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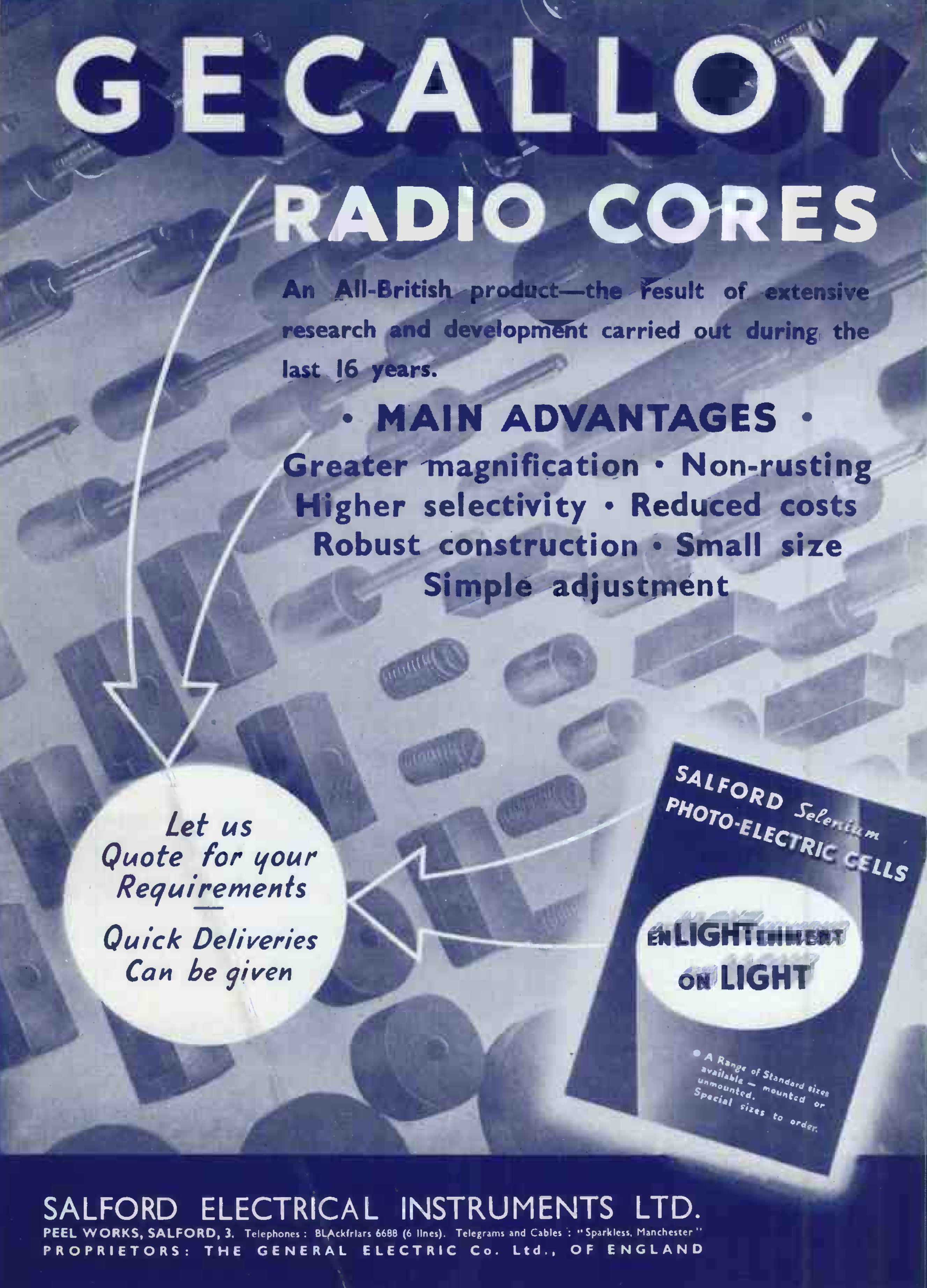
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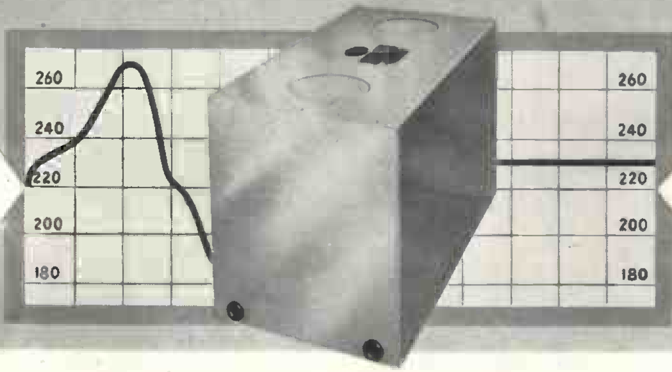

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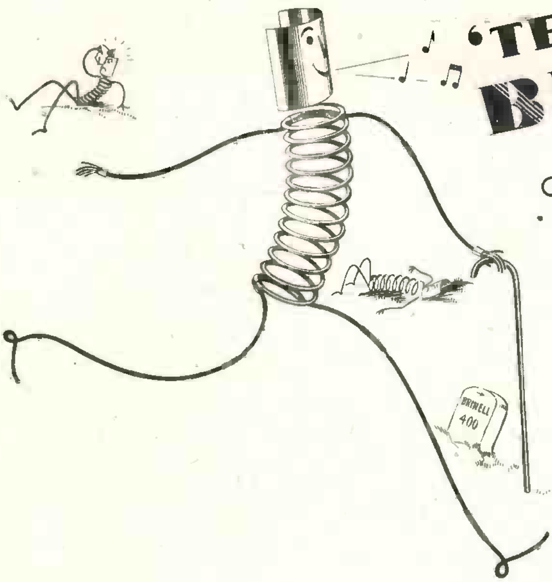

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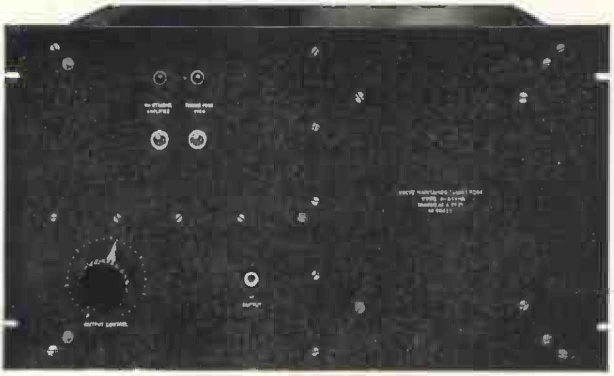

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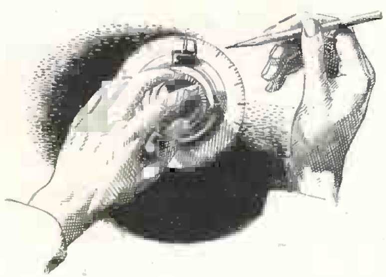

