WIRELESS ENGINEER

SEPTEMBER 1947

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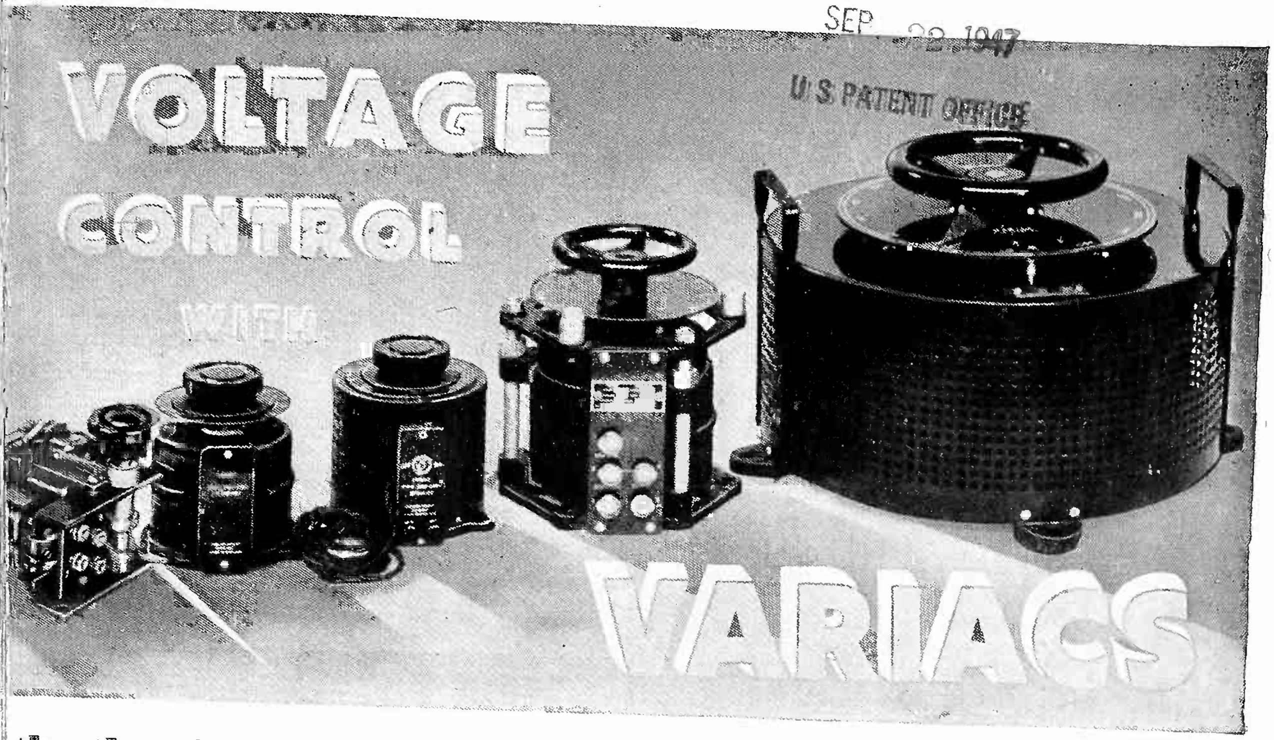
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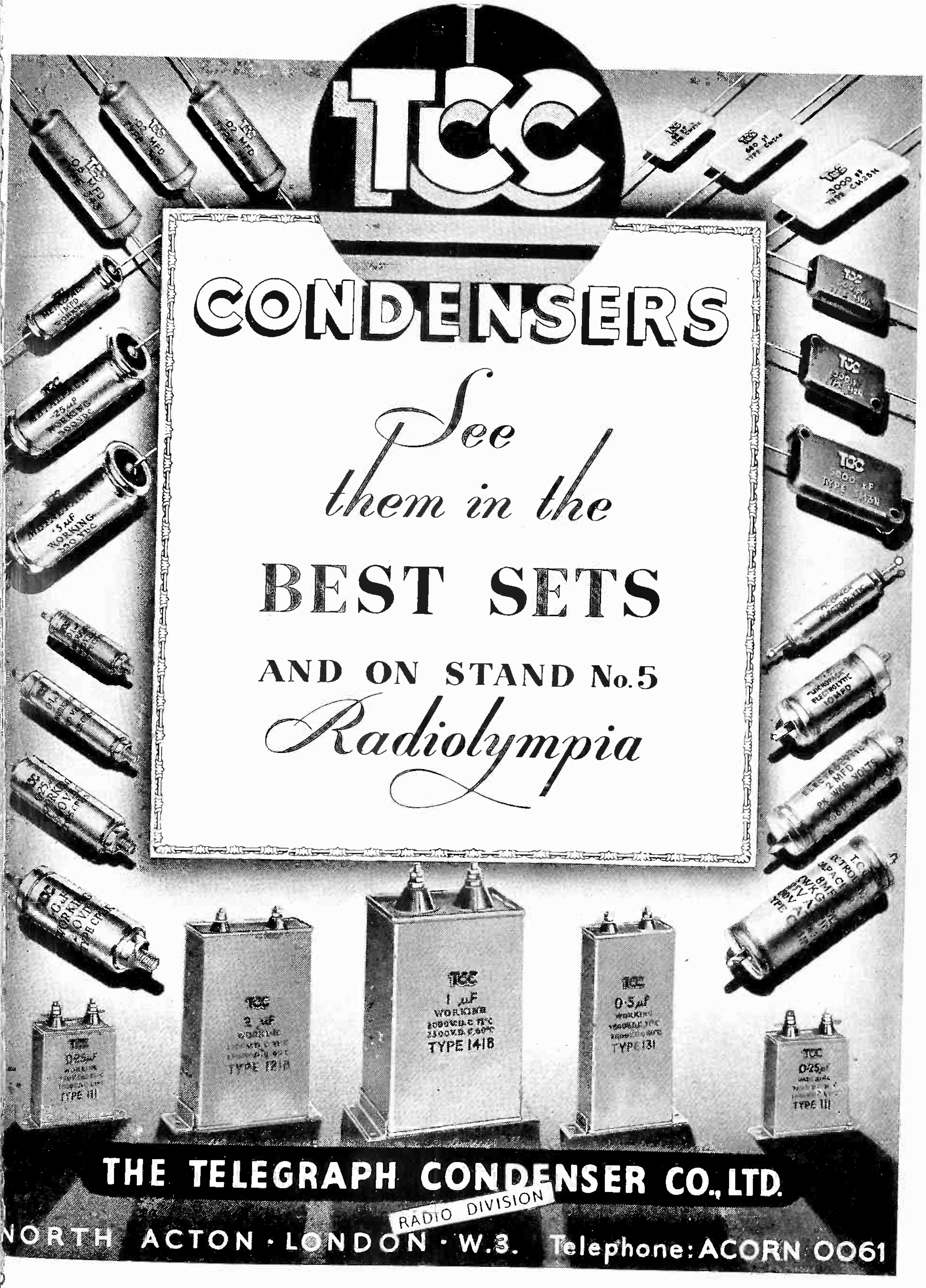

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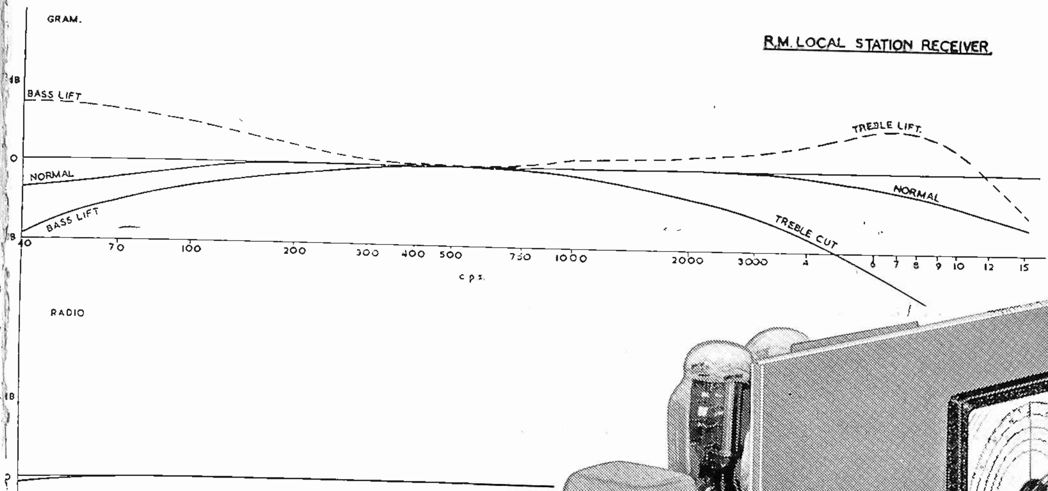

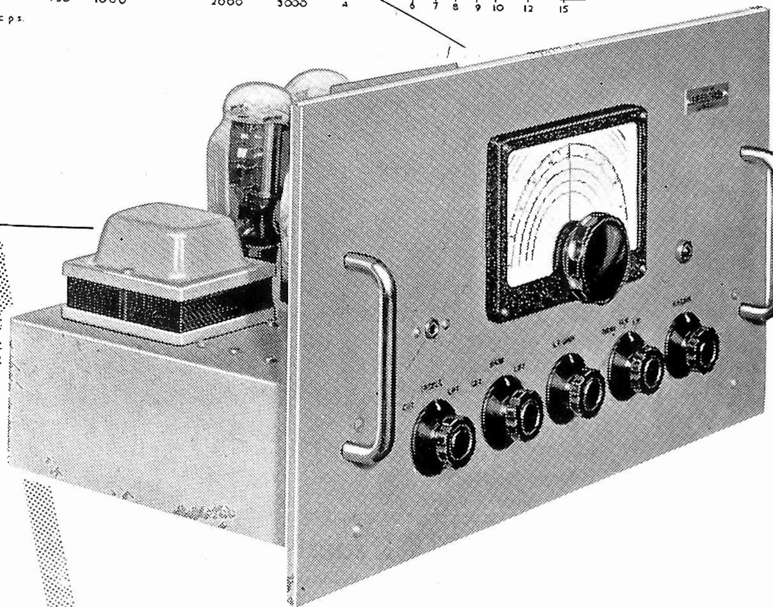

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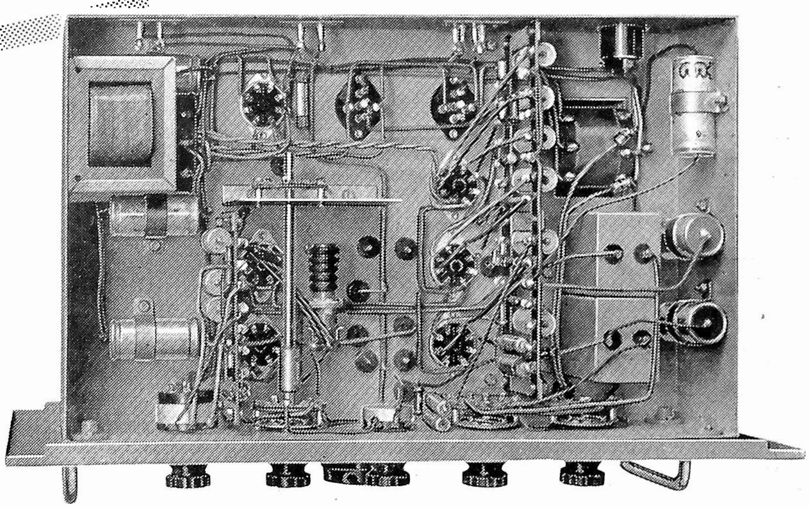

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WIRELESS ENGINEER

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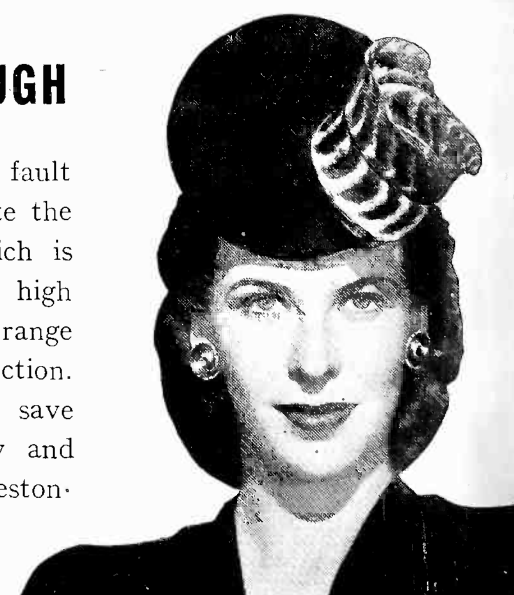

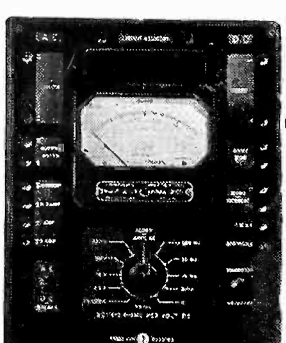

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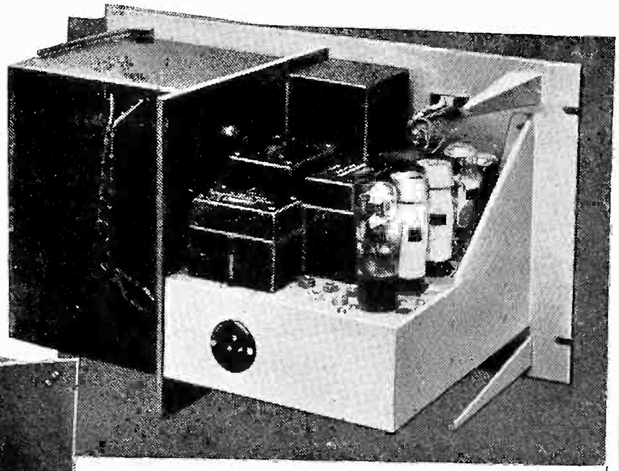

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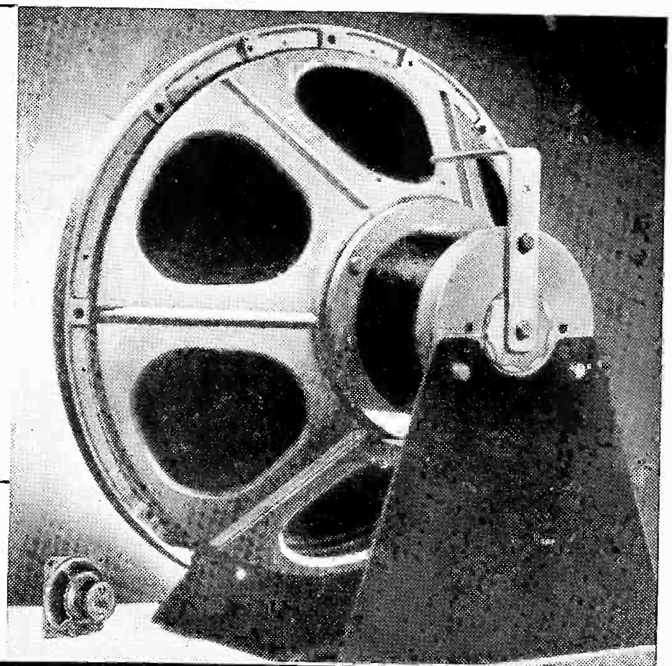

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EDITORIAL

The Mechanism of Magnetic Attraction

To calculate the mechanical force on an element of current-carrying conductor in a magnetic field, one multiplies the current by the length and by the component of the magnetic induction normal to the length. There must be an equal and opposite mechanical reaction on the source of the magnetic field. If the resultant magnetic field is made up of several components due to different sources they can each be considered separately in order to determine the reactions on the different sources. The element of conductor may be replaced by a moving electric charge.

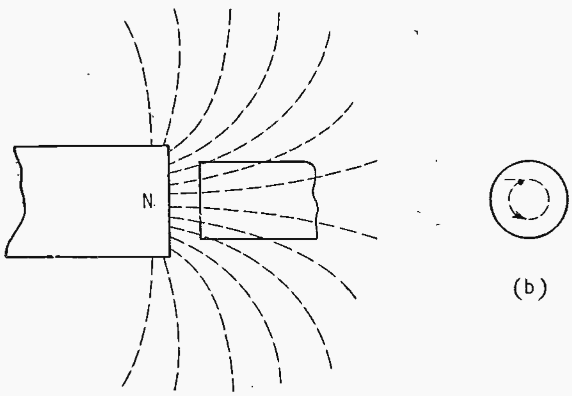
We now propose to apply these elementary principles to the case of a piece of iron in the field of a permanent magnet. Every atom of the iron consists of a stationary nucleus in which we are not interested, and a number of revolving electrons. The whole mass of iron may be pictured as relatively empty space in which myriads of electrons revolve in planes which are controlled by the joint action of neighbouring atoms and the externally applied field. Each electron may be regarded as a small current-carrying coil situated in a magnetic field which is the resultant of two component fields, one due to all the other revolving electrons in the mass of iron, and the other due to the neighbouring magnet.

It is interesting to consider the nature of the forces that can act on the electron. If the magnetic field is uniform and normal to the plane of rotation, the force can only tend to increase or decrease its radius of rotation; if the field is uniform and in the plane of rotation, the force can only tend to rotate the plane in which the electron revolves. Translational forces can only be caused by non-uniformity of the magnetic field. These considerations apply either to the resultant or to the component fields. If one could integrate the forces acting on all the electrons in the mass of iron due to the resultant magnetic field one would obtain the resultant force acting on the mass, but it is much more enlightening to picture the integration carried out separately for the two component magnetic fields. The integration of all the forces due to the field produced by the rotating electrons in the mass of iron must be zero, since every elemental force has an equal and opposite reaction on some other part of the mass of iron. If the magnet could be removed without any change in the electronic structure of the iron, the integrated force would remain unchanged and it must obviously be zero in this case since the piece of iron, which is now, in effect, a permanent magnet, could not tend to move or rotate. There will, of course, be stresses within the iron but no externally applied force tending to move it. We are neglecting the effect of the earth, which is, of course, an externally applied magnet.

We are left, therefore, with the other term in the integration, namely the force on the iron due to the rotation of its electrons in the magnetic field of the magnet *unaffected by the presence of the iron*. We are neglecting any small effect that the presence of the piece of iron may have on the electronic orientations within the magnet. The point that we wish to emphasize is that, if we are not concerned with internal forces within the mass of iron, but only with the external forces tending to move it, then we are not interested in the resultant magnetic field but only in the field as it would be if the piece of iron were not there.

This throws light upon a point which has probably worried many who have tried to obtain a clear physical picture of what is happening in the iron.

Fig. 1 (a) shows the north pole of, say, a cylindrical bar magnet and a piece of iron



(a) (b)

Fig. 1.

placed near it. In Fig. 1 (b) we are supposed to be situated on the pole and looking at the face of the piece of iron. The magnetic flux is going from us into the iron and the result of the magnetization is an orientation to some extent of the electron orbits in the direction to increase the flux; a typical electron orbit is shown, greatly magnified, in the figure. Now in order to exert a force of attraction or replusion on this electron there must be a magnetic field in the plane of the paper and a little consideration shows that if the field were radially outwards, the electron, and consequently the mass of iron, would be attracted, whereas if the field were radially inwards the iron would be repelled. The fact that the iron is attracted shows that the field causing the attraction diverges on passing into the iron which is true of the original magnet field shown in Fig. 1 (a) although the resultant field converges on entering the iron.

In Fig. 2 a horse-shoe magnet is attracting an iron plate; the magnetic field shown is that due to the magnet alone in the absence of the iron plate. The electron orbits will be orientated to some extent toward planes normal to the field as indicated in Fig. 2,

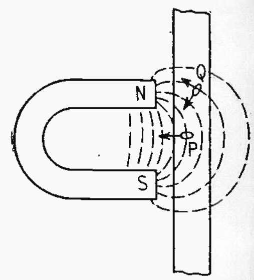


Fig. 2.

and the forces on the electrons will be of a complex character, made up of forces in the general direction of the field, as in Fig. 1, and of forces at right angles to the field, but acting in both cases in the direction in which the flux through the orbit will be increased. At a point such as P the electron is urged in the direction shown because one side of its orbit is in a stronger field than the other side and there is consequently a resultant force on it. At a point such as Q both types of force will be operative, or at least, a resultant force which may be regarded as made up of two such components.

This method of approach brings out very clearly that the attractive force on the iron is not exerted on any surface polarity but acts throughout the mass, and that the force acting at any point does not depend on the resultant magnetic induction at the point but on the rate at which the magnetizing force due to the magnet alone is changing either longitudinally or laterally. G. W. O. H.

THE TRAVELLING-WAVE TUBE*

Centimetre-Wave Amplifier

By R. Kompfner

SUMMARY.—A theory of a tube based on the principle of interaction between travelling waves and electrons is developed with the aid of a number of simplifying assumptions. To begin with, the modulation of the beam by the wave is considered ignoring any reaction of such modulation on the wave. Similarly, the wave produced by a modulated beam is investigated. Next, the influence of the modulation of a beam, which has been produced by a wave, on that wave, is calculated and this process is carried on for an infinite number of actions and reactions. The sum of all these actions, representing the complete interaction between electrons and wave, is derived for the case of wave and electrons travelling at the same velocity. Expressions for the amplification and the noise factor of a tube under these conditions are given.

A description is then given of experiments on a coaxial line with a helical inner conductor, which has been chosen as a structure for slowing down the wave to velocities of practicable electron beams. The interaction of beam and wave is investigated and is found to accord substantially with theory. Tubes are described which are run as amplifiers and the results obtained are given.

1. Introduction

PROGRESS in the technique of radio has for some time been intimately connected with a tendency to employ ever shorter wavelengths. This necessarily led to ever smaller circuit components and spacings in valves, until a point was reached where devices based on conventional conceptions ceased to function efficiently and eventually to function at all. A very important step forward was made with valves of the drift-tube or klystron type, for they succeeded by turning a very serious difficulty of the conventional valve into an advantageous and, indeed, an essential feature. The difficulty lay in the fact that the transit time of electrons in the inter-electrode space becomes considerable in comparison with the time of one cycle of the operating frequency. Together with the use of non-radiating, highly-resonant structures for circuits the utilization of the transit time in the drift-tube has enabled it to perform very well at frequencies at which the conventional triode, tetrode, etc., can only be made to work under difficulties involving the use of microscopically fine wire-mesh grids and spacings of extremely small clearances and tolerances. At these wavelengths the drift-tube has still a very macroscopic and robust structure and is easily built and handled.

However, as the wavelength is still further reduced transit-time reappears as difficulty, even with drift-tubes. In all valves, particularly in drift-tubes, the energy interaction between electron stream and electromagnetic field is very much localized. There is thus a limit to the frequencies which can be reached even by drift-tubes and that is again given by transit-time, just as in the case of the conventional valve. It is a natural and logical step to seek an alternative to interaction by means of intense localized fields; such an alternative is given by the interaction between an electron stream and a *travelling* electromagnetic field. Obviously, wave and electrons must travel at about the same velocity, so that particular electrons will stay in the same phase of the field for a considerable time and so experience a cumulative effect. Thus, for instance, some electrons will be accelerated all the time while they travel with the corresponding portion of the field and others will be retarded all the time. This makes up for the fact that we cannot expect travelling fields to have intensities as high as those of localized and stationary fields. Stationary fields, or standing waves as they can be termed, are usually characterized by high intensities; however, electrons spend very little time in them, and it will be shown later that the energy transfer between travelling field and electrons can be made considerably more effective than the energy transfer between electrons and a localized stationary field.

For reasonable electron-beam voltages (reasonable being more than a few hundred and less than a few thousand volts) it turns out that the wave is required to travel at velocities around one-tenth of that of light. This rules out at once the use of ordinary

* MS. accepted by the Editor, October, 1946.

waveguides or transmission lines of the coaxial type with cylindrical symmetry. The former have indeed phase velocities higher than that of light, while, in addition, the fundamental mode in the latter offers only transverse electric fields, which are not so desirable as axial fields from several points of view.

A loaded transmission line, consisting of an inner conductor in the form of a helix concentric with a solid metallic outer conductor, has been found to be very suitable for slowing down the wave to the desired value, and has been successfully used in the experiments to be described later on. At this stage it is appropriate to mention that both transverse and axial fields do exist in such a transmission line, the latter mainly within the helix, and the former mainly between the helix and the outer conductor. Thus, the assumption of periodic electric fields travelling with velocities of the order of one-tenth of that of light is physically realizable and is made the basis of the following calculations where the results of the interaction between electrons and travelling wave are estimated.

2. Assumptions and Definitions

In this section a theory of interaction between an electron beam and a travelling wave will be outlined, subject to a number of rather drastically simplifying assumptions. The assumptions are :—

(*a*) that it is admissible to calculate the effect of the wave on the beam as if it were isolated; i.e., ignoring any reaction of the beam on the wave.

(*b*) that it is similarly admissible to calculate the effect of the modulation of a beam on the wave, ignoring the effect of the wave on the beam.

(*c*) that any displacements of electrons from their undisturbed positions are very small. This is equivalent to postulating small-signal conditions.

(*d*) that attenuation of the wave due to losses in conducting surfaces, and in any dielectric, is neglected.

(*e*) that space-charge repulsion effects are neglected.

(*f*) that we are dealing with a very thin electron beam composed of electrons of uniform initial velocity.

A wave is characterized by the peak voltage V, its wavelength λ and a constant velocity of propagation u. V is related to the mean signal power W by

$$V = \sqrt{2WZ_0} \text{ volts} \quad \ldots \quad \ldots \quad (1)$$

where Z_0 is the characteristic impedance of the transmission line along which the wave is travelling. The instantaneous voltage at any point x in the line and at the time t is described by

$$V(xt) = V \begin{matrix}\sin\\ \cos\end{matrix}\left\{\omega t - \frac{2\pi x}{\lambda}\right\} \text{volts} \quad \ldots \quad (2)$$

where ω is the angular frequency of the wave.

An electron beam is shot through the line in the direction of travel of the wave. The beam current is denoted by I_0 and its uniform velocity v is given by the relation

$$v = \sqrt{\frac{2e}{m}V_0} \text{ cm/sec} \quad \ldots \quad \ldots \quad (3)$$

where V_0 is the accelerating potential.

The field at the point of the cross-section of the line where the electron beam is situated is resolved into a *transverse* field ϕ_T (or radial, if the line is rotationally symmetrical) and an *axial* field ϕ_A.

Now in a planar line

$$\phi_T = \tau\frac{V}{D} = \frac{\tau}{D} V \sin\left(\omega t - \frac{2\pi x}{\lambda}\right) \text{volts/cm} \quad \ldots \quad (4)$$

where D is the distance between the conductor on which the voltage V is supposed to exist and the other conductor which is supposed to be at earth potential. τ is a numerial factor, less than unity, indicating how much weaker the field is at the point of the electron beam than it would be if λ were very large compared with D. τ is determined by the geometry of the line and by the kind of wave propagated in the line. The planar configuration has been chosen in order to simplify the expressions. There is, however, no principal difficulty in the way of choosing any other type of configuration.

Similarly, the axial field ϕ_A is given by

$$\phi_A = \alpha\frac{\partial V}{\partial x} = \frac{2\pi\alpha}{\lambda} V \sin\left(\omega t - \frac{2\pi x}{\lambda}\right) \text{volts/cm} \quad (5)$$

For the sake of convenience, a field which accelerates an electron in the positive direction has been considered a positive field. Further Equ. (5) presupposes that the voltage giving rise to the field ϕ_A is of the form $V\cos\left(\omega t - \frac{2\pi x}{\lambda}\right)$.

3. First Order Beam Displacement

If t_0 is the time of entry into the line of an electron, then the force on it at time t is given by

$$m\frac{d^2s}{dt^2} = e\phi \sin\left[\omega t_0 + \frac{2\pi}{\lambda}(u-v)(t-t_0)\right] \quad \ldots \quad (6)$$

where ϕ is the amplitude of the field, in both the axial or transverse case; $(u - v)(t - t_0)$ is the longitudinal or axial shift of an electron relative to the wave; $v(t - t_0) = x$ the distance travelled; and s is the distance from the undisturbed position.

$\frac{d^2s}{dt^2}$ integrated gives

$$\frac{ds}{dt} = -\frac{e\phi\lambda}{2\pi m(u-v)}\left\{\cos\left[\omega t_0 + \frac{2\pi}{\lambda}(u-v)(t-t_0)\right] - \cos \omega t_0\right\}$$

$$= \frac{e\phi x}{mv}\frac{\sin \theta/2}{\theta/2}\cdot\sin(\omega t_0 + \theta/2) \quad \ldots \quad (7)$$

where $\theta = \frac{2\pi x}{\lambda}\left(\frac{u}{v} - 1\right)$ is the transit angle of an electron relative to the wave.

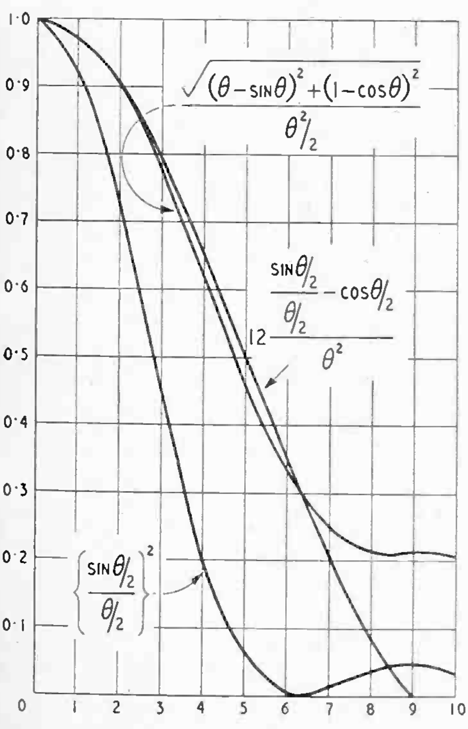


Fig. 1. *Values of three expressions as functions of the transit angle.*

Another integration gives the displacement

$$s = \frac{e\phi x^2}{mv^2}\left[(\sin\theta - \theta)^2 + (1 - \cos\theta)^2\right]^{\frac{1}{2}}\theta^{-2}$$
$$\sin\left[\omega t_0 + \tan^{-1}\frac{\theta - \sin\theta}{1 - \cos\theta}\right] \quad (8)$$

The amplitude of Equ. (8) is plotted in Fig. 1.

When $u = v$, $\theta \to 0$ and

$$s = \frac{e\phi x^2}{2mv^2}\sin \omega t_0 = \frac{\tau V x^2}{4V_0 D}\sin \omega t_0 \quad (9)$$

in the transverse field case, which is identical with the deflection obtained within a pair of parallel plates of length x when the frequency is very low.

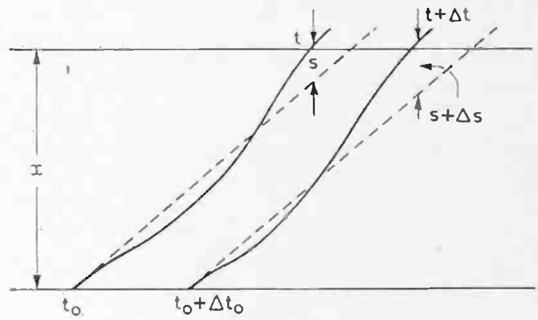


Fig. 2. *The space-time diagram of the electron flow in the valve.*

4. Current distribution in Beam

The effect of the *axial* displacement of the beam on its current distribution can be treated as follows:—

By the principle of conversation of charge it follows that:

$$\Delta t_0 . I_0 = \Delta t . I_x$$

$$\text{or } I_x = I_0\frac{\partial t_0}{\partial t} \quad \ldots \quad (10)$$

where Δt_0 is the small time interval taken by a particular amount of charge to cross the plane $x = 0$; I_0 is in the initially uniform beam current; Δt is the time interval taken by the same amount of charge to cross the plane x; and I_x is the beam current at x.

From the "space-time" diagram, Fig. 2, we also have

$$[t - t_0]v + s = x \quad \ldots \quad (11)$$

$$[(t + \Delta t) - (t_0 + \Delta t_0)]v + (s + \Delta s) = x \quad (12)$$

Hence $(\Delta t - \Delta t_0)v + \Delta s = 0$

$$\text{or } \frac{\partial t_0}{\partial t_{(x)}} = 1 + \frac{1}{v}\frac{\partial s}{\partial t_{(x)}} \quad \ldots \quad (13)$$

and $I_x = I_0\left(1 + \frac{1}{v}\frac{\partial s}{\partial t_{(x)}}\right)$ .. .. (14)

In the special case when s is given by Equ. (8)

$$I = I_0\left\{1 + \frac{\omega}{v}\frac{e\phi x^2}{mv^2}\left[(\sin\theta - \theta)^2 + (1-\cos\theta)^2\right]^{\frac{1}{2}}\theta^{-2}\cos\left[\omega t_0 + \tan^{-1}\frac{\theta - \sin\theta}{1-\cos\theta}\right]\right\} \quad .. \quad .. \quad .. \quad (15)$$

That is the current at x due to a voltage wave of the form

$$+V\cos\left(\omega t - \frac{2\pi x}{\lambda}\right)$$

We recall that ϕ was given by $|\phi_A| = \frac{2\pi\alpha V}{\lambda}$

5. Voltage Induced by Transverse Displacement Modulation

In order to determine the voltage induced by a transverse displacement modulation of the beam we consider a beam modulated in the way shown in Fig. 3; Λ is the wavelength in the beam as determined by the frequency and the beam velocity in accordance with the relation

$$\frac{\omega}{v} = \frac{2\pi}{\Lambda}$$

This will be termed " displacement modulation."

