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WIRELESS ENGINEER

The Journal of Radio Research & Progress

Vol. XIX NOVEMBER 1942 No. 230

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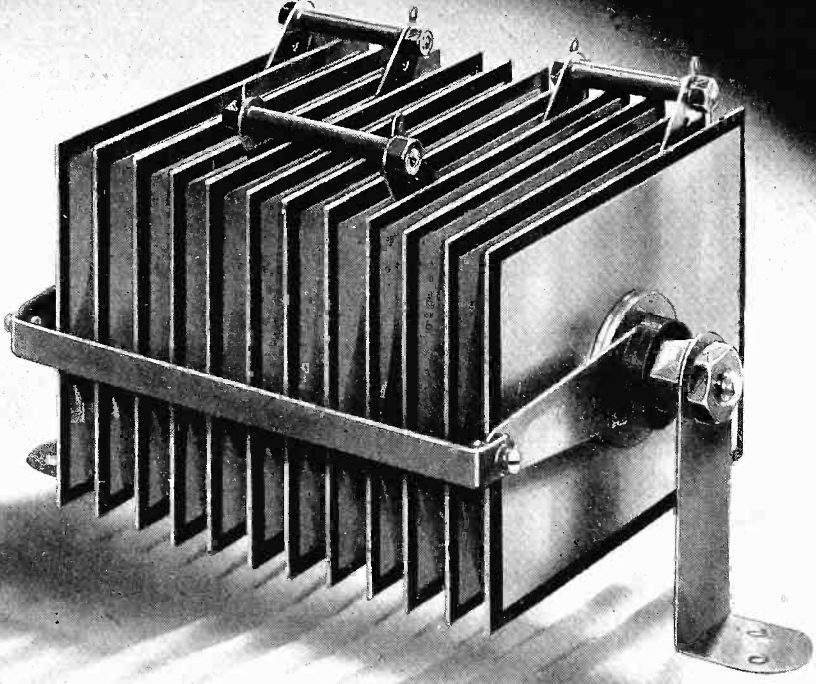

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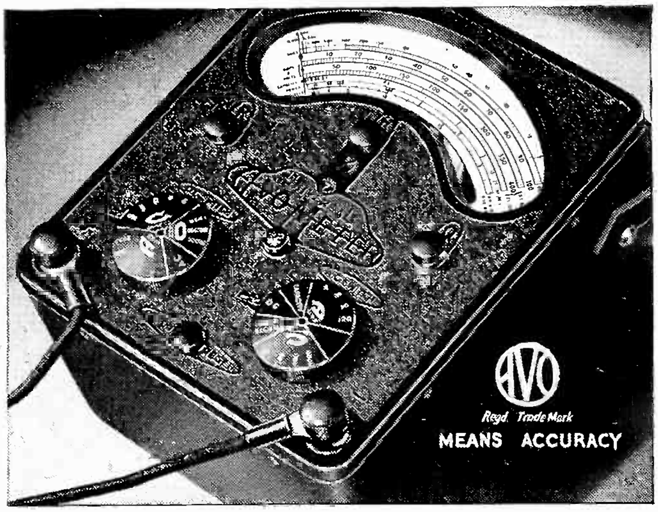

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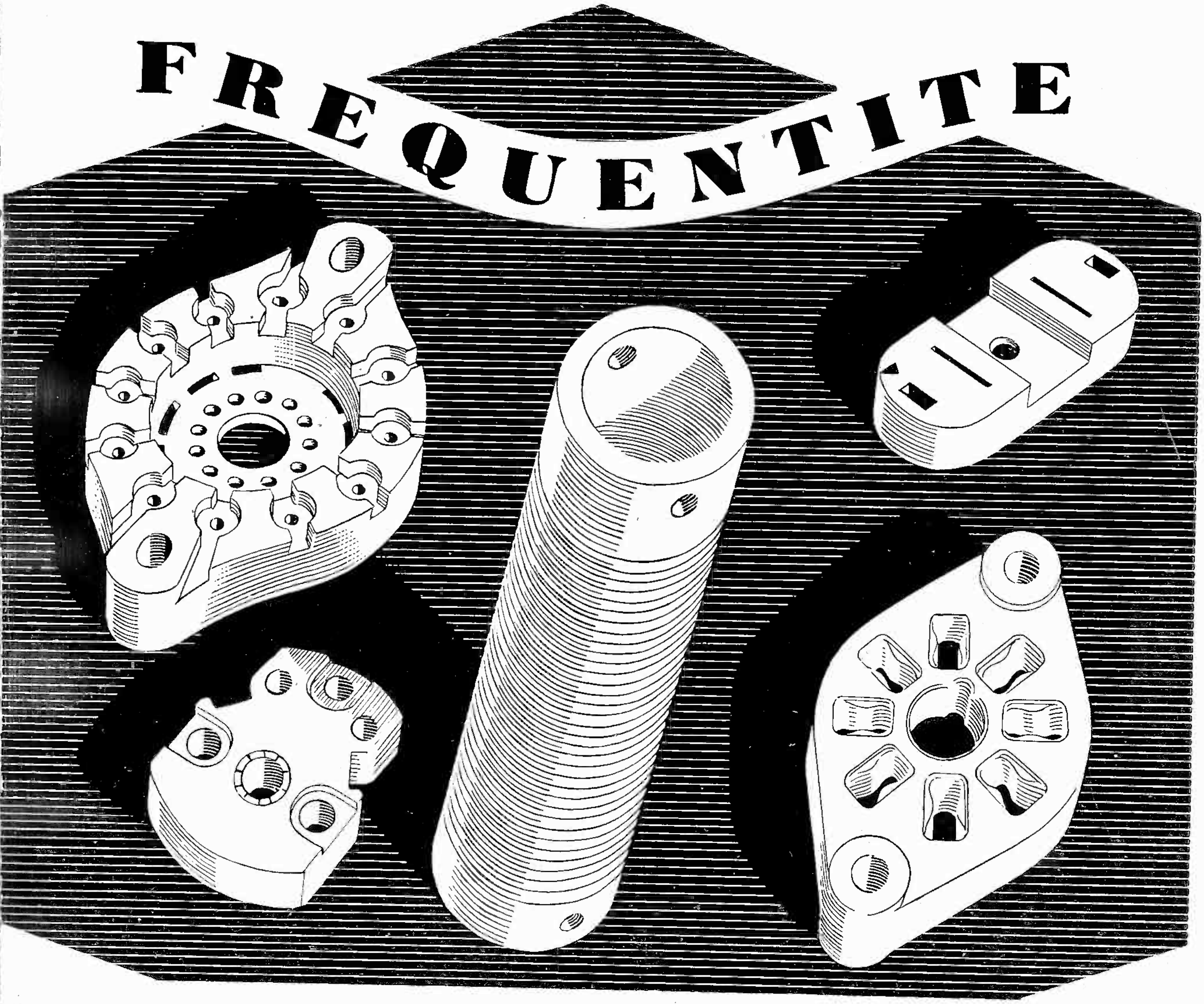

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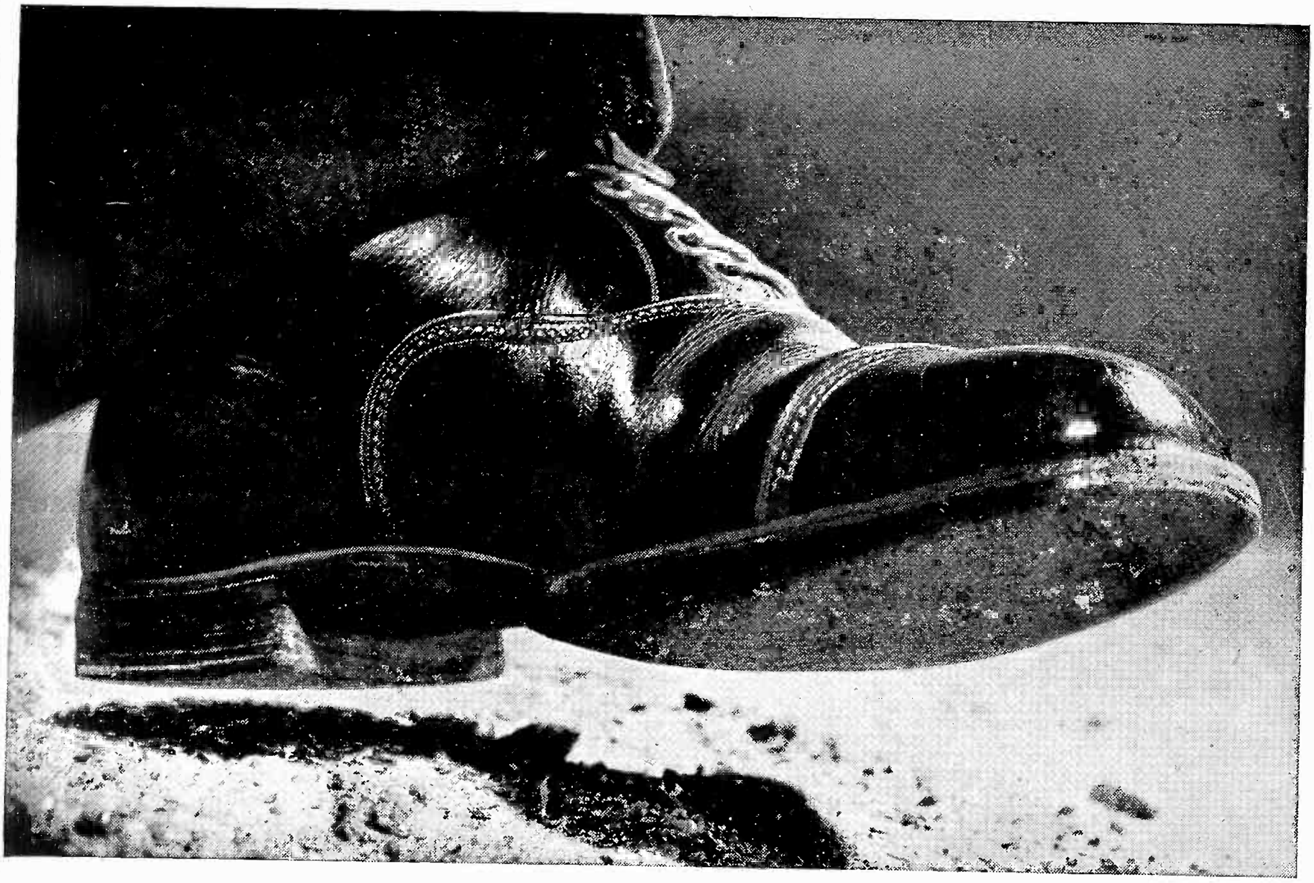

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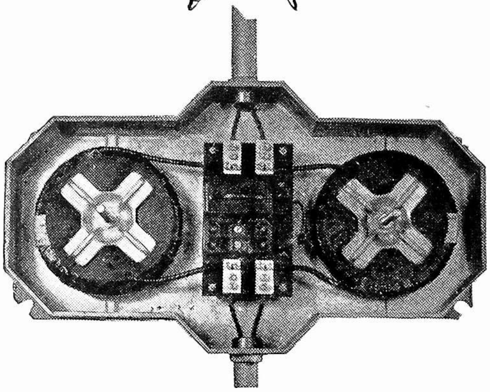

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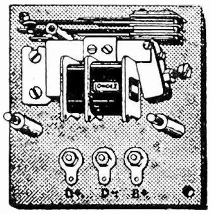

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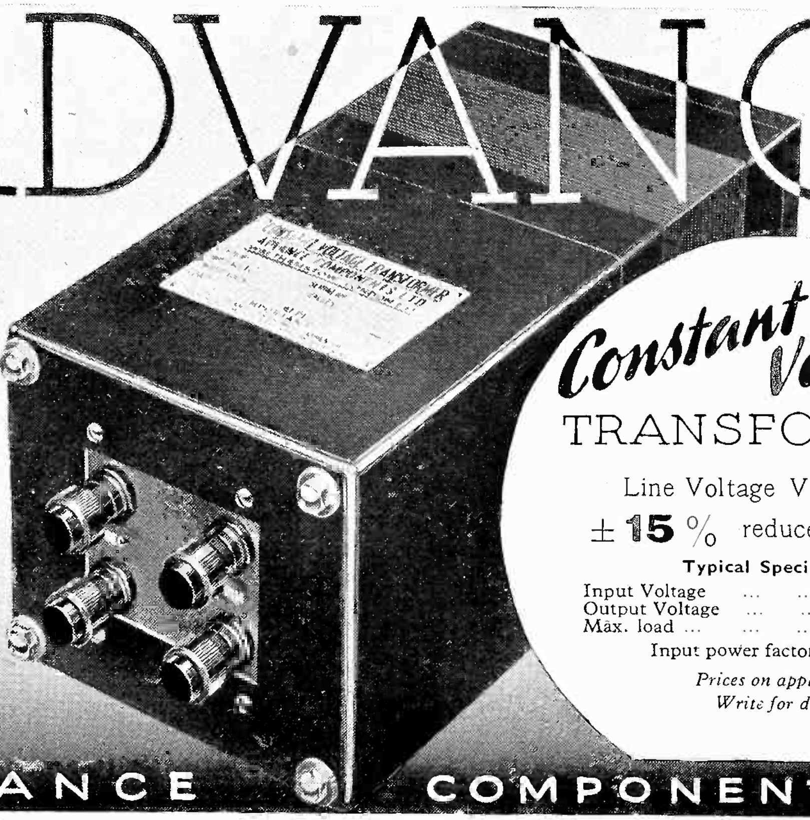

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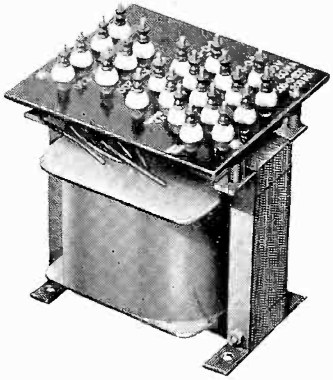

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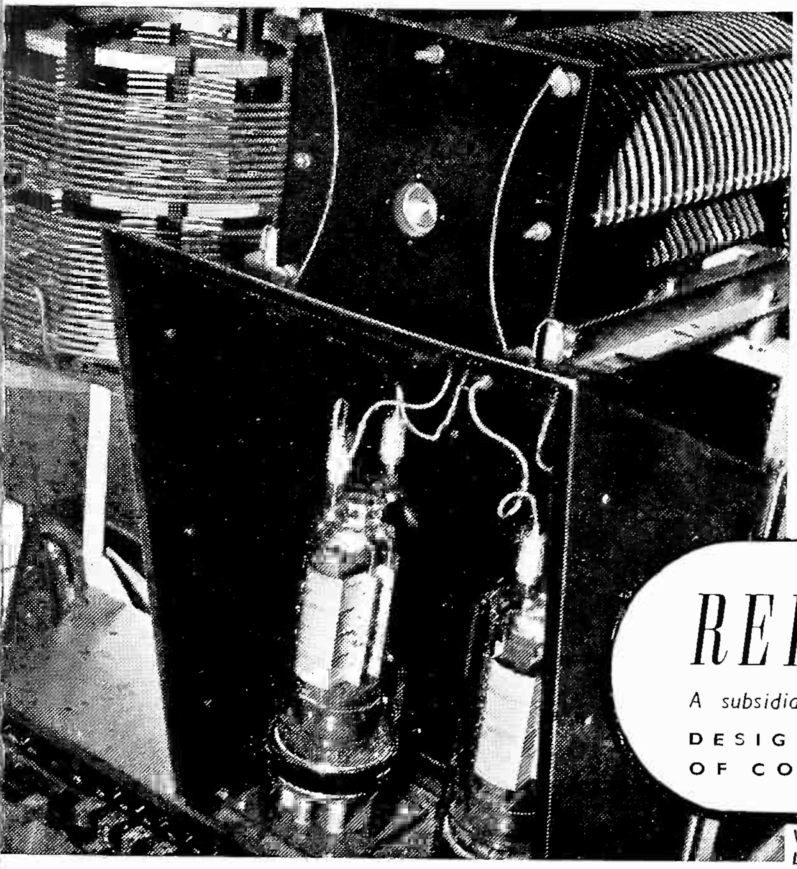

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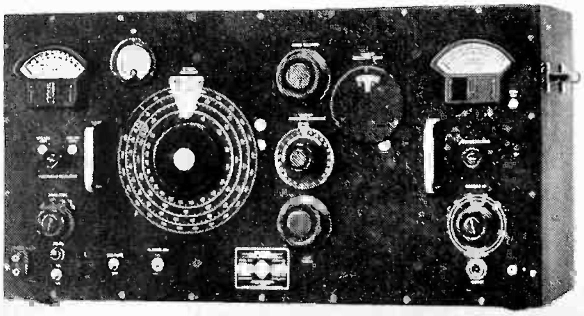

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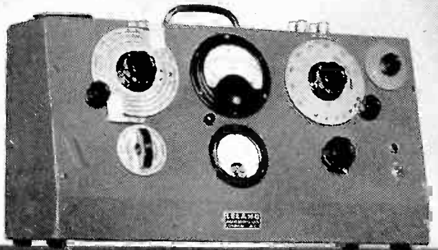

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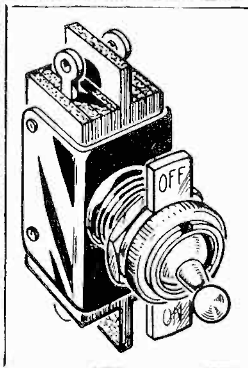

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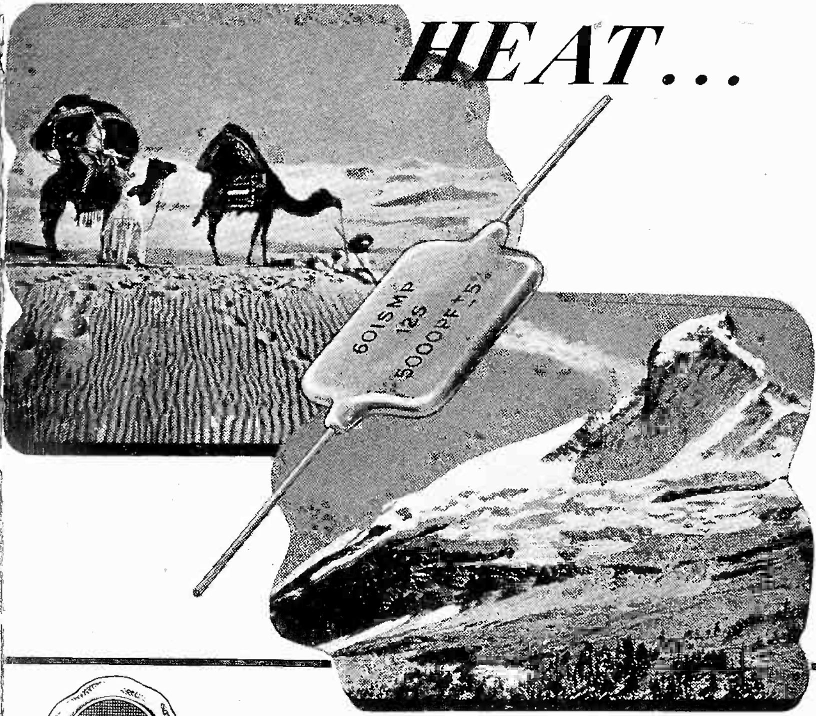

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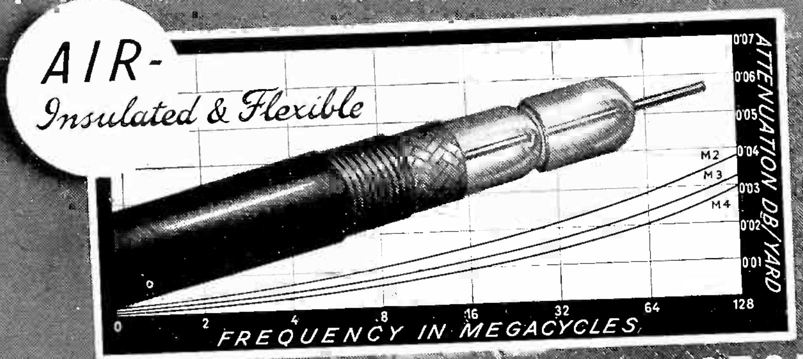

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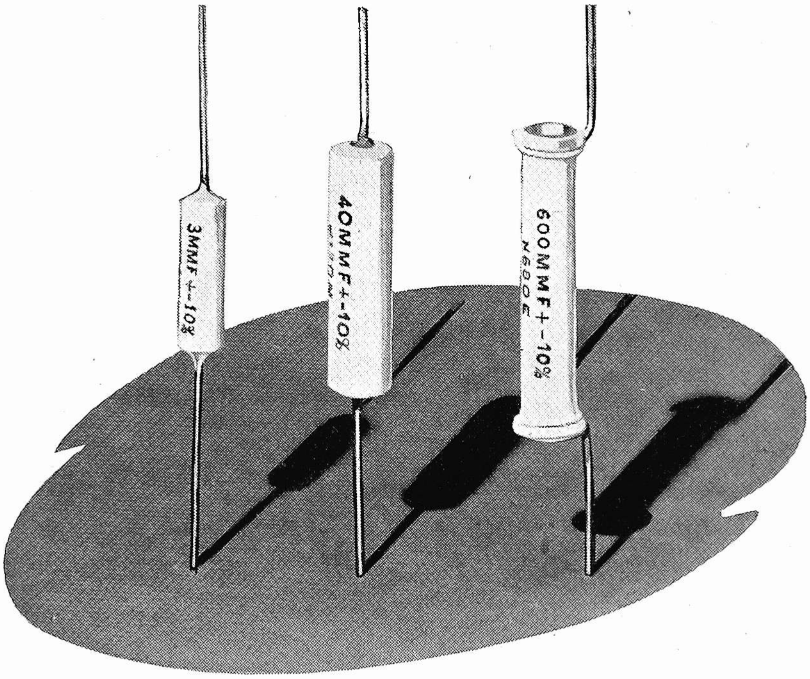

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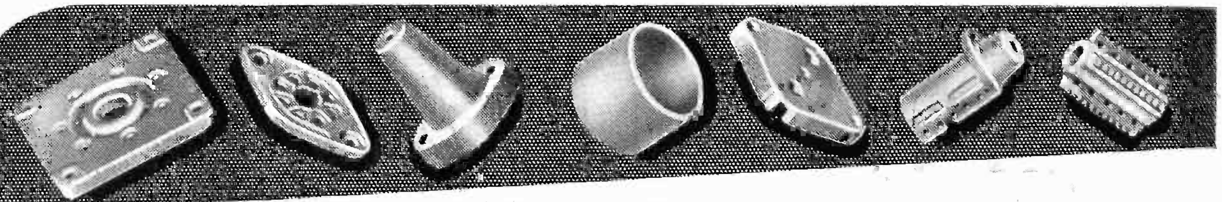

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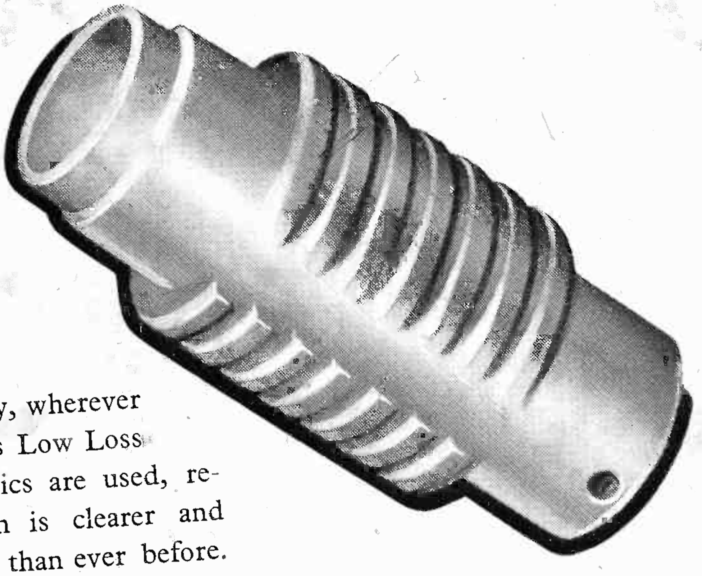

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Editor HUGH S. POCOCK, M.I.E.E.
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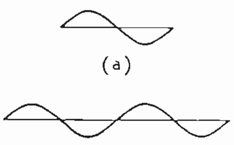
VOL. XIX NOVEMBER 1942 No. 230

Editorial

Current Distribution Along a Straight Wire in a Uniform Field

If a straight wire exactly one wavelength long were placed parallel to the direction of the electric field in a uniform electromagnetic field, what would be the nature of the current distribution along the wire? There is little doubt that most people who had not given much thought to the question would immediately sketch Fig. 1 (a) and regard it as a case of resonance. If the length of the wire were doubled so that it was now exactly equal to two wavelengths the sketch would merely be duplicated as in Fig. 1 (b). That this cannot be the case is obvious, however, for the fact that the wire would carry equal and opposite currents in the two halves, and would consequently not radiate energy at right angles to itself nor consequently absorb energy from a wave arriving in that direction. This was pointed out by Alford[1] in a recent paper in which he developed formulae for calculating the current distribution in such cases for any length of wire.


(a)
(b)
Fig. 1.

If ∂x be an element of length of the conductor, v its potential and C the capacitance per unit length, its charge will be changing at the rate of $C\partial x \frac{\partial v}{\partial t}$ and this must equal the difference between the currents entering and leaving the element; hence

$$C\frac{\partial v}{\partial t} + \frac{\partial i}{\partial x} = 0 \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Neglecting resistance, if L be the inductance per unit length and $E\partial x$ the e.m.f. induced in the element by the electromagnetic wave, the difference of potential between the ends of the section will be $E\partial x - L\partial x \frac{\partial i}{\partial t}$ and therefore

$$\frac{\partial v}{\partial x} = E - L\frac{\partial i}{\partial t} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Eliminating v we have

$$\frac{\partial^2 i}{\partial x^2} - CL\frac{\partial^2 i}{\partial t^2} = C\frac{\partial E}{\partial t} \quad \ldots \quad \ldots \quad (3)$$

If we limit ourselves to purely alternating currents of one frequency and put $E = \hat{e}\cos\omega t$, the solution of this equation may be written as follows:

$$\begin{aligned} i = &\left(A_1 - \frac{\hat{e}}{2z_0}\cdot\frac{\sin Kx}{K}\right)\cos(\omega t + Kx) \\ &+ \left(A_2 + \frac{\hat{e}}{2z_0}\frac{\cos Kx}{K}\right)\sin(\omega t + Kx) \\ &+ \left(A_3 + \frac{\hat{e}}{2z_0}\frac{\sin Kx}{K}\right)\cos(\omega t - Kx) \\ &+ \left(A_4 + \frac{\hat{e}}{2z_0}\frac{\cos Kx}{K}\right)\sin(\omega t - Kx) \quad \ldots \quad (4) \end{aligned}$$

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[1] "Coupled Networks in Radio-frequency Circuits." *Proc. I.R.E.*, Feb. 1941, p. 55.

where the constants A_1, A_2, A_3, A_4 depend on the boundary conditions at the end of the wire, and $z_0 = \sqrt{\frac{L}{C}}$.

ωt is the angle of phase change in time t at any point on the wire and Kx is the angle of phase change in length x at any moment. Since $K\lambda = 2\pi$, $K = 2\pi/\lambda$.

In our case if a is the length of the line, $i = 0$ when $x = 0$ and when $x = a$; putting $x = 0$ we have then

$$(A_1 + A_3) \cos \omega t + \left(A_2 + A_4 + \frac{\hat{e}}{Kz_0}\right) \sin \omega t = 0 \qquad (5)$$

This must be true for all values of ωt; if $\omega t = 0$ it becomes

$$A_1 + A_3 = 0 \qquad \ldots \quad \ldots \quad \ldots \quad (6)$$

whereas if $\omega t = \pi/2$ it becomes

$$A_2 + A_4 + \frac{\hat{e}}{Kz_0} = 0 \qquad \ldots \quad \ldots \quad (7)$$

At the other end of the wire $x = a$ and (4) becomes

$$\left(A_1 - \frac{\hat{e}}{2z_0} \cdot \frac{\sin Ka}{K}\right) \cos (\omega t + Ka)$$
$$+ \left(A_2 + \frac{\hat{e}}{2z_0} \frac{\cos Ka}{K}\right) \sin (\omega t + Ka)$$
$$+ \left(A_3 + \frac{\hat{e}}{2z_0} \frac{\sin Ka}{K}\right) \cos (\omega t - Ka)$$
$$+ \left(A_4 + \frac{\hat{e}}{2z_0} \frac{\cos Ka}{K}\right) \sin (\omega t - Ka) = 0 \qquad \ldots \quad \ldots \quad (8)$$

This also must be true for all values of ωt; putting $\omega t = 0$ we have

$$(A_1 + A_3) \cos Ka + (A_2 - A_4) \sin Ka = 0$$

which from (6) reduces to

$$(A_2 - A_4) \sin Ka = 0$$

Hence $A_2 = A_4$ except when $\sin Ka = 0$ $\qquad \ldots \quad \ldots \quad (9)$

Putting $\omega t = \pi/2$ in (8) we have

$$(A_3 - A_1) \sin Ka + \frac{\hat{e}}{Kz_0} \sin^2 Ka$$
$$+ (A_2 + A_4 + \frac{\hat{e}}{Kz_0} \cos Ka) \cos Ka = 0$$

or substituting for $A_2 + A_4$ from (7)

$$A_1 - A_3 = \frac{\hat{e}}{Kz_0} \cdot \frac{1 - \cos Ka}{\sin Ka} \qquad \ldots \quad (10)$$

Hence from (6)

$$A_1 = - A_3 = \frac{\hat{e}}{2Kz_0} \cdot \frac{1 - \cos Ka}{\sin Ka} \qquad (11)$$

and from (7) and (9)

$$A_2 = A_4 = - \frac{\hat{e}}{2Kz_0} \qquad \ldots \quad \ldots \quad (12)$$

If these values of A_1, A_2, A_3 and A_4 are substituted in (4) the formula can be very much simplified, giving finally

$$i = \frac{\hat{e}}{Kz_0} \left[1 - \frac{\cos K\left(x - \frac{a}{2}\right)}{\cos \frac{Ka}{2}} \right] \sin \omega t \qquad \ldots \quad \ldots \quad (13)$$

This enables the current distribution along the wire to be determined. In any calculation of the actual value of the current, the value to be assigned to z_0 might cause some trouble as the values of L and C per cm of length of an isolated wire in space are open to some discussion. We shall confine ourselves, however, to relative values and assume that z_0 is a constant. As the length a of the wire is varied, $\frac{\hat{e}}{Kz_0}$ remains constant, and the relative amplitude of the current along the wire is given by the factor in brackets.

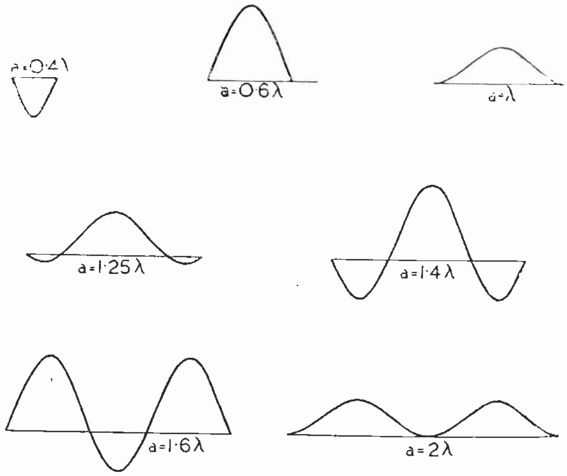

Fig. 2.

If $a = \lambda/2$ or $3\lambda/2$ or any odd number of half wavelengths, $\cos Ka/2 = 0$ and the second term becomes infinitely great (see equation 9). The formula fails then because it is a case of resonance and we have neglected all losses including that due to radiation. This neglect will not seriously affect the amplitude or distribution of the current except in the immediate neighbourhood of resonance.

The distribution has been calculated for seven typical values of a/λ and the results are given in the Table and plotted in Fig. 2. It will be noticed that a phase reversal has occurred between $a = 0.4\lambda$ and 0.6λ, the current in each case being in quadrature with the electromotive force $\hat{e} \cos \omega t$, since in formula (13) the current $i = \hat{e} \sin \omega t$. A positive sign indicates a lagging current. Resonance occurs for $a = 0.5\lambda$ and it is then, of course, that the phase reversal occurs. Another reversal occurs when $a = 1.5\lambda$, as is seen from the curves for $a = 1.4\lambda$ and 1.6λ.

G. W. O. H.

TABLE

$\frac{x}{a}$	a/λ						
	0.4	0.6	1.0	1.25	1.4	1.6	2.0
0	0	0	0	0	0	0	0
0.1	− 0.73	1.2		− 0.41	− 2.0	3.1	
0.125			0.29	− 0.39			1.0
0.2	− 1.36	2.4		0	− 1.84	4.22	
0.25	− 1.31		1.0	0.46			2.0
0.3	− 1.84	3.4		1.0	0.39	2.4	
0.375			1.71			0	1.0
0.4	− 2.14	4.0		2.0	3.1	− 0.75	
0.5	− 2.24	4.22	2.0	2.41	4.22	− 2.24	0

Reduction of Band Width in F.M. Receivers*

By D. A. Bell, M.A., B.Sc.

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SUMMARY.—This paper discusses the possibility of using a high degree of negative feed-back of frequency modulation in the I.F. section of a frequency modulation receiver, for the purpose of (a) minimising the necessary I.F. band width and (b) making the detected output independent of amplitude without the use of an amplitude-limiter in the I.F. amplifier.