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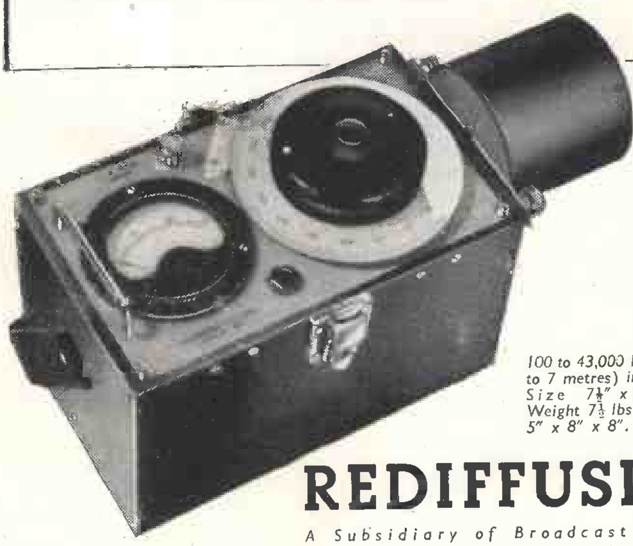

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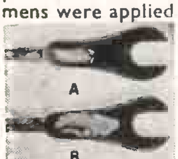
The illustration shows the result of a practical test made using nickel-plated spade tags and bare copper braid. The parts were heated in air to 250° C, and to identical specimens were applied ½" lengths of 14 S.W.G. 40/60 solder. To sample A, single cored solder with resin flux was applied. The solder fused only at point of contact without spreading. A dry joint resulted, having poor mechanical strength and high electrical resistance. To sample B, Ersin Multicore Solder was applied, and the solder spread evenly over both nickel and copper surfaces, giving a sound mechanical and electrical joint.



ECONOMY OF USING ERSIN MULTICORE SOLDER

The initial cost of Ersin Multicore Solder per lb. or per cwt. when compared with stick solder is greater. Ordinary solder involves only melting and casting, whereas high chemical skill is required for the manufacture of the Ersin flux and engineering skill for the Multicore Solder incorporating the 3 cores of Ersin Flux. However, for the majority of soldering processes in electrical and radio equipment Multicore Solder will show a considerable saving in cost, both in material and labour time, as compared either with stick solder or single cored solder. Cored solder ensures that the solder and flux are put just where they are required, and by choice of suitable gauge, economy in use of material is obtained. The quick wetting of the Ersin flux as compared with resin flux in single core resin solder ensures that with the correct temperature and reasonably clean surface, immediate alloying will be obtained, and no portions of solder will drop off the job and be wasted. Even an unskilled worker, provided with irons of correct temperature, is able to use every inch of Multicore Solder without waste.

ALLOYS

Soft solders are made in various alloys of tin and lead, the tin content usually being specified first, i.e. 40/60 alloy means an alloy containining 40% tin and 60% lead. The need for conserving tin has led the Government to restrict the proportion of tin in solders of all kinds. Thus, the highest tin content permitted for Government contracts without a special licence is 45/55 alloy. The radio and electrical industry previously used large quantities of 60/40 alloy, and lowering of tin content has meant that the melting point of the solder has risen. The chart below gives approximate melting points and recommended bit temperatures.

ALLOY Tin Lead	Equivalent B.S. Grade	Solidus C.°	Liquidus C.°	Recommended bit Temperature C.°
45/55	M	183°	227°	267°
40/60	C	183°	238°	278°
30/70	D	183°	257°	297°
18.5/81.5	N	187°	277°	317°

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The wider use of zinc plated components in radio and electrical equipment has made it advantageous to use solder which is antimony free, and thus Multicore Solder is now made from virgin metals to B.S. Specification 219/1942 but without the antimony content.

IMPORTANCE OF CORRECT GAUGE

Ersin Multicore Solder Wire is made in gauges from 10 S.W.G. (.128"—3.251 m/ms) to 22 S.W.G. (.028"—.711 m/ms). The choice of a suitable gauge for the majority of the soldering undertaken by a manufacturer results in considerable saving. Many firms previously using 14 S.W.G. have found they can save approximately 33⅓%, or even more by using 16 S.W.G. The table gives the approximate lengths per lb. in feet of Ersin Multicore Solder in a representative alloy, 40/60.

S.W.G.	10	13	14	16	18	22
Feet per lb.	23	44.5	58.9	92.1	163.5	481

CORRECT SOLDERING TECHNIQUE

Ersin Multicore Solder Wire should be applied simultaneously with the iron, to the component. By this means maximum efficiency will be obtained from the Ersin flux contained in the 3 cores of the Ersin Multicore Solder Wire. It should only be applied direct to the iron to tin it. The iron should not be used as a means of carrying the solder to the joints. When possible, the solder wire should be applied to the component and the bit placed on top, the solder should not be "pushed in" to the side of the bit.

ERSIN MULTICORE SOLDER WIRE is now restricted to firms on Government Contracts and other essential Home Civil requirements. Firms not yet using Multicore Solder are invited to write for fuller technical information and samples.

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WIRELESS ENGINEER

Editor HUGH S. POCOCK, M.I.E.E. Technical Editor Prof. G. W. O. HOWE, D.Sc., M.I.E.E.

VOL. XXI APRIL, 1944 No. 247

Editorial

The Application of Helmholtz's Theorems to Aerial Characteristics

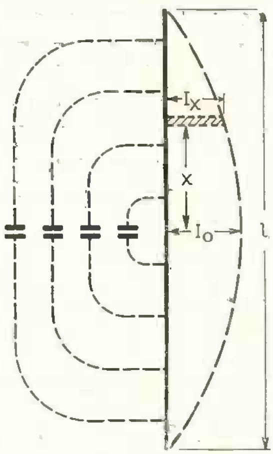
IN this number we publish an interesting and important paper by R. E. Burgess of the National Physical Laboratory on Aerial Characteristics. It is not customary to dedicate scientific articles to the memory of scientists of the past, or we might have suggested the dedication of this article to the memory of Helmholtz, for, although his name is not mentioned, the article is largely an application of principles and theorems which he propounded and discussed. It is true that he confined himself to direct currents, which was not surprising in the year 1853, but it was shown later that the same principles applied to alternating currents. As we pointed out in the Editorial of July 1943, he was interested in physiological problems and the distribution of currents and electromotive forces in parts of the body, that is to say, in three dimensions, and he merely gave linear networks with lumped constants as simple examples.

For the Principle of Superposition and the derivation therefrom of the so-called Thévenin's Theorem Mr. Burgess quotes from Shea's well-known text-book. Helmholtz credits du Bois-Reymond with the invention of the name "Superposition Principle," and says that it follows directly from Kirchhoff's general formulæ. Helmholtz's statement of the principle is as follows: "If in any system of conductors, electromotive forces exist at various points, the potential at every point of the system is the algebraic sum of the potentials which would be produced by each of the electromotive forces acting alone." Shea merely substitutes currents for potentials. Helmholtz then says: "if two points of such a network are connected to other conductors, it behaves as a conductor of a certain resistance, the magnitude of which can be calculated by the ordinary rules for branched networks, and of an electromotive force equal to the potential difference that existed between the two points before they were connected by the other conductors." He also says: "What applies to conducting bodies applies also to the special case of a linear network." It was exactly 30 years later that Thévenin published exactly the same theorem without any reference to Helmholtz, and his name has stuck to it ever since.