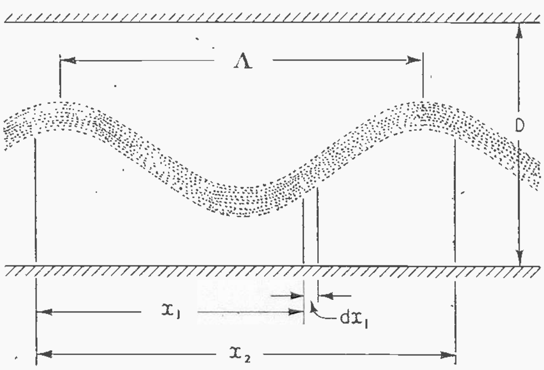


Fig. 3. *A transverse deflection modulated beam of electrons is illustrated.*

Let $s(xt)$ denote the transverse displacement of the beam. Considering only an element of length dx_1 at x_1, the amount of charge contained within that length, denoted by dq, is given by

$$dq = \frac{I_0}{v}\cdot dx_1 \quad .. \quad .. \quad .. \quad (16)$$

and this elemental charge is moving to and fro across the line with an apparent transverse velocity v' given by

$$v' = \frac{\partial s(x_1 t)}{\partial t} \quad .. \quad .. \quad .. \quad (17)$$

The elemental current induced in the line is

$$di_1 = -\frac{\tau\, dq\, .\, v'}{D} = -\frac{\tau I_0}{vD}\cdot\frac{\partial s(x_1 t)}{\partial t} \quad .. \quad (18)$$

one half of which will flow to the right (the forward direction) and one half to the left (backwards) producing an element of voltage at x_1

$$dV_1 = \tfrac{1}{2}di_1\, .\, Z_0 = -\frac{\tau I_0 Z_0}{2vD}\frac{\partial s(x_1 t)}{\partial t}\, .\, dx_1 \quad (19)$$

This elemental voltage wave will be propagated both in the forward and backward directions with the velocity u and to obtain the complete voltage at a point x_2 we have to sum, between $x_1 = 0$ and $x_1 = x_2$, all the elemental voltages which are travelling forward, and between $x_1 = x_2$ and $x_1 = l$ the elemental voltages travelling backwards.

By way of illustration, let us assume that

$$s(x_1 t) = s_0 \sin\left(\omega t - \frac{2\pi x}{\Lambda}\right) \quad .. \quad (20)$$

which is a uniform displacement modulation of amplitude s_0.

We have

$$\frac{\partial s(x_1 t)}{\partial t} = \omega s_0 \cos\left(\omega t - \frac{2\pi x_1}{\Lambda}\right) \quad .. \quad (21)$$

and

$$dV_1 = -\frac{\tau\omega I_0 Z_0 s_0}{2vD}\cos\left(\omega t - \frac{2\pi x_1}{\Lambda}\right)dx_1 \quad (22)$$

At this point x_2 the elemental voltage, taking the ensuing phase-shift into account, will be

$$dV_{12} = -\frac{\tau\omega I_0 Z_0 s_0}{2vD}\cos\left[\omega t - \frac{2\pi x_1}{\Lambda} - \frac{2\pi(x_2 - x_1)}{\lambda}\right]dx_1 \quad .. \quad .. \quad (23)$$

due to the forward-travelling wave and

$$dV^*_{12} = -\frac{\tau\omega I_0 Z_0 s_0}{2vD}\cos\left[\omega t - \frac{2\pi x_1}{\Lambda} + \frac{2\pi(x_1 - x_2)}{\lambda}\right]dx_1 \quad .. \quad .. \quad .. \quad (24)$$

due to the backward-travelling wave.

The complete voltage at x_2 due to all forward-travelling waves excited between $x_1 = 0$ and $x_1 = x_2$ is given by

$$V_2 = \int_{x_1=0}^{x_1=x_2} dV_{12} = -\frac{\pi\tau I_0 Z_0 s_0 x_2}{D\Lambda}\frac{\sin\theta/2}{\theta/2}\cos\left(\omega t - \pi x_2\frac{\Lambda+\lambda}{\Lambda\lambda}\right) \quad .. \quad .. \quad .. \quad (25)$$

where $\theta = 2\pi x_2\frac{\Lambda + \lambda}{\Lambda\lambda} = \frac{2\pi x_2}{\lambda}\left(\frac{u-1}{v}\right)$

as before.

The amplitude of (25) is plotted in Fig. 1. When $u \to v$, $\theta \to 0$ and (25) reduces to

$$V_2 = -\frac{\pi \tau I_0 Z_0 s_0}{\Lambda\lambda} x_2 \cos\left(\omega t - \frac{2\pi x_2}{\lambda}\right) \quad (26)$$

Equ. (25) represents a wave travelling with a velocity $\frac{2uv}{u+v}$ and of varying amplitude, while (26) represents a wave travelling with the velocity u and uniformly increasing amplitude.

The voltage at x_2 due to backward-travelling waves denoted by V_2^* can be calculated in a similar manner ; if the total length of the transmission line is l we have

$$V_2^* = -\frac{\pi \tau I_0 Z_0 s_0 (l - x_2)}{D\Lambda} \frac{\sin\phi}{\phi} \cos\left\{\omega t - \pi l \frac{\Lambda + \lambda}{\Lambda\lambda} + \pi x_2 \frac{\Lambda - \lambda}{\Lambda\lambda}\right\} \quad (27)$$

where $\phi = \pi(l - x_2)\frac{\Lambda + \lambda}{\Lambda\lambda}$.

When $u = v$, Equ. (27) reduces to

$$V_2^* = -\frac{\tau I_0 Z_0 s_0}{2D} \sin\left[\frac{2\pi}{\lambda}(l - x_2)\right] \cos\left(\omega t - \frac{2\pi l}{\lambda}\right) \quad \ldots \quad \ldots \quad \ldots \quad (28)$$

Equ. (27) represents a wave of varying amplitude travelling backwards at a rate given by $\frac{2uv}{u-v}$, while (28) represents a kind of standing wave, its amplitude varying with distance. No energy is being passed along.

The amplitude of (28) will be less than that of (26) provided

$$\frac{x_2}{\lambda} > \frac{2}{\pi}$$

Hence this wave will be of little importance for tubes many wavelengths long.

6. Voltage Induced by Density Modulation

Let the density-modulation of the beam be $I = I\,(xt)$.

An element of charge dq at x_1, dx_1 long, will then be given by

$$dq = \frac{I}{v} dx_1 = \frac{I(x_1 t)}{v} dx_1 \quad \ldots \quad \ldots \quad (29)$$

If dV_1 is the potential across the line due to the presence of dq then by definition (Equ. 5) the potential at the place of the electron beam is $\alpha \,.\, dV_1$. dV_1 will be proportional to dq.

Hence we write

$$dV_1 = -p \,.\, dq \quad \ldots \quad \ldots \quad \ldots \quad (30)$$

where p is some constant of proportionality.

The energy of the element of charge dq at x_1 is

$$\tfrac{1}{2} dq \,.\, \alpha \,.\, dV_1 \quad \ldots \quad \ldots \quad \ldots \quad (31)$$

and the rate of change of energy with time (that is, the power flowing into the line) is

$$2dW = \tfrac{1}{2}\alpha \frac{\partial(dq \,.\, dV_1)}{\partial t} \quad \ldots \quad \ldots \quad (32)$$

We write $2dW$ because $1dW$ can be imagined to flow away to the right with $1dW$ flowing to the left.

$$\text{But } dW = \frac{(dV_1)^2}{Z_0} \quad \ldots \quad \ldots \quad \ldots \quad (33)$$

$$\text{Hence } \frac{\alpha}{2}\frac{\partial(dq \,.\, dV_1)}{\partial t} = 2\frac{(dV_1)^2}{Z_0} \quad \ldots \quad (34)$$

But $dq \,.\, dV_1 = -p \,.\, (dq)^2$

$$\text{and } \frac{\partial(dq \,.\, dV_1)}{\partial t} = -2p \,.\, dq \frac{\partial(dq)}{\partial t} = -2dV_1 \frac{\partial(dq)}{\partial t} \quad \ldots \quad \ldots \quad \ldots \quad (35)$$

which gives, when inserted in (34)

$$dV_1 = -\frac{\alpha Z_0}{2} \cdot \frac{\partial(dq)}{\partial t} = -\frac{\alpha Z_0}{2v}\frac{\partial I(x_1 t)}{\partial t} dx_1 \quad \ldots \quad \ldots \quad \ldots \quad (36)$$

Equ. (36) is analogous to (19), and all the subsequent steps in Section 5 have to be repeated in this section.

Let the density modulation of the beam be of the form

$$I(x_1 t) = aI_0 \sin\left(\omega t - \frac{2\pi x_1}{\Lambda}\right) \quad \ldots \quad (37)$$

where a is a dimensionless number representing the depth of modulation, then

$$\frac{\partial I(x_1 t)}{\partial t} = \omega a I_0 \cos\left(\omega t - \frac{2\pi x_1}{\Lambda}\right) dx_1 \quad (38)$$

and

$$dV_1 = -\frac{\alpha\omega a I_0 Z_0}{2v} \cos\left(\omega t - \frac{2\pi x_1}{\Lambda}\right) dx_1 \quad (39)$$

which is similar to Equ. (22) except that a replaces τ and S_0/D is exchanged for a.

Hence the voltage at x_2 due to forward-travelling waves is

$$V_2 = -\frac{\pi\alpha a I_0 Z_0 x_2}{\Lambda} \frac{\sin\theta/2}{\theta/2} \cos\left(\omega t - \pi x_2 \frac{\Lambda + \lambda}{\Lambda\lambda}\right) \quad \ldots \quad (40)$$

and that due to backward-travelling waves

$$V_2^* = -\frac{\pi\alpha a I_0 Z_0 (l - x_2)}{\Lambda} \frac{\sin\phi}{\phi} \cos\left\{\omega t - \pi l \frac{\Lambda + \lambda}{\Lambda\lambda} + \pi x_2 \frac{\Lambda - \lambda}{\Lambda\lambda}\right\} \quad (41)$$

7. Noise-Voltage Induced by Shot Fluctuation

The general cases treated by way of examples in Sections 5 and 6 are useful in describing the manner in which shot noise enters into the line.

We will treat the case of transverse interaction first. Consider a beam of thickness d; a shot-noise voltage will be induced into the line by virtue of the random fluctuations of charge density across the beam. It is sufficient to treat the low-frequency case of a pair of deflecting plates, D distant from each other, through which a beam of mean current I_0/cm width is shot. Let the beam be of infinite width in the direction perpendicular to the direction of travel, so that the problem becomes one-dimensional, as shown in Fig. 4.

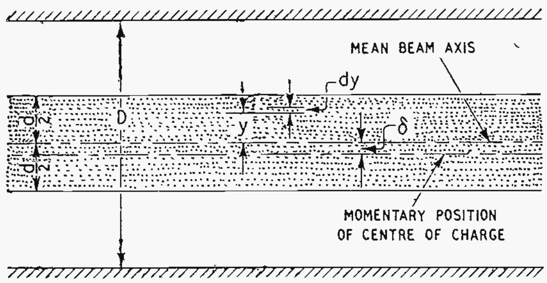


Fig. 4. *Random charge density distribution in the electron beam.*

We imagine all the charge between the plates to be concentrated in a plane, the so-called centre of charge plane, which will move to and fro between the plates in accordance with the momentary charge distribution. In other words, the centre of gravity of the electron cloud will fluctuate, and once we know the rate at which it moves we can apply Equ. (25), which will give us the voltage induced in the line.

The current in the thin layer dy at y cm from the mean beam axis is $\frac{dy}{d} I_0$ where I_0 is the current in the whole beam.

Suppose there is a momentary excess i in that layer. That will entail a shift δ of the position of the centre of charge away from the beam axis. By elementary mechanical analogy we have

$$\delta \,.\, I_0 = y \,.\, i$$

or taking mean squares .. (42)

$$\overline{\delta^2} = \overline{i^2} \,.\, \frac{y^2}{I_0^2} \qquad \ldots \quad (43)$$

$$\text{But } \overline{i^2} = 2e\frac{dy}{d} I_0 df\Gamma^2 \qquad \ldots \quad (44)$$

where Γ^2 is the usual space-charge smoothing factor.

By the theorem of the linear addition of the mean squares of fluctuations we find the resultant mean-square displacements of the position of the centre of charge; denoted by $\overline{\Delta^2}$ as follows:

$$\overline{\Delta^2} = \int_{-d/2}^{+d/2} \overline{\delta^2} = \frac{2edf\Gamma^2}{I_0 d}\int_{-d/2}^{+d/2} y^2 dy$$

$$= \frac{2edf\Gamma^2 d^2}{12\, I_0} \qquad \ldots \quad (45)$$

For a very narrow band of frequencies we can write

$$s(x_1 t) = \overline{\Delta} \sin\left(\omega t - \frac{2\pi x_1}{\lambda}\right) \qquad \ldots \quad (46)$$

or identify Δ with s_0 and proceed according to Equ. (25). Thus the mean-squared shot voltage denoted by $\overline{V_2^2}$ is found to be

$$\overline{V_2^2} = \frac{\pi^2\tau^2 Z_0^2\, 2eI_0 df\Gamma^2}{12}\, \frac{x_2^2 d^2}{\Lambda^2 D^2}\, \frac{\sin^2(\theta/2)}{(\theta/2)^2} \quad (47)$$

The case of the interaction of the shot fluctuations with the axial fields is treated as follows:—

The density modulation of the electron beam has been described by Equ. (37) where I_0 is the amplitude of the a.c. component of the beam current. In the case of shot-noise, for a very narrow band of frequencies, we put

$$\overline{a^2} I_a^2 = 2eI_0\, df \,.\, \Gamma^2 \qquad \ldots \quad (48)$$

$$\text{hence } \overline{a^2} = \frac{2e\, df\,\Gamma^2}{I_0} \qquad \ldots \quad (49)$$

This gives, in conjunction with Equ. (40) an expression for the mean-square induced shot-voltage, again denoted by $\overline{V_2^2}$ as follows:

$$\overline{V_2^2} = \frac{\pi^2\alpha^2 Z_0^2\, 2eI_0\, df\Gamma^2\, x^2}{\Lambda^2} \cdot \frac{\sin^2(\theta/2)^2}{(\theta/2)^2} \qquad \ldots \quad (50)$$

8.—Voltage Induced by a Signal-Modulated Beam

So far we have treated the interaction between wave and beam as if it were purely a case of either action of wave on the beam, or of action of the beam on the wave. Thus we are not strictly justified in talking of *inter*-action, up to now. In this and the following sections, however, we are going a step further; we will enquire into what happens when a density modulation which itself has been produced in a beam by a wave induces a secondary wave in the line. This will be done for the general case of beam and wave not having the same velocity.

The special case of the velocities being equal (i.e., $u = v$) can be derived from the general case and can be used in deriving the beam-density modulation due to that secondary wave, and again, of the tertiary wave induced in the line by that density modulation, and so on. Thus, the general scheme of higher-order waves is developed and eventually summed for an infinite number of higher-order waves. This sum of all the waves can truly be said to represent the result of *inter-action* between wave and beam.

Let the initial voltage be

$$V \cos\left(\omega t - \frac{2\pi x}{\lambda}\right) \quad \ldots \quad (51)$$

The axial field will be

$$\phi = \frac{2\pi\alpha V}{\lambda} \sin\left(\omega t - \frac{2\pi x}{\lambda}\right) = \phi_A \sin\left(\omega t - \frac{2\pi x}{\lambda}\right) \quad \ldots \quad (52)$$

and remembering that

$$\omega t_0 = \omega t - \frac{\omega x}{v} = \omega t - \frac{2\pi x}{\Lambda}$$

the resultant displacement modulation can be put into the form

$$S = \frac{e\phi_A}{m}\left\{\frac{\lambda}{2\pi(u-v)}\right\}^2\left[\sin\left(\omega t - \frac{2\pi x}{\Lambda}\right)\left(1 - \cos\theta\right) - \cos\left(\omega t - \frac{2\pi x}{\Lambda}\right)\left(\sin\theta - \theta\right)\right] \quad \ldots \quad (53)$$

where $\theta = \frac{2\pi x}{\lambda}\left(\frac{u}{v} - 1\right)$ as before.

By Equ. (14) this is equivalent to a density modulation

$$I = I_0 + \frac{\omega I_0 e\phi_A}{vm}\left\{\frac{\lambda}{2\pi(u-v)}\right\}^2\left[\cos\left(\omega t - \frac{2\pi x}{\Lambda}\right)\left(1 - \cos\theta\right) + \sin\left(\omega t - \frac{2\pi x}{\Lambda}\right)(\sin\theta - \theta\right] \quad \ldots \quad (54)$$

The elemental voltage induced in a line element dx_1 at x_1 is found by inserting (54) into (36) and is written

$$dV_1 = -\frac{\alpha Z_0\omega^2 Ie\phi_A}{2v^2 m}\left\{\frac{\lambda}{2\pi(u-v)}\right\}^2\left[-\sin\left(\omega t - \frac{2\pi x}{\Lambda}\right)\left(1 - \cos\theta\right) + \cos\left(\omega t - \frac{2\pi x}{\Lambda}\right)\sin\theta - \theta\right)\right] dx_1 \quad \ldots \quad (55)$$

where θ stands now for $\frac{2\pi x_1}{\lambda}\left(\frac{u}{v} - 1\right)$

Taking the phase shifts into account, the voltage at the point x_2 will be

$$dV_{12} = -\frac{\alpha Z_0 I_0\omega^2 e\phi_A}{2v^2 m}\left\{\frac{\lambda}{2\pi(u-v)}\right\}^2$$

$$\times\left[-(1-\cos\theta)\sin\left(\omega t - \frac{2\pi x_1}{\Lambda} - \frac{2\pi}{\lambda}(x_2 - x_1)\right) + (\sin\theta - \theta)\cos\left(\omega t - \frac{2\pi x_1}{\Lambda} - \frac{2\pi}{\lambda}(x_2 - x_1)\right)\right] dx_1 \quad \ldots \quad (56)$$

V_2 is the sum of all the voltages generated between $x_1 = 0$ and $x_1 = x_2$, and is obtained by integrating Equ. (56) between these limits, which gives

$$V_2 = +V\frac{2\pi^3\alpha^2 Z_0 I_0}{V_0}\frac{x^3}{\lambda\Lambda^2}\left[\frac{2\sin\theta/2}{\theta/2} - 2\cos\theta/2\right]\theta^{-2}\sin\left(\omega t - \frac{2\pi x}{\lambda}\left(\frac{u}{v} + 1\right)\right) \quad \ldots \quad (57)$$

where $\theta = \frac{2\pi x}{\lambda}\left(\frac{u}{v} - 1\right)$ as before.

The function of θ occurring in (57) has been plotted in Fig. 1.

When $u \to v$,

$$V_2 = +V\frac{2\pi^3\alpha^2 Z_0 I_0 x^3}{3!\,V_0\,\lambda^3}\sin\left(\omega t - \frac{2\pi x}{\lambda}\right) \quad (58)$$

It is worth while to recall that the original signal voltage was of the form

$$V\cos\left(\omega t - \frac{2\pi x}{\lambda}\right)$$

Similarly it can be shown that this secondary voltage described by Equ. (58) gives rise to a third-order voltage of the form

$$-V\frac{4\pi^6\alpha^4 Z_0^2 I_0^2 x^6}{6!\,V_0^2\,\lambda^6}\cos\left(\omega t - \frac{2\pi x}{\lambda}\right) \quad \ldots \quad (59)$$

and so forth, *ad infinitum.*

It will be observed that each voltage is 90° out of phase with the previous one; and the amplitude of each can be obtained from the previous one by multiplying by some factorials and a dimensionless term.

$$\frac{2\pi^3\alpha^2 Z_0 I_0 x^3}{V_0\lambda^3} \quad \ldots \quad (60)$$

Let this term be denoted by z^3; then summing all the partial voltages and taking account of phases by the symbol j the total resultant voltage V_T can be written in a series:

$$V_T = V\left[1 - (-j)\frac{z^3}{3\,!} + (-j)^2\frac{z^6}{6\,!} - (-j)^3\frac{z^9}{9\,!} + \ldots\ldots\right] \quad \ldots \quad \ldots \quad (61)$$

This can be separated into a real and an imaginary part :

$$V_T = V\,[R + jX]$$

The summation of this series has been carried out by Mr. H. Ashcroft, who gives the following expressions :

$$R = \tfrac{1}{6}\sum_{m=0}^{5} e^{ze^{(2m+1)j\pi/6}} = \tfrac{2}{3}\cosh\frac{\sqrt{3}}{2}z\cos\frac{z}{2} + \tfrac{1}{3}\cos z$$

$$X = \frac{d^3R}{dx^3} = +\tfrac{2}{3}\cosh\frac{\sqrt{3}}{2}z\sin\frac{z}{2} - \tfrac{1}{3}\sin Z \quad (62)$$

We are chiefly interested in the (amplitude)² of V_T and this can be expressed in closed form by

$$V_T^2 = V^2\left[R^2 + X^2\right] = V^2\cdot\tfrac{1}{9}\left[\left(2\cosh\frac{\sqrt{3}}{2}z + \cos\tfrac{3}{2}z\right)^2 + \sin^2\tfrac{3}{2}z\right]$$
$$= V^2\,\Phi \quad \ldots \quad \ldots \quad (63)$$

which tends to $\qquad V^2\cdot\tfrac{1}{9}\,e^{\sqrt{3}z} \quad \ldots \quad (64)$

as z is made large.

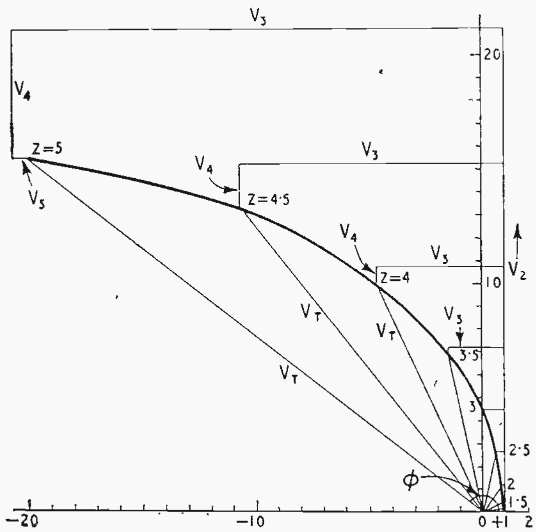


Fig. 5. *Partial and total voltages for various values of z ; u = v. The initial voltage V is represented by the distance* 0 *to* + 1.

Φ is simply the power amplification A of the tube as a function of all the parameters of z, and has been plotted in Fig. 6. When z is small, the series can be stopped at the second terms and we have

$$A = 1 + \frac{z^6}{(3\,!)^2} \quad \ldots \quad \ldots \quad \ldots \quad (65)$$

all the higher-order voltages contributing only to a negligible extent.

However, in practice, large values of z will be more interesting, and we observe the important result that the wave can be then considered to grow exponentially with distance, since z is simply proportional to distance. Thus the electron beam introduces negative attenuation into the line.

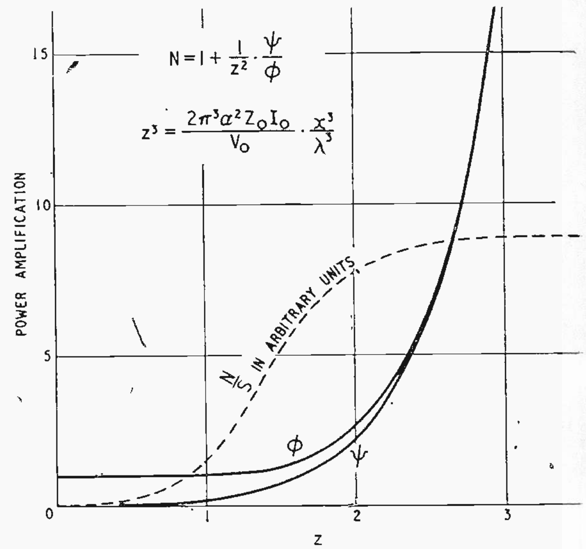


Fig. 6. *Φ and Ψ and noise/signal ratio N/S are shown as functions of z.*

The total and partial voltages in their phase relationship as a function of z have been plotted on the vectorial diagram of Fig. 5. The phase angle of the total voltage is given by

$$\tan\phi = \frac{X}{R} \quad \ldots \quad \ldots \quad \ldots \quad (66)$$

which tends to $+\tan\dfrac{z}{2}$ for large values of z.

9.—Total Noise Voltage

In the case of axial interaction of beam and fields and when $u = v$ it has been shown [see Equ. (50)] that the first-order shot noise voltage induced in the line is described by

$$\overline{V_2}^2 = \frac{\pi^2\,\alpha^2\,Z_0^{\,2}\,2eI_0\,df\,.\,\Gamma^2\,x^2}{\lambda^2} \quad \ldots \quad (67)$$

Writing

$$\overline{V}_2 = \pi\alpha\,Z_0\sqrt{2eI_0\,df\,\Gamma^2}\,.\,\frac{x}{\lambda}\cos\left(\omega t - \frac{2\pi x}{\lambda}\right) \quad \ldots \quad \ldots \quad (68)$$

for the r.m.s. shot-voltage, we obtain the resultant density-modulation of the beam by the use of Equ. (15) ; the voltage induced by this in the line is found as before by the use of (36), etc., and is

$$\overline{V'_2} = -\frac{2\pi^4 \alpha^3 Z_0^2 I_0 \sqrt{2eI_0 df \Gamma^2}}{4!\, V_0} \frac{x^4}{\lambda^4} \sin\left(wt - \frac{2\pi x}{\lambda}\right) \quad \ldots \quad \ldots \quad (69)$$

Similarly we can find the next order shot-voltage and so on *ad infinitum.*

The sum of all individual voltages can be expressed by the series :

$$V_T^* = \frac{|\overline{V_2}|}{z}\left\{z + (-j)\frac{z^4}{4!} + (-j)^2\frac{z^7}{7!} + (-j)^3\frac{z^{10}}{10!} + (-j^4)\frac{z^{13}}{13!} + \ldots\right\} \quad (70)$$

where $z^3 = \dfrac{2\pi^3\alpha^2 Z_0 I_0 x^3}{V_0 \lambda^3}$ as before. Equ. (70) can again be separated into a real and an imaginary part,

$$V_T^* = \frac{|\overline{V_2}|}{z}(R^* + jX^*)$$

where

$$R^* = \tfrac{1}{3}\left(\cosh\frac{\sqrt{3}}{2}z \sin\frac{z}{2} + \sqrt{3}\sinh\frac{\sqrt{3}}{2}z \cos\frac{z}{2} + \sin z\right) \quad \ldots \quad \ldots \quad \ldots$$

and

$$X^* = \tfrac{1}{3}\left(\cosh\frac{\sqrt{3}}{2}z \cos\frac{z}{2} - \sqrt{3}\sinh\frac{\sqrt{3}}{2}z \sin\frac{z}{2} + \cos z\right) \quad \ldots \quad \ldots \quad \ldots \quad (71)$$

while

$$\overline{(V_T^*)^2} = \frac{\overline{V_2}^2}{z^2}\tfrac{1}{9}\left\{\left[\cosh\frac{\sqrt{3}}{2}z - \cos\frac{z}{2}\right]^2 + \left[\sqrt{3}\sinh\frac{\sqrt{3}}{2}z - \sin Z\right]^2\right\} \quad \ldots \quad (72)$$

$$= \frac{\overline{V_2}^2}{z^2}\,.\,\Psi.$$

This is the mean-square amplitude of the shot-voltage introduced into the line by the electron beam. Ψ has been plotted in Fig. 6. For small values of z, the series can be stopped at the first term and we have

$$(\overline{V_T^*})\partial = \overline{V_2}^2$$

Hence at first the shot voltage amplitude increases linearly with distance.

Of greater interest is the behaviour of the tube for large values of z. Ψ then approaches

$$\tfrac{1}{9}\, e^{\sqrt{3}z} \quad \ldots \quad \ldots \quad \ldots \quad (73)$$

which is identical with the value of Φ when z is large.

The mean-square shot-voltage can then be written

$$\overline{(V_T^*)^2} = \sqrt[3]{2}\, e\,\Gamma^2 df\,.\, I_0^{\frac{1}{3}} \alpha^{\frac{2}{3}} Z_0^{\frac{1}{3}} V_0^{\frac{2}{3}} \tfrac{1}{9} e^{\sqrt{3}z} \quad (74)$$

Thus the noise power induced into the line by the electron beam also grows exponentially with distance, when z is large.

10.—Signal-to-Noise Ratio of an Amplifier

The signal-to-noise performance of a tube is commonly defined by a noise factor N, which is given by

$$N = \frac{\text{signal-to-noise ratio at input}}{\text{signal-to-noise ratio at output}}$$

The mean-square noise voltage at the input is $KT\,df\,.\,Z_0$. If we arbitrarily make the signal $\overline{(\text{voltage})^2}$ at the input equal to the noise $\overline{(\text{voltage})^2}$, that is also $KT\,df\,.\,Z_0$, then the signal $\overline{(\text{voltage})^2}$ at the output is $A.KT\,df\,Z_0$. The noise $\overline{(\text{voltage})^2}$ at the output, however, is given by the sum of the amplified input noise $\overline{(\text{voltage})^2}$ $A.\,KT\,df\,Z_0$ and the shot $\overline{(\text{voltage})^2}$ introduced by the electron beam ; i.e., expression (72).

Since the numerator of N is unity, we have

N = Noise-to-signal ratio at output.

$$= \frac{A\,.\,KT\,df\,Z_0 + \dfrac{\overline{V_2}^2}{z^2}\,.\,\Psi}{A\,.\,KT\,df\,Z_0} \quad \ldots \quad (75)$$

A, however, is equal to Φ and thus

$$N = 1 + \frac{\overline{V_2}^2}{Z^2}\cdot\frac{1}{KT\,df\,.\,Z_0}\cdot\frac{\Psi}{\Phi} \quad \ldots \quad (76)$$

When z is large, Ψ/Φ approaches unity and

$$N = 1 + \frac{2e\Gamma^2}{KT}\left(\tfrac{1}{4}\alpha^2 Z_0 I_0 V_0^2\right)^{\frac{1}{3}} \quad \ldots \quad (77)$$

For sufficient amplification z has to be at least 3. In that case, Equ. (77) gives the noise factor of the tube to a good approximation.

11.—Experiments

11.1 *Preliminary Investigations.*

Among various structures which suggested themselves for the purpose of slowing down a wave, the simplest seemed to be a coaxial line with the inner conductor coiled into a helix. Accordingly such a line was built and investigated for its propagation velocity, attenuation and characteristic impedance, using a source of 10 cm wavelength. The propagation velocity was deduced from a measurement of standing waves in the line and it was found that the wave travels along the turns of the helix with approximately the velocity of light. The attenuation constant α' of the line was deduced from the observed Q-value when short-circuited at both ends, and the characteristic impedance Z_0 was estimated from the standing-wave ratio in a line of known impedance connected to the helical line at one end, the other end being non-reflectively terminated. Typical values of a line having a propagation velocity of one-tenth of that of light, of 18 s.w.g. copper wire and 5 turns/cm are:

$$\alpha' \approx 2 \text{ db/metre}$$
$$Z_0 \approx 500 \text{ ohms}$$

11.2. *Experiments on the Interaction of Wave and Beam*

To be able to arrive at an estimate of the performance of a tube based on the interaction between an electron beam and a travelling wave, we needed to know the actual field strengths, axial and transverse, in the helical line for a given energy in the wave. This knowledge was gained by a series of experiments using the arrangement shown in Fig. 7. Means had to be found for feeding power into, and out of, the helical line without interfering with an electron beam which it was proposed to inject, alternatively, along the axis of the helix, and through the space between helix and the outer conductor. The structure shown was found to function satisfactorily, the rhumbatron-like attachments enabling good matching to be obtained between input and output line on the one hand and the helical line on the other.

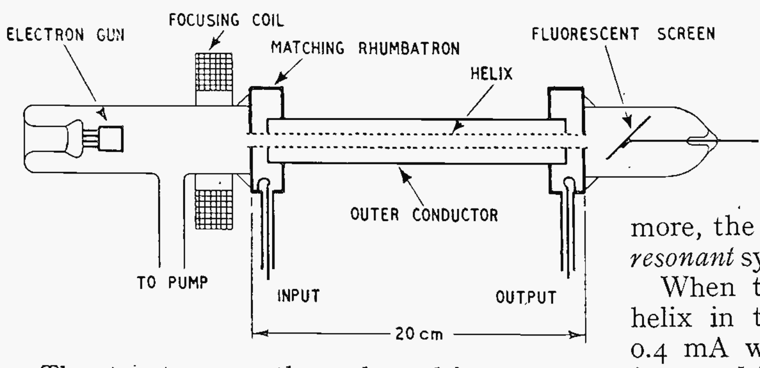


Fig. 7. *An experimental tube for determining the axial and transverse field strengths.*

The structure was then adapted for evacuation, and an electron beam shot through the space between helix and outer conductor. At the far end was placed a fluorescent screen upon which a luminous spot was formed by the electron beam. When r.f. power was sent through the helix and the beam voltage adjusted to the value of 2,400 volts, the luminous spot drew out into a line, roughly in a radial direction. From the magnitude of the deflection, and the amount of r.f. power an average value for the transverse field strength between helix and outer conductor could be deduced using Eqs. (1), (4) and (9). The appropriate weakening factor τ was found to be about 1/4.

Next, a weak beam was shot along the axis of the helix, and the maximum voltage increments, given to the electrons by a known amount of r.f. power, were measured by means of a collector at the far end biased negatively with respect to the cathode. The corresponding weakening factor of the axial field, α, was found to be about 1/6; this is the factor by which the field along the axis is weaker than that close to the helix.

