reference to their effect on the thickness mode of vibration in relatively thick plates. Empirical data are given, leading to a method of designing crystals, for quantity production, exhibiting low temperature-coefficients and freedom from operating defects over a wide temperature-range. It is found that the controlling design-features above approximately 5 Mc/s are different from those below 2 Mc/s, while in the intermediate range the design-considerations applicable to either region may be applied.

1931. Magnetostriction [Classification of Effects: Variation of Magnetic Properties under Mechanical Strain: Variation of Joule Effect: Mechanism of Magnetostriction: Applications: etc.].—P. Baron. (*Rev. Gén. de l'Élec.*, Oct. 1942, Vol. 51, No. 10, p. 439 onwards.) With 11 diagrams.

1932. "The Inductance Authority" [Book Review].—E. M. Shiepe. (*Communications*, Feb. 1943, Vol. 23, No. 2, p. 42.) With 38 inductance charts, etc.

1933. Standard Values of Resistors [facturers' Agreed Values for ± 20%, ± 10% and ± 5% Fixed Resistors].—(*Electronic Eng:g*, March 1943, p. 430.) *Cf.* 1198 of April.

1934. Bridge for measuring Storage-Battery Resistances [of Order of 0.004 Ohm, with Accuracy within about 2%: Use of 3 kc/s Frequency]. — E. Willihnganz. (*Sci. Abstracts*, Sec. B, Jan. 1942, Vol. 45, No. 529, p. 12.)

1935. The Compensation of Random Fluctuations in a D.C. Bridge Amplifier.—Brentano & Schleiger. (*See* 1861.)

1936. On the Direct-Current High-Voltage Measurement [Proposed Precision Standard based on Expression connecting Voltage with Minimum Wavelength of X-Rays generated in Given Material].—S. Oketani. (*Electrotech. Journ.* [Tokyo], April 1941, Vol. 5, No. 4, pp. 67–68.)

1937. Test Generators and Chambers [Tests involving Vibration, Humidity, Temperature, and Pressure for Component Parts subjected to Simulated Severe Field Conditions during Design and Production].—W. W. MacDonald. (*Electronics*, Feb. 1943, pp. 82–86 and 203..207.)

1938. An Automatic Production Tester [Motor-Operated Rotary Switch enables Unskilled Worker to Check 120 Circuits in 4 Minutes: A.C. and D.C. Bridge makes Static Comparison between Standard & Electronic Equipment coming off Assembly Lines: Pointer travelling over Numbered Dial indicates Location of Wiring Errors: Machine rejects Incorrect Resistance, Capacitance, and Inductance Values].—D. A. Griffin & N. B. Smalley. (*Electronics*, Feb. 1943, pp. 58–61 and 140..150.)

1939. The Law of the Moving-Iron Instrument.—G. F. Tagg. (*Journ. I.E.E.*, Part II, Feb. 1943, Vol. 90, No. 13, pp. 73–78.) For a discussion of this paper see *Nature*, 10th April 1943, Vol. 151, No. 3832, p. 423.

1940. Theory of the Force or Torque of Soft-Iron Electrical Instruments.—C. V. Drysdale. (*Journ. I.E.E.*, Part II, Feb. 1943, Vol. 90, No. 13, pp. 79–83.)

SUBSIDIARY APPARATUS AND MATERIALS

1941. The Making Visible and Photographing of the Field of Hertzian Waves ["Spark Styctography"].—Arkadiew & Penner. (*See* 1820.)

1942. An Improved Cosmic-Ray Radio Sonde.—Pickering. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, p. 140.) Abstract only.

1943. Marked Oscillograph Tracings.—Ahlquist. (*Gen. Elec. Review*, March 1943, Vol. 46, No. 3, pp. 179–182.)

Description of a method for imposing distinguishing marks on the various traces given by a multi-element electrical oscillograph. Wire screens of various meshes are placed in the paths of the light beams giving the different traces.

1944. "A Guide to Cathode-Ray Patterns" [Book Reviews]. — Bly. (*Communications*, Feb. 1943, Vol. 23, No. 2, p. 42: *QST*, March 1943, Vol. 27, No. 3, p. 52.)

1945. A New Frequency-Comparison Circuit for the Cathode-Ray Tube.—Rawcliffe. (*See* 1926.)

1946. From Filamentary Beam to High-Vacuum Tube [Development of the C.R. Tube with Gas Concentration: Design of the High-Vacuum Tube]: *also* The Development of the AEG High-Vacuum Oscillograph Tubes [including Dual-Ray & Post-Acceleration Types]: *and* The Further Development of the Cathode Ray Tube to the High-Performance Tube [including Technical Design: Recording Speed: Sensitivity: etc.].—Brüche: Steudel: Katz. (*Jahrbuch AEG-Forsch.*, Dec. 1941, Vol. 8, No. 3, pp. 130 onwards.)