Mr. Burgess also employs the Reciprocal Theorem again with a reference to Shea's text-book. Helmholtz's 1853 paper was in two instalments, and in the second he announced and proved this Reciprocal Theorem, saying that it was merely the application to conducting bodies of a theorem which Green had used in similar electrostatic problems. As Helmholtz propounded it, it stated that in a conducting system containing no electromotive forces, if a and b are two conductor cross-sections, then an e.m.f. acting at a will produce the same current through b, as the same e.m.f. acting at b would produce through a. He was evidently picturing three-dimensional masses of conducting material. Mr. Burgess has established a very important fact quite contrary to the commonly accepted view with regard to the impedance and effective height of an aerial under varying conditions, and he has done this by going back unconsciously to 1853 and applying the theorems of Helmholtz to the aerial problem.

If the Figure represents diagrammatically an aerial with an e.m.f. E_o induced at its centre, the current at the centre can be represented by I_o and the current at any point at distance x by I_x. The effective length as a transmitter is equal to the actual length l reduced in the ratio I_{mean}/I_o.

The impedance of the aerial $Z_a = E_o/I_o$. Now by Helmholtz's reciprocal theorem the same e.m.f. E_o induced at x would produce a current I_x at the centre, and therefore an e.m.f. E_o/l induced at x would produce a current I_x/l at the centre. If an equal e.m.f. E_o/l be induced in every centimetre of the length, which would be the case if the received electric field $\mathcal{E}$ in the direction of the aerial had this value, the total current produced at the centre would be the sum of all these l elements of current; in other words, it would be the mean value of I_x taken over the whole length. Hence the received current at the centre is equal to I_o reduced in the same ratio l_{eff}/l, that is it is equal to



$$\frac{E_o}{Z_a}\frac{l_{eff}}{l} = \frac{\mathcal{E} \, . \, l_{eff}}{Z_a}.$$

If, on breaking the receiving aerial at the centre, the p.d. is found to be e_o, then on closing it, Helmholtz's "make and break" theorem says that the current will be e_o/Z_a; hence $e_o = \mathcal{E} \, . \, l_{eff}$. If, instead of merely closing the break in the aerial we insert an impedance Z, the resulting current will be $e_o/(Z + Z_a) = \mathcal{E} \, l_{eff}/(Z + Z_a)$ where Z_a is the impedance of the aerial measured at the break, i.e. E_o/I_o.

Hence the ratio l_{eff}/l and the impedance of the aerial are the same for transmission and reception, irrespective of the distribution of the aerial characteristics. This proposition forms the basis of the first section of Mr. Burgess' paper, and except that it is concerned with alternating and not direct currents, it is a direct application of the principles propounded by Helmholtz over ninety years ago. Although not so intended, the paper is a worthy tribute to the memory of one of the great pioneers of electrical science. G. W. O. H.

AERIAL CHARACTERISTICS*

Relation Between Transmission and Reception

By R. E. Burgess, B.Sc.

(Radio Department, National Physical Laboratory)

SUMMARY.—In Section 1 of the paper it is shown that the impedance of an aerial is the same for reception as for transmission as a consequence of its behaviour as a linear network, which permits the application of the Superposition Principle and Thévenin's Theorem. It is also shown by applying the Reciprocal Theorem, that the effective height and the polar diagram are the same in the two conditions. A generalised definition of effective height is introduced which specifies the radiating or receiving properties of an aerial as a function of the direction of transmission (θ, ϕ) and of the polarisation (α) of the electric vector.

Section 2 comprises a critical discussion of the four methods commonly used in the calculation of aerial impedance, namely

(*a*) the method based directly on the field equations; (*b*) the Poynting vector method; (*c*) the induced e.m.f. method, and (*d*) the transmission line method.

The errors in the papers where differences between the transmitting and receiving impedances have apparently been found are indicated.

In Section 3 the simplifying assumptions usually made in the calculation of aerial impedance are discussed, namely

(*a*) sinusoidal distribution of current; (*b*) zero current at the end of an open aerial; (*c*) concentration of current and charge along the axis, and (*d*) perfect conductivity.

Introduction

It has often been suggested in investigations of aerials that the impedance, effective height and polar diagram may not be the same for reception as for transmission. This present paper is the outcome of an attempt to resolve the problem by reference to the fundamental principles which apply to all linear systems of which an aerial is one.

The first section of the paper is concerned with demonstrating the identity of the impedance and effective height of an aerial for any condition of excitation. An investigation of the arguments

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

which led some writers to suggest that the identity may not hold has resulted in a critical examination of the methods of calculation of aerial impedance which is presented in the second section. The third section briefly discusses the simplifying assumptions usually made in these methods of calculations.

1. Equality of Impedance and of Effective Height for Transmission and Reception

(a) *The equality of the impedance for reception and transmission.*

It is proposed to demonstrate that the fundamental laws which apply to a linear circuit are also applicable to an aerial, and thus that the impedance of a given aerial is unique and independent of its mode of excitation.

The fundamental theorem relating to a linear circuit is the Principle of Superposition which may be stated as follows (*cf.* Ref. 1, p. 50).

" The current produced at any point in a network due to any number and distribution of e.m.fs in the network is the sum of the currents which would be produced if the individual e.m.fs were applied separately."

Thévenin's Theorem follows at once from the Superposition Principle (Ref. 1, p. 55) showing that an active linear two-terminal network is equivalent to an e.m.f. in series with an impedance as regards its external behaviour.

The derivation of Thévenin's Theorem is applicable to an infinite network having distributed constants as well as to one having lumped constants. In fact if the circuit equations are correctly formulated they should be equivalent to the set of electromagnetic field equations which apply to the system considered. This brings out the point that the real basis of circuit theory is the electromagnetic field, and although Carson[2] has stressed this it still remains insufficiently appreciated.

Thus all circuit elements, even of the simplest type (e.g. an inductor) are in reality infinite systems, but it is a matter of practical convenience to designate more or less well defined circuit elements with the names inductor, capacitor, and resistor in order to simplify analysis. Usually these approximations are reasonably accurate, but in some cases they are of limited validity.

The equations of the electromagnetic field apply to all systems of conductors, and the distinction between " lumped " and " distributed " constants just as that between " circuit " and " aerial " is an arbitrary one. In practice the term " aerial " implies that the radiation resistance of the system is not negligible compared with the ohmic resistance, while the term " circuit " implies the converse.

Thus the rigorous theory of circuits rests on the field equations which are linear (in the absence of ferromagnetic media and non-ohmic conductors) for the relations between the currents and charges on the conductors, and the potentials and fields to which they correspond are linear.

It is therefore concluded that an aerial is a linear system to which the Principle of Superposition and thus Thévenin's Theorem applies, and the latter may be expressed as follows for the case of an aerial :—

" If an external impedance Z be connected between any two terminals of an aerial the current i_0 flowing in Z is given by

$$i_0 = \frac{e_0}{Z + Z_0} \quad \quad (1)$$

where the e.m.f. e_0 is dependent on the mode of excitation but independent of Z and the effective impedance Z_0 of the aerial is independent of both the excitation and Z."