If $|\phi|$ is the amplitude of the field at the axis, and x the length of the helix, the maximum voltage increment is given by

$$\Delta V = |\phi|\, x$$

Comparing this with the corresponding process in a rhumbatron of shunt impedance Z, it can be shown that the 'equivalent shunt impedance' of the helical line can be described by the expression

$$Z \text{ equ.} = \frac{4\pi^2 \alpha^2 x^2}{\lambda^2} Z_0$$

Taking practicable values, such as $\alpha = \frac{1}{6}$, $x = 60$ cm, $\lambda = 1$ cm, $Z_0 = 500$ ohms we have

$$Z \text{ equ.} \approx 2{,}000{,}000 \text{ ohms},$$

a value considerably higher than is commonly obtained with rhumbatrons. Furthermore, the helical line is an essentially *non-resonant* system.

When the r.f. power emerging from the helix in the presence of a beam of about 0.4 mA was measured, it was found to be *increased* by 49% over the power emerging in the absence of the beam. This occurred at a beam voltage of 2,440 volts. At 2,200 volts there was *decrease* of 40%.

Next, the density modulation in the beam was measured as a function of beam voltage. This was accomplished by passing the beam through a rhumbatron after it had traversed the helix. The result is shown in Fig. 8.

A number of observations were then made on the amount of shot-noise introduced into the line by the electron beam. When the beam was shot through the space between helix and outer conductor, the noise power was too small to be observed. When the

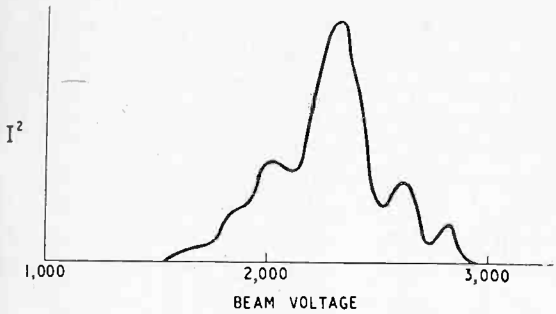


Fig. 8. *Density modulation of the beam current as function of beam voltage.*

beam was shot along the axis of the helix, however, it could be observed, though the measurements indicated a certain degree of 'smoothness' of the beam, believed to be due to the mechanism of space-charge smoothing near the cathode. If, as a first approximation, Equ. (50) is taken to describe the way shot-noise power is introduced into the line, the 'randomness' of the beam was reduced by a factor Γ^2 of 0.075.

11.3. *Experiments on Amplifiers*

Since experiment had shown that more power can be obtained from the helix than is put in, merely by shooting a beam of the right voltage along the axis of the helix, this mode of operation was chosen for the next experiments on the travelling-wave tube as amplifier. In this mode, the length of helical line can be envisaged to be a buncher and catcher combined. The wave in the first portion of the helix velocity-modulates the beam, resulting in a density-modulation or bunching, which in turn induces a wave in the helix of gradually increasing amplitude which supports the initial wave. This is, of course, a rather rough qualitative picture, applying only to small amplification.

It was desired to make an amplifier with as good a signal-to-noise performance as possible, and from the theory as developed at that time it appeared that such a tube should be many wavelengths long. Accordingly, measurements were made on a long copper helix enclosed in, and supported by, a glass tube. The attenuation was found to be rather high and this seemed to be due to the presence of the glass near the helix. When a glass envelope a good deal wider than the helix, and supporting the helix only by means of widely spaced dimples was tried, the attenuation was considerably reduced, and such a dimpled tube was then used for the vacuum envelope. The complete tube is shown on Fig. 9. The helix was about 66 cm long and of No. 18 s.w.g. copper wire wound on a ¼-in mandrel. The wavelength in the tube was 7.7 mm, corresponding to a beam voltage of 1,830 volts. (The free-space wavelength was 9.1 cm). The cold insertion loss of the tube, due to loss in the copper and glass, and to mismatches, was about 3.5 db. The electron beam was produced by a standard cathode-ray tube electron gun and focused magnetically by means of a short coil outside the tube. A thick soft-iron tube surrounded the main portion of the tube, to prevent stray magnetic fields from deflecting the long and thin electron beam.

With this tube, a net power gain of 6 was obtained with a beam current of 119 μA and the overall noise factor of the receiver of 16 db was improved by 2 db.

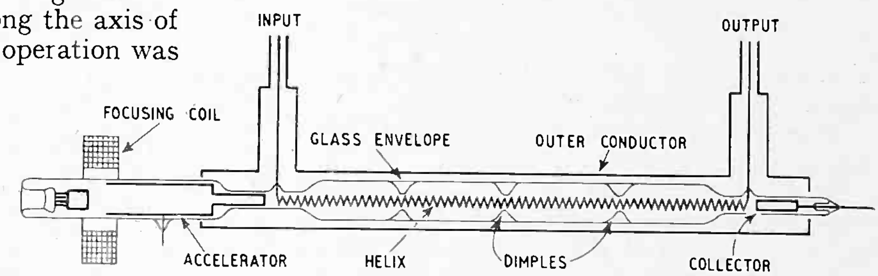


Fig. 9. *The complete travelling-wave tube as an amplifier.*

There was evidence of oscillations being present most of the time at wavelengths not far from the signal wavelength. These oscillations persisted down to beam currents as small as 20 μA.

It was further noticed that the noise factor of the tube depended on the fraction of beam current coming right through to the collector; only when more than 90% of the beam current was collected was there any improvement in the overall signal-to-noise ratio. This is believed to be additional evidence of the existence of space-charge smoothing in the electron beam.

Next, a helix of different proportions, held in a dimpled quartz tube, was tried using somewhat different input and output matching arrangements. This helix was wound of No. 22 s.w.g. copper wire on a 3/16-in mandrel with about 7 turns per cm and its length was 60 cm. A net power gain of 14 was obtained with a beam current of 40 μA

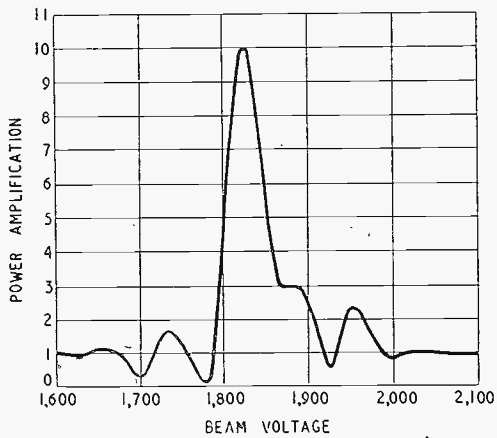


Fig. 10. *Variation of power amplification with beam voltage.*

coming through to the collector out of 50 μA total beam current. The overall noise factor of tube plus receiver was then improved by 4 db which corresponds to a noise factor of the tube by itself of 11 db.

Since the operation of the tube depends on the fact that wave and electrons travel with about the same velocity, the beam voltage has to be controlled within narrow limits. A graph showing power amplification against beam voltage is shown in Fig. 10.

These experiments fully confirmed the expectation that an amplifier could be built, on the principle of the interaction between travelling waves and an electron beam and that such an amplifier could be made with a signal-to-noise performance sufficiently promising to warrant further interest and study.

12.—Acknowledgments

The work forming the subject of this paper has been carried out for the Admiralty and is published by permission of the Board of Admiralty. It was initiated at the Physics Department, Birmingham University in 1942 and carried on, after a move in 1944, at the Clarendon Laboratory, Oxford University. All the investigations described in this paper were completed before the end of 1944.

The writer is indebted to many for very helpful discussions and interest; at Birmingham these were chiefly: Professor P. B. Moon, Dr. R. R. Nimmo, Professor J. Sayers and Dr. G. Voglis, and at Oxford: Dr. J. H. E. Griffiths, Dr. A. H. Cooke, and Dr. B. Bleaney. Very able assistance in the actual work, experimental as well as theoretical, was given by Mr. E. E. Vickers, Mr. J. Hatton and Mr. H. Ashcroft at various times.

RADIOLYMPIA

The fifteenth National Radio Exhibition opens at Olympia on October 1st, but there is to be a private view on September 30th. It will be open daily, except Sundays, from October 1st to 11th, between 11 a.m. and 10 p.m. Admission will be 2s. 6d.

The number of exhibitors is 186 and, in addition to broadcasting and television equipment, navigational aids and industrial electronic apparatus are now included.

The non-commercial exhibitors include the Ministry of Supply and the Metropolitan Police Force.

Wireless Engineer stand number is 242.

Institution of Electrical Engineers

The new president of the I.E.E. is P. Good, C.B.E., director of the British Standards Institution. He takes office on September 30th. Among the new members of the council are: T. E. Goldup, a director of Electronic Transmission Equipment, Ltd., and H. L. Kirke, C.B.E., head of the B.B.C. Research Department.

In the Radio Section the new chairman is C. E. Strong, O.B.E., B.A.I. (Standard Tele communication Laboratories) and the vice-chairman is F. Smith, O.B.E., (M.O. Valve Co.). The ordinary members are: C. F. Booth (G.P.O. Research Station), H. W. Forshaw, O.B.E. (M. of S., Directorate of Telecommunications Research and Development [Defence]), E. L. E. Pawley, M.Sc. (Eng.), (B.B.C.), and J. A. Ratcliffe, O.B.E., M.A. (Cavendish Laboratory).

BELLING & LEE

We are asked to correct an error which occurred in the Belling-Lee advertisement in the August issue. The first paragraph implied that the spigotless version of the B8A valve was known as the B8B. This is incorrect. The spigotless version is an accepted variation and comes within the standard specification of the B8A.

PERMEABILITY OF DUST CORES

Horatio W. Lamson

(*General Radio Company, Cambridge, Massachusetts*)

IN the February 1947 issue of *Wireless Engineer*, P. R. Bardell cites evidence indicating that the ferro-magnetic granules in dust cores have dimensions along the flux exceeding their transverse dimensions, thus affording a larger composite or effective permeability μ_c for a given volumetric concentration ratio p than could be attained with symmetrical granules such as hypothetical cubes or spheres.

The writer was interested in investigating Bardell's hypothesis somewhat further by considering, purely for convenience, a centimetre cube of the composite core material traversed by flux perpendicular to two opposite faces. The reluctance of this flux path would then be $1/\mu_c$.

For purposes of analysis, consider that the individual granules have the form of identical right cylinders which are all perfectly aligned, end to end, along the flux with appropriate axial and transverse separations. A portion of the flux will thus traverse the maximum number of these granules from face to face, while the remainder of the flux will follow a wholly non-magnetic path having a permeability of unity. Fringing effects are to be considered negligible. On this hypothesis it will be legitimate to consider the granules congregated, by an axial and a transverse displacement, into a solid ferro-magnetic cylinder having an axial length λ, a uniform cross-section A, and a volume $p = \lambda A$. The non-magnetic flux path will then have a length of unity and a cross-section $1 - A$. If μ is the normal permeability of the ferro-magnetic material at the induction which it carries, the total reluctance to the flux traversing the granules will be :

$$\frac{\lambda}{\mu A} + \frac{1-\lambda}{A} = \frac{\mu - \lambda(\mu - 1)}{\mu A}$$

and the reluctance of the non-magnetic path will be $1/(1-A)$.

Equating the parallel combination of these two reluctances to $1/\mu_c$ and noting that the concentration ratio p equals $\lambda A/1$, it follows that the composite permeability is given by :

$$\mu_c = 1 + \frac{p}{k-\lambda} \qquad \text{(1)}$$

wherein k is the ratio of the normal to the intrinsic permeability $(\mu - 1)$ of the ferro-magnetic material :

$$k = \frac{\mu}{\mu_i} = \frac{\mu}{\mu - 1} \qquad \text{(2)}$$

It should be noted that specific values of μ, μ_c, and p demand a unique value of λ given by :

$$\lambda = k - \frac{p}{\mu_c - 1} \qquad \text{(3)}$$

and a total ferromagnetic cross-section p/λ, regardless of the configuration of the cross-section of the individual granules and of their distribution in the cross-section of the composite core.

In the design of toroidal dust-core inductors, the fractional part of μ achievable as a composite permeability is significant. From Equation (1) :

$$\frac{\mu_c}{\mu} = \frac{k - \lambda + p}{\mu(k-\lambda)} \approx \frac{1 + \dfrac{p}{1-\lambda}}{\mu} \qquad \text{(4)}$$

the third member assuming a sufficiently large μ so that k becomes unity. It is of interest to note that, to obtain a desired value of μ_c/μ with a specific concentration, the value of λ must be increased when a ferro-magnetic material having a larger permeability is chosen.

The ratio, λ, of the flux path in the granules to the total flux path must lie within the limits :

$$p \leqslant \lambda \leqslant 1 \qquad \text{(5)}$$

Taking λ at its maximum value, Equation (1) becomes :

$$\text{Max}\ \mu_c = 1 + p(\mu - 1) \qquad \text{(6)}$$

which defines the "concentric rings" curve given by Bardell ; while taking λ equal to its minimum value gives :

$$\text{Min}\ \mu_c = 1 + \frac{p}{k-p} = \frac{\mu}{p + \mu(1-p)} \qquad \text{(7)}$$

which defines his "solid ring with airgap" curve.

The second member of (7) was derived by the writer (*Wireless Engineer*, November 1946) to give the effective permeability assuming uniform cubical granules having a random distribution but with opposite faces perpendicuar to the flux.

In Figs. 1–3 the Bardell curves of μ_c versus p, Equations (6) and (7), are given—assuming normal permeabilities of 100, 1000, and 10,000. Between these limiting values, a series of graphs for specific values of λ have been computed from Equation (1). These figures demonstrate the relationships between the parameters μ_c, p, and λ for widely differing values of μ.

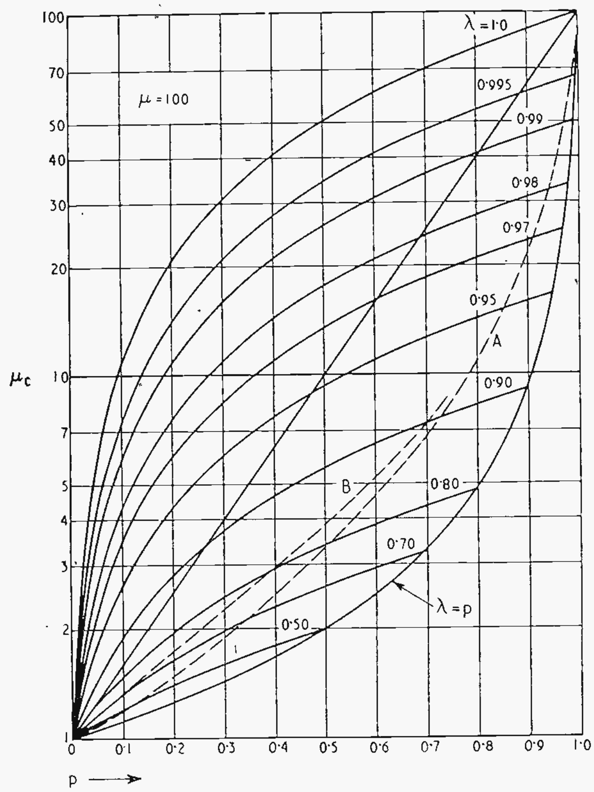


Fig. 1. *Bardell curves of μ_c versus p for $\mu = 100$. Curves A and B represent Equations* (10) *and* (11) *respectively.*

The linear diagonal corresponds to the exponential relation:

$$\mu_c = \mu^p \quad \ldots \quad (8)$$

It can be shown that the λ curve which is tangent to (8) at $p = 0$ is given by:

$$\lambda = k - 1/(\log_\epsilon \mu) \quad \ldots \quad (9)$$

These have the values $\lambda = 0.793$, 0.856, 0.892, for $\mu = 100$, 1000, 10,000, respectively. Any larger value of λ can satisfy (8) for a specific p value; smaller values of λ cannot satisfy (8).

The dashed curves labelled A represent the equation:

$$\mu_c = 1 + p/(k - \sqrt[3]{p}) \quad \ldots \quad (10)$$

which was previously derived by the writer, (*Wireless Engineer*, November 1946), assuming uniform cubical granules perfectly aligned both axially and transversely.

In *Wireless Engineer*, June 1946, R.E. Burgess gives the equation:

$$\mu_c = 1 + 3p\bigg/\left(\frac{\mu + 2}{\mu - 1} - p\right) \quad \ldots \quad (11)$$

which is valid for spherical granules at lower concentrations. The dashed curves labelled B depict Equation (11) extended up to the maximum concentration $p = 0.74$ attainable with uniform spheres.

It would seem that the curves A and B together stipulate the *maximum* values of μ_c attainable assuming a uniform distribution of identical symmetrical granules, such as spheres or cubes or the statistical equivalent thereof. Bardell shows a curve for cubic granules with truncated corners which lies slightly above A and is an approximate extrapolation of B. Therefore, for a given concentration, any larger empirical value of μ_c obtained would indicate asymmetrical granules having their major dimension more parallel with than transverse to the direction of the flux.

Consequently, whenever λ exceeds $\sqrt[3]{p}$, i.e., from (3), if the ratio:

$$\frac{\lambda}{\sqrt[3]{p}} = \frac{k}{\sqrt[3]{p}} - \frac{\sqrt[3]{p^2}}{\mu_c - 1} \quad \ldots \quad (12)$$

exceeds unity, the cubical granules must have undergone a longitudinal expansion resulting in a longitudinal composite permeability exceeding that given by Equation (10).

Bardell considers the granules to have the form of rectangular slabs with dimensional ratios 10 : 2 : 1 and gives the curve C in Fig. 2 for the composite permeability. It is convenient to define m and n as the ratios of the longitudinal dimension of the granular slabs to their major and minor transverse dimensions, respectively, ($m < n$). The Bardell slabs, therefore, have the elongation ratios $m = 5$ and $n = 10$. To compute the composite permeability when m differs from n, it is not only necessary to know the values of these ratios but it is also essential to specifiy some hypothesis defining the distribution of the granules throughout the transverse cross-section of the core.

Not knowing what hypothesis Bardell used in computing curve C, the writer made an assumption which is logical from various points of view—namely, that the insulation between adjacent granules has a uniform thickness at all points. It can then be shown that the extent of the ferro-magnetic paths in the major and minor transverse directions are :

$$\text{Major } \lambda' = \frac{\lambda}{\lambda + m(1 - \lambda)} \quad .. \quad (13)$$

$$\text{Minor } \lambda'' = \frac{\lambda}{\lambda + n(1 - \lambda)} \quad .. \quad (14)$$

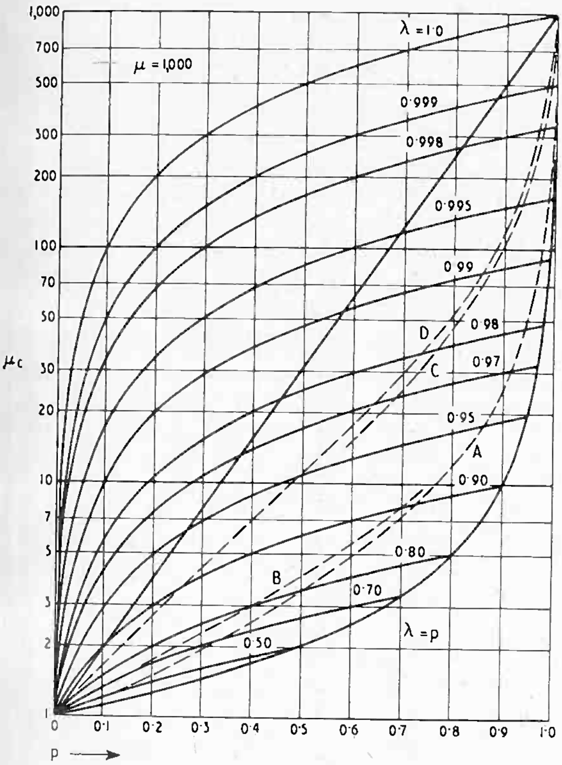


Fig. 2. *The Bardell curves for* $\mu = 1{,}000$. *Curves A and B represent Equations* (10) *and* (11) *while curve C is for rectangular slabs of ratios* 10 : 2 : 1. *Curve D gives values of longitudinal* μ_c.

For analysis these slabs may then be congregated into a rectangular prism having the volume :

$$p = \lambda\lambda'\lambda'' \quad .. \quad .. \quad .. \quad (15)$$

Substituting (13) and (14) into (15) gives the cubic equation involving the longitudinal λ only.

$$\lambda^3 - p\,[\lambda^2(1 - m - n + mn) + \lambda(m + n - 2mn) + mn] = 0 \quad (16)$$

It may be noted that this relationship between λ, p, and the elongation ratios is independent of the permeability of the ferro-magnetic material. Introducing Bardell's m and n values into (16) :

$$\lambda^3 - 36p\lambda^2 + 85p\lambda - 50p = 0 \quad .. \quad (16a)$$

Applying Cardan's solution to (16a), the values of λ were obtained for specific values of p. For p less than about 0.22, Equation (16a) has only one real root ; for larger values of p it has three real roots, only one of which is applicable to this problem. These data were then substituted in (1) to obtain the values of longitudinal μ_c, depicted by curve D in Fig. 2. It is apparent that Bardell must have used a somewhat different distribution hypothesis in obtaining curve C.

The assumption of elongated-slab granules for which m and n exceed unity leads to transverse values λ' and λ'' which differ (generally being smaller) from the longitudinal λ. Consequently, when λ' or λ'' replaces λ in Equation (1), smaller values for the composite permeabilities μ_c' and μ_c'' for flux in the major and minor transverse directions through the medium are to be expected. Again considering the Bardell slabs and assuming uniform insulation thickness, the following ratios of the longitudinal to the two transverse permeabilities were computed when $m = 5$ and $n = 10$.

TABLE 1.

p	μ_c/μ_c'	μ_c/μ_c''
0.9	4.247	7.848
0.8	4.206	7.315
0.7	3.952	6.401
0.6	3.619	5.447
0.5	3.217	4.345
0.4	2.745	3.523
0.3	2.238	2.651

A measurement of these three composite permeabilities should furnish a confirmation of this hypothesis of granular elongation. To investigate this question, the writer cut a centimetre cube from a molybdenum-permalloy toroidal dust core manufactured by the Western Electric Company and measured the initial values of its composite permeability in three directions, using a technique which permitted a reasonably accurate evaluation of permeability ratios and allowed for any leakage flux. The core had a known longitudinal μ_c of 125 which, according to Legg and Given, satisfies (8) *empirically* when μ is taken as 220 therein, (*Bell System Technical Journal*, July 1940). Consequently, the material tested had a volumetric concentration of 0.895. Using this value of p, the data given in Table II were computed for each of four assumed values of the initial permeability of the molybdenum-permalloy. The transverse permeability μ_c' (corresponding to m) was measured along the axis of the toroid, while μ_c'' (corresponding to n) was measured along the radius of the toroid.

These data confirm Bardell's hypothesis, by indicating a definite granular elongation, although with distinctly smaller m and n values than he proposes.

TABLE II.

Assumed μ	1,000	2 000	5,000	10,000
μ_o	125	125	125	125
μ_c'	86.7	96.0	103.5	106.5
μ_c''	39.8	50.4	62.1	67.1
μ_c/μ_c'	1.44	1.30	1.21	1.17
μ_c/μ_c''	3.14	2.48	2.01	1.86
λ	0.99378	0.99328	0.99298	0.99288
λ'	0.99056	0.99108	0.99147	0.99162
λ''	0.97793	0.98238	0.98555	0.98656
m	1.523	1.330	1.217	1.178
n	3.607	2.652	2.074	1.900

Bardell depicts this granular elongation to be produced by an actual crushing of initially symmetrical granules. If a hydrostatic pressure exists during the compression of the toroidal cores, it is interesting to speculate whether his slabs might not be formed by the direct cohesion of sufficient numbers of symmetrical and undistorted granules to give statistically averaged values of m and n exceeding unity.

It should be noted that smaller values of transverse μ_c are not, *a priori*, proof of slab granules. The writer wishes to point out that, to explain the μ_c values encountered in practice which lie above curve A or curve B extrapolated (truncated cubes), it is not imperative to assume slab granules with elongation ratios exceeding unity. As an alternative hypothesis, it is conceivable that the process of core formation results in a larger average thickness of insulation between uniform cubical granules in a transverse than in a longitudinal direction. Equation (10) assumes uniform insulation in all directions between aligned cubes so that $\lambda = \lambda' = \lambda'' = \sqrt[3]{p}$. Had the insulation thickness in the major and minor transverse directions been, respectively, s and t times that in the longitudinal direction ($s < t$), then $\lambda > \lambda' > \lambda''$ under the condition of (15), and it can be shown that :

$$\lambda' = \lambda/\{\lambda + s\,(1 - \lambda)\} \quad \ldots \quad \ldots \quad (17)$$

$$\lambda'' = \lambda/\{\lambda + t\,(1 - \lambda)\} \quad \ldots \quad \ldots \quad (18)$$

Comparing (17) and (18) with (13) and (14) and assuming $s = 5$ and $t = 10$, it is apparent that the longitudinal μ_c values given by curve D and the permeability ratios tabulated above would be obtained.

Both of the foregoing hypotheses are based on the assumption of uniform granules prismatic in shape. On the other hand, if one departs from the consideration of uniform granules, existing values of μ_c could conceivably be obtained by a close packing of spherical granules having some statistical distribution of diameters which would permit a maximum concentration exceeding 0.74 and approaching unity. The smaller values of transverse μ_c observed by the writer could then be attributed to greater average values of transverse separation produced in the moulding operation. This hypothesis, which would be difficult of mathematical analysis, appears to be quite logical although it is, admittedly, at variance with Bardell's photomicrographic evidence of slab granules.

While debate is still open as to which of several theoretical hypotheses best describes actual performance, the writer will cite two empirical formulae which have come to his attention. The first of these, applicable to molybdenum permalloy, is due to Legg and Given and, as mentioned above, consists of writing 220 for μ in (8). The second is due to Leigh Page and was cited by Burgess in *Wireless Engineer*, November 1946. It is obtained from (11) by inserting the empirical factor $(1 - 0.96\sqrt[3]{p})$ in the denominator.

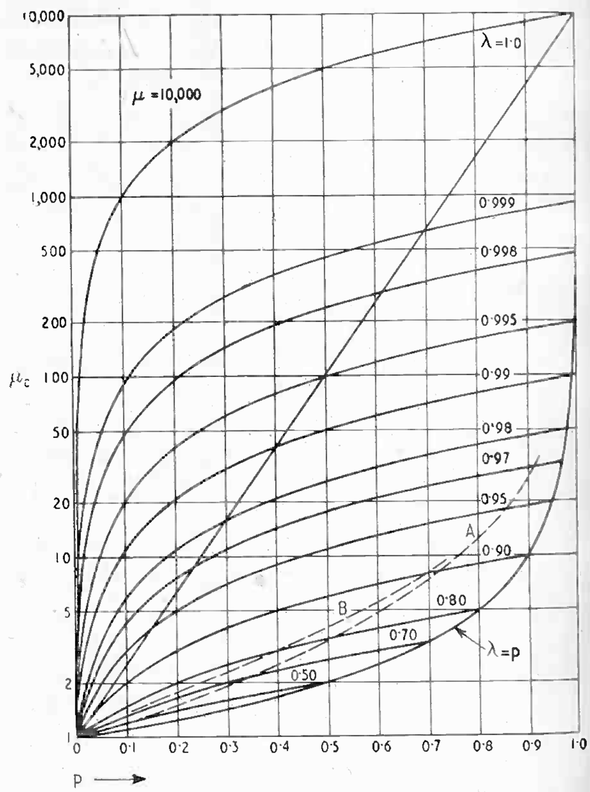


Fig. 3. *Bardell curves for* $\mu = 10{,}000$ *with equations* (10) *and* (11) *represented by curves A and B.*

ELECTRO-ENCEPHALOGRAPH AMPLIFIER

By Denis L. Johnston, B.Sc.(Eng.)

(*Continued from page 242, August issue*)

2.2.2. *Low-Frequency Response*

THE coupled-cathode circuit has a property of time constant lengthening that does not appear to be generally recognized. When there is a single self-bias cathode-load resistor R_1, as in Fig. 20(*a*), the input impedance seen from the preceding stage is obviously $2R_3$. However, when the cathode loads are divided, as is necessary for the insertion of a differential control, Fig. 20(*c*), the input impedance is that of each valve functioning individually as a cathode-follower, the individual values being

$$R_I = \frac{(R_2+R_3+R_5)\,[R_4+r_a+R_2+(R_1+R_2)\,\mu]}{R_4+r_a+R_2+\mu R_1}$$

The value of the differential cathode control alters this impedance very little for it is shunted by $2(R_1 + R_2)$ which is itself small compared with the input impedance.

In the circuit used the calculated value of dynamic input impedance is 24 megohms. A slightly lower impedance was observed, probably due to traces of grid current. This can be reduced by changing the circuit constants so that the valves work at a more negative grid potential, at the expense of gain. A stable value of 10 megohms was obtained by placing a stabilizing resistor R as in Fig. 20(*c*): it is ineffective in the position Fig. 20(*d*).

A time constant of 10 seconds is obtained with this dynamic impedance and the push-pull coupling capacitors of 2 μF each (effectively in series). This corresponds to a loss of 3 db at a frequency of one cycle in 60 seconds. In the present design the time constant per stage is reduced to two seconds by choosing a lower value of R when the higher value of time constant is not required.

No special provision is made in the amplifier for the correction of phase shift at very low frequencies, as the long time constant is available if required, but a useful compensating circuit has been noted in the literature[47].

The 2-μF coupling capacitors must be of high quality with an insulation resistance not less than 10^9 ohms. For a steady potential-difference of 100 volts there is then sufficient leakage current to produce 0.1 volt bias across a one-megohm grid leak, an amount

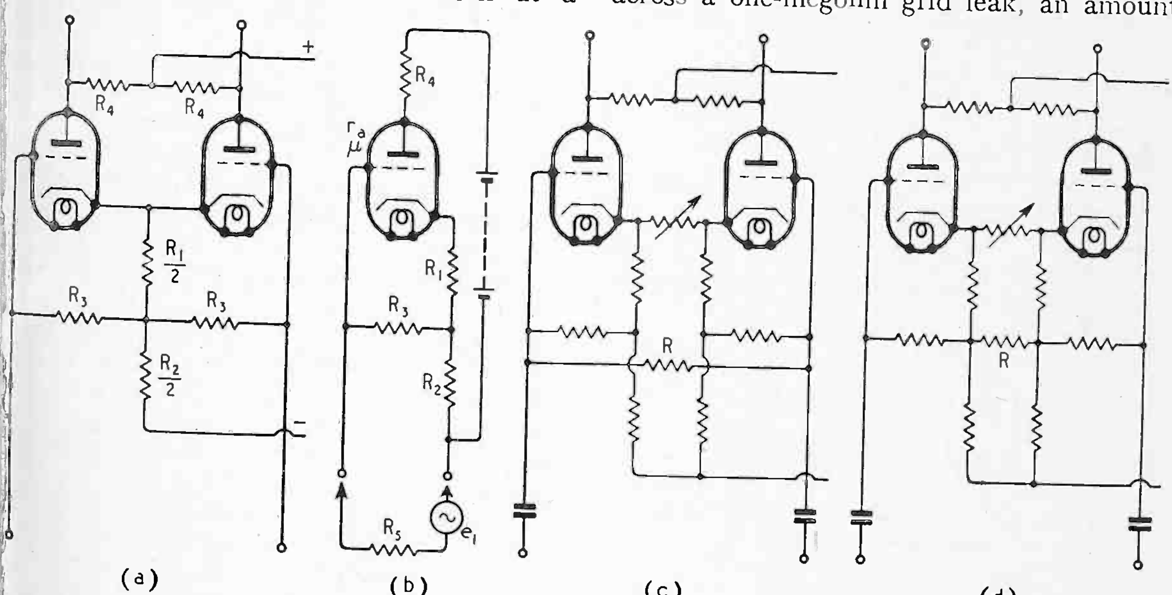


Fig. 20. *Simple coupled-cathode amplifier with self-bias* (a) *and equivalent cathode-follower circuit of one side of amplifier with inphase signals* (b). *A time-constant lengthening arrangement with stabilizing resistor R is shown at* (c) *and an ineffective position for R at* (d).

that is rather high and only tolerable if the capacitor leakage resistance is very stable. Oil-filled paper capacitors of 1,000-volt rating have been found satisfactory.

Time constants of less than the maximum overall value of one second are selected by switching smaller capacitors in series with the 2-μF components at one position of the inter-stage coupling, Fig. 21. To avoid a switching surge when the low-frequency control is operated the pairs of capacitors are connected together differentially by resistors R sufficiently high in value not materially to reduce the overall time constant. The resistor maintains the pairs of capacitors at equal potentials. It is not satisfactory to place leak resistors across individual capacitors rather than differentially, as small inequalities between the two sides of the amplifier will lead to considerable distortion of waveform for short time constants. At all times the 2-μF capacitors remain in series to block the direct potential from the preceding stage, so the switched capacitors need not be of especially high insulation resistance. The overall time constant of 1 second corresponds to a low-frequency response 3 db down at 0.15 c/s.

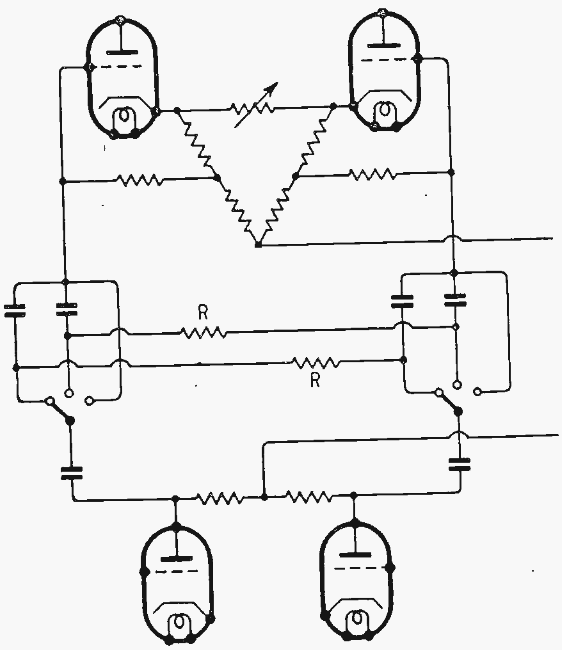


Fig. 21. *Arrangement for selecting value of amplifier time constant.*

2.2.3. *High-Frequency Response.*

The high-frequency response of the circuit shown in Fig. 36 is 3 db down at 10 kc/s and is sufficiently high for viewing biological potentials on an oscilloscope connected to the anodes of the penultimate stage. To obtain a higher frequency response it is necessary to reduce the anode loads, and to increase the current load on the h.t. stabilizer circuits in order to maintain the same amplification.