1. Introduction

THE benefits of frequency modulation, as compared with amplitude modulation, are considerably increased by using a large frequency swing, as for example ± 75 kc/s; but the use of so wide a band in the receiver has two disadvantages: (i) the I.F. amplifier must have so much wider band width than that appropriate to an A.M. receiver that it is impracticable to use the same frequency, and a completely independent set of I.F. transformers is necessary, (ii) the audio-frequency amplifier must have a definite cut-off at the upper limit of the desired A.F. band, otherwise additional noise components, corresponding to the greater band width, will be present in the A.F. amplifier.

One suggestion for reducing the band width in an F.M. receiver has been disclosed by Nyquist.[1] According to his method, frequency modulated signals are applied to a frequency discriminator circuit having an electrically controlled variable reactance as one of its tuning elements; this circuit is connected to a system of differential rectifiers, etc., whose output controls the variable reactance in such a way that the centre frequency of the circuit always follows up the instantaneous changes of frequency

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

of the applied signal. (In Nyquist's published circuits the variable reactance is a coil with an iron core whose permeability is varied by superimposed D.C. from the control system.) Provided the control system is sufficiently sensitive (or the signal sufficiently strong), the signal is therefore always very close to the centre frequency of the discriminator (i.e. the frequency at which its output passes through zero), so that the frequency is detected by a null method.* Nyquist implied also that as the circuit is retuned to follow frequency changes, its band width need not be sufficient to cover the frequency modulation of the signal, but may be very narrow.

There will then be a current in the controlling circuit just sufficient to shift the centre frequency of the discriminator from its normal value to the frequency of the applied signal, and provided that the variable tuning element has a linear control characteristic, the current in the control circuit will vary linearly with the changes in frequency of the applied signal: a portion of the current in the control circuit may therefore be used as the detected output, representing the frequency modulation of the applied signal. Since it is a null method of detecting the frequency modulation, the output is in principle independent of the amplitude of the applied signal, so that there is no need for a limiter to precede this frequency detector; there will, however, be a second-order effect of the amplitude of the signal, owing to the finite sensitivity of the controlling system, and the magnitude of this will appear below.

Nyquist's published circuits were confined to the case of a receiver in which the frequency discriminator circuit formed the only tunable circuit, a restriction which could not be tolerated in practice. The obvious expedient is to transfer the discriminator to the intermediate-frequency section of a superheterodyne receiver, and instead of varying the tuning of the discriminator, vary the frequency of the local oscillator so as to keep the I.F. signal always on the centre frequency of the discriminator. Here it must be remarked that Chaffee arrived at a system approximating to this from the concept of negative feed-back in frequency modulation[2], but he did not propose approaching the limit at which it becomes a null method of frequency detection, rendering an independent limiter unnecessary, suggesting rather a reduction of the frequency swing to something like 50 per cent. of its original value as a means of reducing receiver distortion and (to a less extent) noise. However, Carson, in a mathematical analysis[3], showed that under suitable conditions this system could be equivalent to a normal limiter plus discriminator receiver in its capabilities of reducing noise and interference.

2. Minimum Band Width Necessary in Discriminator

Whatever band width is sufficient for the single resonant circuit in the arrangements proposed by Nyquist[1] will be sufficient for both discriminator and I.F. amplifier in the superheterodyne arrangement suggested in the last paragraph of Section 1.

It seems certain on general grounds that the necessary band width in the I.F. amplifier cannot be less than the audio-frequency band to be handled, and in a symmetrical system (double side band) will be twice the audio-frequency band width. There are two arguments which indicate the necessary band width more precisely.

According to one argument, the frequency-modulated wave is resolved into an infinite series of side bands, whose amplitude coefficients are Bessel functions and whose frequency differences from the carrier are multiples of the modulation frequency. In order to respond to the frequency modulation, the receiver must accept at least the first pair of side bands (or one of them in a single side band system); but the first side bands are spaced from the carrier by an amount equal to the modulation frequency, and the required acceptance band is therefore equal to twice the audio-frequency band (once in a single side band system).

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* In any null method of measurement, e.g. a Wheatstone bridge, the setting obtained by a simple observation can never be guaranteed to be exactly the null point, but only to differ from it by no more than a detectable amount; similarly, in the frequency following method of indicating frequency changes, there must always be a residual output from the discriminator to operate the controlling system, but this does not invalidate the statement that it operates as a null method of frequency detection.

An alternative line of approach is to suppose that a square wave frequency modulation is applied to the signal, and examine the response of the I.F. amplifier in terms of its time constant. The modulation wave form is shown in Fig. 1, and if one wished to examine the response of the circuit by Heaviside's operational method, one might represent the successive stages in the modulation as follows :—

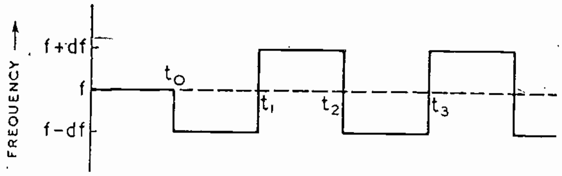

Fig. 1.

(I) For $t < t_0$ the circuit has reached a steady state with applied E.M.F. = $E \sin 2\pi ft$;

(II) At $t = t_0$, apply $-E \sin 2\pi ft$ and $E \sin 2\pi(f - df)t$;

(III) at $t = t_1$, apply $-E \sin 2\pi(f - df)t$ and $E \sin 2\pi(f + df)t$;

and so on for successive reversals. (The negative term at each stage serves to remove the previous frequency, while the positive term introduces the new frequency.)

Now whenever an E.M.F. is applied suddenly to an oscillatory circuit, the response of the circuit contains two components, the transient, which is a damped oscillation at the natural frequency of the oscillatory circuit, and the steady state response at the frequency of the applied E.M.F. ; accordingly, each of the stages (II), (III), etc. of the modulation sets up a damped free oscillation of the tuned circuit. If the total response of the circuit is to be predominantly at the frequency of the applied signal, the transient component must on the average be small compared with the steady state component ; this will only be true if the time constant of the circuit is short compared with the periodicity of reversal of the modulation, which corresponds to the circuit being able to accept a square wave amplitude modulation of that periodicity. The circuit band width is therefore related to the modulation frequency in very much the same way as in amplitude modulation, even if the frequency modulation is very small.

3. Signal Reception by the Frequency Following Method

It was shown in section (1) that by applying an extreme degree of negative feed-back to an F.M. receiver, the discriminator tuning can be arranged to follow very closely the variations of instantaneous frequency of the frequency modulated signal, and such a receiver will be described as a "frequency following" receiver. A schematic diagram of a superheterodyne receiver is shown in Fig. 2, and we have now to examine its working and determine the effect of restricted band width in the I.F. amplifier and discriminator.

The frequency-modulated signal received by the aerial is taken to be

$$E_a \sin\left(\omega t + \frac{k}{f}\sin ft\right)$$

having instantaneous frequency

$$(\omega + k\cos ft)/2\pi$$

where $k/2\pi$ is the frequency excursion for the depth of modulation existing at the time of observation. It will be assumed for the present that the oscillator angular frequency is $\omega + \omega_2 + ak\cos ft$ where $\omega_2/2\pi$ is the intermediate frequency and a is a feed-back factor ; the oscillator voltage is then

$$E_0 \sin\left[(\omega + \omega_2)t + \frac{ak}{f}\sin ft\right]$$

and it is assumed that $E_0 > E_a$. If these two voltages are applied simultaneously to a distortionless multiplicative mixer, the output of the mixer will be

$$E_2{}^1 = (E_0 - E_a)\sin\left[(\omega + \omega_2)\,t + \frac{ak}{f}\sin ft\right] + \frac{E_a}{2}\left\{\cos\left[\omega_2 t - (1 - a)\frac{k}{f}\sin ft\right] - \cos\left[(2\omega + \omega_2)t + (1 + a)\frac{k}{f}\sin ft\right]\right\} \quad \ldots \quad (1)$$

The I.F. amplifier is arranged to accept only a limited band in the neighbourhood of ω_2 so the only effective term is

$$E_2 = \frac{E_a}{2}\cos\left[\omega_2 t - (1 - a)\frac{k}{f}\sin ft\right] \quad \ldots \quad (1a)$$

This represents a frequency modulated wave with the depth of modulation reduced in the ratio $(1 - a) : 1$ compared with the received signal. If the original modulation is complex, and the frequency changer non-linear, it is possible for high-order combinations of side bands to produce additional frequencies near ω_2, but with a reasonably well-designed frequency changer these cross-modulation effects (depending on 4th and higher power terms in the mixer characteristic) will be negligible compared with the conversion conductance at the desired difference frequency, so that there is no appreciable distortion from this cause. The other necessary condition is that the oscillator frequency should vary in linear relation to the voltage applied to it from the discriminator; the reactance-valve frequency modulator is such a well-tried piece of equipment that for the purposes of this paper it may be taken for granted that if the modulating voltage is of the form $\sin ft$, the R.F. oscillation has the desired form $\sin (\omega^1 t + \frac{k^1}{f} \sin ft)$. We have also to ensure that the signal applied to the reactance valve is truly of the form $\sin ft$ and the restriction of the I.F. band width is one of the relevant factors here.

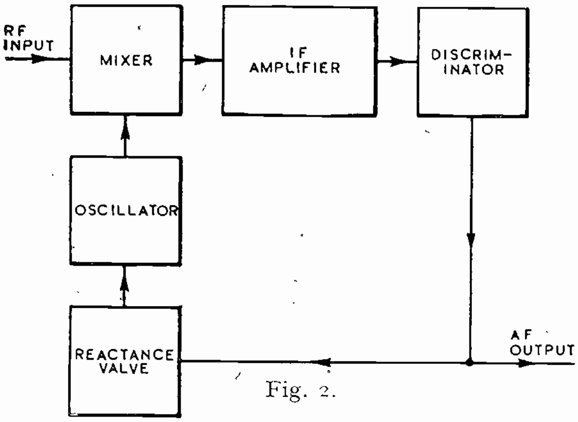

Fig. 2.

The I.F. signal as given by equation (1a) can be expanded in the form of carrier and side bands, the coefficients being Bessel functions as follows:—

$$E_2 = \frac{E_a}{2}\Big\{J_0(x)\cos\omega_2 t + J_1(x)[\cos(\omega_2 - f)t - \cos(\omega_2 + f)t] + J_2(x)[\cos(\omega_2 - 2f)t + \cos(\omega_2 + 2f)t] + \ldots\ldots + J_n(x)[\cos(\omega_2 - nf)t + (-1)^n\cos(\omega_2 + nf)t]\Big\} \quad \ldots \quad (2)$$

For the sake of simplicity, consider a discriminator using only a single frequency selective circuit having the linear characteristic:

$$V = Eh[1 + (\omega_2 - \omega)/f_m] \quad \ldots \quad \ldots \quad (3)$$

where V is the output voltage of the frequency selective circuit, h/f_m its slope constant, $\omega_2 \pm f_m$ the extent of its band width, and E the (constant) applied voltage of angular frequency ω. Then as ω is varied from $\omega_2 + f_m$ to $\omega_2 - f_m$, V varies from 0 to twice the value which it has when $\omega = \omega_2$. According to equation (3), then, the response of the discriminator to the carrier and first side bands of equation (2) is

$$V_1 = \frac{E_a h}{2}\Big\{J_0(x) + J_1(x)(1 + \frac{f}{f_m})\cos(\omega_2 - f)t - J_1(x)(1 - \frac{f}{f_m})\cos(\omega_2 + f)t\Big\} \quad \ldots \quad \ldots \quad (4)$$

The various components of V_1 are shown diagrammatically in Fig. 3. The maximum output will occur when all three vectors are in line, that of frequency $\omega_2 - f$ adding to the carrier and that of $\omega_2 + f$ subtracting, while the minimum output will occur when the two side band vectors are transposed. The peak-peak modulation is therefore

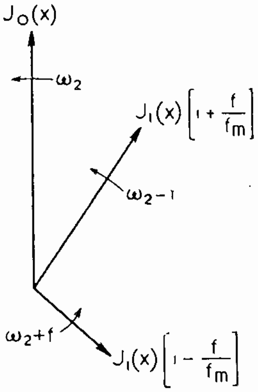

Fig. 3.

$$E_{pp} = \tfrac{1}{2}E_a h\Big\{J_0(x) + \frac{2f}{f_m}J_1(x) - [J_0(x) - \frac{2f}{f_m}J_1(x)]\Big\}$$
$$= \tfrac{1}{2}E_a h\Big\{\frac{4f}{f_m}J_1(x)\Big\} \quad \ldots \quad \ldots \quad (5)$$

Now x is the modulation index, and in the I.F. amplifier of Fig. 2, $x = (1 - a)k/f$, since $(1 - a)k$ is the peak instantaneous frequency change in the I.F. amplifier. But if the carrier frequency had been shifted very slowly by an amount $\pm(1 - a)k = \pm fx$, the peak-peak change in discriminator output would have been

$$\tfrac{1}{2}E_a h\Big\{1 + \frac{f_x}{f_m} - (1 - \frac{f_x}{f_m})\Big\} = \tfrac{1}{2}E_a h\Big\{\frac{2f_x}{f_m}\Big\} \quad (6)$$

Since the definition of shifting the carrier very slowly can only be in terms of the band width of the discriminator, the same result would be obtained by extending the band width of receiver and discriminator indefinitely, and then allowing the frequency modulation to occur at the desired angular frequency f; the difference between equations (5) and (6) therefore represents the loss of signal amplitude due to restricting the received signal to the first pair of side bands. Taking out the common factor $\frac{1}{2}E_a h(2f/f_m)$ comparison can be made between x and $2J_1(x)$; $[2\,J_1(x)]/x$ is plotted against x in Fig. 4 for values of x from 0 to 1. It should be noted that x is the instantaneous frequency shift divided by the modulating frequency; obviously one would not expect to make x greater than unity when the pass band of the receiver is restricted to plus and minus the maximum modulation frequency.

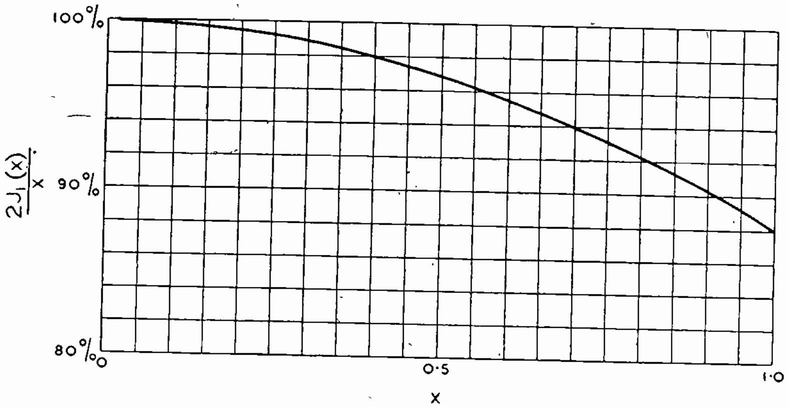

Fig. 4.

The next step is to determine the harmonic distortion, and in order to get an idea of its magnitude, we sum the energy of the *odd* side bands outside the received band, and compare with the energy of *all* side bands inside the received band. (*Even* side bands outside the received band are discarded, because the use of a balanced discriminator will eliminate even harmonic distortion; the energy so excluded is represented by the drop in amplitude of the fundamental.) With maximum frequency modulation, $x = f_m/f$, and at $f_m/f = 3$ the fifth side band has amplitude $J_5(x) = 0.043$. But the 5th harmonic is not audible, and can only produce an audible 3rd harmonic by combination with the 2nd and 8th side-bands; J_8 (3) will be negligible so that the third harmonic will be proportional to $J_5(3) \times J_2(3) = 0.043 \times 0.486 = 0.0209$, say 2.1 per cent. This refers to 100 per cent. modulation; if the modulation is reduced, x decreases proportionately and the harmonic distortion falls away as shown in Fig. 5.

It should be remembered, however, that this is assuming a perfectly-balanced discriminator system. Any unbalance due to asymmetry of circuits or detuning will introduce some 2nd harmonic.

4. Limiting Action

The foregoing section has established that for practical purposes the band width can be restricted so as to accept only the first side bands and that the modulation of both the oscillator voltage and the I.F. can be represented by their instantaneous frequencies. The instantaneous frequencies of the various signals are therefore as follows:—

Received signal aerial:

$$\omega \;+ k \sin ft$$

Oscillator voltage:

$$\omega \;+ \omega_2 + ak \sin ft$$

I.F. Signal:

$$\omega_2 - (1 - a)k \sin ft$$

Let the modulation constant of the local oscillator be μ, so that its frequency is $\omega + \omega_2 + \mu V$ where V is the feed-back voltage applied to it from the discriminator.

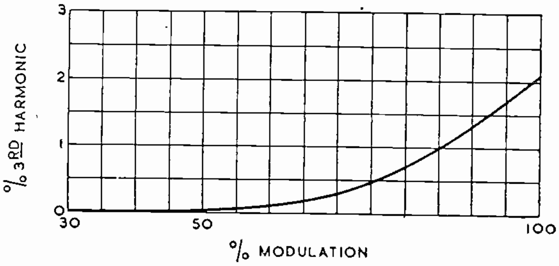

Fig. 5.

Let D be the discriminator constant, so that the output voltage from the discriminator is

$$V = DE_2(1 - a)k \sin ft \quad \ldots \quad \ldots \quad (7)$$

Note that the amplitude E_2 of the I.F. signal appears in this equation, since no limiter is included in the I.F. stages. Substituting this value of V in the expression for the oscillator frequency,

Oscillator frequency

$$= \omega + \omega_2 + \mu DE_2(1 - a)k \sin ft \quad (8)$$

But we already have

Oscillator frequency

$$= \omega + \omega_2 + ak \sin ft \quad \ldots \quad \ldots \quad (9)$$

$$\therefore \quad ak \sin ft = \mu DE_2(1 - a)k \sin ft \quad (10)$$

Solving equation (10) for a,

$$a = \frac{\mu DE_2}{1 + \mu DE_2} \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

It follows that the intermediate frequency is

$$\omega_2 - \left(1 - \frac{\mu DE_2}{1 + \mu DE_2}\right)k \sin ft \quad \ldots \quad (12)$$

and from the discriminator characteristic (7),

$$V = DE_2\left\{1 - \frac{\mu DE_2}{1 + \mu DE_2}\right\}k \sin ft$$

$$= \frac{DE_2}{1 + \mu DE_2}\, k \sin ft \quad \ldots \quad (13)$$

If μDE_2 is large compared with unity,

$$V \doteqdot (1/\mu)k \sin ft \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

From equation (14) it will be seen that under favourable conditions (strong signal at the discriminator), the feed-back voltage is independent of signal strength and of discriminator characteristic, since neither E_2 nor D appear in equation (14); but distortionless output requires that the modulation factor of the local oscillator, μ, shall be constant. The voltage V is then simply proportional to the frequency modulation of the received signal.

It has now been demonstrated that the frequency following receiver gives an output proportional to the instantaneous frequency of the received signal, and independent of its amplitude. It will therefore give all the improvements in signal/interference ratio which are associated with frequency modulation.

5. Other Features of Frequency Following

It has already been implied in the introduction that if the band width of an F.M. signal could be sufficiently reduced in the I.F. stages of the receiver, it would be possible to use the same I.F. amplifier for A.M. and F.M. reception. Another advantage of the "frequency following" scheme is that one could naturally arrange for the automatic frequency adjusting circuit to be effective on slow changes of frequency, as well as on modulation, so as to provide automatic tuning correction, which is especially desirable on a F.M. receiver because it is both more necessary and more difficult to secure accurate tuning of a F.M. than an A.M. receiver. It is more difficult because the receiver band width (in the normal F.M. receiver) is greater, and the energy of a F.M. signal is more uniformly distributed over the band width than that of an A.M. signal. But it is more important, because the comparative immunity of F.M. reception from impulsive interference is dependent on accurate tuning of the receiver to the carrier of the desired signal. In addition, detuning of the receiver may lead to harmonic distortion at high percentage modulation, owing to the instantaneous signal frequency running beyond the discriminator cut-off in one direction.

It is probable also that the limiting action obtained as described in section 4 will be better than that of a conventional overloaded amplifier limiter, in that a greater amplification can be obtained from the valves in the I.F. chain and there is possibly less risk of trouble with blocking effects in D.C. circuits of long time constant.

6. Acknowledgments

The author wishes to thank Mr. L. H. Bedford for his helpful interest in this work, and the Management of A. C. Cossor Ltd. for permission to publish it.

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[2] U.S. Patent No. 2 075 503 and *Proc. I.R.E.*, 1939, Vol. 27, p. 317.

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Harmonic Distortion in Audio-Frequency Transformers—3

By *Norman Partridge, Ph.D., B.Sc.(Eng.), A.M.I.E.E.*

(Part 2 of this article was published in the October, 1942, issue)

THE present section is devoted to a consideration of the influence in practice of the facts set out in Parts 1 and 2 upon audio-frequency transformer technique. The most important deductions are given in the form of theorems and it will be convenient to start at once with the first of these.

Theorem 1. If the frequency and harmonic distortion characteristics are specified, the power handling capacity obtainable by suitable design from audio-frequency transformers of different sizes is directly proportional to their volumes providing the said transformers have the same geometrical proportions, employ the same core material, and are used under similar conditions.

Proof :—Consider a transformer in which the length of the magnetic circuit, the cross sectional area of the core, and the number of primary turns are l, A and N respectively. Let the linear dimensions be multiplied by any constant k. The new parameters become kl, k^2A and N. If the initial ($B_m = 0$) value of the impedance of the first transformer at any selected low frequency were Z, then the new value is :—

$$Z \cdot \frac{k^2A}{A} \cdot \frac{l}{kl} = Z \cdot k$$

But it is required that the frequency response shall not be altered. To secure this at the low frequencies, Z must be restored to its original value by reducing the turns to $\frac{N}{\sqrt{k}}$:—

$$Z \cdot \frac{k^2A}{A} \cdot \frac{l}{kl} \cdot \frac{N^2}{kN^2} = Z$$

This same adjustment to the turns also corrects the response at the high frequencies. The leakage inductance is proportional to the product of the square of the turns and the length of the mean turn (l_t). Hence if L_e were the original value of the leakage inductance :—

$$L_e \cdot \frac{N^2}{kN^2} \cdot \frac{kl_t}{l_t} = L_e$$

The frequency characteristics of the two transformers are therefore identical when $B_m = 0$, i.e. at no load.

The harmonic distortion produced by the first transformer, at any given frequency and applied voltage, will be (by equation 9) :—

$$\Delta'_H = S'_H \cdot \frac{10^9}{8\pi^2} \cdot \frac{l}{N^2A} \cdot \frac{R}{f}\left(1 - \frac{R}{4Z'_f}\right)$$

and that produced by the second design under the same conditions will be :—

$$\Delta''_H = S''_H \cdot \frac{10^9}{8\pi^2} \cdot \frac{k\,(kl)}{N^2(k^2A)} \cdot \frac{R}{f}\left(1 - \frac{R}{4Z''_f}\right)$$

$$= S''_H \cdot \frac{10^9}{8\pi^2} \cdot \frac{l}{N^2A} \cdot \frac{R}{f}\left(1 - \frac{R}{4Z''_f}\right)$$

where S'_H and S''_H are the distortion coefficients of the core material at the appropriate values of B_m, while Z'_f and Z''_f are the impedances of the transformers at these same values of B_m.

It follows that, for the transformers to have identical frequency and harmonic distortion characteristics on load, the peak flux density must be the same in each case thus making $Z'_f = Z''_f$ and $S'_H = S''_H$. This condition ensures that the variation of impedance with load is the same for both transformers, the impedances having already been shown to be identical when $B_m = 0$. The relative terminal voltages required to produce this result are given by the relationship :—

$$\frac{V''}{V'} = \frac{k^2A}{A} \cdot \frac{N}{\sqrt{k}\,.\,N} = \sqrt{k^3}$$

Hence the relative powers handled by the transformers, being proportional to the squares of these voltages, vary directly as k^3

or directly as the volumes of the transformers.

. . . . .

It is evident from equation (9) that the distortion produced by any given transformer operating under stated conditions can be varied by substituting one core material for another. Excluding the effect of the correction factor $(1 - \frac{R}{4Z_f})$, the distortions produced will be proportional to the distortion coefficients of the materials. If the attenuation at the low frequencies is not to be increased, the permeability of the materials selected must be such that the impedance of the transformer is not reduced. A glance at the figures given for the five silicon steels studied in Part 2 will show that the control of distortion by the selection of core material is not likely to provide any considerable scope.

The harmonic distortion produced by a transformer at any one low frequency can always be made as small as one wishes by making the factor l/N^2A sufficiently small (see equations 7 and 9). It should be noted that I_H/I_f, Z_{sp} and S_H are functions of B_m which is itself a function of N and A. Thus in addition to the explicit variation of distortion with N and A shown in equations (7) and (9), there is also an implicit dependence on N and A through the intermediacy of the variable B_m. In other words, changes in N or A will usually result in changes in I_H/I_f, Z_{sp} and S_H.

When the frequency response over a band of frequencies has to be considered it is not possible to reduce the factor l/N^2A indefinitely owing to the necessity of restricting the maximum value of the leakage inductance. As a simple illustration, suppose N to be doubled. Ignoring the effect of this change upon S_H and $(1 - \frac{R}{4Z_f})$, the distortion would be reduced to a quarter of its original value. But the primary inductance, and with it the leakage inductance, would be increased fourfold. Hence doubling the turns has the effect of bodily moving the frequency response curve two octaves towards the bass.

The next two theorems deal with the restraint placed upon the control of harmonic distortion by the necessity of maintaining the frequency characteristic unaltered. For this purpose the attenuation at low frequencies will be defined as that occurring at zero load, i.e. $B_m = 0$.

Theorem 2. If the initial attenuation ($B_m = 0$) at any low frequency is specified, the harmonic distortion produced by an audio-frequency transformer having a closed magnetic circuit cannot be controlled directly by modifying N, A or l (other conditions remaining unchanged) but only indirectly thereby through the intermediacy of the variable B_m.

Proof:—The initial attenuation caused by a transformer having a closed magnetic circuit at any low frequency is a function of l/N^2A for any one core material. Hence this factor must be constant for all such transformers producing identical attenuations.

Consider two transformers in which the parameters are N_1, A_1, l_1 and N_2, A_2, l_2, such that $l_1/N_1^2 A_1 = l_2/N_2^2 A_2$. The harmonic distortions produced by these transformers will be (by equation 9):—

$$\Delta'_H = S'_H \,.\, C \,.\left(1 - \frac{R}{4Z'_f}\right)$$

and $$\Delta''_H = S''_H \,.\, C \,.\left(1 - \frac{R}{4Z''_f}\right)$$

where $$C = \frac{10^9}{8\pi^2} \cdot \frac{l_1}{N_1^2 A_1} \cdot \frac{R}{f}$$

$$= \frac{10^9}{8\pi^2} \cdot \frac{l_2}{N_2^2 A_2} \cdot \frac{R}{f}$$

Hence the distortion is not directly influenced by the particular set of values chosen for N, A and l, but is dependent upon resultant changes in S_H and Z_f.

These changes in S_H and Z_f depend in turn upon the change in B_m brought about by the new values assigned to N and A. If B'_m and B''_m be the peak flux densities attained in the cores of the above-mentioned transformers:—

$$B''_m = B'_m \cdot \frac{N_1}{N_2} \cdot \frac{A_1}{A_2}$$

therefore

$$B''_m \cdot \frac{N_1}{N_2} \cdot \frac{l_2}{l_1} = B'_m \cdot \frac{N_1^2 A_1}{l_1} \cdot \frac{l_2}{N_2^2 A_2}$$

and $$B'_m = B''_m \cdot \frac{N_1}{N_2} \cdot \frac{l_2}{l_1}$$

Hence it is possible to vary B_m without violating the condition that l/N^2A shall remain constant. But the corresponding changes in S_H and Z_f will depend upon which portions of the $S_H - B_m$ and $Z_{sp} - B_m$ curves are in question (see Figs. 8 and 9). A reduction in the peak flux density may produce an increase, a decrease or even no change at all in either S_H or Z_f. It will be remembered that R/Z_f is limited to values between 0 and 1, and therefore the factor $(1 - \frac{R}{4Z_f})$ must always be between 1 and 0.75.

. . . .

Theorem 3. If the frequency characteristic ($B_m = 0$) and the maximum power are specified, the peak value of the harmonic distortion produced by an audio-frequency transformer at any one low frequency cannot be reduced by modifying the size of the transformer (the geometrical proportions being unaltered) or by modifying the number of primary turns, so long as the peak flux density at the stated frequency and power remains higher than that at which the maximum distortion occurs.

Preamble :—Fig. 13 shows a common form of the curve connecting transformer distortion with peak flux density at constant frequency. This curve approximates to the $S_H - B_m$ curve, but departs from it on account of the factor $(1 - \frac{R}{4Z_f})$. It will be seen that if the peak flux density at maximum load falls between ϕ_1 and ϕ_2, say at ϕ_x for example, the peak distortion will occur at some loading less than the maximum, namely when $B_m = \phi_1$. For any reduction in this peak value of the distortion by modifications in accordance with the terms of the theorem, it is contended that the new peak flux density at the maximum load (ϕ_x) must be made less than ϕ_1.

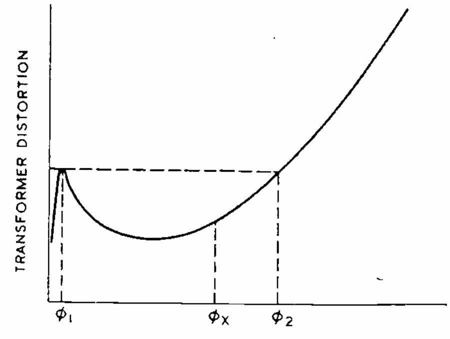

Fig. 13.—*Typical form of transformer distortion curve at a constant low frequency. This follows the S_H–B_m curve when R/Z_f approximates to unity.*

Proof :—Consider a transformer having the parameters l, A and N. Let the linear dimensions be multiplied by a factor k. Then, from the proofs to Theorems 1 and 2, for the same frequency characteristic the new parameters will be kl, k^2A and $N/\sqrt{k}$ and the distortions produced by the two transformers will be :—

$$\Delta'_H = S'_H \,.\, C \,.\left(1 - \frac{R}{4Z'_f}\right)$$

and $$\Delta''_H = S''_H \,.\, C \,.\left(1 - \frac{R}{4Z''_f}\right)$$

these distortions being identical at any one value of the peak flux density.

Let B_m be the peak flux density in the core of the smaller transformer when it is delivering the specified maximum power at any chosen low frequency. The peak flux density in the core of the larger transformer, when operating under identical conditions of load, will be :—

$$B_m \cdot \frac{A}{k^2A} \cdot \frac{\sqrt{k}\,.\,N}{N} = \frac{B_m}{\sqrt{k^3}}$$

The whole of the distortion-load characteristic below this flux density ($B_m/\sqrt{k^3}$) is evidently common to both transformers. Therefore if the maximum distortion occurs within this portion of the curve it, also, will be common to both transformers. Hence no reduction in this maximum distortion can be brought about unless the flux density at full load in the larger transformer ($B_m/\sqrt{k^3} = \phi_x$ Fig. 13) is made less than the flux density at which the maximum distortion occurs in the smaller transformer ($= \phi_1$, Fig. 13).

. . . . . .

In many instances the foregoing is tantamount to stating that harmonic distortion cannot be reduced by increased size alone. As an example of this it has been calculated that to lessen the peak distortion produced at 50 c/s by a standard 12-watt output transformer manufactured by the author, the overall dimensions would have to be increased from approximately $3\frac{1}{2}$in. cubed to 5ft. 5in. cubed and the weight from $4\frac{1}{2}$ lbs. to 16 tons!

It is, of course, possible to circumvent this prodigious employment of material by modifications outside the terms of the theorem. For example, the factor l/N^2A can be increased and the response at high frequencies restored by modifying the coil design and thus improving the coupling between primary and secondary. But a limit is soon reached beyond which this procedure becomes impracticable.

There usually remains some form of limitation upon the possible values that may be assigned to N, A and l even when a transformer has to operate only at one low frequency. The most important in practice arises from the necessity of keeping the resistances of the windings reasonably low. The effect of this in combination with the characteristic shape of the $S_H - B_m$ curve indicated in Fig. 13 is the subject of the next theorem. The proof of this theorem does not take into account the effect of the factor $(1 - \frac{R}{4Z_f})$, but since this cannot exceed the limits of 1 and 0.75 its omission does not invalidate the practical significance of the statement.

Theorem 4. If the resistances of the windings and the maximum power are specified, the peak value of the harmonic distortion produced at any given low frequency by audio-frequency transformers of different sizes but having the same geometrical proportions and core material will vary inversely as the square of the linear dimensions so long as the maximum flux density at the given frequency remains above that at which the peak distortion occurs in the case of the smallest transformer.