A special mode of excitation is the transmitting condition in which the applied e.m.f. is lumped at the terminals, and it is thus concluded as a corollary that the impedance of an aerial is the same for transmission and reception.

Recently Fränz[3] used similar arguments to demonstrate the uniqueness of the value of the impedance of an aerial. Some writers had already given less general proofs by considering particular models. For example, Colebrook[4] has considered an aerial as a transmission line having uniformly distributed constants with an arbitrary distribution of the exciting field, and found that the system obeyed Thévenin's Theorem. A more general proof was given by Wilmotte[5] who considered the case in which the constants of the aerial are not assumed to be uniformly distributed, with, however, the proviso that " the distribution of the constants of the aerial is independent of the applied e.m.fs." This proviso is unnecessary, since in a linear system the constants must be independent of the excitation, and thus Wilmotte's proof is more general than his wording suggests. Wilmotte considered that as the current distribution and in particular the integral of the current along the aerial was not the same for reception as for transmission, the radiation resistance would not be the same in the two conditions. This argument is incorrect, but unfortunately it has led to the widespread belief that the impedance of an aerial is not the same for reception as for transmission.

Niessen and de Vries[6] in a paper on the impedance of a receiving aerial obtained results which differed from those found by Labus[7] for a transmitting aerial, and concluded that a real difference existed, but this arose from an error in their method of calculation which will be discussed in section 2 (*c*).

(b) Equality of effective height for reception and transmission.

The radiating properties of an aerial are only completely known when the polarisation and field intensity produced at all points on a surface surrounding the aerial are specified. For simple aerials the properties can be specified in terms of an "effective height." Thus if a linear aerial carries a current distribution $i_t(z)$ for a terminal current i_0 the effective height for transmission normal to the aerial is given by

$$h_t = \frac{1}{i_0}\int i_t(z)\,.\,dz \qquad \ldots \quad \ldots \quad \ldots \quad (2)$$

The effective height of a simple aerial for reception is the ratio of the induced e.m.f. e_0 appearing at its terminals to the uniform inducing field E parallel to the aerial :—

$$h_r = \frac{e_0}{E} \qquad \ldots \quad \ldots \quad \ldots \quad (3)$$

Since any aerial behaves as a linear circuit, the Reciprocal Theorem (Ref. 1, p. 52) can be applied to it. This theorem states that if any e.m.f. at one point in a circuit produces a certain current at any other point in the circuit, the same e.m.f. acting at the second point would produce the same current at the first point. Now an e.m.f. i_0Z_0 applied to the terminals of an aerial produces the transmitting current distribution $i_t\,(z)$ having value i_0 at the terminals, and thus in reception of a wave of field distribution $E(z)$ parallel to the conductor, the e.m.f. $E(z)\,dz$ induced in the element dz at z produces a current

$$di = E(z)dz\frac{i_t(z)}{i_0Z_0}$$

at the terminals which is equivalent to an e.m.f. $Z_0\,.\,di$ at these terminals. Thus the total induced e.m.f. appearing at the terminals is given by

$$e_0 = \frac{1}{i_0}\int E(z)\,i_t(z)\,.\,dz \qquad \ldots \quad \ldots \quad (4)$$

where, it must be remembered i_t is the current distribution in the *transmitting* condition for a terminal current i_0.

Equation (4) is a useful form of the Reciprocal Theorem which is of particular value calculating the e.m.f. e_0 induced by any arbitrary distribution of exciting field E. When E is uniform we find

$$\frac{e_0}{E} = \frac{1}{i_0}\int i_t(z)\,.\,dz$$

and thus $h_r = h_t$ $\qquad \ldots \quad \ldots \quad \ldots \quad (5)$

Hence the Reciprocal Theorem leads to a general proof of the equality of effective height for reception and transmission.

A specialised proof of this equality was given by Wilmotte[5] who considered the aerial as a transmission line with arbitrarily varying parameters along its length, but he again introduced the unnecessary proviso that the constants should be independent of the excitation.

For complex aerial systems the simple conception of effective height is no longer applicable, but it may be extended in the following manner :— Let P be a point in the aerial system and let a sphere of radius r large compared with the wavelength and the dimensions of the system be drawn about it, and let Q be any point on the sphere having polar co-ordinates $(r,\ \theta,\ \phi)$. If a current i_0 of angular frequency ω is flowing at the terminals due to a transmitter connected to them, the electric field E at Q will in general be elliptically polarised with the plane of ellipse in the spherical surface. Let the electric field component of polarisation α be $E\,(\alpha)$ at Q. Then the effective height h of the aerial system is given by

$$\frac{\omega h i_0}{c^2 r} = E(\alpha) \qquad \ldots \quad \ldots \quad \ldots \quad (6)$$

This definition of effective height h like $E(\alpha)$ is a function of the direction of transmission $(\theta,\ \phi)$ and of polarisation (α) and may be termed the "generalised effective height"; for simple aerials it coincides with the usual significance of the term given by equation (2). For example the effective height of a short dipole of length $2l$ is equal to l in the usual notation, while the generalised effective height has the form

$$h(\theta,\ \phi,\ \alpha) = l\cos\alpha\sin\theta$$

which for maximum transmission or reception $(\alpha = 0$ and $\theta = 90^\circ)$ agrees with the usual form.

The "generalised effective height" for reception is defined as the ratio of the e.m.f. e_0 appearing at the terminals of the aerial system to the incident plane polarised field intensity E producing it, where E is due to a distant source having coordinates $(\theta,\ \phi)$ and polarisation (α). It is seen that the generalised effective height is also the same for reception and transmission as a consequence of the Reciprocal Theorem by considering transmission between the aerial system and a short dipole at $(\theta,\ \phi)$ on the sphere with inclination (α).

It is concluded that the polar diagram of an aerial system and the various measures of it (directivity, gain) are identical for reception and transmission. This remark applies even in the presence of the earth, for this does not affect the linearity of an aerial system.

2. Summary of the Methods of Calculation of Aerial Impedance

The four main methods of calculating aerial impedance are now briefly discussed. For a useful survey of the theory of antenna impedance the reader is referred to a recent paper by Schelkunoff[8].

(*a*) *Method based directly on the field equations.*

This is the classical method which was used by Abraham[9] and recently by Page and Adams[10] to consider the electrical oscillations of a perfectly conducting prolate spheroid. The technique is that of expressing Maxwell's equations in terms of the curvilinear co-ordinates appropriate to the shape of conductor, and on satisfying the boundary conditions at the conductor, solving the resulting differential equation. The natural modes of oscillation are thus determined, and from the damping of these oscillations the radiation resistance can be found. The main difficulty of the method is to express the equations for the oscillations in terms of known functions or of rapidly converging series.

The chief limitation of the method is that of shape, since the spheroidal conductor is the only one amenable to exact analysis, as other shapes involve a discontinuity at the ends which make the analysis either approximate or intractable. The shape which is of the greatest practical interest is the cylinder, but an exact analysis of this shape would appear to be impossible, although a number of investigators have endeavoured to develop a reasonably accurate theory.

