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Editorial.

The Effect of the Earth on Short-wave Radiation from Vertical and Horizontal Aerials.

IT is nearly twenty years since Sommerfeld published his paper on the radiation from a vertical aerial, and during the interval a number of mathematical physicists have worked at the problem. Sommerfeld took into consideration the nature of the ground, but assumed the earth to be plane; at that date little was known of the action of the Kennelly-Heaviside layer, and it was generally assumed that the only part of the radiation from the antenna, which was of practical importance, was that propagated along the surface of the earth. Sommerfeld, therefore, confined himself to radiation in this direction and his results are not applicable to radiation at a considerable angle to the earth's surface, which radiation we now know may be of greater importance than that propagated horizontally. Although recent experiments have shown that for long distance short-wave transmission the best results are obtained by directing the beam in the horizontal direction, it is not because the waves travel around the earth along the surface, but because the beam which is radiated tangentially appears to suffer less attenuation in its trajectory in the upper atmosphere between the two stations. In the simple assumption of long waves travelling over a plane earth of infinite conductivity, the problem was closely analogous to the transmission of alternating currents along a transmission line of zero resistance, and one could imagine the electric field to be confined between a lower infinite plane and an upper cone. As soon as the earth resistance is taken into account this simple analogy must be given up. The waves are no longer spherical and merely retarded and attenuated by the earth's resistance. Sommerfeld showed that the effect of the resistance was to split up the waves into two parts, the lower part attached to the earth and propagated, as a cylindrical surface wave, the upper part, freed from the guidance of the earth and propagated as a spherical wave into space. The splitting up is a continual process, some of the energy of the surface wave being continually lost by radiation into space. Considerable light was thrown on the nature of these processes by the diagrams which were published by Epstein in 1911, showing the lines of force for different conditions as calculated from Sommerfeld's results.

In all these researches the radiation was assumed to leave the aerial as if the latter were a vertical dipole of a height which could be neglected in comparison with the wavelength. With the recent development of short wave transmission and with our knowledge of the important *rôle* played by the upper atmosphere, the assumptions made in many of these earlier researches are no longer tenable. We are concerned now with the radiation from aerials which are not only of a height comparable with the wavelength, but which are situated at a distance above the ground which is also comparable with the wavelength; we are also concerned with the distribution of the radiation, that is to say, how the radiated energy varies with the angle of inclination. It is no longer permissible to assume that the aerial is vertical since horizontal aerials are now largely employed and are of special interest from a theoretical point of view.

One of the most important contributions on this subject was that of T. L. Eckersley in his paper before the Institution of Electrical Engineers in 1927. A paper has just been published by M. J. O. Strutt in the *Annalen der Physik* (page 721, 1929), in which the subject is treated in a somewhat different manner, and it is satisfactory to note that the formula derived for a vertical dipole is identical with that obtained by Eckersley. A large number of numerical examples are calculated and curves plotted showing the distribution of radiation for different values of the dielectric constant and conductivity of the earth, the assumed wavelength being always 30 m. It is interesting to note that the dielectric constant appears to be the more important characteristic, and that conductivities of such a value that the conduction currents are equal to the displacement currents do not appreciably modify the results obtained for an ideal dielectric earth with no conduction currents. As one would expect, an increase in the dielectric constant of the earth increases the energy radiated in the upper hemisphere for the same aerial current; especially is this noticeable in directions near the horizontal. As one raises a vertical dipole above the earth the horizontally radiated energy increases, but the high-angle radiation may increase or decrease. The maximum radiation occurs at an angle between 20 and 40 degrees to the horizontal; although that in the horizontal direction is zero, it is quite considerable a few degrees above the horizontal. The radiation is much less than would be obtained with a perfectly conducting earth, since, even if the earth were a perfect dielectric, *i.e.*, free from losses, a certain fraction of the energy would be radiated into the lower hemisphere and thus lost.

The horizontal dipole leads to some striking results; if it is near the earth the radiation is nearly symmetrical about a vertical axis and does not exhibit the pronounced directive effect which one might expect. The total useful energy radiated from a horizontal dipole always increases with its height whatever the nature of the earth, whereas with a vertical dipole it may increase or decrease, depending on the nature of the earth. Perhaps the most important result of the investigation is that the usefully radiated energy of a horizontal antenna, if placed at a proper height, is not less than that from a similar vertical antenna, which agrees with the results of long distance measurements with both types of aerials.

G. W. O. H.

Moving Coil Loud Speakers.

With Particular Reference to the Free-Edge Cone Type.

By C. R. Cosens, M.A.

Object of Discussion.

THE general outlines of the design of a moving coil loud speaker are well known; we require a *diaphragm* or "cone," suitably suspended, attached to a *coil*, which moves in a *magnetic field*. But as soon as we try to get down to dimensions and numerical values for these three, diaphragm, coil, and field, it is found that ideas are, at best, somewhat vague.

Now although loud speakers in general are not suitable for simple mathematical treatment, it so happens that the "moving-coil free-edge cone" is amenable to analysis if we make certain simplifying assumptions; and the results so obtained appear to resemble the results of experiment sufficiently closely to be of value for design purposes. As it is generally agreed that this type of loud speaker can be made to give the most realistic reproduction of any which is at present available, it appears worth while to give the method of dealing with the problem in *E.W. & W.E.*, together with graphs and tables of results for some particular cases.

For perfect reproduction we may say vaguely that we want the relative volumes of different parts of the musical scale to be correct, but to treat the subject mathematically we require a definition of "volume."

Lord Rayleigh ("Theory of Sound," Vol. II, para. 245) defines "*intensity*" of sound at a point as follows:—

"*The rate at which energy is transmitted across unit area of a plane parallel to the front of a progressive wave may be regarded as the mechanical measure of the intensity.*"

If the "intensity" as above defined be integrated over a closed surface containing a source of sound, we may call the result the "*Output*"; this is clearly the mean rate at which the source of sound does work upon the air, and we shall denote it by W. This gives a numerical value to what is usually called volume.

As we want a numerical measure of how far our reproduction falls short of perfection, we must first consider how "perfect" reproduction should be defined. It is clear that what we need is that the *output* of sound given by the loud speaker shall be proportional to the intensity in the studio at the transmitting station, independent of frequency. We therefore have to consider the whole chain of apparatus from the microphone to the loud speaker, and it is desirable to know the frequency characteristics of each part of the chain. In default of other information, we must make some assumption as to the frequency characteristic of the pieces of apparatus in the chain other than the loud speaker itself (with which it is essential to consider the power stage of the receiver, since the loud speaker is the load in the anode circuit of the latter). It is found convenient to work in terms of $\mathcal{E}_g$, the R.M.S. value of the E.M.F. applied to the grid of the receiver power stage, and to assume some relation between $\mathcal{E}_g$ and the intensity of sound in the transmitting studio. The most simple assumption is that the E.M.F. $\mathcal{E}_g$ applied to the grid of the power stage of the receiver is proportional to the E.M.F. generated by the microphone system in the transmitting studio at any frequency.

We must also assume that when a sound of given intensity is produced in the studio, the energy absorbed from the air by the microphone and converted into electrical energy will be proportional to the original intensity of the sound, irrespective of frequency. (If this is not true for the microphone alone, an attenuation network will be used to correct it, and the whole combination of microphone and network will form the "microphone system.")

Now if the microphone system feeds into a fixed resistance, such as the windings of a potentiometer used for volume control, the electrical energy generated will be proportional to the *square* of the generated E.M.F.; to which the receiver E.M.F. $\mathcal{E}_g$ has in turn been assumed proportional.

Hence $\mathcal{E}_g^2$ will be proportional to the sound intensity in the transmitting studio, and if we want perfectly faithful reproduction we must have our loud speaker output proportional to this, *i.e.*

$$W \propto \mathcal{E}_g^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

irrespective of frequency.

Types of Distortion.

If at any one frequency W is not proportional to $\mathcal{E}_g^2$ we shall have *amplitude distortion.* We shall show that this only occurs as a second order effect, if at all.

If the ratio of W to $\mathcal{E}_g^2$ is not the same at all frequencies we shall have *frequency distortion.* We shall show that this does occur, and consider how its effects may be minimised.

If we have two different frequencies to be dealt with at the same time, in the absence of the above forms of distortion their relative *amplitudes* would be preserved; although their relative *phases* might be altered, giving *phase distortion.* This inevitably occurs wherever there is iron present, and in any land-line, as well as in any loud speaker. As regards the reproduction of music and speech this form of distortion is of no consequence; the Helmholtz theory of hearing assumes that the ear performs a harmonic analysis of a complex sound by means of resonators, and is sensitive to the relative *amplitudes* of the component pure tones, but not to their relative *phase.*

Assumed Shape and Rigidity of Diaphragm.

The only real difficulty met with in the analysis is that of estimating the reaction of the air on the moving diaphragm or "cone"; fortunately a result obtained by Lord Rayleigh many years ago appears applicable, at least as a first approximation to the actual facts.

In "Theory of Sound," Vol. II, § 302, there is given a discussion of the reaction of the air on a perfectly rigid plane circular disc, moving harmonically in a perfectly fitting aperture in an infinite plane baffle, the disc and baffle forming the boundary of a semi-infinite mass of gas (in our case, air).

As a first approximation to the effect of the air on an actual loud speaker diaphragm, we may take *double* the values given by Rayleigh (since we have air on *both* sides of the diaphragm, whereas Rayleigh's disc had air on *one* side only).

The form of loud speaker which we are to analyse is then provided with a perfectly plane circular diaphragm, which is absolutely rigid. An actual practical diaphragm is of conical form, and the air pressures on the front (concave) side will be greater than those for the plane disc, but this is partly compensated for by the pressures on the back (convex) side of the cone being less than for the plane disc. In any case the effect of the proximity of the magnet system will be to introduce errors at least as great as those due to the actual diaphragm being conical instead of plane, and it would appear impossible to allow for the effect of the magnet. The human ear is fortunately insensitive to differences of sound intensity less than 3 or 4 to 1 (or else loud speaker reproduction would be even less satisfactory than it is), and therefore our results will be of some value, even if there are actually considerable errors. It is probable that the difference between calculation and practice would not exceed, say, 25 per cent., and the *relative* errors as between different frequencies would be less than this.

Again, it is obvious that no actual diaphragm is perfectly rigid, but it would appear that the difficulties of analysis of a non-rigid diaphragm would be enormous. The effects of want of rigidity would be felt most in the reproduction of the higher frequencies, where the diaphragm would have two types of motion, a simple movement as a whole, and an internal vibration of the type met with in fixed-edge reed-driven cones. The effects in practice appear to be an accentuation of the higher frequencies (which is very desirable, as will be seen; but for this effect we should have little or nothing above about 1,500 cycles); at the lower frequencies the effects will be negligible.

Finally, we cannot have an infinite baffle, but the error due to assuming our baffle infinite will be small except at the lowest frequencies.

Approximate Analysis of Moving Coil Free-edge Loud Speaker.

(We assume all quantities measured on the absolute C.G.S. electromagnetic system.)

Consider a cylindrical moving coil of radius c, free to move axially in a uniform radial magnetic field, rigidly fixed to a circular diaphragm of radius C, coaxial with the coil, which moves in an aperture in a plane "baffle."

Let : γ = Total length of wire in moving coil.

B = Flux-density in air-gap.

x = axial displacement of coil at any instant.

$v = \frac{dx}{dt}$ = (instantaneous) velocity of coil.

F = driving force on coil, tending to increase x, due to current in coil.

i = Current in coil at any instant.

write also $\Psi = \gamma B$.

Due to the current i in the coil, the mechanical force F produced will be

$$F = \Psi i \quad \ldots \ldots (2)$$

Due to the motion of the coil in the magnetic field, a back E.M.F. will be generated, given by :

$$e_b = \Psi v \quad \ldots \ldots (3)$$

Mechanical Constants.

Let the ends of the coil be supposed disconnected and the ends insulated, and let the coil and diaphragm be made to vibrate by an axial force of instantaneous value F dynes, with a frequency $f = \frac{\omega}{2\pi}$ oscillations per second. The equation of the resultant motion will be of the form :

$$m\frac{d^2x}{dt^2} + \beta\frac{dx}{dt} + hx = F \quad \ldots \ldots (4)$$

where m = the "Effective mass" of the coil, diaphragm, etc., including that of a mass of air moving with the diaphragm (the "adherent air"), and β is a "damping coefficient," while h is the restoring force for unit displacement due to the suspension (usually made negligible). As shown in Lord Rayleigh's "Theory of Sound," m and β vary with frequency.

Electrical Constants of Coil.

Let r_c and l_c be the effective A.C. resistance and inductance of the coil supposed *immovably fixed* in the air-gap of the field-magnet (*e.g.*, as measured on a Heaviside-Campbell bridge).

Connections of Coil and Associated Apparatus.

Let the moving coil be connected to the secondary of an output transformer of step-down ratio ρ : 1, the primary of which is in the anode circuit of a valve as shown in Figure 1. Let μ and R_a be the ampli-

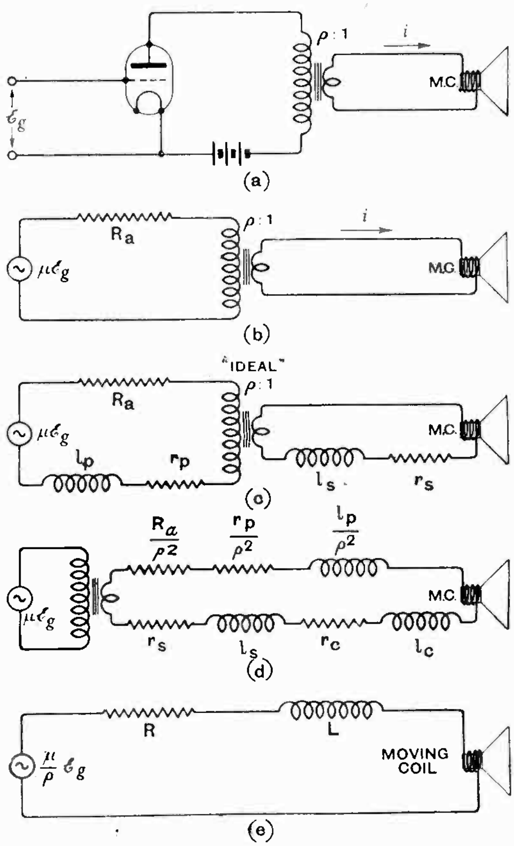

Fig. 1.

fication factor and slope-resistance ("impedance") of the valve. Let r_p, r_s, l_p, l_s be the primary and secondary resistances and leakage inductances of the transformer.

If a harmonic E.M.F. $e_g = E_g \sin \omega t$ applied to the grid of the valve cause a current i to flow in the moving coil, we can replace the valve by an ordinary resistance R_a, and an E.M.F. μe_g acting in series with it, as in Figure 1(b).

We now replace the actual transformer by an "ideal" transformer having the imperfections (r_p, r_s, l_p, l_s) outside the transformer itself; and finally we transfer everything to the secondary of the transformer, and if we imagine the imperfections r_c and l_c of the coil also taken outside, we can replace the whole by the arrangement of Figure 1(e), where:

$$\left.\begin{aligned} R &= \left(r_c + r_s + \frac{1}{\rho^2}r_p + \frac{1}{\rho^2}R_a\right) \\ L &= \left(l_c + l_s + \frac{1}{\rho^2}l_p\right) \end{aligned}\right\} \quad \ldots (5)$$

and where the moving coil is now supposed to have no resistance or inductance (but still to generate the E.M.F. given by (3) due to motion in the magnetic field).

Then:

$$L\frac{di}{dt} + Ri + \Psi v = \frac{\mu}{\rho}E_g \sin \omega t \quad \ldots (6)$$

Combining (2) and (4), we have:

$$m\frac{d^2x}{dt^2} + \beta\frac{dx}{dt} + hx = \Psi i \quad \ldots (7)$$

It will be found convenient to solve (6) and (7) for $v = dx/dt$ in terms of

$$e_g = E_g \sin \omega t.$$

Using the Heaviside operator notation ($D \equiv d/dt$), (6) and (7) become:

$$(LD + R)i + \Psi v = \frac{\mu}{\rho}E_g \sin \omega t \quad \ldots (6a)$$

$$\left(mD + \beta + \frac{h}{D}\right)v = \Psi i \quad \ldots (7a)$$

since ($v \equiv dx/dt \equiv D\,.\,x$, and therefore

$$x = \frac{1}{D}\,.\,v).$$

Eliminating i between (6a) and (7a), we have:

$$(LD + R)\left(mD + \beta + \frac{h}{D}\right)v + \Psi^2 v = \frac{\mu}{\rho}\Psi E_g \sin \omega t \quad \ldots (8)$$

We may leave the complementary function of (8) out of consideration for the present, since it will represent a "transient" term rapidly damped out, and confine our attention to finding a Particular Integral. Before proceeding in the usual manner, note that h/D is to operate on v, which will clearly be a simple harmonic function of period $\omega/2\pi$; hence we may write

$$\frac{h}{D} = \frac{hD}{D^2} = -\frac{h}{\omega^2}\,.\,D$$

for the purposes of finding the particular integral we require.

Hence (8) becomes:

$$[LD + R]\left[\left(m - \frac{h}{\omega^2}\right)D + \beta\right]v + \Psi^2 v = \frac{\mu}{\rho}\Psi E_g \sin \omega t \quad \ldots (8a)$$

If, for brevity, we now write:

$$\tau = \frac{1}{\beta}\left(m - \frac{h}{\omega^2}\right);\ Q = \frac{\Psi^2}{\beta} \quad \ldots (9)$$

(a consideration of dimensions shows that τ is a period of time, *i.e.*, seconds, while Q is of the dimensions of an absolute C.G.S. unit of resistance) we have:

$$(LD + R)(\tau D + 1)v + Qv = \frac{\mu}{\rho}\frac{\Psi}{\beta}E_g \sin \omega t \quad \ldots (10)$$

whence

$$v = \frac{\mu\Psi}{\rho\beta}E_g\frac{1}{\tau LD^2 + (L + \tau R)D + (R + Q)}\sin \omega t$$

$$= \frac{\mu\Psi}{\rho\beta}E_g\frac{(R+Q-\omega^2\tau L)-(L+\tau R)D}{(R+Q-\omega^2\tau L)^2-(L+\tau R)^2D^2}\sin \omega t$$

$$= \frac{\mu\Psi}{\rho\beta}E_g\frac{(R+Q-\omega^2\tau L)\sin\omega t-(L+\tau R)\omega\cos\omega t}{(R+Q-\omega^2\tau L)^2+\omega^2(L+\tau R)^2}$$

$$= \frac{\mu\Psi}{\rho\beta}\frac{E_g \sin(\omega t - \lambda)}{\sqrt{(R + Q + \omega^2\tau L)^2 + \omega^2(L + \tau R)^2}} \quad \ldots (10a)$$

If $\mathcal{E}_g$ be the R.M.S. value of the E.M.F. e_g applied to the grid of the power valve, then $E_g{}^2 = 2\mathcal{E}_g{}^2$. Remembering that $\frac{\Psi^2}{\beta} = Q$, and writing

$$A^2 = 2\frac{\mu^2 Q}{\rho^2\beta}\mathcal{E}_g{}^2\frac{1}{(R + Q + \omega^2\tau L) + \omega^2(L + \tau R)} \quad \ldots (11)$$

it is seen that we can write (10a) in the form:

$$v = A\,.\,\sin(\omega t - \lambda) \quad \ldots (12)$$

(the value of λ is not at present important).

Output of Sound W.

W being defined as the mean rate at which work is done on the air by the loud speaker, and remembering that the cone or diaphragm is assumed perfectly rigid, and the suspension free from energy loss, it is clear that this must be equal to the mean rate at which the coil does work on the diaphragm. Now by Equation (4) the force exerted by the coil is :

$$F = m\frac{d^2x}{dt^2} + \beta\frac{dx}{dt} + hx \quad .. \quad (4)$$

Hence at any instant, the rate of doing work is :

$$F \, . \, v = mv\frac{d^2x}{dt^2} + \beta v\frac{dx}{dt} + hvx$$

Since $v \equiv dx/dt$ we may write this

$$F \, . \, v = mv\frac{dv}{dt} + \beta v^2 + hx\frac{dx}{dt}$$

W being the average value of Fv, we must integrate this expression over a complete cycle and divide by $2\pi/\omega$. Thus :

$$W = \frac{\omega}{2\pi}\left[m\int_0^{2\pi/\omega} v\frac{dv}{dt} \, . \, dt + \beta\int_0^{2\pi/\omega} v^2 dt + h\int_0^{2\pi/\omega} x\frac{dx}{dt} \, . \, dt \right] \quad .. \quad (13)$$

v and x both being harmonic functions of period $2\pi/\omega$, the first and third integrals vanish when taken over a complete cycle,

$$\left(\int_0^{2\pi/\omega} v\frac{dv}{dt}dt = A^2\int_0^{2\pi/\omega} \sin(\omega t - \lambda)\cos(\omega t - \lambda) \, dt = 0\right)$$

And :

$$\int_0^{2\pi/\omega} v^2 \, . \, dt = A^2\int_0^{2\pi/\omega} \sin^2(\omega t - \lambda) \, . \, dt = \tfrac{1}{2}A^2 \, . \, 2\pi/\omega.$$

Hence 13 becomes :

$W = \frac{1}{2}A^2\beta$ and on substituting for A^2 from (11) we have :

$$W = \frac{\mu^2}{\rho^2}\mathcal{E}_g{}^2\frac{Q}{(R + Q - \omega^2\tau L)^2 + \omega^2(L + \tau R)^2} \quad .. \quad .. \quad .. \quad (14)$$

Radiation Resistance.

If $\mathfrak{I}$ be the R.M.S. value of the current i flowing in the coil at any instant, we may apply the term "Radiation Resistance" to a quantity S, defined by the relation

$$W = \mathfrak{I}^2 S \quad .. \quad .. \quad (14a)$$

From (7a) $\left(mD + \beta + \frac{h}{D}\right)v = \Psi i$

substituting for v from (12), we have :

$$i = \frac{A}{\Psi}\left[mD + \beta + \frac{h}{D}\right]\sin(\omega t - \lambda)$$

$$= \frac{A}{\Psi}\left[\left(m - \frac{h}{\omega^2}\right)D + \beta\right]\sin(\omega t - \lambda)$$

$$= \frac{A\beta}{\Psi}[1 + \tau D]\sin(\omega t - \lambda).$$

Therefore

$$i = \frac{A\beta}{\Psi}[\sin(\omega t - \lambda) + \omega\tau\cos(\omega t - \lambda)]$$

which may be written

$$i = \frac{A\beta}{\Psi}\sqrt{(1 + \omega^2\tau^2)}\sin(\omega t - \lambda').$$

On squaring this and integrating over a complete cycle, afterwards dividing by $2\pi/\omega$, we find the R.M.S. value of i is given by :

$$\mathfrak{I}^2 = \tfrac{1}{2}\frac{A^2\beta^2}{\Psi^2}(1 + \omega^2\tau^2)$$

$$\therefore \quad \mathfrak{I}^2 S = W = \tfrac{1}{2}\frac{A^2\beta^2}{\Psi^2}S(1 + \omega^2\tau^2).$$

But $W = \frac{1}{2}A^2\beta$, and equating these values of W we find that :

$$S = \frac{\Psi^2}{\beta(1 + \omega^2\tau^2)} = \frac{Q}{1 + \omega^2\tau^2}.$$

Substituting $S(1 + \omega^2\tau^2)$ for Q in (14), we find that $(1 + \omega\tau)$ is a factor of numerator and denominator, and after further reduction we arrive at

$$W = \frac{\mu^2}{\rho^2}\mathcal{E}_g{}^2\frac{S}{(R + S)^2 + \omega^2(L - \tau S)^2} \quad (15)$$

Where

$$S = \frac{\Psi^2}{\beta(1 + \omega^2\tau^2)} = \frac{\gamma^2 B^2}{\beta(1 + \omega^2\tau^2)} \quad .. \quad (15a)$$

and

$$\tau = \frac{m - \dfrac{h}{\omega^2}}{\beta} \quad .. \quad .. \quad .. \quad (15b)$$

Value of β.

Lord Rayleigh (Theory of Sound, Vol. II, para. 302) has dealt with the reaction of the air on a rigid circular plane disc moving in a closely fitting aperture in an infinite plane baffle, the disc and baffle being the boundary of a semi-infinite mass of gas (*i.e.*, air in our case). Now we have air on *both* sides of the diaphragm and baffle, and as suggested earlier in this paper, if we double Lord Rayleigh's values, so as to allow for air on both sides of the diaphragm, we shall obtain at any rate an approximation to the actual state of affairs for a practical " cone " diaphragm.

We then have:

$$\beta = 2\pi C^2 a\sigma\left[1 - 2\frac{J_1 z}{z}\right] \quad .. (16)$$

where:

$$z = \frac{4\pi}{a} Cf$$

C = Radius of disc in cm.

a = Velocity of sound in air (33,300 cm./sec.).

σ = Density of air (0.00128 gm. per cu. cm.).

Assuming a disc of 20 cm. diameter (*i.e.*, $C = 10$ cm.) as approximately the usual practice, the function β has been worked out from the values of $J_1(z)$ given in Professor G. N. Watson's "Theory of Bessel Functions." ($J_1(z)$ is the ordinary Bessel function of the first kind, of order 1.) The graph of this function has been plotted in Fig. 2, and as tables of Bessel functions may not be immediately available to the reader, who may wish to work out values for himself, four-figure values are given for a few values of z in Table I.

From the ascending series for $\left(1 - 2\frac{J_1(z)}{z}\right)$

$$1 - 2\frac{J_1(z)}{z} = \left[\frac{(z/2)^2}{1^2 . 2} - \frac{(z/2)^4}{1^2 . 2^2 . 3} + \frac{(z/2)^6}{1^2 . 2^2 . 3^2 . 4} \text{ etc.}\right]:$$

it is at once seen that for small values of z, $\frac{J_1(z)}{z}$ is approximately represented by the first term of the series, and will therefore be proportional to z^2, that is to (frequency)^2, and substituting for z in terms of $\omega = 2\pi f$, we find that for small values of z, β is approximately given by $\beta \approx \frac{\pi\sigma}{a} C^4 \omega^2$ .. .. (17)

The approximation is also shown in thick dotted lines on the graph of Fig. 2 (showing $1 - 2\frac{J_1(z)}{z}$ with logarithmic ordinates as well as logarithmic abscissæ) from which it will be seen that it is roughly true up to about $z = 3$ or 4.

For large values of z, $\frac{J_1(z)}{z}$ becomes small compared to 1, and we have very roughly,

$$\beta \approx 2\pi\sigma a C^2 \quad .. \quad .. \quad .. \quad ..(17a)$$

The value of these approximations will be seen subsequently.

(If the graph or table of values of this function is required for a different diameter of diaphragm, say C' cm., we must multiply the value of β by $C'^2/100$, for any given value

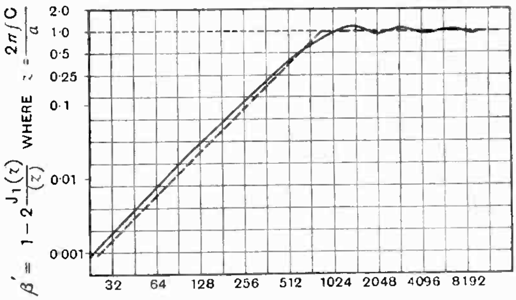

Fig. 2.

of z, and, if we are thinking in terms of frequency, we must remember that the value of z corresponding to any given frequency must be multiplied by $C'/10$.)

Fig. 3 shows the damping coefficient β plotted on semi-log paper. The ordinates are those of Fig. 2 multiplied by $2\pi C^2 a\sigma$.

The Value of m.

The "effective" mass m of the diaphragm or cone is greater than the static mass m_0 (the mass of the diaphragm alone) by a quantity Δm, representing the mass of a quantity of air carried with the diaphragm, which we may call the "adherent air." Lord Rayleigh (*loc. cit.*) has worked out the value of Δm for various frequencies in terms of $z = \frac{4\pi}{a} Cf$. He arrived at a function of z which he referred to as $K_1(z)$; but this is *not* either of the Bessel functions usually referred to as K functions by mathematicians,

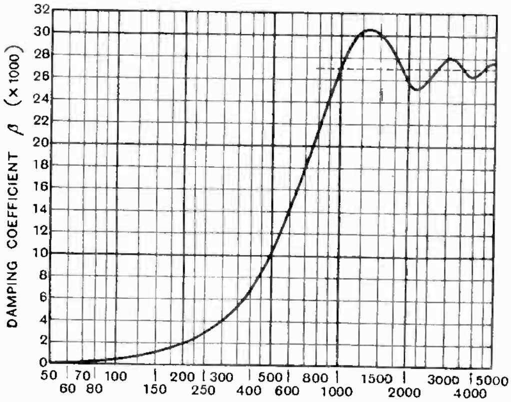

Fig. 3.

in fact although closely allied, it is not a true Bessel function at all (it is not a solution of Bessel's equation). After some difficulty in trying to identify it, the writer referred the question to Professor G. N. Watson, who pointed out that it is closely connected with Struve's functions, usually represented by a (Clarendon) **H**, in fact Rayleigh's

$$K_1(z) \equiv z\mathbf{H}_1(z).$$

This should on no account be confused with the ordinary Bessel function of the third kind usually represented by $H_2{}^1(z)$ and tabulated, for example, in Jahnke and Emde's Funktionentafeln. Values of Struve's functions do not appear to have been tabulated until Professor Watson published them in the tables at the end of his "Theory of Bessel Functions," where they are given to seven places.

Doubling Rayleigh's values (to allow for air on *both* sides of the diaphragm), and using the modern notation for Struve's functions we find that

$$\triangle m = 4\pi\sigma C^3 \cdot \left[\frac{\mathbf{H}_1(z)}{z^2}\right] \quad \ldots \quad \ldots \quad (18)$$

As these tables may not be easily accessible to the reader, values of $\mathbf{H}_1(z)$ as well as of $\triangle m$ are given in the table for a few widely-spaced values of z such as are of importance for calculating $\triangle m$.

The values of $\triangle m$ are calculated for a diaphragm of 20 cm. diameter (*i.e.*, for $C = 10$, $\sigma = 0.00128$, σ being the density of air, as before) and a graph of $\triangle m$ is given in Fig. 4.

It will be seen that $\triangle m$ is approximately 7 gm. at low frequencies, and begins to drop rapidly about $z = 3$ or 4. This dropping of $\triangle m$ would be very useful in helping to prevent the loss of high notes were it not that the static mass m_0 cannot be made small compared to $\triangle m$. It is with great difficulty that a diaphragm and coil weighing as little as 10 gm. can be constructed, most frequently we find the weight is more like 15 or even 20 gm. For purposes of calculation a 10 gm. diaphragm and coil has been assumed, but it must be remembered that this is rather an ideal to be aimed at than the actual weight of the average existing coil and diaphragm. The "effective" mass, $m = m_0 + \triangle m$ will therefore vary between about 17 gm. at low frequencies to about 10 gm. at the highest frequencies, and the decrease is not sufficient to give us much help with high note reproduction, as will be shown later.*

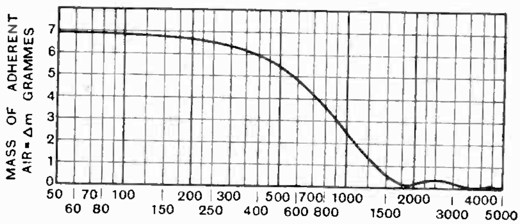

Fig. 4.