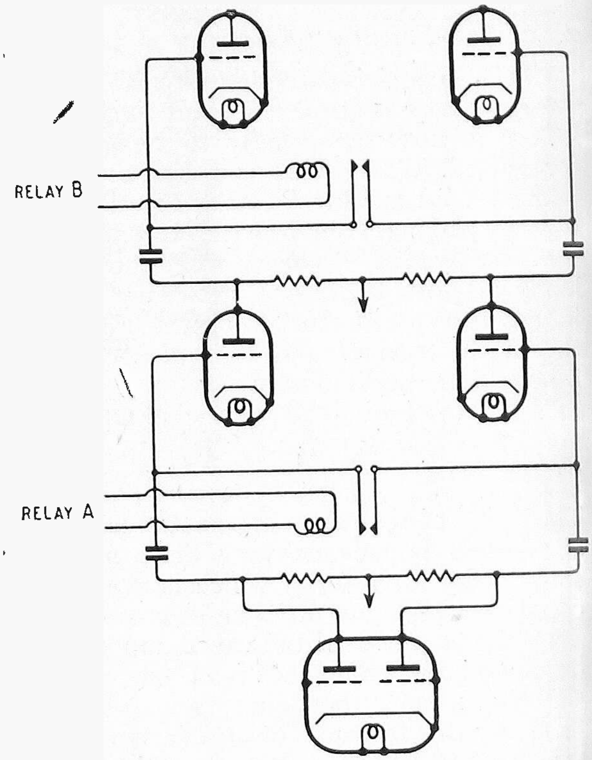


Fig. 22. *Relays A and B for "muting" the capacitor-coupled stages to reduce blocking time.*

Most of the stray capacitance to earth that restricts the high-frequency response is between the coupling capacitor foil and its can. Its effect is reduced if the can is insulated from earth, but the stability of the amplifier is impaired. This is undesirable, for no trace of instability is normally to be found. The chassis layout reproduces the balanced circuit arrangement of Fig. 36 and the amplifier is well screened by the closed chassis. Where cables are taken to the controls on the hinged panels they are grouped by stages of amplification so that wires at widely different signal potentials are not brought together (Fig.2.)

Several values of high-frequency response can be selected by means of a switch that places a capacitor differentially across the anodes at the second stage. It is worth noting that the effective output impedance of this stage is not approximately the value of the anode loads, but is considerably lower due to the feedback arrangement over the first two stages.

2.2.4. *Reduction of Blocking Time*

A differential amplifier with couplings of long time constant may "block" for a period of a minute or more under certain conditions unless precautions are taken to prevent this nuisance.

Blocking is initiated by an excessive input signal or accidental disconnection of the input, or by the action of operating the gain and frequency response controls. A large signal then passes through the amplifier, driving the valve at one side of each stage into a condition of grid current, and some time is then required before the grid leaks bring the coupling-capacitor potentials back within the working range of the valve grids. Capacitor-coupled stages will "unblock" progressively, and the least blocking time will be realised in an amplifier with few stages capacitor coupled.

For the purposes of electro-encephalography the inputs of a number of amplifiers are connected to electrodes placed on the patient's scalp through a number of contact selector switches shown in Fig. 4. During an examination adjustments are required from time to time and it is while doing this that lengthy "blocking" periods can be very tiresome. It is a general rule that all variable controls should be as far "forward" in the amplifier as possible so that switching surges are subject to the least possible amplification. In the experimental design it was undesirable to place a gain control across the anodes of the fourth stage, because the impedance conditions at this point were not constant, owing to appreciable grid current loading by the grids of the output stage of power amplification.

In this experimental equipment a Recorder ON/OFF switch is provided. Before making an adjustment this is turned to OFF, so disconnecting the outputs of the amplifiers from the recorder. At the same time the switch operation causes the pairs of grids at the fourth and third stages (in that order) to be short circuited by relays fitted in the amplifier chassis. The blocking impulse is thus "caught" and dispersed rapidly, because the time constant at each stage with the relay closed is that given by the anode load and coupling capacitor only. (Fig. 22.)

When the adjustment of the input connections has been completed the recorder switch is turned to ON, and the relays open again in the reverse order, first, the 3rd

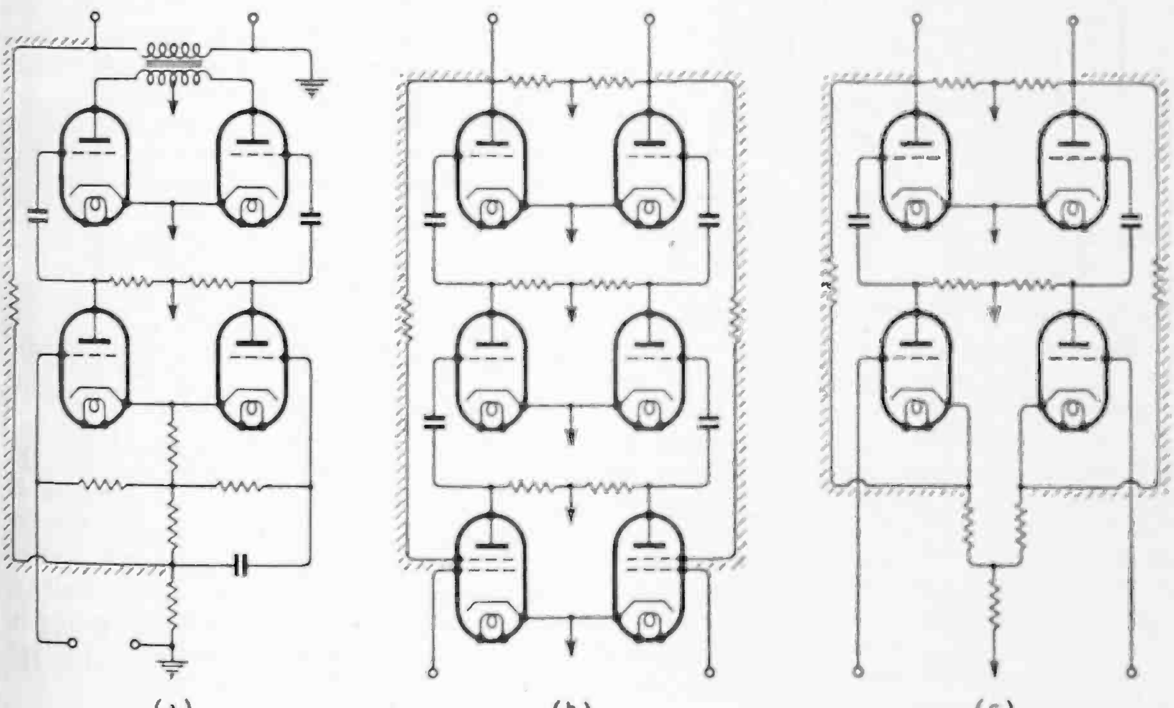


Fig. 23. (a) *Moir's negative feedback circuit*; (b) *negative feedback to grids of first stage*; (c) *negative feedback to first stage cathodes.* (*Feedback paths are shaded.*)

stage and then the 4th stage grids. This timing of the relays is obtained very simply by making the total switch motion 90 degrees and spacing the contacts controlling the relays within this angular motion. No blocking is noticeable if the switch is turned at such a rate that the 90 degree motion takes four seconds.

The grid current is restricted under conditions of blocking by resistors of 47 kΩ in series with the grid connections. Voltage drop across these resistors provides a convenient means of detecting the presence of a faulty valve with appreciable grid current. The degree of blocking is reduced considerably by attention to the static balancing of the direct voltage at differential points in the anode and cathode circuits.

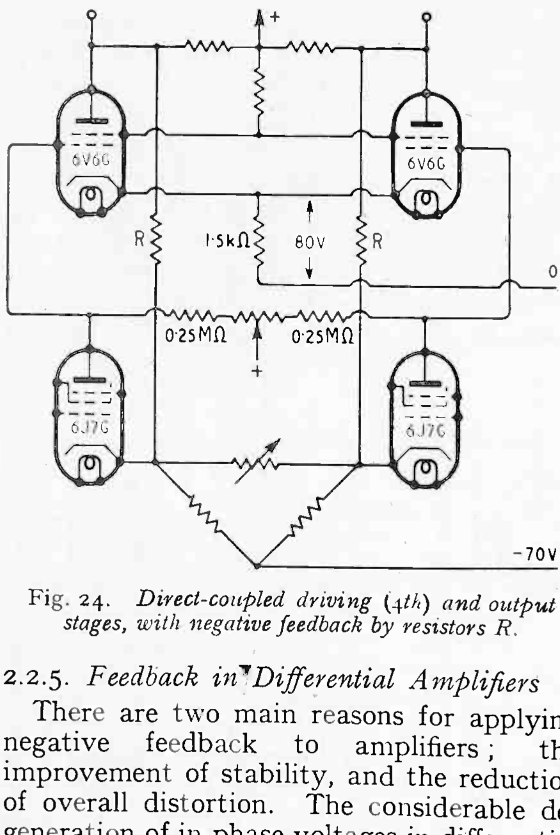


Fig. 24. *Direct-coupled driving (4th) and output stages, with negative feedback by resistors R.*

2.2.5. *Feedback in Differential Amplifiers*

There are two main reasons for applying negative feedback to amplifiers; the improvement of stability, and the reduction of overall distortion. The considerable degeneration of in-phase voltages in differential amplifiers leads to a high degree of stability, but it is not easy to arrange for the reduction of distortion by negative feedback. However, the overall distortion is very much less than in a single-sided amplifier because of the push-pull mode of operation, and for the present purposes the performance is adequate without the provision of feedback.

Moir[48] has shown a method of applying negative feedback to an audio-frequency amplifier where the input is single-sided and this is indicated in Fig. 23(*a*). When the input is differential, feedback must be taken over each side of the amplifier to one of the electrodes of the valves in the first stage, as in Fig. 23(*b*) or (*c*), but it becomes necessary to balance the two feedback paths and the circuit loses the attraction of the degeneratively balanced amplifier.

2.3. *Output Stage*

2.3.1. *Direct-Coupled Drive Circuit*

The output stage is directly coupled to the preceding stage as shown in Fig. 24. The grids of the 6V6G valves are brought up to the same working potential as the anodes of the stage before by a relatively large common cathode load. This arrangement satisfies the requirement mentioned in Section 1.3 that there should be the least possible number of inter-stage capacitor couplings. It would not be easy to obtain the required time constant if this coupling were not direct, because the maximum satisfactory value of grid leak for the 6V6G valve is about 0.25 MΩ.

The anode load at the fourth stage is high for the reasons already discussed and is itself about 0.25 MΩ. A coupling capacitor of 8 μF would then be needed to realize a time constant of two seconds per stage, and the low value of grid leak would entail a 6-db loss of amplification. With direct coupling each 6V6G grid works from a 0.25-MΩ load impedance, and it was found that the static balance conditions remained constant over long periods if the precaution was taken of ageing all new 6J7G and 6V6G valves before use. Change in static balance when the differential cathode control is at maximum attenuation is reduced by the negative feedback circuit through the resistors *R*. Feedback is zero at minimum attenuation.

2.3.2. *Recorder Drive Arrangements*

A balanced-armature moving-iron recorder is normally employed with the present amplifier. The coils are stationary and can accordingly be wound for an impedance of the same order as the anode-load resistance of the pentode-output stage. The recorder coils are connected differentially across the pair of anodes because the wattage dissipation in a multi-pen recorder would be excessive if the h.t. current were fed to the centre point of the coils.

Some forms of recorder incorporate a

double-resonant system to obtain higher frequency response and more constant characteristic of phase shift with frequency than is realized in a single-resonant system. Cut-off occurs at about 100 c/s, and between zero frequency and 100 c/s the response falls off by about 3 db [Fig. 25]. This falling characteristic is desirable for some purposes, but where necessary it can be compensated at the output stage by modifying the cathode circuit as in Fig. 26. The corrected response is given in Fig. 25.

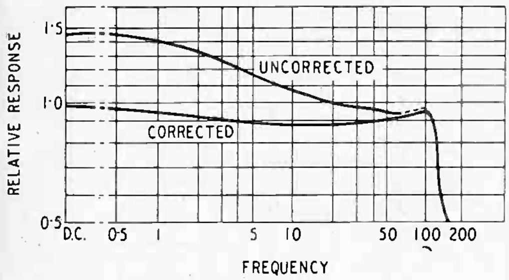


Fig. 25. *Frequency response of recorder and driving amplifier, with and without correcting circuit.*

Rochelle-salt crystal recorders are sometimes employed. They may be driven directly from the anode loads of the output stage. Moving-coil recorders are, by their nature, difficult to design with a coil impedance high enough to match the driving impedance of the anode output from a medium-sized power valve: some recent designs are better in this respect through the use of the higher flux densities obtained when using the newer permanent-magnet materials. Normally the

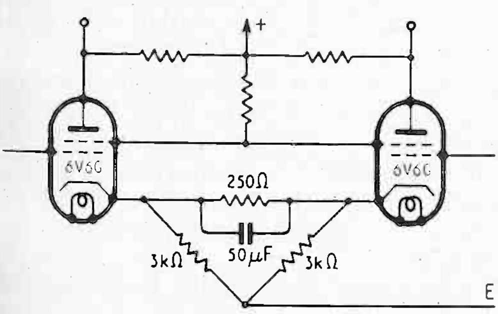


Fig. 26. *Frequency-response correcting circuit applied to cathode of output stage.*

critical damping of the moving-coil system is provided electrically and the driving impedance required in typical commercial designs is of the order of a few hundred ohms. This can be obtained with a cathode-output amplifier. Transformer coupling is impracticable at frequencies of the order of 1 c/s.

The present amplifier can be modified for cathode-output working as in Fig. 27. The impedance of the differential cathode output is approximately 600 Ω, and the voltage swing available without distortion approximately 50 V p-p. The voltage amplification of the output stage is lost when using the cathode-output arrangement, but this is partly compensated by the greater efficiency of a moving-coil recorder.

3. Electronicaly Stabilized Supplies

3.1. *Discussion of Performance*

Degenerative voltage and current stabilizing circuits have recently received a good deal of attention in the literature. Outstanding applications of the technique have been made by Hansen[49], in controlling a 40-kV electrostatic generator constant to 0.02 per cent, and by Vance[50] with an h.t. supply for an electron microscope variable in potential between 20 and 100 kV and stable to 0.007 per cent over an interval of 30 seconds. Hunt and Hickman have stated[51] that the stability obtained in a mass spectroscope with degenerative stabilization was better than with batteries. Brown[52] has described stabilized current and voltage supplies for this instrument.

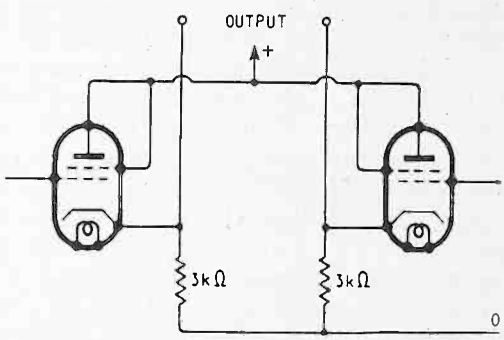


Fig. 27. *Modification as a cathode output amplifier.*

A number of designs of amplifiers that employ stabilized power supplies are noted in Section 1.1 and references[39,53–55]. Hitherto a performance adequate for electro-encephalographic work has not been achieved without batteries for some current or reference voltage supplies. The measures adopted in the present design to eliminate all batteries are outlined below.

The actual performance at the several sections of the high-tension and heater-supply stabilizer circuits is represented in

Fig. 28. The fluctuations that appear at the amplifier output when the mains supply changes abruptly by 1 volt r.m.s. in 230 V is equivalent to 3 μV peak-to-peak signal input, when the amplifier time constant is one second. The fluctuation is less for slow changes in supply voltage, and is, of course, reduced when the amplifier is operated at a time constant less than one second. When advantage is taken of the time-constant lengthening property of the amplifier circuit, to obtain in overall time constant of 5 or 10 seconds, it is advisable to run the equipment from a stabilizing mains transformer capable of reducing the supply-voltage variations by about ten to one.

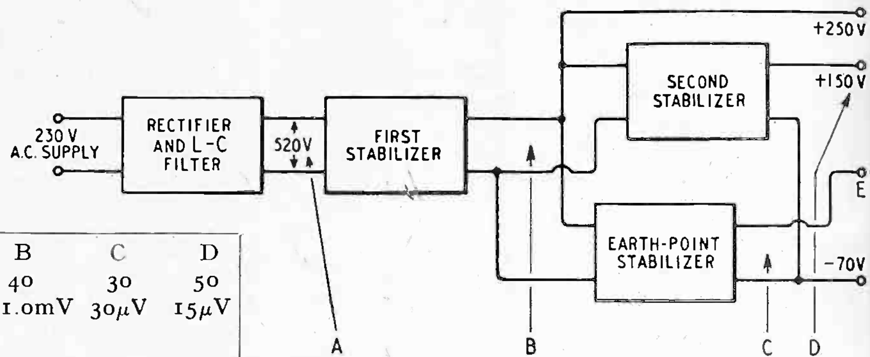


Fig. 28. *Performance at the several stages of h.t. stabilization.*

	A	B	C	D
Output impedance	850	40	30	50
A.C. ripple voltage	0.15V	1.0mV	30μV	15μV
Peak d.c. fluctuation due to 1V r.m.s. abrupt change in 230V a.c. supply ...	2.2V	50mV	500μV	100μV

At an amplifier time constant of one second fluctuations in output voltage are due about equally to residual changes in output of h.t. and heater supplies after stabilization. The anode load adjustment at the first stage of the amplifier, *R* in Fig. 10, has two slightly different optimum settings, the one where residual supply frequency ripple is at a minimum (an equivalent input signal level of less than 0.3 μV p-p is obtainable), and the other optimum for minimum fluctuation due to abrupt changes in supply voltage. The latter point of balance is found by adjusting *R* for the minimum change in recorder deflection when the stabilized h.t. voltage is altered slightly by applying an additional load resistor by means of a test jack (" BAL " of Fig. 36.)

3.2. *Requirements of H.T. Stabilizing Circuit*

D.C. stabilizing circuits are of two distinct types, bridge-balanced and degenerative : in addition there are combined arrangements of degenerative circuits with subsidiary balancing for complete stabilization at a particular load. In general, balanced stabilizers require occasional adjustment and this is an unsatisfactory feature in a commercial design. It is better practice to use a degenerative type designed with a degree of stabilization adequate for the purpose in view.

A comprehensive review of the subject was made by Hunt and Hickman[51] who give expressions for computing the performance of ten types of circuit, which they have classified into four groups :

(1) Transconductance Bridge
(2) Amplification Factor Bridge
(3) Simple Degenerative Amplifier
(4) Combination circuits involving two or more of the foregoing classes.

Useful discussions of the degenerative type have been given by a number of authors[56–59]. They give other references, and as the literature is rather extensive no further discussion will be made here of the many arrangements that have been developed.

The limiting factor in h.t. stabilizers which employ single-valve stages of amplification of the negative feedback voltages, is the loss of stabilization with changes in heater-supply voltages. In the present design this effect is reduced by a substantial factor, first by the use of coupled-cathode circuits throughout for the same reasons that they were employed in the early stages of signal amplification, and, secondly, the provision of stabilized direct-current supply to the heaters in the second and third stages of stabilization.

A " floating " type of supply must simulate the characteristics of the battery h.t. supply that it replaces, as already discussed in Section 2.1.3. The present circuit employs three stages of stabilization. The first is a series-type degenerative stabilizer which is situated on the power-unit chassis. The output voltage is 320 V and this supply is used for the third and fourth stages of the amplifier. The second stage of stabilization is situated physically on the amplifier chassis adjacent to the input stages of the amplifier: the output is at 220 volts, with a ripple level not exceeding 15 μV: the negative pole is common to the other supply and is maintained at − 70 volts to earth potential by a third stage of stabilization. The potentials to earth of the two positive supplies are consequently + 150 V and + 250 V.

The third stage of stabilization is, with the second, at the amplifier chassis and the two form a symmetrical pair of circuits. The "floating" supply feeds the second stage of the signal amplifier, which is part of a cascade circuit which includes the first stages of amplification and the cathode-coupling pentode load of Fig. 10(*a*). This special supply is equivalent to a carefully insulated high-tension battery. The function of the third stabilizer circuit is to degenerate the amplitude of any induced or leakage currents between the h.t. supply and chassis earth.

The reference voltage for the second and third stages of stabilization is derived from a cold-cathode valve, followed by an RC filter circuit. The first stage of stabilization is controlled by the output voltage of the second which is transmitted back to the power-unit chassis through a screened pair of wires cabled with the other interconnections. This cable has to be several feet in length to allow for opening the cabinet in which the chassis are mounted. Any voltage picked up electrically or electromagnetically appears equally in each conductor of the pair, and consequently it is rejected by the coupled-cathode amplifier employed in the first stabilizing stage.

In both the h.t. and the heater supply stabilizers, the cold-cathode valve which provides the reference voltage is followed by an RC filter with a time constant of several seconds (i.e., several times the constant for the signal amplifier), for the purpose of reducing the effects of noise and fluctuation in voltage that are always present in these valves. The filter reduces the rate of change of fluctuations in reference voltage below that rate to which the amplifier will respond. A cyclic fluctuation or "ticking" of up to 100 mV is commonly experienced with 70-volt regulating valves. Specimens exceeding this value are not used in this position in the circuit.

(To be concluded)

ELECTROMAGNETIC WAVES IN A VACUUM

Relative Directions of the Electric and Magnetic Vectors

An interesting letter on this subject by Dr. N. S. Japolsky was published in *Nature* of April 26. He pointed out that the usual assumption that the electric and magnetic vectors are mutually perpendicular is only true in certain circumstances. The curl of H is perpendicular to the time derivative or rate of change of D, and not necessarily to the vector D, and similarly the curl of $\mathcal{E}$ is perpendicular to the time derivative of B and not necessarily to the vector B itself.

In plane-polarized plane waves they are mutually perpendicular, but in rotating waves in which the vectors rotate, they are not mutually perpendicular except in some special cases, such as circularly-polarized plane-waves, in which the electric and magnetic vectors are perpendicular to each other and rotate with the same angular velocity. They are also mutually perpendicular in spherical waves as radiated from an ordinary aerial, the electric vector being always in the axial plane, and the magnetic vector perpendicular to it.

Except for such special cases, in waves in which the vectors rotate they are not mutually perpendicular. As Japolsky says, this point is usually overlooked because until quite recently very little attention was given to the study of such waves. Dr. Japolsky was at one time at the Technological Institute of Leningrad, but has been for many years at the Royal Institution in London. He has contributed several articles to the *Philosophical Magazine* dealing with what he calls electromagnetic whirls, the idea being that electronic particles may really be microscopic electromagnetic whirls, in which, as he points out, the electric and magnetic vectors may not be mutually perpendicular.

G. W. O. H.

NEW BOOKS

Television Simplified

By MILTON S. KIVER. Pp. 375 + vii, with 222 illustrations. Macmillan & Co., Ltd., St. Martin's Street, London, W.C.2. Price 27s.

This book is of American origin and all the examples are taken from American practice, which differs quite considerably from British television in certain important matters, such as, the use of negative modulation, horizontal polarization, vestigial sideband transmission and frequency modulation for the sound channel. In spite of this a very large amount of the material in the book is as applicable in this country as in the U.S.A.

In his preface the author says " It is the purpose of this volume to aid the thousands of radio men and women who will design, construct and repair television sets to bridge the gap between the modern ' pure ' sound receiver and the more complex television circuits." He has succeeded in his purpose and the book should form an excellent introduction to television for those who are well versed in the practice of sound equipment but have little knowledge of television.

The book starts off with chapters on the general principles of television, very short waves and television aerials, and then goes on to treat in more detail wide-band circuits, detectors, and a.g.c. circuits, v.f. amplifiers, d.c. restoration, c.r. tubes, synchronizing and deflexion systems. There is a chapter on complete receivers, and others on colour television, frequency modulation and servicing.

The treatment is almost entirely non-mathematical, but the explanations of the operation of the various circuits are clear and will unquestionably be helpful to the beginner. There are very few errors, but there are some. On p. 199, the author refers to a triode or pentode limiter fed with a v.f. signal having positive-going sync pulses and providing d.c. restoration in the grid circuit. The *circuit* is substantially the same as one previously shown as an amplifier and he comments that the reader may be puzzled to distinguish between the two. He goes on to say that the difference lies in the value of the grid leak which is 0.5 MΩ for d.c. restoration in an amplifier and 1–3 MΩ for a limiter. The difference of performance, however, occurs not through the use of a different value of grid leak, but because a much lower anode voltage (triode) or screen voltage (pentode) is used for a limiter than for an amplifier.

Something has also gone wrong with Fig. 9.12 which shows the sync pulse waveforms for even and odd frames. The line pulses are drawn coincident prior to the frame pulse, but displaced after the frame pulse.

The deflexion circuits and their characteristics are dealt with in a very superficial manner and while this may seem adequate for the beginner there is nothing to warn him of the many difficulties and pit-falls encountered in practice. W. T. C.

Interference from Industrial R.F. Heating

By A. TURNEY, B.Sc. Technical Report M/T 88. Published by The British Electrical & Allied Industries Research Association, 15, Savoy Street, London, W.C.2. Price 3s. 6d.

Elementary Radio Servicing

By WILLIAM R. WELLMAN. Pp. 260 + xi. Macmillan & Co. Ltd., St. Martins St., London, W.C.2. Price 21s.

Plastics for Electrical and Radio Engineers (2nd Edition)

By WALTER J. TUCKER and R. S. ROBERTS. Pp. 167 + xi. The Technical Press Ltd., Gloucester Road, Kingston Hill, Surrey. Price 15s.

British Research in the Radio Field

From the Secretary, The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2. Price 1s.

A report from the Research Committee of the Institution which reviews the facilities for research in the radio field and which makes recommendations for the stimulation and co-ordination of British radio research.

Wireless Direction Finding (4th Edition)

By R. KEEN. Pp. 1059 + xii with 630 illustrations. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 45s.

The B.B.C. Year Book, 1947

The twentieth B.B.C. Year Book, giving a review of the year's broadcasting, including television.

Pp. 152. B.B.C. Publications Dept. The Grammar School, Scarle Road, Wembley, Middx. Price 2s. 6d.

Lewis's Medical, Scientific and Technical Lending Library (Supplementary Catalogue), 1944-1946.

Pp. 176. H. K. Lewis & Co., Ltd., 136, Gower St., London, W.C.1. Price 5s. to non-subscribers, 2s. 6d. to subscribers.

Television

Vol. III (1938–1941), Pp. 486 + xii; Vol. IV (1942–1946), Pp. 510 + xiv.

Published by R. C. A. Review, Radio Corporation of America, R.C.A. Laboratories Division, Princeton, New Jersey, U.S.A. Price $2.50 each, or $1.50 each, paper bound.

Collection of papers by R.C.A. authors. Many are reprinted in full, but some are summarized. Appendices to Vol. III include summaries of the papers of Vols. I and II which are out of print and which cover 1936–1938.

Electronic Engineering Patent Index

Edited by FRANK A. PETRALGIA. Pp. 476 + viii. Published by Electronics Research Publishing Co., 2, West 46th St., New York 19, N.Y., U.S.A. Price $14.50.

Contains some 2,000 patents granted during 1946, classified according to subject and reproduced in full from the annual file for 1946 of the Gazette of the U.S. Patent Office.

Rubber in Industry

" Developments in Rubber " is a loose-leaf binder containing a number of reprints of articles dealing with the technical aspects of rubber and rubber-metal bonds in industry. Copies are available for Engineers and Education Institutions and applications should be made on official notepaper to Andre Rubber Co., Ltd., Kingston By-Pass, Surbiton, Surrey.

CORRESPONDENCE

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

Comparison of A.M. and F.M.

To the Editor, "Wireless Engineer."

SIR,—We are accustomed to Britain, with smaller technical resources, being later than the U.S.A. in some branches of radio development, but even in this country we are not in the state of mind implied by M. G. Nicholson's paper in your July issue. F.M. has been studied here from the point of view of point-to-point communications even more than broadcasting, and communications engineers are well aware of the effects of bandwidth on fidelity and of the difference in atmospheric noise level between 1 Mc/s and 50 Mc/s and upwards.

In discussing adjacent-channel interference, Nicholson omits to explain that Hans Roder's paper, which was published in 1937 (only one year after Armstrong's classic f.m. paper), was concerned with the case in which the two interfering signals are allocated channels which overlap by 50 per cent; i.e., one carrier is situated on the limiting frequency of the other channel. In the light of present-day knowledge this is an utterly unpractical condition, since two transmitters which are expected to be within usable range of the same receiving station would always be given clear channels.

I am surprised to hear that the suppression of a weak modulated signal by a strong carrier in a linear detector, the "rectifier discrimination" effect, "does not appear to be generally appreciated." For example, my paper on "F.M. Communication Systems" (*Wireless Engineer*, May, 1943), specifically mentioned this factor when discussing the effects of modulated interference in f.m. and a.m. systems. However, I overlooked at that time a point which Nicholson does not seem to have considered: in the usual f.m. receiver having a discriminator circuit and two diodes, the signal is converted from f.m. to combined f.m. and a.m. and the a.m. is then detected in linear rectifiers. Therefore, the "rectifier discrimination" phenomenon should still be effective in the f.m. receiver, in addition to the superior selectivity obtained in f.m. from the limiter and balanced discriminator.

We are familiar with the characteristics of pre-emphasis plus de-emphasis systems, and the figures quoted in my 1943 paper included an allowance for the necessary reduction in modulation depth (taken from the R.C.A. experimental results, Nicholson's Reference 5).

Since 1943, I have made some studies of impulse noise, but it must first be pointed out that Nicholson's radar analogy is fallacious. The discrimination between transmitted pulse and echo in a radar receiver depends entirely on the time difference, and the only amplitude requirement in the receiver is to avoid "paralysis" so that the time discrimination can be effective. A radar transmitter causes severe interference on an a.m. telephony receiver. As an alternative to f.m. for impulse elimination, wide-band a.m. plus an amplitude-limiter is proposed, but there are several objections to this:—

(i) The a.m. system must have the same bandwidth, and therefore the same transmitter channel spacing, as the f.m. system. But owing to the lack of "capture effect" on a.m., common-channel transmitters must be separated by much greater distances, and the total number of transmitters which can be operated is reduced.

(ii) The receiver must remain wide-band (e.g., 150 kc/s) up to the impulse-limiting circuit, and this may be embarrassing since the limiter should work at a high level to render negligible the transition region between conduction and non-conduction in the diode.

(iii) The impulse limiter must be a fairly elaborate circuit in order to follow the modulation envelope, and if clipping of the higher modulation frequencies is to be avoided, only those components of the pulse which are substantially higher in frequency can be cut.

The net result is that the wide-band a.m. system can never be quite as good as a correctly adjusted f.m. system (which cuts impulses exactly at modulation level), is about as costly as the additional i.f. limiter stage in the f.m. receiver, and lacks the f.m. advantages on all other types of noise.

So far as I am aware, all properly controlled tests of f.m. versus a.m. systems have led to the conclusion that the balance of advantage is with f.m. This would appear to be supported by the decision of the B.B.C., after the extensive trials reported in the *B.B.C. Quarterly* of July, 1946, to continue with f.m. development, and by the use of f.m. for multi-channel telephone links by the British Post Office.

D. A. BELL.

British Telecommunications Research Ltd.,
Taplow, Bucks.

"The Doppler Effect in Propagation"

To the Editor, "Wireless Engineer."

SIR,—Your correspondents, Messrs. R. E. Burgess and F. S. Atiya did quite right to point out in the August issue the error in my article "Doppler Effect in Propagation," wherein the implications of relativity principles were neglected. In the interest of demonstrating the approximate relationship between the observed "shift" of the Washington standard frequency and the changes in propagation geometry, the fallacy of the two "classical" Doppler equations was unobserved. Fortunately, as Burgess agrees, the error is negligible in its effect on the remainder of the argument. I can confirm that at least one quite well-known and recently published text-book of Optical Physics commits the same error as I did.

As Mr. Essen says in his letter, the limitation of accuracy imposed by the Doppler Effect upon the comparisons between frequency standards remote from one another, using a high-frequency radio link, was demonstrated as long ago as 1935. Improvements in the accuracy with which the absolute value of frequency standards can be determined and the greater knowledge of propagation conditions now available, suggested that the subject of the article might yet be of interest.

Replying to Mr. Essen, the average value of the apparent frequency-shift during steady, daytime conditions over several days at 1600 G.M.T. was chosen because the time was then about the most suitable for the highest-frequency reception with a relatively stable path. It was also a convenient time because the comparisons apparatus was not in use for other work. The example chosen was then a shift of -3 parts in 10^8. Fairly steady beats of as great as ± 6 parts in 10^8 have at various other times been obtained. Much greater, but widely varying, difference frequencies have been indicated during disturbed or rapidly changing conditions of reception, complicated by wave-interference associated with "scattering" and with multiple-path signals, one or another path being only momentarily predominant.