Proof :—Consider a transformer in which the number of primary turns, the length of the mean turn, and the cross sectional area of the wire are N, l_r and a. Let the linear dimensions of the transformer be increased by a factor k making the new values N, kl_r and k^2a. If the resistance of the original winding was r, the new resistance will be :—

$$r \cdot \frac{kl_r}{l_r} \cdot \frac{a}{k^2a} = \frac{r}{k}$$

But it is required that the resistance shall be unaltered. This result can be achieved in the same winding space by increasing the turns to $\sqrt{k} \, . \, N$ and reducing the wire area to $k^2a/\sqrt{k}$. The resistance then becomes :—

$$r \cdot \frac{kl_r}{l_r} \cdot \frac{\sqrt{k} \, . \, a}{k^2 \, . \, a} \cdot \frac{\sqrt{k} \, . \, N}{N} = r$$

Ignoring the effect of the correction factor $(1 - \frac{R}{4Z_f})$, the distortions produced by the smaller and the larger transformers respectively will be :—

$$\Delta'_H = S'_H \cdot \frac{10^9}{8\pi^2} \cdot \frac{l}{N^2A} \cdot \frac{R}{f}$$

and $$\Delta''_H = S''_H \cdot \frac{10^9}{8\pi^2} \cdot \frac{kl}{(kN^2)(k^2A)} \cdot \frac{R}{f}$$

$$= \frac{\Delta'_H}{k^2}$$

If B_m be the peak flux density in the core of the smaller transformer when delivering the stated maximum power at any chosen low frequency, the corresponding peak flux density in the core of the larger transformer will be :—

$$B_m \cdot \frac{A}{k^2 \, . \, A} \cdot \frac{N}{\sqrt{k} \, . \, N} = \frac{B_m}{\sqrt{k^5}}$$

So long as this new flux density remains above that at which the peak distortion occurs in the smaller transformer, the corresponding peak value of the distortion coefficient (S_H) will be common to both equations above. Hence the ratio of the maximum distortions produced by the transformers is k^2 which is the reciprocal of the ratio of the squares of the linear dimensions.

. . . .

It is well known that an air gap in the magnetic circuit of a transformer improves the linearity of the impedance. But this improvement in the linearity does not result in a reduction in the voltage distortion produced by the transformer.

Theorem 5. No useful reduction in the magnitude of the harmonic distortion produced by an audio-frequency transformer due to the non-linear characteristics of the core material can be effected by the introduction and/or adjustment of an air gap in the magnetic circuit of the transformer providing the dimensions of the said air gap are kept within practical limits and the hysteresis loop is not displaced.

Preamble :—A " useful reduction " in the distortion is one that will enhance the performance of the transformer in practice. The use of this expression in the theorem implies that minor variations of no practical importance can be brought about.

The "practical limit" to the length of an air gap is the point at which a further increase would cause the attenuation at the considered frequency to be appreciably increased owing to the lowering of the impedance of the transformer.

The hysteresis loop will not be displaced providing the polarising field strength (H_{DC}) experienced by the core material remains unchanged. Thus the theorem is applicable to all transformers functioning in the normal cyclic condition. But it will not apply to transformers carrying a polarising current unless this current is readjusted after each change of air gap.

The rigid proof of this theorem which takes account of all factors involved is too long to be given here. The following is therefore an abbreviated version.

Proof:—The harmonic distortion produced by a transformer having a closed magnetic circuit has been shown by equation (2) to be :—

$$\frac{V_h}{V_f} = -\frac{I_h}{I_f}\cdot\frac{Z}{Z_f}$$

$$= -\frac{I_h}{I_f}\cdot\frac{I_f}{V_f}\cdot Z$$

since $$Z_f = \frac{V_f}{I_f}$$

The effect of introducing an air gap into the magnetic circuit will be to increase the magnetising current at the fundamental frequency by an amount necessary to maintain the flux in the gap. The harmonic current on the other hand will remain unaffected since the flux wave-form is substantially undistorted. Let the new current at the fundamental frequency be I_f'. The distortion will now be :—

$$\frac{V_h'}{V_f} = -\frac{I_h}{I_f'}\cdot\frac{I_f'}{V_f}\cdot Z$$

$$= -\frac{I_h}{V_f}\cdot Z$$

$$= -\frac{I_h}{I_f}\cdot\frac{Z}{Z_f} \quad \text{as before}$$

since $$V_f = I_f Z_f$$

In other words, a gap improves the linearity of the impedance by reducing I_h/I_f. But the gap also reduces the impedance (Z_f) in exactly the same proportion and therefore the distortion, which varies as the product of I_h/I_f and $1/Z_f$, remains unchanged.

. . . .

The use of an air gap to improve the inductance of a choke or transformer carrying D.C. is well known. As a result of the foregoing theorem it is possible to apply the data given in Part 2 to such components. It has been shown that the distortion produced by a gapped transformer is substantially the same as that produced by a non-gapped transformer in which the magnetic conditions within the core material are the same. Hence the presence of a gap will not in any way influence the method of calculating the harmonic distortion that will be produced.

The procedure is briefly as follows. The strength of the polarising field must be calculated by known methods from a knowledge of the transformer design data and the D.C. carried by its windings. The appropriate distortion coefficient is thus determined and its value can be taken from curves such as those in Fig. 10. Equation (9) can then be used as in the case of non-gapped components. Alternatively, if it is preferred to work in terms of the current distortion and the relative specific choke impedance, the appropriate values applicable to the polarised condition can be taken from suitable curves (see Figs. 11 and 12) and substituted in equation (7). But it is important to understand that the current distortion and the transformer impedance as obtained in the manner just described will not be the true current distortion and impedance of the gapped transformer. They will be those of a similar non-gapped transformer in which the core material is operating under identical conditions of polarisation and alternating flux density. The presence of the gap will cause both the current distortion and the impedance to be considerably less than those relating to a non-gapped transformer (H_{DC} remaining constant). But, as proved above, the transformer distortion will be approximately the same for both components.

Notes on Tracking Circuits*

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SUMMARY AND INTRODUCTION.—Two resonant circuits are said to "track" if they are tuned by the same mechanical movement and if they show a constant difference in their resonant frequencies throughout the tuning range. Circuits having this property are used for the signal and oscillator circuits of modern superhet receivers and modern design practice requires in addition that the variable tuning elements in both circuits are identical.

In addition to this "ordinary" type of tracking or "tracking with constant difference of frequency" we can think of other types of tracking, and one of the problems touched in the following notes deals with "tracking with constant difference of wavelength."

Section 1 of the notes shows how the principle of duality can be used to derive design formulae for systems with variable inductances from design formulae with variable capacities, of which a large number are published. A convenient set of formulae is given as a specific example.

Section 2 shows how a similar circuit transformation can be used in order to derive circuits which track with constant difference of wavelengrh from circuits which track with constant difference of frequency.

Section 3 finally gives a formula which allows an easy calculation of the "error curve" which is applicable to all of the preceding tracking schemes. (The error curve gives the deviation of the actual difference in resonant frequency or wavelength from the required difference; this difference can be made zero in the usual tracking schemes only at a finite number of positions—usually three—in the tuning range.)

This formula requires only a knowledge of the three tracking frequencies (or wavelengths) and allows thus an adjustment of the error curve in order to meet specific requirements without having first to calculate the circuit constant. The formula is a generalisation and adaptation of a formula previously published by Wald.†

1. Use of the Principle of Duality for the Derivation of Design Formulae for Inductance-tuned Systems

As the design problem for circuits using variable capacitances as tuning elements has been dealt with in numerous publications[1] it seems useful to show how these results can be applied to circuits using a variable inductance as tuning element.

Suppose we construct an image of the system with a variable capacitance in the following way: we replace

an inductance of a henries	by a capacitance of $K . a$ farads (K being a suitably selected constant), .. (1.1)
a capacitance of b farad	by an inductance of $\frac{b}{K}$ henries, .. (1.2)
a parallel connection of 2 elements	by a series connection of the corresponding 2 elements;

the operating frequency ω remains unchanged.

We see then the following taking place in the change over from the original to the image circuit: if the original circuit contained an inductance of a henries, with an impedance $Z_L = ja\omega$, then the image circuit circuit contains a capacity with an admittance

$$Y'_C = jKa\omega = K . Z_L \quad .. \quad .. \quad (1.3a)$$

Similarly, if the original circuit contained a capacity with an impedance $Z_C = 1/jb\omega$, then the image circuit contains an inductance with the admittance

$$Y'_L = K/jb\omega = K . Z_C \quad .. \quad .. \quad (1.3b)$$

Thus, each impedance of the original circuit is replaced by an admittance of proportional size $Y' = KZ$ .. .. (1.4)

Furthermore, wherever in the original circuit two impedances are connected in series and "add up" according to

$$Z = Z_1 + Z_2 \quad .. \quad .. \quad .. \quad (1.5)$$

then we have in the image circuit two

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† *Wireless Engineer*, Vol. 17, p. 105.

[1] For the latest contributions to this field see two papers by A. L. Greene and R. Payne Scott, "Superheterodyne Tracking Charts," first published in *A.W.A. Technical Review*, Vol. 5, 1941, pp. 77–91 and 251–274, and reprinted in *Wireless Engineer*, 1942, pp. 243–250 and 290–302. These papers, notably the first one, contain also an extensive bibliography.

admittances $Y'_1 = KZ_1$ and $Y'_2 = KZ_2$ which add up to

$$Y' = Y'_1 + Y'_2 = KZ_1 + KZ_2 = K\,.\,Z \quad \ldots \quad \ldots \quad (1.6)$$

And conversely, if we have in the original circuit two impedances Z_1 and Z_2 connected in parallel, so that their combined impedance is given by

$$1/Z = 1/Z_1 + 1/Z_2 \quad \ldots \quad \ldots \quad (1.7)$$

then the corresponding elements are connected in series and have a combined admittance of

$$\frac{1}{Y'} = \frac{1}{Y'_1} + \frac{1}{Y'_2} = \frac{1}{KZ_1} + \frac{1}{KZ_2} = \frac{1}{KZ} \quad \ldots \quad \ldots \quad (1.8)$$

Thus the operations of series or parallel combination leave unchanged the relationship already established for the impedance elements: $Y' = K\,.\,Z$, and as every impedance (admittance) between two points of a network can be calculated as the result of a suitable number of series or parallel combinations of impedances (admittances), we see that any result which we may have obtained for the original circuit in terms of impedances will be valid in terms of corresponding admittances for the image circuit (and vice versa).

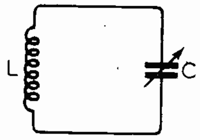


Fig. 1.

Suppose we have in the original circuit a generator connected across the tuning condenser. The circuit will then be resonant at those frequencies at which the impedance offered to this generator is infinite. In the image circuit we have then a generator connected in series with the corresponding tuning inductance—and from what has just been said about the correspondence of impedances and admittances— it follows that this generator will "look" at the same frequency into an infinite admittance, i.e. it will find again a resonant response. In short, the resonant frequencies of original system and image system are identical, and, if the original system consisted of two circuits in tracking condition, the image system will again consist of two circuits in tracking condition. However, due to the change over from capacitances to inductances and vice versa, we have achieved the desired change in the variable tuning element.[2]

As an example we take the capacitance tuned circuits which are treated by Terman, in *Radio Engineering*, p. 563 of the 2nd Edition.

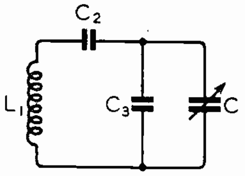
According to this we have the following solutions, in terms of auxiliary constants, which are explained later.

Case (a) Trimmer capacitance in parallel to the tuning condenser:

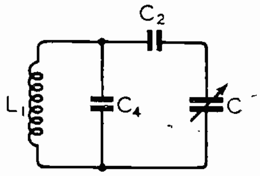
$$C_2 = C_0 f_0^2 \left(\frac{1}{n^2} - \frac{1}{l^2}\right) \quad \ldots \quad \ldots \quad (1.9)$$

$$C_3 = \frac{C_0 f_0^2}{l^2} \quad \ldots \quad \ldots \quad \ldots \quad (1.10)$$

$$L_1 = L\left(\frac{l}{m}\right)^2 \left(\frac{C_2 + C_3}{C_2}\right) \quad \ldots \quad \ldots \quad (1.11)$$



Case (a)
Fig. 2.



Case (b)
Fig. 3.

Case (b) Trimmer capacitance in parallel to the coil:

$$C_2 = C_0 \frac{f_0^2}{n^2} \quad \ldots \quad \ldots \quad \ldots \quad (1.12)$$

$$C_4 = \frac{C_0 f_0^2}{l^2 - n^2} \quad \ldots \quad \ldots \quad \ldots \quad (1.13)$$

$$L_1 = L\left(\frac{l}{m}\right)^2 \left(\frac{C_2}{C_2 + C_4}\right) \quad \ldots \quad (1.14)$$

The constants occurring in these formulae are defined as follows:

f_0	intermediate frequency
F_1, F_2, F_3	frequencies at which exact tracking is required

$$a = F_1 + F_2 + F_3 \quad \ldots \quad \ldots \quad (1.15)$$

$$b^2 = F_1F_2 + F_2F_3 + F_1F_3 \quad \ldots \quad (1.16)$$

$$c^3 = F_1F_2F_3 \quad \ldots \quad \ldots \quad \ldots \quad (1.17)$$

$$d = a + 2f_0 \quad \ldots \quad \ldots \quad \ldots \quad (1.18)$$

---

[2] The value of K is thereby immaterial; it controls only the impedance level of the image system.

$$l^2 = (b^2d - c^3)/2f_0 \quad \ldots \quad \ldots \quad (1.19)$$

$$m^2 = l^2 + f_0^2 + ad - b^2 \quad \ldots \quad (1.20)$$

$$n^2 = (c^3d + f_0^2l^2)/m^2 \quad \ldots \quad \ldots \quad (1.21)$$

C_0 = capacitance required to tune L to f_0.

From these solutions we can construct the following dual images:

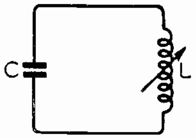
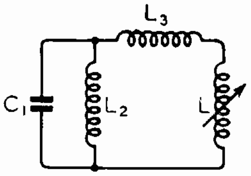
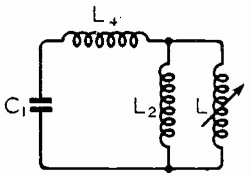


Fig. 4.



Case (a)
Fig. 5.



Case (b)
Fig. 6.

Case (a): Trimmer coil in series with tuning coil

$$L_2 = L_0f_0^2\left(\frac{1}{n^2} - \frac{1}{l^2}\right) \quad \ldots \quad \ldots \quad (1.22)$$

$$L_3 = \frac{L_0f_0^2}{l^2} \quad \ldots \quad \ldots \quad \ldots \quad (1.23)$$

$$C_1 = C\left(\frac{l}{m}\right)^2\left(\frac{L_2 + L_3}{L_2}\right) \quad \ldots \quad (1.24)$$

Case (b): Trimmer coil in series with tuning capacitance

$$L_2 = L_0\frac{f_0^2}{n^2} \quad \ldots \quad \ldots \quad \ldots \quad (1.25)$$

$$L_4 = \frac{L_0f_0^2}{l^2 - n^2} \quad \ldots \quad \ldots \quad \ldots \quad (1.26)$$

$$C_1 = C\left(\frac{l}{m}\right)^2\left(\frac{L_2}{L_2 + L_4}\right) \ldots \quad \ldots \quad (1.27)$$

where the constants are calculated from the tracking frequencies in the same way as before, except that now

L_0 = inductance required to tune C to f_0.

In the practical application of these formulae there is one point to be considered: In the capacitance tuned case, by taking the solution (b), we can make the self-capacitance of the inductance part of the capacitance C_4, and thus we can adhere closely to the theoretical solution. There is no corresponding dual step in the inductance tuned case, and therefore the self-capacitance of the inductance tuner, varying over the tuning range may make it necessary to correct the solution thus obtained.

2. Derivation of Circuits which Track with Constant Difference of Wavelength from Circuits which Track with Constant Difference of Frequency

In order to achieve tracking with constant difference of wavelength we proceed as follows:

We construct to a pair of circuits which track with constant difference of frequency "images" according to the following rules: We replace

an inductance of a henries	by a capacitance of $a' = \frac{K_2}{a}$ farad, (2.1)
a capacitance of b farad	by an inductance of $b' = \frac{K_2}{b}$ henries, (2.2)
the series combination of 2 elements	by the series combination of the corresponding 2 elements,
the parallel combination of 2 elements	by the parallel combination of the corresponding 2 elements,
the operating frequency ω	by the operating frequency $\omega' = \frac{K_1}{\omega}$. .. .. (2.3)

K_1 and K_2 are chosen so as to fulfil the condition: $K_1 . K_2 = 1$. .. .. (2.4)

In these circumstances the impedance of, say, an inductance a in the original circuit $Z_L = ja\omega$ is replaced in the image circuit (at the image frequency) by

$$Z'_C = \frac{1}{ja'\omega'} = -j\frac{a}{K_2}\frac{\omega}{K_1} = -Z_L \quad (2.5)$$

Similarly the impedance of a condenser $Z_C = 1/jb\omega$ in the original circuit is replaced in the image by

$$Z'_L = jb'\omega' = j\frac{K_2}{b}\frac{K_1}{\omega} = -Z_C \ldots \quad (2.6)$$

Thus, the absolute values of the impedances remain unchanged.

If the original circuits were resonant (i.e. possessed infinite impedance) at the frequencies ω and $\omega_1 = \omega + \omega_0$ then the image circuits will be resonant at the image frequencies

$$\omega' = \frac{K_1}{\omega} \text{ and } \omega'_1 = \frac{K_1}{\omega + \omega_0} \quad \ldots \quad (2.7)$$

In terms of wavelength instead of frequencies we get

$$\lambda' = \frac{2\pi V}{\omega'} = \frac{2\pi V}{K_1} \cdot \omega$$

(V = velocity of el.-magn. waves)

$$\lambda'_1 = \frac{2\pi V}{\omega'_1} = \frac{2\pi V}{K_1} \omega_1 = \frac{2\pi V}{K_1} (\omega + \omega_0) \quad \ldots \quad \ldots \quad (2.8)$$

The difference in wavelength, λ'_0, is

$$\lambda'_0 = \lambda'_1 - \lambda_1 = \frac{2\pi V}{K_1} \omega_0 = \text{const.} \quad (2.9)$$

It will be noticed that ω_0 and the angular frequency ω'_0 which is associated with λ'_0 according to $\omega'_0 \lambda'_0 = 2\pi V$ again fulfil the condition (2.3)

$$\omega_0 \cdot \omega'_0 = \omega_0 \frac{2\pi V}{\lambda'_0} = K_1 \quad \ldots \quad \ldots \quad (2.10)$$

To give an example we will apply this theory to the design formulae used in the previous section.

Suppose two capacitance tuned circuits are wanted which track with constant difference of wavelength and which give zero tracking error at the wavelengths λ'_1, λ'_2, λ'_3, (all quantities relating to these circuits being denoted by "dashed" signs).

The circuits desired are of the type shown in Figs. 1 and 2 of Section 1 (the quantities L, C and so on appearing henceforth as L', C' according to the convention just introduced).

The image circuits to these, which tune with constant difference of frequency, are then of the type shown in Fig. 4 and Fig. 6 and the "tracking frequencies" for these will be

$$F_1 = \frac{\omega_1}{2\pi} = \frac{1}{2\pi} \frac{K_1}{\omega'_1} = \frac{K_1}{4\pi^2 V} \lambda'_1 = \alpha\lambda'_1$$
$$F_2 = \alpha\lambda'_2 \qquad F_3 = \alpha\lambda'_3 \quad \ldots \quad \ldots \quad (2.11)$$

The constants of the image circuits are related to those of the wanted circuits by the relations (2.1) and (2.2); thus,

$$L'C = C'L = L'_1 C_1 = C'_2 L_4 = C'_3 L_2 = K_2 \quad \ldots \quad \ldots \quad (2.12)$$

The tracking frequencies being known, we are able to calculate the auxiliary coefficients a, b^2, c^3, etc. according to the equations 1.15–1.21 and from this the constants of the image circuits. Equation 2.12 enables us to retranslate the results into the constants of the desired circuits. If we carry through these steps in general terms we are led to design formulae for the wanted circuits and we will find that these can be given a form similar to those used for the design of the image circuits.

The constants of the image circuits are given (equations 1.25–1.29) in terms of an inductance L_0 which resonates with the fixed capacitance C at the frequency f_0. Similarly we will express the wanted constants in terms of a capacitance C'_0 which resonate with the fixed inductance at the wavelength λ'_0.

This C'_0 is related to L_0 by our general correspondence relation

$$C'_0 L_0 = K_2 \quad \ldots \quad \ldots \quad \ldots \quad (2.12a)$$

(To prove this equation we have only to multiply the two equations $\omega_0{}^2 L_0 C = 1$ and $\omega'_0{}^2 C'_0 L' = 1$ and take account of equations 2.10 and 2.12.)

Further to this we will find it useful to introduce the following auxiliary quantities, in strict analogy to equations 1.15–1.21.

$$a'_1 = \lambda'_1 + \lambda'_2 + \lambda'_3 \quad \ldots \quad \ldots \quad (2.13)$$
$$b'^2 = \lambda'_1\lambda'_2 + \lambda'_1\lambda'_3 + \lambda'_2\lambda'_3 \quad \ldots \quad (2.14)$$
$$c'^3 = \lambda'_1\lambda'_2\lambda'_3 \quad \ldots \quad \ldots \quad \ldots \quad (2.15)$$
$$d' = a' + 2\lambda'_0 \quad \ldots \quad \ldots \quad \ldots \quad (2.16)$$
$$l'^2 = (b'^2 d' - c'^3)/2\lambda'_0 \quad \ldots \quad \ldots \quad (2.17)$$
$$m'^2 = l'^2 + \lambda'_0{}^2 + a'd' - b'^2 \quad \ldots \quad (2.18)$$
$$n'^2 = (c'^3 d + \lambda'_0{}^2 l'^2)/m'^2 \quad \ldots \quad (2.19)$$

On account of equation (2.11) these coefficients stand in a very simple relation to the corresponding "undashed" coefficients defined by the equations 1.15–1.21, namely

$$a = F_1 + F_2 + F_3 = \alpha a'$$
$$b'^2 = \alpha^2 b^2$$
$$c'^3 = \alpha^3 c^3 \quad \ldots \quad \ldots \quad \ldots \quad (2.20)$$

and so on.

Following these preliminary steps we get the following final results

$$C'_2 = \frac{K_2}{L_4} = \frac{K_2}{L_0}\cdot\frac{l^2 - n^2}{f_0^2} = C'_0\frac{l'^2 - n'^2}{f'^2_0} \qquad (2.21)$$

$$C'_3 = \frac{K_2}{L_2} = \frac{K_2}{L_0}\frac{n^2}{f_0^2} = C'_0\cdot\frac{n'^2}{f'^2_0} \qquad (2.22)$$

$$L'_1 = \frac{K_2}{C_1} = \frac{K_2}{C}\left(\frac{m}{l}\right)^2\left(\frac{L_2 + L_4}{L_2}\right)$$

$$= L'\left(\frac{m'}{l'}\right)^2\frac{K_2/C'_3 + K_2/C'_2}{K_2/C'_3}$$

$$= L'\left(\frac{m'}{l'}\right)^2\left(\frac{C'_2 + C'_3}{C'_2}\right) \qquad (2.23)$$

If we had aimed at a circuit as shown in Fig. 3, the image circuit would have been of the type shown in Fig. 5 with the design formulae as given in equations 1.22–1.24. These give then, retranslated, the design formulae

$$C'_4 = \frac{K_2}{L_2} = C'_0\frac{\frac{1}{n'^2} - \frac{1}{l'^2}}{f'^2_0} \qquad (2.24)$$

$$C'_2 = \frac{K_2}{L_3} = C'_0\frac{l'^2}{f'^2_0} \qquad (2.25)$$

$$L'_1 = \frac{K_2}{C_1} = L'\left(\frac{m'}{l'}\right)^2\left(\frac{C'_2}{C'_2 + C'_4}\right) \qquad (2.26)$$

In the same way, if the desired circuits are inductance-tuned according to the type of Figs. 4 and 5 we get the design formulae (image circuit as shown in Figs. 1 and 3)

$$L'_2 = \frac{K_2}{C_4} = L'_0\frac{l'^2 - n'^2}{f'^2_0} \qquad (2.27)$$

$$L'_3 = \frac{K_2}{C_2} = L'_0\frac{n'^2}{f'^2_0} \qquad (2.28)$$

$$C'_1 = \frac{K_2}{L_1} = C'\left(\frac{m'}{l'}\right)^2\left(\frac{L'_2 + L'_3}{L'_2}\right) \qquad (2.29)$$

and finally for circuits of the type shown in Fig. 6 (image Fig. 2)

$$L'_2 = \frac{K_2}{C_3} = L'_0\frac{l'^2}{f'^2_0} \qquad (2.30)$$

$$L'_4 = \frac{K_2}{C_2} = L'_0\frac{1}{f'^2_0\left(\frac{1}{n'^2} - \frac{1}{l'^2}\right)} \qquad (2.31)$$

$$C'_1 = \frac{K_2}{L_1} = C'\left(\frac{m'}{l'}\right)^2\left(\frac{L'_2}{L'_2 + L'_4}\right) \qquad (2.32)$$

3. Calculation of the Error Curve from a Knowledge of the Three Tracking Positions

The circuits described in Section 1 are specialisations of the circuits shown in Figs. 7 and 8.

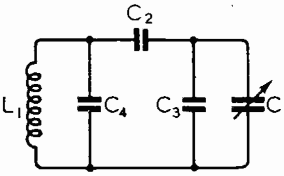


Fig. 7

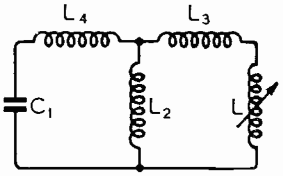


Fig. 8

We obtain these circuits which were marked "case (a)" by putting C_4 or L_4 equal to zero. Similarly the circuits marked "case (b)" are obtained by putting C_3 or L_3 equal to zero.

The circuits described in Section 2 are obtained by appropriate corresponding specialisations from the circuits shown in Figs. 9 and 10.[3]

It will be shown later in this section that circuits of these rather general types give the required tracking difference in frequency or wavelength exactly only at three positions of the tuning range (at the best). Over the rest of the tuning range there will be a "tracking error."

This error can be conveniently calculated from the following expressions, which contain only the values (in frequency or wavelength) at which the tracking error is zero (the "tracking frequencies" or the "tracking wavelengths") and two more constants already defined in Sections 1 and 2 by the aid of the same tracking positions.

These expressions are :—

(a) for tracking with constant frequency difference :

---

[3] These specialisations (L'_4, C'_4, L'_3, or $C'_3 \rightarrow \infty$) lead to a set of circuits in which some of the components have denominations different from those used in Section 2. Had we used these "logical" denominations the asymmetry in the indices encountered in eqn. (2.12) would not have occurred. On the other hand, we would have been compelled to rewrite eqns. 1.9–1.14 and 1.22–1.27 which we used for the calculation of the image circuits to suit the new denominations.

$$\Delta f = \frac{(f+d)}{2f_1(f^2+l^2)}(f-F_1)(f-F_2)(f-F_3)$$

$$\approx \frac{(f+d)}{2f_1(f_m^2+l^2)}(f-F_1)(f-F_2)(f-F_3) \quad \ldots \quad \ldots \quad (3.1)$$

where F_1, F_2, F_3 are the tracking frequencies f_m, a mean value of f and d and l are defined by equations 1.18 and 1.19.

(b) for tracking with constant difference of wavelength:

$$\Delta\lambda' = \frac{(\lambda'+d')}{2\lambda'_1(\lambda'^2+l'^2)}(\lambda'-\lambda_1)(\lambda'-\lambda_2)(\lambda'-\lambda_3)$$

$$\approx \frac{(\lambda'+d')}{2\lambda'_1(\lambda'^2_m+l'^2)}(\lambda'-\lambda_1)(\lambda'-\lambda_2)(\lambda'-\lambda_3) \quad \ldots \quad \ldots \quad (3.2)$$

where λ'_1, λ'_2, λ'_3 are the tracking wavelengths, λ'_m a mean value and d' and l' are defined by (2.16) and (2.17).

Proof: We give here first the proof for a capacitance-tuned system, tracking with constant frequency difference.

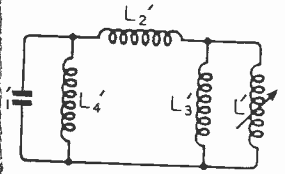


Fig. 9.

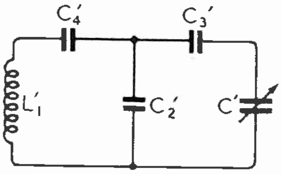


Fig. 10.

The resonant frequency of the circuit shown in Fig. 7 can be calculated from

$$f_1^2 = m^2\frac{f^2+n^2}{f^2+l^2} \quad \ldots \quad \ldots \quad (3.3)$$

where

$$(2\pi f)^2 = 1/LC \quad \ldots \quad \ldots \quad \ldots \quad (3.4)$$

$$(2\pi m)^2 = 1/L_1\left(C_4 + \frac{C_2C_3}{C_2+C_3}\right) \quad (3.5)$$

$$(2\pi n)^2 = 1/L(C_2+C_3) \quad \ldots \quad (3.6)$$

$$(2\pi l)^2 = 1/L\left(C_3 + \frac{C_2C_4}{C_2+C_4}\right) \quad (3.7)$$

At the tracking frequencies we have

$$f_1 = f + f_0$$

$$f_1^2 = f^2 + 2ff_0 + f_0^2 \quad \ldots \quad \ldots \quad (3.8)$$

and get therefore

$$[f^2 + 2ff_0 + f_0^2](f^2+l^2) = m^2(f^2+n^2) \quad \ldots \quad \ldots \quad (3.9)$$

$$f^4 + 2f_0f^3 + (f_0^2 + l^2 - m^2)f^2 + 2f_0l^2f + f_0^2l^2 - m^2n^2 = 0 \quad (3.10)$$

Let the roots of this 4th degree equation be

$$F_1,\ F_2,\ F_3,\ F_4.$$

Then

$$F_1 + F^2 + F_3 + F_4 = -2f_0 \quad (3.11)$$

This means that with positive values for the tracking frequencies F_1 F_2 F_3 the fourth root must be negative, or there can be at the best tracking at three frequencies.

Incidentally we see that

$$F_4 = -d \quad \ldots \quad \ldots \quad \ldots \quad (3.12)$$

where d has the meaning used in Section 1.

To get the expression for the tracking error Δf consider

$$f_1^2 - (f+f_0)^2 = (f_1+f+f_0)(f_1-f-f_0)$$

$$= 2f_1 \times \Delta f \quad \ldots \quad \ldots \quad (3.13)$$

with an imperceptible error. Thus

$$\Delta f = \frac{1}{2f_1}\left[m^2\frac{f^2+n^2}{f^2+l^2} - (f+f_0)^2\right]$$

$$= \frac{m^2(f^2+n^2) - f + f_0)^2(f^2+l^2)}{2f_1(f^2+l^2)} \quad \ldots \quad \ldots \quad (3.14)$$

The numerator of this expression is a polynomial of 4th order, and its value can therefore be expressed in product form as shown hereafter:

$$\Delta f = \frac{(f-F_1)(f-F_2)(f-F_3)(f-F_4)}{2f_1(f^2+l^2)} \quad \ldots \quad \ldots \quad (3.15)$$

F_1, F_2, F_3, F_4 are the values of which we know already that they will make the error $\Delta f \equiv 0$. Using equation 3.12, this gives

$$\Delta f = \frac{(f+d)}{2f_1(f^2+l^2)}(f-F_1)(f-F_2)(f-F_3) \quad \ldots \quad \ldots \quad (3.16)$$

As f^2 is very small compared with l^2 we can replace it by a mean value f_m^2 and get

$$\Delta f \approx \frac{(f+d)}{2f_1(f_m^2+l^2)}(f-F_1)(f-F_2)(f-F_3) \quad \ldots \quad \ldots \quad (3.17)$$

The case of an inductance-tuned system tracking with constant frequency difference needs no separate proof if we make use of the dual relationship existing between the circuits of Figs. 7 and 8. The equations defining our auxiliary constants are now

$$(2\pi f)^2 = 1/LC \quad \ldots \quad \ldots \quad \ldots \quad (3.18)$$

$$(2\pi m)^2 = 1/C_1\left(L_4 + \frac{L_2L_3}{L_2 + L_3}\right) \quad (3.19)$$

$$(2\pi n)^2 = 1/C(L_2 + L_3) \quad \ldots \quad \ldots \quad (3.20)$$

$$(2\pi l)^2 = 1/C\left(L_3 + \frac{L_2L_4}{L_2 + L_4}\right) \quad \ldots \quad (3.21)$$

The case of circuits which track with constant difference of wavelength can be linked with the proofs just given if we make use of the proportionality existing between frequency and wavelength in the actual and the image circuits. (d.f. equation 2.11).

To get an expression for the tracking error $\Delta\lambda$ we consider

$$\lambda'^2_1 - (\lambda' + \lambda'_0)^2 = 2\lambda'_1 \times \Delta\lambda \quad (3.22)$$

with an imperceptible error, from which

$$\Delta\lambda = \frac{\lambda'^2_1 - (\lambda' + \lambda'_0)^2}{2\lambda'_1} = \frac{1}{\alpha}\,\frac{f_1^2 - (f + f_0)^2}{2f_1}$$

$$= \frac{1}{\alpha}\Delta f. \quad \ldots \quad \ldots \quad (3.23)$$

Δf is here given by (3.1).

Again making use of the proportionality just mentioned we can replace in the expression (3.1) the various magnitudes by their "dashed" equivalents and are thus led to equation 3.2.

Correspondence

"Pulsatance, Rotatance or Velocitance?"

To the Editor, "The Wireless Engineer"

SIR,—In one of your recent issues you asked for suggested variants to the word "pulsatance." I suggest the word "omegance."

Ilminster, Som. E. H. ULLRICH.