The Value of τ.

Numerical values of $\tau = \frac{1}{\beta}\left(m - \frac{h}{\omega^2}\right)$ have been worked out assuming a static mass of 10 gm. for coil and diaphragm, and neglecting $\frac{h}{\omega^2}$ in comparison with m. Owing to the ω^2 in the denominator, the neglected term becomes very small at all but the lowest frequencies, where its influence helps to decrease τ, and therewith the back E.M.F.

* For a discussion of the reaction of the air on a diaphragm, and a *bibliography*, see the Editorials *E.W. & W.E.*, March and April, 1929.

due to motion of the coil in the magnetic field. A small amount of control due to the suspension cannot in practice be avoided, and provided it be not excessive will do good rather than harm. But the presence of h will produce a low-frequency resonance, and we must therefore, by keeping h from becoming too large, make this resonance below the lowest frequency we wish to reproduce. In actual practice, however, even a fairly stiff control does not do as much harm as might be expected; the resonance is in any case heavily damped, and unless the control is intentionally made very stiff (*e.g.*, by excessive stretching of the stockinette or rubber sheet connecting diaphragm and baffle before fixing) it is difficult to detect an objectionable "wolf note."

We may note that as an approximation, we may take m as nearly constant at low frequencies, and since β varies as ω^2 in this region we find that τ varies as $\frac{1}{\omega^2}$, or in other words $\omega^2\tau$ is approximately constant, up to say $z = 3$ or about 500 cycles per second. We shall see that this is very desirable in the interests of keeping up the radiation resistance S, which tends to decrease with increase of frequency. Unfortunately, at the higher frequencies, that is for the larger values of z, we have β nearly constant (see Fig. 2) and the help obtained from decreasing m is not sufficient to compensate for this. If it were possible to make a coil and diaphragm whose weight was negligible compared to $\triangle m$ (say $\frac{1}{2}$ gm. for a 20 cm. diameter diaphragm), the decrease of m would be a great help, but unfortunately this is impossible. We then find that for the higher frequencies τ tends to become roughly constant; this would apply above, say, 700 cycles with our size of diaphragm.

From Equation (15a) we have:

$$\text{Radiation resistance } S = \frac{\gamma^2 B^2}{\beta(1 + \omega^2\tau^2)}$$

It will be seen that the numerator of this fraction depends only on the coil and induction in the air gap, while the denominator depends only on the cone or diaphragm. The quantity $\frac{10^6}{\beta(1 + \omega^2\tau^2)}$ has been worked out and plotted in Fig. 5 (values also given in table); for any particular coil and gap induction we have only to multiply values of this function taken from the graph by $\gamma^2 B^2/10^6$ to obtain the radiation resistance S. It will be seen from Fig. 5 that S is practically constant up to say 500 cycles, and is not drooping excessively until we reach 1,500

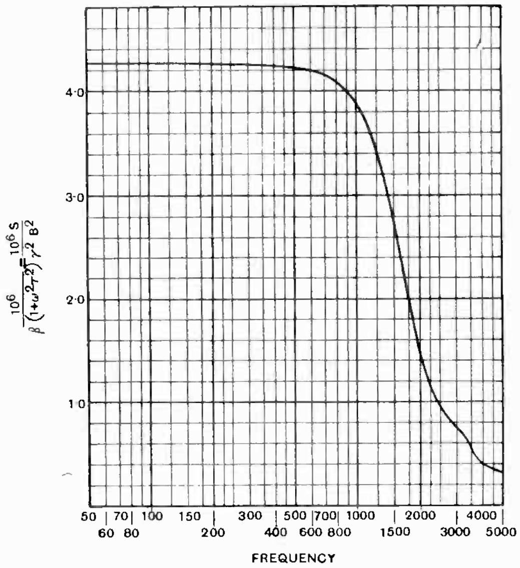

Fig. 5.

cycles (it is doubtful if any but a musician's ear will detect a decrease of intensity of anything less than 2 to 1). But above 1,500 cycles S drops off very rapidly indeed. Now, if we had *constant current* through the moving coil at all frequencies for the same E_g, the sound intensity would be directly proportional to S (actually S multiplied by the square of the current), and it would therefore drop off badly above 1,500 cycles. But in fact, owing to the inductance of the moving coil, the current decreases rapidly with increasing frequency, and it is found that the acoustic output at 1,000 cycles is only about half that at say 200 cycles, making matters much worse than before.

In calculating out S we find that $\omega^2\tau^2$ is always large compared to 1, hence the denominator of (15a) is very nearly equal to $\beta\omega^2\tau^2$. We have seen that at low frequencies β varies as ω^2, while τ varies as $\frac{1}{\omega^2}$, hence $\beta\omega^2\tau$ is practically constant; in fact, if we substitute the approximation of (17) for β we have

$$S = \gamma^2 B^2 \frac{\pi\sigma}{am^2} C^4 \quad \ldots \quad \ldots (19)$$

this approximation being fairly satisfactory up to say $z = 3$, or with our diameter of diaphragm, 800 to 1,000 cycles. For higher frequencies we must use the accurate formula (15a).

Motional Capacity.

Referring to Equation 15, we see that the denominator contains two parts :—

$(R + S)^2$, a (resistance)^2,

and $\omega^2 (L - \tau S)^2$, a (reactance)^2.

S is usually negligible compared with R. Now the term τS occurring in the expression $(L - \tau S)$ represents the effect of the back E.M.F. set up in the coil due to its motion in the magnetic field. The effect of this back E.M.F. is frequently taken account of by means of the so-called "Motional capacity," we must see to what extent this is legitimate and find the value of this capacity, which we shall call K (the symbol C being already in use for the radius of the diaphragm).

Since, as suggested in the last paragraph, $\omega^2\tau^2$ is large compared to 1, we may write $S = \dfrac{\gamma^2 B^2}{\beta\omega^2\tau^2}$ nearly, and since $\tau = \dfrac{m}{\beta}$ we find on substituting these values that $\tau S = \dfrac{\gamma^2 B^2}{\omega^2 m}$.

Hence the expression $\omega^2(L - \tau S)^2$ becomes equal to

$$\left(\omega L - \frac{1}{\omega\left[\dfrac{m}{\gamma^2 B^2}\right]}\right)^2$$

But if we wish to represent the effect of the back E.M.F. in the coil by a capacity (the "motional capacity") in series with it, instead of by an addition of $(-\tau S)$ to its inductance, we should find the reactance expression to be $\left(\omega L - \dfrac{1}{\omega K}\right)$. Hence the motional capacity is seen, by a comparison of the expressions, to be given by

$$K = \frac{m}{\gamma^2 B^2} \quad \cdots \quad \cdots \quad (19a)$$

Now below say 250 cycles, $\triangle m$ does not vary much from its maximum value of about 7 gm. for a 20 cm. diameter diaphragm, so that we can take m as being a constant, *i.e.*, 7 gm. greater than the static mass of coil and diaphragm, that is, the "motional capacity" is very closely a constant quantity below 250 cycles. Above 250 cycles the effect of the assumed K will be very small, it will bear but little relation to the actual facts, but this is of no importance; since the back E.M.F. due to the motion of the coil is negligible, it does not matter whether we represent it accurately by diminishing the coil inductance by τS, or somewhat inaccurately by a "motional capacity" of Equation (19a).

Transfer to Practical Units.

We *measure* R and L in *practical* units, but so far we have supposed we were using *absolute* units. As the practical system is self-consistent, our equations will be equally true if we express everything in practical units, using a suitable conversion factor where necessary. The only quantities whose numerical values are still required which have already been calculated are τ and S. τ is a period of time, expressed in seconds in either system, no conversion factor is therefore necessary; S has so far been expressed in absolute units of resistance, and must therefore be divided by 10^9 to reduce to ohms.

Actual Case Taken.

As it was proposed to make several alternative coils and diaphragms for experimental purposes, it was thought that it would be easier to wind comparatively low resistance coils and use a 25 : 1 step-down transformer. In the particular case given in the graphs the output stage is a pair of B.T.H. B.12 valves arranged in push-pull, with Ferranti transformer. [The B.12 is very similar to the L.S.5a, but from the makers' curves and data the B.12 appears to be suitable for a rather higher anode voltage (425 as against 400), and to have a slightly straighter characteristic, but the two makes of valve are so alike that the figures for the B.12 could be used for an L.S.5a without serious error.]

The constants are, Slope Resistance 2,900 ohms; Amplification factor 2.9. Assuming a moving coil of 100 turns 36 S.W.G. copper, 50 mm. diameter, the D.C. resistance is about 10 ohms, we may allow say 15 for the A.C. resistance (increase due to eddies, etc.). Messrs. Ferranti informed the writer that they had some measurements of the working

A.C. resistance and leakage inductance of an output transformer very similar to that used, as measured on an A.C. bridge at the primary terminals with the secondary short-circuited. By multiplying by $1/\rho^2$ these can be transferred to the secondary, and we find approximately that the resistance is 2.75 ohms and the leakage inductance 616 microhenrys, when so transferred to the secondary. The valve slope-resistance transferred to the secondary is $2 \times 2{,}900 \times 1/25^2 = 9.6$ ohms approximately (the two valves are in series for the audio-frequency currents).

It is estimated that the inductance of a 100-turn coil, 50 mm. in diameter, when in place on the core is about 2,500 microhenrys. Substituting these numerical values in the equations for R and L we have :

$R = 2.75 + 9.6 + 15 = 27$ ohms, to the nearest ohm,

$L = 2{,}500 + 616 = 3{,}116$ microhenrys.

S = Radiation resistance $= \dfrac{\gamma^2 B^2}{\beta(1 + \omega^2\tau^2)}$

X = Effective Reactance $= \omega(L - \tau S)$

Z = Effective Impedance $= \sqrt{(R+S)^2 + X^2}$

$\mathfrak{I}$ = Current in moving coil $= \dfrac{\mu}{\rho}\dfrac{\mathcal{E}_g}{Z}$ (for $\mathcal{E}_g = 1$)

W = Output $= \dfrac{\mu^2}{\rho^2} E_g{}^2 \dfrac{S}{Z^2} = \mathfrak{I}^2 S$ (for $\mathcal{E}_g = 1$)

The results are given in Fig. 6, and in the Table.

To see the effect of different number of turns on the moving coil, and of different B, output curves have been plotted for a 50-turn coil with $B = 3{,}000$, and also for a 100-turn coil with $B = 10{,}000$. They are given, together with the output curve for the 100-turn coil and $B = 3{,}000$ repeated, in Fig. 7.

It is found that the instrument for which

TABLE FOR A 20 CM. DISC.

z	f Cycles per sec.	$J_1(z)$	$\mathbf{H}_1(z)$	β abs. units.	$\Delta m.$ gms.	S milli-ohms.	$\omega(L-\tau S)$ ohms.	W microwatts if $\mathcal{E}_g = 1$.
0.16	42.4	0.0797	0.0054	86.3	6.89	94.70	−4.11	6.79
0.2	53	0.0995	0.0085	134.8	6.88	94.72	−2.91	6.86
0.3	79.5	0.1483	0.0190	302.6	6.86	94.70	−1.08	6.93
0.4	106	0.1960	0.0336	536.4	6.82	94.69	−0.10	6.94
0.5	132.5	0.2423	0.0522	835.0	6.78	94.67	+1.01	6.93
0.6	159	0.2867	0.0746	1197	6.73	94.66	1.79	6.91
0.8	212	0.3688	0.1301	2103	6.61	94.61	3.16	6.84
1.0	265	0.4401	0.1985	3238	6.45	94.55	4.39	6.75
1.2	318	0.4983	0.2774	4577	6.26	94.44	5.56	6.65
1.4	371	0.5419	0.3645	6096	6.04	94.31	6.68	6.52
1.6	424	0.5699	0.4570	7766	5.80	94.13	7.79	6.37
2.0	530	0.5767	0.6468	11428	5.26	93.63	9.96	6.05
2.5	662.5	0.4971	0.8632	16260	4.49	92.59	12.63	5.58
3.0	795	0.3391	1.0201	20900	3.68	90.77	15.27	5.05
3.5	927.5	0.1374	1.0916	24880	2.89	88.19	17.89	4.50
4.0	1060	−0.0660	1.0697	27890	2.17	84.29	20.51	3.93
5.0	1325	−0.3276	0.8078	30540	1.05	72.20	25.72	2.79
6.0	1590	−0.2767	0.4782	29490	0.43	55.84	30.93	1.78
8.0	2120	+0.2346	0.4881	25420	0.25	29.28	41.35	0.65
10.0	2650	+0.0435	0.8918	26760	0.29	19.77	51.75	0.31
12.0	3180	−0.2234	0.5839	28000	0.13	14.90	62.15	0.17
14.0	3710	+0.1334	0.4732	26490	0.08	10.53	72.54	0.09
16.0	4240	+0.0904	0.8171	27000	0.10	8.19	82.93	0.06

N.B.—Last 3 columns refer to 100-turn coil 50 cm. in diameter moving in a field $B = 3{,}000$.

The following numerical values were then calculated and plotted for a 100-turn coil of 50 mm. diameter moving in a gap-flux of 3,000 C.G.S. lines per sq. cm., with a diaphragm weighing 10 gm., 20 cm. diameter.

curves are given in Fig. 6 gives volume too great for comfort (even for dancing) in a room 40 × 15 feet, when the R.M.S. value of $\mathcal{E}_g$ is about 100 volts (judged by the anode milliammeter just not flickering, with a grid bias of 140 volts). Under these conditions the maximum output, at 100 to 150 cycles, is seen from Fig. 6 to be about 7 microwatts per $(\text{volt})^2$, totalling 7×100^2 microwatts, or about 0.07 watt. It is most surprising what a loud noise can be made for an expenditure of less than a tenth of a watt of actual acoustic energy!

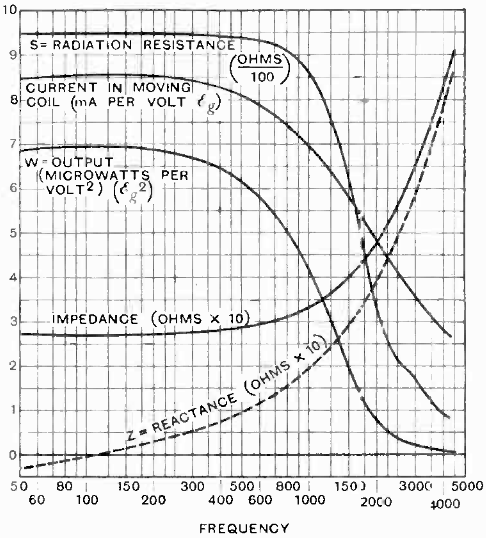

Fig. 6.

To produce this acoustic energy, the power stage takes about 70 milliamps at 425 volts, say 30 watts, so that looked at from the point of view of ratio of acoustic energy to anode supply energy in power stage, the efficiency is of the order of $\frac{1}{4}$ per cent. (Note that in both cases we have the best frequency, the power and efficiency at higher frequencies are very much less.) It is interesting to note that the value of K, the "motional Capacity" comes out to be

$$K = \frac{m}{\gamma^2 B^2} = \frac{17}{1500^2 \times 3000^2}$$

$$= \frac{17}{20{\cdot}2} \times 10^{-12} = 0.84 \times 10^{-12}$$

absolute electromagnetic units of capacity. Multiplying by 10^9 to give farads, and then by 10^6 to give microfarads, we find $K = 840$ microfarads. (This value seemed so enormous that the writer spent some time fruitlessly seeking the error, having a vague memory that the usual value of K used by designers was of the order of 1 microfarad. For example, L. E. T. Branch, *Wireless World*, June, 1928, gives a value of about 0.74 microfarad for a particular cone and coil. But it soon appeared, on looking up the article, that this was with the resistances and reactances referred to the *primary* of the output transformer, whereas we are referring to the *secondary*. The value referred to the primary is obtained by dividing K by the square of the transformer ratio (25), giving $\frac{840}{(25)^2} = 1.34$ microfarads, which seems about the sort of value that other workers are in the habit of using.) It is interesting to note that on working out the curve for Reactance by the use of the "motional capacity," results were obtained within 1 or 2 per cent. of the exact values. The effect on the resultant curves of intensity of acoustic output was too small to be shown on the graph. It appears therefore that the approximation obtained by using the "motional capacity" is sufficiently good for all practical purposes.

Design of Moving Coil and of Field-magnet.

First assuming that we are restricted to a 20 cm. diameter cone, let us consider what will determine the design of the moving coil and field-magnet.

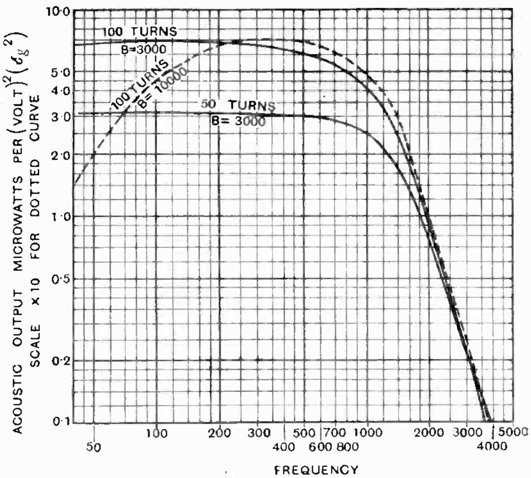

Fig. 7.

The equations we have to consider are :

$$W = \frac{\mu^2}{\rho^2} \mathcal{E}_g{}^2 \frac{S}{(R + S)^2 + \omega^2(L - \tau S)^2} \cdots \quad (15)$$

and $$S = \frac{\gamma^2 B^2}{\beta(1 + \omega^2\tau^2)} \quad \cdots \quad \cdots \quad \cdots \quad (15a)$$

Numerical calculation of a few cases will show that in any case S is small compared with R, but unfortunately τS is not small compared with L at low frequencies. Still, at first sight it seems that to get great intensity for a given $\mathcal{E}_g$ we should make S as large as possible. This is true within limits, but needs qualification. If we only wished to reproduce *one* frequency, it would be possible to work out the optimum value of S. But unfortunately if we make S too large the back E.M.F. (which is represented by the term in τS) becomes very great indeed at low frequencies, and even when multiplied by ω^2 we find that the denominator of (15) becomes very large, *i.e.*, the impedance of the moving coil at low frequencies goes up. This effect can be seen by comparing the curve of W in Fig. 7 for 100 turns and $B =$ 10,000 with that for 100 turns and $B = 3{,}000$ (for the latter S is only $(3/10)^2 = 0.09$ of S for the former). The dropping off of W at low frequencies is clearly indicated. We must therefore make S large, but not too large.

Looking at Equation (15a) we see that the denominator is dependent only on the size of the cone, the numerator depending on the coil. If we are to have a given S, does it matter how we obtain it ? It is proportional to the square of the product of (length of wire in coil) $\times$ (flux density in gap). There would be an advantage in using a permanent-magnet field, if possible, with which we can easily obtain a flux-density of 3,000 in a 4-millimetre gap 12 mm. long. (A value actually measured with a Grassot Fluxmeter is 3,130 lines per sq. cm.) Can we get an equally good result with $B = 3{,}000$ as with $B = 10{,}000$ by increasing the length of wire on the moving coil ? Unfortunately not, for the inductance L in (15) is largely the inductance of the coil, and it is this which cuts down the current in the coil at high frequencies, where we have already lost a lot by the rapid decrease of S. Therefore we must *keep down the coil inductance in the interests of high notes.* This means that we must not use more wire than is absolutely necessary, and must wind it in as *large a diameter coil as possible* (since having the coil diameter and doubling the turns to get in the same length of wire will give us twice the inductance). (Thus the design originated by Dr. McLachlan with a 2in. diameter coil would appear better from the high-note point of view than some of the commercial moving coil loud speakers with a coil diameter of about ¾in.)

Hence, for a given S use the minimum of wire on as large a diameter of coil as possible, in as strong a field as possible.

(It may, however, be possible to use a permanent magnet field with satisfaction, but it means that we must sacrifice volume, or provide a bigger power stage. As a matter of fact a 100-turn 2in. coil in a field of $B = 3{,}000$ worked from two B.12 valves in push-pull with a 25 : 1 step-down transformer will give more volume than can be used in quite a large room, without overloading except in the very loudest passages, and it is debatable whether, given an A.C. supply, the big power valves (filaments run off A.C.) and rectifier to supply 450 volts to their anodes is really more bother than a field-magnet with its accompanying rectifier and accumulator, and a somewhat smaller rectifier for anode supply to say two D.E.5a's, since in any case it is desirable to have a separate rectifier for the power stage, in the writer's opinion.)

Pentodes.—Dr. McLachlan has pointed out that if we had a power valve with an effective slope-resistance that was very high, the effects of inductance in cutting down high notes, and of back E.M.F. in cutting down low notes could be reduced to be nearly negligible, even with a much larger S than usual. The pentode provides the means.

It has been suggested that some method of compensating the inductance of the moving coil should be used. If we had only to deal with a single frequency it would be simple to resonate to it by a condenser shunted across the terminals, but it is obvious that it is impossible to do anything of this sort with a loud speaker which is to reproduce *all* frequencies, as the improvement in one frequency will mean that all other frequencies will suffer badly (it is easy to try this experimentally ; the result is musically damnable).

Another suggestion is to think of the moving coil as the primary of a transformer, and provide it with a short-circuited secondary. This may be either attached to and moving with the coil, or it may be fixed to the field-magnet. In the first case, we may wind the moving coil on a closed metal former, or cover the paper former with copper foil before winding.* It can easily be shown that the effect is to increase the effective resistance of the coil, and to reduce its effective inductance. But the mechanical force exerted by the magnet field on the current-carrying former, or short-circuited secondary, is *directly opposed* to that exerted on the moving coil itself (since the secondary balancing current is opposite in direction to the primary current), in fact with a given field-magnet we can show that Ψ^2 (and hence S) varies directly as the "effective inductance" of the coil (in a transformer this would be the leakage inductance referred to primary), hence any compensation by this method can only be partial. It would appear better that the short-circuited ring secondary should be attached to the field-magnet, then any force acting on it will not matter, as it will not oppose motion of the coil; something of this sort is believed to be used in certain commercial instruments. But the metal of the pole-pieces themselves is quite a good conductor, and will act as a short-circuited secondary to some extent, without special provision of a copper ring, hence the improvement resulting from fitting such a ring to an existing moving coil loud speaker is less than might be expected.

The desired end might be attained by means of a compensating winding, consisting of a coil having the same number of turns as the moving-coil but wound upon and fixed to the pole-piece. This would be connected in series with the moving coil, so that the magnetic effect of the current through it opposed that of the moving coil. If L_1 and L_2 be the self-inductances of the fixed and moving coils, and M the mutual inductance between them, the effective inductance of the two coils in series would be

$$L_1 + L_2 - 2M = L_1 + L_2 - 2k\sqrt{L_1 L_2}$$

where k is the coefficient of coupling. If we suppose $L_1 = L_2 = L$, which will be approximately true, the effective inductance comes out to $2L(1 - k)$; this will be less than the inductance L of the original coil without any compensating winding provided that k is greater than $\frac{1}{2}$, otherwise the compensating winding will only increase instead of reducing the inductance. The success of the method would then depend upon the possibility of making the coupling coefficient k considerably greater than $\frac{1}{2}$; Mr. E. B. Moullin, who suggested this form of compensating winding to the writer, is doubtful if this large value of k could actually be attained.

With the advent of the pentode, the effect of inductance of the moving coil at high frequencies would be much less marked and no compensation would probably be necessary, or even desirable, in practice.

* L. E. T. Branch, *Wireless World*, Aug. 1st, 1928, p. 122.

Variation in Diameter of Cone.

An examination of the curves shows that for a given E_g, W drops at 5,000 cycles to only about 1/160 of the value it had at say 500 cycles. Now $W = \mathfrak{I}^2 S$, and from the curves for $\mathfrak{I}$ and S we see that $\mathfrak{I}$ has dropped to about $\frac{1}{4}$ of the value it had at the lower frequency (and hence $\mathfrak{I}^2$ to 1/16 of its value), while S has dropped to 1/10 of its old value. By the methods suggested above, we might be able to compensate for the drop in I, but no juggling with the *electrical* properties of the moving coil or output stage can alter the shape of the curve for S; this depends on the size of the cone or diaphragm and its weight. The question then arises whether an alteration in the size of the cone is likely to give us a more constant value of the radiation resistance at the higher frequencies. We have seen (Equation 19) that up to about $z = 3$, $S = \gamma^2 B^2 \frac{\pi\sigma}{am^2} C^4$ is a very good approximation, and up to this point the curve of S is very nearly horizontal. Since $z = \frac{4\pi}{a} Cf$, it would appear that we could make the point of departure from a straight line at $z = 3$ occur at a higher frequency, say 3,500 cycles, by reducing C, the radius of the cone, to 1/5 of its original value, 10 cm., giving us a cone of 2 cm. radius. But in reducing C to 1/5th of its original value, we find that S, which is proportional to C^4, is reduced to 1/625th of its previous value! The radiation resistance of the speaker is in any case so low that it is a very inefficient machine (say $\frac{1}{4}$ per cent.), so that we cannot afford to cut its efficiency thus drastically. Furthermore, in actual practice there would be physical difficulties in providing efficient baffle action to reproduce low notes satisfactorily. It will be seen, then, that we cannot decrease the diameter of the cone to any great extent unless we are prepared to provide an output stage capable of handling about a kilowatt in order to provide enough sound energy to fill a small room. Increasing the diameter of course makes matters worse so far as high-note reproduction is concerned. A few rough calculations show that values of C from 7 or 8 to 10 cm. (giving a cone of 6 to 8 ins. diameter, say) will probably have to be adopted.

How do we obtain any sensation of high notes at all from such a loud speaker?—If the state of affairs is really as bad as the curves indicate, it seems surprising that we hear any high notes whatever, especially in view of the phenomenon of A. M. Mayer, (*Phil. Mag.*, Vol. II, p. 500, 1876, referred to by Rayleigh, "Sound" II, para 386), namely that if two sounds of different frequency occur at the same time, the higher tends to be obliterated by the lower, although the reverse never seems to occur.

Several suggestions may be advanced.

(a) *Insensitivity of the ear.* A variation of intensity of 4 : 1 is only just noticeable (this can be shown by putting a Moullin voltmeter across the grid leak of one of the valves of an amplifier and regulating the volume control to give readings of ratio 2 : 1 during the tuning-note, when the decrease is barely perceptible; since W varies as the square of the volts this gives a ratio of the intensities of sound 4 : 1. Ask anyone to detune or alter the volume control until the sound is reduced to what he thinks is "about half as loud," and it is found that the Moullin voltmeter readings have a ratio of about 4 : 1; *i.e.*, a variation of intensity in the ratio of 1 to 16 produces the sensation of "about half as loud").

(b) *Want of rigidity of diaphragm.* An actual diaphragm or cone is *not* perfectly rigid, and it appears that this is the real reason why the moving coil speaker produces any high notes at all. The writer must own that he did not appreciate the enormous effect of this want of rigidity of cone until he saw actual experimental curves of output plotted against frequency for several different types of moving coil speaker, shown by the research department of the B.T.H. Co., at the 1929 Exhibition of the Physical and Optical Societies.* It appears that even with a very flexible suspension at the edge of the cone, at all but the lowest frequencies there is superposed on the motion of the cone as a whole an elastic vibration of the material of the cone itself, this effect beginning at as low a frequency as 200 cycles. Illustrations of the calculated modes of vibration in such a case are given by Rayleigh ("Sound," Vol. II, Fig., in para. 206), and some experimental results are illustrated in the Editorial in *E.W. & W.E.* for December, 1927, from experiments by S. Hill on a "Kone" speaker. At the higher frequencies the number of possible modes of vibration (each corresponding to one particular frequency) is very great, and the peaks of the "resonance curve" overlap, it is also probable that due to slight want of exact symmetry the individual modes of vibration are not very sharply differentiated but merge into one another, giving a "flatly tuned" effect, so that the resultant output curve is more uniform than might be expected. In practice, therefore, we actually get the effect of a good high register, although, as might be expected, the exact results depend on the nature of the "want of rigidity," *i.e.*, upon the elastic properties of the material from which the cone is constructed.

(c) *Other effects tending to give high note reproduction.* Eddy currents in the pole-pieces tend to reduce the effective inductance of the moving coil, even without any special damping ring.

The cone has also a certain focusing effect, which is not apparent with a plane disc, giving more prominence to the high notes on the concave side (front). But this effect is frequently exaggerated, for making a cone with a plane face by sticking a circle of paper

* See "An Apparatus for the Projection of Frequency-Output Characteristics," C. G. Garton and G. S. Lucas: *E.W. & W.E.*, Feb. 1929, p. 62, especially Fig. 9.

over the concave side to form the base of the cone does not have much effect in reducing the high notes. The effect would be, no doubt, more noticeable in the open, but in a room where reflection of the sound from walls, etc., takes place there does not seem to be much in it.

Other suggestions. Before the advent of the moving coil loud speaker, searchers after quality frequently used two or more loud speakers together, in order that the deficiencies of one might be covered by the other. With a reed-drive cone and a horn type instrument, quite pleasing results could be obtained. It might be possible to design a horn type speaker specially for the purpose of giving good reproduction on high frequencies, arranging for the resonances which are inseparable from this type to be below say 500 cycles. This might be fed through a high-pass filter cutting off at say 700 cycles, and used in parallel with the moving-coil instrument. Rough experiments with an ordinary horn type instrument seem hopeful, but a specially designed instrument is really necessary.

Another possibility is to interpolate a filter in the middle of the L.F. amplifier, designed to attenuate the frequencies below 700 cycles evenly, with a gradual cut-off from 700 to 2,000 cycles, leaving the frequencies above 200 practically unchanged. This could be done by the use of resistance in conjunction with inductance and capacity in the filter, in order to ensure gradual cut-off.

But, on the whole, the increased output at high frequencies due to elastic vibrations of the diaphragm itself is probably sufficient to do all that is required, in fact the use of a stiff varnished paper for the cone will sometimes appear to overdo it and give too much high frequency. (Ford's thin blotting paper is found very satisfactory for cones.)

Transients.

So far we have only considered the particular integral of (8). There is also a complementary function to be considered. This represents the free oscillations of the mechanical-electrical combined system. The necessary arithmetic is tedious, but without much difficulty it can be shown that no free oscillation will last long, as it will be damped down to 1/100 of its original amplitude in about 2 or 3 cycles, whatever the frequency. There is a small point not often considered, namely, the response of a receiver and loudspeaker system to transient sounds in the transmission (*e.g.*, a revolver shot). So far it will be noticed that we have not bothered about phase-differences, which are in general different for different frequencies. This is because the ear is really a resonating instrument which performs a mechanical harmonic analysis of any musical sounds heard, and is independent of phase. [This, the Helmholtz theory of hearing, has been denied, but the evidence for its substantial accuracy appears overwhelming. A suggestion as to possible errors in the contrary evidence and an account of an experiment may be found in the "British Journal of Psychology" (general section), Vol. XIII, Part I, July, 1922. "A vindication of the resonance theory of audition," by Dr. H. Hartridge and the writer; also "U.S.A. Bureau of Standards, Technical Papers," No. 127, *Effect of Phase of Harmonics upon Acoustic Quality*, by Lloyd and Agnew.]

This is extremely fortunate, for a receiver or transmitter in which any iron is present is bound to produce different phase-changes for different frequencies, as indeed is any transmission line.