Differential propagation of high and low frequency transmissions from WWV has also been observed. For example, some comparisons showed frequency errors which themselves diverged by 4 parts in 10^8, with fairly steady beats with the local standard in both cases, sometimes with a simultaneous difference in sign. This effect does not seem to persist for longer than 15 or 30 minutes and is difficult to demonstrate, because it requires comparatively stable conditions on two frequency bands undergoing divergent treatment in the ionosphere, with freedom from random scattering, etc., in both bands.

H. V. GRIFFITHS.

Westerham,
Kent.

Cavity Resonators and Electron Beams

To the Editor, "The Wireless Engineer"

SIR,—In a recent article on "Cavity Resonators and Electron Beams," Mr. J. H. Owen Harries has derived some results which seem to show that there are fundamental limitations to the upper frequency which can be generated by beam-resonator combinations. Furthermore, the upper frequency appears to be of the order of 30,000 Mc/s. Of course, Mr. Harries' results do not forecast a sharp cutoff frequency but they do show a very marked falling off in efficiency above this frequency.

These results appeared to contradict the experimental evidence which shows that the efficiencies of both magnetrons and reflex klystrons do not alter very rapidly with frequency from 1,000 Mc/s to the highest frequencies yet reached.

An examination of Mr. Harries paper shows that his results do not give the correct frequency dependence of efficiency. In his work the efficiency of the circuit (the proportion of the energy generated which can be coupled into a load) is given by an expression of the form

$$\eta_c = 1 - b\left(\frac{\lambda_0}{\lambda}\right)^{\frac{5}{2}} \quad \ldots \quad \text{Equ. (38)}$$

where b is a constant for a given tube geometry and type of modulation. λ_0 is a reference wavelength taken as 10 cm in his work and λ is the wavelength at which η_c is to be measured. The correct expression (under the same approximations as Mr. Harries) is

$$\eta_c = 1 - b\left(\frac{\lambda_0}{\lambda}\right)^{\frac{1}{2}}$$

Mr. Harries Equ. (39) for the output power should read

$$P_L = \frac{V_0 B^2 \eta_0}{R_{B0}}\left[1 - \frac{0.77}{\eta_0}\frac{1}{\Psi_0}\left(\frac{\lambda_0}{\lambda}\right)^{\frac{1}{2}}\right]$$

The reasoning which leads to these changes is as follows. Harries parameter Ψ can be shown, after reduction, to equal R_0/R_b where R_0 = parallel resonant impedance of resonator and R_b = beam impedance.

Equ. (28.2) gives $\eta_c = 1 - b/\Psi$

so we have to investigate the frequency dependence of R_0/R_b. It is well known that $R_0 \propto \lambda^{\frac{1}{2}}$ for similar resonators; Harries states that $R_b \propto \lambda^{-2}$ but this is not correct. There are two cases to be considered (a) Electrostatic focusing, and (b) Magnetic focusing.

Case (a): Maximum current through a tunnel length l, diameter $d = 38.9 \times 10^{-6}\left(\frac{d}{l}\right)^2 V^{\frac{3}{2}}$ amps.

For similar resonators this is invariant; R_b is therefore a constant for a given resonator shape.

Case (b): In the magnetic case the maximum current is given by $32.5 \times 10^{-6} V^{\frac{3}{2}}$ which is independent of the hole area or length. R_b is again a constant.

We therefore see that $R_0/R_b \propto \lambda^{\frac{1}{2}}$ and not as $\lambda^{\frac{5}{2}}$ which leads to the results given above. It should perhaps be pointed out that a much more refined analysis, dealing with the actual process of energy conversion in any given type of tube is necessary before the results can be brought into line with experiment. Experiment does, however, agree approximately with the $\lambda^{\frac{1}{2}}$ variation.

It appears that, though no tube engineer is likely to under-estimate the practical difficulties, there are no fundamental limitations to the generation of power at millimetre wavelengths. It also seems unnecessary to postulate a connection between the difficulties of millimetre generation and the various new phenomena in the field of propagation research.

A. H. BECK.

Standard Telecommunication
Laboratories, Enfield, Middx.

To the Editor, "Wireless Engineer"

SIR,—Mr. Beck bases his criticism upon the deduction that R_b is a "constant"; that is, that the total electron beam current that can enter the resonator from a cathode is independent of the area of the cathode and of the area of the aperture through which the electrons enter the resonator. This is the kind of deduction which Euclid called "absurd"! Mr. Beck quotes his cases (*a*) and (*b*) in support, but his formulae are not complete expressions for the electron beam parameter R_b. For example, no account is taken of the cathode-source of the electrons.

His argument therefore falls to the ground. I do not know to what experiments Mr. Beck refers when he says that they contradict my results.

Mr. Beck misquotes me at the extreme end of his letter. I did not postulate a " connection " between the propagation difficulties found around 1 cm wavelength and the existence of a limit to the performance of resonator-valves at the same part of the wavelength gamut. On the contrary, I said (Section 10) that it was a " singular coincidence " that two unconnected but fundamental phenomena should both adversely affect radio communication at the same part of the gamut. I am sorry that this does not seem as interesting to Mr. Beck as it does to me, but I am, I fear, unrepentant and still find it well worthy of comment that, at this particular part of the gamut, one finds not merely one but two separate obstacles which have to be taken into account when one is trying to establish communication.

J. H. Owen Harries.
Harries Thermionics Ltd.,
London, W.1.

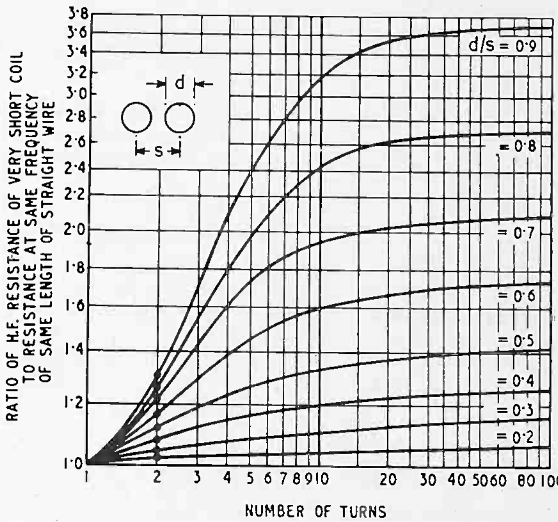
Q of Solenoid Coils

To The Editor, " Wireless Engineer "

Sir,—Mr. Callendar points out (*Wireless Engineer*, June 1947) that there is little indication in my article as to how far Butterworth's correction factor for coils of few turns can be relied on. That is a deficiency of which I was acutely aware and I can only plead lack of time for making the large number of measurements necessary to fill this gap.

Very tentatively, we can deal with short coils in the following way. Suppose we try to plot curves of ϕ (ratio of h.f. coil resistance to resistance of the same length of straight wire at the same frequency) against the number of turns (n), for various spacing ratios. We know that the curve has to approach asymptotically the values given in column 1 of Table VIII (*Wireless Engineer*, March 1947, p. 88). Also we know two more points, those for $n = 1$ and $n = 2$ values come from Butterworth's exact solution of the problem of two parallel wires carrying high-frequency currents in the same direction (*Proc. Roy. Soc.*, 1925, 107A, p. 708). From these we can draw a plausible looking curve, being guided by the very rough device suggested previously (*Wireless Engineer*, February 1947, p. 39) namely that ϕ should be diminished by $\frac{100}{n}$% when n is greater than, say, 20. The results of this procedure are shown in the diagram. Of course, as the ratio of length to diameter increases the curves become modified even for the smaller n values, in what is at the moment, an unpredictable way.

All this juggling with doubtful approximation is clearly quite unsatisfactory, and, as Mr. Callendar



remarks, further experimental work would be useful. It has, however, to be remembered that exact knowledge of the h.f. resistance of coils of two or three turns is likely to be required rather infrequently. The total resistance of circuits containing such coils will usually be dominated by other features of the circuits.

R. G. Medhurst.
G.E.C. Research Laboratories,
Wembley.

WIRELESS PATENTS

A Summary of Recently Accepted Specifications

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

DIRECTIONAL AND NAVIGATIONAL SYSTEMS

581 683.—Amplifier utilizing selective feed-back through a delay network, particularly for the pulsed signals employed in radiolocation.

Standard Telephones and Cables Ltd. and M. M. Levy. Application date 6th June, 1941.

581 696.—Radiolocation system in which the exploring beam covers a conical field of observation in alternately diverging and converging spiral paths.

A. L. Hodgkin. Application date 16th September, 1943.

581 724.—Directive-aerial system including a horn-shaped reflector having two variable earthing points for oscillating the maximum lobe of radiation in order to define an approach path.

Standard Telephones and Cables Ltd. and E. O. Willoughby. Application date 2nd May, 1941.

581 762.—Directive aerial comprising a number of forked waveguide dipoles, each provided with spaced apertures, for controlling the relative phasing of the energy-flow inside and outside the guides.

Board of Trustees of the Leland Stanford Junior University. Convention date (U.S.A.) 10th July, 1940.

581 806.—Radiolocation system in which a cathode-

ray indication is given only when echo-signals of equal strength are received on each of two diverging d.f. aerials.

C. S. Agate and A. H. Cooper. Application date 25th September, 1941.

582 933.—Radiolocation indicating-device in which a neon flash-lamp co-operates with a compass-scale rotating synchronously with the exploring beam.

R. J. Stevens. Application date 16th April, 1941.

582 934.—Preventing variable-polarization effects in the transmitted and reflected signals of a radiolocation system.

Marconi's W.T. Co. Ltd., J. M. Furnival, N. M. Rust and G. E. Partington. Application date 5th August, 1941.

583 036.—Receiver for radiolocation in which, during each quiescent interval, the gain is progressively increased whilst the bandwidth is progressively decreased.

The British Thomson-Houston Co., Ltd (communicated by the General Electric Co.) Application date 30th September, 1943.

583 320.—Balanced-bridge arrangement for minimizing undesired pick-up by the horizontal leads of an Adcock or like aerial.

P. G. Redgment and C. S. Wright. Application date 13th September, 1944.

583 361.—Radio-beacon of the equi-signal type in which the two transmitting aerials are energized in fixed out-of-phase relation, and distinctive " on " and " off " course signals are produced by periodically interrupting the radiation from at least one aerial.

W. J. O'Brien. Convention date (U.S.A.) 2nd March, 1942.

583 475.—Radiolocation system in which the echo-signal is brought into line with a datum calibration mark against a time-base which can be speeded-up to permit the closer scrutiny of a selected signal.

C. A. Lewis, R. J. Pumphrey, O. L. Ratsey and D. S. Watson. Application date 27th August, 1943.

583 743.—Aerial switching arrangement, particularly for radiolocation, in which quarter-wave blocking stubs are opened and closed by spark-gap discharges.

C. J. Banwell, C. H. Westcott and R. J. Lees. Application date 24th November, 1944.

RECEIVING CIRCUITS AND APPARATUS

(*See also under Television*)

583 285.—Method of wiring-up the component parts, say of a radio receiver, by depositing a metallic-powder paste upon a carrier or chassis of insulating material.

Murrayfield Nominees Ltd. and P. Plowman. Application date 13th October, 1944.

583 558.—Superheterodyne mixing-stage having coaxial-line resonators for handling frequencies that are too high for direct amplification.

Standard Telephones and Cables Ltd. (assignees of G. J. Lehmann). Convention date (U.S.A.) 30th October, 1943.

583 800.—Diode shunt across the input circuit of a detector valve to limit the effect of interference.

M. Slaffer and C. S. Wright. Application date 19th December, 1942.

584 014.—Motor-car radio set in which the volume and tuning controls, as well as the on-off switch, can be set for operation by the foot of the driver.

E. F. McDonald, Jr. Application date 3rd July, 1944.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

583 183.—Preparing and processing the photo-sensitive mosaic electrode of a television transmitter c.r. tube.

Co. Para la Fabricacion de Contadores y Material Industrial and P. Viteau. Application date 15th February, 1944.

TRANSMITTING CIRCUITS AND APPARATUS

(*See also under Television*)

583 136.—Two-scale instrument for promptly indicating when a radio transmitter is over-modulated.

A. E. Hochstein. Application date 4th September, 1944.

583 161.—Balanced bridge made of transmission-line elements for protecting the receiving circuits against outgoing signals in a combined transmitter and receiver.

The General Electric Co. Ltd. and D. C. Espley. Application date 2nd January, 1941.

583 465.—Construction and operation of an adjustable plunger or shorting-piece used for tuning transmission-line circuits.

T. C. Finnimore and C. S. Wright. Application date 1st July, 1942.

583 697.—Construction of waveguide having sufficient longitudinal flexibility to permit some degree of bending without loss of electrical efficiency.

Callender's Cable and Construction Co. Ltd. and D. T. Hollingsworth. Application date, 17th November, 1944.

583 951.—Junction-piece for coupling a single waveguide to a forked or divided waveguide.

G. E. F. Fertel and C. S. Wright. Application date 7th June. 1944.

SIGNALLING SYSTEMS OF DISTINCTIVE TYPE

582 979.—Pulse-modulation system in which two saw-tooth oscillation-generators are fed with out-of-phase components of a common frequency.

Standard Telephone and Cables Ltd. and R. B. Shepherd. Application date 11th September, 1942.

583 262.—Multivibrator gating-circuit for selecting a given pulse-train from other trains of different repetition-frequency, particularly for multichannel signalling systems.

Standard Telephones and Cables Ltd. and C. W Earp. Application date 26th November, 1943.

583 511.—Double-stability pulse-modulating system in which the leading and trailing edges of each square waveform are significant factors.

Standard Telephones and Cables Ltd. and D. M. Ambrose. Application date 26th September, 1941.

583 799.—Duration-modulated pulsing system in which the modulation-depth is controlled so as to economize power.

Standard Telephones and Cables Ltd., P. K. Chatterjea and C. T. Scully. Application date 7th August, 1942.

ABSTRACTS AND REFERENCES

Compiled by the Radio Research Board and published by arrangement with the Department of Scientific and Industrial Research

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. The abbreviations of the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to the World List practice.

ACOUSTICS AND AUDIO FREQUENCIES

4.13 **2654**

The Vibrations of Certain Coupled Systems.—gel. (*See* 2728.)

..213(26.03) **2655**

Underwater Sound Propagation.—(*Tele-Tech*, ril 1947, Vol. 6, No. 4, p. 39.) Experimental dence is given of the existence of sound channels depths of 300–400 ft in the Atlantic and –700 ft in the Pacific; their depth depends on vertical temperature gradient.

.32 : 621.396.722 **2656**

Distortion and Acoustic Preferences.—J. Moir. oc. *Inst. Radio Engrs, W. & E.*, May 1947, 35, No. 5, p. 495.) Comment on 612 of March. also 2554 of August and back reference.

414 **2657**

roperties of Simple and Multiple Cylindrical ustic Resonators.—P. Wirz. (*Helv. phys. Acta*, Feb. 1947, Vol. 20, No. 1, pp. 3–26. In German.) fine structure of the resonance curves of acoustic nators observed by Zickendraht (3030 of 1942) und to be due to interference effects. A method scribed for obtaining the true resonance curves from them evaluating the decrement, which is ood agreement with the value obtained from photographic records of the amplitude of the oscillations excited by short-time application of a stimulus of the same frequency as that of the resonator. The well-known formulae for the frequency correction at the mouth of the resonator can be improved by the introduction of a term taking account of the width of the flange there. Experiments with bundles of similar tubular resonators are described, and a method is given for observation of the air motion at the mouth of an excited resonator.

534.845.1 **2658**

Measurement of Sound Absorption by Phase Shift Determinations.—G. Sacerdote. (*Alta Frequenza*, April 1947, Vol. 16, No. 2, pp. 98–100. In Italian, with English, French and German summaries.) The absorption of an acoustic material can be found from phase difference measurements at three points in a Kundt's tube.

534.861.1 **2659**

Acoustical Design of Broadcast Studios.—J. Peterson. (*Tele-Tech*, March 1947, Vol. 6, No. 3, pp. 52–55, 127.) A discussion of modern surface treatments to eliminate echoes and other objectionable features.

534.861.1 **2660**

The Acoustical Design of F.M. Studios.—E. J. Content. (*Tele-Tech*, April 1947, Vol. 6, No. 4, pp. 30–34.) A discussion of the factors involved in the improvement of overall frequency response and sound distribution in the studio.

534.88 **2661**

Sonar — The Submarine's Nemesis.—McProud. (*See* 2777.)

621.395.623 **2662**

Sensitivity and Impedance of Electro-Acoustic Transducers.—P. Vigoureux. (*Proc. phys. Soc.*, 1st Jan. 1947, Vol. 59, No. 331, pp. 19–30.) Using the method of equivalent electric circuits the output voltage is deduced in terms of the radiation resistance and the pressure. The radiation resistance can be measured by purely electrical means. The construction of impedance and admittance diagrams is explained, and it is shown how the maximum acoustic output can be obtained from electrical measurements without any acoustic measurements.

621.395.623 : 534.835 **2663**

Telephone Transmissions in Noisy Surroundings.—G. Nicolle. (*Ann. Radioélect.*, Jan. 1947, Vol. 2, No. 7, pp. 78–86.) The methods adopted to improve the signal/noise ratio usually involve some process favouring the signal, such as bringing the microphone close to the mouth of the speaker, and reducing the noise by insulation and making the apparatus as directional as possible. An alternative method proposed makes use of a differential action of two microphone elements, equally sensitive to the surrounding noise, with a directional arrangement allowing speech to affect only one of the elements. A very marked improvement in the signal/noise ratio is thus obtained without the use of sound insulation.

621.395.623.73 2664
Wide Range Loudspeaker Developments.—H. F. Olson & J. Preston. (*RCA Rev.*, June 1946, Vol. 7, No. 2, pp. 155–178.) A reprint was abstracted in 993 of April.

AERIALS AND TRANSMISSION LINES

621.315.212 : 621.392.029.64 2665
Guided Waves in a Coaxial Line.—G. Goudet & J. Lignon. (*Onde élect.*, April 1947, Vol. 27, No. 241, pp. 152–159.) Discussion of propagation in the annular space of coaxial cables to see whether normal cables can be used for u.h.f. transmission. Coaxial cables should be designed for propagation only of the fundamental waveleng h. At the higher frequencies waveguides should be used.

621.315.212 : 621.397.74 2666
The Provision in London of Television Channels for the B.B.C.—H. T. Mitchell. (*P.O. elect. Engrs' J.*, April 1947, Vol. 40, Part 1, pp. 33–36.) An account of recently installed coaxial cable and the associated repeater equipment.

621.315.213.12 : 621.397.5 2667
Development of an Ultra Low Loss Transmission Line for Television.—E. O. Johnson. (*RCA Rev.*, June 1946, Vol. 7, No. 2, pp. 272–280.) A 300-Ω parallel-wire polyethylene dielectric feeder having an attenuation less than 0.8 db per 100 ft at 50 Mc/s. It is weatherproof and cheap to manufacture.

621.38/.39].029.64 2668
Microwave Electronics.—J. C. Slater. (*Rev. mod. Phys.*, Oct. 1946, Vol. 18, No. 4, pp. 441–512.) This comprehensive article is essentially a set of notes for lectures delivered during the winter of 1945–46. It is written from the standpoint of a physicist and includes chapters dealing with (*a*) the four-terminal network and the transmission line, (*b*) waveguides, (*c*) resonant cavities, (*d*) applications of the theory of resonant cavities, (*e*) electronics of the reflex klystron and magnetron.

621.392.029.64 2669
On the Transmission of H_0 Waves in Guides of Circular Cross-Section.—M. Jouguet. (*C. R. Acad. Sci., Paris*, 31st March 1947, Vol. 224, No. 13, pp. 998–1000.) In a straight guide the H_0 wave is practically stable for accidental curvatures which on the average balance out, but its attenuation only approximates to the theoretical value if these curvatures are very small. See also 1667 of June and back references.

621.392.21 2670
Propagation Characteristics of a Uniform Line.—C. Micheletta. (*Alta Frequenza*, Feb. 1947, Vol. 16, No. 1, pp. 47–49. In Italian.) Simple formulae are derived for the attenuation and phase constants, using results given by Macdiarmid & Orchard (2476 of 1946).

621.392.22 2671
Non-Uniform Transmission Lines and Reflection Coefficients.—L. R. Walker & N. Wax. (*J. appl. Phys.*, Dec. 1946, Vol. 17, No. 12, pp. 1043–1045. Summary in *Bell Syst. tech. J.*, April 1947, Vol. 26, No. 2, p. 393.) A first-order differential equation for the voltage reflection coefficient of a non-uniform line is derived and is applied to the calculation of the resonant wavelengths of tapered lines.

621.392.4.029.58 + 621.396.67.029.58] : 621.317.3 2672
The Testing of High-Frequency Aerial Systems & Transmission Lines.—E. J. Wilkinson. (*Proc. Instn Radio Engrs, Aust.*, Feb. 1947, Vol. 8, No. 2, pp. 4–20.) A full description of the aerial arrays and transmission lines used at Shepparton, Victoria, Australia, for operation on frequencies between 6 and 22 Mc/s and the theoretical considerations underlying their design. The procedure for setting up and testing the system is given in detail. A series of appendices deal with switching and matching stubs, transmission-line unbalance, behaviour of λ/4 and λ/2 lines and evaluation of line terminations.

621.392.43 : 621.317.33 2673
Impedance Measurement on Transmission Lines.—D. D. King. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, pp. 509–514.) "A derivation of the formulas available for the measurement of terminal impedances on transmission lines is given in terms of hyperbolic functions. The accuracy and usefulness of a number of different methods are considered. Results are obtained in a form suitable for convenient application to practical measuring problems involving standing-wave and resonance-curve methods."

621.392.43 : [621.317.72.029.56/.58 2674
The "Micromatch".—Jones & Sontheimer. (See 2853.)

621.396.615.141.2 : 621.314.2.029.64 : 621.315.613.7 2675
Waveguide-Output Magnetrons with Quartz Transformers.—Malter & Moll. (*See* 2712.)

621.396.67 2676
Recent Theories of the Aerial: Part 4.—E. Roubine. (*Onde élect.*, April 1947, Vol. 27, No. 241, pp. 160–169.) Conclusion of 2012 of July and 2332 of August. Outlines are given of a symbolic method for the integration of the Hallén equation and of the methods of King & Harrison (193 and 1934 of 1944), of Bouwkamp (2197 of 1944), of King & Middleton (1771 of 1946) and also of the modifications of Hallén's theory suggested by Miss Gray (1931 of 1944). It is impossible at present to decide which of these theories is best, owing to the difficulty of measuring input impedance accurately.

621.396.67 2677
2 500-foot Vertical Antenna.—(*Electronics*, May 1947, Vol. 20, No. 5, pp. 188, 190.) A German aerial system supported by an electrically driven, captive helicopter.

621.396.67.029.64 2678

Microwave Omnidirectional Antennas.—H. J. Riblet. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, pp. 474–478.) Design considerations for omnidirectional 3-cm and 10-cm aerials are summarized. Elements used in the construction of aerials of this type are described.

621.396.67.029.64 2679

Parallel Plate Optics for Rapid [aerial] **Scanning.**—S. B. Myers. (*J. appl. Phys.*, Feb. 1947, Vol. 18, No. 2, pp. 221–229.) Consideration of the problem of shaping two curved parallel plates, between which the energy feed is placed so that circular motion of the feed will produce an oscillating beam at a straight aperture. The latter serves as a line source for a bifocal reflector which facilitates the desired scanning. The method was developed to obviate rapid movement of parabolic aerials.

21.396.67 : 517.512.2 2680

Fourier Transforms in Aerial Theory : Part 1.— . F. Ramsay. (*Marconi Rev.*, Oct./Dec. 1946, ol. 9, No. 83, pp. 139–145.) " The radiation attern of a narrow-beam aerial can be formulated s the Fourier Transform of the aperture excitation. xamples are given of simple equiphase aperture haracteristics and the evaluation of the corresponding polar diagrams. Four basic patterns are otted, corresponding to the symmetrical, in-phase citations known as ' constant ', ' triangular ', osine ', and ' cosine squared '."

1.396.671 2681

Partially-Screened Open Aerials.—R. E. Burgess. *ireless Engr*, May 1947, Vol. 24, No. 284, pp. 5–149.) " A simple approximate theory based the transmission-line equations is developed an open aerial, a portion of which is enclosed a concentric conducting screen. The voltage and rrent distributions in the transmitting case are duced. From these the effective heights of the reened ' and unscreened portions of the aerial are culated and it is found that as the length of the screened portions increases so the effective height the screened portion tends to equality with its gth, as was first demonstrated experimentally by ith-Rose and Barfield.

The susceptance of the aerial is calculated on assumption of no losses and it is found that the i-resonant frequencies are displaced by the sence of the screens while the resonant frencies occur when the length of the inner contor or of the screen is equal to an odd number uarter-wavelengths.

A simple equivalent circuit is given for an aerial ch is short compared with the wavelength."

396.671.4 2682

adiation Resistance of Horizontal and Vertical als carrying a Progressive Wave.—E. M. Wells. *rconi Rev.*, Oct./Dec. 1946, Vol. 9, No. 83, 129–138.) An extension of L. Lewin's analysis 2 of 1939) to the case of progressive waves, g van der Pol's method.

396.674 2683

esign Values for Loop-Antenna Input Circuits.— . Browder & V. J. Young. (*Proc. Inst. Radio s, W. & E.*, May 1947, Vol. 35, No. 5, pp. 525.) A theoretical treatment of the problem ng to formulae and charts for the choice of inductances, Q values and coupling coefficients of loop-aerial coupling transformers for obtaining optimum signal/noise ratio. The case of cable connection of the loop to the receiver is also considered.

621.396.677 2684

Aircraft Antenna Pattern Plotter.—O. H. Schmitt & W. P. Peyser. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 88–91.) If measurements are made on a scale model of an aircraft and its aerials, the signal wavelength being proportionately reduced, the actual radiation pattern of the full-size installation can be predicted. Technical details of a system using microwaves and automatic recording are given.

621.396.677 2685

A Current Distribution for Broadside Arrays which optimizes the Relationship between Beam Width and Side-Lobe Level.—C. L. Dolph : H. J. Riblet. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, pp. 489–492.) Discussion of 2487 of 1946. Riblet gives a generalization of Dolph's methods which removes the limitations that (*a*) the spacing between radiators $\geqslant \lambda/2$; (*b*) the beam width is characterized by the existence of a first null ; (*c*) the current distribution is in phase ; (*d*) the current distribution is symmetrical about the centre position of the array.

In his reply Dolph shows how the calculations necessary in the application of his methods may be simplified.

621.396.677 : 621.396.93 2686

Various Papers on Direction-Finding.—(*See* 2780 to 2783.)

621.396.677.029.64 : 538.566 2687

Electromagnetic Fields in a Paraboloidal Reflector.—E. Pinney. (*J. Math. Phys.*, April 1947, Vol. 26, No. 1, pp. 42–55.) Continuation of the mathematical treatment of 1909 of 1946. The case of a radiating dipole backed by a dummy reflector, both dipoles being perpendicular to the axis of the paraboloid, is considered in detail.

621.396.679.4 : 621.315.24 2688

A Six-Wire Transmission-Line Application.—J. C. Wadsworth : A. J. E. Robertson. (*Proc. Instn Radio Engrs, Aust.*, March 1947, Vol. 8, No. 3, pp. 16–17, 19.) Comment by Robertson on 1686 of June and the author's reply.

621.392.029.64 621.396.67 2689

The Physical Principles of Wave Guide Transmission and Antenna Systems. [Book Review]—W. H. Watson. Oxford University Press, 207 pp., 20s. (*Wireless Engr*, May 1947, Vol. 24, No. 284, pp. 154–155.) " Its aim is to describe to physicists and engineers with theoretical interests the way in which the technique of handling radio-frequency transmission lines has been extended to deal with waveguides . . . The book can be unreservedly recommended to anyone in any way interested in waveguides."

CIRCUITS AND CIRCUIT ELEMENTS

621.314.2.015.33.029.5 2690

Electromotive Impulse Transformer.—B. Lavagnino & V. Zerbini. (*Alta Frequenza*, Feb. 1947, Vol. 16, No. 1, pp. 31–36. In Italian, with English, French and German summaries.) The heavily damped two-winding moving-coil galvanometer can transfer the time integral of an e.m.f. of short duration from one winding to the other at a constant ratio. Such a device might be used as a coupling transformer for pulse amplifiers.

621.316.722 **2691**
Nonlinear Limiter.—E. R. Brill. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 198..202.) A limiter using germanium crystal rectifiers whose current/potential characteristic follows a cube root law. When the limiter is used in combination with a cathode-ray screen with a cube law a linear overall transfer characteristic is obtained.

621.316.935 **2692**
Negative Resistance Effects in Saturable Reactor Circuits.—J. M. Manley & E. Peterson. (*Trans. Amer. Inst. elect. Engrs*, December Supplement 1946, Vol. 65, pp. 870–881.) General properties of oscillations produced; three types distinguished, incommensurable, subharmonic, and harmonic. Experimental data are in general agreement with theory.

621.318.323.2.042.15 **2693**
Iron-Dust Cores.—Gleadle. (*See* 2816.)

621.318.33.042.029.3 **2694**
Magnetic Parameters in the Calculation of Reactors and Transformers for Audio-Frequency.—G. Monti-Guarnieri. (*Alta Frequenza*, Feb. 1947, Vol. 16, No. 1, pp. 3–30. In Italian, with English, French and German summaries.) Methods of calculation involve three dimension ratios, defining the shape of the laminations and core, and also a 'parallel-harmonic' permeability depending on the ratio B/H. Nonlinear distortion is discussed and corrections are applied in the calculation of polarized and non-polarized reactors to account for distortion limitation. An appendix describes apparatus and methods for determining the magnetic parameters and graphs used.

621.318.572 **2695**
Electronic Counters.—I. E. Grosdoff. (*RCA Rev.*, Sept. 1946, Vol. 7, No. 3, pp. 438–447.) The use of resistance-coupled multivibrators in ring-chain and series-chain counters is described; gate and switching problems are discussed and applications suggested.

621.318.7 **2696**
Insertion Loss and Insertion Phase Shift of Multi-Section Zobel Filters with Equal Image Impedances.—W. Saraga. (*P.O. elect. Engrs' J.*, Jan. 1947, Vol. 39, Part 4, pp. 167–172.) The method given in 1045 of 1943 (Stanesby, Broad & Corke) can be applied to any given filter network which possesses a lattice equivalent. To simplify the derivation of these lattice equivalents for multi-section Zobel filters with equal image impedances, the reactance/frequency functions of a large number of such filters are tabulated.

621.318.74 **2697**
Narrow Band-Pass Filter using Modulation.—N. F. Barber. (*Wireless Engr*, May 1947, Vol. 24, No. 284, pp. 132–134.) The signal is modulated in two channels by equal voltages in phase quadrature, and the products are passed through low-pass filters, then further modulated by quadrature voltages and recombined. The final frequency is the same as that of the original signal and phase changes are preserved.

621.319.5.015.33 **2698**
Generation of Pulse Voltages.—L. Vallese. (*Alta Frequenza*, April 1947, Vol. 16, No. 2, pp. 68–86. In Italian, with English, French and German summaries.) Fundamental principles, with typical circuits and some experimental results.

621.392.5 **2699**
Minimum Phase-Shift Networks.—L. A. Zadeh. (*Wireless Engr*, May 1947, Vol. 24, No. 284, p. 157.) Discusses briefly the suggestion that such networks should be termed 'minimum net phase-shift networks', where 'net phase-shift' is defined as the total angle swept by G (the complex gain of the network) in the G-plane when ω varies from zero to the value in question.

621.392.5.016.24/.25 **2700**
On the Calculation of the Active and Reactive Power of Certain Electrical Networks.—M. Parodi. (*Rev. gén. Élect.*, March 1947, Vol. 56, No. 3, pp. 143–144.) Expressions for the active and reactive power of a dissipative network, in terms of its input reactance and of the constants characterizing the losses, are derived from a relation due to N. I. Korman (738 of 1945).

621.392.52 : 621.396.611.21 **2701**
Crystal Filters.—I. Edvin. (*Elektrotechnika, Budapest*, March 1947, Vol. 39, No. 3, pp. 41–47. In Hungarian, with English, French and German summaries.) The behaviour of lattice and other types of filter sections is described and results obtained for band-, low- and high-pass filters are discussed. Methods of soldering connecting wires to nodal points of the crystal are described. Balls of solder may be used on the supporting wires to create artificial reflection points.

621.396.611.1 **2702**
An RC Circuit giving Over-Unity Gain [at a particular frequency].—C. L. Longmire. (*Tele-Tech*, April 1947, Vol. 6, No. 4, pp. 40–41, 112.) Applications are discussed.

621.396.611.21 + 537.228.1 **2703**
Quartz Oscillators.—P. Vigoureux. (*J. Brit. Instn Radio Engrs*, March/April 1947, Vol. 7, No. 2, pp. 46–62.) General review of subject; methods of cutting, nature of equivalent circuit, oscillator characteristics, applications to frequency multiplication and division, clocks and filters.

621.396.611.21 : 621.316.726 **2704**
Stability of Crystal Oscillators.—A. J. Zink, Jr. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 127–129.) Discussion of factors affecting crystal oscillator frequency drift and methods of minimizing it.

621.396.611.3 **2705**
On a Formula relative to the Reflection of Waves.—P. Marié. (*C. R. Acad. Sci., Paris*, 10th Feb. 1947, Vol. 224, No. 6, pp. 379–381.) The interpretation of a formula derivable from the papers noted in 1376 and 1377 of May.