For example, Hallen[11] has calculated the impedance of an imperfectly conducting dipole, with the assumptions that the current vanishes at the end, and that the ratio of length to radius is large although the logarithm of the ratio is regarded as finite. The integral equation for the current is solved by taking the method of successive approximation two stages and the convergence and hence accuracy of this method is better the thinner the aerial.

The difficulty in applying the results for the spheroidal aerial to the cylinder is to know how to choose the equivalent dimensions for it seems that any *a priori* choice is somewhat arbitrary, since exact equivalence cannot hold.

The method based on the field equations is capable of greater accuracy than other methods since it usually involves fewer simplifying assumptions. For example the current distribution is not chosen beforehand, but is determined by the boundary condition of zero tangential electric force at the surface of a perfect conductor, and thus certain inconsistencies of other methods are avoided.

(*b*) *The Poynting vector method*

This method consists of integrating the Poynting vector $\frac{c}{4\pi}(E \times H)$ over a closed surface (usually spherical) described about the aerial, at a large distance from it. Thus if i_0 is the terminal current the power radiated is given by

$$P = R_0 i_0^2 = \frac{c}{4\pi}\int (E \times H)dS \quad .. \quad (7)$$

where R_0 is the radiation resistance at the terminals. It is usually assumed in calculating E and H that the current distribution is sinusoidal.

The disadvantage of this method is that it only gives the resistive component of the terminal impedance, since it is concerned with the distant field. The degree of accuracy with which it gives the radiation resistance depends upon the closeness of the postulated current distribution to the actual distribution, and the thinner the aerial the better this approximation is. The error is most obvious for a dipole which is a multiple of a wavelength, for the predicted radiation resistance is then infinite since radiation occurs although the terminal current is zero ; in actual fact the radiation resistance reaches finite maxima in these regions.

(*c*) *The induced e.m.f. method*

This method, as outlined by Pistolkors[12] consists of evaluating the integral of the product of the current $i(z)$ and the electric force $E'(z)$ at the surface of the aerial which is set up by the postulated current distribution. The current $i(z)$ in the element dz at z does work against the induced e.m.f. $E'(z) \,.\, dz$ and the complex Poynting vector integrated over the aerial gives the power which is supplied to it. In the case of a perfectly conducting aerial with zero external impedance between its terminals this (complex) power has an active part which corresponds to the radiation resistance R_0 of the aerial and a reactive part corresponding to the reactance X_0: considering the case where i is in phase with i_0 along the aerial, we have

$$(R_0 + jX_0)i_0^2 = Z_0 i_0^2 = -\int E'(z)i(z)dz \quad (8)$$

This method gives the same value of radiation resistance as the Poynting vector method for the same postulated current distribution, and has the advantage of giving the reactance as well.

The method is frequently misunderstood and incorrectly formulated, and inconsistencies are found in many papers on the subject. The important point is that at the surface of a perfectly conducting aerial the resultant longitudinal electric force must vanish. (The gradient of the scalar potential along an aerial must not be confused with this electric force, since the former represents only the contribution of the charges to the field). Now a sinusoidal distribution of current would give rise to a non-zero value of electric field at the surface of the conductor, and thus this distribution which is usually assumed to hold in a transmitting aerial, violates the boundary conditions. This point is discussed in Section 3(a) in greater detail.

Hence in a transmitting aerial, the current distribution must in fact depart from the sinusoidal to just the extent that makes the field vanish everywhere along the aerial. In a receiving aerial the distribution of current must be such as to produce at every point on the aerial a field exactly equal and opposite to the longitudinal component of the incident field.

The incorrect formulation of the induced e.m.f. method leads to the "Radiation Paradox" as Schelkunoff[8] has termed it. For if a sinusoidal distribution of current be assumed to exist on the transmitting aerial, the resultant field is not zero, implying the existence of a distributed impedance along the aerial which is known to lead approximately to the impedance Z_0 appearing at the terminals from comparison of experiment with the values deduced by this method. And yet if i is given the correct distribution for transmission the field must vanish, leading as it should to zero distributed impedance. Schelkunoff then asks why the incorrect sinusoidal distribution should lead so nearly to the right value when such a fundamental discrepancy is present, but he offers no answer. The following considerations may serve to explain the apparent paradox.

Let a generator of e.m.f. e be connected to the aerial terminals where the current produced is i_0 and the distribution along the aerial is $i_t(z)$ appropriate to the transmitting condition. The complex Poynting vector integrated over the whole system gives the active and reactive parts of the power supplied by the generator. Now the longitudinal field and hence the Poynting vector is zero along the aerial itself, and thus the power *appears* to emerge entirely at the source, for there we have

$$Z_0 i_0^2 = P = \int E i_0 \,.\, dz = e i_0$$

This only tells us that $Z_0 i_0 = e$ which is perfectly correct but of no assistance in calculating the impedance Z_0.

Now consider the case of reception in which the incident field has the distribution $E(z)$ and the terminals are short-circuited, the current at this point being i_0. Then if $i_t(z)$ is the current distribution in the transmitting condition corresponding to the terminal current i_0, we have from equation (4) that the induced e.m.f. is

$$e_0 = \frac{1}{i_0}\int E(z) i_t(z) \,.\, dz$$

and thus $i_0 = \dfrac{e_0}{Z_0} = \dfrac{1}{i_0 Z_0}\displaystyle\int E(z) i_t(z)\, dz$

$$\text{giving } i_0^2 Z_0 = \int E(z) i_t(z) \,.\, dz \qquad \ldots \quad (9)$$

This equation gives the relation between any distribution $E(z)$ of incident field and the current i_0, it produces at the aerial terminals. Now consider the field $E'_s(z)$ which would be produced by the sinusoidal current distribution is having the value i_0 at the terminals ($x = 0$). This field must be equal and opposite to the incident field $E(z)$ required to support i_s on the aerial in the receiving condition and thus we can write (10) as

$$Z_0 = -\frac{1}{i_0^2}\int E'_s(z) i_t(z) \,.\, dz \qquad \ldots \quad (10)$$

It should be noted that $i_t(z)$ is the true transmitting current distribution even though E'_s is derived from a sinusoidal distribution of current.

Now since $i_t(z)$ is approximately sinusoidal we see that the impedance is given *approximately* by

$$Z_0 = -\frac{1}{i_0^2}\int E'_s(z) i_s(z) \,.\, dz \qquad \ldots \quad (11)$$

where $i_s(z)$ is the sinusoidal distribution corresponding to i_0 at the terminals. Equation (11) is the form which is usually used for the calculation of impedance by the induced e.m.f. method and the error it gives is seen to depend on the departure of $i_s(z)$ from $i_t(z)$. Because the true distribution does not usually depart considerably from the sinusoidal, the usual form (11) of the induced e.m.f. method gives a value of impedance which may not be too seriously in error, at least for the resistance.

The thin dipole has been analysed using the induced e.m.f. method by Labus[7]. Comparison with the more accurate theory of Hallen shows agreement except in the region where the aerial is a multiple of a wavelength long where Labus predicts an infinite resistance while both the resistance and reactance found by Hallen remain finite, is in fact they should.