But when we come to a transient noise, such as a revolver shot, the effect is possibly different; it is merely shock-excitation of *all* the resonators in the ear, and depends on the steepness of the wave-front. Now if we suppose the transient shock to be harmonically analysed over a long period of, say, a second, we find that the steepness of the wave-front *does* depend on the relative phases of the component harmonics, hence the effect of phase changes in the amplifier is to alter the steepness of the wave front. In general it appears to reduce the steepness, and the reproduction of a revolver shot in the studio comes out of the loud speaker as a duller sound, more like a drum-bang or a slamming door.

Summary of Suggested Method of Design.

In view of the fact that high frequencies are in fact reproduced through resonant vibrations of the diaphragm of which we have taken no account, the practical uses of the analysis would appear to be as follows from the point of view of design.

First, replace the actual arrangement shown in Fig. 8a by that shown in Fig. 8b, in which :

$$\left.\begin{aligned} R &= \left(r_c + r_s + \frac{1}{\rho^2} r_p + \frac{1}{\rho^2} R_a\right) \\ L &= \left(l_c + l_s + \frac{1}{\rho^2} l_p\right) \end{aligned}\right\} \ldots \text{(Eq. 5)}$$

$$K = \frac{m}{\gamma^2 B^2}$$

(m being the static mass + about 7 gm. for mass of adherent air) (Eq. 19a).

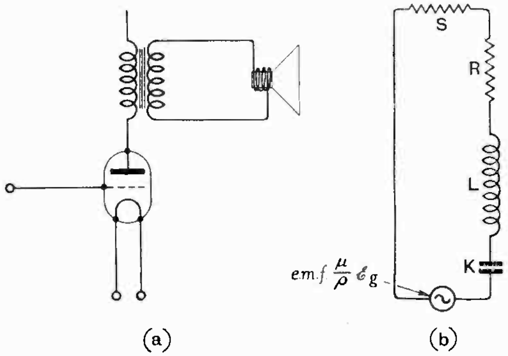

Fig. 8.

Neglecting S, as small compared with R, work out the current I in the circuit of Fig. 8b for an assumed $\mathcal{E}_g$, at various frequencies.

Assuming equation (19) $S = \gamma^2 B^2 \frac{\pi\sigma}{am^2} C^4$,

calculate S, and then $W = I^2 S$. The results will be within a few per cent. of the truth up to the point where elastic vibrations of the diaphragm begin, say, 200 to 300 cycles (for the equations hold up to 800 cycles or so for a rigid diaphragm).

This will give a very fairly true idea of what is happening to the low frequencies, and if we keep the coil inductance down by using a large-diameter coil, and not too many turns, the high frequencies will be brought up by elastic vibrations of the diaphragm.

(With a pentode in the output stage, R is so large compared with L and K that these may almost be neglected.) It is not much use basing design on predictions of what is going to happen to a rigid diaphragm at several thousand cycles, because if the diaphragm *were* rigid we should hear next to nothing.

In practice, it is found that a moving-coil speaker designed from these formulæ gives very satisfactory results.

Marconi Appeals.

MR. Justice Luxmoore, in the Chancery Division of the High Court of Justice on June 18th, gave his reserved judgment on two important wireless appeals by Marconi's Wireless Telegraph Co., Ltd., against decisions of the Comptroller-General of the Patent Office.

In the first place, he granted the appeal of the Marconi Company against the decision of the Comptroller, which gave to the Brownie Wireless Company a compulsory licence to manufacture valve receiving sets at royalties reduced from the usual basis of 12s. 6d. per valve stage to 10 per cent. on the wholesale selling price of the receiver, subject to a minimum charge of 5s. on the first valve and 2s. 6d. on each additional valve stage included in the apparatus sold.

His Lordship held that there was no case for granting a compulsory licence and he dealt also with various points in connection with the terms of the Marconi Company's General Licence to manufacturers, known as the " A.2 " Agreement, and he contended that there was nothing in the various clauses of this agreement which was unreasonable from the point of view of the licensees, and that with regard to the question of the licence agreement providing for the payment of royalties on non-patented articles, that again was not unusual, and in His Lordship's judgment there was nothing unreasonable in a patentee saying :

" I will grant you a licence in respect of my patent, but I want your wholehearted support in the development of my patent. I am only prepared to grant you a licence on such terms as will insure that support."

In the case of the second appeal which was in regard to the granting by the Comptroller of a compulsory licence to the Loewe Radio Co., Mr Justice Luxmoore held that there was no case for the granting of such compulsory licence as there was no evidence to show that a licence had been refused by the Marconi Company, negotiations between the Loewe Radio Company and Marconi's having been broken off by the Loewe Company.

His Lordship, however, gave as his opinion that a licence on the basis of the payment of royalties would be unreasonable if the amount as fixed by the Comptroller were agreed—namely, 10s. for each triple valve and 7s. 6d. for each double valve, provided the licence was limited to the manufacture of triple and double valves.

In both these cases, therefore, the appeal of the Marconi Company against the decision of the Comptroller of the Patent Office was allowed and the orders of the Comptroller with respect to compulsory licences discharged.

Receiver with Aperiodic High-frequency Amplification.

By M. Von Ardenne.

IN comparison with tuned high-frequency amplifiers, in which an oscillatory circuit is necessary for each stage of amplification employed, the aperiodic amplifier with resistance coupling is simpler and, in consequence, cheaper to build. In an aperiodic amplifier it is possible to choose the number of tuned circuits without reference to the number of stages or to the amplification afforded by each stage, and to design the couplings as appears desirable for attaining the required selectivity. In addition, an aperiodic amplifier with resistance coupling, on account of the reduction of the anode current owing to the presence of the anode resistances, offers the advantage of a relatively small anode current, so that even when a large number of stages are employed dry batteries will adequately supply the anode current.

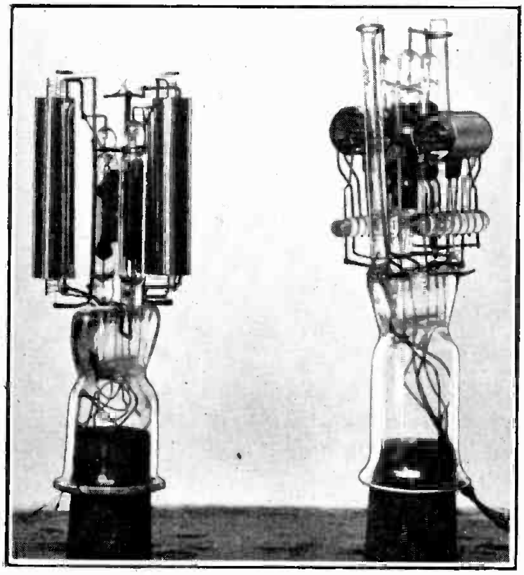

Fig. 1.—*The old (right) and new (left) types of H.F. valves.*

Up to the present, aperiodic amplifiers have been available in the form of the Loewe high-frequency double valve, which made its first appearance on the market about three years ago. Such a valve gives a degree of amplification which is only adequate for long range reception when used in conjunction with an out-door aerial. To provide a receiver sensitive enough for reception with a frame aerial or small indoor aerials, a much greater degree of amplification is necessary. The connection in cascade of a number of valves of the type mentioned is hardly practical, on account of the high current required in the inner grid circuits; in consequence, a new type of multiple valve for high-frequency amplification, which, by employing only a single grid in place of the original two, does away with the inner grid current, has been developed by Dr. Siegmund Loewe and the author.

Compared with the older system, which is shown in the right-hand illustration of Fig. 1, the new system, shown on the left of the same Fig., has far smaller incidental capacities. Not only has it been possible to dispense with the glass rods which, on account of the high dielectric constant of glass, increase the stray capacities very considerably, but in addition all the critical leads have been appreciably shortened. As it is intended that several valves should be connected in cascade, the grid and anode leads in the pinch have been widely separated from one another in the new valve, and are not too close to the battery leads. Although in the new valves no attempt has been made to improve the characteristics by the use of an extra (space-charge) grid, the amplification per stage obtained is a little better than that afforded by the older type, and at the same time the variation of amplification with frequency is, within the broadcast band, smaller.

Fig. 2 shows the various stages in the manufacture of the valve. The connections to the socket correspond with those in the original high-frequency valve, as can be seen from Fig. 3, with the exception that the terminal to which the space-charge grid was originally connected is now joined to the grid-leak of the second stage. It is therefore possible to use the new high-frequency valve in any receiver in which the older type has previously been employed.

There is one important difference between the two in the fact that in the new valve the couplings are so designed that the valve possesses a high degree of amplification within the broadcast band of wavelengths only. In the new valve *low-frequency amplification does not take place.* This point is of fundamental importance for the construction of multi-stage aperiodic amplifiers, for in this way distortion and low-frequency reaction through the resistance of the source of anode current can be avoided. If the valves, as hitherto, are so designed that low-frequency voltages are transferred to the grid of the next stage, it is a necessary consequence of the presence of stray capacities that the amplification per stage is greater for low frequencies than for high. As soon as small voltage variations occur in the grid circuit of the first valve, whether through microphonic action or otherwise, the high degree of low - frequency amplification gives rise to the appearance of very large low-frequency voltages in the last stage of the high-frequency amplifier ; these voltages will in most cases be greater than the high-frequency voltage to be expected at this point. The result of this is that the grid-voltage of the last valve of the high-frequency amplifier swings to and fro over so large a part of the curve that linearity of response can no longer be assumed. In this way the high-frequency voltages are modulated by the low-frequency disturbances, and reception becomes distorted.

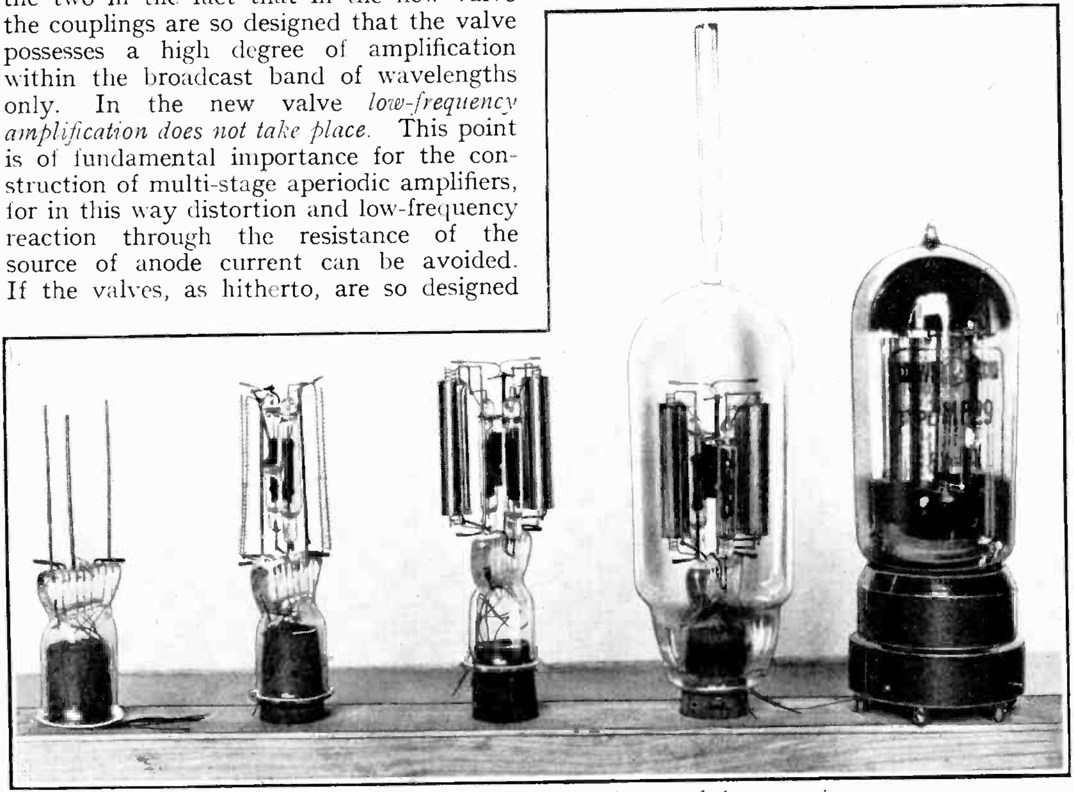

Fig. 2.—*The various stages in manufacture of the new valve.*

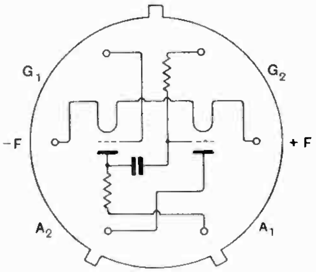

Fig. 3.

It will, therefore, be seen that it only becomes possible to construct a high-frequency amplifier such as that shown in the accompanying diagram, in which six high-frequency stages are connected in cascade, and operated without distortion from a single source of current, when the high-frequency valves amplify but very little at low frequency. In particular the use of mains apparatus for the supply of filament and plate current to high-frequency double valves is rendered much easier when they are designed on the lines described. In addition the omission of the space-charge grid facilitates considerably the use of battery eliminators with the new aperiodic amplifier.

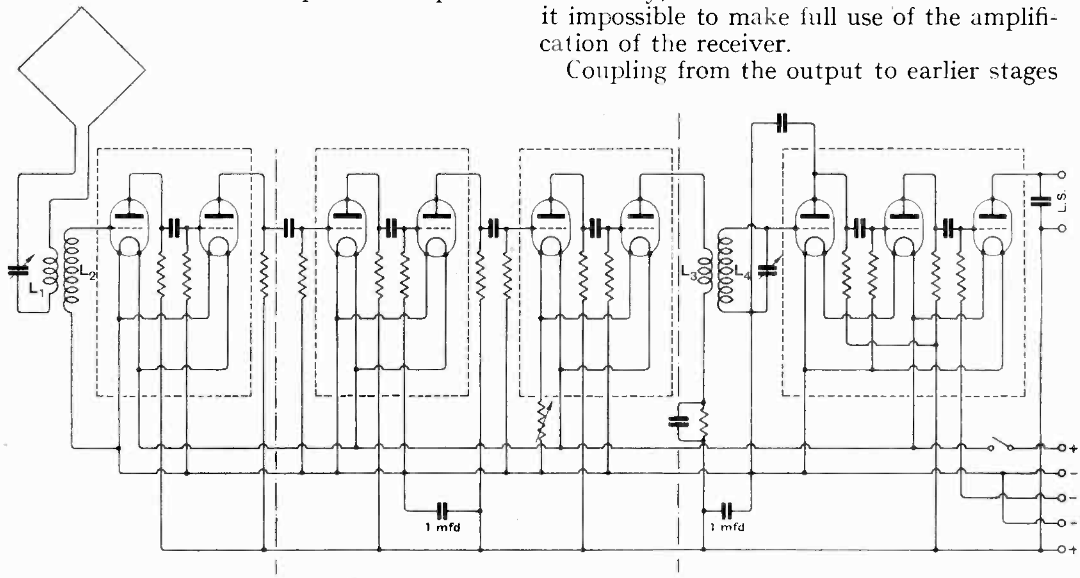

Fig. 4.—*Circuit using 3 H.F. stages.*

If in connecting in cascade several high-frequency valves of the new type care is taken that the parts of the circuit lying outside the valves have but small stray capacities, it is found that the degree of amplification afforded by a circuit which, like that of Fig. 4, makes use of three high-frequency valves, is in the neighbourhood of 5,000 to 10,000 times. Subject to the above proviso the degree of amplification is sufficiently independent of frequency to provide high, even, and adequate sensitivity over the whole of the broadcast band. A circuit such as that of Fig. 4, however, only gives the very high sensitivity required when screening is correctly carried out.

The construction of high-frequency amplifiers with a high degree of amplification makes a special technique of screening necessary. No matter whether this high amplification is obtained with ordinary valves, screened valves, or an aperiodic amplifier, it must constantly be borne in mind that as soon as even a small portion of the high-frequency energy from the output of the amplifier succeeds in getting back to the input or to one of the earlier stages, oscillation will ensue. Such oscillation, which usually sets in long before the amplifier has been brought to its maximum sensitivity, introduces distortion and makes it impossible to make full use of the amplification of the receiver.

Coupling from the output to earlier stages can arise through very different causes, and can be combated in many ways. In all high-frequency amplifiers it is primarily necessary to ensure that there is no coupling between the tuned circuits of the various stages. Magnetic coupling, which is chiefly due to the coils themselves, can be avoided by enclosing these in boxes or thin shells of some conducting material, while capacitative coupling, which mostly occurs be-

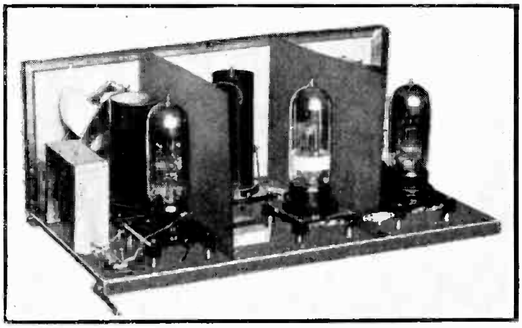

Fig. 5.—*Each stage separately screened.*

tween the tuning condensers, can be prevented by metal caps over the condensers. If we wish to be certain of removing all couplings, it is necessary to enclose each separate stage in a metal box, as has been done, for example, in the receiver illustrated in Fig. 5. By building the whole apparatus in metal boxes, however, the cost is very considerably increased.

For this reason it appeared worth while to investigate more closely the share which each part of the circuit contributes towards the production of the unwanted oscillations. Using only a medium degree of high-frequency amplification, such as is necessary for distant reception with an out-door aerial, complete screening with metal boxes is not usually necessary. It generally suffices for this purpose to cover in the coils and condensers with metal, and in wiring to take care that critical leads are well separated. For frame-aerial receivers one must take particular care that a portion of the high-frequency field set up by the last tuned circuit does not find its way through some small aperture in the screen to the frame.

Since the frame aerial, which is necessarily connected to the input side, obviously cannot be screened,* it is very important in setting up any receiver with a high degree of amplification at high-frequency to ensure that no high-frequency currents or voltages get through into the battery or loud speaker leads. To reduce the likelihood of any such coupling it is advisable in all such receivers to adopt the principle of connecting the frame at one end of the receiver and the batteries and loud speaker at the other. By the use of by-pass condensers and high-frequency chokes, high-frequency currents can be kept completely away from all leads and parts of the circuit which are outside the screening.

Often, however, there are couplings within the receiver itself, even when the successive stages are completely screened from one another. These couplings can mostly be traced back to the high-frequency voltage-drop across the high-frequency resistances of the various connecting wires. To reduce these couplings, the effects of which have

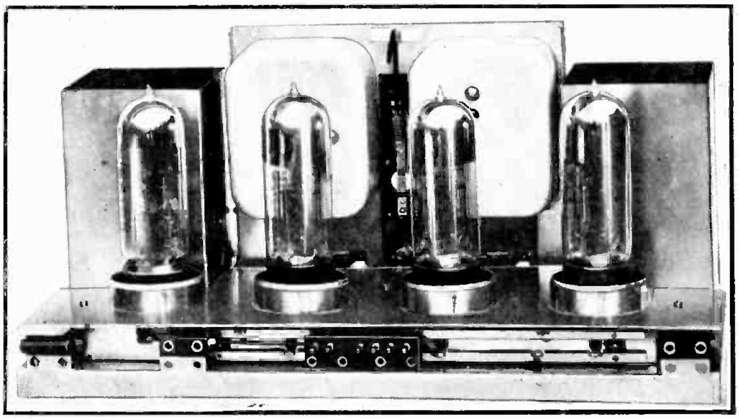

Fig. 6.—*Back view of the new receiver.*

hitherto been seriously under rated, it is necessary, especially in the last stages, where the high-frequency currents are naturally greatest, to connect the anode-leads through condensers to the screening. With very high degrees of amplification, such as are obtained, for example, with the new aperiodic amplifier described below, even this precaution is not enough. To obtain complete stability with such an amplifier it is found necessary to bring all leads through which coupling might be set up to points which are connected through sufficiently large condensers (about 1 microfarad) to the screens, using the shortest possible leads. In cases where the negative filament lead, and with it all filament connections are connected to the screens, and where no grid-bias is used on the high-frequency valves so that these leads also are connected to the screens, we have to regard as critical the anode leads, the positive leads from the source of filament current, and, if four-electrode valves are in use, the leads to the space-charge grids. From the points which are directly connected by condensers with the screens, and at which therefore no high-frequency voltages can arise, the leads to the remainder of the apparatus *must radiate out separately*. In Fig. 6 is shown the

* Only the electrostatic field can be screened.

back of the new Loewe long-range receiver. The arrangement of the valve-sockets and the components used for coupling may be seen from Fig. 7. This arrangement is more certain and cheaper from the commercial point of view than the complete screening in metal boxes shown in Fig. 5.

In order to simplify the operation of a receiver, and to keep the cost of building down, it is necessary to obtain the requisite selectivity with as small a number of tuned circuits as possible. For the solution of this problem it is necessary, with an aperiodic amplifier, to know first of all the resistance on the input and output sides of the amplifier. Since the grid-capacity of the first stage of the amplifier does no more than increase the effective self-capacity of the circuit connected before it, it is only necessary to investigate the ohmic resistance at the input. An ohmic resistance occurs at the input owing to the grid-current. If, as in Fig. 4, no grid-bias is used, but the grid-return lead is simply connected to the negative end of the filament, the grid-current resistance is already in the neighbourhood of some 100,000 ohms. This can be neglected in comparison with the much smaller apparent resistance connected in parallel with it, which is due to the reaction through the grid-anode capacity and to the capacitative load in the plate circuit of the first stage. This apparent resistance has a very great influence on the selectivity in the case of aperiodic amplifiers. For this reason the author has made a number of measurements with the older type of high-frequency double valve, and has taken these results into consideration in designing the new valve.† With the older valve, under normal operating conditions, the apparent resistance in the grid circuit of the first stage amounted to about 21,000 ohms at 500 metres. In this respect the new valve is decidedly better, for at 500 metres its input resistance is about five times greater (100,000 ohms). Since the higher the value of the input resistance, the closer is the coupling that can be employed to attain a given selectivity, the new valve may be regarded as "more sensitive" even when it is worked under such conditions that it gives exactly the same voltage-amplification as the older type.

The resistance at the output side of the amplifier is fixed by the impedance of the last valve. Since this value for the usual high-frequency valve is in the neighbourhood of 10,000 ohms, it is essential to employ at this point a loose coupling to the following tuned circuit. If the couplings at the input and output sides of the amplifier of Fig. 4 are correctly adjusted for the purpose, that circuit provides, in addition to very high sensitivity, a selectivity which, *with only two tuned circuits*, is amply sufficient for the majority of places at which reception is carried out.

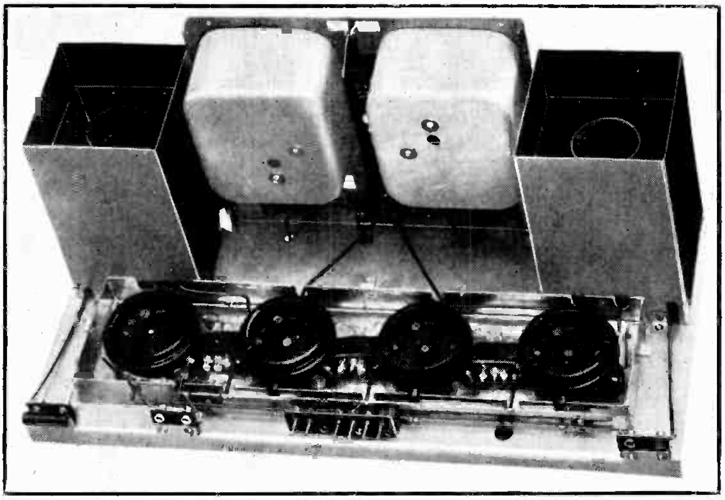

Fig. 7.—*The new receiver showing disposition of parts.*

† M. von Ardenne: "Die aperiodische Verstarkung von Rundfunkwellen," Jahrbuch. d. drahtl. Telegt., 1929, April.

Low-frequency Amplification with Transformers.

By P. R. Dijksterhuis and Y. B. F. J. Groeneveld.

(Of Philips' Gloeilampenfabrieken, Holland.)

MUCH has been written on the subject of low-frequency amplification by means of choke coils and transformers. Several writers have been successful in developing theories, and have furnished us with clear descriptions of the manner in which the L.F. transformer functions. The object of the following article is certainly not to repeat what is already known, but rather to reveal the manner in which the Philips Laboratory at Eindhoven (Holland) is successfully constructing transformers with *very special materials.*

In order to show clearly that the transformer thus produced does really fulfil the reasonable conditions required of it, we shall first of all enumerate these conditions.

Let us start by saying that the properties of *a low-frequency* transformer can only be discussed *in combination with the triode* in the anode circuit of which it is coupled. That will of course be quite clear.

In Fig. 1 the diagram of connections of such a combination is given.

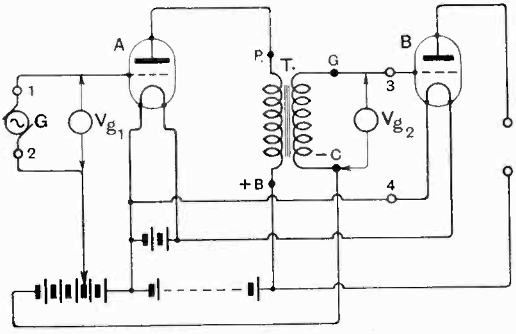

Fig. 1.—*Diagram showing transformer and associated circuit.*

The connection of the triode *A* with the transformer *T* forms an "amplification stage." The input terminals of this stage 1 and 2 receive an alternating voltage V_{g_1}, while the voltage V_{g_2} at the output terminals 3 and 4 is handed on to the input terminals of the next stage; that is, between the grid and filament of the triode *B*.

We say that the stage *AT* amplifies, when V_{g_2} is actually greater than V_{g_1}. The *amplification* of this stage we can now define as the quotient:

$$\frac{V_{g_2}}{V_{g_1}}$$

The weak high-frequency oscillations, which are induced by the transmitting station in our receiving aerial, after being amplified by a high-frequency amplifier, are converted by the detector valve into waves of audible frequency. The audio frequency alternating voltages produced in this way between anode and filament of the detector valve are usually too weak to work a loud speaker properly when the same is coupled in the anode circuit of the detector valve.

The weak oscillations must therefore now be strengthened with the aid of one or more amplifying stages in order to gain such a strength as will render the voltage between grid and filament of the final valve sufficient to make the loud speaker produce the desired quantity of sound.

The requirements laid down for the amplifying stage are as much quantitative as qualitative. The alternating voltages which are generated between the grid and filament of the final valve must be a true image of the voltages delivered to the input terminals of the amplifier.

If V_{g_1} (in Fig. 1) be any given periodic function of the time, then we can resolve these into the sum of a number of sinoidal voltages, each with a fixed amplitude and a fixed initial phase.

Now we say that the amplification is free of distortion when it satisfies the following conditions:

1. That in V_{g_2} the same components appear as in V_{g_1}.

2. That the amplitudes of the corresponding components are proportionate.

3. That the angles of the initial phases are similar to those of the corresponding components of V_{g_1}.

Differently formulated, the first condition means: "absence of amplitude distortion." The second and third conditions coincide with the requirement: "absence of frequency distortion." A transformer amplifier cannot, from its very nature, completely satisfy these three conditions. But the whole thing can be so well designed that the ideal is very closely approached.

The first condition is as a rule easy to fulfil. The third condition is not however. Fortunately our ear does not notice difference in the phase angles.

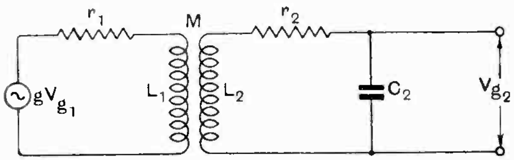

Fig. 2.—*Circuit of amplifier stage.*

The second condition is rather more important. The tone-quality of the human voice or of a musical instrument is determined by the overtones and harmonics and by the amplitudes with which these are produced. In order to preserve this "tone-quality" it is necessary for all the overtones to be amplified proportionately. *This means that the ratio of the amplitudes of a sinoidal alternating voltage before and after amplification must be independent of the frequency of this voltage.*

In order to determine to what extent the transformer amplifier can fulfil this, we must observe the properties of a stage based on the diagram shown in Fig. 2.

It is well known that a triode having any given impedance coupled in its anode circuit is identical with an alternating current generator of which the E.M.F. $= gV_{g_1}$ having the internal resistance $= r_1$. Here g is the voltage amplification factor, and r_1 the internal resistance of the triode used, increased by the resistance of the primary coil. Let the primary self induction of the transformer be L_1, the secondary L_2, and M the coefficient of the mutual induction between the two coils. Then it is well known that owing to the magnetic leakage

$$M^2 < L_1 L_2.$$

We get therefore $M^2 = k^2 L_1 L_2$, in which we call k the coupling coefficient between the two circuits. The resistance of the secondary coil is r_2, while the self capacity of the secondary coil added to the input capacity of the next valve is C_2. The self capacity of the primary coil as well as the capacity between both coils need to be brought into the calculation in the case considered. Also the iron losses need to be taken into account separately, but for simplicity's sake are considered to be included in the other damping resistances.

In order to treat the formulæ simply, we shall introduce some new constants:

$$a_1 = \frac{r_1}{L_1}$$

this represents the primary damping factor;

$$a_2 = \frac{r_2}{L_2}$$

represents the secondary ditto, and

$$\omega_2 = \frac{1}{\sqrt{L_2 C_2}}$$

represents the secondary system's own frequency.

With this data given, we find that, with very close approximation, the following formula is suitable for expressing the *amplification* as a function of the frequency.

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g\dfrac{n_2}{n_1}}{\sqrt{\left\{1-(1-k^2)\dfrac{\omega^2}{\omega_2^2}\right\}^2+\left\{\dfrac{a_1}{\omega}-(a_1+a_2)\cdot\dfrac{\omega^2}{\omega_2^2}\right\}^2}} \quad \ldots \quad (1)$$

In the above, $\omega = 2\pi f$, where f represents the frequency. $\frac{n_2}{n_1}$ gives the proportion of the number of secondary windings to that of the primary windings. This we will call the "transformer ratio."

The above formula appears somewhat complicated at first, but is simpler than it looks if we take the different terms into account separately.

The denominator is obviously the root of the sum of two squares. The magnitude of these terms depends apparently on the frequency, and as can be seen from the formula, we can give to the frequency such values that one term or the other vanishes; so that the denominator becomes the same as the remaining term, through which the root form disappears from it.

These two special frequencies, which simplify the amplification formula so much, are calculated by placing the two binomials situated between the brackets one after the other, equal to zero.

The frequencies found from this, which we shall write as ω_0 and ω_s, appear to fix two very important points of the transformer characteristic. By the characteristic of an amplification stage we mean the graphical representation of amplification as a function of the frequency.