1947. Quantities and Terms in Geometrical Electron Optics [Electron Lens, Mirror, Prism, Microscope, etc.].—Henneberg & Brüche. (*Arch. f. Tech. Messen*, Dec. 1942, Vol. 12, Part 138, J834-3, Sheet T133.)

1948. Electron Optics [Electrostatic Lenses: Image-Formation by Thin & Thick Lenses: Immersion Objectives; etc.].—Grivet. (*Rev. Gén. de l'Élec.*, Nov. 1942, Vol. 51, No. 11, p. 473 onwards.) With 20 diagrams.

1949. Simplified Electron Microscopy [Brief History of Development of Electron Microscope leading to Introduction of General Electric Instrument with Horizontal Electron Path, Electrostatic Lenses, and Simplified Operation].—C. H. Bachman. (*Electronics*, Feb. 1943, pp. 78–81, 195, and 200.)

1950. Electrostatic Electron Microscopy: II.—Bachman & Ramo. (*Journ. Applied Phys.*, Feb. 1943, Vol. 14, No. 2, pp. 69–77.)

"This paper is a continuation of the description of problems arising in the development of an electrostatic electron microscope (1511 of May). The present article discusses depth of focus, lens & field stops, shielding, manufacturing tolerances, choice of number of stages of magnification, & alternative methods of viewing & recording the final image . . ."

1951. Optical Constants of Electron Microscopes.—Marton & Hutter. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, p. 140.) Abstract only.

1952. A Research into the Physical Factors concerned in Indirect Radiography: VI—The Effect of Varying the Coating Thickness of the Fluorescing Material of a Screen on the Luminous Output Obtained.—Stanford. (*Sci. Abstracts*, Sec. B, Feb. 1942, Vol. 45, No. 530, pp. 44–45.)

1953. Quenching of Fluorescence of Aluminium Oxide by Absorbed Vapour [and Its Mechanism].—Kasparov. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 30th Aug. 1940, Vol. 28, No. 6, pp. 514–516: in English.)

1954. A Hard-Valve Single-Sweep Time-Base.—Cossor, Ltd. (*Electronic Eng:g*, March 1943, p. 418.) Description of a modification by Messrs. A. C. Cossor of their original hard-valve circuit.

1955. An Electronic Curve Tracer [Device in which Spot of Light is forced to follow Curve on Recorder Chart and which Integrates the Area under the Curve: eliminates Manual Planimeter Method and Consequent Personal Errors].—Padva. (*Electronics*, Feb. 1943, Vol. 16, No. 2, pp. 87–90 and 202.)

1956. A Differential Electronic Stabiliser for Alternating Voltages [Abstract of Paper read before Measurements Section, I.E.E.].—Glynne. (*Electronic Eng:g*, April 1943, Vol. 15, No. 182, pp. 482–483.) *See* 1957, below.

1957. A Differential Stabiliser for Alternating Voltages, and Some Applications.—Glynne. (*Journ. I.E.E.*, Part II, April 1943, Vol. 90, No. 14, pp. 101–110: Discussion pp. 110–115.)

Summaries were dealt with in 519 of February and 1225 of April. The main purpose of the paper is to describe the construction of a differential electronic stabiliser which has been designed and constructed by the author to provide a supply unaffected by fluctuations in the mains voltage, for testing a.c. instruments. A simple mathematical theory is developed for a bridge, consisting of two lamps and two resistors, which is an essential part of the apparatus, and experimental evidence of the accuracy of the theory is given. The stabiliser, when supplied from the public mains, is capable of giving a steady power output of some hundreds of watts and of dealing with variations of ± 2% in the supply voltage.

Applications of the stabiliser to the testing of d.c. and a.c. indicating instruments and of light- and heavy-current integrating meters are described, and an account is given of the use of stabilised voltages for a.c. potentiometry. A suggestion is made for the calibration of a d.c./a.c. transfer voltmeter.

1958. Production of Tungsten.—(*Science & Culture*, Jan. 1943, Vol. 8, No. 7, pp. 302–304.)

1959. Formation of Negative Ions in the Process of Surface Ionisation of Alkali Halides on Heated Tungsten.—Yonov. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 30th Aug. 1940, Vol. 28, No. 6, pp. 512–513: in English.)