621.396.611.4 : 537.533 **2706**
Cavity Resonators and Electron Beams.—J. H. Owen Harries. (*Wireless Engr*, March–May 1947, Vol. 24, Nos. 282–284, pp. 71–80, 109–118 & 135–142.) General theoretical treatment of funda-

mental principles and limitations in radio-valve technique using a modulated electron beam supplying power to a load through a resonator. Energy transfer and power output conditions are analysed; it is shown that the maximum theoretical conversion efficiency η_0 is 43%, attained when the small-signal transit angle is about $\pi/2$ and the ratio of the peak voltage in the resonator along the beam to the steady voltage at entry is rather greater than unity. The overall efficiency is $\eta_0\eta_c$ where η_c is the efficiency of transfer from resonator to load. In a given system the adjustable parameters are the beam current and the resonator-load coupling, and the criteria for obtaining maximum overall efficiency are discussed.

The influence of wavelength on the efficiency and power output given by present electron-stream-resonator technique is considered in detail; it is concluded that this technique is only useful down to wavelengths of about 1 cm. Application of the theory is exemplified by considering specific shapes of resonator.

Techniques for measurement of Q and of electric field and field integrals at microwavelengths and the use of models are discussed.

21.396.615 : 621.316.726

Frequency Instability of Self Oscillators.—E. Green. (*Marconi Rev.*, Oct./Dec. 1946, Vol. 9, No. 83, pp. 151–158.) The conditions for single-frequency operation are analysed for an oscillator connected through a long line to an unmatched load. 2707

1.396.615.14

Improving Stability of U.H.F. Oscillators.— A. Helber. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 103–105.) Mathematical analysis of the factors governing frequency stability during load impedance changes, and a method of reducing frequency variations in a 1 000-Mc/s oscillator by means of a series capacitor in the anode circuit. 2708

1.396.615.14

Microwave Oscillators using Disk-Seal Tubes.— M. Gurewitsch & J. R. Whinnery. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, pp. 462–473.) Typical design and performance data are given for oscillators using three disk-seal valves now on the market. "A general small-signal oscillator theory is presented and applied to the re-entrant disk-seal-tube microwave oscillator. It is shown how information on frequency of oscillation, tuning, and frequency stability can be obtained." 2709

.396.615.14

Generating Microwaves.—S. Freedman. (*Radio News*, March 1947, Vol. 37, No. 3, pp. 35–37 . . 128.) General account of the various methods employed, from the Barkhausen-Kurz stage onwards, with a table in which these methods are compared as regards the energy interchange, output, energy limits, ease of adjustment, frequency flexibility and cost. A short description is also given of the Okada-Freedman method, which uses ordinary valves with special circuit arrangements. 2710

396.615.14.012.2

Circles—A Means of Analysis of Resonant Microwave Systems: Part 2.—W. Altar. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, pp. 478–484.) Mathematical proof of the relationships on which are based the circle diagrams described in part 1 (2360 of August). 2711

621.396.615.141.2 : 621.314.2.029.64 : 621.315.613.7

Waveguide-Output Magnetrons with Quartz Transformers.—L. Malter & J. L. Moll. (*RCA Rev.*, Sept. 1946, Vol. 7, No. 3, pp. 414–421.) Tests at a wavelength of 1.25 cm show that quartz dielectric waveguide, or parallel-plate transmission-line transformers give performance substantially identical with that obtained with vacuum transformers. The use of quartz increases transformer width and reduces the length. 2712

621.396.619.13 : 621.396.622

Applying the 1N34 as Discriminator for F.M.—N. L. Chalfin. (*Radio News*, March 1947, Vol. 37, No. 3, pp. 55, 150.) The germanium 1N34 crystal provides greater output with less residual hum than a conventional 6H6 valve. A discriminator circuit is given which uses two 1N34 units or a single 1N35. The latter consists of two matched 1N34s. 2713

621.396.619.16

A Note on a Phase Modulator Principle.—R. A. Wooding, Jr. (*Proc. Instn Radio Engrs, Aust.*, April 1945, Vol. 5, No. 8, pp. 13–16, 24.) A practical circuit for producing quasi-phase modulation. 2714

621.396.645

Design for a High-Quality Amplifier.—D. T. N. Williamson. (*Wireless World*, April & May 1947, Vol. 53, Nos. 4 & 5, pp. 118–121 & 161–163.) Discussion of the basic requirements, the design of the push-pull output stage, the output transformer and phase-splitter and driver stages. A practical circuit is shown using tetrode output valves connected as triodes and details of the performance and effect of feedback are given. 2715

621.396.645

Design of Transmission Line Tank Circuits.—W. C. Hollis. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 130–134.) A discussion of tank efficiency, condition for resonance, selectivity, impedance of tank circuit, and conditions for maximum impedance with graphical design procedure. 2716

621.396.645 : 518.3

Cathode Follower Nomograph.—M. B. Kline. (*Electronics*, May 1947, Vol. 20, No. 5, p. 136.) Relates gain, amplification factor and ratio of cathode load resistance to valve anode resistance. 2717

621.396.645 : 621.396.822.08

Linearity Range of Noise-Measuring Amplifiers.—R. L. Bell. (*Wireless Engr*, April 1947, Vol. 24, No. 283, pp. 119–122.) In the amplification of noise voltages there is a finite probability of the occurrence of any peak value of voltage, however large, and all those greater than a certain value will produce overloading of the amplifier. 2718

The errors in mean and mean square output voltages resulting from an assumption of linear amplification are calculated in the two cases of amplifiers with resistive and selective output loads.

621.396.645.36

Cancellation of Even Harmonic Distortion in Push-Pull Operation.—G. F. Craven & G. R. O. 2719

538.313+538.691 **2755**
The Helical Motion of Particles in a Constant Uniform Magnetic Field.—F. Ehrenhaft. (*C. R. Acad. Sci., Paris,* 21st April 1947, Vol. 224, No. 16, pp. 1151–1152.) Particles of Fe, Ni, Mn, Cr, Sb, etc., describe helical paths between the poles of an electromagnet. Photographs are given.

538.56 : 535.13 **2756**
The Reflection of an Electromagnetic Plane Wave by an Infinite Set of Plates : Part 1.—J. F. Carlson & A. E. Heins. (*Quart. appl. Math.,* Jan. 1947, Vol. 4, No. 4, pp. 313–329.) This problem may be formulated as a single inhomogeneous Wiener-Hopf integral equation, and as such it may be solved rigorously using the method of Fourier transformation. The functional form of the various surface current densities, as well as the electric field, is determined. It is shown how some of the results obtained may be interpreted in a simple physical manner, and the relation to ordinary grating theory is pointed out.

538.569.4.029.64 **2757**
Thermal and Acoustic Effects attending Absorption of Microwaves by Gases.—W. D. Hershberger, E. T. Bush & G. W. Leck. (*RCA Rev.,* Sept. 1946, Vol. 7, No. 3, pp. 422–431.) 15 substances, gaseous at normal temperature and pressure, strongly absorb microwaves, the absorbed energy appearing as heat or sound. Methods of measurement are described and the results are tabulated and discussed.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 : 621.396.822
551.510.535
551.594.6 **2758**
Reports on the International Conference of U.R.S.I. (International Radio-Scientific Union).—Y. Rocard. (*Rev. sci., Paris,* 1st Nov. 1946, Vol. 84, No. 3260, pp. 500–501.)

(*a*) Ionosphere. M. Nicolet discusses the formation of the various regions, and criticizes the conclusions of Kiepenheuer (*Annales d'Astrophysique,* 1945, Vol. 8, p. 210).

(*b*) Extraterrestrial electromagnetic noise. Work referred to in 323 of 1946 (Appleton), 1825 of 1946 (Hey : Stratton), and 3599 of 1946 (Hey, Parsons, & Phillips) is considered : see also 402 of February (Appleton).

(*c*) Atmospherics. Discussion of the work of F. A. Berson & S. Petterssen on the geographic distribution in winter of the disturbance centres and their relation to air mass and front distribution. Summer conditions, which were studied by C. K. M. Douglas, are much more complex, and it is difficult to draw definite conclusions from them.

523.323 : 621.396.812 **2759**
Effect of the Moon on Radio Wave Propagation.—(*See* 2903.)

523.746 "1947.03" **2760**
A Giant Sunspot.—(*Nature, Lond.,* 22nd March 1947, Vol. 159, No. 4038, p. 396.) The sunspot group of March 3–17, 1947, was unusually large but was not accompanied by exceptional geomagnetic disturbances.

523.78 "1946.11.23" :621.396.822.029.63 **2761**
Micro-Wave Solar Noise Observations during the Partial Eclipse of November 23, 1946.—A. E. Covington. (*Nature, Lond.,* 22nd March 1947, Vol. 159, No. 4038, pp. 405–406.) Results on 2 800 Mc/s from Ottawa, Canada ; equivalent temperature of noise-generating region (2.2% of projected area and containing sunspot group) is 1.5×10^6 °K in excess of the average surface temperature of 5.6×10^4 °K.

537.591 **2762**
Non-Primary Cosmic-Ray Electrons above the Earth's Atmosphere.—G. J. Perlow & J. D. Shipman, Jr. (*Phys. Rev.,* 1st March 1947, Vol. 71, No. 5, pp. 325–326.) Summary of data obtained from a V-2 rocket experiment on the presence of electrons of energy $< 5 \times 10^8$ eV above the earth's atmosphere.

537.591 **2763**
Highly Ionizing Particles in the Cosmic Radiation.—V. Veksler, N. Dobrotin & V. Khvoles. (*J. Phys., U.S.S.R.,* 1945, Vol. 9, No. 4, pp. 277–279.)

537.591.15 **2764**
Presence of a Penetrating Component in Extensive Showers in the Atmosphere.—A. Mura, G. Salvini & G. Tagliaferri. (*Nature, Lond.,* 15th March 1947, Vol. 159, No. 4037, pp. 367–369.) Confirmation by an improved experimental technique.

537.591.15 **2765**
The Lateral Extension of Auger Showers.—D. V. Skobeltzyn, G. T. Zatsepin & V. V. Miller. (*Phys. Rev.,* 1st March 1947, Vol. 71, No. 5, pp. 315–317.)

537.591.15 **2766**
Cosmic-Ray Bursts in an Unshielded Chamber and under One Inch of Lead at Different Altitudes.—H. Bridge & B. Rossi. (*Phys. Rev.,* 15th March 1947, Vol. 71, No. 6, pp. 379–380.)

538.71(479.22) **2767**
100 Years of Magnetic Observations at Tbilis [Tiflis].—M. Z. Nodia. (*Viestnik Akad. Nauk, S.S.S.R.,* 1946, No. 7, pp. 47–53. In Russian.)

550.384.3(68) **2768**
The Earth's Magnetic Field in Southern Africa at the Epoch, 1 July 1930.—E. N. Grindley. (*Philos. Trans.,* 29th April 1947, Vol. 240, No. 818, pp. 251–294.) Analysis of a large number of observations to determine the secular variation in the magnetic intensity, declination and inclination. Probable 'normal' values are shown by maps with isomagnetic lines.

551.510.52 : 621.396.812.029.64 **2769**
Radar Reflections from the Lower Atmosphere.—H. T. Friis. (*Proc. Inst. Radio Engrs, W. & E.,* May 1947, Vol. 35, No. 5, pp. 494–495.) Using a 3-cm radar transmitter and a double-detection receiver, each with a shielded-lens aerial pointing upwards, echoes apparently from stratifications in the lower atmosphere have been received on clear, calm nights. During the day and on windy nights such echoes are usually unobtainable.

551.510.535 **2770**
Note on the [extent and density of the] **Sporadic-E Layer.**—O. P. Ferrell. (*Proc. Inst. Radio Engrs, W. & E.,* May 1947, Vol. 35, No. 5, pp. 493–494.)

551.510.535 : 551.500.2(51) 2771
Ionosphere Reflections and Weather Forecasting for Eastern China.—E. Gherzi. (*Bull. Amer. met. Soc.*, March 1946, Vol. 27, No. 3, pp. 114–116.) Day-time investigations at Zi Ka Wei observatory, using 20-W aerial power on a frequency of 6 Mc/s, show that when the Pacific trade-wind is dominating the weather, E-layer reflections are obtained. When the Siberian air mass is predominant, reflections come from the F layer. In general, F_2-layer reflections are found when tropical air is predominant. With approaching typhoons, the E-layer echo becomes very strong. It is suggested that similar effects might be observed in the eastern parts of the U.S.A.

551.510.535 : 621.396.11 2772
The Application of Ionospheric Data to Radio Communication Problems: Part 2.—Appleton & Beynon. (*See* 2895.)

551.510.535 : 621.396.11 2773
Oblique Radio Transmission in the Ionosphere, and the Lorentz Polarisation Term.—Beynon. (*See* 2896.)

551.510.535 : 621.396.6 2774
Ionosphere Equipment for Field Use.—Musselman. (*See* 2929.)

551.57 : 621.396.82 : 629.135
551.57 : 621.319.74 : 629.135 2775
Electrostatic Ills and Cures of Aircraft: Parts 1 & 2.—Beach. (*See* 2916.)

551.593.9(54) 2776
Measurement of the Intensity of the Night Sky Light at Calcutta.—S. N. Ghosh. (*Indian J. Phys.*, Dec. 1946, Vol. 20, No. 6, pp. 205–213.) Measurements on 50 nights during 1943–1945 show that on undisturbed nights the intensity decreased to a minimum about local midnight and then increased. On disturbed nights accompanied by magnetic disturbance the intensity variation followed generally that of maximum ionization of the F region. Other nights, when the night sky intensity varied abnormally but did not follow the electron density of the F region, were free from magnetic disturbance.

LOCATION AND AIDS TO NAVIGATION

534.88 2777
Sonar — The Submarine's Nemesis.—C. G. McProud. (*Radio News*, March 1947, Vol. 37, No. 3, pp. 47–49..141.) Describes, with photographs and block diagrams, the R.C.A. QCQ-2 and the Submarine Signal Co.'s WCA-2 equipments and their operational principles. See also 1750 and 3605 of 1946.

621.396.674 : 621.396.62 2778
A Portable Direction Finding Receiver.—J. M. S. Watson. (*R.S.G.B. Bull.*, April 1947, Vol. 22, No. 10, pp. 161–164.) Equipment for operation in the 1.7-Mc/s band.

621.396.93 : 551.594.6 2779
The Location of Thunderstorms by Radio Direction-Finding.—F. Adcock & C. Clarke. (*J. Instn elect. Engrs*, Part III, March 1947, Vol. 94, No. 28, pp. 118–125. Discussion, pp. 133–140.) Polarization error due to the presence of ionospheric reflections is the main source of inaccuracy in the crossed-loop cathode-ray direction finders now used. Various systems (including time-delay methods) for improving the accuracy of location are considered and compared. Details are given of an experimental 10–30-kc/s twin-channel cathode-ray direction finder, using brilliance modulation to eliminate ionospheric components of the lightning pulse and errors due to overloading; this direction finder has crossed-loop aerials but may be adapted for the spaced-loop or Adcock types. A summary was noted in 2126 of July; see also 1786 of June.

621.396.93 : 621.396.677 2780
The Development and Study of a Practical Spaced-Loop Radio Direction-Finder for High Frequencies.—W. Ross. (*J. Instn elect. Engrs*, Part III, March 1947, Vol. 94, No. 28, pp. 99–107. Discussion, pp. 133–140.) The instrument is of the rotating type and uses two single-turn 1-m square vertical coaxial screened loops 3 m apart. The field strength required for an arc of silence of ± 5° varies from 1.5 μV/m to 4 μV/m for a vertically polarized ground wave between 3 and 15 Mc/s. The instrument is particularly useful for taking bearings on steeply incident ionospheric waves, where Adcock direction-finders are very inaccurate. The polarization error which may be introduced by the essentially non-uniform current distribution along loops is analysed and discussed. Examples of site errors reducing the accuracy of the instrument are given. See also 2783 below.

621.396.93 : 621.396.677 2781
The Use of Earth Mats to reduce the Polarization Error of U-Type Adcock Direction-Finders.—R. L. Smith-Rose & W. Ross. (*J. Instn elect. Engrs*, Part III, March 1947, Vol. 94, No. 28, pp. 91–98. Discussion, pp. 133–140.) Polarization errors introduced by the buried horizontal feeders of a four-aerial U-type Adcock direction-finder were found to be greatly reduced between 3 and 10 Mc/s by an earthed wire mat of 0.6-m square mesh 31 m in diameter (about five times the aerial spacing) laid symmetrically around the aerial system on or near the ground. Earthing the mat was found to be essential; on high-conductivity ground direct earth connections could be used, but on low-conductivity ground it was necessary to connect sets of radial wire extensions of various lengths to the mat, each set resonating roughly independently of the others to provide a low-impedance path to earth for the periphery of the mat at various frequencies between 3 and 10 Mc/s. Provided that the feeders were not too large in diameter, and were bonded to the mat, it was found unnecessary to bury them. The polarization error, besides being considerably reduced, should be more independent of weather conditions and therefore more accurately predictable.

621.396.93 : 621.396.677.029.58 2782
Site and Path Errors in Short-Wave Direction-Finding.—W. Ross. (*J. Instn elect. Engrs*, Part III, March 1947, Vol. 94, No. 28, pp. 108–114. Discussion, pp. 133–140.) Measurements made with four-aerial Adcock and portable rotating H-type direction-finders on sites chosen by visual inspection as good (i.e. flat and open over at least 1 km²) showed that the site and/or path errors varied with the transmitter bearing, frequency (6–15 Mc/s) and

distance (50–600 m and 3–16 km) in an entirely random manner through ±3° and more for the distant transmitters. Ground-wave propagation was assumed throughout. Explanations are given, and it is concluded that a local calibration for supplying a detailed correction curve to observed bearings is not, in general, possible in the short-wave band, but may still be useful when assessing the overall reliability of a particular installation.

621.396.93 : 621.396.677.029.62 **2783**
An Experimental Spaced-Loop Direction-Finder for Very High Frequencies.—F. Horner. (*J. Instn elect. Engrs*, Part III, March 1947, Vol. 94, No. 28, pp. 126–133. Discussion, pp. 133–140.) This direction-finder uses two single-turn 28-cm square vertical coaxial screened loops 157 cm apart, and the field strength required for an arc of silence of ± 5° is 20 μV/m for a vertically polarized ground wave between 30 and 100 Mc/s. For high-angle waves (e.g. from aircraft) it appears to be more accurate than the rotating-H Adcock type provided that care is taken to eliminate errors due to loop resonances. A similar instrument using 92-cm loops 220 cm apart to give increased sensitivity (4 μV/m) at 30 Mc/s is described briefly. The polarization error introduced by calibrating with an elevated transmitter so close that the wave from it has appreciable curvature is evaluated and discussed. See also 2780 above.

621.396.93 : 621.396.677.029.63 **2784**
Some Experiments on Conducting Screens for a U-Type Spaced-Aerial Radio Direction-Finder in the Frequency Range 600-1 200 Mc/s.—R. R. Pearce. (*J. Instn elect. Engrs*, Part III, March 1947, Vol. 94, No. 28, pp. 115–117. Discussion, pp. 133–140.) A simple direction-finder was used to investigate the effect of large earth screens. A metal plate (or a λ/12 mesh of wire) not less than 4λ in diameter was required to reduce the polarization error of the direction-finder to about 1°.

621.396.96 : 535.37 **2785**
Luminescence and Tenebrescence as Applied in Radar.—Leverenz. (*See* 2796.)

621.396.96 : 621.385.832 **2786**
A Survey of Cathode-Ray-Tube Problems in Service Applications, with Special Reference to Radar.—Bradfield, Bartlett & Watson. (*See* 2984.)

621.396.96 : 621.385.832 **2787**
War-Time Developments in Cathode-Ray Tubes for Radar.—Jesty, Moss & Puleston. (*See* 2983.)

621.396.96 : 621.396.1 **2788**
Radar Allocations.—J. Markus. (*Electronics*, May 1947, Vol. 20, No. 5, p. 150.) A note on the allocation of the frequency bands 3 000–3 246 Mc/s, 9 320–9 500 Mc/s and 5 460–5 650 Mc/s for ship-borne radar by the Federal Communications Commission.

621.396.96 : 621.396.812 **2789**
A Theory of the Performance of Radar on Ship Targets.—Wilkes & Ramsay. (*See* 2904.)

621.396.96 : 621.396.82 **2790**
The War in the Ether.—E. B. Addison. (*J. R. aero. Soc.*, May 1947, Vol. 51, No. 437, pp. 425–436. Discussion, pp. 436–439.) A lecture dealing mainly with the use of radio as a weapon, and the tactics evolved to use it in the defence of Britain and in the protection of our bombers when attacking targets in enemy territory.

621.396.96.029.64 : 531.55 **2791**
Centimetre Radar for Precision Gun-Laying.—H. A. M. Clark. (*Proc. R.S.G.B.*, Spring 1947, No. 1, pp. 7..15.) Discussion of applications of radar to naval gunnery with emphasis on close range sets. A 3-cm auto-following set of this type is described in some detail.

621.396.96 **2792**
Principles of Radar. [Book Review]—Staff of Radar School, Massachusetts Institute of Technology. McGraw-Hill Publishing Co., London, 2nd edn, 25s. (*Wireless Engr*, May 1947, Vol. 24, No. 284, p. 155.) "It deals with each aspect of the whole wide field of radar with equal thoroughness and specialized knowledge, while achieving a remarkable consistency of treatment and organic unity."

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 : 539.163.2.08 : 620.191.33 **2793**
High Vacuum Leak Testing with the Mass Spectrometer.—W. G. Worcester & E. G. Doughty. (*Trans. Amer. Inst. elect. Engrs*, December Supplement 1946, Vol. 65, pp. 946–955. Discussion, p. 1170.) See also 2441 of August.

533.5 : 539.163.2.08 : 620.191.33 **2794**
Spectrometer Vacuum Leak Detector.—G. A. Doxey. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 142..194.) Cracks are detected in high vacuum systems by measuring leakage of helium into the system with a mass spectrometer. See also 2441 of August.

535.37 **2795**
Luminescent Materials.—S. György. (*Elektrotechnika, Budapest*, April & May 1947, Vol. 39, Nos. 4 & 5, pp. 70–73 & 81–86. In Hungarian, with English, French and German summaries.) A review of the more important luminescent materials, with an account of investigations by the author and E. Nagy of the band structure and temperature dependence of the luminescence of manganese-activated zinc silicate and zinc-beryllium silicate phosphors. A relation is found between the temperature dependence of the luminescence and that of the electrical conductivity.

535.37 : 621.396.96 **2796**
Luminescence and Tenebrescence [i.e., opposite of luminescence] **as Applied in Radar.**—H. W. Leverenz. (*RCA Rev.*, June 1946, Vol. 7, No. 2, pp. 199–239.) A comprehensive description of the properties of phosphors and 'scotophors' [i.e., opposite of phosphors] developed during the war for delay screens for cathode-ray tubes. Examples of typical radar displays are given; operating voltages were usually limited to 5 kV and trace persistences were required up to 30 sec. The energy imparted per signal pulse for typical p.p.i. operation is calculated for different screens and radar images are discussed in relation to the properties of the human eye. Methods are listed for converting cathode rays into visible radiation; only cathodo-luminescence and cathodo-tenebrescence have found practical application in radar. Ideal and real performances of phosphors and 'scotophors'

are contrasted and an idealized picture given of the mechanism of luminescence and tenebrescence.

Cascade screens comprising stratified layers of different phosphors which give an increase in phosphorescence and a decrease in initial lumines-ence largely overcome the difficulty of low pene-ration of the cathode rays due to the 5-kV voltage mitation. They are operated at low luminescence y using the enhanced sensitivity of the dark-dapted human eye.

Long persistent images were produced having ark traces on a bright field using (*a*) negative nodulation of luminescence ('c.r. burn' method) nd (*b*) tenebrescent screens of 'scotophors'.

Tabular summaries of some of the more useful .r.t. screens are given as an aid to radar indicator esigners and there is an extensive bibliography.

35.377 **2797**

The Thermoluminescence and Conductivity of hosphors.—R. C. Herman & C. F. Meyer. (*J. ppl. Phys.*, Feb. 1947, Vol. 18, No. 2, pp. 258–259.) orrection and addendum to 743 of March.

7.226.8 **2798**

Power Factor and Temperature Coefficient of lid (Amorphous) Dielectrics.—M. Gevers & F. K. Pré. (*Trans. Faraday Soc.*, 1946, Vol. 42A, . 47–55. Discussion, pp. 75–78.) In amorphous lectrics, including those consisting of a crystalline ss containing many lattice irregularities and purities, the dielectric constant and the power tor are, in general, almost independent of fre-ency and the ratio of the temperature coefficient the dielectric constant to the power factor is irly constant. An explanation of these pro-rties is based on the peculiar structure of such ids.

.226.8 **2799**

The Distribution of Relaxation Times in Dielectrics. . G. Garton. (*Trans. Faraday Soc.*, 1946, Vol. A, pp. 56–60. Discussion, pp. 75–78.) The iation of loss angle with frequency in dielectrics xplained by the existence of a distribution of xation times due to the presence of elements—bles or ions—which oscillate between 'wells' of ying potential depth whose distribution is ermined by considerations of temperature and osity.

228.1 **2800**

ffect of Foreign Ions on the Properties of helle-Type Crystals.—B. Matthias & W. Merz. *v. phys. Acta*, 31st July 1946, Vol. 19, No. 4, 227–229. In German.) All Rochelle-type crystals e a maximum in the resonance-frequency/perature curve at a point about 80° K above Curie temperature. Addition of Tl to KH_2PO_4 s both the maximum and the Curie temperature n amount approximately proportional to the concentration. The alkali ions produce the osite effect.

533 :[546.26-1 + 546.28 **2801**

easurement of the Thermo-Electron Emission Graphite, Silicon and Silicon Carbide.—A. n & G. Busch. (*Helv. phys. Acta*, 15th Feb. Vol. 20, No. 1, pp. 33–66. In German.) ew method was used, the inner wall of the ng chamber serving as anode for the emitted electrons. For graphite the constants in the emission formula $I = AT^2\ e^{-\phi/KT}$ were found to be $\phi = 4.39$ eV, $A = 15$ A/cm² (°K)². The corre-sponding values for silicon were 3.59 eV and 8 A/cm² (°K)². The results for single crystals of silicon carbide varied widely depending on the surface layer. The results are shown graphically.

538.221 **2802**

A New Magnetic Material of High Permeability.—O. L. Boothby & R. M. Bozorth. (*J. appl. Phys.*, Feb. 1947, Vol. 18, No. 2, pp. 173–176.) A descrip-tion of the preparation, heat treatment, and pro-perties of 'supermalloy', a magnetic alloy of iron, nickel, and molybdenum. As 0.001-inch insulated tape in transformer cores, it has an initial per-meability of 50 000–120 000, and permits a three-fold increase in the frequency range transmitted.

538.221 : 621.317.41.029.63 **2803**

A Method to Measure Complex Permeabilities of Metals at U.H.F.—Johnson, Rado & Maloof. (*See* 2852.)

538.23 : 669.157.82 **2804**

Demagnetizing Coefficients and Hysteresis Losses of Rectangular Iron-Silicon Strips.—E. H. Sond-heimer. (*Proc. Camb. phil. Soc.*, April 1947, Vol. 43, Part 2, pp. 254–261.) Investigation of the variation of the demagnetization coefficient N with the dimensions of the specimen and its intensity of magnetization. Hysteresis loss is approximately independent of N.

546.431.821 : 548.3 **2805**

Crystal Structure of Barium Titanium Oxide and Other Double Oxides of the Perovskite Type.—H. D. Megaw. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 224–231.) Compounds of the perovskite type having the empirical formula $A^{2+}B^{4+}O_3$ show distortion from the ideal structure, depending on the size of the A^{2+} cation.

546.431.821 : 621.315.611.011.5 **2806**

The Permittivity of Polycrystals of the Perovskite Type.—D. F. Rushman & M. A. Strivens. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 231–238.) The main features of the dielectric polarization pheno-mena occurring in barium titanate and the mixed Ba/Pb/Sr titanates are discussed. The behaviour of these compounds can be explained by a displace-ment of the equilibrium position of the titanium ion in the crystal structure.

62"1946" **2807**

Progress in Engineering Knowledge during 1946.—Alger, Stokley, Faust, Robinson, Tugman, Kuyper & Haylon. (*See* 2996.)

621.315.6 + 537.226 + 621.317 **2808**

A General Discussion on Dielectrics.—(*Trans. Faraday Soc.*, 1946, Vol. 42A.) A special number incorporating papers and discussions at the con-ference at Bristol University, 24th–26th April 1946. For abstracts of selected individual papers, see Materials, General Physics and Measurements sections.

621.315.611.015.5 + 537.529 **2809**

Electric Breakdown of Solid Dielectrics.—A. von Hippel. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 78–87. Discussion, pp. 87–90.) The experi-mental facts are described for both crystalline and amorphous solids and the theory is propounded that excess electrons, accelerated in the applied field, produce impact ionization, avalanche formation and breakdown. In the author's opinion, in the absence of an applied field these electrons are stopped by a friction barrier of lattice vibrations in the material. In the discussion various alternative theories are put forward.

621.315.612.015.5 2810

The Electrical Performance of Ceramic Dielectrics at Elevated Temperatures.—H. A. Frey & J. M. Jesatko. (*Trans. Amer. Inst. elect. Engrs*, December Supplement 1946, Vol. 65, pp. 911–920. Discussion, pp. 1126–1128.) Data on the variation of resistivity with temperature of porcelain, steatite, glass and zircon compositions; the effect of voltage gradient is also stated and a method given for determining approximately the conditions for breakdown.

621.315.612.3.029.5 2811

Steatite for High Frequency Insulation.—J. M. Gleason. (*Proc. Instn Radio Engrs, Aust.*, April 1945, Vol. 5, No. 8, pp. 2–12.) A detailed account of the physical and electrical properties of steatite and steatitic ceramics, with a short discussion of production methods and insulator design.

621.315.616.9.011.5 + 541.64 2812

The Dielectric Properties of High Polymers.—R. B. Richards. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 194–197.)

621.315.616.9.011.5.029.5 2813

The Dielectric Properties of Chlorinated Polythenes at Radio Frequencies.—W. G. Oakes & R. B. Richards. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 197–205.) Measurements over the range 10^4–10^8 c/s. Increase of the average dipole orientation relaxation time with increase of chlorine content is in accord with the change from a flexible or rubbery to a rigid state.

621.315.616.9.011.5.029.5 2814

Dipole Orientation in Solutions of Esters in Polyisobutene and Polythene.—K. W. Plessner & R. B. Richards. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 206–213.) Power factor/frequency curves are given for the range 10^4–10^8 c/s and are discussed with reference to relaxation times and dipole orientation.

621.315.616.9.029.5 2815

Dielectric Dispersion and Absorption in Natural Rubber, Neoprene, Butaprene NM and Butaprene S, Gum, and Tread Stocks.—W. C. Carter, M. Magat, W. C. Schneider & C. P. Smyth. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 213–220.) The dielectric constants of various elastomers, gums and treads were measured over a wide range of frequency. The results obtained show reasonable agreement with predictions from the Fuoss-Kirkwood theory. The abnormally high losses of tread stocks are due to a superposition of Debye effect, Maxwell-Wagner effect and d.c. conductance.

621.318.323.2.042.15 2816

Iron-Dust Cores.—G. H. M. Gleadle. (*Wireless Engr*, May 1947, Vol. 24, No. 284, pp. 156–157.) Results are given of measurements on Ferrocart rings. See also 1692 and 1693 of June.

621.396.611.21 : 537.228.1 2817

Quartz Oscillators.—Vigoureux. (*See* 2703.)

621.775.7 : 621.396 2818

Powder Metallurgy and Its Application to Radio Engineering.—N. Fetherston & L. W. Cranch. (*Proc. Instn Radio Engrs, Aust.*, May 1945, Vol. 5, No. 9, pp. 3–14.) Applications of powder metallurgy include the production of self-lubricating bearings, porous metal filters, Alnico permanent magnets, tungsten rods for wire drawing, silver-graphite and silver-tungsten contacts, iron-dust cores etc. The methods used for obtaining powdered copper and iron are described and also sintering processes and the manufacture of iron-dust cores. The selection of the grade of magnetic material best suited for a specified frequency application is discussed and practical applications of iron-dust cores of various types are given.

666.1 : 621.385 2819

Glass in the Radio Industry. F. Violet, A. Danzin & A. Commin. (*Ann. Radioélect.*, Jan. 1947, Vol. 2, No. 7, pp. 24–74.) An account of the development of glass technique in valve manufacture, showing how research on glass composition, expansion coefficients, the physics of glass-to-metal seals, etc., has led to a progressive replacement of empirical by scientific processes. A detailed description is given of modern mass-production methods of manufacture of valve feet with projecting pins.

669.152.5 2820

New Magnetic Alloy.—(*Elect. Times*, 17th April 1947, Vol. 111, No. 2893, p. 437.) 'Hiperco', consisting of 35% cobalt, 64% iron and 1% chromium gives the highest saturation point of any magnetic material yet known.

669.108.1 : 669.5 2821

A New Zinc-Base Finish for Steel Parts.—J. A. Williams. (*Materials & Methods*, March 1947, Vol. 25, No. 3, pp. 95–96.) Method of zinc plating, which gives a hard, long-wearing surface with the appearance of chromium plating and has greater corrosion resistance than tin finishes formerly used.

669.45.778 : 621.315.22 2822

F3 Lead Alloy—An Improved Cable Sheathing.—L. F. Hickernell & C. J. Snyder. (*Trans. Amer. Inst. elect. Engrs*, December Supplement 1946, Vol. 65, pp. 1136–1141.) Discussion on 3647 of 1946.

621.318.22 : 669 2823

Magnet Steels and High Performance Magnet Alloys. [Book Review]—W. Jessop & Sons, Sheffield. (*Overseas Engr*, March 1947, Vol. 20, No. 234, p. 278.) Gives information on metallurgical aspects of the manufacture of permanent magnets, with a résumé of the theory of magnetization, demagnetization and artificial aging. The properties and treatment of various alloys are tabulated.