It follows, first, then that:

$$\left\{\frac{a_1}{\omega_0} - \frac{a_1 + a_2}{\omega_0} \cdot \frac{\omega_0^2}{\omega_2^2}\right\} = 0 \quad .. \quad (2)$$

and that

$$\omega_0^2 = \omega_2^2 \cdot \frac{a_1}{a_1 + a_2} \quad .. \quad (3)$$

If we substitute this value in formula (1), the amplification appears, in the case of frequency $= \omega_0$, as:

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g \cdot \frac{n_2}{n_1}}{1 - (1 - k^2)\frac{a_1}{a_1 + a_2}} \quad .. \quad (4)$$

In the case of the Philips transformer type 4003 combined with valve type A415, for which the transformer is designed, the expressions used have on an average the following values:

$$(1 - k^2) = \text{approx. } 0.01 \,.\, a_1 = \frac{r_1}{L_1} = \text{approx. } 400 \text{ sec.}^{-1}$$

$$a_2 = \frac{r_2}{L_2} = \text{approx. } 250 \text{ sec.}^{-1} \omega_2^2 = \frac{1}{L_2 C_2} = 42.2 \times 10^6 \text{ sec.}^{-2}$$

Continuing, formula (4) becomes:

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g \cdot \frac{n_2}{n_1}}{1 - (1 - k^2)\frac{a_1}{a_1 + a_2}} = \frac{g \cdot \frac{n_2}{n_1}}{1 - \frac{4}{650}} = \text{approx. } g \cdot \frac{n_2}{n_1} \quad .. \quad (5)$$

while the frequency at which this amplification takes place results from (3), *i.e.*:

$$\omega_0^2 = \omega_2^2 \frac{a_1}{a_1 + a_2} = \text{approx. } 26 \times 10^6$$

from which, $f_0 = \frac{\omega_0}{2\pi} =$ about 800 cycles per second.

Hence we get the following important rule:

In the range of medium frequencies (in the Philips transformer type 4003 about 800 cycles), the amplification which takes place may be easily calculated from the formula:

Amplification = triode amplification factor × transformer ratio.

We term this amplification in the following. 100 *per cent. amplification.*

It follows secondly that:

$$\left\{1 - (1 - k^2) \cdot \frac{\omega_s^2}{\omega_2^2}\right\} = 0 \quad .. \quad (6)$$

and that:

$$\omega_s^2 = \frac{\omega_2^2}{1 - k^2} \quad .. \quad .. \quad (7)$$

This frequency, which clearly is influenced very strongly by the magnetic leakage, we call the "*leakage-frequency*" $= \omega_s$.

Substituting this value in (1), the amplification for this leakage frequency becomes:

$$\frac{V_{g_2}}{V_{g_1}} = g \cdot \frac{n_2}{n_1} \cdot \frac{\omega_2\sqrt{1 - k^2}}{a_1 + a_2} \quad .. \quad (8)$$

If the factors a_1 and a_2 are small, while the magnetic leakage is big (that is to say with k small), it appears from formula (8) that the amplification at the leakage frequency may be many times $g \cdot \frac{n_2}{n_1}$; *i.e.*, many times 100 per cent., so that a high peak appears (see Fig. 3). The frequency at which this leakage peak appears depends (as appears from formula 7) on ω_2^2, that is to say on L_2 and C_2, the secondary self induction and the secondary coil capacity respectively, and also on the size of $(1 - k^2)$, that is, on the magnetic leakage. In the case of the Philips transformer type No. 4003 used in the anode-circuit of the triode A415, it follows that:

$$\omega_s^2 = \frac{\omega_2^2}{1 - k^2} = 42.2 \times 10^8$$

from which it follows that $f_s = \frac{\omega_s}{2\pi} = 10{,}000$ cycles p. sec. The amplification at these frequencies is obtained by substituting the values found for the different quantities in formula (8).

It will be seen that

$$\frac{V_{g_2}}{V_{g_1}} = \text{approx.}\, g \frac{n_2}{n_1}$$

The amplification turns out to be approximately 100 per cent., so that in the case of the transformer stage mentioned the production of a leakage peak is prevented. This is solely due to the fact that the expression $\alpha_2 = \frac{r_2}{L_2}$ has reached the above mentioned value of 250. This is obtained by using for the secondary coil a special nickel-alloy, by which the resistance is brought up to about 60,000 ohms, a value which in combination with the secondary self induction of about 250 henrys accounts for the effective value of α_2. If the secondary coil were made out of ordinary copper wire, the resistance as well as the value of α_2 would diminish to about 1/5 ; on account of which, according to formula (8), a greater amplification than 100 per cent. (*i.e.*, a peak) would necessarily follow (see a, Fig. 3).

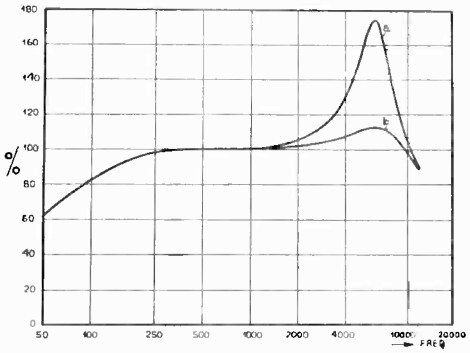

Fig. 3.—*Percentage amplification curve.*

Another matter which is of interest in an amplification is the amplification of the lower tones. This is a specially important point in the case of music reproduction, because the harmonics of which a composition is formed are supported by the fundamental tones. If these are too weak the harmonics lack their support, and the music sounds thin and rarefied. But in literature dealing with the subject it is not stated at what low frequencies a proper amplification is desired. In general, it can be said from experience, that reproduction (provided a good loud speaker is used), is sufficiently true if the amplification of voltages having a frequency of 50 cycles per second amounts to 50 to 60 per cent.

For the very low frequencies which we are discussing here, formula (1) can be simplified to :

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g \cdot \frac{n_2}{n_1}}{\sqrt{1 + \left(\frac{\alpha_1}{\omega}\right)^2}} \quad \ldots \quad \ldots \quad (9)$$

In the case of the above-mentioned combination (Philips transformer type 4003 with valve A415), $\alpha_1 = \frac{r_1}{L_1}$ = about 400, so that with a frequency of 50 cycles per second, *i.e.*, $f = 50$ or $\omega = 314$, it follows that :

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g \cdot \frac{n_2}{n_1}}{\sqrt{1 + \left(\frac{\alpha_1}{\omega}\right)^2}} = \text{approx. 60 per cent.}$$

In order to obtain satisfactorily large values for the self-inductances L_1 and L_2 and to give the coupling coefficient k its right value, it is necessary to place the two coils on an iron core.

Most radio transformers on the market contain the ordinary silicon-iron alloy core which is also employed in power transformers and other electrical machinery. The self inductance of a coil which is wound on a core of such material is in a large degree dependent on the amplitude of the alternating flux, that is, on the A.C. voltage on the terminals, and on the magnetisation which is set up by the D.C. flowing in the anode circuit of the triode.

Calculations made concerning this point show that the self-induction varies depending on these very circumstances in the ratio of 1 to 5.

That shows that L_1 (and consequently α_1 in a similar ratio) can change with the amplitude. From formula (9) it is at once clear what the influence on the amplification of low frequencies must be. Those low tones which are already weak are scarcely amplified at all, so that relatively they become still weaker, and natural reproduction is excluded.

By extensive experiments the Philips laboratory has succeeded in manufacturing for the core a material which is a special nickel-iron alloy, prepared in a very special way, so that all the difficulties met with in the use of normal silicon-iron are overcome. Over and above this, the new core alloy has a much greater permeability than the ordinary iron, so that for a given primary self induction the transformer can be manufactured about three times smaller than if it were provided with the ordinary silicon-iron core.

It is an advantage to have the ohmic resistance of the primary as small as possible. The normally used enamelled copper wire has only a low elasticity, so that it often breaks when being wound on the coil and requires joining repeatedly. These unwanted joints are weak points. Corrosion is often set up by chemical action and consequently breaks occur.

For these reasons the primary coil of the Philips transformer type 4003 is made of a special silver alloy wire having a suitable elasticity for winding and having no tendency to corrode. The components of the alloy are such that the specific resistance of it is approximately that of copper.

The effective design of the Philips transformer type No. 4003 is based on the use of three special materials, as follows :

(1) In the *core* the special *nickel-iron* alloy, which, notwithstanding the small dimensions of core and primary coil, provided a great primary self-inductance, is not, as in the case when ordinary silicon-iron is used, dependent on the amplitude of the voltages to be amplified.

(2) In the *secondary coil* the *nickel-alloy* which prevents a leakage-resonance peak in the curve. Owing to the magnetic properties of this alloy the secondary resistance increases very much with higher frequencies, so that according to formula (1) the amplification falls off rapidly with frequencies above the leakage-frequency. The special nickel wire used for the secondary coil possesses a considerable strength for winding purposes and is also proof against external chemical action.

(3) The special *silver alloy* used in the *primary* has a low resistance, and at the same time a high mechanical strength.

Some Additional Notes on Low-frequency Amplification by Means of Transformers.

Readers who ask themselves the question why the transformation ratio cannot be raised higher than 1 : 3 only need to apply formulæ (7) and (8) in conjunction with (9). In order to get a satisfactory amplification of low tones, $\alpha_1 = \dfrac{r_1}{L_1}$ must have a definite value. The value of r_1 being fixed by the triode chosen, L_1 follows as a result.

A larger transformation-ratio than that in the present case means an increase of L_2. The coil-capacity C_2 cannot be made less than a fixed amount (about $100\mu\mu$F), from which it necessarily follows that $\omega_2{}^2 = \dfrac{1}{L_2C_2}$ is decreased by increasing the transformer ratio.

The value of $(1 - k^2)$ of formula (7) also cannot be made smaller without making the transformer bigger, more intricate, and consequently more costly. Most transformers made by manufacturers have $1 - k^2 =$ about 0.02 ; Philips type 4003 has $1 - k^2 = 0.01$.

In these cases the leakage-resonance-frequency will in consequence be lower. According the formula (8) the amplification at this frequency also falls off, which means that a greater transformation-ratio than is used in type 4003 will give the following results :

(1) A decrease in the amplification of the higher tones, if the increase is obtained by means of an increase of L_2, or :

(2) A decrease in the amplification of the lower tones, if the higher transformation ratio is obtained by diminishing the number of primary windings, and thus L_1.

A given triode such as Philips type A415 valve requires a certain value of the primary inductance, *i.e.*, the core and the number of primary windings, to provide a sufficient amplification of the lower frequencies.

On the other hand, the transformation ratio and consequently the number of secondary windings, together with the resistance of the secondary, are governed by the amplification required of the higher frequencies.

The Transformer Characteristic.

To draw right conclusions from a transformer-characteristic it is necessary to know the data of the triode valve in the anode circuit of which it works.

Since a transformer-stage is a voltage amplifier, we have to consider the ratio of the A.C. voltages on the grids of two consecutive triodes as a function of frequency; *i.e.*, the ratio $\frac{V_{g_2}}{V_{g_1}}$ in Fig. 1.

The voltmeters with which the voltages are measured should give no load, neither

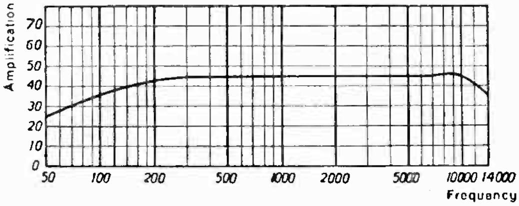

Fig. 4.—*Characteristic of Philips transformer.*

capacitative nor resistive; otherwise the transformer will not be functioning under normal conditions.

Most useful for this purpose are "valvemeters" working with anode-detection, provided that the following conditions are kept to:

(1) Input condenser used in all cases.
(2) No grid currents allowed to flow.

The diagram of connections for these measurements is shown in Fig. 1. In this G is a generator of sinoidal voltages of audible frequencies, while V_{g_1} and V_{g_2} are triode-voltmeters.

The characteristic of the Philips transformer type 4003 as given in Fig. 4 used in combination with the A415 type valve is obtained in the way described above.

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The Moving Coil Loud Speaker.

By H. M. Clarke, B.Sc.

THE problem of obtaining uniform response from the moving coil loud speaker has of late attracted considerable attention from the technical experts, and much has recently been published on the subject. The author's present object is to suggest a method for controlling the electrical impedance and the motional impedance of the instrument so as to obtain any required characteristic change with frequency.

It is proposed to consider the final or output stage only and in this case it may be said that the response frequency characteristic is affected by five primary phenomena. The first phenomenon is the waveform of potential difference applied to the grid of the output stage and is hereafter assumed to be a faithful representation of the waveform of the sound which it is desired to reproduce.

The second is the output characteristic of the valve or valves to the anode circuit of which the loud speaker is connected.

The third is the electromagnetic characteristic of the loud speaker circuit when no sound is being emitted.

The fourth is the physical characteristic of the moving system of the instrument; the fifth being the acoustic characteristic of the atmosphere and auditorium.

Of these, the first can be controlled independently of the others. The last will be taken as referring to a semi-infinite medium depending only upon the effective area of the diaphragm, in which case, as soon as a particular moving system has been constructed and suspended the effect of the atmosphere is predeterminate, and, moreover, the fourth is settled, in that the mechanical driving force required to produce a certain acoustic effect at any frequency is fixed.

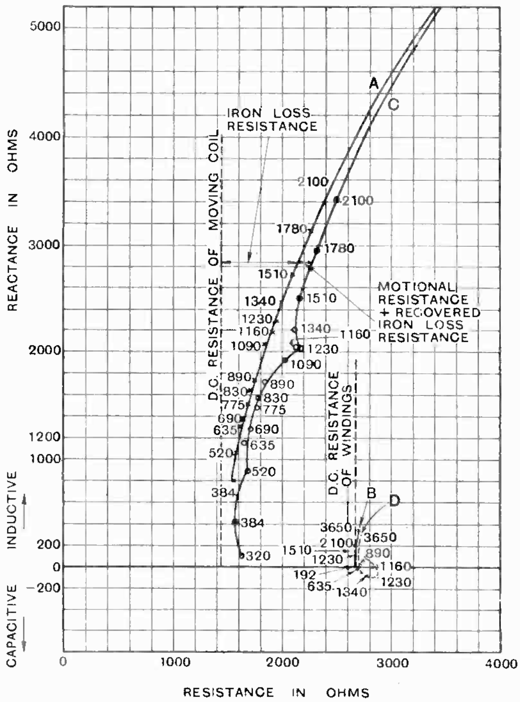
The crux of the matter is how to control the driving force so as to give the loud speaker the correct sound-frequency characteristic. This force is proportional to the current flowing in the moving coil; there is, therefore, a certain relation between current and the desired acoustic effect. With the given grid voltage waveform, however, the current which flows in the instrument is mainly determined by the second and third of the primary phenomena mentioned above, namely, the anode characteristic and the electromagnetic characteristic of the instrument. The former does not vary with frequency, but the latter varies considerably.

It is possible to make the latter effect negligible by having a moving coil with a resistance which is low compared with the valve anode resistance, but it must be remembered that the impedance of the moving coil rises rapidly with frequency, and it is necessary to have the impedance at a high-frequency small compared with the anode resistance. In these circumstances the current is constant and very much below that for maximum power output of the valve. This inefficient use of the output stage is not the worst feature of such control. It is inevitable that the suspension of the moving system should impose natural frequencies of vibration upon the moving coil in such a way as to vary the motional impedance of the instrument over wide limits. At one of these resonant frequencies much less current is required to produce the same acoustic effect as that required at a non-resonant frequency.

An obvious way to correct this is to shunt the instrument with a filter circuit of such a resistance as to by-pass the current to the desired extent. Unfortunately, the shunting effect of the filter circuit does not decrease with increase of frequency rapidly enough if, as happens to be the case, the impedance of the instrument rises rapidly. The filter circuit can only be used with good effect if the impedance of the instrument does not vary with frequency. The present object is to indicate a method of obtaining a constant impedance non-inductive instrument which lends itself to damping with filter circuits, which allows of the use of the maximum power output available, and which may be controlled externally to obtain any required response characteristic.

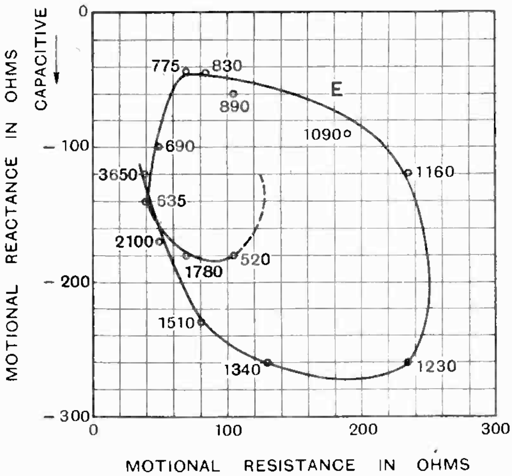
Curve *A* shows the variation of impedance of a typical moving coil instrument with frequency. This curve was taken at constant current with no steady magnetic flux in the air-gap and therefore the instrument was silent.

The points to notice are the increase of resistance, and the increase of impedance, with frequency. The increase of resistance indicates hysteresis and eddy current losses in the iron near the gap, and is undesirable, since the power available in a given output circuit is limited, if for no other reason. The three-fold increase of impedance between 0 and 2,100 frequency shows that the current-frequency characteristic of a valve



Constant current vector impedance-frequency curves of moving coil loud speaker, 1,400-turn moving coil.

output circuit containing this instrument will be much modified, unless the output valve has a high internal resistance. The increase of resistance can be reduced to a great extent by laminating radially the iron near the air-gap, but although this eliminates eddy current losses, it does not affect hysteresis; nor does it reduce the reactance of the moving coil, which is the chief factor in the rise of impedance.



Motional impedance uncompensated; vector difference of impedances with and without D.C. field.

Hysteresis, eddy currents and self-induction can be reduced to a negligible quantity by employing a compensation winding, which is now offered as the solution of the problem of loud speaker response control.

The arrangement used by the author was to wind on the inner pole half as many turns as on the moving coil, and to insert a coil (with half as many turns as on the moving coil) in the air-gap outside the moving coil and fixed to the outer pole. The result is that the *moving* coil is evenly flanked by as many *fixed* turns as itself contains. These windings were then connected in series in such a direction that the fixed windings magnetically opposed the moving coil.

Curve *B* shows the test results over the same range of frequency as in Curve *A*.

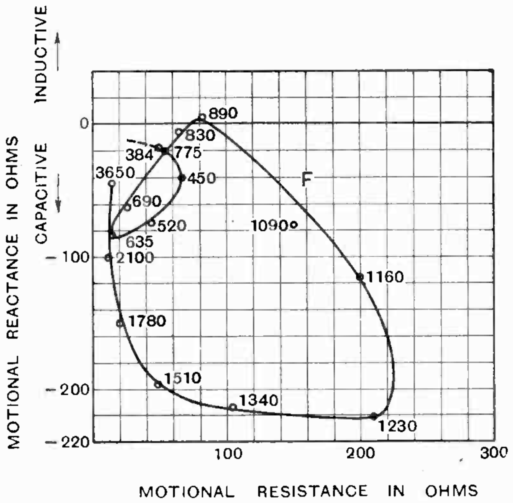
The points are so close together as to be almost unplotable to the same scale as curve *A*, but it is necessary to show them to the same scale in order to bring out clearly the improvement in power factor and in the impedance characteristic brought about by compensation. Curves *G* and *H* are enlargements of *B* and *D* with an offset origin.

Of course, in the compensated instrument there is double the amount of copper resistance, but it will be seen that the uncompensated instrument reaches this value before 3,000 frequency. The principal feature is that where curve *A* shows an increase of 230 per cent. in impedance, curve *B* shows only 4 per cent. for the same range of frequency.

It should be mentioned that the curves were made on the same instrument, the compensation windings being disconnected to obtain curve *A*.

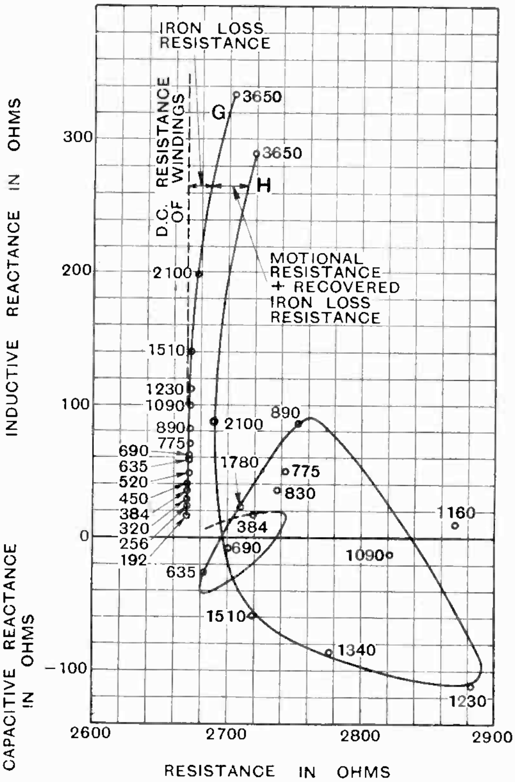
While it is obvious that with constant current the impedance may be kept fairly constant when the direct current field is zero, it is necessary to know the effect of this field to obtain the motional characteristic. It is here that the individuality of the particular instrument asserts itself and demands special consideration.

When the air-gap contains no steady flux and when, therefore, no sound is being emitted, it does not matter what means are used to locate the moving coil in the gap. Therefore curve *A* is typical of an uncompensated instrument and curve *B* is typical of the same instrument when compensated. Methods of suspension and dynamic resonances do not enter into the question. Curves *C* and *D*, however, apply only to the particular instrument used by



Motional impedance compensated; vector difference of impedances with and without D.C. field.

the author, since they refer to operating conditions, which are affected by the method of suspension. At the same time, the forms of these curves may be taken to be typical of what happens in most cases, modifications being introduced by the mass of the moving parts, the area of the dia-



Constant current vector impedance-frequency curves. Curves B and D enlarged and with offset origin. G Field off—compensated. H Field on—compensated.

phragm, the resonances of the suspension, the damping of the suspension and air friction. Curves *C* and *D*, then, are typical impedance-frequency characteristics with main field energised, uncompensated and compensated respectively.

The cusps on *C* indicate resonances with the natural frequencies of suspension and correspond with loops in curve *D*. These loops are more clearly shown in curve *H*. The irregularity of the latter compared with the smoothness of *C* is more apparent than actual and is brought about by the fact that the uncompensated curves are spread over a larger range of values. That the irregularity is common to both can be seen when motional impedance curves are plotted. These are given in curves E and F, and are obtained by taking vector differences of pairs of impedances at the same frequency, field on and off. Curve E is the uncompensated case, curve F the compensated.

More points are necessary to establish E and F with precision, and the linking-up shown is intended to convey the general form only. It is not intended to use these curves otherwise than to show that the motional impedances differ but slightly in the two cases, that compensation has not been materially affected by the presence of the direct current field, and that the ratio of maximum to minimum motional resistance is appreciably the same in the two cases.

It is obvious that the compensated instrument will take almost constant current at all frequencies if connected in the anode circuit of an output valve. Now since curve F represents motional impedance at constant current, it is clear that the horizontal component of this impedance is to a certain scale a measure of the motional power input to the moving system. It will not be wholly available for sound production, but the immediately important point is that it varies considerably, in the present case about sixteenfold. If the instrument be now shunted with a filter circuit resonating at about 1,250 frequency, and having a resistance sufficient to reduce the current in the instrument to one-quarter of its value when unshunted, the motional power input curve becomes almost uniform over the working range, so far as that particular resonance is concerned. The other resonances might be treated in the same way.

The resistance of the filter circuit depends upon the output anode resistance as well as the instrument resistance. If the latter is made equal to the former, or so nearly equal as to affect the current when the series impedance in the anode circuit varies, the valve current will rise at resonance owing to the pronounced shunting effect at that frequency. This can best be illustrated by the use of symbols.

Let R_1 represent the resistance of the instrument, including an amount R_2, the motional resistance at resonance, and R_2^1 the motional resistance remote from resonance. Let R_3 be the resistance of the filter circuit at resonance, and R_4 the internal resistance of the output valve.

Then the current at a frequency remote from resonance $\propto \dfrac{1}{R_1 + R_4}$ and the motional power $\propto \dfrac{R_2^1}{(R_1 + R_4)^2}$.

The current at resonance $\propto \dfrac{1}{R_4 + \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_3}}}$

i.e.
$$\frac{1}{R_4 + \dfrac{R_1 R_3}{R_1 + R_3}}.$$

Of this current, only $\dfrac{R_3}{R_1 + R_3}$ passes through the instrument, so that the instrument current at resonance

$$\propto \frac{R_3}{R_1 + R_3} \times \frac{1}{R_4 + \dfrac{R_1 R_3}{R_1 + R_3}}$$

i.e.
$$\propto \frac{R_3}{(R_1 + R_3)\, R_4 + R_1 R_3},$$

and the motional power

$$\propto \frac{R_2 R_3^2}{\{(R_1 + R_3)\, R_4 + R_1 R_3\}^2}.$$

If this is to equal the power at non-resonance, then $\dfrac{R_2^1}{(R_1 + R_4)^2}$ must equal

$$\frac{R_2}{\left\{\left(\dfrac{R_1 + R_3}{R_3}\right) R_4 + R_1\right\}^2}$$

Suppose $R_2 = a^2 R_2^1$, then $(R_1 + R_4)$ must equal

$$\frac{1}{a}\left\{\left(\frac{R_1 + R_3}{R_3}\right) R_4 + R_1\right\}.$$

If R_1 is made equal to R_4, then 2 must equal

$$\frac{1}{a}\left\{\frac{R_1 + R_3}{R_3} + 1\right\} \text{ or } R_3 = \frac{R_1}{2(a - 1)}.$$

Since, in the present case, $R_2 = 16 R_2^1$, a equals 4, and it will be seen that R_3 should be one-sixth of R_1. If R_4 is large compared with R_1, R_3 should be one-third of R_1 to give the same shunting effect.

This arrangement produces an instrument and damping circuit arranged so as to give constant motional power input with varying frequency, provided that the choke and condenser of the damping circuit be chosen to give the necessary rate of change of impedance of the damping circuit with frequency. Other characteristics may be obtained by suitably adjusting the damping circuits or by shunting the compensation winding in different ways in conjunction with a change in the number of compensation turns, and it should not be difficult to get practically any response curve desired.

In conclusion, it may be remarked that while compensation can do little towards increasing the facility with which the moving parts take up a particular motion, the improvement of power factor is a step in the right direction in that it facilitates the rise of the current to its full value. With regard to a transition from one frequency to another, or from one amplitude to another, the shunting circuit provides means of dissipating electrically the unwanted kinetic energy and so of cutting down the period of time during which transients are maintained.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

On the Writing of Scientific Papers.

To the Editor, E.W. & W.E.

SIR,—Mr. F. M. Colebrook's excellent article omits one important point often overlooked by scientific writers, viz., the choice of a suitable title. It is presumed that every scientific paper is written with the idea that it may be used for future reference; the title should, therefore, be chosen with a subject-matter index in view.

Many scientific papers, especially those in German technical publications, have titles which may fitly be described as " verbal processions " in which it is difficult to discover the key-words under which they might be looked for in a reference index.

As one who has to keep up several of these indexes I am emphatically of opinion that scientific titles should be as short and concise as possible, and that the key-word should come, if not absolutely first, at all events in a forward and conspicuous position.

W. H. MERRIMAN.

Frequency Modulation.

To the Editor, E.W. & W.E.

SIR,—In his letter, published in the May issue, Mr. Holmblad appears to be in error in his conception of the frequency modulation system, or at least in the formula he employs in translating that system into a mathematical expression. The formula he uses is

$$i = A \sin (\omega t + k \sin mt) \qquad (1)$$

where A is the constant amplitude, ω the cyclic carrier frequency, m the cyclic signal frequency, and k a modulation constant.

The best way of approaching the subject is to consider first the expression for an unmodulated carrier wave

$$i = A \sin \omega t \qquad (2)$$

It includes two parameters, A representing amplitude, and ω cyclic frequency. When A is given a periodic variation and ω kept constant we have the ordinary amplitude modulation; and when A is kept constant and ω has a periodic variation, frequency modulation arises. Now, if ω is given a periodic variation between limits $\omega + k$, $\omega - k$ and if this cycle of variation is repeated $m/2\pi$ times per second, then to obtain from (2) the expression for frequency modulation we have to substitute $\omega + k \sin mt$ for ω. This gives

$$i = A \sin t\,(\omega + k \sin mt)$$
$$= A \sin (\omega t + kt \sin mt) \qquad (3)$$

It will be seen that (3) differs from (1) in having an extra t factor in the second term.

The method employed by Mr. Holmblad for splitting his expression (1) into a series of side-band terms is not applicable to the expression (3), and I have not succeeded in devising or discovering an alternative method.

The conclusions arrived at in Mr. Holmblad's letter are, of course, invalidated by his initial error; but I hasten to add that this letter is not intended to justify the claim made on behalf of the frequency modulation system that it requires a band of only 100 or so cycles for speech transmission. It sounds too good to be true. Perhaps one of your readers may be able to split the expression (3) into the sum of a series of simple sine terms. For this purpose it is legitimate to assume that k and m are both small compared with ω.

G. H. MAKEY.

The Patent Office, W.C.2.

Abstracts and References.

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PROPAGATION OF WAVES.

SUR LES PROPRIÉTÉS DIÉLECTRIQUES DES GAZ IONISÉS DANS LES CHAMPS DE HAUTE FRÉQUENCE (On the Dielectric Properties of Ionised Gases in H.F. Fields).—H. Gutton. (*Bull. d.l. Soc. franç. d. Phys.*, 1st February, 1929, p. 30S.)

An application of the author's previous work (April Abstracts, p. 204) to a theory of the propagation of waves in the upper atmosphere, which demands neither discontinuity of ionisation nor the existence of several layers. "The band of absorption corresponds to an ionisation which is greater in proportion as the wave is shorter; and corresponds therefore to a layer proportionately higher. At this layer there is produced a reflection of metallic nature, which is the more perfect the higher the layer and the less the pressure—since the damping of the electronic oscillations is less. Short wave reflection is thus better than long wave. It is natural to suppose, since atmospheric ionisation is a solar effect, that this ionisation is greater by day than by night, so that by day the reflecting layer is lower. One imagines that for waves of a few hundred metres [under these conditions] the damping almost completely suppresses reflection, and daylight range is less than night range. For shorter waves, some dozens of metres in length, the daylight range retains a higher value since reflection still takes place at very high levels."

SUR LA CONSTANTE DIÉLECTRIQUE DES GAZ IONISÉS (The Dielectric Constant of Ionised Gases). —H. Gutton. (*Comptes Rendus*, 6th May, 1929, V. 188, pp. 1235–1237.)

Developing his previous work on the R.F. resonances in ionised gases, the writer arrives at an equation representing the variations of the dielectric constant as a function of the number of ions for a pulsation ω:

namely $$K = 1 + \frac{0.278 \times 10^{10} N}{35.5 \times 10^{10} N^{3/4} - \omega^2}$$

This formula allows the value of ionisation to be found corresponding to resonance with any pulsation ω. Thus for $\lambda = 248.7$ m., resonance is produced for an ionisation $N = 1.9 \times 10^8$ electrons per cm^3.

TRANSIENT EFFECTS WITH IONS OF LOW MOBILITY. —H. P. Walmsley. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 365.)

With a variable ionisation, the currents produced show a lag with time behind the changes producing them. With mobile ions this effect is negligible, but it is of importance with ions of very low mobility. Any change causing a redistribution of such ions in the electric field which is employed to measure the currents produces transient effects which may be comparable in magnitude to the currents measured, and which persist for an appreciable time.

AN INVESTIGATION OF SHORT WAVES.—T. L. Eckersley. (*E.W. & W.E.*, May, 1929, V. 6, pp. 255–260.)