1960. An X-Ray Study of the Structure of Rectifying Selenium Films [and the Effects of Impurities (Not Highly Influential), Heat Treatments, Polishing, etc: Rectifying Action is at Se Counter-Electrode Interface: etc.].—Clark & Roach. (*Sci. Abstracts*, Sec. B, Jan. 1942, Vol. 45, No. 529, pp. 5–6.)

1961. Glow-Discharge Lamps for Black-Out Purposes [Advantages over Incandescent: Successful Design of 3-Watt Lamp with Semi-Cylindrical Electrodes: Life of Many Thousand Hours].—Gerber & Jaeger. (*Bull. de l'Assoc. Suisse des Élec.*, 24th Feb. 1943, Vol. 34, No. 4, pp. 93–95: in German.)

1962. The Contraction of the Plasma in a Magnetic Field.—Reichrudel & Spiwak. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 10th Sept. 1940, Vol. 28, No. 7, pp. 609–613: in German.)

1963. Positive and Negative Point-to-Plane Corona in Pure and Impure Hydrogen, Nitrogen, and Argon.—Weissler. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, pp. 96–107.)

1964. Corona Blackout in High-Voltage Machines [and the Use of Aquadag & of the Semiconducting Synthetic Resin "Coronox"].—Hill, Berberich, & Askey. (*Sci. Abstracts*, Sec. B, Feb. 1942, Vol. 45, No. 530, p. 35.)

1965. The Coordination of the Insulation in High-Voltage Installations.—Rump. (*See* 1841.)

1966. Freon [Abstract of Paper read before A.I.E.E. Convention].—Skilling & Brenner. (*Electronic Eng:g*, April 1943, Vol. 15, No. 182, p. 483.)

"Freon gas has an unusually high electric strength and will withstand 2½ times the voltage of air under same conditions." *See* also 562 of February.

1967. An Artificial Suspension-Insulator String.—Soper. (*BEAMA Journ.*, April 1943, Vol. 50, No. 70, pp. 100–103.)

"The paper gives a description of new laboratory apparatus by means of which an experimental study can be carried out, at low voltages, on the voltage distribution over the units of a string of suspension-type insulators, with or without grading-ring control."

1968. Dielectric or Puncture Strength of Porcelain and Other Ceramic Materials.—Rosenthal. (*Electronic Eng:g*, March 1943, Vol. 15, No. 181, pp. 408–411.)

1969. Dielectric-Constant/Temperature Characteristics of Polystyrene at High Frequency.—Koga & Sadi. (*Electrotech. Journ.* [Tokyo], April 1941, Vol. 5, No. 4, p. 79.) The coefficient is negative, like that of Rutile and its mixtures.

1970. "1943 Plastics Catalog" [Book Review].—(*Communications*, Jan. 1943, Vol. 23, No. 1, p. 48.)

1971. Dielectric Losses at High Frequencies in Glass Fabric [and Its Suitability for H.F. Cables: Tests on Wavelength of 106 m].—Skanavi. (*Sci. Abstracts*, Sec. B, Feb. 1942, Vol. 45, No. 530, p. 38: from *Journ. of Phys.* [of USSR]).

1972. New Products—Glass Articles Moulded by New "Multiform" Process [Process particularly Applicable to Manufacture of Coil Forms, Tube Sockets, Coaxial-Line Beads, and Other Insulating Parts requiring High Accuracy in Dimensions: Multiform Process employs Combination of Cold-Moulding Batch Materials and Subsequent Fusing to attain Shapes, Perforations, Grooves and Threads not usually attainable by Hot Moulding: Finished Work Translucent or Opaque in Appearance owing to presence of Occluded Gases in Glass].—(*Electronics*, Feb. 1943, Vol. 16, No. 2, pp. 180–182.)

1973. Rubber: Natural *versus* Synthetic.—Pickles. (*Journ. Roy. Soc. Arts*, 16th April 1943, Vol. 91, No. 4637, pp. 256–265.)

Paper describes types, processing, chemical formulae, physical properties, etc., of synthetic rubbers and how they compare with natural rubbers, and ends with a discussion of prospects of the industry.

1974. Acid Neutralisation in Insulating Papers.—McLean. (*Bell Lab. Record*, Feb. 1943, Vol. 21, No. 6, pp. 136–139.)

Hydrochloric acid is liberated from chlorinated impregnants, particularly at high temperatures and under high voltages. The acid and salts formed by its reaction with the metal electrodes decompose the paper. This can be delayed by addition of calcium and magnesium to the paper.