November Meetings

AT the next meeting of the I.E.E. Wireless Section, at 5.30 on Wednesday, November 4th, the chairman of the Section, Dr. R. L. Smith-Rose, will deliver a paper jointly with Miss A. C. Stickland, M.Sc., on "A Study of Propagation over the Ultra-Short-Wave Radio Link between Guernsey and England on Wavelengths of 5 and 8 metres (37.5 and 60 Mc/s)". A discussion on "Plastics in Radio Production" will be opened by C. C. Last at an informal meeting at 5.30 on Tuesday, November 17th.

Book Reviews

Wave Guides

By H. R. L. LAMONT, M.A., Ph.D. One of the series of monographs on physical subjects published by Methuen & Co., Ltd., 36, Essex Street, London, W.C.2. Pp. 102 with 32 Figs. Price 4s.

This subject, now vital in radio engineering for ultra high frequencies, has been entrenched too long in a maze of learned reports. Dr. Lamont's little book, written from the G.E.C. laboratories, forces it into open discussion and will correct the common prejudices and misconceptions. The ordinary radio expert, vaguely aware that electromagnetic power *can* be "guided" along the interior of a hollow conducting pipe if wavelength becomes comparable with cross-section of the guide, realises that applications are thereby confined to an extremely high-frequency spectrum, and is apt to resent the consequent intrusion of devices usually left to optics or acoustics. Further he suspects that he will be called upon to handle not merely the Bessel functions familiar to all high-frequency engineers, but also "a lot of forgotten Victorian mathematics." It is true that power transmission along closed guides was discovered by Rayleigh and Lodge half a century ago, and then forgotten until very recent years; but Dr. Lamont's book will remove the excuse for both the technical and the mathematical prejudices of the unadaptable.

The book wisely takes care over the physical interpretation of boundary conditions, a crucial stage in electromagnetics usually left unexplained in the equations; an extra page or two would have been useful in elaborating, perhaps graphically, the way in which the *J* and *Y* and *H* functions of the Bessel equation are physically to be distinguished, so as not to leave the numerical tabulations as haphazard as in most accounts. Dr. Lamont is also wise in not concealing the difficulties in passing from scalar to vector wave equations. But here the background becomes too tightly compressed for comfort—an inevitable complaint over such a tiny monograph. We recollect the paradox that larger treatises are often clearer than the more elementary and Dr. Lamont might well have recommended Bateman's masterpiece "The Partial Differential Equations of Mathematical Physics" (1932) as companion reading, whereas he only mentions of Bateman the smaller and earlier "Electrical and Optical Wave-motion."

The examples in patterns of lines of force for wave-guides and resonators, the treatment of phase velocity and group velocity, and the "elementary waves" from which progressive waves can be synthesized, appear more clearly than in the original papers. Borgnis's theory of resonator damping becomes usefully accessible in English, and there is much valuable critique on attenuation and "Q," to replace the difficult papers commonly referred to. The book ends with chapters on closed resonators and on the radiation from horns, thus making contact with circuit theory and antenna theory of the more conventional frequency ranges.

M. J.

Electrical Counting with Special References to counting Alpha and Beta Particles

By W. B. Lewis, M.A., Ph.D. Pp. 144 with 73 Figs. Cambridge University Press, Bentley House, 200, Euston Road, London, N.W.1. Price 10s. 6d.

The author is a lecturer in the Cavendish Laboratory where a great deal of work on this subject has been done. Some parts of the book would not interest the radio engineer unless he were also interested in nuclear physics and the counting of alpha and beta particles, but at least half the book would interest anyone concerned with the design of amplifiers. The counting depends on the amplification of minute electrical impulses and has necessitated a lot of careful research into what one might call the threshold of possible amplification. Chapters III and IV deal with the limitations of amplifiers and their design. Full particulars with the value of every component are given for a 4-valve stabilised high-gain amplifier with resistance-capacitance coupling. Chapter V is a short one of three pages dealing with oscillographic recording. Chapter VI returns to amplifiers and discusses feedback and stabilisers. Then follow chapters dealing with "triggered" circuits such as squeggers, multivibrators and flip-flop circuits, recording counters and Geiger-Müller Tube Counters. It will be seen that there is much in the book of importance to anyone interested in the design and application of amplifiers.

G. W. O. H.

I.E.E. Premiums

CERTIFICATES for the three Wireless Section Premiums for papers during the 1941-42 I.E.E. Session were presented at the first meeting of the new Session. The Duddell premium (£20) was awarded to O. S. Puckle for his paper "Time Bases." Dr. D. C. Espley and D. O. Walter received the £10 Ambrose Fleming premium for their paper "Television Film Transmitters Using Apertured Scanning Discs." Another £10 premium was awarded to J. E. Thwaites and F. J. M. Laver for their paper "The Technique of Frequency Measurement and its Applications to Telecommunications."

I.E.E. Wireless Section

Chairman's Inaugural Address

DR. R. L. SMITH-ROSE, in his inaugural address as chairman of the Wireless Section of the I.E.E. for the 1942-43 Session, gave a brief survey of the origin and growth of the Section of which he had been a member since its formation just over twenty-three years ago. He referred to the proposals which had been made some time ago to form a new Institute of Wireless Engineers and to the steps which have been taken rendering such a course unnecessary. One such step was the decision, made in 1926, that, while it was essential that the standard of qualification for membership of the Institution should be maintained, more opportunity should be afforded to the physicist engaged in wireless work to become a member. Dr. Smith-Rose said that it was particularly opportune to draw attention to it at the present time, when a large number of men engaged on wireless work would probably refer to themselves as radio-physicists rather than wireless or radio engineers.

When considering some of the problems which confront the Institution, especially in regard to future membership, the chairman said: "The Institution has continually endeavoured to make the Wireless Section meet all the needs of the professional wireless or radio engineer in this country, even in the presence of some attempted competition from some other organisations. While it is natural to find that such an extensive and rapidly growing profession as radio engineering requires more than one society or association to deal with the workers of various technical attainments, it is clearly necessary for the Institution to carry out the duties set by its Charter, of maintaining the standard and prestige of the properly qualified and experienced member of the engineering profession . . . Only by maintaining the highest standards of knowledge and experience in the profession can wireless or radio engineering progress rapidly and efficiently on its assigned path."

Dr. Smith-Rose remarked that with the continued and rapid increase in radio and electrical communications technique, it is becoming all too clear that the student of the future will have an impossible task in endeavouring to assimilate the fundamentals of his subject if this is to continue to be regarded as a mere accessory to a main course in physics or electrical engineering. "There must be many who, like myself," he said, "in taking up some branch of radio work twenty or more years ago did not have a single lecture on radio communication in the course of our university education, and there are to-day many graduates entering the profession whose radio knowledge has been gleaned from a few mathematical lectures on the classical theory of electric waves. . . . I suggest that this Institution should consider using its influence with those responsible for the Science and Engineering faculties of our universities with a view to arranging courses in Communications Engineering on a standing equivalent to the degree courses in either Physics or Electrical Engineering at the present time."

In common with most chairmen of the Section, Dr. Smith-Rose surveyed briefly the progress of the particular field of radio work in which he has been engaged for the past twenty-two years, namely, the Radio Research Board. He referred to the fact that, apart from the research and investigation work conducted under its auspices, the Radio Research Board has "organised and maintained for fourteen years past a service supplying a comprehensive series of Abstracts and References which are published monthly in *Wireless Engineer*. These abstracts are unique in wireless technical literature and are greatly appreciated by radio engineers and research workers in all parts of the world."

In the introductory remarks to the third and by far the largest part of the chairman's address, which dealt with the speed of travel of wireless waves, he referred to the controversy and confusion which exists as to the proper use of the terms frequency and wavelength and quoted the metrical classification of wavelengths and corresponding frequencies published in *Wireless Engineer* of August, 1942. In referring to the velocity of light he said that it was interesting to note that the development of radio-frequency technique had assisted and facilitated its measurement on a laboratory scale. In his recent experiments W. C. Anderson used the principle of modulating the light beam with a radio-frequency through the agency of a Kerr cell containing a suitable organic liquid which was subjected to an alternating electric field at a frequency of from 14 to 56 Mc/s. This gave a value of 2.9977×10^{10} cm/sec. in vacuo.

A difficulty which lies in the way of determining wave velocity in the radio-frequency spectrum is that of producing the equivalent of a mirror which, in the manner similar to its use in the case of light, will reflect the waves with a known phase change and with a negligible time delay. The use of an aerial system, with its associated energising apparatus involves a delay of some milli-seconds which is comparable with the travel of the waves over hundreds of miles. It is for such reasons as this that many of the determinations in the past have led to an inaccurate estimation of the speed of travel of wireless waves.

Dr. Smith-Rose referred to the work of Ross and Slow of the Radio Department of the National Physical Laboratory, who, in 1937, made a determination of the phase velocity of radio waves transmitted along the surface of the ground using apparatus already developed and in use for other investigations. The average result over the range 20–120 meters (2.5–15 Mc/s) was 2.95×10^{10} cm/sec. $\pm$ 5 per cent.

He also referred to the comprehensive investigation of the velocity of medium radio waves carried out during the years 1934-5 in the laboratories of the U.S.S.R. under the direction of Professors L. Mandelstam and N. Papalexi. The method employed comprises a determination of the time of transit of waves between a sending and reflecting station by measuring the phase difference between the two sets of waves, the ratio of whose frequencies is rational. Modification of the phase throughout all parts of the apparatus was traced with an accuracy of one part in 1000, and the number of whole wavelengths and fractions of a wavelength between the two stations deduced. The results gave a velocity within the limits of 2.990 and 2.995×10^{10} cm/sec. for transmission over a clear air path or over sea or fresh water.

In his concluding remarks the chairman said that our present knowledge leaves the problem of the measurement or calculation of the actual time of transit or radio waves between sender and receiver still open to investigation. For the solution of this problem a knowledge of the free space speed is only one requirement; it still needs a precise specification of the actual path, rectilinear or otherwise, followed by the waves, and of any modification to the velocity value produced by atmospheric or ionospheric conditions.

I.E.E. Students' Section

THE second meeting of the London Students' Section of the Institution of Electrical Engineers will be held on November 2nd, when the chairman, G. M. Childs, B.Sc. (Eng.), will give his inaugural address. At the meeting arranged for November 16th C. W. Eggleton will give a paper on "The Frequency Stability of Tuned Circuits." Both meetings will begin at 7 p.m. The honorary secretary of the Section is C. C. Barnes of 9, Cranley Road, Ilford, Essex.

Paper Economy

A USEFUL paper economy scheme adopted by one large concern using envelopes for inter-office communications is to rule off the envelopes into squares large enough to contain the name and department to which the contents of the envelope may be addressed. By this means the envelopes can be made to do more journeys as members of the staff are induced to keep their writing within the square instead of sprawling it all over the envelope.

Back Numbers

OUR Publishers have asked us to state that they require the following issues of *Wireless Engineer* to complete a set of volumes for a reader in the United States:—

January 1924; October 1929; April, October and November 1930; November 1931; October 1933; August, September and November 1934; January, February, March and September 1935.

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.

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

546 182.—Counteracting the non-linear response of a piezo-electric crystal when used for recording or reproducing sounds.

Electrical Research Products Inc. Convention date (U.S.A.) 30th March, 1940.

546 478.—Electro-strictive type of sound reproducer, more particularly for demodulating carrier-wave signals.

Standard Telephones and Cables (assignees of W. P. Mason). Convention date (U.S.A.) 23rd January, 1940.

AERIALS AND AERIAL SYSTEMS

545 779.—Method and apparatus for relaying ultra-short-wave signals unidirectionally along a dielectric guide.

The Board of Trustees of the Leland Stanford Junior University. Convention date (U.S.A.) 24th August, 1939.

546 409.—Non-rotatable crossed-frame aerial and coupling circuit which can be employed to give directional or non-directional reception as desired.

K. H. Meier. Convention date (Switzerland) 26th June, 1939.

546 460.—Gear for raising or lowering the trailing aerial of an aeroplane.

Lear Avia Inc. Convention date (U.S.A.) 27th September, 1939.

547 035.—Tapered feed line for directional aerials of the rhombic type.

Marconi's W.T. Co. and O. M. Bohm. Application ate 4th February, 1941.

DIRECTIONAL WIRELESS

46 184.—Aerial arrangement for a radio-naviga-ional beacon designed to radiate a number of pproach paths each defined by two overlapping eams.

Standard Telephones and Cables (assignees of . G. Kandoian). Convention date (U.S.A.) 1st February, 1940.

46 341.—Capacitance phase-shifting device for a adio-navigational beacon of the overlapping-eam type.

Aga-Baltic Akt. Convention date (Sweden) 4th anuary, 1940.

46 970.—Blind-landing system for aircraft in hich indication to the gliding path is given by the tersection of radio waves of two different fre-uencies.

Standard Telephones and Cables, and H. P. illiams. Application date, 2nd January, 1941.

RECEIVING CIRCUITS AND APPARATUS

(See also under Television)

546 132.—Frequency-modulating arrangement in which two steady frequencies are combined and the resultant oscillation is applied to a non-ohmic resistance connected across the source of signals.

A. C. Cossor and D. A. Bell. Application dates 13th February and 2nd December, 1941.

546 141.—Permeability-tuned set with a band-spreading device applied to the short-wave band whereby the same tuning inductance is utilised on three wavebands.

A. H. Cooper. Application date 26th November, 1940.

546 200.—Negative feed-back arrangement, which is designed to increase the effective band-width, and the " loop " gain obtainable in an amplifier.

Standard Telephones and Cables (assignees of E. H. Perkins). Convention date (U.S.A.) 20th April, 1940.

546 248.—Permeability tuning with accurate tracking for the local-oscillator and signal-frequency circuits of a superhet receiver.

Marconi's W.T. Co. (assignees of V. D. Landon). Convention date (U.S.A.) 2nd January, 1940.

546 505.—Ultra-short-wave receiver in which the cathode of a rectifying valve is arranged at the centre of a dipole aerial.

S. R. R. Kharbanda ; M. C. Goodall ; and Pye. Application date 21st March, 1941.

546 703.—Means for controlling volume-range expansion or contraction in accordance with variations in the amplitude or percentage modulation of the reproduced signals.

Radio Corporation of America. Convention date (U.S.A.), 30th March, 1940.

546 721.—Receiving circuit which gives a high signal-to-noise ratio from a frequency-modulated wave.

Standard Telephones and Cables (assignees of O. D. De Lange). Convention date (U.S.A.) 9th April, 1940.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

546 212.—Frequency-multiplying system in which component parts of the original signal are combined in phase-opposition.

Farnsworth Television and Radio Corporation. Convention date (U.S.A.) 29th April, 1940.

546 323.—Television receiver for frequency-modulated signals with provision for preventing "white-spot" interference.

Hazeltine Corporation (assignees of J. C. Wilson). Convention date (U.S.A.) 2nd August, 1940.

546 462.—Television system in which a "raster" distribution of charges is produced by the action of an electron stream on a screen made of deformable material. Addition to 543 485.

Ges zur Forderung Ec Technischen Hochschule of Zurich. Convention date (Switzerland), 22nd May, 1940.

546 470.—Optical system for using a rotating colour-filter disc with a television transmitter of the mosaic screen type to produce coloured pictures.

J. L. Baird. Application date 13th January, 1941.

546 507.—Protective circuit for preventing damage to the screen of a cathode-ray tube when the high voltage is switched off.

Philco Radio and Television Corporation (assignees of S. C. Spielman). Convention date (U.S.A.) 21st March, 1940.

546 519.—Cathode-ray television transmitter in which the scanning beam passes through and beyond the mosaic screen, and is then returned to neutralise the electrostatic charges.

Marconi's W.T. Co. (assignees of H. A. Iams). Convention date (U.S.A.) 15th May, 1940.

546 827.—Circuit for repeating only predetermined pulses in a periodic pulse wave as used, say, for synchronising in television.

Hazeltine Corporation (assignees of J. C. Wilson). Convention date (U.S.A.) 1st March, 1940.

546 830. — Automatic frequency-control system particularly applicable to television and like short-wave receivers.

Hazeltine Corporation (assignees of J. A. Rado). Convention date (U.S.A.) 30th December, 1939.

546 932.—Television receiver for a system in which the picture signals are amplitude modulated whilst the synchronising pulses are frequency modulated.

Hazeltine Corporation (assignees of A. V. Loughren) Convention date (U.S.A.) 7th February, 1940.

546 987.—Multi-coloured television system with interlaced scanning and means for changing and controlling the colour of illumination during the scanning sequence.

Hazeltine Corporation (assignees of J. C. Wilson). Convention date (U.S.A.) 6th September, 1940.

547 075.—Projecting television pictures outside a cathode-ray tube having a paraffin layer as a screen or light-modulating device.

Farnsworth Television and Radio Corporation. Convention date (U.S.A.) 7th September, 1940.

547 124.—Television receiver of the kind in which the picture is formed by varying the incidence of an electron stream of uneven density with respect to a control aperture.

Standard Telephones and Cables (assignees of M. W. Baldwin, Jnr.). Convention date (U.S.A.) 31st July, 1940.

547 182.—Means for improving the balancing or matching of a signal modulating stage to the subsequent amplifier stage.

Farnsworth Television and Radio Corporation. Convention date (U.S.A.) 19th October. 1940.

TRANSMITTING CIRCUITS AND APPARATUS

(*See also under Television*)

546 168.—Means for stabilising the operation of the carrier-wave generator in a frequency-modulating circuit.

Marconi's W.T. Co. (assignees of J. L. Hathaway). Convention date (U.S.A.) 27th June, 1940.

546 476.—A quarter-wave network for coupling, say, an unbalanced or single-sided valve circuit to a balanced push-pull amplifier.

Marconi's W.T. Co.; A. T. Starr; and E. Green. Application date 14th January, 1941.

546 677.—Means for automatically stabilising the mean frequency of the carrier-wave in a frequency-modulated signalling system.

Electrical Research Products Inc. Convention date (U.S.A.) 30th March, 1940.

546 693.—Automatic gain-control system designed to deal with conditions of severe attenuation in a carrier-wave transmission-line.

Standard Telephones and Cables, and B. B. Jacobsen. Application date 24th January, 1941.

547 061.—Means for directly coupling the cylindrical anode of an ultra-high-frequency oscillator to a tuned load.

Marconi's W.T. Co. (assignees of R. B. Ayr). Convention date (U.S.A.) 27th May, 1939.

547 183.—Means for stabilising the mean carrier-wave frequency in a frequency-modulating system covering a wide frequency sweep.

Marconi's W.T. Co., and W. T. Ditcham. Application date 14th February, 1941.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

546 376.—Push-pull amplifier, or oscillation generator, in which both electrode systems are contained in a single tube and in which re-entrant parts of the tube form the two anodes.

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

546 415.—Preparing or processing the surface of conducting surfaces, such as the resonating electrodes used for generating very high frequencies by velocity modulation.

Standard Telephones and Cables, and C. H. Foulkes. Application date 7th January, 1941.

546 475.—Construction of iron-plated nickel electrodes, particularly for voltage dividing valves of the Stabilovolt type.

Marconi's W.T. Co. and C. P. Fagan. Application date 14th January, 1941.

546 583.—Method of coating the electrodes, other than the cathode, of an electron-discharge tube so as to protect them during the photo-electric processing of the cathode.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 20th July, 1941.

546 584.—Process for depositing a fluorescent coating on the viewing screen of a cathode-ray tube.

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

546 586.—Construction and assembly of the electrodes and screens or shields of a multigrid high-powered amplifier for ultra-short waves.

Standard Telephones and Cables (assignees of S. O. Ekstrand and V. L. Ronci). Convention date (U.S.A.) 24th August, 1940.

546 732.—Construction of an electron-discharge tube for preventing breakdown under high voltages.

The British Thomson-Houston Co. Convention date (U.S.A.) 30th April, 1940.

546 764.—Composition of a photo-electric cathode giving a high response to blue light and practically zero response to infra-red rays.

Marconi's W.T. Co. (assignees of E. A. Massa and E. W. Pike). Convention date (U.S.A.) 28th March, 1940.

546 771.—Construction of discharge tube comprising resonant structures for velocity-modulating an electron stream.

Standard Telephones and Cables (assignees of C. V. Litton). Convention date (U.S.A.) 13th July, 1940.

546 774.—Construction of discharge tube comprising toroidal resonant structures for velocity modulating an electron stream.

Standard Telephones and Cables (assignees of C. V. Litton). Convention date (U.S.A.) 16th July, 1940.

546 846.—Construction and arrangement of the focusing electrodes in a cathode-ray tube, particularly for reproducing television pictures.

Hazeltine Corporation (assignees of R. C. Hergenrother). Convention date (U.S.A.) 25th July, 1940.

547 074.—Construction of a rectifier tube for comparatively high-frequency currents whereby the difficulty of insulating the associated transformer windings is minimised.

Farnsworth Television and Radio Corporation. Convention date (U.S.A.) 5th March, 1940.

SUBSIDIARY APPARATUS AND MATERIALS

545 804.—Method of neutralising the static capacitance of a piezo-electric crystal in a radio-frequency filter circuit.

Marconi's W.T. Co. and A. T. Starr. Application date 11th October, 1940.

545 936.—Selector devices for separating selected signals from a dielectric guide carrying a multiplicity of carrier-waves.

The Board of Trustees of the Leland Stanford Junior University. Convention date (U.S.A.) 24th August, 1939.

546 205.—Construction of a rotary attenuator or impedance network for handling frequencies of the order of 30 megacycles.

Standard Telephones and Cables ; R. M. Barnard ; F. L. J. Jarvis ; G. R. Wicks ; and W. Kram. Application date 31st December, 1940.

546 231.—Arrangement for minimising the self-inductance of the cathode-supply conductors in a high-frequency amplifier.

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

546 284.—Means for adjusting the operating range of a radio altimeter of the variable-frequency type.

Electrical Research Products. Convention date (U.S.A.) 30th December, 1939.

546 319.—Electrode system for controlling and varying the resonant frequency of a piezo-electric crystal.

Marconi's W.T. Co. (assignees of W. R. Koch). Convention date (U.S.A.) 18th May, 1940.

546 336.—Testing equipment including a variable attenuating network, and a number of preset tuned circuits, for testing the sensitivity of a wireless set.

Murphy Radio Ld. ; J. E. Marshall ; S. H. Cohen ; H. G. T. Bissmire ; L. Driscoll ; and A. H. Beattie. Application date 6th November, 1940.

546 754.—Circuit for deriving a direct current strictly proportional to a frequency, particularly for a frequency meter.

W. W. Triggs (communicated by Brown, Boverie et Cie). Application date 1st February, 1941.

546 864.—Inductance coil with a core of powdered iron, the particles of which are suspended in an insulating composition in direct contact with the turns of the wire.

Marconi's W.T. Co. (assignees of R. L. Harvey and C. Wentworth). Convention date (U.S.A.) 31st January, 1940.

546 928.—Means for minimising current consumption in an alarm circuit which indicates abnormal circuit conditions in unattended repeater stations with automatic gain control.

Standard Telephones and Cables (assignees of B. A. Fairweather and D. M. Terry). Convention date (U.S.A.) 22nd August, 1940.

546 976.—Rectifying circuit designed to maintain a constant output potential in spite of variations in the A.C. input.

Automatic Telephone and Electric Co. and M. O. Williams. Application date 5th February, 1941.

547 010.—Relay circuit in which a high-slope pentode is coupled to a photo-electric cell or similar high-impedance input.

Vacuum-Science Products and H. S. Molyneux-ffennell. Application date 7th February, 1941.

547 038.—Copper-oxide rectifier circuit with means for compensating for temperature effects on the efficiency of the rectifier.

Standard Telephones and Cables (assignees of D. B. Penick). Convention date (U.S.A.) 17th February, 1940.

Abstracts and References

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

PROPAGATION OF WAVES

3181. ON THE PROPAGATION OF ELECTROMAGNETIC WAVES IN TUBES.—Ya. L. Al'pert. (*Journ. of Tech. Phys.* [in Russian], No. 16, Vol. 10, 1940, pp. 1358–1364.)

The absorption of electromagnetic waves in a cylindrical tube is considered. A method was proposed by Rytov (*see* 2860 of 1940) for determining the coefficient of absorption α with an accuracy up to the first degree of d, which is a small parameter characterising the depth of the penetration of the field into the metal. In the present paper an approximate method proposed by Leontovich (no reference is given: for work on supersonics *see* 1931 of 1940) is used for calculating α with an accuracy up to d^2 (eqn. 15). It is shown that if d^2 is neglected the same result is obtained as by Rytov's method. The limits of the applicability of Rytov's method are also established. Finally an exact solution of the problem is given, from which it can be seen that if the accuracy is limited to d^2 the same expression for α is derived as by the approximate method of Leontovich.

3182. THE PROPAGATION OF [Decimetric & Centimetric] ELECTROMAGNETIC WAVES ALONG PARALLEL CONDUCTING PLANES.—V. I. Bunimovich. (*Journ. of Tech. Phys.* [in Russian], No. 18, Vol. 10, 1940, pp. 1541–1550.)

For previous work *see* 176 of January and back references. A theoretical discussion is presented of the propagation of electromagnetic waves between parallel conducting planes. The waves are assumed to be plane, *i.e.* independent of coordinate z (if axis OZ is perpendicular to the planes). The methods used are similar to those adopted in the theory of long lines. A general case of two infinite planes is considered first. The system is then limited by two further planes, perpendicular to the XY plane and parallel to the OX axis, giving an infinitely long tube of rectangular cross-section. Finally, the tube is limited by two further planes perpendicular to its walls and an enclosed parallelepiped (rectangular resonator) is obtained. For each case, equations are derived for determining the current density in the planes and the potential difference between them. In addition the following equations are derived: (9) for determining the characteristic impedance of the system in the case of two infinite planes; (17) for determining the attenuation constant of a tube; and (23) for determining the natural wavelength and damping constant of the resonator. In an appendix, alternative methods for deriving equation (17) are suggested.

3183. "WAVE GUIDES" [Book Review].—H. R. L. Lamont. (*Electrician*, 21st Aug. 1942, Vol. 129, p. 194.) For previous work by the same writer *see*, for example, 4373 of 1940.

3184. DIFFRACTION OF ULTRA-SHORT RADIO WAVES [3 m Wavelength: Radiation with Horizontal Polarisation gives Greater Field-Strength than Radiation with Vertical, at Points beyond Hills but just Outside Their Shadow (Converse to 4 of 1940): Deductions regarding Curved-Earth Propagation and Superior Efficiency of Horizontal Polarisation in Certain Cases].—J. S. McPetrie & J. A. Saxton. (*Nature*, 5th Sept. 1942, Vol. 150, p. 292.) For the light-diffraction work mentioned *see* 2684 of 1939.

3185. NEW FIELD-INTENSITY RECORDER [Portable: Frequencies 26–155 Mc/s].—Kline. (*See* 3320.)

3186. The Reciprocity Theorem of the Electromagnetic Field.—Dällenbach. (*See* 3260.)

3187. Equations for the Propagation of Radiated [Thermal] Energy and the Similitude of Radiating Systems.—A. S. Nevski. (*Journ. of Tech. Phys.* [in Russian], No. 18, Vol. 10, 1940, pp. 1502–1509.)

Differential equations (8) and (9) determining the propagation of radiant heat in a radiating medium are derived and conditions (14), (15) and (19) of similitude of radiating systems established.

3188. The Thermal Radiation of Water Vapour in the Atmosphere: Corrections to Typographical Errors.—F. Möller. (*Gerlands Beiträge z. Geophysik*, No. 3/4, Vol. 58, 1942, p. 388.) *See* 637 of March.

3189. Absorption and Emission of Radiation in the Atmosphere [Short Survey, including Dobson's Suggestion that Stratospheric Temperature depends on Relative Amounts of Ozone & Water Vapour].—(*Nature*, 1st Aug. 1942, Vol. 150, pp. 144–146.)

3190. Observable Infra-Red Solar Spectrum extended from 14 to 24 μ.—A. Adel. (*Sci. News Letter*, 11th July 1942, Vol. 42, No. 2, p. 25.) For previous work *see* 2626/7 of 1941.

3191. "Annals of the Astrophysical Observatory of the Smithsonian Institution: Vol. 6" [Radiation from the Sun: Book Review].—C. G. Abbot & others. (*Nature*, 22nd Aug. 1942, Vol. 150, pp. 226–227.) This favourable review, by C. E. P. Brooks, contains some criticisms of the analytical methods.

3192. Change of Sign of the Thermal Diffusion Factor [with Composition, shown by Chapman (701 of 1941) to be Theoretically Possible, now found to occur in Neon-Ammonia Mixtures].—K. E. Grew. (*Nature*, 12th Sept. 1942, Vol. 150, p. 320.)

3193. Condensation due to Adiabatic Compression [including Suggestion that Descending Air *may* produce Fog, if it is Supersaturated].—A. E. Ruark. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 727: summary only.)

3194. The Image Quiescence in Astronomical Observations as a Criterion for Turbulence [suggesting a New Method of Investigation].—E. Wahl. (*Gerlands Beiträge z. Geophysik*, No. 1, Vol. 59, 1942, pp. 49–73.) Continued from No. 3/4. Vol. 58, 1942.

3195. "Dynamische Meteorologie: Physik der Atmosphäre: Band 2" [Second Edition: Book Review].—H. Koschmieder. (*Gerlands Beiträge z. Geophysik*, No. 1, Vol. 59, 1942, p. 91.)

3196. "Einführung in die Physik der Atmosphäre" [Vol. I—Statics & Thermodynamics: Book Review].—P. Raethjen. (*Zeitschr. f. tech. Phys.*, No. 6, Vol. 23, 1942, p. 165.) "By no means only an 'introduction'..."

3197. Frequency/Altitude Characteristics of the Ionosphere at Vertical Incidence.—A. I. Likhachev. (*Journ. of Tech. Phys.* [in Russian], No. 17, Vol. 10, 1940, pp. 1434–1446.)

Observations made by the ionospheric station at Tomsk during 1939 and the early part of 1940 are discussed in detail and the following conclusions are reached:—(1) The main ionising agent of the upper layers of the atmosphere is the ultra-violet radiation of the sun: this causes normal ionisation. (2) Sharp variations in the ionisation of separate regions are caused by radiations of a different kind which have not yet been investigated at the Tomsk station. (3) No simple and direct relationship was observed between variations in the shape of frequency/altitude characteristics and variations in the magnetic field of the earth. (4) The E layer acts both as a reflecting and as a refracting layer. In the first case the screening of layers lying above begins at reflection frequencies exceeding 5000 kc/s. (5) The splitting up of echo F_2 into three components takes place when the reflecting E layer is absent. (6) Inter-layer reflection occurs mainly during periods of intensified magnetic activity. Under these conditions, the "*M*" signal may travel along two different paths.

(7) The ionised G layer has a concentration of the same order as, or slightly lower than, that of the F_2 layer, and is found at altitudes of the order of 400–600 km. (8) The whole depth of the atmosphere becomes ionised, the separate layers corresponding to the ionisation maxima of this ionised medium. (9) In some cases, with the appearance of the aurora, ionised regions with a steep concentration gradient may be observed at heights from 600 to 1200 km. (10) A distinct splitting up of the $F_2{}^c$ and $F_2{}^x$ components into two components each may be observed. This phenomenon often coincides with an intensification in the magnetic activity. (11) The blurring of the echo-signal F_2 is due to the absence of a well defined ionisation maximum corresponding to the F_2 layer.

3198. "Drahtloser Ueberseeverkehr" [Transoceanic Wireless Communication and the Work of the Telefunken Company: Propagation & Installations: Book Reviews].—P. Kotowski & H. Wisbar. (*Alta Frequenza*, June 1942, Vol. 11, No. 6, pp. 298–300: *E.T.Z.*, 18th June 1942, Vol. 63, No. 23/24, p. 295.)

3199. Remark on Grosskopf & Vogt's Paper "The Measurement of Electrical Conductivity for Stratified Ground" [376 of February].—W. Pfister. (*Hochf:tech. u. Elek:akus.*, April 1942, Vol. 59, No. 4, pp. 118–119.)

The above work is based on the formulae for the Zenneck surface wave whose existence has been finally rejected by the work of Niessen, Wise, and Burrows. Propagation over a plane earth is due to what Sommerfeld called a space wave (because its propagation constants agree with those of free space) but what is better called a ground wave, to distinguish it from ionospherically reflected waves and from the discredited surface waves. This type of wave, like the surface wave, yields a rotating-field ellipse, which however differs slightly in form from that of the surface wave.

For such a ground wave the ratio ρ of the components at the earth's surface (putting $h = k_0$ for air, in place of Zenneck's $h = k_0 k_1/\sqrt{k_0^2 + k_1^2}$, and making use of the boundary conditions for the Hertz vector for vertical polarisation) is given by $\rho = \sqrt{\epsilon - 1 - j2\sigma/f}/(\epsilon - j2\sigma/f)$. This is practically identical with Zenneck's $1/\sqrt{\epsilon - j2\sigma/f}$, differing from it only at high frequencies and for small values of ϵ. The actual conclusions arrived at by Grosskopf & Vogt are therefore correct. But the field-strength equation just employed for obtaining ρ ($\mathfrak{E}_y = k_0^2 A[1 + jk_0^2/k_1^2 \cdot \sqrt{k_1^2 - k_0^2}\, y]$) is important in another way, for it correctly represents the height-dependence of the field strength, from which also it is possible to draw conclusions as to the ground conductivity: this point will be gone into thoroughly in another place. For stratified ground the surface wave should similarly be replaced by the Sommerfeld space-wave type, so that in Grosskopf & Vogt's fundamental formulae ρ would be altered as above and $h = k_0$ substituted for the complex expression for h. But the later approximate formulae and the practical results remain unchanged.

The writer then compares the physical meanings of the surface wave and the ground wave. The former is bound to the neighbourhood of the surface. Its energy decreases with distance from the surface, in both directions: more sharply, of course, in the ground. Propagation velocity and attenuation in the direction of propagation are dependent on the constants of both media, air and ground. The wave is, so to speak, conducted along the earth's surface by the surface itself.