Long abstract, illustrated, of the I.E.E. paper referred to in June Abstracts, p. 321. Among the points here mentioned are the following:—Very short skip distance effects; in recent tests, reflection at practically normal incidence has been observed on waves down to 30 m. At 11.27 km. distance, all waves from 60 to 30 m. showed marked vertical reflection, which appeared to be less on the longer waves than on the shorter. "These results are interesting in connection with the very long (Stôrmer) echoes." Elimination of fading; the use of two slightly different frequencies; "recent tests seem to indicate that there is a big gain in using modulated waves instead of pure C.W., with a much higher speed of working"; use of two aerials spaced many wavelengths apart; use of combination of signals from a horizontal and a vertical aerial. Different types of fading:—at the edge of the skip distance the more bent (and incidentally less attenuated) of the two rays, circularly polarised by the earth's field, is alone received; at slightly greater distances both rays combine and produce marked inverse or "polarisation" fading; at great distances the horizontal ray diminishes in importance and the fading is mainly of the "interference" type. Magnetic storm fading is dealt with, and the considerable increase of "whistlers" (January Abstracts, p. 38) during such storms is referred to. The concluding section discusses theory, more particularly the rôle of the Heaviside layer; the conception of this as a complex structure of scattering clouds necessitates revision of the usual ray theory. If the scattering in the lower levels of the layer is particularly intense, the emergent ray may be very highly diffused and the emergent energy may entirely lose its ray formation.

TRANSOZEANISCHE DRAHTLOSE TELEGRAPHIE MIT KURZEN WELLEN (Transoceanic Wireless Telegraphy on Short Waves).—H. Rukop. (*Verhandlungen der Ges. deut. Naturforsch.* 90 Versamm.)

The complete paper, an abstract of which was referred to in March Abstracts, p. 145.

ACTIVITÉ SOLAIRE ET PROPAGATION (Solar Activity and Propagation).—R. Mesny. (*L'Onde Élec.*, March, 1929, V. 8, pp. 103–110.)

A survey of the work done on this subject by Espenschied, Anderson and Bailey, Pickard, Maurain, and Austin (see earlier Abstracts).

THE SCATTERING OF LIGHT BY ELECTRONS.—G. Glockler. (*Phys. Review*, No. 1, 1929, V. 33, p. 116.)

As an example of the writer's conclusions, an encounter with an electron with 1,000 v. velocity would shift the green Hg-line 5461 by 685 A.U.

REFRACTION OF LIGHT WAVES BY ELECTRONS.—S. K. Mitra and H. Rakshit. (*Nature*, 25th May, 1929, V. 123, p. 797.)

Assuming that long-distance reception of wireless waves is due to refraction by electrons in the Heaviside layer, the writers use Larmor's velocity formula to deduce that for a wavelength of 10^5cm., an electron density N of 0.3 per c.c. is enough to produce the observed bending round the earth. In the case of light waves, λ is of the order of 10^{-5}cm., leading to a large value of N in order that light rays may bend round the earth, and a still larger value if the bending is to be observed in the laboratory. After mentioning that the writers have—so far unsuccessfully—tried to detect such bending, the letter describes the reasoning (from Langmuir's formula for the density of space charge at the surface of a hot plane surface) which leads them to believe that such bending could be produced and detected in the laboratory. A thoriated tungsten strip, say 10 cm. long, would be used to form the electron atmosphere; since at a distance of only 0.1 mm., the electron density falls to one ten-thousandth of its value at the surface, it would probably be advantageous to pull the electron cloud upwards by a positively charged plate held a few millimetres above the surface.

THE EFFECT OF STRONG ELECTRIC AND MAGNETIC FIELDS ON THE RECTILINEAR PROPAGATION OF GAMMA RAYS.—J. H. J. Poole and A. J. Clarke. (*Roy. Dublin Soc.*, 26th March, 1929; short summary in *Nature*, 25th May.)

Testing J. J. Thomson's suggestion that just as electrons show some of the characteristics of very high frequency wave trains, so very hard gamma rays might possess some of the properties of charged particles (*cf.* February Abstracts, pp. 113–114), the writers have been unable to detect any deflection of such rays either by electric or magnetic fields.

OZONE ABSORPTION DURING LONG ARCTIC NIGHT.—G. M. B. Dobson. (*Nature*, 11th May, 1929, V. 123, p. 712.)

Referring to Wood's supposition that an extension of the ultra-violet spectra of sun or stars could be obtained near the pole at the end of winter, on the assumption that the atmospheric ozone is formed by ultra-violet solar radiation and should therefore be of low value at that time and place, the writer states that regular and consistent results show that the lowest ozone values at any time of year are in the tropics, the highest being in high latitudes in spring (when it is about twice the autumn value). The solar ultra-violet radiation tends to reduce rather than to increase the amount of ozone, since there is far more energy in the longer waves (which decompose ozone) than in the shorter ones (which form it). What does form the ozone is not, at present, certain; but the connection found between the amount of ozone and magnetic disturbance might suggest some action associated with the aurora, though occurring lower down. See also April Abstracts, pp. 202–203.

THE ABSORPTION OF ULTRA-VIOLET LIGHT IN OZONE.—A. Läuchli. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 321.)

Measurements of the absorption coefficient over the range 238–334 $\mu\mu$, using a differential ozone meter.

FORMATION OF OZONE BY KATHODE RAYS.—A. L. Marshall. (*Journ. Am. Chem. Soc.*, December, 1928, V. 50, pp. 3178–3197.)

Ozone is both formed and decomposed under the influence of these rays, and with continued raying a steady state is reached (independent of the current) with an ozone concentration of 1 mol. to 1,700 of oxygen, as compared with 1 to 12 with the silent electric discharge. The cathode-ray tube by which these tests were made is described. It can be loaded up to 200 kw., with a current of 0.001 A.

THE TRANSFER OF HEAT BY RADIATION AND TURBULENCE IN THE LOWER ATMOSPHERE.—D. Brunt. (*Proc. Roy. Soc.*, 2nd May, 1929, V. 124 A, pp. 201–218.)

Author's summary:—A simplifying assumption as to the nature and extent of the effects of radiation and absorption by water-vapour in the atmosphere, based on Hettner's measurements of absorption by water-vapour, makes it possible to reduce the problem of the transfer of heat by radiation and absorption to a tractable form. This transfer is found to be analogous to the conducting of heat in a solid, the ordinary coefficient of molecular conductivity being replaced by a much larger coefficient, the radiative diffusivity K_R.

The transfer of heat by eddies in a turbulent atmosphere is evaluated for a compressible atmosphere, and it is shown that the eddy flux of heat is proportional to the difference between the lapse rate and the adiabatic, and to the eddy-diffusivity K, defined by Taylor.

The relative magnitudes of K_R and K are considered. K is normally of the order of 10^3 in inversions but is usually greater than 10^5 when the atmosphere is fairly turbulent. Both radiation and turbulence tend to smooth out any bends in a temperature height curve.

MESSUNGEN DES BRECHUNGSEXPONENTEN VON WASSER ZWISCHEN 23 UND 73 CM. WELLENLÄNGE (Measurements of the Index of Refraction of Water between 23 and 73 cm. Wavelength).—E. Frankenberger. (*Ann. der Phys.*, 19th April, 1929, Series 5, V. 1, No. 7, pp. 948–962.)

The index for pure water was found to be quite constant throughout the wave-range; apparently also down to 10 cm. Contrary to previous results, weak salt and colloidal solutions showed no dispersion, for a wave-range 50–60 cm. (*See also* Martey and Jones, Abstracts 1928, V. 5, p. 522.)

MAGNETIC SUSCEPTIBILITY OF OZONE.—V. I. Vaidyanathan. (*Indian Journ. Phys.*, 30th November, 1928, V. 3, pp. 151–163.)

Tests leading to the conclusion that ozone is diamagnetic.

AN ANALYSIS OF THE CHANGES OF TEMPERATURE WITH HEIGHT IN THE STRATOSPHERE OVER THE BRITISH ISLES.—L. H. G. Dines. (*Roy. Met. Soc.*, summarised in *Nature*, 4th May, 1929, V. 123, p. 700.)

THE PROPAGATION OF SOUND IN GASES.—D. G. Bourgin. (*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 821–841.)

The first part develops the ideas and equations for a theory which takes account of the collision excitation and de-excitation of the molecules composing the gas. In brief, it is assumed that under the influence of collisions of the first kind some molecules are thrown into states of higher energy from which they may return to lower energy levels either spontaneously or as the outcome of collisions of the second kind. The second part advances a theory of sound propagation in a mixture of two gases—the first attempt, the author believes, to deal with this problem.

T.S.F. ET MÉTÉOROLOGIE (Wireless and Meteorology).—De la Forge. (*QST Franç.*, March, 1929, V. 10, pp. 8–12.)

An article on Fuch's paper dealt with in January Abstracts, p. 40.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

SOLAR STREAMS OF CORPUSCLES AND MAGNETIC STORMS.—S. Chapman. (*Nature*, 25th May, 1929, V. 123, p. 811.)

A short summary of the paper in *Monthly Not., R. Astron. Soc.*, for March. The writer uses Milne's result that the Doppler effect will enable upward moving atoms to climb out of the absorption lines associated with them, and to be accelerated away from the sun; the acceleration diminishes as the distance increases, and for the greater part of the journey to the earth's orbit the motion is nearly uniform; the time—between one and two days—agreeing with the lag often observed after the passage of a spot over the central meridian of the sun before the arrival of the storm. While individual atoms are moving nearly radially, the stream as a whole is rotating with the sun and so overtakes the earth; magnetic storms therefore begin near the sunset meridian of the earth. It is estimated that the breadth of a stream when crossing the earth's orbit is of the order of 50 earth-radii, so that it would take 25 minutes to sweep over the earth. Discussing the difficulty of explaining how the corpuscles can penetrate deeply enough into the atmosphere to give rise to low-level auroræ, it is suggested that the extrapolation used to estimate the resistance of air at extremely low density may be at fault.

ON LIGHTNING: THE KELVIN LECTURE.—G. C. Simpson. (*Engineer*, 3rd May, 1929, V. 147, pp. 483–484.)

Summary of the lecture before the I.E.E. Cathode ray oscillograms have now proved that the main discharge of a lightning flash consists of a unidirectional current starting at zero, rising to a maximum and then decreasing more or less rapidly to zero. Clouds are practically perfect non-conductors, and—having no capacity—cannot act in the Leyden jar manner. But the channel of the flash, once formed, has capacity and self-induction, and if its resistance is not too great it will oscillate like an aerial. Thus the combined effect is somewhat similar to that of a singing arc. The quantity of electricity in an average flash varies between 10 and 50 coulombs. The potential reached in a cloud before the passage of a 20-coulomb flash is in the neighbourhood of 1,000 million volts; the energy in such a flash is about 10^{17} ergs; the average duration is greater than one-thousandth of a second. The mean current is of the order of 20,000 A., but instantaneous values are far greater and seem sometimes to approach 100,000 A. A copper conductor having a cross section of 0.08 sq. inch can safely carry the most violent discharge likely to occur, but a local resistance (*e.g.*, a bad earth) of 10 ohms may raise the potential of the conductor to a million volts. The writer believes that practically all troublesome surges in lines are due to direct strokes, *not* to induction.

THE PAST COLD WINTER AND THE POSSIBILITY OF LONG-RANGE WEATHER FORECASTING.—W. J. Pettersson. (*Nature*, 25th May, 1929, V. 123. pp. 796.)

The writer considers that at present all attempts to forecast the weather more than a week ahead are not more than 50 per cent. successful, owing to the neglect of direct terrestrial influences such as that of the physical state of the surface waters of the oceans, and to the insufficient attention given to Bjerknes' "polar front" theory. He quotes Witting's Baltic observations of 1927 and gives reasons for thinking that the very large cold layer at 10 fathoms found there may well account for the cold winter of 1928. He suggests that international co-operation in the systematic study, at least once but preferably twice a year, of the physical states of the Baltic and other seas and oceans in and around Europe, followed by a quick publication of results, would sometimes save millions of pounds by the prediction—in good time—of winters such as that of 1928–1929.

MAGNETIC STORMS AND SOLAR ACTIVITY, 1874 TO 1927.—W. M. H. Greaves and H. W. Newton. (*Monthly Not., Roy. Astron. Soc.*, 89, November, 1928, pp. 84–92.)

Supplementary to the paper referred to in Abstracts, 1928, V. 5, p. 579.

RADIAL LIMITATION OF THE SUN'S MAGNETIC FIELD: SUN'S GENERAL MAGNETIC FIELD AND THE CHROMOSPHERE.—S. Chapman. (*Monthly Not., Roy. Astron. Soc.*, 89, November, 1928, pp. 57–79 and 80–84.)

PROPERTIES OF CIRCUITS.

OUTPUT CHARACTERISTICS OF THERMIONIC AMPLIFIERS.—B. C. Brain. (*E.W. & W.E.*, March, 1929, V. 6, pp. 119–127.)

"All the data required to fix the operating conditions of a valve for maximum undistorted output can be obtained (by the aid of a slide-rule and five minutes work) from a knowledge of two valve constants. These constants are embodied in the information which usually accompanies commercially made valves." They are the amplification factor m, and the constant k which can be calculated from any set of simultaneous values of V_a, I_a and E_g. The writer deals first with the generally accepted rule that for best power output the coupled load resistance should be twice the value of the A.C. resistance of the output valve, and shows that this valve-resistance should be taken for peak-value of anode current and *not*, as is common practice, at the working bias (the latter method leading to serious error when applied to pentodes). He then deduces that for triodes the ideal load resistance should be about 1.6 times the A.C. resistance of the valve at the working bias. But if the mean anode current with this optimum load resistance exceeds the makers' limitation (as frequently happens) the load resistance may have to be much greater than the optimum value. After showing how to allow for this, and for voltage drop along filament and the use of A.C. for filaments, he enumerates three points emerging from his investigation :—the maximum output from a valve is proportional to the 2.5 power of the anode voltage and to the constant k; the output of valves of identical construction but with differing m values operating with the same anode voltage is inversely proportional to the 1.5 power of m; the grid bias for maximum output is directly proportional to the anode voltage and inversely proportional to m.

SUR LES TRANSFORMATEURS INTERMÉDIAIRES ET LA REPRODUCTION SANS DISTORSION (Intermediate Transformers and Distortionless Reproduction). — I. Podliasky. (*L'Onde Élec.*, March, 1929, V. 8, pp. 111–118.)

Referring to Jouaust's paper and to Turner's letter on the English practice of using low resistance valves and reducing the leakage flux of the transformer, to avoid trouble with the "parallel resonance" (January and May Abstracts, pp. 41 and 268), the writer offers some remarks which support Turner and which may assist in the pre-calculation of "aperiodic" transformers; these have been confirmed by tests on English types of distortionless ("uniform spectrum") transformers. Curves of the Marconi "Ideal," Ferranti, and G.I.K. transformers are given, showing the absolute flatness at the region of parallel resonance, a gradual rise towards the upper end of the musical spectrum and a resonant point (leakage resonance) at the limit of this spectrum. The writer's mathematical investigation of the conditions for parallel and series resonance is applied, as an example, to the calculation of such a transformer.

The often-raised question of "phase reproduction" is then discussed briefly; it is concluded that the ordinary reproduction curve (taken by applying an A.C. voltage of constant amplitude and variable frequency to the grid and measuring the voltage at the ends of the transformer secondary by an instrument representing about the impedance of the input circuit of the next valve) justifies its name, in that it completely represents the reproduction of complex sounds.

ÜBER DIE HÖCHSTLEISTUNGEN UND VERZERRUNGEN BEI ENDVERSTÄRKERN (On Maximum Output, and Distortion, in Power Amplifiers).—H. Bartels. (*E.N.T.*, January, 1929, V. 6, pp. 9–17.)

It is shown that the maximum obtainable A.C. output, as a function of anode load of the valve, is *not* (as has hitherto been assumed) reached at the anode voltage corresponding to the condition $R_a = 2\ R_i$,* but continually increases with the anode voltage up to a value twice as great as at that point. At the same time, the distortion due to the curvature of the valve characteristic decreases. More important still, the increase of anode voltage is accompanied by an increasing breadth of transmitted frequency band: a 50 per cent. increase of voltage doubles the frequency band. *See also* Hanna and collaborators, Abstracts, 1928, V. 5, p. 344.

OPTIMALE INDUKTIVITÄT VON SCHWACHSTROMTRANSFORMATOREN (Optimum Inductance of "Small Current" Transformers).—G. Pfeifer. (*E.N.T.*, April, 1929, V. 6, pp. 157–161.)

In commercial telephony, where the undistorted transmission of only three octaves is quite enough, the question of a linear frequency characteristic presents no difficulty and a transformer can therefore be designed with an eye to maximum efficiency. The writer deals first with a 1 : 1 transformer, obtaining an equation from which he derives curves showing the best ratio L/R for various frequencies (of which the 5,000 p.p.s. is the most important for speech) at any particular value of r/L. Here L is the inductance of each winding, r its resistance; R is the resistance of the generator or of the receiver (since a 1 : 1 transformer is being considered, these are assumed equal); the ratio r/L for modern transformers varies from 10 to 60. He then shows how to apply his results to transformers of ratio other than unity.

EFFECT OF ANODE-GRID CAPACITY IN ANODE-BEND RECTIFIERS.—E. A. Biedermann. (*E.W. & W.E.*, March, 1929, V. 6, pp. 135–139.)

Conclusion of the paper referred to in April Abstracts.

ÉTUDE D'UN SYSTÈME OSCILLANT : SUPERRÉACTION (Study of an Oscillating System: Super-regeneration). — T. Konteschweller. (*QST Franç.*, March and April, 1929, V. 10, pp. 13–17 and 33–34.)

A mathematical analysis : to be continued.

* With transformer coupling: R_i being the internal resistance of the last valve.

OSCILLAZIONI PROPRIE DEL TRIODO IN ACCOPPIAMENTO MAGNETICO (Natural Oscillations of a Triode with Magnetic Coupling).—R. Malagoli. (*N. Cimento*, July, 1928, V. 5, pp. 239–255.)

The author deals first with the internal resistance of a valve with control grid, and the dependence of this resistance on the values in the associated circuits. He then investigates the electrostatic relation between grid and anode, and the formation of oscillations between these electrodes, giving an expression for the pulsations of grid-current as a function of the circuit constants and the grid/anode capacity. Under certain conditions these oscillations are of such low frequency that they can be heard in a telephone receiver directly connected.

NON-REACTIVE COUPLING.—(German Pat. 452814, Banneitz.)

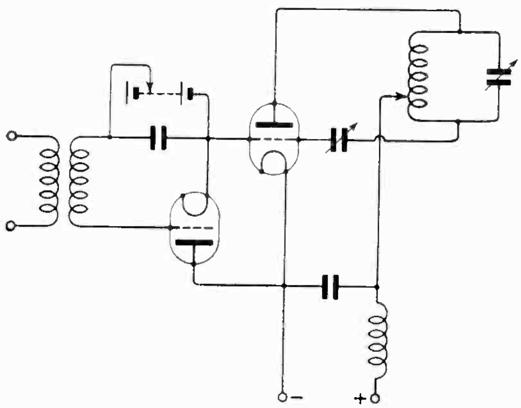
Parallel to the coupling inductance, which forms part of the secondary circuit inductance, is connected a capacity which forms—with the coupling inductance—a circuit so out-of-tune with the working frequency that reaction on the primary circuit is reduced to a minimum.

DAMPING AND OSCILLATION: EXCITATION OF APERIODIC SYSTEMS.—F. Tank and K. Graf. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 369.)

Circuits containing only resistance and inductance, or resistance and capacity, when suitably connected and coupled together through any type of amplifier, can be made to generate oscillations. The paper considers the cases of various forms of amplifier.

HOCHFREQUENZSTEUERUNG MIT GITTERGLEICHSTROM (H.F. Control by Grid Direct Current). K. Krüger and H. Plendl. (*Naturwiss.*, 15th March, 1929, V. 17, pp. 180–181.)

In the grid-lead of a reaction-coupled transmitter valve a resistance, selective for H.F., is



connected—in the form of a control triode as in the diagram.

Externally this arrangement resembles an ordinary grid-controlled telephone transmitter, but its action is described as fundamentally different. The control valve is so biased as to present a very high resistance to the grid current of the main valve, so that it blocks the oscillation of this. If a H.F. voltage is applied to the grid of the control valve, this blockage is removed for that particular frequency, and the main valve can oscillate to it or to one of its harmonics. Thus a large power can be controlled, without intermediate steps, by a small power such as is given by a quartz-oscillator. For reception, also, very high amplification or a relay action can be obtained.

TRANSMISSION.

ZUM PROBLEM DER ERZEUGUNG KURZER ELEKTRISCHER WELLEN DURCH BREMSFELDER (On the Problem of the Production of Short Electric Waves through "Brake-fields").—H. E. Hollmann. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 128–132.)

Author's summary:—For more exact examination of the short-wave oscillations (13–18 cm. wave region) found by Pierret and by Hollmann, using a French short-wave valve Type Métal TMC, electrode systems were used by which the number of grid turns could be varied in addition to changes in tuning and working conditions. No oscillations were found corresponding to Pierret's theory, in which—contrary to the B-K ideas—the frequency depends also on the spacing of the grid wires. But oscillations in the grid system were obtained of double the frequency of the B-K zone, down to a wavelength of 13 cm. The intensive oscillations at 17–18 cm. were traced to an oscillating circuit built up of the grid spiral and its supports.

GENERATION OF SHORT ELECTRIC WAVES BY THE METHOD OF BARKHAUSEN AND KURZ.—F. Tank and E. Schiltknecht. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 368.)

An experimental investigation was made of the B-K method and the results are used as a basis for a theory. "The oscillation phenomena depend on a control effect of the oscillating space charges on the space-charge density of the emission current, which latter must, therefore, have reached its saturation value. The effect of the external circuit, coupling effects, harmonic oscillations and the behaviour in a magnetic field are also dealt with."

VACUUM TUBES AS OSCILLATION GENERATORS.—D. C. Prince and F. B. Vogdes. (*Gen. Elec. Review*, May, 1929, V. 32, pp. 288–294.)

This final part of the series concludes the treatment of a high-frequency circuit with square current waves, referred to in May Abstracts, p. 269.

MODULATING SYSTEM FOR SEPARATELY EXCITED TELEPHONE TRANSMITTING SET. (German Pat. 470322, Schäffer, pub. 18th January, 1929.)

A system of modulation designed to avoid the danger of secondary emission, which is liable to occur—particularly in water-cooled oscillators—if the D.C. path to the grid is given a high resistance during the grid-current modulation. A diagram of this arrangement is given in *Zeitschr. f. Hochf. Tech.*, April, 1929, p. 151.

GENERATION OF SHORT WAVES. (German Pat. 453289, Esau.)

Spark dischargers are fed with A.C. of high frequency above the audible zone, so that the successive trains of damped waves form a practically undamped wave-train.

SIGNALLING BY FREQUENCY MODULATION.—N. E. Holmblad. (*E.W. & W.E.*, May, 1929, V. 6, pp. 260–261.)

Referring to the Westinghouse patent abstracted on p. 170 of the March issue, and in particular to the claim that the width of the side-bands is reduced to a few hundred cycles only, the writer analyses the process and comes to the conclusion that for small values of k (modulation constant) it gives the same width of side-band as the ordinary amplitude-modulation, while for large values of k much broader side-bands are introduced.

RECEPTION.

LA QUALITÉ DE LA RÉCEPTION RADIOPHONIQUE (Quality of Radiotelephonic Reception).—P. David. (*L'Onde Élec.*, March, 1929, V. 8, pp. 119–129.)

Completion of the paper referred to in June Abstracts, p. 328. After detection the current has to be amplified by one or more L.F. stages: the coupling, by resistance or transformer, has to fulfil certain conditions in order to avoid distortion. General conditions for a transformer are given as: transformation ratio not too high (2.5 to 3 as a maximum for ordinary French valves): inductance sufficiently large to assure reproduction of low frequencies—" plenty of wire and plenty of iron ": distributed capacity and core losses sufficiently slight to assure reproduction of high frequencies. These conditions seem rather contradictory, but curves of a transformer designed by Decaux, and of another (special for television) made by the Bell Telephone Company, show that transformer coupling is by no means incompatible with quality. The first curve shows no appreciable weakening until below 100 frequency: the second " realises perfection." With resistance coupling non-uniform distortion is more easily avoided, but even here care must be taken: *e.g.*, the shunt path formed by the valve capacity must be negligible compared with its ordinary conductance; this imposes a maximum on the internal resistance of the order of 200,000 ohms; recent special valves with resistances round a megohm are by no means satisfactory for fidelity. On the other hand, for the bass frequencies the coupling capacities must be large enough: 10 mμF. is not too great.

Distortion depending on the characteristic curves of the valves is then considered. For transformer coupling, grid current changes would produce distortion if they were not prevented by suitable bias. With resistance coupling there is no distortion due to the grid, but plate distortion is more difficult to avoid, since the grid mean voltage is not fixed and distortion, due to the characteristic-bend, is liable to arise. Non-linear distortion due to the iron cores of a transformer-coupling is referred to briefly, together with its cure. On the whole, the author is inclined to prefer the transformer-coupling, chiefly on account of its greater stage amplification. Loud-speakers are treated in a short section, the next section dealing with the possibility of correcting the total distortion by opposing the various partial distortions. In the final section the author quotes the dicta of various workers as to the strength of signals necessary for good reception. Espenschied's ideas (10–50 mv./m.), lead to a range of 25 and 50 km. for a 5 and 10 kw. transmitter respectively; Goldsmith is less exigent, with 45 and 160 km. for 5 and 50 kw.; Edwards and Brown gave 18 and 45 km. for 1 and 10 kw., or about double these ranges for open country. These values refer to 200–600 m. waves; they could be increased slightly for " long " waves (1,500 m.). Actual French practice considers as " normal " ranges 5 to 10 times as great as these. The writer considers the truth to be somewhere between the American and French ideas.

In the discussion Raven-Hart asks: (1) If it is not possible to improve quality without losing selectivity (and without having to use a band-pass filter) by employing two or more tightly coupled circuits tuned to neighbouring but not identical frequencies. (David refutes this: the plan rounds off the top of the curve but diminishes the slope of the sides. To work well, complex arrangements would be necessary to give, in addition to resonance with the wanted band, a counter-resonance with systematic stifling of the interfering waves—which would appear to him to come under the title of filters). (2) Why Beatty's " demodulation effect " had not been taken into account (David condemns this article as founded on an " insufficiently precise geometrical analysis " and as neglecting the effect of reaction on the damping). (3) Would not anode detection, being less sensitive to weak signals, reduce the necessary selectivity by suppressing such weak interfering signals as were let through by the tuning circuits? (Anode detection may be just as bad as grid, from this point of view: it all depends on the input amplitude at the detector). (4) Is it not best to reduce the upper frequencies, in view of the subjective greater loudness of these as heard by the ear? (This plan raises special difficulties, but the question is worthy of investigation). Finally, Borias suggests adjusting the carrier frequency to one extremity of the band passed by the tuning circuits, instead of to its middle; only one modulation band would be received, the amplitude would be halved, but the frequency-range doubled. Moreover, if the side-band furthest away from the interfering station were chosen, the interference would be reduced. Also the beats between the two side-bands would be avoided. (David replies that the remark is very interesting, that no doubt the plan is adopted unknowingly by many listeners, and that this is one reason for the discrepancy between working and theoretical ranges; but he considers that in view of the loss in amplitude and of the fact that the actual shape of the resonance curves prevents the full advantage described by Borias from being obtained, the gain obtained does not really affect his conclusions).

SELEKTIVITÄT UND FERNEMPFANG (Selectivity and Distant Reception).—M. v. Ardenne. (*Rad. f. Alle*, May, 1929, pp. 193–201.)

Observations on signals from the European broadcasting stations (*cf.* March Abstracts, p. 161) are here plotted so as to show the effects on selectivity of various values of effective damping (from 0.08 to 0.005), and of a directively efficient frame aerial.

NOTE ON THE PROBLEM OF SELECTIVITY WITHOUT REDUCING THE INTENSITY OF THE SIDE-BANDS.—W. B. Lewis. (*E.W. & W.E.*, March, 1929, V. 6, pp. 133–134.)

A receiver with an aperiodic R.F. amplifier is receiving strong but unwanted telephony and weak wanted telephony on a neighbouring wavelength. An oscillator is coupled up and tuned exactly to the weak carrier wave, the R.F. current supplied being made several times greater than that of the unwanted signals. After detection the envelope of the R.F. current is the combination of beats (*a*) of infinite period with the wanted carrier; (*b*) of supersonic frequency with the unwanted carrier and sidebands, and (*c*) of audio-frequency with the wanted sidebands: the result being that only the wanted telephony is heard, with no diminution of the higher frequencies if the amplifier is correctly designed. In preliminary experiments, anode-bend detection was abandoned as signals were only wiped out if the supplied oscillations overloaded the valve; with a crystal detector the arrangement worked in the manner expected, but a rushing noise was heard which appeared to originate in the detector: this was not serious for loud signals. Quality was good with these, but faint signals were "horribly distorted"—partly, if not wholly, owing to relative wobbling of carrier and oscillator frequencies.

KURZE UND LANGE WELLEN DER DRAHTLOSEN TELEGRAPHIE (Short and Long Waves in Wireless Telegraphy).—F. Kiebitz. (*Naturwiss.*, 29th March, 1929, V. 17, pp. 205–208.)

A survey of the relative behaviour of short and long waves so far as radiation and reception is concerned, but not as regards propagation. A point mentioned relating to the strength of signal necessary for reception is that theoretically at least one electron is necessary for each period, in order that the current may still be sinusoidal after amplification to the 10th power or so; for a 475 m. wavelength this implies a current of 10^{-13} A. This is for telegraphy, where a current has to be merely either present or not present; for telephony it must be variable in amplitude in the ratio of at least 100 to 1, so that the minimum current becomes about 10^{-11} A. if, in spite of its atomic structure, it is to reproduce speech.

THE THEORY OF PUSH-PULL: PART III.—N.W. McLachlan. (*Wireless World*, 15th May, 1929, V. 24, pp. 505–509.)

Final part of the article in the issues of 13th June, 1928, and 30th January, 1929. "New method of treating the output circuit. The causes and prevention of parasitic oscillations." The new method of treating the output involves the use of two separate transformers and two separate loud speaker coils, coupled mechanically but with a minimum of electromagnetic coupling.

AERIALS AND AERIAL SYSTEMS.

UNTERSUCHUNG DER BRAUCHBARKEIT VON RAHMENANTENNEN FÜR SENDEZWECKE (Investigation of the Utility of Frame Aerials for Transmitting Purposes).—W. Nestel. (*Zeitschr. f. tech. Phys.*, No. 4, 1928, V. 9, pp. 143–145.)

The radiation efficiency (ratio of applied H.F. input to radiated output) increases with decreasing wavelength and can reach the same order of magnitude as that of a vertical aerial: the frame aerial has, moreover, several advantages for short-wave transmission, *e.g.*, simplicity of electrical connection, and ease of wavelength adjustment.

TUBE FRAME AERIAL. (German Pat. 453291, Geles.)

An insulated wire runs axially up a vertical conducting tube. At one end, tube and wire are connected directly or through an air condenser: at the other, they are connected through one winding of a H.F. coupling transformer.

FRENCH SYSTEM OF DIRECTIONAL AERIALS FOR TRANSMISSION ON SHORT WAVES.—H. Chireix. (*E.W. & W.E.*, May, 1929, V. 6, pp. 235–244.)

VALVES AND THERMIONICS.

BADANIE PRZEBIEGÓW ELEKTROSTATYCZNYCH W LAMPIE KATODOWEJ NA MODELU (The Investigation of Electrostatic Phenomena in Valves by Means of Models).—J. Groszkowski. (*Wiadómosci i P. Inst. Radjotec.*, Warsaw, 15th March, 1929, V. 1, 21 pp.)