1975. Molecular Rotation in Organic Solids.—(*Bell Lab. Record*, Feb. 1943, Vol. 21, No. 6, p. 140.)

Polar molecules which are approximately circular about some axis may be capable of rotational movement even in the solid state. This is manifested by high dielectric constant. Photographs of models of molecules suitable for dielectric materials are included in this short article.

1976. The Determination of the Electrical Properties of Soil at a Wavelength of 5 Metres.—McPetrie & Saxton. (*See* 1822.)

1977. A Note on the Design of Iron-Cored Coils at Audio-Frequencies.—Payne-Scott. (*See* 1910.)

1978. Method for the Microscopic Viewing of Magnetic Sound-Recordings.—Heidenwolf. (*Lorenz-Berichte*, Dec. 1941, No. 3/4, p. 119 onwards.) With 9 diagrams.

1979. Magnetostriction.—Baron. (*See* 1931.)

1980. THE MAGNETIC PROPERTIES OF IRON–CERIUM ALLOYS.—Clark, Pan, & Kaufmann. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, p. 139 : summary only.)

1981. HYPERSIL, A NEW MAGNETIC STEEL, AND ITS USE IN TRANSFORMERS.—Hodnette & Horstman. (*Sci. Abstracts*, Sec. B, Feb. 1942, Vol. 45, No. 530, p. 36.)

1982. ELECTRONIC ENERGY BANDS IN BODY-CENTRED IRON, *and* ELECTRONIC ENERGY BANDS IN FACE-CENTRED IRON.—Manning : Greene & Manning. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, pp. 190–202 : pp. 203–210.)

1983. ADJUSTING SENSITIVE RELAYS. — Fisher. (*Electronics*, Feb. 1943, Vol. 16, No. 2, pp. 70–73 and 200–201.)

1984. IMPROVED TIMING DEVICE [for Relay-Testing].—Rowson. (*Sci. Abstracts*, Sec. B, Jan. 1942, Vol. 45, No. 529, p. 13.)

1985. A NEW DRUMM BATTERY [Production of New Model : Claims for Improved Effectiveness in Traction and Elimination of Self-Discharging].—(*Elec. Review*, 7th May 1943, Vol. 132, p. 615.)

1986. DRY-BATTERY CONSTRUCTION [Causes of Failure : Unsatisfactory Methods of Construction].—Bennett. (*Elec. Review*, 7th May 1943, Vol. 132, pp. 618–619.)

1987. " ELECTROPLATING : A SURVEY OF MODERN PRACTICE " [Book Review].—Field & Weill. (*Elec. Review*, 21st May 1943, Vol. 132, p. 680.)

1988. SOLDERLESS WIRE JOINTING [Rakos Process]. —(*Elec. Review*, 14th May 1943, Vol. 132, p. 646.)

The union of two wires is effected by means of a device somewhat resembling a miniature spot welder. The absence of flux eliminates the danger of corrosion.

1989. THE METALLURGY OF FILLET-WIPED SOLDERED JOINTS [Reduction of Wiped Cable Joint to Fillet Proportions gives over 60% Saving in Solder and a Better Joint].—Schumacher, Bouton, & Phipps. (*Bell S. Tech. Journ.*, Jan. 1943, Vol. 22, No. 1, pp. 73–79.)

1990. SOFT SOLDERING AS APPLIED TO TELEPHONE AND RADIO EQUIPMENT [and the Two Main Types of Faulty Joint : Causes & Prevention of the High-Resistance Joint (particularly the Insufficient Temperature Difference between Many Electric Irons and M.P. of Common Solders)].—Guest. (*Sci. Abstracts*, Sec. B, April 1942, Vol. 45, No. 532, p. 69.)

1991. ELECTRIC SOLDERING IRONS [Simple Apparatus for Assessing " Work Capacity " of Soldering Irons : Analysis of Thermal Characteristics]. — Hoban. (*Elec. Review*, 21st May 1943, Vol. 132, pp. 681–683.)

STATIONS, DESIGN AND OPERATION

1992. PACK COMMUNICATIONS EQUIPMENT FOR FIRE FIGHTING.—Meyerson. (*Communications*, Jan. 1943, Vol. 23, No. 1, pp. 14–16, 19 and 47.) Continued from 1770 of June.

1993. SOME NEW THOUGHTS ON WERS [War Emergency Radio Service : a Commentary on Recent Developments].—Hart. (*QST*, April 1943, Vol. 27, No. 4, pp. 24–25 and 76 . . 82.)