For excitation by an aerial the propagation of electromagnetic waves does *not* occur in this form. The ground wave is nothing more or less than the limiting case, for grazing incidence, of a direct and a ground-reflected wave. Propagation occurs predominantly in the air, and the air alone determines the propagation constant. The ground-wave amplitude is made up of a constant component and a component, phase-displaced with respect to this, which increases linearly with height above the surface. In the ground the wave decreases exponentially: the energy penetrating there is taken from the air above, but it is small compared with the energy transported in the direction of propagation. The fact that the field in the ground and immediately above it has a strong similarity to the field of a surface wave is no justification for the use of the latter for quantitative calculations; especially in view of the fact that the ground wave, as represented above, is not only more correct but simpler to deal with mathematically.

The writer ends by remarking that a later paper by Grosskopf (964 of April) covers many of the points in the present comment, but at the same time adds to its importance, when one considers that the Norton surface wave employed is nothing more than a component of the Sommerfeld space wave. "One must guard against attributing to this component an independent physical significance."

3200. THE THEORY OF NON-UNIFORM LINES.—K. W. Wagner. (*Arch. f. Elektrot.*, 28th Feb. 1942, Vol. 36, No. 2, pp. 69–96.)

Recent papers on special cases are those of Didlaukis & Kaden (1880 of 1937) and of Zin (2763 of 1941 and back references), on wide-band cables and their irregularities; of Burrows and Wheeler on the "exponential" line (458, 1453, & 1454 of 1939); and of Eckart on the quadripole theory of ideal inhomogeneous lines (2408 of 1941). The present treatment is a general one.

Author's summary:—"In the first part of this work the theory is developed of electric lines whose inductance and capacitance are arbitrarily variable in space. The effect of losses through resistance and leakage is taken approximately into account. As regards limiting conditions it is assumed for the most general case that the line is connected at both ends with arbitrarily meshed networks: each mesh contains resistance, inductance, and capacitance and is ohmically, inductively, and capacitively coupled to all the others. This general case includes all simple special cases, such as lines with open or short-circuited ends, termination with ohmic resistance, capacitance, or inductance, or with the series or parallel arrangement of these elements.

"With the expression e^{pt} for the dependence on time the stationary state for alternating voltage or current of angular frequency ω is obtained by putting $p = i\omega$ (forced oscillations and waves). The same expression, in the absence of an external e.m.f., gives the free oscillations of the system composed of the line with its end networks. Differential equations and limiting conditions determine the eigenvalues p_k [eqn. 8b] and with them the normal functions [of voltage and current: eqn. 9]. For each natural oscillation the spatial distributions of voltage and current along the line and in the connected networks are given by these functions with the addition of a factor [A_k: eqn. 11] which is termed the amplitude of such a normal process.

"The main problem to be solved for any transient process consists in the calculation of the amplitudes of the normal processes, from which the transient process is built up. This task, often of extreme mathematical difficulty, is solved with the help of the Heaviside reciprocal energy law. For the arbitrary given initial state of the line and associated networks, and for a certain (for instance the kth) normal process, the reciprocal electric energy and the reciprocal magnetic energy are obtained: their difference, divided by twice the difference of the electric and magnetic energies of the kth normal process, gives the required amplitude of this normal process [A_k, above: the relation is shown in eqn. 12].

"Along the line, the energies are represented as integrals which remain to be calculated [for the above calculation of A_k] over the whole length. By means of the differential equations of the normal functions, formulae are derived which express these integrals in terms of the values of the functions at the ends of the line, thus saving the integration [*see* section 5: the integrals in the numerator of eqn. 14 for A_k are thus treated]. For the associated networks the reciprocal energies are readily expressed in matrix form, as are also the energies themselves.

" In the second part of the work the theory outlined above is employed for the calculation of the forced oscillations and waves, and of the building-up process, in the so-called Bessel line [inductance linearly increasing and capacitance linearly decreasing in the same ratio, from beginning to end of line: eqns. 17a & b. So called because, as is shown, the spatial distribution of voltage and current is represented by cylindrical functions]. The calculation is carried out in a numerical example and the results explained with the help of curves.

" Following on, the ' power ' lines are dealt with, in which the spatial variation of inductance and capacitance is represented by powers with arbitrary, whole or fractional, positive or negative exponents [eqn. 42 : " Fig. 8 shows how full of possibilities this expression is "]. A limiting case of the ' power ' line are the ' exponential ' lines. . . . Their theory can in general be derived from that of the ' power ' lines. Only the special case of the exponential line with constant wave velocity [eqn. 52a] requires special consideration, since the formulae valid for the general case cannot be applied to it. The results found for this special case—action of the line as a high-pass filter with voltage transformation—describe also the behaviour of a loudspeaker with exponential horn.

" Quite generally, the theory of non-uniform electrical lines can be transferred in its entirety to analogous mechanical arrangements : for example, to the movement of air and vibrations in tubes of variable diameter, to the torsional vibrations of elastic waves with varying cross section, to the longitudinal vibrations of non-uniform bars, and to similar systems."

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

3201. AN INVESTIGATION OF IMPULSE SPARK DISCHARGES : PART I [the Question of Leader Velocities]. — V. S. Komel'kov. (*Journ. of Tech. Phys.* [in Russian], No. 17, Vol. 10, 1940, pp. 1426–1433.)

In studying damped impulse spark discharges, several investigators have observed the presence of a leader and a main channel in the discharge. It appears therefore that such investigations can be used for studying the nature of lightning. Accordingly a detailed experimental investigation was undertaken by the author in which the discharge between two needles was studied for a negatively polarised incident wave (1/300 μs). In addition to the spark gap a damping resistance and a measuring resistance (for use with a cathode-ray oscillograph) were included in the discharge circuit. Discharge voltages between 350 and 750 kv were used. A report on experiments is presented and a number of oscillograms and curves are shown. The main conclusion reached is that the whole range of leader velocities observed in lightning discharges can be obtained in a laboratory by the use of suitable damping resistances.

3202. ON THE ELECTRICAL BREAKDOWN IN GASES [Discussion of Results of Cloud-Chamber Investigations : Criterion for Occurrence of Discharge, and Explanation of the Much Shorter Building-Up Times for Large Pressure × Distance Values : etc.].—H. Raether. (*E.T.Z.*, 2nd July 1942, Vol. 63, No. 25/26, pp. 301–303.)

The researches were referred to in 3334 of 1939. It is deduced that " if the avalanche takes place in a field strong enough for the critical multiplication [which occurs when the space-charge field attains about the strength of the applied field] to extend to the anode, the conditions for the formation of a channel are satisfied and a discharge takes place. This simple requirement yields very good values for the sparking field-strength at atmospheric pressure, as table 1 shows."

3203. THE MECHANISM OF THE ELECTRIC SPARK [Refutation of Meek's Criterion for Spark Formation : Error in Derivation of Formula for Radial Field : etc.].—J. Zeleny : Meek. (*Journ. Applied. Phys.*, July 1942, Vol. 13, No. 7, pp. 444–450.)

3204. POLARITY AND STRENGTH OF LIGHTNING-STROKE FIELD FLUCTUATIONS.—H. Wichmann. (*Gerlands Beiträge z. Geophysik*, No. 1, Vol. 59, 1942, pp. 32–41.)

Author's summary :—" The polarities of 1300 fluctuations, recorded by different methods, were determined. It was thus found that the sign of the ' total field fluctuation ' at great distances (above 10 km) from the point of observation was negative, while in the neighbourhood of the point of observation it was positive. At points of transition from one polarity to the other, both polarities seem to appear, for one and the same stroke, one after the other : more generally negative–positive. By comparing these records with the older investigations of C.T.R. Wilson it was possible to show that the field strengths measured for lightning strokes have been underestimated from 10 to 100 times." Thus a value of 100 v/cm given by Wilson for the sudden field change for a certain stroke must be interpreted as from 750 to 7500 v/cm. " With such values it is perhaps possible to explain the discrepancy which has previously existed between the measured small lightning field-strength fluctuations of, as a rule, 25 to 50 v/cm and the field strengths of 30 000 or 10 000 v/m necessary for ionisation by collision for the further extension of the flash." For previous work *see* 658 of March.

3205. THE SETTING-IN AND DURATION OF LIGHTNING-FIELD FLUCTUATIONS.—H. Wichmann. (*Gerlands Beiträge z. Geophysik*, No. 1, Vol. 59, 1942, pp. 42–48.)

Improved technique (658 of March) and more sensitive instruments have shown that whereas the writer's former measurements on the start of these fluctuations gave 0.1–0.01 s as the delay before the attainment of the first high field strength for strokes to earth, as a general thing smaller variations occur some tenths of a second earlier, and these are themselves preceded by a slow increase (+) of the field lasting on the average some 10 seconds. This last phenomenon is especially marked for strokes between clouds.

" A mean value for the duration of the field variations of a stroke is given by 1300 measurements as about 0.4 s. Strokes to earth, included in this figure, show on the average a shorter duration of about 0.1–0.2 s, while strokes between clouds show a longer one of 1.0–1.5 s. During an actual thunderstorm the duration of the field variations increases with decreasing frequency of flashes, particularly to earth, and occasional values over 2.5 s are found."

PROPERTIES OF CIRCUITS

3206. Resonators for Ultra-High Frequencies.—C.G.A. von Lindern & G. de Vries. (*Alta Frequenza*, May 1942, Vol. 11, No. 5, pp. 247–248: summary, from *Rev. tech. Philips*, July 1941, Vol. 6, No. 7, p. 217 onwards.)

The coefficient of resonance, ϵ, of a circuit measures the percentage width of the resonance band and is inversely proportional to the damping factor of the circuit: in a very general way it can be expressed as the ratio between the energy of the field and the energy dissipated per period. Looked at in this way, the concept of the coefficient of resonance may be applied to circuits with distributed constants.

The resistance of a circuit at high frequencies is not purely ohmic, but is due above all to skin effect whose calculation is not easy for non-rectilinear conductors, except in some cases. For instance it is possible to calculate directly the skin resistance of a flat spiral, by considering that a long thin bar, coiled into a spiral, doubles its dissipative resistance because the current concentrates on the inside face of the turns, where the field is maximum. It is thus found that a flat spiral has an ϵ proportional to $R\sqrt{f}$, where R is the radius of the coil. But in practice the ϵ of such a coil does not increase with f but decreases, because since it is not possible to reduce the capacity of the resonator below a certain limit, an increase in f should have a corresponding decrease in R, for the sake of tuning.

On the other hand, too large a radius for the coil brings loss by electromagnetic radiation. Such loss can be avoided by making the coil in a toroidal shape. The toroidal cavity resonator may be considered as the limit to which a toroidal coil, reduced to a single turn, tends. Applying to the toroidal cavity the concept of the resonance coefficient proposed above, it can be said that, apart from other factors relating to the shape of the cavity, this coefficient is proportional to the ratio between the volume and the superficies: that is to say, to the radius (the writer compares this relation to Sabine's reverberation law).

In toroidal cavity resonators the capacitive element is essentially represented by a condenser with concentrated capacitance. To increase the resonance coefficient of the circuit and at the same time to raise the resistance at resonance, the inductive reactance may be increased to its maximum by increasing the dimensions and eliminating any concentrated capacitance. The toroidal cavity thus passes into the Lecher coaxial system, in which the cavity retains only a central axis, more or less elongated: or, when the dimensions attain the order of magnitude of the wavelength, into the resonance cavity, where the central axis is completely suppressed. It is to be noted, however, that when the dimensions of the cavity become comparable with the wavelength, the ohmic losses are such that further increases of the volume/superficies ratio will bring no advantage to the resonance coefficient of the circuit.

3207. On the Propagation of Electromagnetic Waves in Tubes, *and* The Propagation of [Decimetric & Centimetric] Waves along Parallel Conducting Planes.—Al'pert: Bunimovich. (*See* 3181 & 3182.)

3208. The Theory of Non-Uniform Lines.—Wagner. (*See* 3200.)

3209. The Vector Potential and Inductance of a Circuit comprising Linear Conductors of Different Permeability [Long Linear Cylinder enveloped by Return Conductor of Eccentric-Annular Cross-Section, Cylinders & Surrounding Medium each being of Different Permeability: Analysis capable of Various Interpretations, including Derivation of Temperature Distribution].—T. J. Higgins. (*Journ. Applied Phys.*, June 1942, Vol. 13, No. 6, pp. 390–398.) For previous work *see* 54 of 1941 and 1135 of April.

3210. A Simple Method of deriving the Form Factor of a Cylindrical Coil [leading to Formula $\phi = \pi^2/(l/D + 0.444)$, giving Excellent Agreement with Nagaoka's Values provided l/D is Not below 0.2].—J. G. Lang. (*Funktech. Monatshefte*, July 1941, No. 7, pp. 104–107.) *Cf.* Müller and Hayman, 1931 Abstracts, pp. 450 and 570.

3211. Negative Resistance for Testing the Quality of Oscillatory Circuits and Their Components [suitable for Wavelengths down to 10 m.].—Wald. (*See* 3321.)

3212. Judging the Fidelity of an Amplifier by means of the Discontinuous Characteristic [Characteristic Function, or Response to a Continuous Voltage or Current applied Suddenly].—J. Haantjes. (*Alta Frequenza*, May 1942, Vol. 11, No. 5, p. 245: summary from *Rev. tech. Philips*, July 1941, Vol. 6, p. 193 onwards.)

3213. Low-Frequency Square-Wave Analysis [of Video & Other Amplifiers].—Preisman. (*See* 3314.)

3214. The Harmonic Analysis of Voltage and Current Curves.—Trnka. (*See* 3296.)

3215. Analysis of the Harmonics of a Multi-Wave Alternating Current: I—The Mathematical-Graphical Determination of the Harmonics: II—The Practical Carrying-out of the Calculation.—K. Heinrich. (*Funktech. Monatshefte*, Oct. 1941, No. 10, pp. 149–152.)

3216. Resonance [Mathematical & Physical Conditions for Occurrence of Harmonic, Multiple-Harmonic, & Sub-Harmonic Resonance: with Photographs of Models].—C. A. Ludeke. (*Journ. Applied Phys.*, July 1942, Vol. 13, No. 7, pp. 418–423.)

3217. Properties of Quartz Oscillators and Resonators in the Region from 300 to 5000 Kilocycles per Second.—Bechmann. (*See* 3332.)

3218. Guiding Lines for the Design Calculations of Oscillatory Circuits for Note-Frequency Generators with Low Harmonic Content.—Steffenhagen. (*See* 3291.)

3219. Electro-Mechanical Analogies and Their Application to Problems of Electro-Acoustics [General Survey of Existing Knowledge, and the Filling of Certain Gaps].—M. Nuovo. (*Alta Frequenza*, March/April & May 1942, Vol. 11, Nos. 3/4 & 5, pp. 157–173 & 214–244.) An English summary will be found at the end of either issue.

3220. Electronically Controlled Variable Capacity [Fixed Condenser with Valve as Variable Series Resistance: Application to Warble-Note Generators, including Air-Raid Warnings].—L. G. Hector & others. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 738: summary only.)

3221. Condenser Smoothing: Performance in Conjunction with Rectifier Circuits.—E. H. W. Banner. (*Wireless World*, Aug. 1942, Vol. 48, No. 8, pp. 190–191.)

3222. A Variable Mutual Inductance with Wide Linear Scale [primarily for Potthoff's "M" Bridge Circuit].—Mathiesen. (*See* 3323.)

3223. Relay Circuits with Delayed Armature Release [Conditions for Good Constancy of Action, and Their Fulfilment: Condenser-less Type (and a New Long-Delay Circuit, Fig. 3): Three Basic Condenser-Type Circuits & Their Special Qualities]: Part I.—A. J. Schmideck. (*Arch. f. Elektrot.*, 31st March 1942, Vol. 36, No. 3, pp. 181–200.)

3224. Concerning the Operational Calculus [and the Difference between the Various Forms].—K. W. Wagner: Angelini. (*Alta Frequenza*, March/April 1942, Vol. 11, No. 3/4, p. 174.) Letter prompted by 2625 of September.

3225. The Application of Matrix Calculus to Problems of High-Frequency Technique [Foundations of the Method, and Application to Coupled Circuits & Series-Connected H.F. Transformers: with 21 Literature References].—M. Päsler. (*Hochf:tech. u. Elek:akus.*, March 1942, Vol. 59, No. 3, pp. 78–85.) *Cf.* 3226 & 3227, below.

3226. Polynomial Quadripoles [Four-Terminal Networks] with Given Losses and Predetermined Frequency-Dependence.—W. Bader. (*Arch. f. Elektrot.*, 28th Feb. 1942, Vol. 36, No. 2, pp. 97–114.)

"The work deals with the development of prescribed frequency-dependencies [assumed as representable by polynomials, completely rational functions] by means of quadripoles whose losses are given and must be taken strictly into account. The quadripole lies, as usual, between a source, with e.m.f. $\mathfrak{U}_0$ and internal resistance R_1, and the secondary load R_2. Those of its properties which are important to us can be described by a relation between the magnitudes of $\mathfrak{U}_0$ and $\mathfrak{U}_2$, namely $U_0^2 = P(x) U_2^2$, or between the source e.m.f and the output voltage, namely $\mathfrak{U}_0 = F(y)\mathfrak{U}_2$, where x is a measure of the frequency and $y=ix$.

"It is possible to calculate a reactance quadripole for any arbitrary (admissible) prescribed characteristic $P(x)$ or $F(y)$ [references "1" & "2": for Piloty's and Bader's papers *see* 959 & 2940 of 1940: also *cf.* 3269 of 1941 and 1933/4 of July]. But since a quadripole cannot be built so as to be loss-free, the properties of the circuit as constructed will deviate from those which were prescribed, though this discrepancy does not detract from the importance of the investigations on reactance quadripoles. It has been attempted in various ways to allow approximately, in the calculations, for the unavoidable quadripole losses; or to render these harmless, by the addition of ohmic resistances, to the extent that they would act only as constant additional damping [reference "3": for Rabe's paper *see* 2937 of 1940 and back reference].

"An exact treatment of the losses is still lacking, although it would not merely be of theoretical interest but would offer practical advantages. In the first place, it would ensure a better, completely satisfactory agreement between the desired frequency characteristic and that obtained. Further, it would often lead to a more economical design of circuit; for when building a circuit on calculations based on the assumption of loss-free components the tendency is to keep as close as possible to the theory by making the losses small, that is by using large, expensive coils with large time constants. If, on the other hand, the losses have been taken into account, there is frequently no need to insist on small values for them; particularly since, as I hope to show later, in many cases the function P or F admissible for loss-free quadripoles can be realised also with loss-possessing quadripoles, provided that an often unimportant factor, greater than unity, is prefixed to the function P or F." The present treatment, by matrices, yields all the circuits of the prescribed properties, and the conditions with which the given function must comply in order that it may be realised with practical—that is, positive—circuit elements. For practical purposes the procedure is summarised in section IV. The writer hopes in a later paper to deal with certain special cases.

3227. The Treatment of Network Problems by means of Matrices.—G. A. Usunoff. (*Arch. f. Elektrot.*, 28th Feb. 1942, Vol. 36, No. 2, pp. 115–122.)

Two papers, one by Quade (716 of 1941) and one by Strecker (2540 of 1940), which appeared in 1940 in this *Archiv*, may be regarded as an elegant introduction of the most modern application of matrix methods to electrotechnical problems. To many electrical technicians this new process seems likely to be extremely fruitful, but others have expressed themselves as sceptical as to the limitations of its usefulness. It will be beneficial to both types if new examples are added to the existing applications: this is the object of the present paper.

Transformation by the transformation matrix ("TM") **C** (**i** = **C** . **i**′, by Kirchhoff's first law) is only one of the various ways in which the impedance matrix ("IM") can be transformed. This transformation fulfils the condition for the invariance of the applied power: further, neither the currents through the separate impedances, nor the impedance values themselves, are changed. It is characteristic of these matrices that their elements are either zero or ±1. It is, however, possible to carry out other transformations of the IM by other TMs: thus the connections between the impedances may remain unchanged by the TM (*i.e.* the structure of the network is the same) while the impedance values are altered.

The writer first considers transformations in which the TM has elements which include not only zero or unity but arbitrary real numbers, and whose form is that of a square: its order is the same as that of the IM. Such a transformation yields a series of equivalent networks in which two or more currents remain constant. Thus in a numerical example (the five equivalent networks of Fig. 2 and accompanying text) "we are now in a position to solve the following problem:—if in a network the impedance value in one branch is altered, how must the values of the other impedances be changed in order that one or more currents in the remaining branches may stay constant?" The other transformation of IM considered here is one which allows the current through an impedance to be changed to any prescribed fraction of its original value, with a subsidiary requirement that its own or one of the other impedances should remain unaltered. Thus in the example of eqn. 11 it is required that the current through Z_5 should be halved while Z_5 itself remains unchanged, whereas in that of eqn. 12 the condition is that Z_4 should be kept constant while the current through Z_5 is halved. In conclusion it is pointed out that the transformation matrices described possess group properties, so that if two different TMs of (say) the first type are multiplied together the result is a matrix of similar form. "It may be expected that many problems in network theory will be successfully linked with the concepts of transformation, groups, and invariance, and a wide field of mathematical treatment thus opened for their solution."

TRANSMISSION

3228. On the Theory of the Klystron.—V. Ya. Savel'ev. (*Journ. of Tech. Phys.* [in Russian], No. 16, Vol. 10, 1940, pp. 1365–1371.)

Webster's theory of the klystron is discussed (3950 of 1939 [and 968 of 1940]). A different method is proposed which enables formulae for determining the power output and efficiency to be derived in a simpler way. Moreover, in this method, the effect of the forces of electrostatic dispersion of the electrons is taken into account in a more general and in a stricter manner. Methods are also indicated for determining the amplification factor, as well as the limiting values of the current and drift length necessary for the appearance of sustained oscillations.

3229. Transit-Time Oscillation at Large Amplitudes [Application of Power-Series Technique: including a Two-Stage Decimetric-Wave Generator in One Vacuum].—W. Kleinsteuber. (*Hochf:tech. u. Elek:akus.*, April 1942, Vol. 59, No. 4, pp. 112–118.)

From the Julius Pintsch laboratories. In a previous work (1861 of 1941) the generation processes in a retarding-field valve were investigated without the usual assumption that the oscillating voltage is small compared with the d.c. voltage. Two mathematical methods were used, and it was shown that the simpler of the two, the power-series method, gave a sufficiently good approximation. In the present paper this method is applied to two other transit-time generators, the "diode-gap" type (*cf.* Müller & Rostas, 406 of February) and the velocity-modulated valve.

Dealing first with the efficiency, as a generator, of a "diode without accelerating field," represented by two electrodes (one or both in the form of a grid) at the same positive d.c. voltage and supplied with a constant stream of electrons from a cathode on the far side of one of them (Fig. 1), the writer arrives at a maximum efficiency, in the first oscillation region, of about 20% (Fig. 4, where the max. efficiency is plotted as a function of α, the transit-time angle depending on the length of gap and the d.c. voltage), which is practically the same as that of a retarding-field generator. But a consideration of the oscillation-onset admittances in the two cases shows that the latter generator is superior to the diode, both when equal d.c. voltages are assumed and when the assumption is that the electrode spacings are equal. Moreover, with the diode a change to cylindrical electrodes brings no improvement, as it does to the retarding-field valve.

Section III deals with the diode-gap as a controlling or driver stage. Fig. 5 shows a cathode followed by four grids and an anode. Between G_2 and G_3, both at the same d.c. potential, there is an oscillatory circuit, excited either by this diode system itself or by an external source (end of p. 116). From the d.c. passing through G_2 an alternating current is produced at G_3, which passes into the amplifying space between G_4 and anode and excites the oscillatory circuit connected across these electrodes. The space between G_3 and G_4 is at first neglected, the only assumption made being that there is no h.f. voltage between these electrodes. The effectiveness of the two-stage generator thus constituted depends on the magnitude of the ratio of the alternating current through G_3 to the d.c. coming from the cathode. For the fundamental oscillation the maximum attainable ratio is in general 2 (Barkhausen's book): in the present case the calculations show (Fig. 7, full-line curve) that for $\alpha = 4.0$ it reaches 1.4, dropping to 1.0 as α increases and reaching nearly the same value of 1.4 for $\alpha = 8.2$: its actual maximum is 1.5 for $\alpha = 3.0$ (calculated by the other mathematical method).

In the case where the diode-gap is self-excited, its oscillation-onset resistance is important. If the cathode-emission is taken as 60 mA and the voltage between the diode-electrodes and cathode as 100 V, this resistance is found to be 55 kilohms when α is taken as 7.5. The corresponding d/λ value (d being the electrode spacing) is given by eqn. 5 as 2.33×10^{-2}, so that for $\lambda = 10$ cm the spacing comes out at 2.3 mm, or 1.2 mm for $\lambda = 5$ cm. But the resonance resistance of the control stage can certainly be made to exceed 100 kilohms for decimetric waves, so that the self-excitation of the control stage is assured. Thus the valve represented in Fig. 5, with proper choice of the d.c. voltages, provides a complete two-stage transmitter in a single vacuum.

In the same section (below Fig. 5) it is mentioned that the G_3G_4 space can be used as the drift-tube space for velocity modulation: the modulation in the G_2G_3 (diode) gap can be kept so low that the electrons are given only velocity differences which generate an alternating current in the following space. A subsequent paper will deal with the combination of such a velocity modulation with the diode-gap amplitude modulation discussed in the present paper. Section IV deals merely with the application of the mathematical method to velocity modulation in general, thus extending Webster's treatment to cover the case of large modulations. No special new results are obtained, but the serviceability of the method is brought out, together with the limit at which it must be replaced by the alternative (integral) technique mentioned at the beginning of this abstract.

3230. BARKHAUSEN-KURZ OSCILLATIONS: THE INFLUENCE OF THE ELECTRON-ASSORTING PROCESS ON THE EFFICIENCY.—B. Kockel. (*Zeitschr. f. tech. Phys.*, No. 6, Vol. 23, 1942, pp. 148–156.)

Theoretical investigations by Kleinsteuber and by the writer (1861 [and 2380] of 1941, and *Zeitschr. f. tech. Phys.*, No. 9, Vol. 22, 1941, p. 215 onwards, respectively) on a valve model with plane electrodes have shown that efficiencies up to $20p$%, (where p is the fraction of electrons not absorbed by the passage through the grid) are possible if no assorting process takes place, at the cathode and retarding electrode, on the good-phase and bad-phase electrons (*see*, for instance, Kapzov, 1929 Abstracts, p. 154). In the present paper the writer considers the same valve model and looks for more exact knowledge on the relation between the assorting process and the efficiency.

In section 1 he deals with the electron motion only (as in the previous work) up to the second passage through the grid ("three-quarter swing"), but a partial impinging on the retarding electrode is assumed, in contrast to the previous work. In this case the electrons enter the coupling space between grid and retarding electrode once only. Section 2 follows the course of the electrons over several swings, so that the assorting process at retarding electrode and cathode is involved several times, and the electrons enter the coupling space again and again.

Author's summary:—"For a plane model of a B-K valve (Fig. 1) the efficiency of oscillation production is calculated as a function of the path-time angle θ (for the electron motion from grid to reversal-point in front of the retarding electrode and back to the grid again); as a function of the ratio β of alternating-voltage amplitude to d.c. voltage between grid and retarding electrode; and as a function of the ratio V_A/V of the opposed voltage on the retarding electrode to the grid voltage. It is particularly investigated how the occurrence of the assorting process, involving the impinging of electrons on the cathode and retarding electrode, affects the efficiency. It is thus found that the functioning of the valve without any assorting process is more favourable than its functioning with the assorting process. The assorting improves the efficiency only when the alternating voltage, and consequently the efficiency, is very low.

"It seems, therefore, that the assorting process does not possess the significance which has previously been attributed to it in explanations of the formation of B-K oscillations. These oscillations are rather to be explained on the same lines as the Benham diode oscillations (no reference is given, but *see* 1374 of 1935; for later work *see* 553 & 3771 of 1936, 2108 & 4030 of 1937, 505 of 1940, and 2071 of 1941). If the path-time angle is correctly chosen, the oscillation occurring in the oscillatory circuit ensures, without any assorting process, that the course of the electron motion is such that a sufficient amount of energy is given up to the oscillatory circuit. The intervention of the assorting process is unnecessary and even harmful." This agrees with the experimental result (Allerding & others, in their "Resotank" paper, 2258 of 1938) that a high efficiency is not bound up with a large retarding-electrode current, and is thus obtainable without assorting taking place at that electrode.

3231. THE GENERATION OF DECIMETRIC WAVES WITH ACORN VALVES (Regenerative Circuits for Wavelengths down to 80 cm).—H. Hehs. (*E.T.Z.*, 16th July 1942, Vol. 63, No. 27/28, p. 335: summary only.)

An editorial note points out that Strutt and others have gone down to 50 cm with that type of valve, and that types now exist which will give wavelengths down to 20 cm in a regenerative circuit.

3232. A GROUNDED-PLATE AMPLIFIER FOR THE FREQUENCY-MODULATED TRANSMITTER 10 kW Type 506A-1 RTE: Large Loss in Plate Tuning Coil & Undesirably Sharp Tuning avoided.—A. A. Skene (Doherty). (*Bell Lab. Record*, July 1942, Vol. 20, No. 11, pp. 270–283.) *See* also 2642 of September.

3233. SYSTEM OF RADIOCOMMUNICATION BY MODULATION OF THE PHASE OF THE CARRIER WAVE.—E. Severini. (*Alta Frequenza*, June 1942, Vol. 11, No. 6, pp. 258–288.)

The theory of frequency and phase modulation is first discussed at some length, tables and diagrams being given to illustrate the series developments of the Bessel functions. The fundamental difference between the two systems is thus brought out. The writer then describes the two main systems of frequency modulation so far used. Consideration of these leads to the conclusion that although they both possess indisputable advantages over amplitude modulation, they both involve such a complexity of circuits that they are suitable for large fixed stations but not for small mobile equipments such as are needed for military, police, or emergency service.

The writer, therefore, has been led to devise a phase-modulation system of transmission and reception for such installations. After describing this system and discussing its advantages (and its disadvantage, compared with frequency modulation, of having "a transmitted band equal in width to that of an amplitude-modulated system"), he mentions that Crosby's paper (2137 of 1939) shows that the transmitter just described does not differ from one of the types used in America and dealt with in that paper. "The receiver, however, is original and may prove to be more practical and simple."

This receiver is illustrated and described on pp. 284–286. "The incoming wave, after amplification, passes to a limiting circuit (always present also in frequency-modulation receivers) . . . which may perhaps take the form of a rapid and powerful automatic volume control. The 600 kc/s frequency is transformed, for reasons given in section 13, by beating with a quartz-controlled 3.6 Mc/s frequency, to 3 Mc/s: the phase displacements remain unchanged by this operation, since the frequency conversion does not affect them. . . . A part of this 3 Mc/s phase-modulated voltage is used to synchronise a separate (3 Mc/s) oscillator which is by preference of the 'transitron' type (1851 & 2296 of 1939 and 1358 of 1940 [and 70 of 1941]). This type of oscillator combines the properties of high frequency-stability and excellent wave-form with the power of being readily synchronised by an external e.m.f. applied to the points *AA* (Fig. 12). This must be enough to maintain phase synchronism between the resulting frequency and the synchronising frequency, but not enough to allow the local oscillator to follow the phase modulation of the synchronising voltage. Such a result is quite easily obtained, thanks to the fly-wheel action of the oscillatory circuit. As a result, the output voltage is perfectly sinusoidal: it is taken to a phase-changing network which yields two voltages exactly in quadrature, but of phases variable at will by a simple adjustment of this network." The way in which these two unmodulated voltages are applied to the two symmetrically connected valves T_1 and T_2 (Fig. 11) so that, at a suitable adjustment of the phase-change network, the signal-modulation vector and an automatically in-phase vector from the network are left on the two grids of T_1, is described with the help of Fig. 13 and adjacent text: the sum of these two vectors represents, as regards the anode circuit of T_1, an amplitude modulation which can be detected as usual.

It is pointed out that the circuits of the transmitter and receiver are so similar that the possibility presents itself of employing a common circuit for transmission and reception, by suitable change-over switching: this would fulfil a long-felt want.

3234. METHOD OF MODULATION WHICH IS ECONOMICAL IN ENERGY [Modulated Carrier, varying in accord with Mean Value of Modulation, taken to Power Amplifier whose Anode D.C. Voltage is varied in Synchronism with the Modulation].—W. M. Hahnemann & others. (*Hochf:tech. u. Elek:akus.*, March 1942, Vol. 59, No. 3, pp. 92–93.) Lorenz Patent, No. 709 282.

3235. AMPLITUDE-STABILITY OF AUTO-OSCILLATORS [Periodic Amplitude Variations, especially in Triode Auto-Oscillators with Automatic Grid Bias].—N. Carrara. (*Alta Frequenza*, May 1942, Vol. 11, No. 5, pp. 195–213.)

In a previous paper (1357 of 1940) the general behaviour was studied of two-terminal networks which present a differential negative resistance; particular attention was given to the case, quite frequent in practice, of the "type N" networks (such as a tetrode connected to constitute a dynatron) combined with voltage-resonant oscillatory circuits [for "type N" and "type S" classification *see* abstract quoted above, and also footnote "2" on p. 195]. The present paper continues the treatment of this case, especially as to the question of amplitude-stability.