679.5 2824

Plastics for Production. [Book Review]—P. I. Smith. Chapman & Hall, London, 2nd edn, 216 pp., 15s. (*Beama J.*, Feb. 1947, Vol. 54, No. 116, pp. 73–76; *Elect. Rev., Lond.*, 11th April 1947, Vol. 140, No. 3620, p. 586.)

MATHEMATICS

7.512.2 : 621.396.67 2825
Fourier Transforms in Aerial Theory: Part 1.—msay. (*See* 2680.)

8.2 2826
Table of the Integral $(2/\pi)\int_0^x (1/t)\tanh^{-1} t\,dt$.—S. Corrington. (*RCA Rev.*, Sept. 1946, Vol. 7, . 3, pp. 432–437.) A 5-figure table for the range = 0 to 1, with detailed explanation of the methods computation and checking.

.5 2827
Analysis of Problems in Dynamics by Electronic cuits.—J. R. Ragazzini, R. H. Randall & F. A. ssell. (*Proc. Inst. Radio Engrs, W. & E.*, May 7, Vol. 35, No. 5, pp. 444–452.) A method of ving integro-differential equations of physical tems by the use of an electronic system, the basic nponent of which is a stabilized feedback plifier which, by external changes in connections, y be used as integrator, differentiator or sign nger.

he application of such amplifiers in systems for solution of linear first-degree equations, simuleous integro-differential equations and equations h variable coefficients is considered.

5 2828
ercury Memory Tanks in New EDVAC [elecic discrete variable] **Computer.**—(*Electronics,* 1947, Vol. 20, No. 5, pp. 168..176.) A tube aining mercury has an X-cut quartz crystal ach end in intimate contact with the mercury. trical pulses, spaced 1 μs apart, are converted ne crystal into ultrasonic pulses which travel ively slowly through the mercury. These are verted to electrical pulses by the second crystal, lified and fed back into the first crystal prong a closed cycle of stored pulses. Multiple ronic switch or gate circuits introduce or withany pulse as required so that a low-loss storage e is provided capable of storing eight 10-digit bers and referring to any one in an average of 200 μs.

8 : 52/59 2829
oice of a 'Reality Index' for Suspected Cyclic tions.—W. O. Kermack : W. Gleissberg. *re, Lond.*, 1st March 1947, Vol. 159, No. 4035, 5–306.) A criticism of Gleissberg's application 'reality index' to data concerning sunspot na (1496 of May).

66 : 621.396.677.029.64 2830
ctromagnetic Fields in a Paraboloidal Re-.—Pinney. (*See* 2687.)

2.1 2831
viside's Operational Calculus Made Easy. Review]—T. H. Turney. Chapman & Hall, n, 2nd edn 1947, 102 pp., 10s. 6d. (*Distrib.* April 1947, Vol. 19, No. 166, p. 242.) dies some additional information and, in some ces, more detailed explanations. For review edition see 1253 of 1945.

MEASUREMENTS AND TEST GEAR

7 + 621.315.6 + 537.226 2832
eneral Discussion on Dielectrics.—(*See* 2808.)

621.317.081.3+53.081.3 2833
International Committee of Weights and Measures.—(*Nature, Lond.*, 8th March 1947, Vol. 159, No. 4036, pp. 325–326.) Includes a recommendation that absolute electrical units based on the m.k.s. or c.g.s. system should be substituted for the present international electrical units based on the mercury ohm and the silver voltameter. The ratios accepted by the Committee are:

1 mean international ohm = 1.000 49 ohm (absolute)

1 mean international volt = 1.000 34 volt (absolute).

621.317.081.3+53.081.3 2834
Absolute Electrical Units.—(*Elect. Rev., Lond.,* 18th July 1947, Vol. 141, No. 3634, p. 94.) In accordance with decisions taken by the International Committee of Weights and Measures (2833 above) the system of electrical units employed at the National Physical Laboratory will be changed on January 1st, 1948, from 'international' to 'absolute' units. The conditions to be satisfied for the issue of N.P.L. certificates after this date are stated.

621.317.1 : 621.396.621.029.62 2835
The Testing Procedure for F.M. V.H.F. Receivers.—Fanker & Ratcliffe. (*See* 2912.)

621.317.32 : 621.396.81 : 621.396.97 2836
BC [broadcasting] **Field Intensity Measurements.**—(*Tele-Tech*, April 1947, Vol. 6, No. 4, pp. 64–65.) A portable set covering the frequency range 200–7 000 kc/s in four bands and with an intensity range from 20 μV/m to 10 V/m.

621.317.33 : 621.392.43 2837
Impedance Measurement on Transmission Lines.—King. (*See* 2673.)

621.317.33.011.5 + 535.341] : 537.226.029.64 2838
Extension of the Measurements of Dispersion and Absorption by Liquids, to the Region of Centimetric Radio-Electric Waves.—Abadie. (*See* 2730.)

621.317.33.011.5 + 535.341] : 537.226.2.029.64 2839
Wave Guide Measurements of Dielectric Absorption of Solutions of Polar Substances in Non-Polar Solvents.—H. W. Hall, I. G. Halliday, W. A. Johnson & S. Walker. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 136–143. Discussion, pp. 155–170.) Variation of dielectric absorption with viscosity at 10^{10} c/s.

621.317.33.011.5 + 535.341] : 621.315.615.029.64 2840
Some Measurements on the Absorption of Centimetric Waves by Liquid Dielectrics.—F. J. Cripwell & G. B. B. M. Sutherland. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 149–152. Discussion, pp. 155–170.)

621.317.33.011.5+ 535.341] : [621.315.615.2.029.5/.6 2841
Dielectric Absorption in Benzene and Liquid Paraffin Solutions at Ultra High Frequencies.—W. Jackson & J. G. Powles. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 101–108. Discussion, pp. 155–170.) The variation of loss angle with frequency conforms to the original Debye theory. Experimental arrangements are described.

621.317.33.011.5 + 535.341] : 621.315.615.9.029.64 2842

Measurements on the Absorption of Microwaves: Parts 1 & 2.—D. H. Whiffen & H. W. Thompson. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 114–129. Discussion, pp. 155–170.) The results of measurements of the absorption of 1.27-cm and 3.26-cm waves and of absorption/temperature variations in a number of liquid hydrocarbons are presented and discussed in relation to relaxation phenomena.

621.317.33.011.5.029.64 : 537.226 2843

The Representation of Dielectric Properties and the Principles underlying Their Measurement at Centimetre Wavelengths.—W. Jackson. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 91–101. Discussion, pp. 155–170.) The representation of the electrical properties of dielectric media is explained and resonance methods of measuring them are compared with the standing-wave method. It is stressed that very great care is necessary in the designing of the standing-wave detector system.

621.317.33.011.5.029.64 : 546.212 2844

Dielectric Properties of Water.—C. H. Collie, D. M. Ritson & J. B. Hasted. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 129–136. Discussion, pp. 155–170.) Description of the apparatus used in measurements at wavelengths of 10.0 and 1.25 cm, over the temperature range 0°–100°C. Experimental results are given and briefly discussed.

621.317.33.011.5.029.64 : 546.212-16 2845

Measurements of the Dielectric Properties of Ice.—J. Lamb. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 238–244.) Measurements were made (*a*) at a frequency of 10^{10} c/s, over the temperature range 0° to −40°C; and (*b*) at a temperature of −5°C, over the frequency range 8×10^3–1.25×10^6 c/s. The loss-factor/temperature curve for 10^{10} c/s shows a sharp elbow at about −5°C, above which temperature the loss factor increases rapidly. Possible explanations of this are suggested.

621.317.33.011.5.029.64 : 621.315.611 2846

Some Measurements of the Permittivity and Power Factor of Low Loss Solids at 25 000 Mc/s Frequency.—R. P. Penrose. (*Trans. Faraday Soc.*, 1946, Vol. 42A, pp. 108–114. Discussion, pp. 155–170.) Dielectric properties were investigated by using a flat circular disk of dielectric inserted at one end of an H_0-mode cylindrical cavity resonator and measuring the consequent variation in resonant length. The derivation of permittivity and power factor is explained and the experimental accuracy discussed.

621.317.333 : 621.319.53 2847

A 2½-Million Volt Surge Generator.—(*Engineer, Lond.*, 28th March 1947, Vol. 183, No. 4757, p. 273.) For testing cables and insulating materials.

621.317.333.82 : 620.179.1 : 621.315.2 2848

The Henley 1 200 000 Volt Impulse Testing Plant: Part 1—The Basic Principles for Cable Testing.—T. R. P. Harrison. (*Distrib. Elect.*, April 1947, Vol. 19, No. 166, pp. 224–227.) The basic circuit and operation of many stages in cascade are described and waveform control and the effect of the circuit inductance discussed. For voltage measurement a c.r.o. is used with a capacitor-type potential divider.

621.317.361 + 531.761 2849

WWV Schedules.—(*Electronics*, May 1947, Vol. 20, No. 5, p. 87.) A summary of the standard frequency transmissions from the National Bureau of Standards, Washington, D.C.

621.317.382.029.6 2850

Microwave Power Measurement.—T. Moreno & O. C. Lundstrom. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, pp. 514–518.) "Possible methods of microwave power measurement are reviewed. The design requirements for bolometric wattmeters are outlined, and examples are given of bolometer elements that have been developed to meet these requirements. A recently developed bolometer element that may be used over an exceedingly wide band of frequencies is included. The results of experiments to investigate sources of error and to determine the accuracy of these wattmeters are summarized. These experiments indicate that, although serious errors are possible, proper usage will hold errors to within a few per cent."

621.317.39 : 531.76 : 621.3.015.33 2851

Pulse Width Measuring Method.—(*Tele-Tech*, April 1947, Vol. 6, No. 4, p. 57.) An instrument with an accuracy of ¼ μs for pulse widths of 3–12 μs independent of repetition frequency.

621.317.41.029.63 : 538.221 2852

A Method to Measure Complex Permeabilities of Metals at U.H.F.—M. H. Johnson, G. T. Rado & M. Maloof. (*Phys. Rev.*, 1st April 1947, Vol. 71, No. 7, p. 472.) Summary of Amer. Phys. Soc. paper. The method involves measurement of the changes in Q and in the resonant frequency when a metal is substituted for the ferromagnetic centre conductor in a coaxial resonator.

621.317.72.029.56/.58] : 621.392.43 2853

The "Micromatch".—M. C. Jones & C. Sontheimer. (*QST*, April 1947, Vol. 31, No. 4, pp. 15–20.) A meter for direct measurement of the standing wave ratio of transmission lines and r.f. power. It operates over the frequency range 3–30 Mc/s and for line impedances of 70–300 Ω and, as a power meter at maximum sensitivity, has a full scale deflection corresponding to approximately 10 W or 40 W with a 70-Ω or 300-Ω line respectively.

621.317.733 2854

Considerations on the Equations of Balance of an A.C. Wheatstone Bridge.—M. Romanowski & G. Leclerc. (*Rev. gén. Élect.*, March 1947, Vol. 56, No. 3, pp. 129–132.) Discussion of the classical methods for reducing the effects of parasitic capacitance and an account of a method, due to J. Carvallo, of eliminating the effect of the capacitances localized at the corners of the bridge. The case where an intermediate point on one of the arms has appreciable capacitance to earth is also considered.

621.317.75.029.64 2855

Microwave Spectrum Analyzers.—H. R. Traver & F. L. Burroughs. (*Tele-Tech*, April 1947, Vol. 6, No. 4, pp. 35–38.) Details of sharply tuned superheterodyne receivers whose frequency of reception is made to sweep across the frequency spectrum at a rate slow compared with the pulse repetition

-quency of the oscillator being studied. Details given of an analyser for 9 300 Mc/s using a -lex klystron as local oscillator.

-.317.761.087 2856
Direct Frequency Measurement.—L. M. Berman. *lectronics*, May 1947, Vol. 20, No. 5, pp. 202.. -.) Summary of 2504 of August.

-.317.79 : 621.396.611 2857
Automatic —[circuit] **Testing Machine.**—(*Toute Radio*, May 1947, Vol. 14, No. 115, pp. 144–145.) -hort account of the principles and operation of - apparatus described by Williams, Marshall, -smire & Crawley (2181 of July).

-.396.615.12 : 621.317.79 2858
-tandard Frequency Generator.—S. J. Haefner & -H. Smith. (*Tele-Tech*, April 1947, Vol. 6, No. -pp. 58–59.) Push-button operation gives fre- -ncies from 40 kc/s to 1 000 kc/s in steps of -kc/s. With an interpolation oscillator con- -ously variable from 10 kc/s to 50 kc/s, any -uency in the above range is obtained.

-396.615.17 : 621.396.822 2859
-oise Signal Generator.—W. P. Dolphin. -.G.B. *Bull.*, April 1947, Vol. 22, No. 10, pp. -160.) The noise factor is defined and it is -n that a noise generator gives a true value for -signal-to-noise ratio independent of the band- -h of the receiver. The generator consists of -turated diode with a resistive load, the noise -ut being controlled by varying the filament -nt. A practical account of the technique -requencies up to 100 Mc/s is given and other - of the generator are indicated.

-THER APPLICATIONS OF RADIO AND ELECTRONICS

-1-15 : 621.317.755 : 535.33 2860
- Infra-Red Spectroscope with Cathode-Ray -ntation.—E. F. Daly & G. B. B. M. Suther- - (*Proc. phys. Soc.*, 1st Jan. 1947, Vol. 59, -31, pp. 77–87.) An instrument by means of - a range of 2.5–3.5 μ, anywhere between - 16 μ, can be scanned in 14 seconds. See also -of 1946.

-1-15 : 621.383.001.8 2861
- Infrared Image Tube and Its Military Applica- —G. A. Morton & L. E. Flory. (*RCA Rev.*, -1946, Vol. 7, No. 3, pp. 385–413.) Description -mponents of an infra-red electron telescope, -rising image tube, objective for forming infra- -mage on photocathode and optical system for -ng reproduced image.

--15 : 621.389 2862
-a-Red Ray Development.—(*Electrician*, 11th -1947, Vol. 138, No. 3591, pp. 933–934.) British -nent, perfected in 1941, consists funda- -lly of a small vacuum container with two flat -el sides, spaced about 0.5 cm apart, lying at -angles to the axis of a telescope. One side -rts a caesium-silver infra-red-sensitive photo- -le, while the other is coated with fluorescent -ial and is electrically conducting. A d.c. -ial of 3–4 kV, derived from a small Zamboni - maintained between the photocathode and -node. Radiation from an infra-red source, after filtering out any visible component, is focused on the photocathode, the electrons from which give an image on the fluorescent screen. With infra-red headlights and binoculars the system was largely used for night driving. The smallest British receiver, a single eyepiece model, weighs only 1¼ lb, compared with 16 lb for the German equivalent. See also 2207 of July.

536.48 2863
Possible Use of Thermal Noise for Low Temperature Thermometry.—E. Gerjuoy & A. T. Forrester. (*Phys. Rev.*, 15th March 1947, Vol. 71, No. 6, pp. 375–376.) Further comment on 483 of February: see also 2185 of July. It is shown theoretically that the minimum measurable temperature, under given conditions, is about 2°K.

537.531 2864
The Physical Properties of Super-Voltage X Rays. —H. Miller. (*Radiography*, April 1947, Vol. 13, No. 148, pp. 37–41.) A general account, with special reference to voltages ranging up to 20 MV, whose use for X-ray therapy gives promise of valuable new possibilities.

539.16.08 2865
Spread of Discharge in Geiger Counters.—J. D. Craggs & A. A. Jaffe. (*Nature, Lond.*, 15th March 1947, Vol. 159, No. 4037, pp. 369–370.)

539.16.08 2866
Simplified Spark Counter.—H. Greinacher. (*Helv. phys. Acta*, 30th April 1947, Vol. 20, No. 2, pp. 222–224. In German.) Uses a symmetrical spark gap with small platinum-ball electrodes sealed in a glass bulb. This is connected in series with a 0.5-MΩ resistor shunted by a small capacitor, a neon lamp, a telephone earpiece and the secondary of a transformer giving about 2 200 V. A tube with a thin end is sealed into the glass bulb to allow the counter to be used for α-particles. Telephone clicks, though weak, are quite audible and the glow tube is bright enough for photographic recording o- α, β or γ rays on a moving film, using a narrow slit

539.16.08 2867
A Method for Measuring the Velocity of the Ion Transfer in Rapid Counter Tubes.—P. Huber, F. Alder & E. Baldinger. (*Helv. phys. Acta*, 31st July 1946, Vol. 19, No. 4, pp. 204–206. In German.)

539.16.08 : 621.318.572.015.33 2868
On the Pulse Shape in Rapid Counter Tubes.— P. Huber, F. Alder, E. Baldinger & F. Metzger, (*Helv. phys. Acta*, 31st July 1946, Vol. 19, No. 4, pp. 207–211. In German.)

539.16.08 : 621.383 2869
The Multiplier as a Counter for Elementary Particles.—K. P. Meyer. (*Helv. phys. Acta*, 31st July 1946, Vol. 19, No. 4, pp. 211–214. In German.)

621.317.39 : 531.719.27 2870
Rate-of-Change Meter.—R. W. Treharne, J. A. Kammerer & R. Hofstadter. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 106–107.) "Varistor-compensated circuit converts nonlinear voltage variables into linear voltage variables. Application in radio altimeters shows rate of climb directly, with short time lag." See also 1863 of 1946.

621.317.39 : 621.396.645 : 539.4 2871
Carrier-Type Amplifier for Electric Gages.—H. C. Roberts. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 92–95.) A RC-coupled amplifier for use with various types of electrical gauge circuits in static and dynamic tests on strains, pressures, etc., in railway rolling stock, bridges and tracks.

621.317.39.083.7 : 629.13 2872
Radio Telemetering for [dynamic] **Testing** [of] **Aircraft in Flight.**—C. L. Frederick. (*Trans. Amer. Inst. elect. Engrs*, December Supplement 1946, Vol. 65, pp. 861–870.) Description of stabilized oscillators modulated by metering equipment; regulated power supplies; f.m. transmitter; automatic frequency-controlled receiver; and heterodyne analyser used by the U.S. Navy in 1945.

621.357.8 : 537.533.73 2873
Electron Diffraction Examination of Electrolytically Polished Surfaces.—J. J. Trillat. (*C. R. Acad. Sci., Paris*, 14th April 1947, Vol. 224, No. 15, pp. 1102–1103.) Tests carried out on samples of pure iron, aluminium and copper show that electrolytic polishing causes the Beilby layer to disappear to an extent depending upon the duration of the operation. The nature of the bath appears to play an important part in the case of aluminium, a metal easily oxidized.

621.365.5 + 621.365.92 2874
Industrial Applications of High Frequency.—M. Descarsin. (*Onde élect.*, April 1947, Vol. 27, No. 241, pp. 121–137.) Basic principles, historical development and numerous applications of both induction and dielectric heating.

621.365.5 : 538.2 2875
Theory of the Heating of Ferromagnetic Materials by Eddy Currents and by Hysteresis.—Jouguet. (*See* 2752.)

621.365.52 2876
Design of Induction Heating Coils for Cylindrical Magnetic Loads.—J. T. Vaughan & J. W. Williamson. (*Trans. Amer. Inst. elect. Engrs*, December Supplement 1946, Vol. 65, pp. 887–892. Discussion, pp. 1165–1166.) Extension of previous paper (148 of 1946) to design of coils for magnetic loads. Variation in impedance of coil circuit with changing temperature necessitates special design of circuit to absorb maximum power. See also 2271 of 1946.

621.365.92.072.8 2877
High Frequency Heating.—J. F. Capper. (*Elect. Times*, 17th April 1947, Vol. 111, No. 2893, pp. 417–421.) Discussion of methods and advantages of automatic loading control.

621.369.2 2878
Some Applications of Infra-Red Lamp Radiation to Treatment [of materials]**, Drying** [of leather, etc.] **and Baking** [of paints and varnishes].—M. Déribéré. (*Rev. gén. Élect.*, Feb. 1947, Vol. 56, No. 2, pp. 71–74.)

621.38.001.8 2879
The Electrical Engineer in the Service of Other Industries.—H. C. Turner & G. M. Tomlin. (*Beama J.*, Feb. 1947, Vol. 54, No. 116, pp. 57–64.) Abridgment of I.E.E. Measurement Section paper. A description of various electronic instruments used in test processes, including a magnetic sorting bridge for indicating variations in purity, heat treatment, hardness and depth of carburization in steels. Two types of vibration analyser are described and details given of the use of supersonic equipment in metal testing and measurement of thickness of metallic films.

621.38.001.8 : 621.317 2880
Valves and Their Industrial Low-Current Applications.—F. Fanchamps. (*Bull. sci. Ass. Inst. électrotechn. Montefiore*, Jan. 1947, Vol. 60, No. 1, pp. 11–34.) Describes the basic principles of valve methods of measurement of various quantities, with applications in engineering and automatic control.

621.383.4 2881
High-Sensitivity Photoconductive Cell.—Hewlett. (*See* 2972.)

621.384.6.07 2882
Stabilizing Linear Particle Accelerators by Means of Grid Lenses.—D. Gabor. (*Nature, Lond.*, 1st March 1947, Vol. 159, No. 4035, pp. 303–304.) The mode of action of grid lenses is outlined, and their advantages described. "Grid lenses may well compete with beryllium foils in the stabilization of linear accelerators for extreme energies."

621.385.833 : [538.311 + 621.316.97].083 2883
Measurement of Feeble Magnetic Fields and of the Effects of Shielding. Application to the Electron Microscope.—Charles. (*See* 2753.)

621.386.1 : 544 2884
Apparatus and Techniques for Practical Chemical Identification by X-Ray Diffraction.—C S Smith & R. L. Barrett. (*J. appl. Phys.*, Feb. 1947, Vol. 18, No. 2, pp. 177–191.)

621.398 : 621.397.6 2885
Miniature Airborne Television Equipment.—Kell & Sziklai. (*See* 2961.)

621.398 : 629.13 2886
Guide Beam Control Technic for V-2 Rockets.—G. Hausz. (*Tele-Tech*, March 1947, Vol. 6, No. 3, pp. 76–80.) The Leitstrahl (LS) system operated on frequencies in the range 42–64 Mc/s and used two narrow beams from a transmitter 5–10 miles behind the launching point and on the line from there to the target. The beams were directed at angles of 0.4° on either side of this line, that on the left being modulated at 5 kc/s and the other at 7 kc/s. The two beams were switched on alternately for 0.01 sec. In the missile, equal amplitude signals were only received when on course. Deviations gave rise to an error voltage which was applied to control circuits to correct the deviations. The high accuracy obtained was largely due to the aerial assembly, which consisted of two horizontal λ/2 dipoles, 220 yd apart, giving a system of very narrow beams, only two of which were used. A capacitor switching system was employed. Details of the transmitter-wagon and missile-borne equipments are given, with block diagrams. See also 2512 of August.

621.398 : 629.13 : 621.397.6 2887
Flying Torpedo with an Electric Eye.—Zworykin. (*See* 2962.)

1.398 : 629.135.52 2888

Radio Control of Model Flying Boats.—V. Welge. *Proc. Inst. Radio Engrs, W. & E.*, May 1947, ol. 35, No. 5, pp. 526–530.) Control is effected variations in amplitude of seven audio modu- ing tones on a carrier in the frequency band 6.0–118.5 Mc/s.

PROPAGATION OF WAVES

1.396.11 2889

On the Field of Radio Waves between Two Semi- nducting [imperfectly conducting] **Surfaces.**— A. Ryazin & L. M. Brekhovskikh. (*Bull. Acad. . U.R.S.S., sér. phys.*, 1946, Vol. 10, No. 3, . 285–305. In Russian.) Starting from Maxwell's uations and boundary conditions (2), the case is cussed where the field is excited by a vertical ole located in the intermediate non-conducting ce at any arbitrary height above the lower dium. The boundary surfaces of the media are umed to be flat and parallel (Fig. 1). The blem is thus similar to that of the propagation radio waves between the surface of the earth the ionosphere if the above assumptions can applied to the latter case.

he main results obtained are: (*a*) At large ances the waves in the intermediate air layer of the surface type as distinct from the space e. (*b*) The variation of the intensity and phase adio waves near the earth's surface is calculated. mmerfeld's solution taking into account only one ndary surface is a particular case of the more eral theory developed in this paper. (*c*) The se velocity of waves, at least of the longer wave- ths, exceeds the velocity of light. (*d*) It is irmed that the attenuation factor in Austin's other empirical formulae is of exponential form.

396.11 2890

n the Propagation and Dispersion of Radio ves.—V. A. Fock. (*Viestnik Akad. Nauk, S.S.S.R.*, , No. 3, pp. 23–34. In Russian.) A general ele- tary survey introducing methods developed he author.

396.11 : 538.566 2891

ffraction of Radio Waves around the Earth's ace.—V. Fock. (*J. Phys., U.S.S.R.*, 1945, 9, No. 4, pp. 255–266.) Full paper, of which mmary was noted in 160 of 1946.

396.11 : 551.5 2892

e Mode Theory of Tropospheric Refraction Its Relation to Wave-Guides and Diffraction.— . Booker & W. Walkinshaw. (*Physical Society ial Report on Meteorological Factors in Radio- e Propagation*, pp. 80–127.) The bearing of theory of waveguides upon refraction, par- arly of radio waves, in the troposphere and diffraction beyond the horizon is explained tail. Propagation curves suitable at any rate qualitative description of the effects of tropo- ic radio refraction are given. Atmospheric gation may be described in terms of a series aracteristic E- or H- waves similar to those n can travel between parallel metal sheets. ower edge of the track of these waves often, ot always, coincides with the earth's surface. height of the upper edge depends on the bution of refractive index with height and the order of the mode involved.

Beyond the horizon the E_1- or H_1- wave becomes predominant. Normally all the characteristic waves leak copiously from the tops of their tracks, but under conditions of superrefraction the degree of this leakage is reduced and may even be entirely suppressed for the first mode at metre wavelengths and below. This wave can then produce at long range a remarkably high field strength within its track.

The degree of leakage is controlled primarily by the lapse-rate of refractive index within the track of the first mode, that is, at heights up to about 35 ft for λ 10 cm, 750 ft for λ 10 m, and 16 000 ft for λ 1 km.

621.396.11 : 551.5 2893

A Variational Method for Determining Eigen-Values of the Wave Equation applied to Tropospheric Refraction.—G. G. Macfarlane. (*Proc. Camb. phil. Soc.*, April 1947, Vol. 43, Part 2, pp. 213–219.) A general method of solution for both real and complex eigen-values corresponding to any type of atmospheric refractive index profile. There existed previously two methods of analysis for problems on the tropospheric refraction of radio waves, the perturbation method applicable to cases where energy leaks considerably from an atmospheric duct, and Rayleigh's method, which may be applied in the case of real eigen-values, or trapped modes of propagation. The present work may be considered as an extension of Rayleigh's method to the case of complex eigen-values. An example is given of the use of the method when the refractive index varies with height according to a power law. See also 2894 and 2892.

621.396.11 : 551.5 2894

A Method for deducing the Refractive-Index Profile of a Stratified Atmosphere from Radio Observations.—G. G. Macfarlane. (*Physical Society Special Report on Meteorological Factors in Radio-Wave Propagation*, pp. 250–252.) A profile of refractive index can be obtained either from one set of radio height-gain measurements at a fixed range and a few measurements of field strength at a constant height, or from two sets of height-gain measurements at different wavelengths. Such a profile may be more reliable for predicting radio field strengths than one obtained from a single meteorological sounding. See also 2893 above.

621.396.11 : 551.510.535 2895

The Application of Ionospheric Data to Radio Communication Problems: Part 2.—E. V. Appleton & W. J. G. Beynon. (*Proc. phys. Soc.*, 1st Jan. 1947, Vol. 59, No. 331, pp. 58–76.) "Graphs are given from which may be estimated the maximum usable frequency of radio waves reflected by an ionospheric layer in oblique incidence transmission. The curves based on the theory given in part 1 of the paper are drawn for such ranges of layer thickness and layer height as are met with in practice. The limitations in the accuracy and applicability of the theory in practice are briefly discussed. Attention is also drawn to the occurrence of abnormal transmission conditions under which long-distance communication via the ionosphere is possible on frequencies exceeding the normally predicted values." For part 1 see 3290 of 1940.

621.396.11 : 551.510.535 **2896**

Oblique Radio Transmission in the Ionosphere, and the Lorentz Polarisation Term.—W. J. G. Beynon. (*Proc. phys. Soc.*, 1st Jan. 1947, Vol. 59, No. 331, pp. 97–107.) The work of Ratcliffe (15 of 1940) upon the appropriateness of the Sellmeyer or Lorentz dispersion formulae in this connection is extended and shown to be consistent with that of Newbern Smith (1586 of 1941). The analysis is applied to a large number of experimental results.

The maximum usable frequencies over distances of 1 000 km and 700 km were found to depart from the values calculated using the Sellmeyer formula by only 0.2 and 0.03 respectively of the amount that would be expected if the Lorentz formula applied.

These experimental results are thus in agreement with the theoretical conclusion of Darwin (1934 Abstracts, p. 606) that the Sellmeyer type of formula is applicable to the case of the refraction of radio waves in the ionosphere.

621.396.11 : 551.510.535 **2897**

Gyro Interaction of Radio Waves.—L. G. H. Huxley, H. G. Foster & C. C. Newton. (*Nature, Lond.*, 1st March 1947, Vol. 159, No. 4035, pp. 300–301.) An outline of preliminary experimental data and discussion of results. For the tests, the modulation introduced by two suitably situated transmitters operating near the gyro-frequency, on 200-kc/s signals from Droitwich, was observed. Certain of the main features of Bailey's theory were confirmed quantitatively. The practical implications of the results are mentioned. For Bailey's theory see 1934 Abstracts, p. 606, and 840 of 1937.

621.396.11 : 551.510.535 **2898**

Predicting Amateur "Conditions".—N. A. Atwood. (*QST*, April 1947, Vol. 31, No. 4, pp. 21–25, 120.) A new method for quick determination of the best 'working area' from a given position using Central Radio Propagation Laboratory maximum usable frequency charts.

621.396.11.029.62 : 551.510.535 **2899**

Six-Metre Transatlantic Signals.—R. Naismith. (*Wireless World*, May 1947, Vol. 53, No. 5, p. 186.) The recent reception of these signals coincided with a high value of vertical-incidence critical frequency for region F_2 and a theoretical maximum frequency for transmission by the tangential ray of 48.9 Mc/s. Alternative modes of propagation are considered and rejected. This therefore is the first proved case of highly efficient transmission over 6 000 km involving only one reflection.

621.396.11.029.64 **2900**

Wave Theoretical Interpretation of Propagation of 10-Centimeter and 3-Centimeter Waves in Low-Level Ocean Ducts.—C. L. Pekeris. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, pp. 453–462.) An analysis of results obtained in the West Indies. "Below the horizon, the 10-centimeter wave was found to propagate by the first normal mode with a theoretical decrement of 1 decibel per nautical mile, as against an observed value of about 0.8 decibel per nautical mile in the first 80 miles from transmitter. Theory verified the observed constancy of decrement with height for this wavelength. Beyond 80 miles the observed rate of attenuation dropped to a low value of 0.2 decibel per nautical mile. This change of slope in the intensity curve is probably due to the emergence of scattered radiation after the direct diffracted beam had been depleted." With the exception of one point there is quantitative agreement between the observed and theoretical distribution of intensity with height for the 10 cm wave.

"The 3-centimeter wave was found to propagate below the horizon by the first and second modes, with theoretical decrements of zero and 0.5 decibel per nautical mile, respectively. The latter agrees with the observed values at high elevations, but near the surface, where theoretically attenuation should be negligible, the observed rate of attenuation exceeds the theoretical value by about 0.3 decibel per nautical mile. This is probably due to attenuation by scattering from horizontal inhomogeneities in the distribution of refractive index, and from the rough surface. Theory verifies the observed increase of decrement and decrease of intensity with height above about 10 feet for the 3-centimeter band."

621.396.4.029.62 **2901**

A Multi-Channel V.H.F. Radio Communications System.—Knox & Brereton. (*See* 2927.)

621.396.41.029.64 **2902**

On the Calculation of Multiplex Radio-Telephone Links on Ultra-Short Waves.—H. Chireix. (*Ann. Radioélect.*, Jan. 1947, Vol. 2, No. 7, pp. 3–12.) Reprint of 1559 of May.

621.396.812 : 523.323 **2903**

Effect of the Moon on Radio Wave Propagation.—(*Nature, Lond.*, 22nd March 1947, Vol. 159, No. 4038, p. 396.) P. A. de G. Howell claims to have observed during 1938–39 and 1944–45 a correlation between long-distance transmission conditions and the moon's phase. High signal level, low noise and little fading are associated with full moon and the reverse with new moon.

621.396.812 : 621.396.96 **2904**

A Theory of the Performance of Radar on Ship Targets.—M. V. Wilkes & J. A. Ramsay. (*Proc. Camb. phil. Soc.*, April 1947, Vol. 43, Part 2, pp. 220–231.) An expression is derived for the power returned to the receiver of a radar installation from a ship surface. Conditions of superrefraction are not considered; under normal conditions, provided a suitable value of effective earth radius is taken, good agreement with experimental results on the variation of signal strength with range is obtained. Measurements using a balloon-borne metallized sphere are also described.

621.396.812.029.64 : 551.510.52 **2905**

Radar Reflections from the Lower Atmosphere.—Friis. (*See* 2769.)

621.396.11 : 551.5 **2906**

Meteorological Factors in Radio-Wave Propagation. [Book Notice]—Physical Society, London, 325 pp., 24s. Report of a Conference held on 8th April 1946 by the Physical Society and the Royal Meteorological Society. Individual papers will be abstracted in due course.