1994. 500-WATT C.W. TRANSMITTER [Radio-Telegraph Equipment tuning from 1500 kc/s to 30 000 kc/s in Five Bands : Rugged Construction and Straightforward Over-All Circuit Design containing a Number of Individually Simple but Collectively Important Electrical and Mechanical Features facilitating Operation and Maintenance by Relatively Inexperienced Personnel]. — (*Electronics*, Feb. 1943, Vol. 16, No. 2, pp. 67–69.) Built by Harvey Radio Laboratories.

1995. CONTROL SYSTEMS IN AIRCRAFT COMMUNICATIONS [Discussion of Operating Control System].—McKee. (*Communications*, Jan. 1943, pp. 52, 53.) *See* also 1672 of June.

1996. " PRINCIPLES OF AERONAUTICAL RADIO ENGINEERING " [Book Review]. — Sandretto. (*Communications*, Feb. 1943, Vol. 23, No. 2, p. 42.)

1997. HIGH - FREQUENCY TELEPHONIC [Wire] BROADCASTING : THE ST. GALLEN–RORSCHACH – HEERBRUGG INSTALLATION [Editorial].—(*Tech. Mitteil. schweiz. Telegr. u. Teleph. Verwaltung*, Aug. 1942, Vol. 20, No. 4, p. 121 onwards.)

1998. PROBLEMS OF WIRELESS MULTIPLE TELEPHONY [Lecture to Zurich Physical Society]. —Tank. (*Bull. de l'Assoc. Suisse des Élec.*, 24th Feb. 1943, Vol. 34, No. 4, pp. 87–93 : in German.)

1999. THE COMPREHENSIVE ASSESSMENT OF TELEPHONE COMMUNICATION EFFICIENCY.—Hughes. (*See* 1902.)

2000. MAINTENANCE OF BROADCAST OPERATIONS IN WARTIME. — Ouimet. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, pp. 93–99.)

" This paper deals with the technical measures taken by the Canadian Broadcasting Corporation to meet the increasing difficulties of maintenance of broadcast operations in wartime. After a brief description of the facilities involved in these plans, the paper outlines steps that have been taken for the physical protection of broadcast plants. The problem of conservation of equipment in the face of acute shortages is then discussed, with the measures that have been taken to prolong the life of tubes, microphones & other equipment. . . . The paper describes the setting up of emergency & standby facilities, such as secondary control centres, stand-by transmitters, frequency-modulation links, & other equipment designed to ensure continuity of service."

2001. Short-Wave Broadcasting Stations [Comprehensive List arranged in Order of Frequency].—(*Wireless World*, May 1943, Vol. 49, No. 5, pp. 134–136.)

GENERAL PHYSICAL ARTICLES

2002. The Specular Reflection of Plane Wave Pulses in Media of Continuously Variable Refractive Properties.—Rose. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, pp. 111–120.)

2003. Physics in 1942 [Crystals & Photons, Thermal Diffusion, the Nucleus, the Neutrino, Cosmic Rays, X Rays, & Active Nitrogen].—Osgood. (*Journ. Applied Phys.*, Feb. 1943, Vol. 14, No. 2, pp. 53–68.)

2004. Papers on Cosmic Rays.—Swann, Wilson, Millikan, Katz, Hazen, & others. (*See* 1834/8.)

2005. Memorial to the Classical Statistics.—Darrow. (*Bell S. Tech. Journ.*, Jan. 1943, Vol. 22, No. 1, pp. 108–142.)

2006. The Concept of Energy [Tracing the Conception of the Physical Nature of Energy by Scientists from Aristotle onwards].—Bell. (*Nature*, 8th May 1943, Vol. 151, No. 3836, pp. 519–523.)

2007. "Franklin's Experiments and Observations on Electricity" [Book Review].—Cohen. (*Nature*, 17th April 1943, Vol. 151, No. 3833, p. 430.)

2008. The Probable Accuracy of the Physical Constants.—Benford. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, p. 212.)

The writer examines the probable errors attached to the values for various physical constants in the summaries published by Birge in 1929 and 1941 (*see* 1304 of April) respectively. He finds that in some cases the difference between the 1941 and the 1929 value of a constant is several times the probable error attached to the 1929 value, and concludes that the assigned probable errors do not apply to the absolute accuracy of the constants but only to accuracy as judged by internal evidence of the experiments. He points out that it is important to make the distinction between consistency and accuracy.

2009. Comments on "The Probable Accuracy of the General Physical Constants."—Birge. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, p. 213.)