Particular attention is paid to the fact that, in suitable conditions, triode auto-oscillators may supply oscillating currents whose amplitude varies periodically with time according to one of two laws: either it varies periodically and regularly from a minimum to a maximum, following a sinusoidal law, or it falls suddenly to zero, remains there for a definite interval, and then mounts to its original value. Such periodic variations, which are generally avoided by judicious design, are occasionally utilised, as for example in super-regenerative receivers. The present treatment is a general one, whereas van Slooten's paper (1418 of 1939), although of great interest, is "incomplete and deals only with a particular type of triode oscillator."

The variations in question are specially easily obtained with triode auto-oscillators with automatic grid bias. For this case it is found that if the biasing (grid-leak) resistance is below a certain limit, no periodic amplitude-variations are possible, whatever the value of the shunt capacity. If, on the other hand, the grid-leak resistance is above that limit, various cases present themselves: (i) if the shunt capacity exceeds a certain value, the amplitude undergoes variations of real type (relaxation oscillations): (ii) if the capacity lies between that value and a smaller limiting value, the variations are of complex type (sinusoidal): and (iii) if the capacity is still smaller, periodic variations of amplitude do not occur, and any occasional variations disappear according to a law of complex damped type or real (exponential) type. The limits for the grid-leak resistance and for the shunt capacity are derived as functions of the characteristics of the triode and of the constants of the oscillatory circuit supplied by this.

3236. TRANSMITTER MAINTENANCE [Day, Night, & Special, at WOR].—C. H. Singer. (*Communications*, April 1942, Vol. 22, No. 4, pp. 8–9, 22, 28–29, and 38.)

RECEPTION

3237. SYSTEM OF RADIOCOMMUNICATION BY MODULATION OF THE PHASE OF THE CARRIER WAVE [particularly suitable for Small Mobile Stations].—Severini. (*See* 3233.)

3238. Frequency-Modulation or Homodyne? Advantages and Limitations of the Systems.—D. A. Bell. (*Wireless World*, May 1942, Vol. 48, No. 5, pp. 106–107.)

3239. A Universal Receiver [with the Three Necessary Requirements of Large Wave-Range (down to 5 m), High Amplification on Short Waves, & Selectivity sufficient for "separating Frequencies differing only by 200–300 c/s": Importance of Good Contacts (Special Alloy employed): Devices for increasing Signal/Noise Ratio and for receiving Imperfectly Stable Stations (1000 c/s Oscillator)].—R. Villem. (*Génie Civil*, 15th July 1942, Vol. 119, No. 17, pp. 214–215: summary only.)

3240. Measurement of the Sensitivity of Receivers for Short [Metric & Decimetric] Waves.—K. Fränz. (*Hochf:tech. u. Elek: akus.*, April 1942, Vol. 59, No. 4, pp. 105–112.)

The writer begins by considering in what direction the results already available for "long" waves must be extended when one comes to deal with metric and decimetric waves. For "long" waves the available knowledge has been satisfactory for some years: the references quoted are to the work of Llewellyn, Williams, and the writer himself (1931 Abstracts, p. 325: 433 of 1938: 3126 of 1939). Here, in each case, it was assumed that all the resistances involved were at room temperatures. For "long" waves this is generally true, and the radiation resistance is also generally negligible compared with the loss resistances in the aerial. "With short waves, however, the radiation resistance is an important quantity: to it is matched the feeder between aerial and receiver, and the signal-voltage/noise-voltage in it is the theoretical optimum, not subject to further influencing. Short waves, in the sense of the present work, include all such waves for which the aerial radiation resistance is no longer negligibly small compared with the loss resistances. The extensions to the earlier calculations, envisaged above, will all be concerned with the fact that resistances of different noise-temperatures have to be considered in the circuits. Since, for instance, for short waves the space between ground and ionosphere is no longer a closed one from the energy viewpoint, special considerations and measurements will be needed to determine the value of the disturbance-field strength in the neighbourhood of the aerial, and thereby the temperature of the radiation resistance. Further, it may be advantageous to form, by retroactively-coupled valves, 'cold' resistances to introduce necessary damping into wide-band amplifiers without producing additional noise (Percival, 2708 of 1939, and Strutt & van der Ziel, reference "8"). For the transit-time-conditioned electronic grid-input-resistance of amplifier valves, a value of the order of the cathode temperature T_k would be expected; Bakker (reference "9") and North & Ferris (2128 of 1941) give the value 1.43 T_k."

"To progress further we must define more precisely the receiver circuit under consideration (Fig. 2). We assume an aerial with radiation resistance R_a, signal-e.m.f. E_s, and noise-e.m.f. E_r, to be connected through a four-terminal network to the receiver with a fly-wheel-circuit resistance equal to R_s. We represent the noise for a short-circuit between first grid and earth by an equivalent noise-resistance $R_{\ddot{a}}$, at room temperature T_o. The ratio of the radiation-resistance temperature to the room temperature we call γ, and the corresponding ratio for the fly-wheel resistance (in which we include also damping due to valves) we designate β. The ratio of the equivalent noise resistance to the fly-wheel resistance is represented by α. We consider the four-terminal network, with the aerial as load, as a two-terminal network of e.m.f. E' and internal resistance R'. In this way we have made an extension to the earlier work (3126 of 1939, cited above) whose calculations we wished to widen to take the case of unequal temperatures. For the receiver sensitivity the determining factor is above all the coupling between the aerial and the input circuit. Without giving the four-terminal network any special properties (apart from the assumption of freedom from loss, always possible to fulfil at short wavelengths) we will measure the coupling by the ratio $x = R_s/R'$: it is the greater, the tighter the coupling, the more the grid circuit is damped by the aerial. When the aerial is matched to the circuit, $x = 1$. The noise at the first grid is made up quadratically of the contributions from the resistances $R_{\ddot{a}}$, R', and R_s (eqn. 2 for V_r^2). For the square of the signal voltage we have, as in the earlier paper, eqn. 3 (for V_s^2). What is required now is to find that value for R', or what comes to the same thing, for the coupling x, which will make the quotient V_r^2/V_s^2 assume its minimum: we find $x^2_{opt} = 1 + \beta/d$. This formula has already been given by Wilke (3241, below): a fuller treatment is contained in a paper by Kleen (*Telefunken-Röhre*, 1941, p. 273 onwards).

"Thus the optimum coupling in no way depends on the temperature of the radiation resistance. This fact has the result that, at any rate in principle, a signal generator whose internal resistance is at room temperature can be used for the correct adjustment of a receiver for all aerial temperatures. The smaller the valve noise α, and the warmer the fly-wheel resistance (*i.e.* the larger β is), the more must the grid circuit be damped."

Section III begins by discussing the disadvantage of using, as a measure of sensitivity, the aerial-e.m.f., or the equivalent signal-generator-e.m.f., required to produce a signal/noise ratio of 1 : 1. Such a measure would be dependent on the accidental value of the aerial resistance, and for this reason the writer suggested in his earlier paper a dipole-reception technique free from this defect. But with ultra-short waves the aerials are generally directive, and, in addition, Fig. 1 shows that such a measure of sensitivity would be dependent on wavelength. "We therefore give below a measure of receiver sensitivity which is independent both of the type of aerial and of wavelength," and the corresponding technique is summed up as follows:—a signal generator with capacitive voltage-divider (Fig. 5) and ohmic internal resistance of the value of the usual cable resistance (70 ohms: *see* Meinke, 3048 of October) is employed. As a measure of sensitivity the power is taken which can be derived as a maximum from the signal generator when the latter's e.m.f. is so adjusted that a signal-voltage/noise-voltage ratio of 1 : 1 is obtained at the receiver output. By dividing this power by the receiver band-width, it can be compared directly with the theoretical minimum value $1kT_0 = 4.0 \times 10^{-21}$ w/c/s.

The relative calibration of the signal generator is carried out by comparison with a long-wave signal generator, heterodyne reception being employed. Since the oscillator of the receiver has an output of a few watts, while the h.f. power to be measured amounts to 10^{-5} watt at most, the relation between the h.f. voltage taken to the mixing valve of the receiver and the resulting i.f. voltage is linear. Both signal generators remain coupled to the receiver during the calibration process, the i.f. generator being coupled to the first i.f. stage by a very small condenser. For various settings of volume control of the receiver, equal powers, from the two signal generators in turn, are made to appear at the output terminals of the i.f. amplifier. Thus the latter need not be linear, it must merely not be over-modulated.

When the two electrodes of the tubular voltage-divider are very close together, the field in the tube will contain an appreciable amount of the strongly damped higher E waves. In a semi-logarithmic representation of the voltage-divider calibration an initial bend would be expected, followed by a straight-line relation between attenuation and divider-adjustment with a slope of 4.01 nepers/cm (Fig. 6 : from the attenuation formula 10 for the E_0 wave, a tube diameter of 1.2 cm being assumed). The measured attenuation was 4.03 nepers/cm, agreeing admirably. Another check on the relative calibration curve of Fig. 6 is against the overlapping portion of the absolute calibration.

This absolute calibration is much more complicated. It is carried out with the bolometer arrangements dealt with by Meinke (*loc. cit.*), and pp. 110–111 are occupied by a theoretical examination of the influence of the current distribution along the filament on the errors of measurements based on a d.c. calibration. The filament actually employed was a tungsten one 15 mm long (*cf.* Meinke) and about 10μ in diameter, and these dimensions are assumed in the calculations. The final conclusion reached is that the procedure is applicable to all waves with which concentric cables, and not wave-guides, are employed : that is, waves down to 10 cm. Fig. 11 shows that the absolute calibration remains practically unchanged over periods of 7 to 9 months.

The measurement of the 1 : 1 signal-voltage/noise-voltage ratio at the receiver output is most precisely carried out with a square-law instrument such as a thermoelement, but in many cases the more convenient linear rectifier can be used (Fränz, 3027 of 1941).

3241. The Sensitivity of Ultra-High-Frequency Receivers [with Special Attention to the U.H.F. Duo-Pentode Type EFF50].—R. Wilke. (*Funtech. Monatshefte*, June 1941, No. 6, pp. 88–92.)

" ~~This problem has already been dealt~~ with fully in a paper by Fränz (3126 of 1939). Strutt's recent book (2975 of 1940) has, however, brought forward a series of new facts, so that it seems desirable to collect again the various results with the addition of practical numerical data, special attention being given to a new h.f. pentode which shows very good u.h.f. properties " [2125 of 1941 (and *cf.* 2666 of September)].

On the basis of equations taken from Strutt's book, the writer arrives at eqn. 13 for the optimum value of x ($= R_k/R_a$, where R_k is the resonance resistance of the input circuit and R_a the transformed aerial-radiation-resistance : x is thus a measure of the coupling between aerial and input circuit) : this equation is $x_{opt} = \sqrt{1 + yp}$ [*cf.* Franz, 3240 above], where $y = R_k/R_{\ddot{a}}$ ($R_{\ddot{a}}$ = equivalent valve-noise resistance) and p is the factor by which $R_a x/(x + 1)^2$ must be multiplied in order to give R_r, the noise-resistance of the aerial/input-circuit combination, in the general case where the valve-input-resistance R_e is *not* necessarily a small fraction only of the total resistance R_{ges} of eqn. 5, as it must be for Strutt's eqn. 4 ($R_r = R_a x/(x + 1)^2$) to be valid. Thus $p = f(R_e/R_{ges}) = 1 \ldots 3$, for when R_{ges} is dominated by R_e the noise-resistance as given by eqn. 4 is increased 2 or 3 times. If p is put equal to unity, the expression for the optimum coupling becomes that already given by Fränz (*loc. cit.*), although in his treatment the aerial radiation-resistance was included as a noise-producer.

With the optimum coupling as given above, the signal/noise ratio S_v is given by eqn. 14, involving both p and y. Since, however, the above relation for p is not known numerically with any precision (" though a new paper by Strutt & van der Ziel [2125 of 1941] has meanwhile dealt with this point further "), a limiting assumption must be made : in regions above 200 Mc/s, concentric conductors and cavity resonators can be used as tuning elements, and with these it is possible to attain parallel resistances R_p large compared with the input resistances of valves, so that $R_k = R_e$, $y = R_e/R_{\ddot{a}} = Z$, and $p = 3$. Eqn. 14 for S_v then becomes eqn. 15, and from this is obtained an expression for the receiver sensitivity

$$e = \sqrt[4]{1 + 3Z} \Big/ \sqrt{3 + (1/Z)(1 + \sqrt{1 + 3Z})^2}.$$

Fig. 3 shows the optimum sensitivity e_{opt} as a function of Z : it is obvious that Z must be increased considerably if a marked improvement in sensitivity is to be attained : so although Z contains only valve properties and can therefore be used as a measure of the suitability of a valve for an input stage, e is a better criterion (always on the assumption, made earlier below eqn. 7 on p. 88, that the first-stage amplification is high enough—in practice about 3—for the total noise-level of the receiver to be determined by the noise voltage at the grid of the first valve).

Fig. 4 shows the variation of the optimum coupling x_{opt} with the resistance-ratio Z : with $y = Z$ and $p = 3$ (as above), $x_{opt} = \sqrt{1 + 3Z}$. " Fig. 4 shows that for the highest sensitivity over-matching [$x > 1$] is always necessary." Fig. 5 shows the ratio of the sensitivity to the optimum sensitivity (that is, e/e_{opt}) as a function of matching error, x/x_{opt}, for four values of Z from 0.1 to 100 : a matching error of 2 reduces the sensitivity by

10%, while one of 10 halves it. The coupling, therefore, is not very critical.

The rest of the paper deals with the data of the EF50, the SF1, the E1F (acorn pentode; originally type 4672), and particularly the EFF50 mentioned earlier in this abstract; all in connection with their suitability for use in an u.h.f. input stage. Fullest details of the EFF50 are given, and its superiority over all the others is brought out. For previous work by the writer, referred to here, *see* 1377 of 1938.

3242. Valve and Circuit Problems of Short-Wave Amplification in Broadcast Receivers : Part I [Analysis & Curves of the Various Valve Resistances & Capacitances, and the Parts played by Transit-Time Effect, Electrode Damping, etc: the Capacitance Variations produced by A.V.C., & the Resultant I.F. Shift] : Part II [Special Problems of the Mixing Stage—Automatic Bias, Oscillation Conditions, Harmonics, etc.].—L. Ratheiser. (*Funktech. Monatshefte*, July 1941, No. 7, pp. 97–104: June 1942, No. 6, pp. 77–87.)

3243. The Influence of the Detector on the Selectivity of a Receiver [Weaker-Signal Suppression in Linear, Quadratic, Logarithmic, & Multiplicative Detectors: Comparative Table of Data].—O. Tüxen. (*Funktech. Monatshefte*, Sept. 1941, No. 9, pp. 129–133.) For a longer paper *see* 2398 of 1941.

3244. Improving the Diode Detector : Design for Negligible Distortion at All Modulation Levels [Disadvantages of "Grid Detector" as Method of abolishing Reactive Shunting: Success of Method using Two Diode Systems].—G. A. Hay. (*Wireless World*, Aug. 1942, Vol. 48, No. 8, pp. 186–187.) *See* also September issue, pp. 222–223.

3245. New Dial-Calibration System [Dials for Superheterodyne Receivers (for D.F., etc.) calibrated wholly by Mathematical Means].—R. L. Drake & R. R. Schmidt. (*Communications*, April 1942, Vol. 22, No. 4, pp. 5–7 and 32.) From Lear Avia, Inc.

3246. The Combating of the Disturbing Action of Atmospheric Processes on Wireless Reception [Survey of Fight against Atmospherics, Fading, & Range Variations, leading to Emphasis on the Importance of Future Accumulation of Statistical Material].—H. Bender. (*Funktech. Monatshefte*, Aug. 1941, No. 8, pp. 113–116.)

3247. Aircraft-Engine Radio Shielding.—D. W. Randolph. (*Journ. Roy. Aeron. Soc.*, July 1942, Vol. 46, No. 379, p. 236: abstract only.)

248. The Protection of Wireless Receiving Installations against Interference due to Electrical Equipment of Motor-Cars [and Methods of satisfying the Recent Law in Germany applying to Car Manufacturers].—(*Génie Civil*, 17th/24th Jan. 1942, Vol. 119, No. 3/4, p. 47: summary, from *Automobiltech. Zeitschr.*, 25th Aug. 1941.)

3249. Factors controlling Man-Made Radio Interference [Examination of the Formula Signal/Noise Ratio at Receiver $= R = E + U + a - NI$].—R. A. Shetzline. (*Bell Lab. Record*, June 1942, Vol. 20, No. 10, pp. 251–253.) "*NI*" being the noise-influence level (at, for instance, the originating point on a telephone line).

3250. Suppressing High-Frequency Disturbances from Telephone Apparatus [Some Steps taken by Bell System to Reduce the "*NI*" (3249, above)].—M. E. Krom. (*Bell Lab. Record*, June 1942, Vol. 20, No. 10, pp. 254–257.)

3251. A British "Austerity" Set ? Ensuring Continuance of Broadcast Reception [Editorial].—(*Wireless World*, Aug. 1942, Vol. 48, No. 8, p. 177.)

3252. Design Data on A.C./D.C./Battery Portables.—J. J. Adams. (*Communications*, Jan. 1942, Vol. 22, No. 1, pp. 11–12 and 31.) From the Zenith Radio Corporation.

3253. German Receivers at the Leipzig Autumn Fair.—(*Alta Frequenza*, March/April 1942, Vol. 11, No. 3/4, pp. 184–192.) Including the Hagenuk piezoelectric telephone set giving (without any supply) communication up to 5 km with line and earth return (*cf.* 2734 of 1941).

AERIALS AND AERIAL SYSTEMS

3254. "Wave Guides" [Book Review].—Lamont. (*See* 3183.)

3255. Simple Construction of a Parabolic Mirror [Suggested Application of R. W. Wood's Use of Mercury rotated with Constant Angular Velocity (forming Central Cavity in form of Paraboloid of Revolution) to Liquefied Synthetic Resin, coated after Hardening with Metal Film].—F. W. Bubb. (*Journ. Opt. Soc. Am.*, July 1942, Vol. 32, No. 7, p. 400.)

3256. Forest-Service Antenna needs No Insulation ["Plumber's Delight" Vertical Radiator with Four Horizontal Quarter-Wave Radials as Earth: 6–7½ Feet long for F.S. Wavelengths].—(*Scient. American*, Aug. 1942, Vol. 167, No. 2, p. 74.)

3257. The Mechanical Problem of the Inner-Conductor Suspension in "Thread-Supported" Coaxial Cables ["Fadenkabel" (*see* 4466 of 1938 & back references): German & Japanese Methods: a New German Solution ("Rope Suspension," due to Wanske) giving Remarkably Firm Support].—O. Cords. (*Hochf:tech. u. Elek:akus.*, March 1942, Vol. 59, No. 3, pp. 89–92.)

3258. Matching Problems with Screened Aerial Leads.—H. Pitsch. (*Funktech. Monatshefte*, Oct. 1941, No. 10, pp. 154–156.)

Difficulties with the simple transformer/line/transformer arrangement when the line length equals or exceeds a quarter wavelength: the cure by means of a terminating resistance: its disadvantage, at the longer waves of the range, that although the matching is chosen for these waves (so as to make the most of them) the presence of the terminating resistance seriously diminishes the voltages obtained: Wilhelm's solution (Fig. 3: Telefunken patent) by connecting the terminating resistance by way of a condenser or filter section, instead of directly: Steinhausen's modification of this (Fig. 4: Telefunken patent) to step up the voltage on short waves by the addition of a short-wave transformer with its primary across the terminating resistance (short-circuiting this for the longer waves: with which, moreover, the main voltage comes at the condenser, not at the resistance): a modified version of this arrangement (Fig. 5), with the secondary winding connected in the upper output lead and the lower output terminal going to the lower end of the primary.

3259. A New Method for deriving Poynting and Other Valid Energy-Flow Vectors.—J. Slepian. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 732: summary only.)

3260. The Reciprocity Theorem of the Electromagnetic Field.—W. Dällenbach. (*Arch. f. Elektrot.*, 31st March 1942, Vol. 36, No. 3, pp. 153–165.)

To adapt it to the requirements of h.f. technique, the original Lorentz theorem has undergone various modifications, namely: "(1) Two transmitting aerials (in particular, dipoles), a great distance apart and arbitrarily oriented, are radiating the same power. Each of these aerials produces a definite field strength at the locality of the other. These field strengths are compared (reciprocity theorem of wireless telegraphy, Sommerfeld & Pfrang: *see* 1931 Abstracts, p. 373). (2) In addition to current and charge densities and the vectors of the electric and magnetic field, an 'impressed electric intensity' and the current distribution due to this are introduced (Carson, 1929 Abstracts, p. 506 [and 1930 Abstracts, p. 450]). (3) To the quantities occurring in the usual Maxwell equations are added, as in (2), 'impressed electric forces' and 'impressed currents' (Ballantine, 1929 Abstracts, pp. 506–507) [for other work *see* de Stefano, reference "4"; Alexander, 1931 Abstracts, p. 553; and Graffi, 1933 Abstracts, p. 31].

"The practically interesting questions can all be dealt with in an illuminating and clear manner by the Lorentz law and in the framework of the usual Maxwell equations. This is shown in the following examples:—(a) The resistance coefficients of a two-*n*-terminal network [*see* Fig. 1 and following text] form a symmetrical matrix: the special case of the four-terminal network (II). (b) For any arbitrary aerial arrangement the radiation characteristic for transmission is the same as that for reception (III). (c) The reciprocity law in the case of two linear aerials: the limiting conditions for the validity of the Sommerfeld-Pfrang reciprocity theorem of wireless telegraphy (IV).

"Before these examples, the reciprocity theorem of the electromagnetic field is again derived (in I) as it was by Sommerfeld, in the most general form, and it is shown what assumptions must be made in order that it may be valid." The validity of eqn. 9, which represents the law in its most general form [div $\{[\mathfrak{E}_1, \mathfrak{H}_2] - [\mathfrak{E}_2, \mathfrak{H}_1]\} = 0$] depends on the characteristic tensors for the materials, ϵ_{ik}, μ_{ik}, σ_{ik}, being at all points in space symmetrical and constant in time. In particular the law is in general not fulfilled for systems which contain ferromagnetics, electron currents in high vacua, or gaseous discharges, since for ferromagnetics μ_{ik} depends on the field strength (so that eqn. 7 becomes invalid), while in the other cases the current density at a given point in space is generally not determined only by the electric field strength at that point, and thus cannot be derived from Ohm's law and from a conductivity σ_{ik} characteristic of that point and constant in time (so that eqn. 8 is no longer fulfilled).

"If Gauss's law is applied to eqn. 9, the reciprocity theorem takes the form of

$$\int_F (\{[\mathfrak{E}_1\mathfrak{H}_2] - [\mathfrak{E}_2\mathfrak{H}_1]\}, \mathrm{d}f) = 0$$

(eqn. 10), where F represents an arbitrary, closed surface containing no discontinuities and df the surface element in the direction of the internal normal." It is this form which is used in the subsequent treatment.

VALVES AND THERMIONICS

3261. Die-Pressed-Glass Valves [Development of the Disc-Base & Basin-Base All-Glass Types, including the Question of Screening].—R. Kretzmann. (*Funktech. Monatshefte*, Oct. 1941, No. 10, pp. 156–159.)

3262. Valve and Circuit Problems of Short-Wave Amplification in Broadcast Receivers: I [General] *and* II [the Special Problems of the Mixing Stage].—Ratheiser. (*See* 3242.)

3263. "Elektronenröhren als Schwingungserzeuger und Gleichrichter" [as Oscillator & Rectifier: Book Review].—H. Rothe & W. Kleen. (*E.T.Z.*, 18th June 1942, Vol. 63, No. 23/24, p. 294.) Vol. 5 of Zenneck's series referred to in 3053 of 1941.

3264. "Grundlagen der Röhrentechnik" [Foundations of Valve Technique: Book Review].—J. Deketh. (*Hochf:tech. u. Elek: akus.*, April 1942, Vol. 59, No. 4, pp. 126–127.) Vol. 1 of the Philips Company's series on Valves. A review of Vol. 2 (Data & Circuits of Modern Receiving & Power-Amplifier Valves) is on p. 127.

3265. The Standardisation of Broadcast Receiving Valves [Recent Progress in France].—M. Adam. (*Génie Civil*, 17th/24th Jan. 1942, Vol. 119, No. 3/4, p. 47: summary, from *Rev. Gén. de l'Élec.*, Oct. 1941.)

3266. A Discharge Phenomenon in Large Transmitting Valves [Investigation of Rocky Point Effect, Its Results in Filament Deformation, and Their Prevention].—J. P.

Heijboer. (*Alta Frequenza*, June 1942, Vol. 11, No. 6, pp. 295–297 : summary, from *Rev. tech. Philips*, July 1941, Vol. 6, p. 208 onwards.)

The writer concludes that it is impossible to combat the trouble at its source (the spontaneous liberation of small amounts of gas) and recommends, for the valve in question, the insertion of a resistance of 20 ohms in series with the anode circuit to prevent the discharge from being oscillatory, to reduce the initial value of the current to 480 A, and to increase the rapidity of its decay (reduction to a half in only 0.002 s). An editorial footnote points out that it is not so much a spontaneous liberation of gas that is concerned as one of particles of metal not adhering well to the electrodes : the effect can be combated to some extent by hindering the detachment of such particles by oxidising the electrodes, subjecting them to very high voltages, or other secret processes known to valve manufacturers : but that in spite of such precautions the effect may still occur, so that the writer's suggestion of the insertion of a resistance is highly to be recommended. For early work on the Rocky Point and analogous effects *see*, for example, Chenot, 1934 Abstracts, p. 94, and back references to Gossling's papers.

3267. A UNIVERSAL CHARACTERISTIC-CURVE RECORDER WITH CATHODE-RAY TUBE AND MULTIPLE RECORDING. — H. J. Griese. (*Zeitschr. f. tech. Phys.*, No. 6, Vol. 23, 1942, pp. 157–165.)

The chief reason why a universal c.r.-tube recorder has not appeared on the market is the need, for quantitative work, of a reference system with scale : such an arrangement is easy when a recorder is to be used for a particular purpose, but for a universal instrument practically each new characteristic curve would require a new coordinate system with its special scale, which would make things complicated. Hollmann in his " characteristic-curve comparator " (1934 Abstracts, p. 325), avoided the use of coordinate systems by the simultaneous tracing of a second characteristic for comparison. The double image formation was carried out by rapid alternation from one curve to the other : various mechanical methods of doing this were given, and also a very simple purely electrical method, " which, however, was unsuitable for the recording of valve characteristics." The writer uses the same principle of dual image formation, the switching being accomplished electrically by the circuit of Fig. 3 ; but instead of a second curve for comparison he can, if he desires, make the beam trace a coordinate system, so that the characteristic presents its usual appearance and is easy to interpret. Further, by electrical commutation to new values of some parameter (such as the grid voltage in a valve) it is possible to obtain on the screen not merely a single characteristic but a whole family of curves.

This last result is obtained by the addition of an auxiliary unit to the " universal recorder " proper. The circuit of this unit is seen in Fig. 13 : with the help of a glow-discharge-tube/condenser combination it produces a " flight-of-steps " variation of the required parameter so rapidly that the various corresponding traces of the characteristic are visible simultaneously. With this unit added, the process is as follows : in the first half-period of the mains voltage, the first characteristic is traced : in the following half-period the coordinate system appears on the screen : in the next, the third (not the second) characteristic is traced. If the number of steps in the parameter-variation is made odd (the number depends on the voltage generating the charging pulses in Fig. 13 and on the value of the condenser C_1), the curves omitted in the first cycle are inserted during the next. If, for instance, five curves are recorded, in each mains-voltage period one curve and one repetition of the coordinate system are traced, so that each of the five curves is traversed by the spot ten times a second, which gives a sufficiently flicker-less picture : Figs. 16 a–c show photographic records of three curve families for a pentode with its suppressor grid connected in turn with one of the other electrodes. If it is so desired, instead of a curve family and a coordinate system two curve families can be recorded for comparison.

3268. ON THE MECHANISM OF SECONDARY EMISSION [Correspondence].—(*Journ. of Tech. Phys.* [in Russian], No. 16, Vol. 10, 1940, pp. 1386–1392.)

Brief communications from M. S. Kosman, N. S. Khlebnikov, S. Yu. Luk'yanov, B. M. Tsarev, and P. S. Tartakovski, in which they discuss the paper by Timofeev " On the Mechanism of Secondary Emission of Electrons from Composite Surfaces " (3095 of 1941) and put forward their own views on the matter. There seems to be very little agreement between them.

3269. SECONDARY EMISSION OF ELECTRONS FROM MOLYBDENUM PLATES COATED WITH BERYLLIUM AND TREATED WITH HCl [Maximum of rather more than 3 Secondaries per Primary at 500 eV].—P. L. Copeland & W. R. Kennedy. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 737 : summary only.)

3270. THE EFFECT OF HIGH ELECTROSTATIC FIELDS UPON THE VAPORISATION AND RESISTANCE OF MOLYBDENUM FILAMENTS, *and* UPON THE CONDUCTIVITY OF TUNGSTEN.—W. P. Reid : P. L. Vissat. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 737 : p. 737 : summaries only.)

3271. CRYSTAL PLANES DEVELOPED BY THE D.C. HEATING OF TANTALUM.—D. B. Langmuir. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 739 : summary only.)

3272. EFFECT OF DOUBLE LAYER ON THE FORCES BETWEEN NEUTRAL MOLECULES AND METAL SURFACES.—W. G. Pollard. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 740 : summary only.)

" Consideration is given to the question whether the existence of a double layer, such as that considered by Smoluchowski (1071 of April) in connection with the electronic work function, will profoundly modify the van der Waals force. . . ."

DIRECTIONAL WIRELESS

3273. The Stratoscope, a New Radio Aid to Navigation [Transmitter emitting Signal of Frequency dependent on Height above Sea Level, giving on C.R. Tube Receiver the Altitude of Transmitting Instrument relative to That of Receiving Instrument, and Approximate Distance, etc.].—(*Journ. Roy. Aeron. Soc.*, July 1942, Vol. 46, No. 379, p. 237 : abstract only.)

3274. German Radiolocation Equipment [for Night Fighters : Swiss Newspaper Statements].—(*Journ. Roy. Aeron. Soc.*, July 1942, Vol. 46, No. 379, p. 222 : abstract only, from *Inter. Avia.*)

3275. Determination of Vertical, for taking Bearings by Stars, by Wireless-Beam Probe [Zenith indicated by Max. Reflected Energy returned from Ionosphere].—H. Simon. (*Hochf:tech. u. Elek:akus.*, April 1942, Vol. 59, No. 4, p. 125.) German Patent No.710 499.

3276. Direction Finding by Minimum-Readings, through Interference having the Same Note Frequency as the Desired Signal [Noise Level raised above Interference Amplitude by Local Noise Generator].—A. Leib. (*Hochf:tech. u. Elek:akus.*, April 1942, Vol. 59, No. 4, p. 124.) Telefunken Patent, No.711 478.

3277. New Dial-Calibration System [Dials for Superheterodyne Receivers (for D.F., etc.) calibrated wholly by Mathematical Means].—R. L. Drake & R. R. Schmidt. (*Communications*, April 1942, Vol. 22, No. 4, pp. 5–7 and 32.) From Lear Avia, Inc.

3278. Airline-Radio Maintenance.—P. C. Sandretto. (*Communications*, May 1942, Vol. 22, No. 5, pp. 5–7 and 26.)

ACOUSTICS AND AUDIO-FREQUENCIES

3279. The Effect of a Plane Screen on the Output of a Loudspeaker.—L. L. Myasnikov. (*Journ. of Tech. Phys.* [in Russian], No. 16, Vol. 10, 1940, pp. 1372–1381.)

The theory of the acoustic field of a piston diaphragm without a baffle plate was developed by Gutin (3747 of 1937) on the basis of an investigation by Hanson (1933 Abstracts, p. 580). No theory is available for the piston diaphragm with a baffle, with the exception of the results obtained by Strutt (1929 Abstracts, pp. 274–275) and McLachlan (" Loudspeakers," Russian Edition) which were based on certain empirical assumptions. In the present paper the theory developed by Gutin and Hanson is extended to cover this case. The theoretical discussion has been verified experimentally and the main conclusions reached are as follows : (1) The addition of a baffle plate alters the directivity of the loudspeaker. In the first approximation the directivity is determined by the dimensions of the plate and not by those of the loudspeaker. (2) The effect of the shape of the plate, *i.e.* whether the plate is circular or square, is very small and could not be determined experimentally. (3) When $ka = 2\pi$, *i.e.* when the wavelength is equal to the radius of the plate, a sharp change in the directivity takes place. If $ka \ll 2\pi$ the directivity of the piston with or without a baffle plate is similar to that of a piston diaphragm in an infinite wall.

3280. The Exponential H.F. Line and the Loudspeaker with Exponential Horn.—Wagner. (In paper dealt with in 3200, above.)

3281. Piezoelectric Telephone Set without Supply.—Hagenuk Company. (In paper referred to in 3253, above.)

3282. Repeater for Submarine Telephone Cable [designed for 20-Year Life at Ocean Bottom].—O. E. Buckley. (*Bell Lab. Record*, July 1942, Vol. 20, No. 11, p. 275.) *See* also *ibid.*, June issue, and 1995 of July.

3283. Radiation Pattern of the Human Voice [Experimental Investigation of Directional Characteristic (using Steinberg's Test Sentences) and Calculation of Total Voice Power, etc.].—D. W. Farnsworth [& H. K. Dunn]. (*Scient. Monthly*, Aug. 1942, Vol. 55, No. 2, pp. 139–143.)

3284. " The Mechanism of the Human Voice " [Book Review].—R. Curry. (*Current Science* [Bangalore], June 1942, Vol. 11, No. 6, p. 247.)