Author's summary: "First the author examines the question of investigation with the aid of models, and the possibility of applying such methods to electronic valves. He then considers the law of similarity between model and subject, as regards inter-electrode capacity and amplification coefficient. The ideas of "local" and "linear" amplification coefficients are introduced: these are discussed as regards the effect on them of the grid and of the edges of the electrode system." The author then describes his method of exploring the electrostatic distribution, taking as an example his model of a French triode Type "R," on a 33 : 1 scale. An alternating potential is supplied to the "plate" and "grid" of this model, the "filament" going to the slider of a potentiometer across the source of A.C. Between the "filament" and the "grid," an exploring electrode can be moved about: this is connected to the grid of a real valve; telephones in the plate circuit of this serve as the indicator, an adjustment being made (for each position of the exploring electrode) by varying the position of the slider of a second potentiometer across the source of A.C.; this slider being connected to the filament of the real valve. The results are given of the measurements of the local amplification coefficient at different points of the space between cathode and grid ("influence of grid mesh and edges"), as well as the distribution of electrostatic field in this space.

THE E.M.F. OF THERMAL AGITATION.—E. K. Sandeman and L. H. Bedford.—*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 774–782.)

Confirmatory evidence has been obtained on Johnson's results (Abstracts, 1928, V. 5, p. 581) and a simple precision formula has been derived for calculating the magnitude of noise disturbance which occurs on the grid of the first stage of any amplifier. This formula is admittedly only applicable under certain conditions (uniform amplification of a given band of frequencies; impedance between grid and filament of first valve a pure resistance shunted by a capacity, within the pass-band of the system) but these conditions usually occur in practice. The formula is

$$N = \frac{JT^{\frac{1}{2}}}{\sqrt{2\pi C}}\sqrt{\tan^{-1} 2\pi RCF_2 - \tan^{-1} 2\pi RCF_1}$$

(the inverse tangents being expressed in radians) where $J = 7.4 \times 10^{-6}$, $T =$ absolute temperature (normally about 293), $R =$ total grid-filament resistance in ohms, $C =$ total g.-f. capacity in farads, F_1 and $F_2 =$ the frequency limits of the pass range of the receiving system in cycles per second.

SUR LA CARACTÉRISTIQUE DE LA LAMPE À TROIS ÉLECTRODES (The Characteristic of the Three-Electrode Valve).—Ch. Jeanjaquet. (*Helvetica Phys. Acta*, No. 7/8, 1928, V. 1, pp. 468–470.)

The space-charge characteristic of an amplifier valve is a $V^{3/2}$-curve only in the ideal case of a very long uniformly hot cathode, *i.e.*, neglecting the end-effects. The paper gives a formula which allows for the cooling effect of the filament leads and which agrees with an experimental curve.

ELECTRON REFLECTION FROM COBALT, AND ELECTRON WAVES.—M. N. Davis. (*Nature*, 4th May, 1929, V. 123, pp. 680–681.)

"Measurements by a number of observers of the velocity distribution of the electrons leaving the surface of a metal under bombardment by a beam of electrons of known velocity have shown that a part of the secondary electrons have the primary velocity, the rest having, in general, a lower velocity. No attempt appears to have been made to resolve the secondary emission into its two components when the secondary emission is studied as a function of the velocity of the primary electrons. This is a preliminary account of the results of such an experiment" [on cobalt].

EXPERIMENTELLES ÜBER DEN ELEKTRONENAUSTRITT AUS METALLEN (Experimental Results on Electron Emission from Metals).—F. Rother and E. Münder. (*Physik. Zeitschr.*, 1st February, 1929, pp. 65–68.)

The writers obtain results contradicting those of Millikan and Eyring with the same arrangement (cylinder and stretched axial wire).

ON ELECTRONS THAT ARE "PULLED OUT" FROM METALS.—E. H. Hall. (*Proc. Nat. Acad. Sci.*, March, 1929, V. 15, pp. 241–251.)

THERMIONIC CURRENT IN DENSE GASES WITH CYLINDRICAL ELECTRODES.—H. König. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 362.)

HYSTERETIC EFFECTS IN THE POSITIVE EMISSION FROM HOT BODIES.—H. P. Walmsley. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 361.)

SHOT EFFECT IN THERMIONIC EMISSION FROM OXIDE-COATED ELECTRODES.—N. H. Williams and W. S. Huxford. (*Phys. Review*, No. 1, 1929, V. 33, p. 118.)

From measurements of the shot effect conclusions can be drawn as to the charges on the positive thermions. From a special barium-oxide-coated hot cathode, both positive and negative ions were emitted; measurements of the ion charges gave the same value as for the electron charges.

DIE ELEKTRONEN- UND IONENSTRÖME IN GASEN BEI NIEDRIGEN DRUCKEN (Electronic and Ionic Currents in Gases at Low Pressures).—G. Spiwak. (*Zeitschr. f. Phys.*, 7th March, 1929, V. 53, No. 11/12, pp. 805–839.)

CONDENSER AS VALVE HEATING ELEMENT.—(Brit. Patent 307325, Graham Amplion and P. Freedman, acc. 5th March, 1929.)

The condenser is raised to the required temperature by means of its dielectric losses.

LES CATHODES À OXYDES: PROPRIÉTÉS, PRÉPARATION (Oxide-coated Cathodes: Properties and Preparation).—— Boussard. (*Bull. d. l. Soc. Franç. d. Phys.*, 15th Feb., 1929, p. 405.)

This paper includes a table according to which the following are the comparative values of the total emission in milliamperes for each watt spent in heating:—pure tungsten 5, thoriated tungsten 30–40, oxide-coated by old methods 30–40, by new methods 100–150. The corresponding slopes of characteristic (mA./v.) are given as 0.1, 0.2, 0.2 and 0.6.

ÜBER DIE SCHWANKUNGEN DER TEMPERATUR LÄNGS EINEM GEGLÜHTEN DÜNNEN WOLFRAMDRAHT (The Temperature Fluctuations along a Thin Annealed Tungsten Wire).—A. Denissoff. (*Zeitschr. f. tech. Phys.*, May, 1929, V. 10, pp. 168–171.)

The author quotes (as an example of the importance of the investigation of the differing local temperatures caused by minute differences of cross section) Becker's statement that the life of a tungsten filament is inversely proportional to the 39th power of the absolute temperature. The method described is a photographic one.

THE SCREEN-GRID VACUUM TUBE.—J. E. Smith. (*Rad. Engineering*, April, 1929, V. 9, pp. 50–54.)

"A semi-technical article covering both the theory and the practical applications of the screen-grid tube, including its use as a space-charge-grid amplifier."

SOME INTERESTING FRENCH VALVES: UNORTHODOX CIRCUITS FOR MULTI-GRID VALVES. (*Wireless World*, 1st May, 1929, V. 24, pp 465–467.)

In the French "bigrille" the inner grid is rarely used as an anti-space-charge grid, but the valve is consistently employed as the frequency changer in superheterodynes, etc. In the "Isodyne" circuit a certain amount of space charge neutralisation is, however, obtained: this is virtually a push-pull arrangement in R.F. amplification, the plate and inner grid being connected to opposite ends of the centre-tapped primary. A special form of valve is the "mixed-grid" valve, in which the two grids are of the same diameter and are interwound, so that there is no "inner" or "outer" grid. The "trigrille" is particularly useful for frequency changing: it can take over the reaction action from the plate, thus definitely separating this action from the feed to the intermediate frequency amplifier. Another three-grid type has the inner and outer grids permanently connected: these are tapped to about half the plate voltage, while the central grid is the control. Then there is a type embodying one filament, two plates, and a grid for each plate; while a valve with one filament, an inner and an outer grid, and two plates, has been used successfully not only for super-heterodyne but also for super-regeneration. Finally, a small "plateless" valve is mentioned, the anode being formed by the metallic deposit on the walls of the bulb. "Its chief characteristic is an almost complete absence of microphonic effect." A French firm's system of nomenclature is described, consisting of the letter A or B and a number. The letter indicates filament consumption (A less than one-tenth, B from one to two-tenths of an ampere) while the number gives amplification factor and mutual conductance: thus A 1404 indicates a μ of 14 and a conductance of 0.4 mA./v.

MULTIPLE VALVES. (French Patent 650441, Philips' Co., pub. 9th January, 1929.)

The one bulb contains several plate-grid systems about a common equipotential cathode, which is a tube indirectly heated (by radiation or electronic bombardment) by an internal filament. The various systems are screened from one another to prevent reaction. The combination of internal filament and tube-shaped cathode can be used for rectifying purposes.

MAKING THE A.C. HEATER TUBE NOISELESS.—A. B. Du Mont. (*Rad. Engineering*, April, 1929, V. 9, pp. 32–33.)

"A review of an investigation of hum and noise caused by various constructions of indirectly heated cathode tubes," ending with the announcement of a new De Forest valve with improved qualities as regards hum, absence of crackling noises, and quick heating.

DIE TELEFUNKEN-RUNDFUNK-RÖHREN 1928 (Telefunken Broadcast Valves, 1928).—G. Jobst. (*Rad. f. Alle*, May, 1929, pp. 208–213.)

RECHERCHES ET ESSAIS SUR LES LAMPES DE T.S.F. (Experiments and Tests on Wireless Valves).—A. Kiriloff. (*QST Franç.*, March and April, 1929, V. 10, pp. 22–29 and 51–55.)

Among the R.F. valves dealt with are the Philips' 430A and 442A, the Marconi screen-grid, and Hull types; also Robinson's two-plate valve for neutralisation. The second instalment (to be continued further) deals with L.F. valves, and refers also to the Galmard coupling-transformer arrangement ("Galmard Survolteur") in which the secondary winding is split to take the coupling condenser, and which is said to form the ideal L.F. coupling, the currents induced in that part of the secondary between condenser and grid neutralising the phase-displacement caused by the large capacity (8–10 mμF.) which is necessary to avoid distortion.

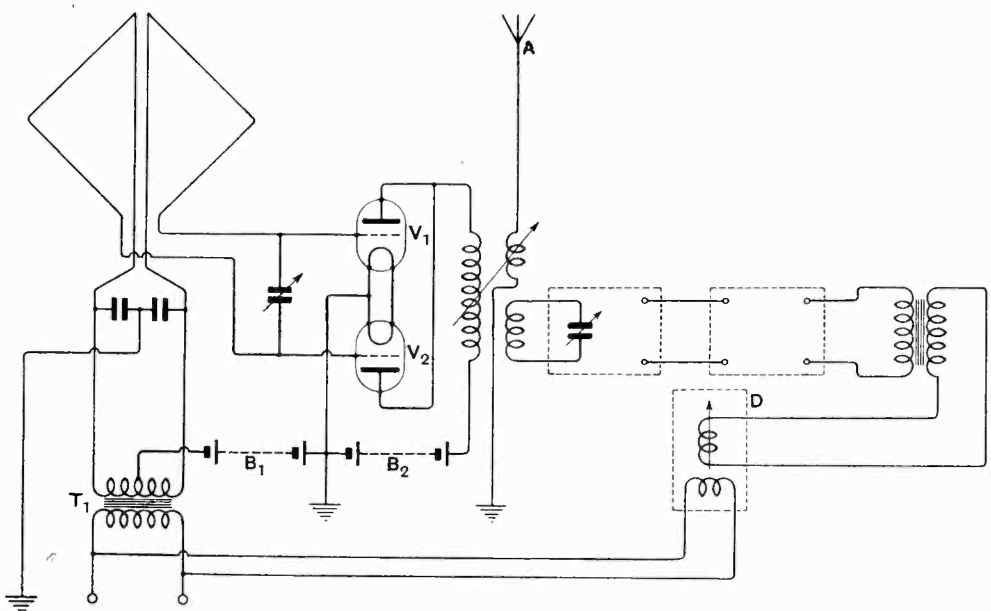
DIRECTIONAL WIRELESS.

DER BORDPEILEMPFÄNGER IM FLUGZEUG (The Direction-finding Receiver for Use on Board Aircraft).—M. H. Gloeckner. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 132–138.)

This second and final part of the paper referred to in June Abstracts deals with results of various flights in which the aircraft has been navigated (a) directly towards a distant transmitter, with no allowance for drift; (b) towards one distant transmitter and away from a second; and (c) by compass, drift being ascertained by the D.F. and allowed for. Comparative results are indicated by diagrams.

DIREKTZEIGENDES FUNKENTELEGRAPHISCHES PEILFAHREN (Direct-reading Wireless Direction-finding Method).—R. Hell. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 138–145.)

The development of this arrangement (intended particularly for aircraft) started with Dieckmann's plan, according to which two frame aerials, at right angles to each other, are connected alternately to a receiver, the output going to a polarised current indicator. A second part of the rotating commutator, which periodically connects the aerials to the receiver, synchronously reverses the connections of the receiver-output to the current-indicator, so that the latter registers a differential effect. This scheme gives four zero-points—*i.e.*, two alternative directions at 180 deg.—and it was found also that while results were good for strong signals (0.5 kw. at 12 km.), at greater distances commutator troubles (sparking and bad contact) developed. The next step therefore was to do away with direct contacts, replacing the commutator by a condenser-system with two sets of fixed plates and one set of continuously rotating plates; this device served to connect the frames alternately to the receiver, and the periodic reversal of the galvanometer was abolished by using a dynamometer whose moving system was permanently connected to the receiver. The fixed coil of the dynamometer was excited from a local A.C. generator mounted on the same axle as the moving condenser plates, in such a way that the A.C. current reached its maximum when one or other of the frames was connected to the receiver. In this way the dynamometer registered the differential effect, and with this arrangement the successful range (steering direct for the transmitting station) was increased to 45 km. The next step was to cut out all mechanical rotating parts and at the same time to obtain a sense-indication which would remove the 180 deg. alternative course. As will be seen from the diagram, one split frame and one (non-directional) aerial is used, and the two valves V_1 and V_2 act as a "commutating device" which connects the frame—in a periodically reversing direction—with the aerial and with the receiver. Their grid circuits are connected so as to act in push-pull fashion both towards the R.F. currents in the frame and towards the L.F. supplied to the transformer T_1 from a local oscillator. Their grid-bias (from B_1) is so adjusted that no plate current flows in either until an A.C. voltage is provided from the transformer: each half-



period of this allows plate-current to flow in V_1 or V_2, and this is reinforced by any R.F. current in the corresponding half-frame. If the frame is at right angles to the bearing-line, the moving coil of the dynamometer *D* only receives the steady output derived from the aerial *A*, and since its fixed coil is fed with L.F. alternating current it shows no deflection. It shows, however, a maximum deflection in one direction when the frame is along the bearing-line, and a maximum deflection in the other direction when the frame is turned through 180 deg. so as to be again along the bearing-line. Thus if the frame aerial is fixed athwartships, the dynamometer needle remains pointing to its central zero so long as the aircraft is heading direct for the transmitting station, moving to left or right as this direction is departed from.

Using a receiver suitable for telephony reception, the Berlin broadcasting station could be steered-to with satisfactory accuracy at 80 km.; while with a heterodyne receiver, using a frame of 1 m.², the Deutschland transmitter at Königswusterhausen gave a maximum deflection of 20 scale divisions at 500 km.

ACOUSTICS AND AUDIO-FREQUENCIES.

Coefficients of Transmission, Reflection and Absorption of Sound.—K. Satô. (*Proc. Imp. Ac., Tokyo*, November, 1928, V. 4, pp. 521–524.)

A simple experimental method is described of measuring the various coefficients for fabric-like materials. A small resonator tuned to a steady source of sound (adjustable in frequency) opens into a conical horn whose mouth is covered by the material under test. At the junction of resonator and horn, a Rayleigh disc measures the sound intensity. Among the results mentioned the transmission and absorption coefficients were found to decrease with increase of frequency for fabrics, but to increase in the case of thick and dense felt or carpet. In English.

Die Wirkung einer endlichen Schirmplatte auf die Schallstrahlung eines Dipoles.—M. J. O. Strutt. (*Zeitschr. f. tech. Phys.*, April, 1929, pp. 124–129.)

German version of the article referred to in May Abstracts, p. 274.

MESSUNG DER SCHALLDURCHLASSIGKEIT MIT HILFE DES HITZDRAHTMIKROPHONS (Measurement of Transparency to Sound by the Hot Wire Microphone).—H. Kietz. (*Physik. Zeitschr.*, 15th March, 1929, pp. 145–160.)

A DIRECT METHOD FOR THE STUDY OF THE CHARACTERISTICS OF AN ACOUSTIC TRANSMITTING SYSTEM.—K. Kobayashi. (*Journ. I.E.E.*, Japan, December, 1928, pp. 1337–1343.)

A method based on the use of a vibrometer provided with a rigid piston diaphragm. (*Cf.* January Abstracts, p. 46.)

ÜBER DEN NACHHALL IN GESCHLOSSENEN RÄUMEN (Echoes in Closed Spaces).—K. Schuster and E. Waetzmann. (*Ann. der Physik*, 12th March, 1929, Series 5, V. 1, No. 5, pp. 671–695); and BERECHNUNG DER SCHALLDICHTE IN EINEM KUGELFÖRMIGEN RAUME (Calculation of Sound Density in a Spherical Space).—K. Schuster. (*Ibid.*, pp. 696–700.)

A DIAPHRAGM-LESS MICROPHONE.—A. L. Foley. (*Sci. News-Letter*, 27th April, 1929, pp. 255–256.)

The sound waves are directed into the air space between two solid metal plates, causing alternating compressions and rarefactions of the air. These rapid changes in the density of the dielectric "permit corresponding electrical surges to cross the space." Development work is continuing and a patent has been applied for.

FIXED GRAIN CARBON MICROPHONE. (German Pat. 452961, Reisz.)

Grains of various sizes are stuck to the base in such a way that they are not covered by the adhesive medium.

BROADCAST RECEIVER FOR THE DEAF. A DESCRIPTION OF A SPECIAL LOUD SPEAKER UNIT WITH SOUND CONDUIT.—C. M. R. Balbi. (*Wireless World*, 8th May, 1929, V. 24, pp. 495–496.)

A LITTLE-SUSPECTED SOURCE OF DISTORTION.—W. F. Sutherland. (*Rad. Engineering*, April, 1929, V. 9, p. 45.)

"The effect on reproduction of loose laminations in the output transformer or impedance," particularly pronounced in push-pull arrangements, since here the direct-current component of the plate current has no effect in magnetising the core and thus adding to the mechanical stiffness of the laminations by tending to keep them spread apart.

DOES A VIBRATING DIAPHRAGM CARRY A MASS OF AIR WITH IT?—G. W. O.H. (*E.W. & W.E.*, March, 1929, V. 6, pp. 117–118.)

In calculations concerned with vibrating diaphragms such as those of loud-speakers, an addition is usually made to the actual mass of the diaphragm "to allow for the mass of the air which is moved with the diaphragm." The writer examines this point to see whether its usual acceptance as an obvious fact is justified, and concludes that the apparent attachment of a quantity of air to the diaphragm is "a convenient fiction which is only necessary in the case of divergent sound waves, because such waves cause a phase displacement between pressure and velocity which can be simulated by an increase of the mass of the diaphragm."

PHOTOTELEGRAPHY AND TELEVISION.

L'AMPLIFICATION DANS LA TÉLÉVISION (Amplification in Television).—G. H. D'Ailly. (*QST Franç.*, March, 1929, V. 10, pp. 45–51.)

The writer shows, from fundamental principles, how amplification in television presents difficulties which do not exist for sound-amplification thanks to the fact that the ear is not sensitive to phase-displacements, and also to the fact that sound reproduction does not involve the sudden large current-changes experienced in reproducing—say—the contour of an image. In a subsequent part he will apply these facts, and his analysis of them, to various common types of amplifier.

MARCONI-WRIGHT FACSIMILE SYSTEM.—G. M. Wright. (*Marconi Review*, January, February and March, 1929, pp. 5–6, 1–8 and 1–8.)

SULLA DIPENDENZA DALLA TEMPERATURA DELL' EFFETTO FOTOELETTRICO DI CONDUCIBILITA NEL JODURO MERCURICO (ROSSO) (On the Dependence on Temperature of the Photo-electric Effect on Conductivity, in Red Iodide of Mercury).—L. Piatti. (*Nuov. Cim.*, January, 1929, V. 6, pp. 14–35.)

ÉTUDE DE LA PRÉPARATION ET DES PROPRIÉTÉS OPTIQUES ET MAGNÉTO-OPTIQUES DES COUCHES TRÈS MINCES DE FER (Study of the Preparation and Optical and Magneto-optical Properties of Very Thin Films of Iron).—M. Cau. (*Ann. de Phys.*, April, 1929, V. 11, pp. 354–449.)

APPLICATION OF TALBOT'S LAW TO PHOTO-ELECTRIC CELLS WITH A NON-LINEAR ILLUMINATION-CURRENT CHARACTERISTIC.—G. H. Carruthers and T. H. Harrison and TALBOT'S LAW, FATIGUE, AND NON-LINEARITY IN PHOTOELECTRIC CELLS.—W. S. STILES. (*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 792–811 and 812–820.)

The writers of the first paper find that Talbot's Law (on the effect of intermittent light on the retina) holds for photoelectric cells even when these have a non-linear characteristic; which unexpected result they suggest is due to the non-linearity of these cells being due to "short-period" fatigue (*i.e.*, fatigue which occurs in the first few seconds after switching on the light). The second paper mathematically investigates this suggestion and shows that, making the "natural" assumptions about the form of the fatigue and recovery curves, obedience to the law implies that the initial response of the cell is proportional to the light-intensity.

and that in the case of non-linear cells the total amount of the fatigue is proportional to the square of the light-intensity.

SELENIUM AND CATHODE RAYS.—C. E. S. Phillips. (*Nature*, 4th May, 1929, V. 123, pp. 681–682.)

The writer has obtained evidence of direct action of cathode rays on the grey crystalline form of selenium; a rapid diminution of resistance taking place. Conditions of the experiment are described, and conclusions drawn.

BECQUEREL EFFECT IN CELLS CONTAINING GRIGNARD COMPOUNDS.—R. T. Dufford. (*Phys. Review*, No. 1, 1929, V. 33, pp. 119–120.)

Grignard reagents are organic magnesium halogen compounds. The greatest photoelectric effects are shown by solutions of those which display the strongest luminescence on oxidation.

ÜBER DEN EINFLUSS DES WASSERSTOFFS AUF DIE LICHTELEKTRISCHE ELEKTRONENEMISSION DES KALIUMS (The Influence of Hydrogen on the Photoelectric Electron Emission of Potassium) and WASSERSTOFFIONEN ALS URSACHE FÜR DAS AUFTRETEN DER LICHTELEKTRISCHEN SPEKTRALEN SELEKTIVITÄT DES KALIUMS (Hydrogen Ions as the Cause of the Photoelectric Spectral Selectivity of Potassium).—R. Suhrmann and H. Theissing and R. Suhrmann. (*Zeitschr. f. Phys.*, No. 7/8, 1928, V. 52, pp. 453–463, and *Physik. Zeitschr.*, No. 22, 1928, V. 29, pp. 811–815.)

ÜBER DIE SÄTTIGUNG DES LICHTELEKTRISCHEN STROMES (On the Saturation of Photoelectric Current).—J. A. Becker. (*Naturwiss.*, 4th January, 1929, V. 17, p. 12).

A defence of the Becker-Müller theory against Suhrmann, who has attacked it on the grounds of his discovery that short wave light gives a saturation effect, while very long wave light produces a current increasing regularly with the applied voltage.

MEASUREMENTS AND STANDARDS.

HIGH-FREQUENCY MEASUREMENTS.—M. v. Ardenne. (*Elektrot. u. Masch:bau.*, 11th November, 1929, V. 46, pp. 1086–1089.)

After a brief description of the technique of modern R.F. measurement, the writer describes the apparatus in his own laboratory. He lays stress on the multiple uses of the valve voltmeter and describes installations (using this instrument) for the measurement of the degree of amplification of R.F. amplifiers, of the logarithmic decrement of an oscillating circuit, and of the selectivity of a receiver. For the investigation of inter-electrode capacities, special apparatus is required. See also January Abstracts, p. 47.

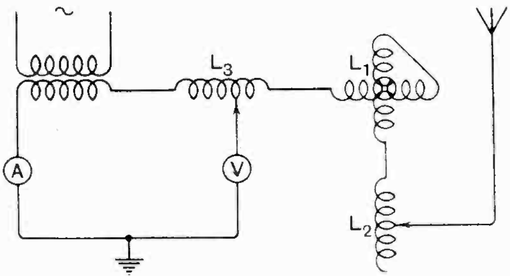
THE MEASUREMENT OF THE VOLTAGE AMPLIFICATION FACTOR OF TETRODES.—W. Jackson. (*E.W. & W.E.*, May, 1929, V. 6, pp. 252–254.)

"The use of a slightly modified form of Miller's alternating current bridge has enabled the values of μ_0 and R_p to be measured directly, simultaneously with the recording of the valve characteristic; so that their variation over the charteristic could be analysed at once."

Commenting on his results, the writer says that it would appear that a variation in anode voltage may be attended by a serious drop in the voltage amplification obtainable from a stage of R.F. amplification employing a four-electrode valve. "Since, however, the anode and screen voltages are in general taken from a common supply, the effect of a drop in battery pressure is not so serious . . ." curves indicating that the voltage amplification shows a slight decrease with decreasing anode and screen voltages, but that the mutual conductance increases at the same time; suggesting a probable increase in stage amplification together with a decrease in H.T. supply current required.

LA MÉTHODE CHIREIX POUR LES MESURES DE RÉSISTANCE EN HAUTE FRÉQUENCE (The Chireix Method for the Measurement of H.F. Resistances).—J. Morel. (*L'Industrie Élec.*, 10th November, 1928, V. 37, pp. 493–496.)

This method, depending on the very tight coupling of a resonant circuit with an oscillator, is said to have great advantages over the usual substitution and resonance curve methods; *e.g.*, the resonant circuit being tightly coupled is furnished with plenty of energy. Applied to the measurement of the R.F. resistance of an aerial, the arrangement is shown in the diagram.



The oscillator is set at the required wavelength, variometer L_1 and inductance L_2 being set so that the total aerial wavelength is much longer than this; A, therefore, shows no appreciable deflection. The inductances are then reduced until A shows a convenient deflection. The voltmeter tapping on L_3 is then adjusted for minimum deflection of V; under this condition, the readings of A and V give the resistance of the circuit to the right of the voltmeter. A second method uses a Chireix R.F. wattmeter.

THE CALIBRATION AND CONSTRUCTION OF A STANDARD FREQUENCY METER.—T. D. Parkin. (*Marconi Rev.*, April, 1929, pp. 18–28.)

A short description of the laboratory standard wavemeter adopted by the Marconi Company, together with an account of the method of calibration by alternator which is used for all accurate frequency measurements.

A LOGARITHMIC DEFLECTION INDICATOR.—M. B. Manifold and A. S. Radford. (*Journ. Scient. Instr.*, May, 1929, V. 6, pp. 145–151.)

An indicating instrument is described giving a deflection proportional to the logarithm of the input current over a current range of approximately 100 to 1 and a frequency range of 50 to 10,000 cycles. It is now accepted practice to measure such quantities as sound intensities in logarithmic units known as T.U.'s or decibels, so that the arrangement finds a wide application in the measurement of acoustical outputs of loudspeakers, transmission of complicated networks, and the like. The instrument is a vibration galvanometer which is fed by a constant-frequency current from a steady oscillator (50-frequency Hartley) through a special transformer; the state of saturation of the mumetal core of this is controlled by the current to be measured flowing in a third winding. The article includes reproductions of autographic records, of the frequency transmission of an electrical filter circuit set to cut off above 1,300 cycles, and of the response curve of a gramophone pick-up. Both these were taken by the use of a gramophone record having a continuously variable note.

EXPERIMENTS ON THE CORONA VOLTMETER.—H. B. Brooks and F. M. Defandorf. (*Bur. of Stds. J. of Res.*, October, 1928, V. 1, pp. 589–633.)

A description of work on a modified form of the Whitehead H.T. Voltmeter depending on the appearance of corona.

AUGMENTATION DE LA SENSIBILITÉ DES APPAREILS DE MESURES ÉLECTRIQUES À PIVOTS (Increasing the Sensitivity of Pivoted Electrical Measuring Instruments).—Quevron. (*Comptes Rendus*, 15th April, 1929, V. 188, pp. 1039–1041.)

The writer uses the stronger field obtainable with a saturated electromagnet and thus gains a greater sensitivity. The plan has hitherto been avoided because of the troublesome stray effects of the stronger field on the moving system, but this difficulty is overcome by a special design which renders the field strictly radial. On a first model, 10^{-8}A. or 10^{-5}V. could be "appreciated by direct reading."

"MEKAPION" VALVE ELECTROMETER FOR MEASUREMENTS AND AUTOMATIC RECORDING.—S. Strauss. (*Elektrot. u. Masch: bau*, 11th November, 1928, V. 46, pp. 1083–1086.)

An automatic method depending on the time of discharge of a condenser, applicable to the measurement of current, dosage of X-rays, illumination curves (by the use of photoelectric cells), study of ultraviolet rays in light (by the use of cadmium cells), etc.

ZUR KORREKTUR VON THERMOELEMENTEN BEI TEMPERATURSCHWANKUNGEN DER KALTEN LÖTSTELLE (The Correction of Thermoelements for Temperature Variations of the Cold Junction).—U. Retzow. (*Zeitschr. f. tech. Phys.*, May, 1929, V. 10, pp. 164–168.)

MEASUREMENT OF THE INTENSITY OF HIGH FREQUENCY MAGNETIC FIELDS.—R. H. Mortimore. (*Phys. Review*, No. 1, 1929, V. 33, p. 113.)

Two methods of measurement, for a wavelength range of 12–30 m., are described; by measuring the voltage-drop in a standard inductance by a valve-voltmeter, and by a thermo-element.

UNTERSUCHUNGEN ÜBER DIE ANFANGSSTRÖME IM QUARZ (Investigations on the Initial Currents in Quartz).—A. D. Goldhammer. (*Zeitschr. f. Phys.*, No. 9/10, 1928, V. 52, pp. 708–725.)

Results of a photographic method of investigation were as follows:—in the first $4-7 \times 10^{-2}$ sec., the dependence on time of the initial current can be represented by the formula $i = a.t^{-n}$; later on, the current falls more rapidly. The current/voltage relation is not linear, but a curve whose slope varies in sense at different time-points. The superposition principle is not fulfilled. The reason is to be found in the conductivity of quartz varying with the current passing; it decreases in the direction of the current and increases in the opposite direction. After the crystal had been earthed for a time, the unipolarity of conductivity changed its direction. The author explains these phenomena by the presence of a number of "fast current-carriers," and the increase of their number under the influence of the passage of a current.

GENERAL PROPERTIES OF PIEZO-ELECTRIC QUARTZ AND THE VALUE OF A QUARTZ OSCILLATOR AS A FREQUENCY STANDARD.—S. Namba and S. Matsumura. (*Res. Electrot. Lab. Tokyo*, April, 1929, No. 248.)

In English. (1) Excitation for various modes of vibration:—(*a*) with two electrodes, Curie-cut and 30-degree cut crystals; superfluous and irregular vibrations; (*b*) with four electrodes using a four-electrode valve. (2) Observation of modes of vibration:—luminous discharge at resonance, lycopodium powder. (3) Frequency characteristics; influences of temperature; effects of air-gap; effects of circuit variations.