A reply to a letter from Benford in the same number of the journal (*see* 2008, above). Birge states that for many years he has emphasised the distinction between consistency and accuracy. The absolute accuracy of a measured result cannot be determined, though the difference, if any, between the internal and external consistency of the data can be noted. The most carefully conducted precision work on physical constants usually seems to contain errors greater than any suspected by the experimenter. As a result of the diversity of the methods now in use in determining most of the general constants, and of the greater attention being paid to systematic errors, Birge considers that the values and probable errors of his 1941 list can be accepted with considerably greater confidence than in the case of any earlier list.

2010. The Ploughing and Adhesion of Sliding Metals.—Bowden, Moore, & Tabor. (*Journ. Applied Phys.*, Feb. 1943, Vol. 14, No. 2, pp. 80–91.)

"Studies of surface damage caused by the sliding of clean metals on one another show that penetration & distortion occur to some depth beneath the surface. Micro-examination shows that welding of the metals takes place even at low speeds of sliding, when the surface temperature-rise due to frictional heat cannot be very high. These results have led to a more quantitative theory of metallic friction. It is suggested that the frictional force between clean metal surfaces is made up of two parts. The first is the force required to shear the metallic junctions formed between the surfaces, the second is the ploughing force required to displace the softer metal from the path of the harder. By using steel sliders of various shapes on a soft metal like indium these two factors have been estimated separately. . . ."

MISCELLANEOUS

2011. Application of the Laplacian Transform to the Study of Electrical Circuits.—Clavier. (*See* 1860.)

2012. "An Introduction to the Operational Calculus: First Edition, 1941" [Book Review].—Seeley. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, p. 121.)

2013. "A Graphic Table combining Logarithms and Anti-Logarithms" [Book Review].—Lacroix & Ragot. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, p. 120.)

"Logarithms and anti-logarithms are presented by parallel scales of the numbers and their logarithms. These enable the five-place logarithm of a number or the number corresponding to a five-place logarithm to be obtained by simply reading a scale."

2014. MECHANICAL INTEGRATION [Summary of 34th Kelvin Lecture to the I.E.E.]—Hartree. (*Elec. Review*, 7th May 1943, Vol. 132, p. 616.)

2015. WAVE ANALYSIS: PART III—ANALYSIS OF PERIODIC WAVE-FORMS [Practical Methods].—Bourne. (*Electronic Eng:g*, April 1943, Vol. 15, No. 182, pp. 472–474.) For previous parts *see* 1320 of April.

2016. WAVEBANDS AND FREQUENCY BANDS.—Editorial. (*Wireless World*, April 1943, Vol. 49, No. 4, p. 95.)

The need for a revised nomenclature for specifying frequency bands and wavelength bands is stressed and possible classifications are suggested.

2017. HISTORY OF THE WIRELESS SECTION, I.E.E. [Chairman's Address].—Smith-Rose. (*See* 1824.)

2018. A REPORT ON THE 1943 I.R.E. WINTER CONFERENCE.—Winner. (*Communications*, Feb. 1943, Vol. 23, No. 2, pp. 15–16, 46–48, 64, 73 and 75.)

Summarises papers read by G. C. Southworth on "Beyond the Ultra-Shorts", by G. H. Brown on "Direct-Reading Wattmeters for Use at Radio Frequencies", and by C. E. Smith on an electromechanical calculator for the rapid solution of antenna patterns. For this last, *see* also *BEAMA Journ.*, May 1943, Vol. 50, No. 71, p. 166 (C. E. Smith & E. L. Gove).

2019. BROADCASTING AFTER THE WAR [Some Problems of the Industry].—Editorial. (*Wireless World*, May 1943, Vol. 49, No. 5, p. 127.) Refers to report of a Committee of the R.M.A., published in the annual report of the Association, and deals with wire *versus* wireless for broadcasting.

2020. RESEARCH AND INDUSTRY [22nd E.R.A. Report].—(*BEAMA Journ.*, April 1943, Vol. 50, No. 70, pp. 97–99: summary only.)

2021. EDUCATION AND TRAINING OF ENGINEERS [Recommendations of an I.E.E. Committee].—(*Elec. Review*, 14th May 1943, Vol. 132, pp. 652–653.)

2022. GLOSSARIES.—Editorial. (*Electronic Eng:g*, March 1943, p. 407.)

Reviews "American Standard Definitions of Electrical Terms" (American I.E.E.) and "Glossary of Terms used in Electrical Engineering, Section 1" (B.S.I.). Points out that the British electron is "fatter" than its American counterpart. The charge on the electron is given as 4.774×10^{-10} e.s.u. in the American work, and 4.803×10^{-10} e.s.u. in the British; while the American value for the mass of the electron is 9.00×10^{-28} grm against the British 9.11×10^{-28}.