3285. Low-Cost Rebuilt Speech-Amplifier System [prompted by Interest in High Fidelity aroused by Frequency Modulation].—W. J. Provis. (*Communications*, April 1942, Vol. 22, No. 4, pp. 14 and 16.)

3286. Contribution to the Acoustics of Radio Studios [Work on which was based the Acoustical Design of Lugano, Zurich, Basle, & Geneva Studios : prefaced by Survey of the Published Literature] : Parts I & III.—W. Furrer. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, March & May 1942, Vol. 8, Nos. 3 & 5, pp. 77–85 & 143–152.) For the middle part *see* 3026 of October.

3287. Broadcast Programme Switching and Preselection [New System at N.B.C. Omaha Station].—P. B. Murphy. (*Communications*, Jan. 1942, Vol. 22, No. 1, pp. 5–7 and 32.)

3288. Harmonic Distortion in Audio-Frequency Transformers [Absence of Procedure for Calculation of Magnitude of Distortion : Need for " Distortion Coefficient " associated with Magnetic Materials, for judging Merits or Demerits in This Respect : Theoretical & Practical Investigation to fill These Gaps].—N. Partridge. (*Wireless Engineer*, Part 1, Sept. 1942, Vol. 19, No. 228, pp. 394–400 ; Part 2, Oct. 1942, Vol. 19, No. 229, pp. 451–456. To be continued.) *See* also 3289 below.

3289. Transformer Distortion : Why It Occurs and How to Calculate It [including Practical Formulae].—N. Partridge. (*Wireless World*, Aug. 1942, Vol. 48, No. 8, pp. 178–182.) For a fuller treatment *see* 3288, above. "Almost all preconceived ideas about it [iron distortion] are now known to have been fundamentally wrong."

3290. Electro-Mechanical Analogies and Their Application to Problems of Electro-Acoustics.—Nuovo. (*See* 3219.)

3291. Guiding Lines for the Design Calculations of Oscillatory Circuits for Note-Frequency Generators with Low Harmonic Content.—K. Steffenhagen. (*Funktech. Monatshefte*, June 1941, No. 6, pp. 92–95.)

With special reference to a generator for the range 30–15 000 c/s with a non-linear-distortion factor (at an output around 0.5 watt) not greater than 4%. A single note-generating valve driving an output valve is used. The treatment leads to the fact emerging that the designer must decide which of three conflicting requirements is to be fulfilled most perfectly : for the "klirr" factor dependent on the non-linearity of the characteristic demands, if it is to be kept low, that the circuit resonance resistance should be much greater than the internal resistance of the valve (eqn. 2) : the obtaining of a high output demands the same condition (eqn. 15) : but to maintain the full sharpness of resonance exactly the opposite condition is required. The writer, for the generator in question, compromises by making the two resistances equal. For a correction to Fig. 7 *see* August issue, No. 8, p. 127.

3292. On the Theory of the Mechanism of Vibration of a Tuning Fork.—Bászel. (*See* 3335.)

3293. Tuning-Fork-Controlled Current Generators and Motors.—Schmidt. (*See* 3383.)

3294. The Attenuation of Sound in Absorbing Tubes [Tubes lined with Absorbent Material : Theoretical & Experimental Investigation].—W. Willms. (*Alta Frequenza*, May 1942, Vol. 11, No. 5, pp. 252–254 : summary, from *Akust. Zeitschr.*, May 1941, Vol. 6, p. 150 onwards.)

3295. An Improved Procedure used in the Measurement and Analysis of Some City Noises in New Orleans.—D. S. Elliott & L. B. Scott. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, pp. 727–728 : summary only.)

3296. The Harmonic Analysis of Voltage and Current Curves.—Z. Trnka. (*Arch. f. Elektrot.*, 28th Feb. 1942, Vol. 36, No. 2, pp. 123–130.)

Most previous methods of such analysis have involved the use of heavy and elaborate multi-frequency generators. It is here shown "that it is possible, with the help of a circular potentiometer whose brush is driven by a synchronous motor, to carry out the analysis of a required harmonic with respect both to amplitude and phase. On the assumption that the 'coupling factor' of the potentiometer [relation between the voltage at any momentary position of the brush and the angle of displacement] is a sine function, an applied voltage $u = f(x)$ will produce a voltage $f(x) \sin \nu x$, whose arithmetical value indicated by a moving-coil instrument is proportional to the coefficient a_ν

$$[a_\nu = (1/\pi)\int_0^{2\pi} f(x) \sin \nu x \, \mathrm{d}x \, ; \; b_\nu = (1/\pi)\int_0^{2\pi} f(x) \cos \nu x \, \mathrm{d}x \, ;$$

and $A_\nu = \sqrt{a_\nu^2 + b_\nu^2}$].

"If the 'coupling function' of the potentiometer is a general periodic function corresponding to the expression $\phi(\nu x) = \bar{a}_1 \sin \nu x + \bar{a}_2 \sin 2\nu x + \ldots \bar{b}_1 \sin \nu x + \bar{b}_2 \sin 2\nu x + \ldots \bar{b}_0/2$, then the analysis gives that harmonic of the curve whose order is identical with the νth order of the harmonic of the coupling function.

"On the assumption of a finite number of harmonics contained in the curve under analysis, these considerations lead to a simplified design of potentiometer, as is shown in the apparatus described" : Fig. 8, consisting of a synchronously driven axle carrying two slip-rings (with their associated d.c. brushes) and nine commutators (with different numbers of bars, for dealing with the first to ninth harmonics in turn), to each of which the angularly adjustable collector brush can be moved at will. In this way the sinusoidal curve produced by the hypothetical circular potentiometer with continuously rotating brush is replaced by a curve made up of a number of rectangular steps (oscillograms, Fig. 9). The simple procedure for the determination of amplitude and phase of each harmonic is described in the first half of p. 129. It is mentioned that a capacitive or inductive coupling could be used as an alternative.

3297. Colour and Music.—V. G. W. Harrison. (*Journ. Roy. Soc. Arts*, 7th Aug. 1942, Vol. 90, pp. 609–612.) *Cf.*, for example, 1931 Abstracts, p. 621 (Patterson) and 2313 of 1941 (Burchfield).

3298. On the Frequency Characteristic Curves of Violins.—H. Meinel. (*Alta Frequenza*, March/April 1942, Vol. 11, No. 3/4, pp. 175–176 : summary only.) Continuing the work referred to in 1066 of 1940.

3299. Modern Science and Musical Theory.—Ll. S. Lloyd. (*Journ. Roy. Soc. Arts*, 7th Aug. 1942, Vol. 90, pp. 581–593 : Discussion pp. 593–594.) A summary was referred to in 2003 of July.

3300. Science in Music.—C. E. Seashore. (*Science*, 24th April 1942, Vol. 95, pp. 417–422.)

3301. Beauty of Music depends on Notes, Not just Taste [Experimental Confirmation].—C. C. Pratt. (*Sci. News Letter*, 2nd May 1942, Vol. 41, No. 18, p. 277 : summary only.)

3302. Simplification of Musical Notation [Suggested 12-Note Arrangement]. — A. G. Smalley. (*Nature*, 15th Aug. 1942, Vol. 150, p. 211.) For previous correspondence *see* 2407 of August: and *cf.* issue of 12th Sept. 1942, pp. 317 and 322–323.

3303. Edge Tones [Experimental Results & Explanation without Recourse to Vortices]. —A. Taber Jones. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 724: summary only.)

3304. Effect of Depth of Liquid on Damping of a Quartz Oscillator [at 4.3 Mc/s].— Krishnan. (*See* 3331.)

3305. One-Dimensional and Two-Dimensional Propagation of Sound Waves in Water, in Tubes and Tanks [Laboratory Measurements in connection with Submarine Communication].—K. Tamm. (*Alta Frequenza*, May 1942, Vol. 11, No. 5, pp. 251–252: summary, from *Akust. Zeitschr.*, Jan. 1941, Vol. 6, p. 16 onwards.)

3306. Propagation of Ultrasonic Waves in Liquid Mixtures, and Intermolecular Forces: II.—R. Prasad [Parshad]. (*Indian Journ. of Phys.*, Feb. 1942, Vol. 16, Part 1, pp. 1–11.) For Part I *see* 2732 of September.

PHOTOTELEGRAPHY AND TELEVISION

3307. Television for Aircraft Pilots [in Fog or Haze: Infra-Red Images converted to Visible Image on Instrument Board].— H. A. Adams. (*Sci. News Letter*, 18th July 1942, Vol. 42, No. 3, pp. 37–38.) U.S.A. Patent No. 2 288 871.

3308. Theoretical Considerations on a New Method of Large-Screen Television Projection: Part III.—F. Fischer & H. Thiemann. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, May, June, & July 1942, Vol. 8, Nos. 5, 6, & 7, pp. 135–143, 169–178, & 199–212). For previous parts *see* 2410 of August & back reference.

3309. Single-Sideband Transmission of Television Signals: D—The Picture Edges [and the Adequacy of a Residual Upper Sideband of 10%].—F. Ring. (*Funktech. Monatshefte*, June 1941, No. 6, Supp. pp. 23–24.)

3310. Television Transmissions from the Dome Theatre in the State Sports Field [Special Programmes from the Berlin Station to Military Hospitals: Receivers in Wards & Viewing Rooms: Lighting Problems due to wish to make the most of the Very Large Stage & Big (2000) Audience in the Theatre: also Acoustic Problems].—H. K. Kölle. (*Funktech. Monatshefte*, June 1941, No. 6, Supp. pp. 21–22.)

3311. Television Reporting [Portable Equipment for Outside Broadcasts].—F. Stumpf. (*Funktech. Monatshefte*, Sept. & Oct. 1941, Nos. 9 & 10, Supp. pp. 33–35 & 37–39.) From the Reichspost-Fernseh-G.m.b.H.

3312. Transmitting Equipment for Television Reporting: III [Fundamental Requirements, and the Advantages of Carrier-Frequency Working].—H. Weber. (*Funktech. Monatshefte*, June 1942, No. 6, Supp. pp. 21–24.) For Part II *see* 2412 of August.

3313. Television Amplifiers [for Standard German Television: Survey].—R. Schienemann. (*Funktech. Monatshefte*, Aug. 1941, No. 8, Supp. pp. 25–31.) From the Telefunken laboratories: lecture to junior engineers.

3314. Low-Frequency Square-Wave Analysis [of Video & Other Amplifiers: and a "Relatively Easy Physical Interpretation" of the Results].—A. Preisman. (*Communications*, March 1942, Vol. 22, No. 3, pp. 14, 16–17, 20, 28, and 35.) For previous work *see* 2897 of 1938.

3315. The Mechanical Problem of the Inner-Conductor Suspension in "Thread-Supported" Coaxial Cables.—Cords. (*See* 3257.)

3316. The Microstructure of Antimony-Caesium Photocathodes.—S. A. Vekshinski. (*Journ. of Tech. Phys.* [in Russian], No. 17, Vol. 10, 1940, pp. 1395–1403.)

Experiments with a light beam of small cross-section (0.08 × 0.86 mm^2) have shown that, contrary to generally accepted opinion, the surface of an antimony-caesium photocathode consists of areas possessing widely different photoelectric properties (photograms 1 & 2). A detailed experimental investigation was therefore carried out in which different stages of the formation of an antimony film on a glass plate were observed microscopically. A number of microphotographs are shown and the results obtained discussed. The main conclusion reached is that the originally amorphous film passes spontaneously at room temperature into a crystalline state, with consequent disruptions and distortions in the structure of the film.

3317. Raman Spectra Measurements with the RCA-931 Photomultiplier Tube.—Rank & others. (*See* 3454.)

3318. Dry Electrically Conductive Paper [for Facsimile Transmission].—(*Sci. News Letter*, 25th July 1942, Vol. 42, No. 4, p. 62.)

MEASUREMENTS AND STANDARDS

3319. Measurement of the Sensitivity of Receivers for Short [Metric & Decimetric] Waves.—Fränz. (*See* 3240.)

3320. New Field-Intensity Recorder [Portable, for Continuous Recording on Frequencies 26–155 Mc/s].—H. W. Kline. (*Electronics*, Jan. 1942, Vol. 15, No. 1, pp. 50..56.) From the General Electric laboratories.

3321. NEGATIVE RESISTANCE FOR TESTING THE QUALITY OF OSCILLATORY CIRCUITS AND THEIR COMPONENTS [Failure of Dynatron Technique for Short-Wave Circuits with Resonance Resistances of only a Few Kilohms: Writer's Variable Negative-Resistance Circuit (suitable for Wavelengths down to 10 m) using Triode/Pentode Combination].—M. Wald. (*Funktech. Monatshefte*, Sept. 1941, No. 9, pp. 140–142.)

3322. MEASURING EQUIPMENT FOR DETERMINING THE LOSS RESISTANCE OF OSCILLATORY CIRCUITS [Constructional Details, with Dynatron Generator & Its Stabilised Mains Supply].—W. Vogtherr. (*Funktech. Monatshefte*, Aug. 1941, No. 8, pp. 116–122.)

3323. A VARIABLE MUTUAL INDUCTANCE WITH WIDE LINEAR SCALE [primarily for Potthoff's "M" Bridge Circuit for measuring Dielectric Loss (at 50 c/s) of Cables *in situ*, etc: Design applicable to Other Purposes].—B. Mathiesen. (*Arch. f. Elektrot.*, 31st Jan. 1942, Vol. 36, No. 1, pp. 43–68.)

Besides the linear scale, the special requirements were that the induced voltage should be displaced by 90°, as accurately as possible, with respect to the primary current; and that the arrangement should be astatic, so as to be affected as little as possible by stray magnetic fields. The scale obtained by the present design was linear over a rotation of about 140°: the maximum mutual inductance was 1 henry.

3324. TEST CONDENSER FOR DIELECTRIC MEASUREMENTS ON INSULATING LIQUIDS [for Voltages up to 40 Kilovolts].—P. Regoliosi. (*E.T.Z.*, 18th June 1942, Vol. 63, No. 23/24, pp. 291–292: summary only.)

3325. WIDE-BAND AMPLIFIER WITH SYMMETRICAL OUTPUT, FOR MEASURING PURPOSES [particularly for Use with Cathode-Ray Oscillograph: for Frequencies up to 2 Mc/s: Input Resistance 10 Kilohms (compared with 850 Ohms Equivalent Noise Resistance of the EF14 Valves employed): Thermal-Noise Voltage Not Exceeding 1% of Useful Voltage for Input Voltages down to 1.9 mV, corresponding to Output Voltage of 4.6 V].—W. Rentsch. (*Funktech. Monatshefte*, July 1941, No. 7, pp. 107–110.)

3326. A SIMPLE METHOD OF MEASURING PHASE ANGLES WITH CATHODE-RAY OSCILLOGRAPHS [using Two C.R. Tubes simultaneously or One with Alternate Switching: Phase Difference measured by D.C. Voltage required to displace One Image so that (*e.g.*) the Null-Point Positions agree].—H. Gerwig & W. Pützer. (*Funktech. Monatshefte*, Aug. 1941, No. 8, pp. 122–125.)

3327. AN ADAPTATION OF THE ANDERSON BRIDGE FOR THE DETECTION OF MINUTE CHANGES IN TEMPERATURE [Particular Bridge Arrangement which, when Nearly Balanced, is Very Sensitive to Slight Change in Condenser-Ratio: Condensers formed from Thin-Walled Silvered Glass Bulbs].—W. L. Kennon & A. B. Cullen. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 728: summary only.)

3328. APPARATUS FOR THE MEASUREMENT OF SMALL THREE-TERMINAL CAPACITANCES [as between Valve Grid & Anode: Use of Equal-Arm Substitution Schering Bridge & Audio-Frequency].—J. R. Tillman & A. C. Lynch. (*Journ. of Scient. Instr.*, Aug. 1942, Vol. 19, No. 8, pp. 122–123.)

3329. A SIMPLE METHOD OF DERIVING THE FORM FACTOR OF A CYLINDRICAL COIL.—Lang. (*See* 3210.)

3330. AUTOMATIC PRODUCTION OF OSCILLATOR SCALES [Arrangement for Rapid Commercial Calibration of Film Scales for 17B Oscillators (3274 of 1939), Nearly Linear but Not Identical].—T. Slonczewski. (*Bell Lab. Record*, July 1942, Vol. 20, No. 11, pp. 270–274.)

3331. EFFECT OF DEPTH OF LIQUID ON DAMPING OF A QUARTZ OSCILLATOR [at 4.3 Mc/s: Damped Frequencies do Not Increase with Liquids of Higher Density or of Greater Viscosity: Change in Magnitude of Damping Effect follows more closely the Order of Absorption Values for Supersonic Waves: etc.].—K. G. Krishnan. (*Indian Journ. of Phys.*, Feb. 1942, Vol. 16, Part 1, pp. 23–26.)

For Fox & Rock's use of a liquid column for a variable quartz resonator *see* 1756 of June.

3332. PROPERTIES OF QUARTZ OSCILLATORS AND RESONATORS IN THE REGION FROM 300 TO 5000 KILOCYCLES PER SECOND.—R. Bechmann. (*Hochf:tech. u. Elek:akus.*, April 1942, Vol. 59, No. 4, pp. 97–105.)

The practical boundary between the transverse ("thickness") vibrations and the longitudinal is at about 300 kc/s, but it is not a sharp one: for instance, it is possible to use the longitudinal mode for a frequency as high as 400 kc/s. But in such a case the dimensions are small and the holder arrangements become difficult. Similarly, the transverse mode can on occasion be employed down to 200 kc/s, but the crystal is very thick, heavy and thus difficult to hold, and out of the question for series production because of the waste of material. Thus in the present paper the lower limit is taken at 300 kc/s and only the transverse mode is considered.

After a short résumé of the fundamental bases for the calculation of quartz crystals vibrating in the transverse mode, derived from the writer's paper dealt with fully in 150 of 1941 [*see* also 2183 of 1941, and for the longitudinal mode *see* 1757 of June], the paper considers the properties of Telefunken oscillators and resonators developed for frequency stabilisation and selection. The curves and data tables given are derived from results obtained in the laboratory and series production of these units. Thus Fig. 8 shows the damping of mounted quartz plates of the $Y_{41°}$ and $Y_{125°}$ cuts:

the full-line curves are drawn through the optimum values, which are only obtained from plates whose diameter/thickness ratio exceeds 15 : 1. Theoretically the damping should increase with the frequency, but the curves show that in the range considered it is practically constant, so that the damping "constant" Q must be inversely proportional to the frequency (Fig. 9). It is also dependent on the orientation: neither of these facts was recognised in the writer's earlier paper (3283 of 1937), where Q was given as 0.25 as a result of practical experience. Improved technique, particularly the systematic decoupling of the transverse oscillations from the longitudinal, have led to a considerable reduction below this value: *see* p. 101, r-h column.

The influence of the diameter/thickness ratio is next considered. For ratios between 70 and 20 (values above 70 only concern very high frequencies and are not dealt with here) round plates must be provided with facets at their edge if multiple resonances are to be avoided. For ratios below 20, for the same purpose a special shape for round plates is necessary, approximately described as that of a flattened ellipsoid of revolution. Recently, to obtain small dimensions and economy in material, the tendency has been to reduce the ratio as much as possible. Previously a value of 10 : 1 was considered the limit, but now quite serviceable oscillators and resonators are made with ratios no greater than 4 : 1 (*see* Fig. 10 and adjacent text). At these small ratios the inductance rises considerably, "because the quartz surfaces, on account of their special shape, are small, and especially because of the increase in the mean gap between electrodes and surfaces."

To obtain sufficiently low temperature-coefficients of frequency with these smaller plate diameters, the usual angle between the plate normal and the optical axis has to be reduced (Fig. 11). Thus while the zero coefficient for a ratio of 20 : 1 is given by an angle of nearly 125°10′, for a 4 : 1 ratio the value is just below 124°. For a fixed ratio the angle depends on the special shape of the plate. This matter of temperature-coefficients, and the maintenance of low values in series production, is discussed further at the end of p. 103 and on p. 104 (*see* also Fig. 14, bottom curves).

The necessity for single resonance in crystals used as resonators and filters is discussed (bottom of p. 102): for round Y-cut plates the serviceable region is limited by an interfering frequency, above the resonance frequency at an interval depending on the diameter/thickness ratio, on the special shape of the plate, and to some extent on the electrode dimensions: its origin is not yet understood. Fig. 12 shows the percentage interval between disturbing frequency and resonance frequency as a function of the ratio. As the ratio decreases the region free from disturbance increases considerably. The next point to be discussed is the accuracy within which the data of a resonator can be maintained with laboratory and with series production; this leads to a consideration of the effect of electrode-gap adjustment on the frequency and inductance (Fig. 13) and finally to the mention of special mountings (including the three-point fixture) where special frequency-constancy is required: such high crystal constancy is only useful when the circuit arrangements are suitable, and there is a growing tendency, for this reason, to use circuits which excite the series-resonance frequency of the crystal.

Finally, methods of measuring the resonance resistance, inductance, and capacitance of quartz resonators are dealt with briefly: Heegner's circuit (1837 of 1939) for exciting the series-resonance frequency is particularly suitable for such measurements in quantity production.

3333. QUARTZ CLOCKS: CONSTRUCTIONAL OUTLINE, RATE AND FREQUENCY.—A. Scheibe. (*Alta Frequenza*, May 1942, Vol. 11, No. 5, pp. 246–247: summary, from *Arch. f. Tech. Messen*, Aug. 1941, Part 122, Sheets T114–115.)

3334. A 100-CYCLE FREQUENCY STANDARD [with Precision Tuning-Fork & Synchronous Clocks: primarily for Calibration of Seismic-Prospecting Timing Oscillators].—P. M. Honnell & L. W. Dickerson. (*Communications*, May 1942, Vol. 22, No. 5, pp. 8–9 and 35.)

3335. ON THE THEORY OF THE MECHANISM OF VIBRATION OF A TUNING FORK [Theoretical & Experimental Investigation prompted by Lack of Published Researches, for Development of High-Precision Time-Standard: Frequency Spectrum investigated according to Coupled-Systems Theory (Wagner, 3824 of 1935), Each Tine being treated as a Vibrator coupled to the Other].—K. Bászel. (*Funktech. Monatshefte*, Oct. 1941, No. 10, pp. 145–148.)

3336. AUXILIARY APPARATUS FOR PRECISION SECONDS-COUNTERS [for Improving the Convenience in Use and Extending the Applications of Torzo's Counter, 2767 of September].—N. La Barbera. (*Alta Frequenza*, June 1942, Vol. 11, No. 6, pp. 301–302.) For previous work by the same writer *see* 2768 of September.

3337. AN ELECTROMETER FOR MEASUREMENT OF VOLTAGE ON SMALL IONISATION CHAMBERS [requiring Low-Capacity Measuring Instrument (usually a Fibre Electrometer): Advantageous Use of Electrometer Triode & High-Impedance Multielectrode Valve functioning together in "Cathode Follower" Mode: Screening to reduce Self-Capacity of Grid & Lead, etc.].—F. T. Farmer. (*Proc. Phys. Soc.*, 1st Sept. 1942, Vol. 54, Part 5, No. 305, pp. 435–438.)

3338. PROGRESS IN ELECTROSTATIC VOLTMETER DESIGN [including the Question of Electrostatic Efficiency and the Practicability of using Liquid Dielectrics of High Permittivity].—E. H. W. Banner. (*BEAMA Journal*, Aug. 1942, Vol. 49, No. 62, pp. 211–214.)

3339. "DIE ELEKTRONENRÖHRE ALS PHYSIKALISCHES MESSGERÄT" [Valve Voltmeter, Galvanometer, & Electrometer: Book Review].—J. Schintlmeister. (*E.T.Z.*, 18th June 1942, Vol. 63, No. 23/24, p. 294.)

3340. Magnetic Fluxmeter [embodying Pulse Generator (Gas-Filled-Valve Circuit) with High-Speed Relays reversing simultaneously the Flux-Producing Current & the Meter Connections: Portable].—E. L. Norton. (*Bell Lab. Record*, June 1942, Vol. 20, No. 10, pp. 245–247.)

3341. An Improved Ayrton & Mather Shunt [for Varying the Sensitivity of Galvanometer while keeping it Critically Damped].—J. B. Reid. (*Journ. of Scient. Instr.*, Aug. 1942, Vol. 19, No. 8, p. 124.)

SUBSIDIARY APPARATUS AND MATERIALS

3342. A Spark Recording Apparatus for Simple Harmonic Motion [Accuracy within 1%].—Krone & Knorr. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 730: summary only).

3343. A Universal Characteristic-Curve Recorder [for Valve Characteristics, Dry-Plate-Rectifier Curves, Amplifier & Generator Characteristics, etc.].—Griese. (*See* 3267.)

3344. New Methods of obtaining Linear Time-Bases for Cathode-Ray Oscillographs [Theoretical & Experimental Investigation of Arrangements all based on the Multivibrator, for Electrostatic Deflection only: the Question of the Highest Attainable Time-Base Frequency].—Johannsen. (*Arch. f. Elektrot.*, 31st Jan. 1942, Vol. 36, No. 1, pp. 1–31.)

A. Fundamental points on the generation of saw-tooth voltages, and the object of the present paper.

B. Relaxation-oscillation circuits with the multivibrator (high-vacuum valves) for generating saw-tooth voltages (survey of simple circuits, with analysis of actions of the various components: improvement of linearity by charging through a pentode: a practical form of circuit: saw-tooth generator with symmetrisation by a single-stage amplifier: by a two-stage amplifier: production of symmetrical time-base voltages without any amplifier (pp. 24–26).

C. Special measures to obtain the greatest possible time-magnification. Conditions at the highest "kipp" frequencies are such as to prolong the fly-back time, and this necessitates the additional device of darkening the fly-back. But it is possible not only to do this but also to darken any other part of the "kipp" period. To darken the forward stroke would, in normal cases, be without object, but in the highest range of frequencies such a proceeding has the advantage that by using the more rapid fly-back the same time-magnification can be obtained with a lower "kipp" frequency, or a greater time-magnification for the same "kipp" frequency. Thus for the earlier limit of frequency of 300 kc/s, with a fly-back time 20% of the forward-stroke time, the time-magnification is increased four times by the use of the fly-back. Fig. 32 shows this for a test-wave of 5 Mc/s (the forward stroke was only partially darkened in order that the two time-extensions could be compared). Naturally the time-base thus obtained is not linear, but it is sufficiently good for most purposes. The darkening of the forward stroke is accomplished by the pulse occurring at the cathode resistance R_K (Fig. 23) as a result of the blocking of the charging valve: this pulse is not in itself strong enough to darken the spot, and an amplifier is therefore interposed. Synchronisation is obtained by the fine adjustment of R_K, as usual: but since the fly-back time varies little with the charging current, if this time is required to be adjustable provision must be made to vary the current of the discharge valve, for example by making the discharge resistance R_E adjustable.

D. The highest attainable time-base frequency. The factors involved, and a comparison between the above high-vacuum-valve circuits and thyratron circuits: Pieplow's special method with the latter, giving frequencies up to 1 Mc/s (109 of 1939), is considered to reach the limit, for such valves and for the amplitudes required: reasons why the high-vacuum valves can give better results, in spite of the fact that the necessary "S" characteristic, innate in the thyratron, has to be produced artificially. Conclusion that the highest attainable "kipp" frequency of adequate amplitude lies in the neighbourhood of 10 Mc/s: for this result more powerful valves must be employed than the broadcast-receiver valves used exclusively in these investigations.

3345. Wide-Band Amplifier with Symmetrical Output, for Measuring Purposes [particularly for Use with Cathode-Ray Oscillograph].—Rentsch. (*See* 3325.)

3346. The Scanning Electron Microscope [specially suitable for exploring Surface Grain (also capable of transmitting Electron-Microscopic Images by Television)], *and* Adapter converting Electron Microscope into Diffraction Camera.—Hillier, Zworykin, & others. (*Sci. News Letter*, 11th July 1942, Vol. 42, No. 2, pp. 20–21: p. 21.)

3347. Increasing the Resolving Power of the Emission-Type Electron Microscope.—Boersch. (*Zeitschr. f. tech. Phys.*, No. 5, Vol. 23, 1942, pp. 129–130.)

The experiments dealt with in 1773 of June led to an increase in resolving power from 3μ to 0.07μ, and the new (1942) edition of Ramsauer's "Elektronmikroskopie" gives a photograph by Mecklenburg in which the resolution of the optical microscope is similarly exceeded. In the present note it is pointed out that the decrease of the lens aperture by a stop (suggested in the previous communication) does diminish the aperture-error circle, but simultaneously increases the diffraction circle. Superposition of the two errors leads to a relation and curves (Fig. 1) defining the best stop diameter, by which (with the same lens) the resolving power can be improved to about 0.01μ. The reduction of the lens aperture diminishes at the same time the chromatic aberration.

3348. The Electron Microscope and Its Uses [Survey with Micrographs].—Barnes & Burton. (*ASTM Bulletin*, May 1942, No. 116, pp. 34–41.) From the American Cyanamid Company.

3349. Remark on the Development of the Electron Microscope [Predominance of Work at the Berlin Technical College (Knoll, Ruska, & others)]. — Matthias. (*Physik. Zeitschr.*, 20th April 1942, Vol. 43, No. 7/8, pp. 129–130.)

3350. Surface Replicas for Use in the Electron Microscope [Successful Technique with Polyvinyl Formal ("Formvar 15–95"): Choice of Thickness of Replica, etc: also a Procedure for preparing Thin Films for holding Various Types of Specimens for Electron-Microscopic or Diffraction Studies]. —Schaefer & Harker. (*Journ. Applied Phys.*, July 1942, Vol. 13, No. 7, pp. 427–433.)

3351. The First Law of Fluorescence [analogous to the Grötthuss-Draper Law in Photochemistry: the Status of Anti-Stokes's Emission, etc.].—J. De Ment. (*Science*, 14th Aug. 1942, Vol. 96, pp. 157–158.)

3352. Iron-Glass Seal made possible by New Invention [to save Nickel & Cobalt: Series of Special Glass Compositions for use with Iron & Certain Iron Alloys].—Hull & Navias. (*Scient. American*, Aug. 1942, Vol. 167, No. 2, pp. 57–58.)

3353. The Production of High Direct-Current Voltage with the Help of a High-Frequency Generator [10 kV or more obtained by Pentode/Transformer/Diode Combination (using a Commercial Output Pentode oscillating at about 50 kc/s): Efficiency only 0.5, but Great Economy in Space, Weight, & Material].—Kinne. (*Funktech. Monatshefte*, Oct. 1941, No. 10, pp. 153–154.) For other work by the same writer *see* 2422 of August.

3354. A General Theory of Electrostatic Generators.—Bobkovski. (*Journ. of Tech. Phys.* [in Russian], No. 17, Vol. 10, 1940, pp. 1404–1425.)

A general theory of electrostatic generators is developed. The effect of load and speed of rotation on the potential ϕ_a of the high-voltage collector, the current I, and the power output W is investigated. The maximum possible values are determined, and suggestions are made regarding the construction of electrostatic generators for laboratory and commercial purposes.

3355. The Electrostatic Generator [Survey of Existing High-Voltage Generators, including Table showing Comparative Data (with Prime & Working Costs) of Types at Carnegie Institute & M.I.T. and of High-Voltage X-Ray Plant & Radium Bomb].—Watzlawek. (*Zeitschr. f. tech. Phys.*, No. 3, Vol. 23, 1942, pp. 59–70.)

3356. A High-Voltage Apparatus for Atomic Disintegration Experiments [giving 100–200 μA Beam Currents at 600 kV: including Investigation of Large Secondary-Electron Currents found (hitherto given Little Attention) and Their Importance].—Craggs. (*Proc. Phys. Soc.*, 1st Sept. 1942, Vol. 54, Part 5, No. 305, pp. 439–456.) *See* also 2797 of September.

3357. The Cyclotron [Survey, with Literature References to 1942].—Watzlawek. (*E.T.Z.*, 16th July 1942, Vol. 63, No. 27/28, pp. 319–326.)

3358. The Penetration of the Inert Gases into Metals [Survey of Work so far accomplished by the Writer, Bartholomeyczyk, & Funk].—Seeliger. (*Naturwiss.*, 24th July 1942, Vol. 30, No. 30/31, pp. 461–468.) *See*, for example, 812 of March.

3359. The Determination of the Life of Metastable Excitation States of Neon from Residual-Current Measurements in Glow Discharges.—Hoffmann. (*Zeitschr. f. Phys.*, 9th July 1942, Vol. 119, No. 3/4, pp. 223–236.)

3360. New Investigations on Cathode Sputtering: II—Determination of the Wall Factor: III—Incomplete Covering of the Cathode of the Anomalous Glow Discharge: IV — Spreading of the Primary Vaporised Particles.—Güntherschulze. (*Zeitschr. f. Phys.*, 31st March 1942, Vol. 119, No. 1/2, pp. 79–99.)

3361. On the Nature of Cathode Sputtering, and the Kinetic Emission of Secondary Electrons: II. — Morgulis. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 2/3, Vol. 11, 1941, pp. 300–302.)

3362. The Cause of High-Voltage Surges in Rectifier Circuits [lies only in Demand for Current exceeding Current-Carrying Capacity of the Gas or Vapour: Experimental Investigation, leading to Curve of Max. Current-Carrying Capacity of Mercury Vapour, as function of Pressure].—Hull & Elder. (*Journ. Applied Phys.*, June 1942, Vol. 13, No. 6, pp. 372–377.)

3363. On the Theory of Non-Stationary Discharges: II—The Light Emission from a Modulated High-Pressure Arc.—Weizel & others. (*See* 3462.)

3364. An Investigation of Impulse Spark Discharges: Part I.—Komel'kov. (*See* 3201.)

3365. On the Electrical Breakdown in Gases [Discussion of Results of Cloud-Chamber Investigations].—Raether. (*See* 3202.)