PIEZO-ELECTRIC RESONANCE-RELAY. (German Pat. 469209, *Radiofrequenz*, pub. 6th December, 1928.)

The luminous charges which are formed when a piezo-electric crystal is excited in a vacuum are used to release the discharge of some other A.C. or D.C. voltage, by means of auxiliary electrodes. Things can be so arranged that the released discharge either continues or ceases when the exciting influence stops. In certain cases the auxiliary electrodes can be dispensed with, the ordinary electrodes carrying the discharge.

NOTE ON A PIEZO-ELECTRIC GENERATOR FOR AUDIO-FREQUENCIES.—A. Hund. (*Bur. of Stds. Journ. of Res.*, February, 1929, V. 2, pp. 355–358.)

After enumerating five different ways of producing audio-frequency quartz-controlled oscillations without using very large crystals, the writer describes and illustrates the method adopted, which consisted in the use of two independent piezo-electric oscillators beating together to give the required note ; results suggest that the arrangement is as good as a tuning fork drive. He refers to the possibility of using only one generator and producing the audible frequency by harmonic division (*see* Abstracts, 1928, V. 5, p. 643).

DIE BEEINFLUSSUNG DES PIEZOELEKTRISCHEN VERHALTENS EINER QUARZPLATTE DURCH RADIUMBESTRAHLUNG (The Effect of Radium Radiation on the Piezo-electric Behaviour of a Quartz Plate).—J. Laimböck. (*Mitt. Inst. f. Ra : forsch.*, No. 221a.)

The piezo-electric constant is considerably increased, to an extent almost proportional to the length of irradiation, by exposure to beta and gamma rays from a Ra preparation. After 7 days there was a rise from 0.6005×10^{-4} to 0.6710×10^{-4}. Left to itself, the quartz gradually returns to its normal condition. Repeated action leads to a decrease of the effect.

THE FORMULA FOR THE OPTICAL ROTATORY DISPERSION OF QUARTZ.—T. Bradshaw and G. H. Livens. (*Proc. Roy. Soc.*, 1st January, 1929, V. 122 A, pp. 245–250.)

After discussing the existing formulæ of Gumlich Kettler, Drude, Lowry and Coode-Adams, and their limitations, the writer proposes a new formula, more complex than Lowry's latest and most accurate one, which fits in with the latest experimental results : in particular, it provides an explanation of the practically constant effect of the infra-red band.

ELASTIC CONSTANTS OF FUSED QUARTZ. CHANGE OF YOUNG'S MODULUS WITH TEMPERATURE. —H. D. H. Drane. (*Proc. Roy. Soc.*, 1st January, 1929, V. 122 A, pp. 274–282.)

When fused quartz is heated, its elastic constants for stretch shear and bulk change all increase, a sharp distinction in behaviour from that of most other elastic solids. The present paper deals with the determination of Young's modulus, and a comparison of the results with those of other workers leads to the conclusion that there must be actual variability of the modulus from one specimen to another. "There remains as a problem the specification of the precise thermal and mechanical treatment necessary to yield a specimen of fused quartz with fixed mechanical and optical characteristics"—for there appears to be some close relationship between the optical anomalies found by Rayleigh in examining specimens of vitreous silica, and the irregularities in mechanical behaviour.

MAGNETOSTRICTION IN NICKEL STEELS.—J. S. Rankin. (*Journ. R. Tech. Coll. Glasgow*, January, 1929, pp. 12–19.)

MAGNETOSTRICTION AND THE PHENOMENA OF THE CURIE POINT.—R. H. Fowler and P. Kapitza. (*Proc. Roy. Soc.*, 2nd May, 1929, V. 124 A, pp. 1–15.)

An investigation of Heisenberg's theory of ferromagnetism (Abstracts, 1928, V. 5, p. 647) to see whether it can "also provide a natural home for the associated phenomena of the Curie point and for magnetostriction." The writers say : "As a result we think we may claim that the change of size at the Curie point and magnetostriction will both fit satisfactorily into Heisenberg's theory. We cannot, of course, go beyond a very rough quantitative comparison."

SUR UN CHRONOGRAPHE ENREGISTRANT LE DIX-MILLIÈME DE SECONDE (A Recording Chronograph registering the Ten-thousandth of a Second).—P. Lejay. (*Comptes Rendus*, 22nd April, 1929, V. 188, pp. 1089–1091.)

This instrument is for use with the author's free-swinging pendulum, which depends on capacity-interaction between an oscillator and an amplifier for its supply of energy.

INFLUENCE OF A VACUUM ON THE RADIUM CLOCK.—S. Borovik and Afanasjeva. (*Leningrad Comptes Rendus*, No. 24, 1928.)

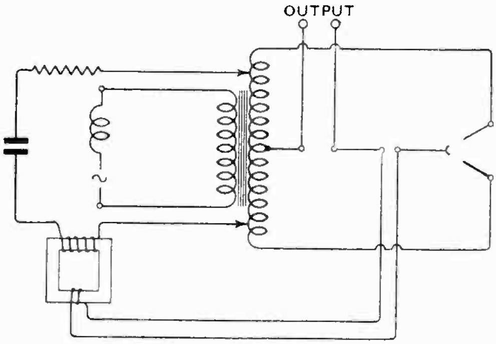
THE ESTABLISHMENT OF A GENERAL FORMULA FOR THE INDUCTANCE OF SINGLE-TURN CIRCUITS OF ANY SHAPE.—V. I. Bashenoff. (*E.W. & W.E.*, May, 1929, V. 6, pp. 245–251.)

ÜBER EIN VERVAHREN ZUR BEURTEILUNG STATISCHER HÄUFIGKEITSKURVEN (A Procedure for the Judging of Static Frequency- or Distribution-Curves).—H. C. Plaut. (*Zeitschr. f. tech. Phys.*, May, 1929, V. 10, pp. 175–177.)

SUBSIDIARY APPARATUS AND MATERIALS.

HOCHFREQUENZ-GLEICHRICHTER-ANLAGE MIT AUTOMATISCHER KONSTANTHALTUNG DER GLEICHSPANNUNG (H.F. Rectifying Plant with Automatic D.C. Voltage Stabilisation).—P. Hermanspann. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 121–127.)

The object was to obtain a high tension (over 20 kv.) D.C. supply more adequately smoothed



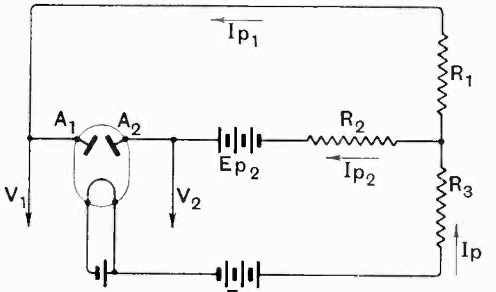
than usual and with stabilised voltage under varying load. For the sake of better smoothing, a Lorenz single-phase generator was used, giving 8,000 p.p.s. Comparative tests were made of air-cored and iron-cored transformers (ring-shaped, to reduce leakage). The latter—whose core was of the very thinnest sheets of "high-frequency iron" such as are used in static frequency-changers —showed a marked superiority.

The voltage stabilisation was performed by shunting the working-circuit by a variable reactance-circuit, and allowing the working current to vary the reactance in such a way as to keep the voltage constant. This was done by passing the (rectified) working current through an auxiliary winding of the iron-cored choke in the reactance-circuit, as shown in the diagram.

As will be seen from the diagram, the reactance-circuit is not right across the transformer secondary but is tapped down; otherwise, the resistance in this circuit would have to be large to keep down the additional load, and this would spoil the sharpness of compensation. Curves are given showing the excellent voltage-stabilisation during a change of output from 1 to 6 amps. (All these tests were on an output voltage of about 80 v. only, for ease of measurement).

Triode Jumper.—H. Nukiyama and K. Nagai. (*Tech. Rep. Tôhoku Imp. Univ., Sendai*, 1929, No. 2, V. 8, pp. 31–39.)

The flow of secondary electrons from "emitting anode" A_1 is gathered to the "collecting anode" A_2: if R_1, R_2 and R_3 are properly chosen, I_{p1} decreases, and at the same time I_{p2} increases discontinuously, when E_p is increased continuously, so that "jumping" phenomena arise.



If the actuating potential is added to E_p, and one or more of the various currents flow through the coils of an electromagnetic relay, a jumping relay is obtained. The three electrodes may be provided by an ordinary triode, or tetrode (the surplus electrode, in the latter case, being kept at a proper potential.) Instead of working the relay directly, the circuit may be connected to a second valve in whose plate circuit the relay functions. Regarding applications, the author says that the relay armature "may be applied to a printing machine directly or be used as a switch of a second relay. The writer also used a relay of this kind with a constant temperature furnace and a constant frequency oscillator and has obtained good results." Mention is also made of use in multiplex telegraphy.

On the Capacity of Dry Electrolytic Condensers.—P. R. Coursey. (*E.W. & W.E.*, March, 1929, V. 6, pp. 128–132.)

Les Piles Électriques d'après les Brevets récents (Primary Batteries according to Recent Patents).—L. Jumau. (*Rev. Gén. de l'Élec.*, 27th April, 1929, V. 25, pp. 649–662.)

This paper describes in some detail not only many recent types of cells, wet and dry, but also various methods of manufacture. It is to be continued.

Ein neuer Glimmlichtröhren Gleichrichter (A New Glow-discharge Rectifier).—J. Preuss. (*Rad. f. Alle*, May, 1929, pp. 220–221.)

Description of the Seibt "Anotron D," for full-wave rectification up to 250 mA. at 1,000 v.

Neue Glimmlichtgleichrichter (New Glow-discharge Rectifiers).—K. Teucke. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 145–148.)

A paper on the Seibt "Anotron."

Die Castings in the Modern Radio.—L. H. Pillion. (*Rad. Engineering*, April, 1929, V. 9, pp. 34–37.)

"A short history of metal moulding and detailed data on present-day die casting as applied to modern industry."

Analysis of Papers Employed in Radio Manufacturing. 1.—The Microscope as an Asset in the Radio Laboratory.—I. L. Gartland. (*Rad. Engineering*, April, 1929, V. 9, pp. 27–32.)

Sparkless Commutation.—(French Patent, 651741, Igra, published 27th February, 1929.)

To prevent sparking of small machines worked near wireless receivers, all the segments of the commutator are connected together through suitably high resistances—this is arranged by cutting a groove round the commutator and filling it with a semi-conducting material.

Recording by Perforating.—M. Metfessel. (*Science*, 5th April, 1929, V. 69, pp. 382–383.)

The use of a pin to replace various types of fountain pen and pencil recorders is recommended as requiring no adjustments or refillings. Such a method has been very successfully used for tuning-fork recording.

An X-Ray Tube with Detachable Ends and Electrodes.—W. Band and A. J. Maddock. (*Journ. Scient. Instr.*, May, 1929, V. 6, pp. 160–163.)

A Braun Tube Hysteresigraph.—J. B. Johnson. (*Bell Tech. Journ.*, April, 1929, V. 8, pp. 286–308.)

A cathode-ray oscillograph is combined with an amplifier and an electrical integrating circuit (condenser and resistance) for the purpose of observing hysteresis loops of magnetic materials. Alternating flux as low as one maxwell may be readily observed.

OSCILLOGRAPHS FOR RECORDING TRANSIENT PHENOMENA.—W. A. Marrison. (*Bell Tech. Journ.*, April, 1929, V. 8, pp. 368–390.)

See June Abstracts, p. 341.

STATIONS, DESIGN AND OPERATION.

DER GLEICHWELLEN-RUNDFUNK (Common Wave Broadcasting).—W. Hahnemann and F. Gerth. (*E.N.T.*, April, 1929, V. 6, pp. 151–157.)

Discussing the advantages and disadvantages of the two possible ways of common wave broadcasting (the system of independent transmitters where the carrier waves are kept constant by the personnel at each station—they must not differ by more than about 15 p.p.s.—and the system in which the carrier frequency is distributed from a central station) it is stated that tests show that the interference zone stretches over more than 90 per cent. of the distance between two stations for the former system, and over only 15 per cent. for the latter. The rest of the paper deals with the Lorenz System now being tried for the district E. Berlin, Stettin and Magdeburg. It concludes by the remark "It must be left to the future to see whether the experience gained will lead to a wide system of common wave transmitter groups. In particular, a decision is needed with regard to the still open question—whether the modulation to all the transmitters must be kept in phase by the introduction of artificial cable."

MARCONI PORTABLE SHORT-WAVE MILITARY TRANSMITTER AND RECEIVER, TYPE S.A.I. (*Marconi Rev.*, October, 1928, pp. 13–22.)

A 25–40 w. set, 7–8 m. wave-range, for telephony and I.C.W. An account of its development and performance is given in the December issue.

LAY-OUT AND TESTS OF A SHORT-WAVE TRANSMITTER. PART I—DESIGN; PART II—RESULTS OF TESTS.—E. Takagishi, E. Iso and S. Kawazoe. (*Res. Electrot. Lab. Tokyo*, Nos. 243 and 246.)

In Japanese. The transmitter is capable of delivering about 1 kw., for a wave-range of 30–40 m., for telephony.

LES CODES MÉTÉOROLOGIQUES (The Meteorological Codes). (*QST Franç.*, March, 1929, V. 10, pp. 33–40.)

Final part of the series whose first part was dealt with in March Abstracts, p. 165.

RADIO SIGNAL TRANSMISSIONS OF STANDARD FREQUENCY, MARCH TO JULY. (*Bureau of Stds., Tech. News Bull.*, March, 1929, No. 143, pp. 22–23.)

A new schedule of signals from WWV. The modulated signals hitherto sent are being replaced by C.W.

EFFECT OF SIGNAL DISTORTION ON MORSE TELEGRAPH TRANSMISSION QUALITY.—J. Herman. (*Bell Tech. Journ.*, April, 1929, V. 8, pp. 267–285.)

GENERAL PHYSICAL ARTICLES.

THE PROBLEM OF THE INTERACTION OF RADIATION AND THE ELECTRON.—R. D. Kleeman. (*Science*, 5th April, 1929, V. 69, pp. 380–381.)

The writer claims to have solved this problem through his deductions, from thermodynamical investigations,of the following electron properties :—(*a*) Possession of internal apart from kinetic energy; (*b*) two different ways of radiation; firstly, on undergoing acceleration, and secondly, on emitting a part of its internal energy as radiation not necessarily connected with its motion; (*c*) the slowing down of its motion and hence increase in internal energy due to the surrounding radiation; (*d*) the force acting upon it when placed in an electric field depends on its internal energy, and in a general way decreases with it. It may therefore happen that under certain conditions it does not possess any electric field at all. "By means of these results and the laws of conservation of energy and momentum, and that radiation is *emitted* in quanta (the nature of the process of emission of radiation does not seem to be determined by thermodynamics), the various phenomena on the interaction of radiation and the electron may be explained—at least there is nothing the writer has not, so far, brought into line. For example, all the inherent difficulties of the Bohr atom, and its antagonism to the Lewis, Langmuir atom, completely disappear. The results thus furnish the solution of a problem in physics and chemistry that has absorbed the attention of scientists for the last thirty years."

THERMODYNAMICAL PROPERTIES OF THE ELECTRON, AND ATOMIC THEORY.—R. D. Kleeman. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 493–504.)

"It appears from this paper that electromagnetic radiation may spread evenly in space, and may be absorbed by electrons and atoms in indefinite amounts, which appear in the form of internal energy. This energy may be radiated in part or altogether into space, but only as a continuous train of waves whose energy is equal to $h\nu$. With this as basis, all radiation phenomena may be explained, of which an outline has been given in this paper."

QUANTUM THEORY OF ATOM DISRUPTURE.—G. Gamow. (*Zeitschr. f. Phys.*, No. 7/8, 1928, V. 52, pp. 510–515.)

An investigation of the radioactive and artificial disintegration of atoms according to the principles of wave mechanics. It is concluded that for disintegrable elements a proton is almost always split off when an alpha particle penetrates the nucleus. The probabilities of penetration for heavier atoms, such as iron, are found to be infinitesimal (using *RaC′* alpha particles), a result completely disagreeing with the ideas of the Viennese workers. An outline of the above investigation, containing further points, is given in *Nature*, 24th November, 1928, V. 122, pp. 805–806.

THE STRUCTURE OF ATOMIC NUCLEI.—(*Nature*, 16th February, 1929, V. 123, pp. 246–248.)

A summarised account of the discussion at the Royal Society on 7th February.

SUR LA THÉORIE SYNTHÉTIQUE DES CHAMPS (The Synthetic Field Theory).—A. Einstein. (*Rev. Gén. de l'Élec.*, 27th April, 1929, V. 25, pp. 644–648.)

A translation of the Unified Field Theory paper, with an introduction by de Donder.

INFLUENCE OF A MAGNETIC FIELD ON THE DIELECTRIC CONSTANT.—J. J. Weigle; and DIELECTRIC ANISOTROPY.—M. Jezewski. (Summarised in *Science Abstracts*, Sec. A., 25th March, 1929, p. 272.)

LES THÉORIES MODERNES DU MAGNÉTISME (Modern Theories of Magnetism).—L. Bruninghaus. (*Rev. Gén. de l'Élec.*, 9th and 16th February, 1929, V. 25, pp. 197–210 and 237–244.)

The writer concludes that the most diverse tests (Weiss, Cabrera, Honda and others) on substances extremely varied in chemical nature and physical state show that in almost every case the atomic moments are whole multiples of an elementary moment which may be called the "experimental magneton." It now remains to find the relation between this and the theoretical Bohr magneton. This perhaps may be done by finding what modifications the quantic conditions undergo in passing from the free atom of a diluted vapour of silver to the firmly-bound atom of a crystal of iron.

UNE HYPOTHÈSE SUR LA NATURE DE L'HYSTÉRÉSIS (A Hypothesis as to the Nature of Hysteresis).—A. Guilbert. (*Rev. Gén. de l'Élec.*, 5th January, 1929, V. 25, pp. 7–17.)

A thermodynamic theory of hysteresis.

ENKELE METINGEN OVER HET BARKHAUSEN-EFFEKT (Some Measurements on the Barkhausen Effect).—G. J. Sizoo. (*Physica*, February, 1929, pp. 43–50.)

DIE POLARISATION DES ELEKTRONSTOSSLEUCHTENS BEI EDELGASEN (The Polarisation of the Electron-impact Light in the Inert Gases).—K. Steiner. (*Zeitschr. f. Phys.*, No. 7/8, 1928, V. 52, pp. 516–530.)

CHART OF THE ELECTROMAGNETIC ENERGY RELATIONS.—W. E. Deming. (*Journ. Opt. Soc. Am.*, January, 1929, V. 18, pp. 50–52.)

A tabulation and a graph, both designed for the rapid answer of such questions as "What frequency corresponds to an electron having a speed of 500 volts?" or "What is the fractional relativity increase in transverse mass of a body moving with a speed of 2×10^{10} cm./sec.?" The wavelengths range from beyond the longest electric waves to beyond the shortest possible wavelength from an oscillating electron (corresponding to a frequency of about 3×10^{22} on the classical theory).

ON THE ELECTROMAGNETIC FIELD OF AN ELECTRON.—THE ELECTRON AS A GRAVITATIONAL PHENOMENON.—D. Meksyn. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 425–433.)

SYMPOSIUM ON QUANTUM MECHANICS.—(*Journ. Franklin Inst.*, April, 1929, V. 207, pp. 449–542.)

Fourteen papers read before the American Physical Society.

THE RELATIVITY THEORY OF DIVERGENT WAVES.—O. R. Baldwin. (*Proc. Roy. Soc.*, 6th March, 1929, V. 123 A, pp. 119–133.)

THE QUANTUM THEORY.—H. S. Allen. (*Nature*, 8th December, 1928, V. 122, Supplement pp. 887–894.)

Light Quanta: the Radiation Problem: Integral Relations in Science: the Rutherford-Bohr Atom: the Quantum Postulates: Matrix Mechanics: Wave Mechanics: the New Outlook.

THE PHYSICAL INTERPRETATION OF WAVE MECHANICS.—G. Temple. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, Part I, pp. 60–82.)

Author's abstract: "The object of this paper is to give an account of the fundamental principles of wave mechanics in a manner which shall make clear the physical significance of all the quantities and processes involved. The principles are illustrated by discussions of the propagation of free electric waves in uniform electromagnetic fields and of bound electric waves in the hydrogen atom. The paper concludes with relativistic wave mechanics (prior to the work of Dirac and Darwin) and a short account of the Compton effect." Later on he says: "Modern quantum theory is content with the quantisation of the optical energy transferred in processes of emission and absorption, and contemplates with equanimity the possibility that free radiation may be governed only by classical laws of continuity. It will be shown in this paper that a similar self-denying ordinance may be welcomed in the theory of electrons."

THE FUNDAMENTALS OF ELECTRODYNAMICS.—W. F. G. Swann. (*Journ. Franklin Inst.*, November, 1928, V. 206, pp. 571–595.)

NEUE WEGE IN DER PHYSIK (Fresh Paths in Physics).—E. Schrödinger. (*E.N.T.*, December, 1928, V. 5, pp. 485–488.)

An address recently delivered in Berlin.

HEATS OF CONDENSATION OF ELECTRONS ON PLATINUM IN IONISED HE, NE, AND A.—C. C. Van Voorhis and K. T. Compton. (*Phys. Review*, June, 1928, V. 31, p. 1122.)

MEASUREMENT OF THE CHARGE OF POSITIVE IONS BY THE SHOT EFFECT.—N. H. Williams and W. S. Huxford. (*Phys. Review*, June, 1928, V. 31, pp. 1120–1121.)

MESSUNG DER WÄRMEENTWICKLUNG BEI DER KONDENSATION VON ELEKTRONEN IN METALLEN (Measurement of the Heat developed by the Condensation of Electrons in Metals).—R. Viohl. (*Ann. d. Physik*, No. 18, 1928, V. 87, pp. 176–196.)

A description of the apparatus and method successfully employed.

LES PELLICULES SPHÉRIQUES ÉLECTRISÉES ET LES ORBITES PRIVILEGIÉES DE BOHR-SOMMERFELD (The charged spherical particles and the Bohr-Sommerfeld "preferential orbits"). —L. Décombe. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 823–826.)

In previous communications the author has connected the spectral emission with the beats occurring between the true pulsations of the electrons which follow these orbits. The present note, combined with the previous work, is designed to "safeguard the undulatory point of view by making it penetrate—in a simple and concrete form—into a domain which has been taken possession of by the theories of emission with a success more apparent than real." A simple physical interpretation is found for the Rydberg constant, as was done before for the Planck constant.

THE WAVE THEORY OF THE ELECTRON.—J. M. Whittaker. (*Proc. Camb. Phil. Soc.*, October, 1928, V. 24, pp. 501–505.)

Dirac has shown how the "duplexity" phenomena of the atom can be accounted for without recourse to the hypothesis of the spinning electron, using the methods of non-commutative algebra. Darwin has given an alternative presentation of the theory, using the methods of wave mechanics; his work can only be given invariance of form at the expense of much additional complication, the four wave functions used by him having to be replaced by sixteen. The present paper describes a method avoiding this difficulty.

ÉTUDE DES RADIATIONS SÉCONDAIRES OBSERVÉES DANS LA DIFFUSION MOLÉCULAIRE DE LA LUMIÈRE PAR LES FLUIDES—EFFET RAMAN (Study of the Secondary Radiations observed in the Molecular Diffusion of Light by Liquids—Raman Effect).—P. Daure. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 826–828.)

By photometric research on halogen derivatives of arsenic and phosphorus, the writer has measured the ratio of the intensities of the positive and negative rays, and the ratio of two secondary rays of the same frequency excited by two different radiations. Regarding the former ratio, Venkateswaren had proposed an exponential formula to connect this with the exciting frequency. The equation which seems to fit in with the observed results is $r = e^{-\frac{n}{21.7}}$ where r is the ratio and n the exciting frequency in wavelengths per millimetre. Results with the second ratio show that the secondary ray increases uniformly with the exciting frequency, but does not follow the N^4 law of molecular diffusion.

ZUR THEORIE DER IONISATION IN KOLONNEN (On the Theory of Ionisation in Columns).—G. Jaffé. (*Ann. der Phys.*, 19th April, 1929, Series 5, V. 1, No. 7, pp. 977–1008.)

An extension of the writer's 1913 and 1914 papers on his theory.

THE ADSORPTION OF HYDROGEN ON THE SURFACE OF AN ELECTRODELESS DISCHARGE TUBE.—M. C. Johnson. (*Proc. Roy. Soc.*, 6th April, 1929, V. 123 A, pp. 603–613.)

Most experiments on the disappearance of gas from discharge tubes are complicated by loss and gain at metal surfaces. Here, the action of hydrogen on glass alone is isolated by the use of the electrodeless discharge: this eliminates internal metal electrodes, and also external "ozoniser" type electrodes which may be open to the objection of allowing slight electrolytic liberation of gases from the glass.

THE MECHANISM OF SPARK DISCHARGE.—L. J. Neuman. (*Proc. Nat. Acad. Sci.*, March, 1929, V. 15, pp. 259–265.)

MISCELLANEOUS.

SUR LA THÉORIE ÉLECTRONIQUE DES MAUVAIS CONTACTS (On the Electronic Theory of Imperfect Contacts).—H. Pélabon. (*Comptes Rendus*, 25th February, 1929, V. 188, pp. 620–622.)

When two conductors are in perfect contact and a field is in existence, the free electrons move in a combined motion with a very great velocity, and Ohm's law is fulfilled. If, on the other hand, the conductors are separated by a very small gap into which the superficial electronic layers penetrate, an "evaporation" of electrons takes place on one of the surfaces and a "condensation" on the other; this method of transportation is much slower, and depends on the strength of the field. Using the mechanism just described, the writer accounts for "all the facts observed with imperfect contacts"; dealing first with D.C., then with A.C.—where he obtains a formula for the rectified current which agrees with his experimental results, and also accounts for the rectifying effect of electrodes in which the only lack of symmetry is that one is more mobile than the other (*see* H. Pélabon, Abstracts, 1929, p. 226)—and finally with H.F. currents, including damped waves. Here, as with the fixed-mobile contacts, the mechanical effect of the electrostatic pressure is called into play. In the above cases the rectified current is in the direction towards the better conductor (towards the mobile conductor in the "symmetrical" fixed-mobile contacts), but it may happen with high frequencies that the mobile electrode rebounds—in which case the rectification is towards the less conducting electrode, as Branly found with PbO_2.

THE EFFECT OF ULTRA-VIOLET AND X-RAYS ON THE STEADY CURRENT CHARACTERISTICS OF CRYSTAL DETECTORS.—W. Jackson. (*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 866–873.)

Ogawa (Abstracts, 1928, V. 5, p. 527) attributes crystal-detector action to the difference of electron emissions from the two electrodes. Palmer suggests that this "cold vacuum tube" analogy is supported by the observed phenomena that improved rectifying properties are obtained when the tendency for electronic emission is increased (*e.g.*, by a small steady potential in the right direction; by heating; by the addition of a small quantity of an impurity, etc.). The writer describes experiments where the effect is tested of rays which should decrease the work necessary to remove an electron, and which therefore might be expected to affect the rectifying property. The effect of ultra-violet rays is to increase conductivity and to decrease slightly the maximum curvature of the characteristic, thus slightly reducing the rectifying properties at the point of best rectification. X-Rays produce on most of the contacts tested the above effect on an exaggerated scale, the unidirectional and rectifying properties being completely destroyed, with no sign of returning after several hours of rest. With a carborundum-steel combination the loss of unidirectional property is noticeable although the rectifying property is retained.

ON THERMOELECTRIC PHENOMENA OF THIN METALLIC FILMS.—T. Terada, S. Tanaka and S. Kusaba. (*Proc. Imp. Acad. Tokyo*, No. 4, 1927, V. 3, pp. 200–203.)

Thin films (5–10μ) show various thermoelectric effects with local heating; for example, if half of a silver film is thicker than the other half, a thermo-current flows from thin to thick.

THE THEORY OF ELECTRICAL RECTIFICATION.—R. de L. Kronig. (*Nature*, 2nd March, 1929, V. 123, p. 314.)

The resistance of a metallic conductor is caused by the transfer of momentum, which the conduction electrons have gained under the influence of the applied electric field, to the ions of the crystal lattice—through collisions; or in the language of wave mechanics, by the scattering of the waves representing the conduction electrons under the action of these ions. Rectification signifies here, therefore, a difference in the scattering power of the circuit for electron waves travelling in opposite directions. The writer suggests that crystal rectification is due to asymmetrical binding of the ions into positions of equilibrium by restoring forces not symmetrical for equal and opposite displacements; such asymmetrical binding would come into play particularly near the boundary, and still more at the edges and corners, of a crystal lattice; it has already been shown to exist even in the interior of certain (rectifying) crystals, by X-ray analysis. The theory thus envisages the possibility of volume rectification (not yet found experimentally) in addition to the usual surface rectification. It would explain the damage to the rectifying property of a point-to-crystal contact when the point is pressed tightly against its base, for in this process the sharp corners are flattened out.

CRYSTAL CLASSIFICATION BY PIEZOELECTRIC TEST.—W. Schneider. (*Zeitschr. f. Phys.*, No. 3/4, 1928, V. 51, pp. 263–267.)

In investigating crystal structure it is often important to know whether the crystal is centro-symmetrical or not. If piezoelectric effects are found the crystal can at once be classed as lacking a centre of symmetry. Test apparatus is described and a list of results given.

DER KUPFERJODÜRDETEKTOR (The Copper Iodide Detector).—E. Habann. (*Zeitschr. f. tech. Phys.*, January, 1929, pp. 25–28.)

Investigation of a new detector, from the results of which various generalisations are drawn as to what ionic properties make a good detector-material.

LE SENS DU COURANT REDRESSÉ PAR UN DÉTECTEUR À CRISTAL (The Direction of the Current rectified by a Crystal Detector).—G. G. Reisshaus. (Summary in *L'Onde Élec.*, March, 1929, V. 8, p. 21A.)

The apparently arbitrary direction of the rectified current, found for example with a copper wire and galena couple, is explained by the theory that the current always flows from the more pointed to the more rounded electrode; the crystal surface being very irregular, with small sharp angles, may—contrary to appearances—be more pointed than the copper wire. The same explanation accounts for the rectifying effects of apparently identical electrodes, *e.g.*, two polished metallic balls. *Cf.* Pélabon and Krönig, above.

THEORETISCHES UND EXPERIMENTELLES ZUM JOHNSON-RAHBEK-EFFEKT (Theoretical and Experimental Investigation of the Johnson-Rahbek Effect).—P. Böning. (*Zeitschr. f. Fernmeld: tech.*, 29th April, 1929, V. 10, pp. 49–55.)

MAN-MADE STATIC: HIGH-VOLTAGE OVERHEAD ELECTRICAL TRANSMISSION LINES AND RADIO INTERFERENCE.—R. L. Smith-Rose. (*Wireless World*, 8th May, 1929, V. 24, pp. 476–480.)

Part I.—Summary of Knowledge and Experience on the Interfering Effects of Overhead Line Networks in Radio Communication. "From the available information as summarised above, it may be fairly definitely concluded that at a wireless receiving station situated outside a minimum distance of the order of half-a-mile from a high voltage overhead distribution line, no interfering or disturbing effects will be experienced due to the existence of the line or the current which it is carrying." The only point upon which no definite information has been traced is the effect of spark discharges from the line on a receiving station not less than half-a-mile away. . . ." This point is dealt with in Part II.—Some Experiments on the Interference Effect of a High-voltage Spark Discharge on a Radio Receiver. "It appears that the minimum distance of half a mile of a wireless receiver from the line, chosen on other grounds [see above] will also ensure freedom from the disturbing effects of spark or arc discharges, except when the receiving station is in electrical connection with the line. In such a case, as previously mentioned [in Part I, where it was pointed out that such connection might reduce the effective distance from the line], the use of special filter circuits in the connection might be necessary and would probably be effective."