2023. "A LABORATORY MANUAL OF ELECTRICITY AND MAGNETISM" [Book Review].—Loeb. (*Journ. Applied Phys.*, Feb. 1943, Vol. 14, No. 2, p. 77.)

2024. "A PRACTICAL COURSE IN MAGNETISM, ELECTRICITY, AND RADIO" [Book Review].—Charlesby & Perkins. (*Communications*, Jan. 1943, Vol. 23, No. 1, p. 48.)

2025. "FUNDAMENTALS OF RADIO" [Book Review].—Everitt. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, p. 120.)

2026. "PRINCIPLES OF RADIO, FOURTH EDITION" [Book Review].—Henney. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, p. 121.) For a previous review *see* 1797 of June.

2027. "FUNDAMENTALS OF ELECTRIC WAVES" [Book Review].—Skilling. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, p. 121.) For a previous review *see* 319 of February.

2028. "THE ELECTRICAL FUNDAMENTALS OF COMMUNICATIONS" [Book Review].—Albert. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, p. 119.)

2029. "PRINCIPLES OF ELECTRONICS" [Book Review].—Kloeffler. (*Electronics*, Feb. 1943, Vol. 16, No. 2, p. 124.)

2030. THE FLUX NAVIGATOR [Electronic Navigating Device for locating Island Transmitter, even in Severe Fog: Magnetic Field from Cable feeding Power to Broadcast Station directs Route of Vessel].—Jones. (*Electronics*, Feb. 1943, Vol. 16, No. 2, pp. 74–77 and 178.)

2031. AUTOMATIC AIRCRAFT RADIO-RECORDER.—Peters: Giffen. (*Communications*, Feb. 1943, Vol. 23, No. 2, pp. 11–14 and 72.)

A transmitter in the aircraft under test is frequency-modulated by the instruments measuring, *e.g.*, stress, temperature, etc., successively. The signal is received on the ground and recorded automatically. As many as seventy instrument indications may be recorded once each in three-quarters of a second. The device was invented by H. D. Giffen.

2032. THE USE OF A THYRATRON IN AN EARTHQUAKE-ALARM SYSTEM.—Sulkowski. (*Sci. Abstracts*, Sec. A, Jan. 1942, Vol. 45, No. 529, p. 37.)

2033. ELECTRONIC MACHINE BALANCES ROTATING PARTS [Indicates on a C.R. Tube Amount & Position of Unbalance].—(*Electronics*, Jan. 1943, Vol. 16, No. 1, p. 101.)

2034. SCALE AUDIBLY INDICATES SELECTED STANDARD WEIGHT [Useful for Blind Persons, or for Weighing in the Dark].—(*Electronics*, Jan. 1943, Vol. 16, No. 1, p. 104.)

2035. Radio Control for Model Gliders.—Custin. (*Model Aeroplane News*, Oct. 1942, Vol. 27, No. 4, pp. 19 and 42–46.)

2036. Electron Microscopy in Chemistry.—Zworykin. (*Electronics*, Jan. 1943, Vol. 16, No. 1, pp. 65–68 and 190.)

2037. Electronic Generators Extend Induction Heating Field [Application to Tin Plate Process].—Humphrey. (*Electronics*, Jan. 1943, Vol. 16, No. 1, pp. 56–58 and 189.)

2038. Variable Waveform Unit for Testing Aluminium Welding [Electronic Control Unit for investigating Spot-Welding Conditions in Aluminium Alloys: involves both Conversion and Energy-Storage Principles to Produce the Various Waveforms].—Dawson & Klemperer. (*Electronics*, Feb. 1943, Vol. 16, No. 2, pp. 62–66 and 201.)

2039. An Automatic Production Tester.—Griffin & Smalley. (*See* 1938.)

2040. Water Divining [Its Alleged Electrical Basis: Survey of Methods & Claims of Water Diviners].—Shipley. (*Distrib. of Elec.*, April 1943, Vol. 15, No. 150, pp. 99–101.) *See* also 945 of March.

2041. The Encephalophone: a New Method for investigating Electro-Encephalographic Potentials.—Beevers & Fürth. (*Electronic Eng:g*, March 1943, pp. 419–420.) *See* also 952 of March.

2042. Static Charges produced on Moving Rubber-Tyred Vehicles.—MacKeown & Wouk. (*Phys. Review*, 1st/15th Feb. 1943, Vol. 63, No. 3/4, p. 140: summary only.)

2043. The Reflection of Light at Glass with Surface Films [Derivation of Formulae, and Experimental Confirmation].—Vašícek. (*Physik. Berichte*, 15th Sept. 1942, Vol. 23, No. 18, pp. 1715–1716: summary of Czech paper.) *Cf.*, for example, 305 of January and 700 & 964 of March.