Niessen and de Vries[6] used the induced e.m.f. method to calculate the impedance of a receiving aerial, but applied the method incorrectly and on obtaining values which differed from those of Labus concluded that these differences really existed between the impedances for reception and transmission. They took as the current distribution of a uniform field parallel to the aerial

$$i_r = i_0 \frac{\cos kz - \cos kl}{1 - \cos kl}$$

and deduced the corresponding longitudinal field which would be set up by this current. But instead of using the corresponding sinusoidal *transmitting* current i_s in the integral (equation 11) they used the receiving current i_r and so obtained incorrect values for the impedance, which agree with those of Labus only when i_r and i_s are equal, that is when the total length of the dipole is an odd number of half-wavelengths.

(*d*) *The transmission line method*

In this method the aerial is represented by a transmission line with uniformly distributed constants and has the advantage of simplicity and of involving conceptions which are already familiar to radio engineers.

Colebrook[4,13] considered the qualitative behaviour of the impedance of an aerial with uniform distribution of constants.

Siegel and Labus[14] placed the method on a quantitative basis by using the results found by Labus[7] for a transmitting aerial carrying a sinusoidal distribution of current and making the assumptions that :—

(i) the characteristic impedance is the mean of the value deduced from the scalar potential along the aerial, and

(ii) the attenuation constant has the value which makes the input resistance of the equivalent line equal to the radiation resistance ; this assumption implies that the effect of radiation can be included in the transmission line equations in the same way as ohmic resistance.

Both these assumptions are of doubtful validity, and the complete analysis is elaborate, for it involves a preliminary calculation of the potentials along the aerial and of the radiation resistance by the induced e.m.f. method.

Schelkunoff[8] has improved on the transmission line method by regarding an aerial as a line with parameters varying slowly along its length. Using Carson's solution of the differential equation of such a system he has been able to express the aerial impedance explicitly in terms of tabulated functions, but the usual assumption of zero current at the end of the aerial is made and thus the results are only applicable to thin aerials.

3. Simplifying Assumptions used in the above Methods

This section of the paper comprises a discussion of the assumptions which are customary in some or all of the four methods of calculating aerial impedance.

(*a*) *Sinusoidal distribution of current*

This assumption is encountered in the last three methods but is absent from the first by its very nature for the sinusoidal distribution leads to a non-zero component of electric field parallel to the surface of the conductor. It is seen from equation (10) that in the induced e.m.f. method a knowledge of the true current distribution is required for an accurate evaluation of the impedance. However, except when the aerial is near a condition of high resonant impedance ($2l$ = odd number of $\lambda/2$ for a dipole) the value of resistance given on the assumption of a sinusoidal distribution is fairly accurate, but this is not necessarily true of the reactance which is always more sensitive to departures from the truth.

It is known[8,11,15] that in a linear uniform perfectly conducting aerial the scalar and vector potentials are propagated sinusoidally, i.e. there is no damping of the potential waves due to radiation. Thus either of these potentials can be written in the form $(A_1 \cos kz + A_2 \sin kz)$ and an integral equation for the current distribution is obtained. One method of solving this equation explicitly is by successive approximations, such as Hallen has carried out, but the complexity of the analysis prevents its being taken more than a few stages. If the exact expressions for the current distribution or a close approach to it is used in the induced e.m.f. method the latter becomes formally identical with the field theory method.

(*b*) *Zero current at the end of an open aerial*

It is usually assumed that in cylindrical aerials the current vanishes at the flat end, but owing to the accumulation of charge which must occur there this represents an approximation which grows worse as the ratio of radius to length increases. This limitation has been recognised by most writers, and the results obtained using this assumption are usually claimed to be applicable only to thin aerials.

The remedy for thick aerials would apparently be to regard the flat end as equivalent to a capacitance loading at the end proportional to the radius.

(*c*) *Concentration of current and charge along the axis*

The scalar and vector potentials corresponding to a given current distribution $i(z)$ are frequently calculated on the (implicit) assumption that the current and charge are concentrated along the axis whereas in fact the distribution is practically superficial at radio-frequencies. For example the longitudinal component of the vector potential at the surface of the aerial is usually written

$$A(z) = \frac{1}{c}\int \frac{i(z_0)e^{-jkr}}{r} dz_o$$

where $r = \sqrt{(z - z_0)^2 + r_0^2}$ in which r_0 is the radius of the aerial. This leads to an error which is most pronounced near the end of the aerial and for thick aerials. By considering the actual distribution of charge and current taking into account the skin effect, Zinke[15] has shown that the distance r should be written

$$r = \sqrt{(z - z_0)^2 + r'^2_0}$$

where the "effective radius" r'_0 lies between about $0.4\, r_0$ for $z - z_0 = 0$ and $1.4\, r_0$ for $|z - z_0| > 6r_0$.

(d) Perfect conductivity

The assumption of perfect conductivity is usually made for simplicity and it leads to a very small error in the impedance of resonant aerials which are those most used in practice. When the conductivity is not perfect the electric force parallel to the conductor does not vanish but is of such a value to balance the internal field $(R' + j\omega L')i(z)$ at every point along the aerial, R' being the ohmic resistance and L' the internal inductance, per unit length. In the analysis of Hallen[11] this relation is taken into account before solving the integral equation for the current and thus his results include the effect of ohmic resistance in a general and fairly exact form.

To a first approximation, however, the impedance for perfect conductivity can be modified by including an additional term calculated on the assumption that the presence of ohmic resistance causes a negligible change in the current distribution. When the conductivity is imperfect the Poynting vector is no longer zero along the aerial but has the value $(R' + j\omega L')i_t^2(z)$ directed inwards, and thus to a first approximation the terminal impedance has an additional term :

$$\Delta Z_0 = +\frac{1}{i_0^2}\int (R' + j\omega L')i_t^2(z) \,.\, dz \quad (12)$$

An equivalent derivation of this expression from circuit theory is obtained by applying the Compensation Theorem (Ref. 1, p. 56), considering the presence of ohmic resistance and internal inductance as equivalent to the introduction of generators at points all along the aerial.

To show the small effect of imperfect conductivity, a numerical example is given. A thin half-wave dipole has an impedance of $(73 + j\,42.5)$ ohm according to the approximate form of the induced e.m.f. method ; if such a dipole is made of copper and has a length of 1 m. (λ 2m or 150 Mc/s). and radius of 0.5 cm. then R' and $\omega L'$ both have the value of 0.1 ohm/m.

For a half-wave dipole of length $2l$

$$\frac{1}{i_0^2}\int_{-l}^{+l} (R' + j\omega L')i_t^2 \,.\, dz = (R' + j\omega L')l$$

very approximately, and thus in the example considered the additional impedance is $(0.05 + j0.05)$ ohm, which is clearly insignificant.

4. Acknowledgments

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REFERENCES

1 T. E. Shea : "Transmission Networks and Wave Filters." Chapman & Hall, London (1929).

2 J. R. Carson : "Electromagnetic Theory and the Foundations of Electric Circuit Theory." *Bell S. Tech. Journ.*, 1927, Vol. 6, pp. 1–17.