PREVENTION OF INTERFERENCE BETWEEN POWER AND COMMUNICATION LINES: PROGRESS IN GERMANY IN 1928.—W. Wagner. (*E.N.T.*, March, 1929, V. 6, pp. 116–117.)

FORMULES RELATIVES À L'ÉTUDE DES BRUITS D'INDUCTION SUR UNE LIGNE DE TÉLÉCOMMUNICATION INFLUENCÉE PAR UNE LIGNE DE TRANSMISSION D'ÉNERGIE (Formulæ regarding Induction Noises in a Communication Line induced by a Power Line).—J. B. Pomey. (*Rev. Gén. de l'Élec.*, 13th April, 1929, V. 25, pp. 555–561.)

MESSUNG DER FERNSPRECHSTÖRWIRKUNG VON STARKSTROMLAGEN (Measurement of Power Station Interference with Telephonic Communication.—L. Roehmann. (*E.T.Z.*, 21st March, 1929, pp. 424–426: Discussion, pp. 432–434.)

HIGH-TENSION MEASUREMENTS AND THEIR TRANSMISSION TO A DISTANCE.—A. Palm. (*Rev. Gén. de l'Élec.*, 23rd March, 1929, V. 24, pp. 463–464.)

French summary of a German paper.

SYSTEMS OF SELECTIVE DISTANT CONTROL.—Y. Shimazu. (*Journ. I.E.E. Japan*, November, 1928, pp. 1213–1231.)

A survey of various methods in use in Europe and America, including the author's own system.

CARRIER TELEPHONE SYSTEM FOR SHORT TOLL CIRCUITS.—H. S. Black, M. L. Almquist, and L. M. Ilgenfritz. (*Journ. Am. I.E.E.*, January, 1929, V. 48, pp. 15–20.)

"Type D" system is described for circuits of shorter lengths than could be spanned economically by the multi-channel types in use for longer distances. It gives one additional telephone circuit per pair of wires, and the equipment can be moved easily from place to place.

WIRED WIRELESS "MONOPHONE" TELEPHONY.—(*Nature*, 11th May, 1929, V. 123, p. 733.)

A paragraph on "a notable invention" announced to the National Academy of Sciences by Squier, the inventor of "wired wireless." The new method, which is called the "monophone," is said to be the perfection of a form of radio guided by telephone lines. "The power taken by a small incandescent lamp would be sufficient to supply five thousand telephones. . . . There would be no difficulty in receiving sound-motion pictures and television." *Cf.* Abstracts, January, p. 53 (O.F.B.) and February, p. 116.

A VOICE FREQUENCY MULTI-CHANNEL TELEGRAPH SYSTEM.—J. M. Owen and J. A. S. Martin. (*P.O. Elec. Eng. Journ.*, January, 1929, V. 21, pp. 267–275.)

A description of the system developed by the G.E.C. with the co-operation of the Post Office. Six separate high speed circuits are provided for telegraph working on a loaded underground cable or other telephone circuit normally adapted to four-wire working. Valve-controlled tuning forks (Eccles and Jordan) are used.

THE TRANSMISSION OF HIGH-FREQUENCY CURRENTS FOR COMMUNICATION OVER EXISTING POWER NETWORKS.—C. A. Boddie and R. C. Curtis. (*Proc. Am. I.E.E.*, January, 1929, V. 48, pp. 37–41.)

The use of tuned choke coils to isolate the communication channel from the remainder of the power system is here treated. Formerly, the natural changes in line characteristics due to switching were so great that a satisfactory communication circuit could not be obtained.

ÜBER DIE STÖRWIRKUNG VON WANDERWELLEN UND DIE GEGENSEITIGE BEEINFLUSSUNG VON TELEGRAPHENLEITUNGEN (The Interference Effects of Surges and the Interaction of Telegraph Lines).—K. Ohashi. (*E.N.T.*, January, 1929, V. 6, pp. 1–8.)

A theoretical investigation.

SOME ADSORPTION ISOTHERMALS FOR A PLANE PLATINUM SURFACE.—W. G. Palmer. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 487–497.)

The method of the electric coherer has been employed to determine the adsorption isothermals of some typical substances. Incidentally it is mentioned that a pure paraffin hydrocarbon of less than 5 carbon atoms in its chain forms on platinum a film so loosely held that the cohering voltage is practically zero.

LUMINOUS DISCHARGE IN GASES AT LOW PRESSURE.—H. Petterson. (*Nature*, 9th March, 1929, V. 123, p. 346.)

Using oscillations of frequency 10^8, and tubes of transparent silica, the writer has obtained the electrodeless discharge in tubes of only 5 mm. diameter under pressures much less than 10^{-5} mm. of mercury. Various effects are described, one of these being only explicable on the assumption that the silica is decomposed, releasing oxygen, by the action of ultra-violet light of very short wave-length generated at the discharge.

LE GRAND ELECTRO-AIMANT DE L'ACADÉMIE DES SCIENCES (The Great Electro-magnet of the Academy of Sciences).—A. Cotton and G. Mabboux. (*Recherches et Inventions*, December, 1928, pp. 453–524.)

A very full illustrated description of the construction and installation of the magnet referred to in Abstracts, 1928, V. 5, p. 529.

RADIOMETER FOR LIGHT FROM PLANETS AND STARS.—C. G. Abbot. (*Sci. News-Letter*, 27th April, 1929, pp. 255–256.)

The moving system is constructed of very small pieces cut from a fly's wing, and is suspended on a very fine quartz thread. Swing is measured by a very small beam reflected from a mirror on to a scale 20ft. distant. "It has been possible to detect the force and analyse the variety of light . . . from stars as small as 3.5 magnitude."

AN INTENSITY GAUGE FOR "SUPERSONIC" RADIATION IN LIQUIDS.—W. T. Richards. (*Proc. Nat. Ac. Sci.*, April, 1929, V. 15, pp. 310–314.)

"The high-frequency sound waves of high intensity . . . recently developed by Wood and Loomis . . . have produced effects in liquid systems, some of which are extremely difficult to account for on the primary properties of compressional waves. Notably the increase in (chemical) reaction velocities . . . has at present no direct or plausible explanation." A reliable measure of the intensity of such compressional waves is a necessary factor in exploring such effects, and the writer describes various attempts to find a satisfactory method :—maintaining a weighted reflecting disc in position : rise in temperature due to absorption of the waves : change in volume of manometric bulbs : retardation of flow of liquid in a capillary tube, etc., etc. The method actually adopted depended on the ear-trumpet principle, the concentrated sound energy being measured as hydrostatic pressure : a small funnel was blown on the end of a capillary tube and immersed in the liquid, the upward displacement of the capillary meniscus giving a measure of the wave-intensity.

CORONA ELLIPSES.—V. Karapetoff. (*Journ. Am.I.E.E.*, March, 1929, V. 48, pp. 203–205.)

A mathematical theory is outlined explaining the general shape of corona cyclograms taken on a cathode-ray oscillograph.

SUR LE CALCUL DES MACHINES ÉLECTROSTATIQUES (The Calculation of Electrostatic Machines).—H. Chaumat. (*Comptes Rendus*, 22nd April, 1929, V. 188, pp. 1096–1098.)

The writer points out how vague are the ideas concerning, say, a Wimshurst machine compared with those about an alternator : "One may say that one multiplies an unknown quantity by an unknown factor." He indicates how such electrostatic machines should be dealt with, and shows the possibility of designing generators to give voltages varying with time according to laws hitherto untried—and possessing perhaps unexpected properties.

COMPARAISON ENTRE LES MACHINES ÉLECTROSTATIQUES ET LES MACHINES DYNAMO À COURANT CONTINU (Comparison between Static Electrical Machines and D.C. Dynamos).—H. Chaumat. (*Comptes Rendus*, 6th May, 1929, V. 188, pp. 1232–1234.)

A refutation of the idea (which "has certainly paralysed the efforts to develop static electrical generators") that these machines have such high internal resistance that the taking of any current from them must cause a quite inadmissible voltage-drop.

POWER FACTOR AND DIELECTRIC CONSTANT IN VISCOUS DIELECTRICS.—D. W. Kitchen. (*Journ. Am.I.E.E.*, April, 1929, V. 48, pp. 281–284.)

The peculiar temperature-variation of dielectric constant and power factor at different frequencies of rosin, rosin oil and castor oil, and the anomalous change in electric double refraction of rosin, are shown to be functions of the viscosity ; this influence of viscosity is explained on the Debye theory of dipole orientation.

ANOMALOUS CONDUCTION AS A CAUSE OF DIELECTRIC ABSORPTION.—J. B. Whitehead and R. H. Marvin. (*Journ. Am.I.E.E.*, March, 1929, V. 48, pp. 186–189.)

ABHÄNGIGKEIT DES WIDERSTANDES ISOLIERENDER UND ANDERER STOFFE VON DER SPANNUNG UND FREQUENZ UND IHRE FOLGEERSCHEINUNGEN : EXPERIMENTELLER NACHWEIS VON RAUMLADUNGEN (The Dependence of the Resistance of Insulating and other Materials on the Voltage and Frequency, and its Results : Experimental Proof of the Existence of Space Charges).—P. Böning. (*Zeitschr. f. tech. Phys.*, March and April, 1929, pp. 82–93 and 118–124.)

THE CHEMICAL ACTION OF ULTRASONIC RADIATION.—Schmitt, Johnson and Olson. (*Nature*, 30th March, 1929, V. 123, p. 506.)

Short notice of a paper in the February issue of the *Journ. of Am. Chem. Soc.*, on further experiments on this action.

LA STÉRILISATION DE L'EAU ET DES LIQUIDES PAR LES CIRCUITS EN METAL EN CONTACT DIRECT AVEC LE LIQUIDE (The Sterilisation of Water and other Liquids by Metal Circuits in direct Contact with the Liquid).—G. Lakhovsky. (*Comptes Rendus*, 15th April, 1929, V. 188, pp. 1069–1071.)

The bactericidal action of silver, described by Doerr in 1900, is explained by the writer as a purely physical effect due to the change of frequency (caused by contact with the mass of metal) in the "very high-frequency oscillations in the core of each cell or microbe." At any rate, the paper gives definite records of the bactericidal property, which the metal loses after a certain amount of use. It can be restored, however, by a treatment which removes the deposits that insulate the microbe from contact with the metal. The white metal platonix produced the same results as silver.

EXPERIMENTS ON THE AMPLIFICATION AND DETECTION OF BIO-ELECTRIC CURRENTS BY MEANS OF THERMIONIC VALVES.—E. Benedetti. (*Nature*, 13th April, 1929, V. 123, p. 590.)

Short note on a Nat. Acad. Lincei (Rome) paper.

"TALKIES" IN THE HOME. (*Scient. Amer.*, April, 1929, p. 354.)

An American Corporation announces that it is ready to supply the public with a standard 16 mm. motion picture projector geared to a phonograph turn-table equipped with electric pick-up. A library service of films and their corresponding records is offered.

TALKING FILMS: NO. 3—THE TRI-ERGON SINGLE-UNIT PROCESS. (*Wireless World*, 10th April, 1929, V. 24, pp. 376–378.)

THE DETECTION OF FLAWS IN RAILS, USING VALVE AMPLIFIERS.—E. A. Sperry. (*Engineer*, 10th May, 1929, V. 147, p. 523.)

A description of the method now being practised by the Sperry Rail Service Corporation of Chicago, which detects flaws or defects representing as little as one-tenth of 1 per cent. of the area of the rail-head, and allows their size, characteristics and exact position to be located. It is equally applicable to non-ferrous metals. Energising (direct) current flows through the portion of the rail between two brushes (which pass over the rail at the rate of about five miles an hour). Midway between these main brushes come three searching brushes connected to the ends and the mid-point of the primary winding of an iron-cored transformer, the two halves of this primary being wound in opposition. The secondary is connected to a four-valve L.F. amplifier which controls a number of relays. One of these controls the release of a spray of paint which is ejected against the side of the rail whenever a defect is found; others control the recording pens and a check buzzer. In addition to its detecting capabilities the apparatus is claimed to have a definite advantageous effect on the rails owing to the magnetising effect of the electricity producing a release of internal strain and an ageing, seasoning and toughening of the metal without affecting its hardness.

MAGNETIC ANALYSIS.—R. L. Sandford. (*Journ. Am.I.E.E.*, January, 1929, V. 48, pp. 7–11.)

A survey of the methods of testing the mechanical characteristics, defects, etc., of ferrous metals, by observations on their magnetic behaviour. *See also* "Apparatus for Thermomagnetic Analysis," by the same author (*Bur. of Stds., J. of Res.*, April, 1929, No. 4, V. 2) illustrated by curves of typical results. "There are influences other than structural transformations which may lead to variations in magnetic characteristics, so that the data of thermomagnetic analysis should always be interpreted with caution. It appears, however, that this hitherto somewhat neglected method should be capable of yielding significant and valuable results."

CO-OPERATION IN SCIENCE AND INDUSTRY.—J. F. Thorpe. (*Nature*, 6th April, 1929, V. 123, pp. 531–533.) And, FINAL REPORT OF THE COMMITTEE ON INDUSTRY AND TRADE (*ibid.*, pp. 538–539.)

DIE BEDEUTUNG DER DRAHTLOSEN TELEGRAPHIE FÜR DIE WISSENSCHAFT (The Importance of Radio Telegraphy in Science).—J. Zenneck. (*Zeitschr. des V.D.I.*, 27th April, 1929, V. 73, pp. 565–573.)

German version of the paper dealt with in April Abstracts, pp. 207, 214 and 219.

RÜCKBLICK AUF DIE WICHTIGSTEN ARBEITEN AUF DEM GEBIETE DER ELEKTROTECHNIK IM JAHRE 1928 (A Survey of the Most Important Developments in Electrical Engineering in 1928).—(*E.T.Z.*, 28th March, 1929, pp. 477–486.)

Some Recent Patents.

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

THERMIONIC CATHODES.

(*Convention date (U.S.A.), 28th October,* 1926. *No.* 279890.)

Valve filaments are made by depositing an oxide coating upon a core or carrier consisting of an alloy of cobalt and nickel and containing a third constituent which may be a ferro-compound of titanium, vanadium, silicon, or manganese added in sufficient quantity to render the alloy forgeable. This alloy replaces the use of platinum, iridium, and similar so-called noble metals, since it has no undesirable reaction with the emissive coating.

Patent issued to Westinghouse Electric & Manufacturing Co.

FREQUENCY MODULATION.

(*Convention date (U.S.A.), 12th July,* 1927. *No.* 293803.)

In receiving signals transmitted in the form of a frequency-modulated carrier wave with constant amplitude, it is usual slightly to detune the receiving circuit and to depend upon the resonance characteristic to secure a quantitative response. The present invention consists in first heterodyning the incoming waves to obtain a frequency-modulated wave of intermediate frequency, which is then analysed by means of a detuned circuit to recover the original signal. In this way the side-band frequencies in telephony transmission can be reduced to a width of only 500 cycles.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

TOROIDAL COUPLING COILS.

(*Application date, 20th October,* 1927. *No.* 304622.)

A toroidal coil is threaded with a number of thin cylindrically wound coils which are moved around the periphery of the toroid so as to vary their mutual coupling. The annular coils may be made of different diameters so that they can be telescoped together to give a high coefficient of coupling.

Patent issued to W. S. Smith and N. W. McLachlan.

LOUD SPEAKERS.

(*Application date, 4th October,* 1927. *No.* 303470.)

The diaphragm is either plane or in the form of a smooth curve, and is substantially unthrottled. A fixed correcting-surface in the form of a plane disc or an annular ring is provided behind the diaphragm, the intervening air-space being adjusted to a critical depth so as to avoid damping. This is stated to eliminate inherent resonance and to give a straight-line response to all frequencies.

Patent issued to The Gramophone Co., Ltd., and A. M. Hallawell.

SOUND-REPRODUCERS.

(*Application dates, 30th January and 27th June,* 1928. *No.* 305429.)

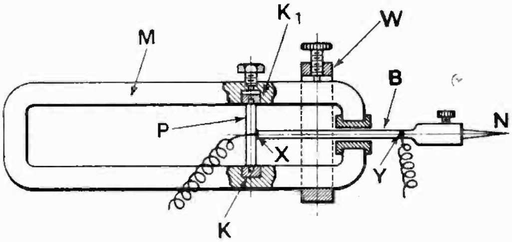
Relates to vibratory sound-reproducers of the kind in which the vibration is at least in part rotational about a real or virtual axis and in which the armature length in a direction perpendicular to the axis is at least as great as the distance of the nearer end of the armature from the axis. When the vibrator is in the form of a plain cantilever reed, as is commonly the case, difficulty is experienced in providing a sufficiently stiff reed which will not become overstressed even when vibrating at large amplitude. According to the invention that portion of the vibratory member which lies between the axis of rotation and the heel of the armature is made stiff, relatively to the armature, either by thickening the metal or by forming webs in it.

Patent issued to M. Trouton and Wireless Music, Ltd.

PICK-UP DEVICES.

(*Convention date (France), 17th February,* 1927. *No.* 285454.)

A laminated blade B, carrying a record needle N, is mounted between the two poles of a permanent or electro-magnet M in such a way as to prevent any movement which is not strictly perpendicular to the lines of force across the pole-gap. This prevents any undesired currents due to parasitic



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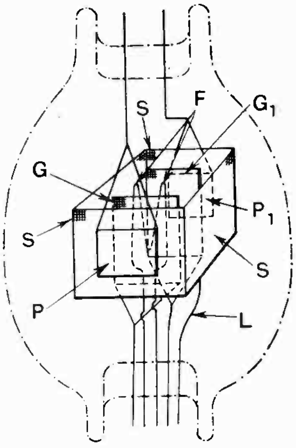
lateral movements of the blade. A pin P mounted in step bearings K, K_1 in the limbs of the magnet serves as pivot for the blade, pressure being adjusted by means of a screw at the bearing K_1. A screw-adjusted stirrup W regulates the width of the air-gap between the poles. The movement of the blade B is constrained in the stated manner by pads of rubber attached to each pole piece as shown. Vibration of the blade at right angles to the magnetic field induces corresponding currents which are collected by leads at the points X, Y, and fed to a pair of earphones, or to the input transformer of a low-frequency amplifier.

Patent issued to H. Hallam and J. R. M. Hélary.

PUSH-PULL S-G AMPLIFIERS.

(*Application date, 28th October*, 1927. *No.* 305251.)

At very high frequencies an undesirable capacity effect comes into evidence between the screening electrode and the plate. This gives rise to high-frequency currents which, flowing to earth through the impedance of the external circuits, create voltage variations and coupling between the screen and the grid. In order to prevent this residual capacity action, particularly in a valve intended for push-pull amplification, two control grids G, G_1 and plates P, P_1 are arranged symmetrically on each side of a central filament F, and the screening electrode S is formed as a box-like structure substantially surrounding both the grids and filament. A single lead L serves to bias the whole screen structure.



No. 305251.

Patent issued to C. S. Franklin.

PREVENTING FADING.

(*Convention date* (*U.S.A.*), *17th August*, 1927 *No.* 295693.)

To prevent fading effects the plane of polarisation of the waves emitted from a directional aerial system is continually varied. Three spaced directional aerials are inclined at different angles to the vertical, and are energised successively from a polyphase source or through suitable phase-regulating impedances. In addition the direction of the transmitted wave is varied slightly. The object is to secure a constant average field strength at the receiving point, in spite of varying reflection effects at the Heaviside layer.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

SCREENED-GRID VALVE CIRCUITS.

(*Application date, 20th October*, 1927. *No.* 304631.)

In order to reduce the damping of oscillatory circuits used in carrier-wave signalling, a screened-grid valve is adjusted to work as a "negative resistance" device. For instance it will operate on the downward slope of its characteristic curve by applying 100 volts to the screen, 6 volts to the control grid, and from 40–80 volts to the anode. A tuned circuit in the anode of the valve is then variably coupled to the oscillatory circuit in question.

Patent issued to W. S. Smith and N. W. McLachlan.

DIRECTION-FINDING BY OSCILLOGRAPH.

(*Application date, 3rd October*, 1927. *No.* 305250.)

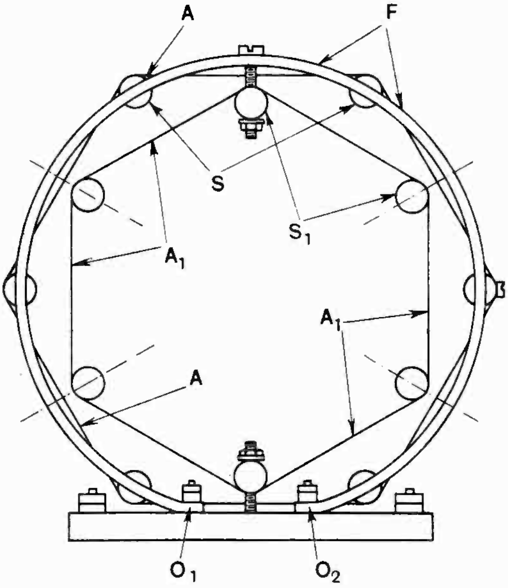
The direction of an incoming signal, or of a casual atmospheric disturbance, is determined by causing the voltages induced in a frame aerial to deflect the path of the ionic stream in a cathode-ray oscillograph. The pick-up voltages from a pair of crossed loop aerials are applied to two corresponding pairs of plates arranged at right angles on the outside surface of the oscillograph tube, and the resulting displacement of the ionic stream from normal indicates the direction of the incoming impulse. In order to remove the 180 degrees ambiguity in direction, the pick-up voltages from the frame aerials are combined with those received on an associated non-directional aerial.

Patent issued to R. A. Watson Watt and L. H. Bainbridge-Bell.

FRAME AERIALS.

(*Application date, 27th September*, 1927. *No.* 305109.)

The aerial wire A is wound over supports S fixed to a resilient or flexible frame F of substantially circular formation. The two metal rings forming the circular frame are broken at a suitable point, the ends O_1, O_2 being mounted on a base, with an intervening gap. The width of the gap determines the tension applied to the windings. A second series of windings A_1 may be strung over a number of draw bolts S_1 extending inside the circular frame. The base may be formed as a turn-table, the ends of the windings making a brushing contact with fixed terminals on the set.



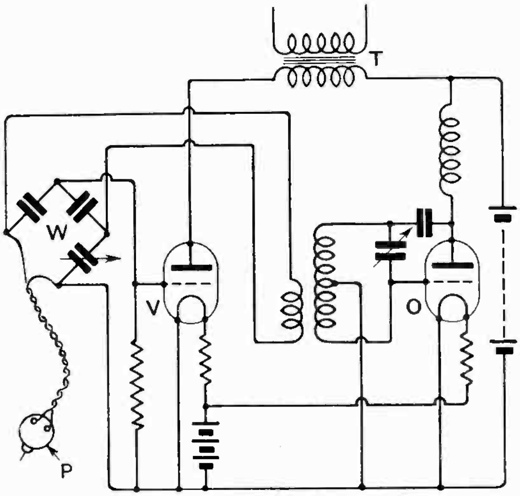
No. 305109.

Patent issued to B. Hesketh.

ELECTROSTATIC PICK-UPS.

(*Application date*, 29*th July*, 1927. *No.* 305052.)

When using an electrostatic type of pick-up for gramophone reproduction, the sensitivity of the arrangement is liable to be affected by the shunt capacity existing across the connecting leads. To remedy this defect, the pick-up *P* is connected in one arm of a balanced Wheatstone bridge *W*.



No. 305052.

Radio-frequency oscillations from a local generator *O* are fed across one diagonal of the bridge, the opposite diagonal being connected across the grid and filament of the input valve *V*, which functions mainly as a detector. As the pick-up moves across the record track, the bridge is unbalanced and modulated radio-frequency impulses are applied to the first valve, which rectifies them, and passes the output to a transformer *T* feeding one or more low-frequency amplifiers.

Patent issued to H. Andrewes and Dubilier Condenser Co., Ltd.

MAINS-SUPPLY UNITS.

(*Application date*, 19*th November*, 1927. *No.* 306436.)

The filaments are fed directly by *AC* current from the mains, whilst the plates are supplied with rectified current from the same source, the necessary components being housed together in one unit. Signal currents to be amplified are applied to a pair of push-pull valves, the filaments of which are supplied in parallel from one section of the secondary winding of the mains transformer. Another section of the secondary supplies heating current to the rectifier unit for the plate current. The plates of the two amplifiers are connected to opposite sides of the secondary winding of the transformer supplying high-tension voltage to the rectifier, so that any voltage variation due to the connection of one portion of the circuit to one point on the secondary is compensated for, and neutralised by, the symmetrical connection of the return path to the opposite side of the same winding.

Patent issued to C. Flanagan.

FREQUENCY-MODULATION SYSTEMS.

(*Convention date* (*U.S.A.*), 1*st September*. *No.* 296678.)

Under ideal conditions signals sent by frequency modulation should not be accompanied by any amplitude variation of the carrier-wave. In practice, however, such amplitude fluctuations are liable to occur, sometimes owing to fading and also to variations in the power input to the transmitter. Accordingly at the receiving end where the circuits are arranged to convert frequency changes into amplitude changes, the output contains the desired signals mixed with undesired amplitude components, and is correspondingly distorted.

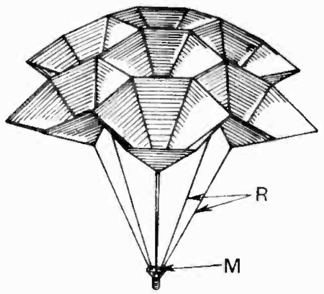
In order to cause the receiving circuits to respond to frequency modulation alone, and to be immune from undesired amplitude fluctuation, the incoming energy is applied co-phasially to two circuits having intersecting resonance curves with maximas lying on different sides of the operative band of signal frequencies. Frequency-modulated energy will then operate one or other of the circuits and so influence the common receiver, whilst amplitude variations are combined in opposition and are thus balanced out.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

LOUD SPEAKERS.

(*Application date* 28*th January*, 1928. *No.* 306263.)

A number of separate diaphragms are symmetrically arranged as shown in the Figure, and are vibrated by the same number of rods *R*, attached to and radiating from a single electromagnetic driving unit *M*. By dividing up the effective vibration surface in this way, a more efficient reproduction of the higher notes is secured since the central area of each separate diaphragm is brought into operation thus forming a total surface larger than that of the central area of a single large diaphragm vibrating under similar conditions. On the other hand, since the natural period of a bank of small equal-sized diaphragms is the same as that of anyone single diaphragm, "drumming" is avoided on the lower notes.



No. 306263.

Further, there is usually sufficient energy available in the driving unit to operate several large-diaphragm speakers, but since such an arrangement is impracticable, the present method allows such energy to be more fully and economically absorbed.

Patent issued to E. V. Mackintosh and C. French.

AUTOMATIC GAIN-REGULATION.

(*Convention date* (*Germany*), *31st August*, 1927. *No.* 296397.)

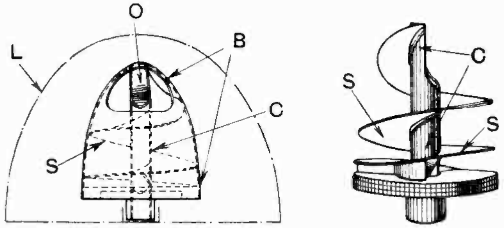
In a combined land-line and radio transmission system, the ether link is subject to "fading" and similar variable attenuation. In order to compensate automatically for this variable factor, it has been proposed to transmit a special "control" frequency, usually lying outside the band of signal frequencies, and to use this special frequency to adjust the grid potential of one or more of the amplifying valves on the receiving side. The present invention consists in distributing the rectified voltage derived from the incoming control frequency so as to adjust the operating grid potential of several of the amplifying stages instead of concentrating the gain control at one valve. This avoids any excessive movement of the operating grid potential and prevents any tendency to distortion or self-oscillation.

Patent issued to Siemens and Halske A-G.

LOUD SPEAKERS.

(*Application date*, *16th November*, 1927. *No.* 305301.)

The horn is built up from a helical vane or strip *S* secured to a cone element *C*. A sleeve portion *B* fits closely over the helical vane, so that the channel formed between the vane and sleeve expands progressively according to a logarithmic law. An



No. 305301.

inverted dome or reflector *L* is placed over the combined unit as shown. Sound waves entering at the bottom of the sleeve travel along the exponential groove between the vane *S* and sleeve *B*, and enter the dome portion through an opening *O* at the top.

Patent issued to M. Ward.

SOUND REPRODUCING DIAPHRAGMS.

(*Application date*, *21st October*, 1927. *No.* 306193.

A disc or diaphragm for sound-reproducing instruments is made from wire gauze, or perforated plates, or interlaced strips of metal, coated with celluloid, ebonite, or wax. The coating solution may contain solid matter in solution, such as fine particles of wood. It is claimed that adequate reproduction of both high the low notes is ensured by the use of a metal diaphragm coated in this way.

Patent issued to W. A. Halden.

DIRECTIONAL AERIALS.

(*Application date*, *18th November*, 1927. *No.* 305733.)

A directional aerial arrangement which is stated to give results comparable to the well-known "Beam" system, but is simpler and less costly to erect, consists of a number of vertical antennæ so spaced apart that the actual radiation resistance of the system as a whole is less than the radiation resistance of the separate antennæ considered in parallel. The spacing necessary to give this effect is from 0.5 to 0.68 of a wavelength, the optimum value being 0.57 wavelength.

Patent issued to T. L. Eckersley.

MULTIPLEX SIGNALLING SYSTEMS.

(*Application date 9th November*, 1927. *No.* 305703.

Where a single carrier-wave is modulated by a number of separate signal frequencies, such as by speech currents and one or more distinct Morse messages, difficulties arise in making the necessary tuning adjustments for heterodyne reception, owing partly to the extreme degree of accuracy to which the local oscillators must be adjusted and also to the necessity for maintaining the heterodyne frequencies in fixed relation so that the incoming signal frequencies may be kept centred on the band filter amplifiers. According to the invention the heterodyne frequencies are so arranged that, for correct reception, the same frequency is obtained at different parts of the multiplex receiver. This uniform frequency from different points is then fed into a common control circuit, and correct adjustment is ensured by the maintenance of a zero or no-beat effect in that circuit. A loud speaker or visible lamp relay may be utilised to indicate the presence of any undesired beat note in the control circuit.

Patent issued to G. A. Mathieu.

FREQUENCY MODULATION SYSTEMS.

(*Convention date* (*U.S.A.*), *18th June*, 1927. *No.* 292469.)

In systems in which signalling is effected by changing the frequency of the carrier-wave, whilst maintaining its amplitude constant, the required frequency-variations are secured by short-circuiting an inductance coil shunted across a piezo-electric crystal, which acts as a master or drive oscillator anchoring the radiated waves about a mean frequency. The modulation changes in frequency so produced are abrupt and are not accompanied by any perceptible change in amplitude. The frequency variations are of the order of 0.1 per cent. of the fundamental crystal frequency. The systems permit of dual transmission, telegraphic signals being sent by means of a frequency change, whilst telephony signals are transmitted simultaneously by amplitude modulation. Provided the rate of Morse keying is kept high, no mutual interference between the messages occurs at the receiving end.

Patent issued to Westinghouse Electric and Manufacturing Co.