2044. A Research into the Physical Factors concerned in Indirect Radiography: VI—The Effect of Varying the Coating Thickness of the Fluorescing Material of a Screen on the Luminous Output obtained.—Stanford. (*Sci. Abstracts*, Sec. B. Feb. 1942, Vol. 45, No. 530, pp. 44–45.)

2045. A Photoelectric Instrument measuring Quality and Quantity of X-Rays for Radiographic Purposes.—Herz. (*Sci. Abstracts*, Sec. B, June 1942, Vol. 45, No. 534, p. 100.)

2046. Photoelectric Equipments for Mass Production [checking Length, Roughness, Shape, etc: by Direct & Contrast Methods: Cigarette Sorting: etc.].—Benda & others. (*Sci. Abstracts*, Sec. B, Jan. 1942, Vol. 45, No. 529, p. 17: summary of a Siemens paper.)

2047. A High-Pressure Cloud Chamber of New Design.—Johnson, Schutt, & De Benedetti. (*Phys. Review*, 1st/15th March 1943, Vol. 63, No. 5/6, p. 222.)

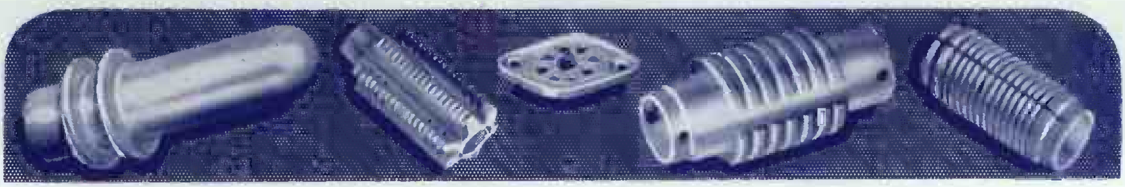
Abstract of paper contributed to American Physical Society. "A cloud chamber is described which operated at a pressure of 200 atmospheres without the difficulty of having to subject its transparent walls to high pressure differentials. The apparatus has already been operated at a pressure of 110 atmospheres giving excellent cosmic-ray tracks. At this pressure its efficiency for observation of rare events such as mesotron decay is about 1000 times that of a chamber of the same size operating at atmospheric pressure."

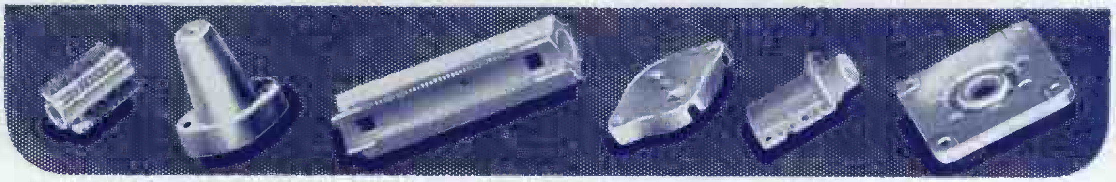
2048. Viewpoints for the Choice of Modern Carrier-Telephony Equipments for Electricity Supply Stations [Automatic Fading Control for Weather Effects: Guarding Against Interference: Automatic Monitoring: Use for Telemetering & Remote Control: etc.].—Wertli. (*Bull. de l'Assoc. Suisse des Élec.*, 2nd Dec. 1942, Vol. 33, No. 24, pp. 714–718: in German.)

2049. Communication by Carrier Currents: Effect and Measurement of the Total Damping and of the Impedance of Lines.—Schwartz. (*Sci. Abstracts*, Sec. B, July 1942, Vol. 45, No. 535, p. 108.)

2050. Overhead Transmission Line Conductors [Advantages of Standardisation: Comparison between Electrical & Mechanical Properties of Steel-Cored Aluminium, Steel-Cored Copper, Cadmium Copper & Hard-Drawn Copper Conductors].—Blackman. (*Distrib. of Elec.*, April 1943, Vol. 15, No. 150, pp. 114–117.)

2051. Power Interference in Communication Circuits in South Africa [Interim Report: Typical Data: Causes & Sources: Counter-Measures].—Adley & others. (*Sci. Abstracts*, Sec. B, April 1942, Vol. 45, No. 532, p. 64.)





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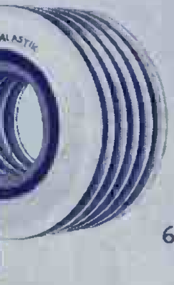
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