3 K. Fränz : "The Analogy between Transmitting and Receiving Aerials." *Hochf:tech. u. Elek:akus.*, 1940, Vol. 56, pp. 118–119.

4 F. M. Colebrook : "The Theory of Receiving Aerials." *Experimental Wireless and Wireless Eng.*, 1927, Vol. 4, pp. 657–666.

5 R. M. Wilmotte : "On the Constants of Receiving and Transmitting Antennae." *Phil. Mag.*, 1927, Vol. 4, pp. 78–91.

6 K. F. Niessen and G. de Vries : "The Impedance of a Receiving Aerial." *Physics*, 1939, Vol. 6, pp. 601–617.

7 J. Labus : "The Calculation of Aerial Impedance." *Hochf:tech. u. Elek:akus.*, 1933, Vol. 41, 17–23.

8 S. A. Schelkunoff : "Theory of Antennas of Arbitrary Shape and Size." *Proc. Inst. Rad. Eng.*, 1941, Vol. 29, pp. 493–521.

9 M. Abraham : "The Electrical Oscillations of a Rod-shaped Conductor treated by Maxwell's Theory." *Ann. des Physik*, 1898, Vol. 66, pp. 435–472.

10 L. Page and N. I. Adams : "The Electrical Oscillations of a Prolate Spheroid." *Phys. Rev.*, 1938, Vol. 53, pp. 819–831.

11 E. Hallen : "Theoretical Investigations into the Transmitting and Receiving Qualities of Antennae." *Nova Acta Reg. Soc. Sci. Upsaliensis*, 1938, Vol. 11, pp. 3–44.

12 A. Pistolkors : "The Radiation Resistance of Beam Antennas." *Proc. Inst. Rad. Eng.*, 1929, Vol. 17, pp. 562–579.

13 F. M. Colebrook : "An Experimental and Analytical Investigation of Earthed Receiving Aerials." *Journ. I.E.E.*, 1932, Vol. 71, pp. 235–251.

14 E. Siegel and J. Labus : "The Impedance of Aerials." *Hochf:tech. u. Elek:akus.*, 1934, Vol. 43, pp. 166–172.

15 O. Zinke : "The Fundamentals of Current and Voltage Distribution on Aerials." *Arch. Elektrotech.*, 1941, Vol. 35, pp. 67–84.

Institution of Electrical Engineers

Wireless Section.—Dr. G. L. Sutherland will open a discussion on "Metals and their Finishes in Radio Construction" at the meeting at 5.30 on April 18th. The Silver Jubilee Commemoration Meeting of the Section has been arranged for May 3rd. The meeting, which will be preceded by a reception and tea, begins at 5.30 and will include a series of six short addresses by past chairmen giving a review of wireless progress. The speakers will be Col. Sir A. Stanley Angwin, Dr. W. H. Eccles, Prof. G. W. O. Howe, Admiral Sir Charles E. Kennedy-Purvis, H. Bishop and Dr. R. L. Smith-Rose.

Cambridge and District Wireless Group.—B. J. Edwards will give a "Survey of the Problems of Post-war Television" at a meeting to be held at 5.30 on April 17th at the Cambridgeshire Technical School, Collier Road, Cambridge. A discussion on "Training for the Radio Industry" will be opened by C. R. Stoner, and R. W. Wilson at a meeting at 5.30 on May 1st, at the Cambridgeshire Technical School.

LOSS-LESS TRANSMISSION LINES*

Analysis by Means of Two Simple Diagrams

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THE following notes give a description of two simple diagrams which have been found useful in the analysis of transmission line problems.

I. The "Clock" Diagram

The first diagram gives the input impedance and the current and voltage distribution for a loss-less transmission line loaded with purely

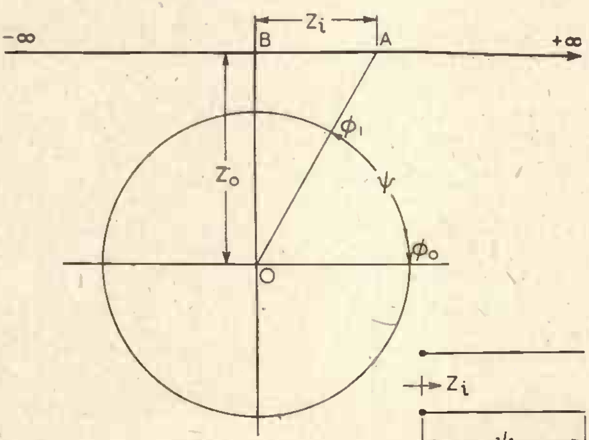

Fig. 1. *Input impedance of an open-circuited loss-less line of electrical length ψ.*

reactive shunt or series components, or for series combinations of such a line with others of different characteristic impedance.

Its basis is the standing wave pattern formed by the voltage and current distribution in such cases. These standing waves are on simple open- or short-circuited lines described by either a sine or cosine function of the electrical length $\psi = 2\pi x/\lambda$ (reckoned from the end of the line), and the input impedance of such lines varies therefore like a tangent or cotangent function. The kind of function to be chosen and the kind of impedance (inductive or capacitive), is in each case simply determined by inspection, keeping in mind that the input impedance of a short open-circuited line can only be capacitive and that of a short short-circuited one only inductive.

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

We shall explain the diagram as it applies to an open-circuited line; the case of a short-circuited line can be dealt with in a perfectly analogous manner, of which an example will be given later.

The input impedance of an open-circuited line is given by

$$|Z_i| = Z_0 \cdot \cot \psi \quad \ldots \quad (1)$$

which equation leads to the diagram of Fig. 1.

A parallel to the X-axis plotted at a "height" Z_0 is intersected by a "ray" from the co-ordinate origin, which forms the angle ψ with the positive X-axis. The intercept $\overline{AB}$ gives the input impedance and the diagram shows clearly how an increase of ψ causes Z_i first to pass through zero to negative (here inductive) values, and later to pass through infinity to positive values again. For every value of ψ indicated at the "clock," we are, at least in theory, able to read off the corresponding value of Z_i.

Conversely, and this is important for later application, if we are given a value Z_i, which is purely reactive, we find from this diagram the length of an open-circuited line, which can completely replace this reactance ("Equivalent line").

Fig. 2 gives an application of this diagram. Here it is shown how to find the input impedance

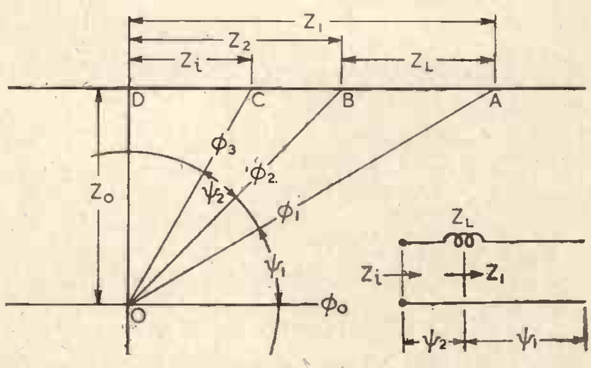

Fig. 2. *Input impedance of an open-circuited line with lumped series inductance.*

of a line, which contains somewhere a reactive series component (here an inductance) Z_L.