3366. The Mechanism of the Electric Spark [Refutation of Meek's Criterion for Spark Formation].—Zeleny. (*See* 3203.)

3367. The Electrical Behaviour of Electro-Negative Gases [Measurements on Frigen (Freon) at 1 Atmosphere, for Homogeneous & Inhomogeneous (Symmetrical & Asymmetrical) Fields: Dependence of Breakdown Voltage on Gap Length: on Pressure (up to

6 Atmospheres) : Effect on Flash-Over Voltages of Insulators : Suppression of Spreading Discharges (Gleitfunken) & Glow-Discharges : Mode of Action (primarily an "Electron-Binding" Effect) : Comparison with Other Gases & Vapours : etc.].—Weber. (*Arch. f. Elektrot.*, 31st March 1942, Vol. 36, No. 3, pp. 166–180.) *Cf.*, for example, 1165 (and back reference) & 1166 of April.

3368. High-Pressure Gas as a Dielectric.—Nonken. (*Elec. Engineering*, Dec. 1941, Vol. 60, No. 12, Transactions pp. 1017–1020.) A summary was dealt with in 1165 of April. For Discussion see *Transactions Supplement*, Dec. 1941, Vol. 60, pp. 1405–1407.

3369. The Search for Cheap, Trained Labour for the Grading and Splitting of Mica.—(*Sci. News Letter*, 6th June 1942, Vol. 41, No. 23, p. 366.)

3370. Dielectric Loss in Paraffin-Wax Solutions [of Long-Chain Molecules containing Dipoles : Calculation of Dependence of V_n (Minimum Energy required to lift a Molecule with n Links over Potential Hill between Two Stable Positions), and hence of log τ, on Chain Length : Satisfactory Agreement with Experimental Values]. — Fröhlich. (*Proc. Phys. Soc.*, 1st Sept. 1942, Vol. 54, Part 5, No. 305, pp. 422–428.) Based on E.R.A. Report L/T.121 : *see* also 2836 of 1941.

3371. The Polarisation Parameters of Several Solid Dielectrics, and Their Changes with Temperature and Composition [Calculation, from Published Data, of the Six Parameters specifying the Polarisation].—Field. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 737 : summary only.) Following on the work of Cole & Cole (*see*, for example, 3150 of 1941 and back references).

3372. Dielectric Measurements on Pigment Suspensions in Linseed Oil : Determination and Calculation of the Dielectric Constants of Mixed Bodies [No General Formula possible : Type of Mixture and Shape of Particles must determine Appropriate Formula : Wiener's Formula very suitable for Present Case : Applicability of Results to Colloids, etc.].—Wachholtz & Franceson. (*E.T.Z.*, 20th Feb. 1941, Vol. 62, No. 8, pp. 177–178 : summary only.)

373. "A.S.T.M. Standards on Electrical Insulating Materials" [Book Review].—A.S.T.M. Committee. (*Communications*, April 1942, Vol. 22, No. 4, pp. 15 and 35.)

374. Experiences with New Materials [Metals (Malleable Cast Irons, Magnesium Alloys, etc.) : Organic Materials (Cibanit, Melamin, etc.) : Oils].—Stäger. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, June 1942, Vol. 8, No. 6, pp. 178–197.)

3375. British Association : No. II—Conference on Mineral Resources [including Manganese, Nickel, & Tungsten : Summaries].—(*Engineer*, 7th Aug. 1942, Vol. 174, pp. 111–113.)

3376. Critical Materials : Their Conservation by the Use of Alternates [in War Production].—Horn. (*Gen. Elec. Review*, July 1942, Vol. 45, No. 7, pp. 407–414.) *See* also *Electrician*, 11th Sept. 1942, Vol. 129, pp. 272–276.

3377. The Action of Thorium in Heater-Element Alloys [Chrome-Nickel & Chrome-Aluminium Steel : Investigation of Beneficial Effect of Addition of Small Percentage of Thorium on Several Properties : due to Effect on Protective Oxide Layer].—Frölich & Barthel. (*E.T.Z.*, 16th July 1942, Vol. 63, No. 27/28, p. 334 : summary only.) *Cf.* Hessenbruch, 2135 of July.

3378. Lead-Calcium Test Castings [Quick & Accurate Technique for estimating Calcium Content (for Cable Sheath)].—Bouton. (*Bell Lab. Record*, June 1942, Vol. 20, No. 10, pp. 248–249.)

3379. On the Anomaly of the Electrical Resistance of Chromium : Supplement to the Investigations of H. Söchtig [whose Explanation is Refuted].—Erfling. (*Ann. der Physik*, 25th Feb. 1942, Vol. 41, No. 2, pp. 100–102.) *See* 207 of 1941.

3380. Using Less Tin in Cable Joining.—Lowe. (*Bell Lab. Record*, July 1942, Vol. 20, No. 11, pp. 276–277.)

3381. Electrical Contact Problems [and Their Solution by Powder-Metallurgical Products : with Curves & Tables, including Elmet Contact Compound Metals].—Compound Electro Metals. (*Engineer*, 21st Aug. 1942, Vol. 174, pp. 146–149.)

3382. Relay Circuits with Delayed Armature Release.—Schmideck. (*See* 3223.)

3383. Tuning-Fork-Controlled Current Generators and Motors.—Schmidt. (*E.T.Z.*, 16th July 1942, Vol. 63, No. 27/28, pp. 327–330.)

Author's summary :—"Largish generators and motors with tuning-fork control have been constructed which stand up to sudden changes from full-load to no-load without falling out of step. This has been done by the use of the so-called 'resistance' generator, which has been developed by the writer into a practical machine [with stationary resistances connected to fixed commutator segments, and revolving brushes at an angle so that centrifugal, lateral, and frictional forces balance each other]. It is shown, by a description of a 1 kw installation, how these machines are constructed." The "resistance" generator can be used either as generator or as braking load.

3384. The Properties of Carbon Resistor Elements.—Rigden & Starks. (*See* 3481.)

3385. FUSING CURRENTS [and the Effect of Conduction: Influence of Fuse Length, etc.].—MacCall: Dudley. (*Electrician*, 28th Aug. 1942, Vol. 129, pp. 218–219.) Prompted by Dudley's article, 2505 of August.

3386. INDICATOR LIGHT GIVES VISUAL INDICATION OF CIRCUIT BREAK.—Littlefuse, Inc. (*Scient. American*, Aug. 1942, Vol. 167, No. 2, p. 79.)

3387. DETERMINING COLOUR IN TELEPHONE CABLES [to Identify the Various Conductors: Use of Munsell Colour Discs].—Wyman. (*Bell Lab. Record*, July 1942, Vol. 20, No. 11, pp. 266–269.)

3388. RIVET, SET BLIND, CAN ALSO SERVE AS ANCHOR [" Rivnut," set with Plier-Type Hand Tool].—Goodrich Company. (*Scient. American*, July 1942, Vol. 167, No. 1, p. 38.)

3389. SOME QUASI-HYSTERESIS CYCLES [in an Iron Bar].—Perkins. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, pp. 724–725: summary only.) Continuing 2521 of August.

3390. DEMAGNETISING FACTORS OF RODS.—Bozorth & Chapin. (*Journ. Applied Phys.*, May 1942, Vol. 13, No. 5, pp. 320–326.)

3391. ON THE INFLUENCE OF THE MAGNETOELASTIC ENERGY ON THE ASYMPTOTIC LAW OF MAGNETOSTRICTION AND THE MAGNETISATION CURVE OF IRON: II, *and* THE MAGNETOSTRICTION AND THE MAGNETISATION OF IRON IN STRONG MAGNETIC FIELDS, TAKING INTO ACCOUNT THE TRUE MAGNETISATION: III.—Rüdiger & Schlechtweg. (*Ann. der Physik*, 25th Feb. 1942, Vol. 41, No. 2, pp. 144–150: pp. 151–166.) For I *see* 2182 of 1941.

3392. INFLUENCE OF ELASTIC STRESSES ON THE MAGNETIC STRUCTURE OF FERROMAGNETIC BODIES.—Schirobokov. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 5, Vol. 11, 1941, pp. 554–564.)

3393. ON THE THEORY OF FERROMAGNETISM AND ANTIFERROMAGNETISM.—Firgau. (*Ann. der Physik*, 19th Sept. 1941, Vol. 40, No. 4/5, pp. 295–329.)

3394. EMISSIVITIES AND TEMPERATURE SCALES OF THE IRON GROUP.—Wahlin & Wright. (*Journ. Applied Phys.*, Jan. 1942, Vol. 13, No. 1, pp. 40–42.) In connection with the researches dealt with in 1534 of May.

STATIONS, DESIGN AND OPERATION

3395. SYSTEM OF RADIOCOMMUNICATION BY MODULATION OF THE PHASE OF THE CARRIER WAVE [particularly suitable for Small Mobile Stations].—Severini. (*See* 3233.)

3396. METHOD FOR THE MULTIPLE USE OF A H.F., PARTICULARLY U.H.F., COMMUNICATION CARRIER [Simultaneous Frequency-Modulation by Telephony & Telegraphy, Frequency-Deviation in Latter being a Multiple of That in Former: Method of Reception].—Ilberg. (*Hochf:tech. u. Elek:akus.*, March 1942, Vol. 59, No. 3, p. 93.) Telefunken Patent, No. 709 452.

3397. FREQUENCY-MODULATION OR HOMODYNE? ADVANTAGES AND LIMITATIONS OF THE SYSTEMS.—Bell. (*Wireless World*, May 1942, Vol. 48, No. 5, pp. 106–107.)

3398. ENGINEERS AND FREQUENCY-MODULATION SELLING.—Green. (*Communications*, April 1942, Vol. 22, No. 4, pp. 10–12 and 34.) " Even if you're on the right track you'll get run over if you just sit there."

3399. THE TESTS THAT PROVED FREQUENCY MODULATION TO BE VITAL TO COMMUNICATIONS [Police-Service Tests by General Electric for F.C.C.].—Du Val. (*Communications*, Feb. 1942, Vol. 22, No. 2, pp. 5–7 and 30.)

3400. BROADCAST TRANSMISSION OVER LINES [General Considerations, with Formulae & Curves: the System in Germany].—Eckel. (*Funktech. Monatshefte*, Sept. 1941, No. 9, pp. 133–140.)

3401. CIVIL DEFENCE EMERGENCY COMMUNICATION NETS: NOTABLE FEATURES IN VOLUNTEER NETWORKS.—Taylor. (*Communications*, Feb. 1942, Vol. 22, No. 2, pp. 16–17 and 20, 32.) *See* also, for example, 2143/4 of July and 2527 of August.

3402. COASTAL RADIO-TELEPHONE SYSTEMS.—Pruden. (*Communications*, Feb. 1942, Vol. 22, No. 2, pp. 12–14.) With references to a number of *Bell Lab. Record* papers.

3403. THE STATUTE CONCERNING RADIOELECTRIC INSTALLATIONS ON BOARD SHIPS [Decree of 14th March 1942: including Obstacle Detectors].—(*Génie Civil*, 15th July 1942, Vol. 119, No. 17, p. 213.)

3404. AIRLINE-RADIO MAINTENANCE.—Sandretto. (*Communications*, May 1942, Vol. 22, No. 5, pp. 5–7 and 26.)

3405. " DRAHTLOSER UEBERSEEVERKEHR " [Transoceanic Wireless Communication and the Work of the Telefunken Company: Propagation & Installations: Book Reviews].—Kotowski & Wisbar. (*Alta Frequenza*, June 1942, Vol. 11, No. 6, pp. 298–300: *E.T.Z.*, 18th June 1942, Vol. 63, No. 23/24, p. 295.)

GENERAL PHYSICAL ARTICLES

3406. EQUATIONS FOR THE PROPAGATION OF RADIATED [Thermal] ENERGY AND THE SIMILITUDE OF RADIATING SYSTEMS.—Nevski. (*See* 3187.)

3407. A NEW METHOD FOR DERIVING POYNTING AND OTHER VALID ENERGY-FLOW VECTORS.—Slepian. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 723: summary only.)

3408. The Magnetic Current in Gases [is the Movement of Magnetic Ions in a Homogeneous Magnetic Field: Experimental Evidence], *and* The Magnetic Current in Liquids.—Ehrenhaft: Banet. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 733: p. 733: summaries only.) *See* also 1889 of July.

3409. The Vibratory Electron in Electrostatics.—Taylor Jones. (*Phil. Mag.*, July 1942, Vol. 33, No. 222, pp. 519–527.) One of the six previous papers was referred to in 1839 of 1941.

3410. The Theory of the Electric Charge and the Quantum Theory: Part III.—Flint. (*Phil. Mag.*, May 1942, Vol. 33, No. 220, pp. 369–383.) For Parts I & II *see* 3630 [and 3631] of 1940, and back reference.

3411. An Interpretation of Wave Mechanics, *and* Quantum Mechanical Systems with Generalised Hamiltonians.—Rosen: Rosen & Ruark. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, pp. 726–727: p. 727: summaries only.)

(i) "In this way one can account for the difference between the predictions of wave mechanics and of classical mechanics without giving up the particle picture in the former. . ." (ii) ". . . the result, at first sight surprising, that in such problems ordinary Cartesian coordinates and velocities commute. This may have some bearing on the problem of electronic motion, since Schott showed that on the basis of the Lorentz equations part of the stored-up energy is expressible as a term proportional to the square of the acceleration. . . ."

3412. Matter Waves and Electricity [Outlines of Theory "destined to bring the Three Basic Phenomena of Nature: Gravity, Electricity, & the Wave Theory of Matter, into One Inseparable Unity": Electricity as a Resonance Effect of Matter Waves].—Lanczos. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, pp. 713–720.)

3413. "Lehrbuch der Elektrizität und des Magnetismus" [an "Experimental Physics of the World Ether": Second, Completely Revised Edition: Book Review].—Mie. (*Naturwiss.*, 24th April 1942, Vol. 30, No. 17/18, pp. 267–268.) An enthusiastic review.

3414. New Concepts of the Solid State [emerging from the Bangalore Researches: the Fallacy of the Debye-Born Theories].—Raman. (*Current Science* [Bangalore], Feb. 1942, Vol. 11, No. 2, Supp. pp. 85–92.)

3415. On the Definition of the Loschmidt Number [and the Difficulties caused by the Present Muddle: Suggested Replacement by "Specific Molecule Number," the Ratio of Number of Molecules to Mass].—Pohl. (*Physik. Zeitschr.*, 20th April 1942, Vol. 43, No. 7/8, pp. 125–128.)

MISCELLANEOUS

3416. Concerning the Operational Calculus [and the Difference between the Various Forms].—Wagner: Angelini. (*See* 3224.)

3417. The Application of Matrix Calculus to Problems of High-Frequency Technique.—Päsler. (*See* 3225.)

3418. The Treatment of Network Problems by means of Matrices.—Usunoff. (*See* 3227.)

3419. The Matrix Theory of Torsional Oscillations [General Case of Vibration of Shaft with Several Rotating Masses].—Pipes. (*Journ. Applied Phys.*, July 1942, Vol. 13, No. 7, pp. 434–444.)

3420. An Infinite Integral [Straightforward Method of evaluating Integrals which contain a Fourier Kernel].—Watson. (*Proc. Cambridge Phil. Soc.*, July 1942, Vol. 38, Part 3, pp. 323–324.)

3421. Common Empirical Equations [Practical Technique for obtaining & checking Suitable Equations to represent Experimental Results].—Espy. (*Communications*, Feb. 1942, Vol. 22, No. 2, pp. 8, 11, and 30–31.)

3422. The Harmonic Analysis of Voltage and Current Curves [Method using Commutator-Potentiometer.]—Trnka. (*See* 3296.)

3423. "Mathematik für Physiker und Ingenieure" [Vol. I—Mathematical Instruments (Integrators, Analysers, etc.): Book Review].—Meyer zur Capellen. (*E.T.Z.*, 2nd July 1942, Vol. 63, No. 25/26, p. 316.) In a series edited by Kratzer.

3424. A Machine for the Computation of [Crystal] Structure Factors [evaluating $2f\cos(hx + ky)$: built chiefly of Meccano Parts].—Evans & Peiser. (*Proc. Phys. Soc.*, 1st Sept. 1942, Vol. 54, Part 5, No. 305, pp. 457–462.)

3425. "The Fundamental Principles of Mathematical Statistics" *and* "Sampling Methods in Forestry and Range Management" [Book Reviews].—Wolfenden: Schumacher & Chapman. (*Nature*, 15th Aug. 1942, Vol. 150, p. 196.)

3426. Science and Culture [Leading Article on Herbert Spencer Lecture].—Tansley. (*Engineer*, 7th Aug. 1942, Vol. 174, p. 114.)

3427. "Science and Education (Current Problems, 15)" [Book Review].—Humby & James. (*Proc. Phys. Soc.*, 1st Sept. 1942, Vol. 54, Part 5, No. 305, pp. 466–467.)

3428. Science and Education [Need for Better Correlation between Science & the Humanities during Formative Years: Suggestions], *and* Education and the War Effort.—Case: Chorlton. (*Nature*, 22nd Aug. 1942, Vol. 150, p. 236: *Engineer*, 14th Aug. 1942, Vol. 174, p. 135.)

(i) "We must think not only of fitting the scientific man to play a conscious part in history but also of giving the scientific outlook to the historian and the classic . . . (iii) "It leaves one breathless" (R. A. Butler's observation at Harrow). For correspondence *see* issues for 21st & 28th August, pp. 155 & 174.

3429. Research as Usual [in Total War].—Blackwelder. (*Science*, 14th Aug. 1942, Vol. 96, pp. 158–159.)

3430. Utilization of Scientific and Technical Resources, and the Need for a Whole-Time Central Scientific & Technical Board [Leading Article].—(*Nature*, 15th Aug. 1942, Vol. 150, pp. 186–191.) *See* also 3157 of October.

3431. Organisation of Science for War [Leading Article].—(*Nature*, 12th Sept. 1942, Vol. 150, pp. 301–305.) *See* also p. 310, and issue for 10th October, p. 434.

3432. Second Report of the War Policy Committee of the American Institute of Physics.—(*Science*, 24th July 1942, Vol. 96, pp. 89–90.) For the first report *see* 3158 of October.

3433. Wartime Design Practice, with Examples of Unprecedented Requirements.—Marshall. (*Communications*, March 1942, Vol. 22, No. 3, pp. 5–6.)

3434. War-Time Relaxations of I.E.E. Regulations.—I. E. E. (*BEAMA Journal*, Aug. 1942, Vol. 49, No. 62, pp. 228–229.)

3435. Publication of Scientific Research carried out in Industry.—Denbigh. (*Nature*, 12th Sept. 1942, Vol. 150, p. 322.)

"There is thus a closer liaison between university and industry in U.S.A., where the non-publication by private enterprise is far less pronounced than has yet been achieved in Great Britain. . . ." For a reply by N. R. Campbell *see* issue for 3rd October, p. 408.

3436. Encouragement of Research in Industry: Some Suggestions to Industrialists & Research Workers.—Benham. (*Nature*, 22nd Aug. 1942, Vol. 150, pp. 235–236.) Prompted by Bragg's remark "Lip service is paid to research because it is respectable and fashionable to do so, but responsible industrialists in private express their disappointment."

3437. Scientific Terminology for India: Comments on Committee Report to Central Advisory Board of Education.—Kothari. (*Sci. & Culture*, Calcutta, Feb. 1942, Vol. 7, No. 8, pp. 376–378.)

3438. Articles and Addresses on the Westinghouse Grand Science Awards, Science Talent Search.—(*Sci. News Letter*, 25th July 1942, Vol. 42, No. 4, pp. 51–55 & 60–62.) *See* 2570 of August.

3439. Typescript does Not make Good Lantern Slides: a Simple Method of overcoming this Disability.—(*Journ. Roy. Soc. Arts*, 21st Aug. 1942, Vol. 90, p. 630.) Reference to the article in *Engineering*, 3rd July, referred to in 2857 of September.

3440. Square Ruled Paper Projection: Correspondence.—Boys. (*Journ. of Scient. Instr.*, July 1942, Vol. 19, No. 7, pp. 111–112.) *See* 2107 of July.

3441. A Report on the 1942 I.R.E. Convention.—Winner. (*Communications*, Jan. 1942, Vol. 22, No. 1, pp. 14, 16 and 21, 29, 32.)

3442. A Report on the 5th Annual Conference of Broadcast Engineers, Ohio, Feb. 1942, *and* on the 20th Annual N.A.B. Convention, Cleveland.—Winner. (*Communications*, March 1942, Vol. 22, No. 3, pp. 7–11 and 26–27: May 1942, No. 5, pp. 14–16 and 34, 35.) The discussions referred to in the second report include shortages, pooling and precautions against sabotage.

3443. Activities of the I.E.N.G.F.: Reunions of the First Quarter 1941–42. (*Alta Frequenza*, June 1942, Vol. 11, No. 6, pp. 303–304.)

3444. "Radio Amateur's Handbook: Defense Edition": Book Review.—American Radio Relay League. (*Communications*, April 1942, Vol. 22, No. 4, pp. 35 and 36.)

3445. "Electronics": Book Review.—Millman & Seely. (*Communications*, April 1942, Vol. 22, No. 4, p. 15.)

3446. Electronically Controlled Variable Capacity: Application to Air Raid Warnings.—Hector & others. (*See* 3220.)

3447. Colour and Music.—Harrison. (*See* 3207.)

3448. A Precision Direct Reading Densitometer [Agfa Ansco Model 11] based on Modification of Hardy's Logarithmic Circuit Amplifier (1929 Abstracts, p. 340).—Sweet. (*Journ. Opt. Soc. Am.*, July 1942, Vol. 32, No. 7, p. 400.)

3449. An Extended Range Galvanometer Deflection Recording System: Use of Three-Metre Focal-Length Mirrors and Multiple Light Source to expand Range of Deflections by more than Three (for Photoelectric Spectrophotometers, etc.) and for Simultaneous Recording of Two Galvanometers.—Pfister & Rank. (*Journ. Opt. Soc. Am.*, July 1942, Vol. 32, No. 7, pp. 397–399.)

3450. Is the Barrier-Layer Photoelement [Lange Selenium Photocell] suitable for Precision Photometric Measurements?—Bjornstahl. (*Zeitschr. f. Instrkunde*, June 1942, Vol. 62, No. 6, pp. 181–186.)

The writer's measurements lead to the conclusion that "the characteristic of the selenium photo-element is not linear for small light intensities. The short-circuit current is not proportional to the intensity of illumination even when this is less than 100 lux: in other words, the sensitivity is variable. With certain elements, however, the sensitivity can be made practically constant over a limited range of light intensity, by the introduction of a series resistance. For intensities above or below this region the photoelement cannot be employed unless special arrangements are made."

3451. A Turbidity Comparator primarily for Assay of Physiologically Active Substances: A.C.-Operated Photoelectric Apparatus with Electronic Stabilisation of Supply to Amplifier & Light Source].—Krebs & others. (*Review Scient. Instr.*, May 1942, Vol. 13, No. 5, pp. 229–232.)

3452. An Ultra-Violet Measuring Apparatus with Modified Ulbricht Sphere, for Large Angles of Incidence Development from Krefft & Rössler's Selenium Cell Instrument].—Larché & Schulze. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 23, 1942, pp. 114–117.) Successfully used for sky-radiation measurements and for tropical-climate tests with artificial illumination.

3453. An Automatic Recording Absorption-Spectrophotometer. — Himmelreich. (*Zeitschr. f. Instr:kunde*, June 1942, Vol. 62, No. 6, pp. 202–203: summary. from *Zeitschr. f. tech. Phys.*, Vol. 22, 1941, p. 148 onwards.)

3454. Photoelectric Detection and Intensity Measurement in Raman Spectra [using the RCA 931 Photomultiplier Tube].—Rank & others. (*Journ. Opt. Soc. Am.*, July 1942, Vol. 32, No. 7, pp. 390–396.)

". . . the initial 230 000 amplification obtainable with this tube is in practice as simple as turning on a light switch. When the ultimate in sensitivity is to be achieved, the initial 230 000 amplification furnished by the cascade-type tube is almost too good to be true . . . It was found that the total dark current for the tube in question was 7.5×10^{-9}A . . . Fluctuations of the dark current set the limit to the smallest observable quantity of luminous flux which can be detected . . . the lower limit appears to be 1.5×10^{-10} lumen. It should be possible to reduce these fluctuations due to thermionic emission to a fraction of their value at room temperatures by refrigerating the photomultiplier tube."

3455. Photoelectric Width Gauge [for Flat Strips or Webbing during Production, with Possibility of Control].—Alexander. (*Electronics*, Jan. 1942, Vol. 15, No. 1, pp. 66..72.)

3456. High-Speed Photoelectric Recorder [Self-Contained, Portable, with Special Advantages].—Clark. (*Gen. Elec. Review*, July 1942, Vol. 45, No. 7, pp. 384–386.) For the original recorder and its uses *see* 1932 Abstracts, p. 422, & 1933 Abstracts, p. 581 (La Pierre), and 3204 of 1936.

3457. Study of the Degree of Polarisation of Light by Polaroids.—Melankholin. (*Journ. of Tech. Phys.* in Russian], No. 18, Vol. 10, 1940, pp. 1481–1485.)

3458. Monochromatic Light Filters.—Ronis. (*Journ. of Tech. Phys.* [in Russian], No. 16, Vol. 10, 1940, pp. 1383–1385.)

A table has been compiled giving the composition of 14 monochromatic light filters covering the range of 370–700 mμ and made up of combinations of coloured selenium-cadmium, copper-cobalt, and nickel glasses with solutions of copper chloride of various concentrations: curves showing the optical density of these filters are given.

3459. Eyes are Most Sensitive Light Recorders [Minimum Energy required for Vision 2.2–5.7 Ten-Billionths of an Erg, representing 58–148 Quanta falling on Eye, or 5–14 Quanta reaching Retina].—Hecht. (*Scient. American*, May 1942, Vol. 166, No. 5, p. 226.) *Cf.* 1576 of 1941.

3460. Simple Construction of a Parabolic Mirror.—Bubb. (*See* 3255.)

3461. On a Comparative Study of the Reflectivities of Aluminium and Silver Films [and Methods of Preparation]. — Ramakrishnan. (*Indian Journ. of Phys.*, Feb. 1942, Vol. 16, Part 1, pp. 12–22.)

3462. On the Theory of Non-Stationary Discharges: II—The Light Emission from a Modulated High-Pressure Arc [and the Effect of Frequency & of Depth of Current-Modulation on the Depth of Light-Modulation & on Phase Conditions, etc.].—Weizel & others. (*Zeitschr. f. Phys.*, 9th July 1942, Vol. 119, No. 3/4, pp. 237–244.) For I *see* 597 of February.

3463. Thermal Effects in the Double Refraction in Flowing Liquids [hitherto Neglected, the Phenomenon being considered purely a Turbulence Effect]: on the Upper Limit of the Maximum Double Refraction.—Björnståhl. (*Zeitschr. f. Phys.*, 9th July 1942, Vol. 119, No. 3/4, pp. 245–264.) For previous work by this writer *see* 4496 of 1938 and 3257 of 1939. *Cf.* 2873 of September.

3464. Determination of Absolute from Relative X-Ray Intensity Data.—Yü: Wilson. (*Nature*, 1st Aug. 1942, Vol. 150, pp. 151–152: p. 152.) Following on 2910 of September.

3465. The Measurement of Radiation for Medical Purposes [Survey leading to Attempt to estimate Total Energy flowing into the Body or absorbed by It from Beams of X and Gamma Rays, & to link These Values to Measurements of Ultra-Violet & Infra-Red Radiations].—Mayneord. (*Proc. Phys. Soc.*, 1st Sept. 1942, Vol. 54, Part 5, No. 305, pp. 405–421.)

3466. Remarks on Physical Model Representations of Energy-Propagation Mechanisms in the "Hit" Region in Radiation-Biological Processes.—Möglich, Rompe, & Timoféeff-Ressovsky. (*Naturwiss.*, 3rd July 1942, Vol. 30, No. 27, pp. 409–419.)

3467. "Wetter und Gesundheit" [Weather & Health, Part I: Reaction-Time Measurement as a Test Method for determining the Influence of the Weather & Solar Activity on Healthy Subjects: Book Review].—Düll. (*Naturwiss.*, 19th June 1942, Vol. 30, No. 25/26, p. 408.) For earlier work *see* 3277 of 1940.

3468. Research on the Practical Problem of Power and Heat from the Sun: a Progress Report from M.I.T.—Sibley. (*Scient. American*, June 1942, Vol. 166, No. 6, pp. 284–286.)

3469. Actinometry and Applications of the Sun's Heat: the Warming of Houses by Water heated by the Sun [Survey, including the Writer's Opposed-Bimetallic-Spiral Actinometer]. — D'Halluin. (*Génie Civil*, 17th/24th Jan. 1942, Vol. 119, No. 3/4, pp. 25–29.)

3470. An Electrometer for Measurement of Voltage on Small Ionisation Chambers.—Farmer. (*See* 3337.)

3471. The Origin of Statistical Fluctuations in Proportional Geiger Counters, *and* Pulse Size as a Function of Pressure in Geiger-Mueller Counters.—Swann: Miller & Montgomery. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 734: p. 734: summaries only.)

3472. " Radioaktivität: I [Fundamentals & Measuring Methods: Book Review]. — Israël. (*Zeitschr. f. tech. Phys.*, No. 6, Vol. 23, 1942, p. 165.) Vol. 2 of " Geophysik, Meteorologie, Astronomie."

3473. The Electrical Prospecting of the Subsoil: the Tracing and Study of Petroliferous Fields and Coal Beds.—Calfas. (*Génie Civil*, 1st Aug. 1942, Vol. 119, No. 18, pp. 217–220.)

3474. A 100-Cycle Frequency Standard [for Calibration of Seismic-Prospecting Timing Oscillators].—Honnell & Dickerson. (*See* 3334.)

3475. Auxiliary Apparatus for Precision Seconds-Counters. — La Barbera. (*See* 3336.)

3476. Resonance [Mathematical & Physical Conditions for Occurrence of Harmonic, Multiple-Harmonic, & Sub-Harmonic Resonance: with Photographs of Models].—Ludeke. (*Journ. Applied Phys.*, July 1942, Vol. 13, No. 7, pp. 418–423.)

3477. Quartz-Crystal Accelerometer [for Vibrations 10–10 000 c/s, Accelerations 10–5000 times Gravity (reducible to 1–500 times, for Upper Frequency Limit of 1000 c/s)].—Fehr. (*Gen. Elec. Review*, May 1942, Vol. 45, No. 5, pp. 269–272.) *See* also *Electrician*, 14th Aug. 1942, Vol. 129, pp. 172–174.

3478. " Practical Solution of Torsional Vibration Problems: Vol. II [including Detailed Description & Method of Use of Various Types of Measuring Instrument: Book Review].—Ker Wilson. (*Current Science* [Bangalore], May 1942, Vol. 11, No. 5, pp. 200–201.)

3479. The Measurement of Torsional Vibrations [General Principles of Operation of Electro-Magnetic Torsiographs: Application of Filter for Separation of Frequencies].—Stansfield. (*Engineer*, 24th & 31st July 1942, Vol. 174, pp. 77–79 & 101–102.)

3480. Applications of the Cathode-Ray Oscillograph in Industry: VI—The Recording of Mechanical Pressure Fluctuations.—Wilson. (*BEAMA Journal*, Aug. 1942, Vol. 49, No. 62, pp. 222—225: to be contd.) For a letter contesting the writer's remarks on the Einthoven string galvanometer see *ibid.*, p. 226: Wilson replies on pp. 226–227.

3481. The Properties of Carbon Resistor Elements [for Mechanical Stress Measurements] with Particular Reference to Their Behaviour under Steady Loads.—Rigden & Starks. (*Journ. of Scient. Instr.*, Aug. 1942, Vol. 19, No. 8, pp. 120–122.)

3482. Measurement of the Gas-Temperature Characteristics in Internal-Combustion Engines [Survey, including Ionisation Method & the Writer's Photocell Method (607 of February)].—Graff. (*Zeitschr. V.D.I.*, 25th July 1942, Vol. 86, No. 29/30, pp. 461–466.)

3483. Liquid-Level Controls [" Series 260 " Remote Controllers, including the " Gauge Pick-Up Unit " (with Level-Sensitive H.F. Condenser connected by Coaxial Cable to Control Cabinet)].—Wheelco Instrument. (*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, pp. 269–270.)

The single valve of the controller generates the h.f. oscillations, detects the resonance (or deviation from it) of the pick-up, and actuates a relay controlling valves or pumps.

3484. An Adaptation of the Anderson Bridge for the Detection of Minute Changes in Temperature.—Kennon & Cullen. (*See* 3327.)

3485. Electronic Moisture Monitor for Furnace Gases in Steel Hardening.—(*Sci. News Letter*, 25th July 1942, Vol. 42, No. 4, p. 62.)

3486. Mechanical Detection of Wheel-Seat Flaws in Railway Axles [and a Defence of the Electrical Conductance Method].—Thornton: Johansen. (*Engineering*, 14th Aug. 1942, Vol. 154, p. 133.) *Cf.* issue for 28th August, p. 174.

3487. Eddy-Current-Type Flaw Detectors for Non-Magnetic Metals [with Five Types of Pick-Up, including Spot-Weld Tester: Eddy-Current-Pattern Changes detected by Bridge Circuits sensitive to Amplitude & Phase Changes: Possibilities of Automatic Scanning & Recording].—Vigness, Dinger, & Gunn. (*Journ. Applied Phys.*, June 1942, Vol. 13, No. 6, pp. 377–383.)