RECEPTION

1.396.619.11/.13 **2907**

Laboratory Tests of Weak Signal Narrow-Band M.—O. G. Villard, Jr. (*CQ*, April 1947, Vol. 3, . 4, pp. 21–26..72.) When an a.m. receiver used for the reception of a.m. transmissions d also of f.m. transmissions by distuning, narrow-nd f.m. gives better results for the same carrier wer on strong signals, but poorer results on weak nals not much above the background noise level.

.396.619.13.029.62 : 621.396.933 **2908**

Comparing F.M. with A.M. for Aircraft Com-nications.—(*Tele-Tech*, April 1947, Vol. 6, . 4, pp. 52–56..111.) "For military [v.h.f.] erations, [narrow-band] f.m. has capabilities for ater range and noise suppression, is less critical to tuning, less susceptible to jamming."

.396.621 + 621.396.69 **2909**

Machine for Receiver Manufacture.—(*Toute la dio*, May 1947, Vol. 14, No. 115, pp. 163–164.) hort account of the equipment described in 1013 une (Sargrove).

396.621 **2910**

igh-Fidelity Receiver.—R. Gondry. (*Toute la io*, May 1947, Vol. 14, No. 115, pp. 136–143.) detailed description, with complete circuit ram and performance curves, of a receiver with able selectivity, low and high tone control, stable expansion, a switch for speech or music a high-power output amplifier.

396.621 : 621.396.61 **2911**

echnical Characteristics of Transmitters.—E. erg. (*Toute la Radio*, May 1947, Vol. 14, 115, pp. 132–134.) Stresses the importance, in lesign of receivers, of detailed knowledge of the uency and modulation characteristics, intensity s, etc., of the transmissions to be received.

96.621.029.62 : 621.317.1 **2912**

e Testing Procedure for F.M. V.H.F. Receivers. M. Fanker & R. A. Ratcliffe. (*Proc. Instn Engrs, Aust.*, March 1947, Vol. 8, No. 3, –12. Discussion, pp. 12–16.) The funda-al operating principles are discussed when they from those of a.m. circuits. The alignment dure and methods for measuring the receiver cteristics are described and values given for al equipment.

96.621.076.2.029.62/.63 **2913**

y High Precision Tunable Receiver for V.H.F. Y. White. (*Tele-Tech*, April 1947, Vol. 6, , pp. 48–51..107.) Description of a receiver permeability tuning and plug-in tank circuits e between 60 and 600 Mc/s.

6.621.078 **2914**

omatic Controls in Modern Receivers.—F. . (*Toute la Radio*, May 1947, Vol. 14, 15, pp. 150–153.) A concise account of ed a.v.c., the Lamb system for parasitic ession and a.f.c. (automatic frequency con- The last is strongly recommended.

6.722 : 534.32 **2915**

ortion and Acoustic Preferences.—Moir. (*See*

621.396.82 : 551.57 : 629.135
621.319.74 : 551.57 : 629.135 **2916**

Electrostatic Ills and Cures of Aircraft : Parts 1 & 2.—R. Beach. (*Elect. Engng, N.Y.*, April & May 1947, Vol. 66, Nos. 4 & 5, pp. 325–334 & 453–462.) In part 1, "the process by which electrification is accumulated [by aircraft in flight] and the mechanism by which radio interference is produced are described." In part 2 various methods for dissipating static charges on aircraft are given. Experimental results show the effectiveness of metallic bristles, with chemically etched points, for suppressing static interference.

621.396.822 : 621.396.615.17 **2917**

Noise Signal Generator.—Dolphin. (*See* 2859.)

621.396.822 : 621.396.621.53 **2918**

Noise-Figure Reduction in Mixer Stages.—M. J. O. Strutt. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, p. 496.) Corrections to 1573 of May.

621.396.822 : 621.396.645 **2919**

Noise Factor: Part 3.—L. A. Moxon. (*Wireless World*, May 1947, Vol. 53, No. 5, pp. 171–176.) Discussion of: noise sources in an r.f. amplifier and the circuit quantities which determine their effect; the meaning of equivalent noise resistance as applied to valve shot noise; formulae for the noise factor; and the use of grounded-grid and neutralized triodes as the first valves in v.h.f. receivers. For parts 1 & 2 see 804 of March and 1196 of April.

621.396.822.029.63 : 523.78"1946.11.23" **2920**

Micro-Wave Solar Noise Observations during the Partial Eclipse of November 23, 1946.—Covington. (*See* 2761.)

621.396.822.08 : 621.396.645 **2921**

Linearity Range of Noise-Measuring Amplifiers.—Bell. (*See* 2718.)

621.396.828 **2922**

The Suppression of Radio Interference from Electrical Appliances.—S. F. Pearce. (*Beama J.*, Feb. 1947, Vol. 54, No. 116, pp. 40–47.) A description of a number of circuits for efficient suppression in a wide range of appliances. The components requiring careful design are the capacitor for earthed appliances and the line inductor for those which are not earthed. For satisfactory performance at frequencies above 30 Mc/s a 'bushing type' capacitor is necessary in which the current-carrying conductor passes through the body of the capacitor. Design particulars are given for filters having an insertion loss of about 80 db in the range 5–100 Mc/s, with a formula for calculating the lowest frequency at which the required attenuation is obtained.

STATIONS AND COMMUNICATION SYSTEMS

621.394.14 **2923**

Table of Q-Code.—(*Radio, Moscow*, June 1946, No. 3, p. 51. In Russian.) With meanings and Russian equivalents.

621.395.44.029.6 **2924**

2 000 Telegrams per Minute by Microwave.—J. Z. Millar. (*Tele-Tech*, March 1947, Vol. 6, No. 3, pp. 36–40.) A description of the equipment of the New York–Philadelphia link. See also 1578 of May.

621.396(675)"1939/1945" **2925**
Development of Telecommunications in the Belgian Congo during the War.—J. G. Jonlet. (*Bull. sci. Ass. Inst. électrotechn. Montefiore*, Feb. 1947, Vol. 60, No. 2, pp. 43–63.) Historical, with some details of the 50-kW short-wave transmitter put into service in 1943. See also 870 of March.

621.396.1 : 621.396.96 **2926**
Radar Allocations.—Markus. (*See* 2788.)

621.396.4.029.62 **2927**
A Multi-Channel V.H.F. Radio Communications System.—J. B. Knox & C. H. Brereton. (*RCA Rev.*, June 1946, Vol. 7, No. 2, pp. 179–198.) A description of the installation of a f.m. network (42–50 Mc/s) on the Canadian Pacific coast. The results of propagation tests are discussed and land profiles of test and operative links are given. The aerial systems and equipment are briefly described and a statistical analysis of recorded field strengths for various stations is shown graphically.

621.396.41.029.64 **2928**
On the Calculation of Multiplex Radio-Telephone Links on Ultra-Short Waves.—Chireix. (*See* 2902.)

621.396.6 : 551.510.535 **2929**
Ionosphere Equipment for Field Use.—G. H. Musselman. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 112–116.) The requirements of a field equipment are listed and modern pulsed measurement systems briefly described. Details are given of a simplified technique with an automatic motor-tuned receiver and a variable-frequency (1.5–4.0 Mc/s) transmitter half a mile distant. Recording is automatic.

621.396.61[/.62].029.64 **2930**
Dishing Out the Milliwatts on 10 kMc/s.—Correction to 1931 of June. The last phrase should read "using a Hallicrafter S-29 portable receiver as i.f./a.f. amplifier."

621.396.619.13 : 621.397.5 (94) **2931**
Frequency Modulation and Television.—N. S. Gilmour. (*Proc. Instn Radio Engrs, Aust.*, July 1944, Vol. 5, No. 5, pp. 3–8.) Discusses modern developments with particular reference to post-war application in Australia.

621.396.619.13.029.62 : 621.396.933 **2932**
Comparing F.M. with A.M. for Aircraft Communications.— (*See* 2908.)

621.396.619.16 **2933**
Pulse Modulation and Demodulation Theory.—M. M. Levy. (*J. Brit. Instn Radio Engrs*, March/April 1947, Vol. 7, No. 2, pp. 64–83.) Modulation is accomplished by shifting in time the position of a periodic train of pulses by an amount proportional to the modulating signal; in demodulation the position of one edge of each pulse is moved in time in synchronism with the modulated pulse, so giving a train of variable-width pulses which after detection yield the modulating signal. The nature of the distortion produced by these processes is studied and it is shown that a distortionless pulse communication system can be evolved by following certain simple rules.

621.396.65 **2934**
Radio Relays for Telegraphy.—F. B. Bramhall. (*Telegr. Teleph. Age*, April 1947, Vol. 65, No. 4, pp. 10, 12..32.) Beamed microwaves of frequencies about 3 000 Mc/s used for communication in the U.S.A. See also 876 of March and 1578 of May, U.D.C. of which should more properly be 621.396.65.

621.396.65 **2935**
Development of Radio Relay Systems.—C. W. Hansell. (*RCA Rev.*, Sept. 1946, Vol. 7, No. 3, pp. 367–384.) Survey of development and requirements. Suggested signal to noise ratios: for printer telegraph, 18 db; for on-off-keyed printer telegraph, 21 db; for ordinary telephone, 40 db; for broadcast, facsimile and television, 50 db; and for high quality music, 60 db. The bandwidth occupied by a phase modulated multichannel relay system is $2B + 2Bd/\sqrt{3}$, where B is the modulation frequency band and d is the peak phase deviation.

621.396.65.029.62 : 621.396.93 **2936**
Frequency Modulation Mobile Radiotelephone Services.—H. B. Martin. (*RCA Rev.*, June 1946, Vol. 7, No. 2, pp. 240–252.) A discussion of the proposed use of frequencies in the ranges 30–44 Mc/s and 152–162 Mc/s for common-carrier mobile radiotelephone communication for motor vehicles and surface vessels.

621.396.712.029.58(945) **2937**
Melbourne Division visits "Radio Australia".—(*Proc. Instn Radio Engrs, Aust.*, Feb. 1947, Vol. 8, No. 2, pp. 22–23.) A brief description of the lay-out of the h.f. broadcasting station at Shepparton, Victoria, Australia. See also 2672 above.

621.396.712(489) **2938**
Broadcasting Equipment.—(*Overseas Engr*, March 1947, Vol. 20, No. 234, p. 279.) A short account of the new equipment and studio arrangements at Radio House, Copenhagen.

621.396.712.3(944) **2939**
Broadcasting Studio Equipment.—L. N. Schultz. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1944, Vol. 5, No. 6, pp. 3–17.) Specification of the complete equipment for station 2GB, Sydney.

621.396.73 **2940**
Emergency Broadcast Pickup Techniques.—G. Riley. (*Electronics*, May 1947, Vol. 20, No. 5, pp. 108–111.) Methods and equipment used for emergency outdoor broadcasts by radio station WOR, New York.

621.396.828.029.56/62 **2941**
The Staggering Band Theorem.—L. E. Rapp. (*QST*, April 1947, Vol. 31, No. 4, pp. 60–61, 136.) A plan to eliminate interference in the amateur frequency bands by devoting particular bands to c.w. transmissions and 'phone transmissions during alternate 24-hour periods.

621.396.931 **2942**
The Development of a Radio Communication Network for the South African Railways.—G. D. Walker. (*Trans. S. Afr. Inst. elect. Engrs*, Dec. 1946, Vol. 37, No. 12, pp. 283–305. Discussion, pp. 305–307.) Sections 1, 2, and 3 give respectively details of the extent of the radio network, the requirements of the service, and the equipment now in use. Eighteen spot frequencies within the band

4–14 Mc/s are used and telephonic as well as telegraphic facilities are provided.

Section 4 deals with aerial design; a stack of three aerials supported between a single pair of towers is used, each aerial consisting of a 2-fold half-wave dipole.

Section 5 deals with the arrangements for matching the aerial to the 600-Ω feeder at more than one frequency; a novel form of compound stub is described.

Section 6 describes some pulse transmissions under conditions of oblique incidence on the ionospheric layers.

SUBSIDIARY APPARATUS

21.313.2 **2943**

The "Electrotor".—(*Elect. Rev., Lond.*, 25th April 947, Vol. 140, No. 3622, pp. 663–664.) Miniature ow voltage (1.5–6 V) d.c. motor of novel design; ing-shaped permanent magnet stator, gap-ring vound rotor with brushes bearing directly upon lared edges of winding. Manufactured in several zes, the smallest weighing 1 gm and being ½ cm . diameter and length, speed 7 000 r.p.m. and oltage 1.5.

1.314.12 : 621.394/.396].66 **2944**

The Amplidyne.—E. C. Barwick. (*Elect. Times*, th April & 1st May 1947, Vol. 111, Nos. 2894 & 95, pp. 449–453 & 485–488.) A description of quick response d.c. generator requiring an excep- nally low field power for excitation. Some pical control circuits are described in part 1. rt 2 describes the application of amplidyne ntrol to such equipment as winding gear, cable ing machinery, and synchronous motors. See o 3765 of 1946.

.314.653 **2945**

Characteristics of Resistance Ignitors.—D. E. rshall & W. W. Rigrod. (*Electronics*, May 1947, l. 20, No. 5, pp. 122–126.) The magnitude of iations of current, voltage and firing time with rating conditions are presented as a guide to igners.

.316.54 **2946**

undamental Properties of the Vacuum Switch.— Koller. (*Trans. Amer. Inst. elect. Engrs*, Aug./ t. 1946, Vol. 65, Nos. 8/9, pp.597–604. Dis- sion, *ibid.*, December Supplement 1946, Vol. 65, 1141–1142.) Summary noted in 2021 of 1946.

316.728 **2947**

esign of Electronically Regulated Power Supplies. . A. Penners & W. Davis. (*Radio, N.Y.*, Feb./ ch 1947, Vol. 31, No. 2, pp. 9–15.) A compre- sive theoretical discussion presenting complete gn data.

352.8 **2948**

vel Batteries.—(*Elect. Rev., Lond.*, 11th April , Vol. 140, No. 3620, p. 571.) Development new type of battery, based on the electro- ical catalysis of oxygen and hydrogen gases, w proceeding on behalf of the British Electrical Allied Industries Research Association at bridge University. A small type of silver– chloride–magnesium dry cell manufactured g the war by the Burgess Battery Co., Antioch, ., delivers a large output at low voltage for rt time. Such a cell 1⅜ inch in diameter, and 3⅝ inches long gave 100 A at a peak of 1.4 V for 1½ minutes when activated by water. For a full account of these cells, see Reprint 90–33 of the Electrochemical Society of America. See also 901 of March, where U.D.C. should read as above.

621.385.832.087.5 **2949**

Recording Oscilloscope Images.—(*Tele-Tech*, April 1947, Vol. 6, No. 4, pp. 45–46.) A beam splitter in the camera for radar oscilloscopes reflects blue light to the camera lens and transmits orange-yellow light for the operator's vision, thus permitting simultaneous inspection and photography.

621.398 **2950**

Magslip Transmission.—(*Engineer, Lond.*, 11th April 1947, Vol. 183, No. 4759, pp. 317–319.) A brief outline of the principles of Magslip transmission and its application to gunnery work. The rapid development of Magslip production during the war is described and the construction of a typical transmitter unit is shown. The rigorous tests necessary to maintain the high standard of mechanical and electrical precision are stressed. See also 2585 of August.

TELEVISION AND PHOTOTELEGRAPHY

621.397 : 38 **2951**

Commercial Applications for Picture Telegraphy.—R. C. Walker. (*Electronic Engng*, Feb. 1947, Vol. 19, No. 228, pp. 44–45.) An account of methods of facsimile transmission using 'Teledeltos', a dry recording paper needing no processing. The system is used for telegraphy and transmission of drawings.

621.397 : 621.357.087 **2952**

Electro-Chemical Recording.—C. P. Fagan. (*Marconi Rev.*, Oct./Dec. 1946, Vol. 9, No. 83, pp. 146–150.) Methods used for facsimile work etc. are briefly described, with special attention to azo-dye recording.

621.397.5 : 6 **2953**

Television System for Industrial Applications.—(*Electronics*, May 1947, Vol. 20, No. 5, pp. 138.. 156.) A television system for visual inspection of operations on a factory production line from a remote point.

621.397.5 : 621.315.213.12 **2954**

Development of an Ultra Low Loss Transmission Line for Television.—Johnson. (*See* 2667.)

621.397.5 : 621.396.67 **2955**

Television Antennas for Apartments.—(*Electronics*, May 1947, Vol. 20, No. 5, pp. 96–102.) The possibility of installing master aerials feeding many receivers is discussed. Existing systems in the U.S.A. for broadcast and short-wave signal reception are described and the difficulties to be overcome in an u.h.f. system are stated. The aerials would probably consist of separate dipoles and reflectors for each local television station, tuned and orientated for optimum reception, and each channel would require a wide-band booster amplifier. Typical proposed designs, both with and without amplifiers, are described and the requirements of the amplifiers and methods of matching to the customer's feeder-line are discussed.

621.397.5(94) : 621.396.619.13 **2956**

Frequency Modulation and Television.—Gilmour. (*See* 2931.)

621.397.6 2957
A New Type of the Mosaic for the Television Pick Up Tubes.—G. Braude. (*J. Phys., U.S.S.R.*, 1945, Vol. 9, No. 4, pp. 348–350.) The mosaic covers both sides of a thin dielectric plate which has a certain amount of leakage between the two faces.

621.397.6 2958
An Experimental Color Television System.—R. D. Kell, G. L. Fredendall, A. C. Schroeder & R. C. Webb. (*RCA Rev.*, June 1946, Vol. 7, No. 2, pp. 141–154.) A description of a demonstration apparatus. Three-colour scanning in sequence is obtained by rotating colour filters synchronized to the frequency of the mains. Three-dimensional colour is obtained by a stereo-attachment for the camera used in conjunction with polarizing material on the rotating colour filters and polarizing spectacles worn by the viewer. The sound channel is transmitted during a portion of the horizontal blanking period.

621.397.6 : 621.383.8 2959
Mimo-Miniature Image Orthicon.—P. K. Weimer, H. B. Law & S. V. Forgue. (*RCA Rev.*, Sept. 1946, Vol. 7, No. 3, pp. 358–366.) For use in airborne television equipment; overall length 9 inches and diameter 1½ inches.

621.397.6 : 621.398 2960
Naval Airborne Television Reconnaissance System.—R. E. Shelby, F. J. Somers & L. R. Moffett. (*RCA Rev.*, Sept. 1946, Vol. 7, No. 3, pp. 303–337.) High-fidelity long-range airborne television reconnaissance system developed by U.S. Navy Department; 20 frames per second, 40 fields per second, 567 lines per frame interlaced and 5 Mc/s bandwidth are used. With peak power of 1 400 W, maximum plane-to-ground range was 200 miles. Satisfactory definition was obtained at altitudes from 5 000 to 10 000 ft.

621.397.6 : 621.398 2961
Miniature Airborne Television Equipment.—R. D. Kell & G. C. Sziklai. (*RCA Rev.*, Sept. 1946, Vol. 7, No. 3, pp. 338–357.) "A developmental television camera, designed especially for airborne applications and using the image orthicon, is described. This camera is part of a complete airborne television transmitter system weighing 50 pounds. The transmitter has a power output of eight watts in the 260-to-380 megacycle range. Experimental results in guiding a medium-angle bomb with the aid of the miniature equipment are given."

621.397.6 : 621.398 : 629.13 2962
Flying Torpedo with an Electric Eye.—V. K. Zworykin. (*RCA Rev.*, Sept. 1946, Vol. 7, No. 3, pp. 293–302.) Memorandum prepared as early as 1934 giving suggestion for controlling guided missiles by television.

621.397.62 2963
Philco Projection TV Receiver.—(*Tele-Tech*, March 1947, Vol. 6, No. 3, pp. 41, 127.) An instrument using a modified Schmidt optical system with a 4-inch 20-kV projection tube to give a 15 inch by 20 inch picture, of great brightness and contrast.

621.397.62 : 621.396.828 2964
On the Reduction of Noise [souffle] **in Certain Television Analysers using Slow Electrons.**—R. Barthélemy. (*C. R. Acad. Sci., Paris*, 31st March 1947, Vol. 224, No. 13, pp. 977–978.) Certain American receivers make use of electron multipliers in the analysers. The modulated fraction of the beam entering the multiplier is very small, about 5–10% of the mean intensity. Improved performance can be achieved by filtration of the beam, either by deviation or by a suitably polarized grid, so that only the useful part of the current passes forward into the multiplier.

621.397.74 : 621.315.212 2965
The Provision in London of Television Channels for the B.B.C.—Mitchell. (*See* 2666.)

621.397.62 2966
Television Receiving Equipment. [Book Review]—W. T. Cocking. Iliffe & Sons, 2nd edn, 354 pp., 12s. 6d. (*J. Brit. Instn Radio Engrs*, March/April 1947, Vol. 7, No. 2, p. 63.) Covers many of the improvements in technique which have been effected in late years and is recommended for the use of students.

TRANSMISSION

621.396.61 : 621.396.621 2967
Technical Characteristics of Transmitters.—Aisberg. (*See* 2911.)

621.396.61.029.62 2968
A Complete 10-Meter Mobile Station.—C. T. Haist. (*CQ*, April 1947, Vol. 3, No. 4, pp. 15–19..76.) Circuits and description of 50-W equipment operated from a 12-V car battery. An 829B h.f. transmitting valve is used in the power amplifier.

VALVES AND THERMIONICS

537.291 2969
Exchange of Energy between an Electron Beam and an Electromagnetic Field of Feeble Intensity.—P. Guénard. (*C. R. Acad. Sci., Paris*, 24th March 1947, Vol. 224, No. 12, pp. 898–900.) An expression is derived for the ratio of the mean power, given up by the beam while traversing the field, to the beam power where it enters the field, for the particular case of small signals.

621.38/.39].029.64 2970
Microwave Electronics.—Slater. (*See* 2668.)

621.383 : 535.215.2 2971
Fatigue of Ag-Cs_2O, Ag-Cs Photoelectric Surfaces.—S. Pakswer. (*J. appl. Phys.*, Feb. 1947, Vol. 18, No. 2, pp. 203–206.) Description of fatigue phenomena for red and blue light. Theory suggests a change in selective absorption caused by polarization of the Cs atoms.

621.383.4 2972
High-Sensitivity Photoconductive Cell.—C. W. Hewlett. (*Gen. elect. Rev.*, April 1947, Vol. 50, No. 4, pp. 22–25.) Construction, performance and applications of a thallous sulphide semiconductor cell developed by G.E.C. (U.S.A.).

621.385 : 666.1 2973
Glass in the Radio Industry.—Violet, Danzin & Commin. (*See* 2819.)

521.385.029.63/.64 2974

Tentative Theory of the Travelling-Wave Valve. —J. Bernier. (*Ann. Radioélect.*, Jan. 1947, Vol. 2, No. 7, pp. 87–101.) The travelling-wave valve is onsidered as made up of a transmission line (or waveguide) of low phase propagation velocity, losed at each end by its characteristic impedance, vith uniformly distributed sources of field, these ources being due to the effect of the electron beam. The gain of such valves is calculated ; it increases vith the current and the length of the line. In eneral the bandwidth decreases as the gain in- reases. The travelling-wave valve is somewhat nalogous to a cascade of triodes coupled by Lecher nes. Modifications of the theory are indicated hen the transmission line has many modes of ropagation and the case is discussed where the line onsists of a waveguide filled with a dielectric of igh refractive index.

21.385.032.7 + 621.32.032.7] : 001.4 2975

Nomenclature System for Glass Bulbs.—A. Brann. *Electronics*, May 1947, Vol. 20, No. 5, pp. 184..188.) merican system for bulbs used in electric lamp and lve manufacture.

1.385.1 + 621.396.694 2976

Tube Registry.—(*Electronics*, May 1947, Vol. 20, p. 5, pp. 254..259.) Summary of valve infor- ation furnished by the R.M.A. Data Bureau. ypes listed are :

5549. Forced-air-cooled triode. Directly heated. .6 V. Anode dissipation 4 kW.

5559 (revised). Indirectly heated, mercury yratron triode. Ionization time 10 μs. Deion- tion time 1 ms.

5557. Same as 5559 (revised) except directly ated.

For 6C23, 8C22 and other valves not listed ove, see 2288 of July.

.385.1.012(4) 2977

Radio Valves : Western European Valves.— I. Drozdoff. (*Radio, Moscow*, June 1946, No. 3, 52–61. In Russian.) Definitions of continental e, and diagrams of valve bases for the E-11 U-11 series.

.385.1.012(4) 2978

Radio Valves : Mains Valves in the [continental] **habetic Series.**—K. I. Drozdoff. (*Radio, scow*, July/Aug. & Sept./Oct. 1946, Nos. & 6/7, pp. 51–60 & 53–62. In Russian.) les of data, with possible equivalents.

385.1.032.216 2979

xide Cathodes. Their Experimental, Theoretical Technical Development.—O. Weinreich. (*Rev. Elect.*, Feb. 1947, Vol. 56, No. 2, pp. 75–90.) ccount of progress from 1904 to 1944. Several ries of electronic emission processes are outlined. elopments associated with the construction agnetrons are described. Experimental studies e mechanism of emission by means of X rays, ron diffraction and pulse voltages are discussed. e technique opens up a wide field for new stigations which may lead to an adequate ry.

85.1.072.2 2980

aracteristics of Certain Voltage-Regulator s.—G. M. Kirkpatrick. (*Proc. Inst. Radio Engrs, W. & E.*, May 1947, Vol. 35, No. 5, pp. 485–489.) Characteristics and stability of a number of valves of types VR75, VR105 and VR150 are examined and an equivalent circuit determined. The results are of value when VR valves are used to provide reference potentials in electronic stabilizers.

621.385.3 : 621.396.813 2981

The Reduction of Microphonics in Triodes.— A. H. Waynick. (*J. appl. Phys.*, Feb. 1947, Vol. 18, No. 2, pp. 239–245.) An analysis of the effect of grid displacement on the anode current of a planar triode.

621.385.3.029.63.015.33 2982

Development of Pulse Triodes and Circuit to give One Megawatt at 600 Megacycles.—R. R. Law, D. G. Burnside, R. P. Stone & W. B. Whalley. (*RCA Rev.*, June 1946, Vol. 7, No. 2, pp. 253–264.) A description of the development of the air-cooled A-2231 valve and its use in a push-pull oscillator circuit tuning over the range 560–640 Mc/s.

621.385.832 : 621.396.96 2983

War-Time Developments in Cathode-Ray Tubes for Radar.—L. C. Jesty, H. Moss & R. Puleston. (*J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 149–166.) A review of the war-time history from the design point of view. For technical reasons, most of the tubes used for radar were electrostatic, little use being made of magnetic deflection. Progress in the design of tube envelopes, electron guns, bases, screens and deflection systems is discussed, with special reference to afterglow screens, rigidity and uniformity of construction, ability to withstand shock and vibration, and semi-mass-production methods. Testing procedures and tubes for particular applications are described, with illustrations of intensity-modulated and deflection-modulated displays and a comprehensive list of tube types.

621.385.832 : 621.396.96 2984

A Survey of Cathode-Ray-Tube Problems in Service Applications, with Special Reference to Radar.—G. Bradfield, J. G. Bartlett & D. S. Watson. (*J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 128–148.) R.A.F., Army and R.N. problems are considered separately. The special requirements associated with radar displays for air interception, air navigation, precision fire-control and the plan position indication of ships, aircraft, towns and shell splashes are reviewed. The need for large projected displays and for the dark-trace tube is discussed, with photography and visibility problems, which have an important bearing upon the choice of tube for a particular purpose. A number of practical applications are described and illustrated.

621.386.032.22 2985

Operations in the Production of Electronic Tube Components.—(*Machinery, N.Y.*, Feb. 1947, Vol. 53, No. 6, pp. 160–164.) Production methods are described for the rotating anode assembly for certain X-ray tubes.

621.396.615.141.2 2986

Theory of the Magnetron as Microwave Generator. —F. Lüdi. (*Helv. phys. Acta*, 20th Feb. 1946, Vol. 19, No. 1, pp. 1–20. In German.) For previous work see 3338 of 1943, 3531 of 1945 and 2354 of August. This article gives theory and experimental results for the multi-segment type of magnetron only.

621.396.615.141.2 **2987**
A Tunable Squirrel-Cage Magnetron — The Donutron.—F. H. Crawford & M. D. Hare. (*Proc. Inst. Radio Engrs, W. & E.*, April 1947, Vol. 35, No. 4, pp. 361–369.) The donutron is an all-metal multi-segment magnetron with a single resonant cavity. "It is tuned by the relative axial displacement of alternate anode segments, through flexure of one wall of the cavity in which the anode structure is supported." The best of 60 models tested can be tuned over a 1.5 to 1 frequency range (in the 6–12 cm waveband) with a single value of voltage and magnetic field. An efficiency of 40–50% was obtained, with a power output of about 50 W which was constant to 3 db over the tuning range. The various possible modes of operation and methods of suppressing or enhancing them are described.

621.396.615.141.2 **2988**
Technical Problems in the Manufacture of Cavity Magnetrons.—G. H. Bézy. (*Rev. gén. Élect.*, Feb. 1947, Vol. 56, No. 2, pp. 68–71.) Discusses the conditions which should be satisfied by anode, cathode and coupling system and describes methods of overcoming certain difficulties in their construction and final assembly.

621.396.615.141.2 **2989**
Space Charge Frequency Dependence of Magnetron Cavity.—W. E. Lamb, Jr, & M. Phillips. (*J. appl. Phys.*, Feb. 1947, Vol. 18, No. 2, pp. 230–238.) A theoretical investigation of the effect produced on the resonant frequencies of a magnetron cavity by the presence of a thin layer of charge surrounding the cathode.

621.396.615.142 **2990**
On the Conversion Efficiency of Velocity-Modulation Tubes of the Reflex Type.—J. Bernier. (*Ann. Radioélect.*, Oct. 1946, Vol. 1, No. 6, pp. 359–382.) For satisfactory efficiency the h.f. voltage should neither be so low that the electrons are not sufficiently checked on their return, nor so high that too much energy is required to control the forward beam. A quantitative study of the effects is made assuming that space-charge effects are negligible, electron trajectories rectilinear and the h.f. field uniform and well defined, though of finite magnitude. The conversion efficiency is calculated (*a*) for different values of the h.f. field supposing all electrons are reflected by the mirror and (*b*) when only half the electrons are reflected by a mirror at the potential of the cathode and the h.f. field is infinitely narrow.

621.396.615.142.2 **2991**
Practical Limitations of the Power and Efficiency of Two-Cavity Klystrons.—P. Guénard. (*Ann. Radioélect.*, Jan. 1947, Vol. 2, No. 7, pp. 13–23.) A discussion with certain simplifying assumptions. For this type of valve the efficiency decreases rapidly with increase of frequency from about 30% for the longer waves to zero for millimetre wavelengths. The h.f. power can exceed 1 kW at wavelengths above 10 cm, but decreases rapidly with increase of frequency and is only a few watts for a wavelength of 3 cm.

621.396.615.142.2 **2992**
Practical Limitations of the Power and Efficiency of Two-Cavity Klystrons.—P. Guénard. (*Onde élect.*, March 1947, Vol. 27, No. 240, pp. 94–103.) See 2991 above. The present paper gives a fuller discussion and includes appendices on (*a*) the efficiency of valves without grids and (*b*) the effects of space charge on longitudinal debunching.

621.396.615.142.2 **2993**
The Maximum Efficiency of Reflex-Klystron Oscillators.—E. G. Linder & R. L. Sproull. (*Proc. Inst. Radio Engrs, W. & E.*, March 1947, Vol. 35, No. 3, pp. 241–248.) "The theory of reflex-klystron oscillators is given in detail. It includes a discussion of relations in a loaded oscillator. It is shown that maximum efficiency for small amplitudes is given by $\eta_0 = 0.169 M^2 i_1 / G_c V_0$, where M is the coefficient of modulation of the gap, i_1 is the effective current, G_c is the shunt conductance of the unloaded resonator, and V_0 is the beam voltage. Possibilities of increasing efficiency are considered, including effects of grid transmission on effective current and on space charge, and effects of multiple electron transits."

621.396.645 : 621.396.822 **2994**
Noise Factor : Part 3.—Moxon. (*See* 2919.)

MISCELLANEOUS

001.4 : [621.32.032.7 + 621.385.032.7 **2995**
Nomenclature System for Glass Bulbs.—Brann. (*See* 2975.)

62"1946" **2996**
Progress in Engineering Knowledge during 1946.—P. L. Alger, J. Stokley, F. H. Faust, E. L. Robinson, J. L. Tugman, W. W. Kuyper & W. D. Haylon. (*Gen. elect. Rev.*, March 1947, Vol. 50, No. 3, pp. 12–55.) A survey of developments in materials, techniques and design and application engineering, with an extensive bibliography.

620.1.05 **2997**
Ingenious New Testing Machine.—(*Overseas Engr*, April/May 1947, Vol. 20, No. 235, p. 320.) For tensile, compression, beam, shear and bending tests and also suitable for many precision pressing operations. Maximum load capacity 25 tons.

621.396 de Forest **2998**
Lee de Forest.—(*Radio Craft*, Jan. 1947, Vol. 18, No. 4, pp. 17–57..130.) A collection of papers describing the work of de Forest, with appreciations from prominent scientists and radio engineers, specially written to mark the 40th anniversary of his invention of the audion.

621.396 Tesla **2999**
Nikola Tesla (1856-1943).—F. Bedeau. (*Onde élect.*, Feb. 1947, Vol. 27, No. 239, p. 75.) A short account of his work on rotating fields and h.f. alternators and oscillators.

621.396.621(100.2) **3000**
Density of Radio Receivers throughout World.—(*Tele-Tech*, March 1947, Vol. 6, No. 3, p. 92.) A table giving the number of receiving sets per 100 population in 85 countries. See also 1588 of May.