Starting from the open end of the line, we find (ray ϕ_1) the input impedance $Z_1 = \overline{DA}$ of the section of length ψ_1. Combining Z_1 with Z_L gives $Z_2 = Z_1 - Z_L$ (Z_L being inductive, carries here the $-$ sign).

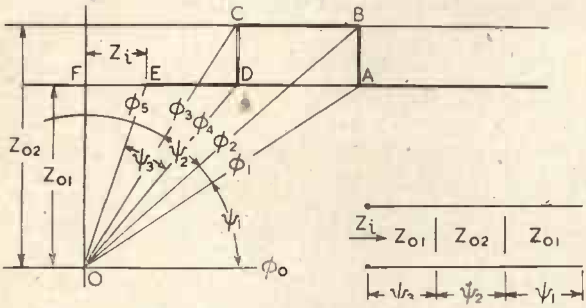

Fig. 3. *Input impedance of a line consisting of sections of different characteristic impedance.*

From Z_2 (intercept $\overline{DB}$) we find ray ϕ_2—i.e., the length of line having an input impedance equal to that of the combination. To this we need only add ψ_2 in order to get ray ϕ_3 and intercept $\overline{DC}$, the wanted input impedance.

Only a small elaboration, namely a second parallel to the X-axis, is required to solve a problem which in the past has often led to an erroneous interpretation of measurements.[1] This problem—illustrated in Fig. 3—is the determination of the input impedance of a line which contains an intermediate section of a line of different characteristic impedance. Let the characteristic impedances of the various line sections be Z_{01} and Z_{02} and let us accordingly

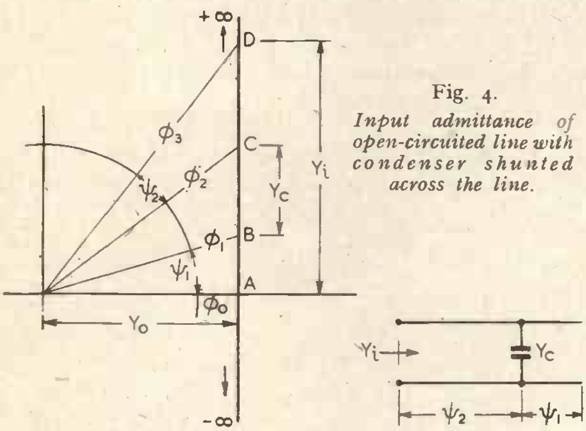

Fig. 4. *Input admittance of open-circuited line with condenser shunted across the line.*

plot 2 impedance parallels, at height Z_{01} and Z_{02}. The procedure is then quite straightforward. Ray ϕ_1 gives (point A on the Z_{01} parallel) the input impedance Z_1 of the first section. Plotting $\overline{AB}$ parallel to the Y-axis enables us to find ray ϕ_2, i.e., to determine the length of line of characteristic impedance Z_{02} which could replace Z_1. To ϕ_2 we add ψ_2, the length of the second section, and find C. Plotting $\overline{CD}$ parallel to the Y-axis brings us back to the Z_{01} impedance level (ray ϕ_4) and to ϕ_4. To this we need only add the length ψ_3 to get ϕ_5 and the final result $Z_i = \overline{FE}$.

The diagram shows clearly that a change in the impedance level causes a change in the equivalent electrical length, and that in the present problem the first increase $\epsilon_1 = \phi_2 - \phi_1$ is not, in general, equal to the subsequent decrease $\epsilon_2 = \phi_3 - \phi_4$. Thus it would be wrong to calculate

$$|Z_i| = Z_{01} \cdot \cot(\psi_1 + \psi_2 + \psi_3).$$

Eqn. (1) can also be expressed as

$$|Y_i| = Y_0 \cdot \tan\psi \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where $Y_0 = 1/Z_0$.

This expression for the input admittance leads to a graphical construction quite analogous to the ones discussed. An example is given in Fig. 4, where the input admittance is determined for a line shunted by a condenser. The figure is self-explanatory. If we had added the horizontal Z_0-scale to this figure, we could have read off directly $Z_i = 1/Y_i$.

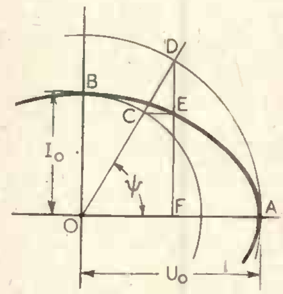

Fig. 5. *Current - voltage locus for loss-less line.*

Such a simultaneous use of admittance and impedance scales will sometimes be required to avoid difficulties arising from inconveniently large magnitudes. If, say, an impedance is too large to be plotted on our diagram, the corresponding admittance is just convenient to handle. The only drawback of working on the reciprocal scale is that instead of plotting simply, say, $Z_c = Z_a + Z_b$ we now have to evaluate by graphical or numerical methods

$$Y_c = \frac{Y_a \cdot Y_b}{Y_a + Y_b}$$

We proceed now to the determination of the current and voltage distribution by the aid of the diagram. The distribution is described for a smooth open-circuited line by

$$|U| = U_0 \cdot \cos\psi \text{ and } |I| = I_0 \cdot \sin\psi \quad \ldots \quad (3)$$

where U_0 and I_0 denote the amplitudes of the voltage and current waves (eqn. 1 and 2). If we plot, say, voltage horizontally and current

[1] This error was pointed out by Lamont (*Phil. Mag.*, Vol. XXIX, 1940, p. 531).

vertically, then these equations are the parameter representation of an ellipse, whose horizontal axis equals U_0 and whose vertical axis equals I_0. Fig. 5 shows such an ellipse and the well known way in which it can be constructed by the aid of auxiliary circles of radii U_0 and I_0.

Fig. 5 repays a somewhat closer study. Suppose

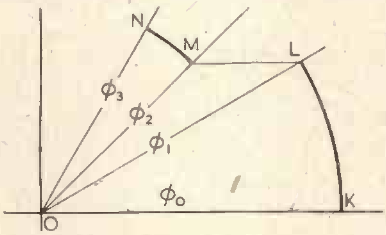

Fig. 6. *Current - voltage locus for the case illustrated in Fig. 2.*

we know that at a certain section of the line to which we ascribe the line angle (angular distance from the actual or fictitious open end) ψ the voltage is U_1 and the current I_1, and for some reason or other we want to represent these on such a scale that $U_1 = \overline{OF}$ and $I_1 = \overline{FE}$, i.e., we wish the ellipse to pass through point E. Then we can easily complete the ellipse by drawing through E parallels to the X- and Y-axis and thus finding the radii $\overline{OD}$ and $\overline{OC}$ of the voltage and current circles as intercepts on the " ray " ψ.

By suitable choice of the scale for I we can achieve that $I_0 = U_0/Z_0$ is represented by a length equal to that representing U_0. In this case the voltage and current circles coincide and the ellipse becomes a circle coincident with these circles.

So far we have only been dealing with the current and voltage distribution along a plain open-circuited loss-less line. It is easily shown that an answer of the same simple form holds good when

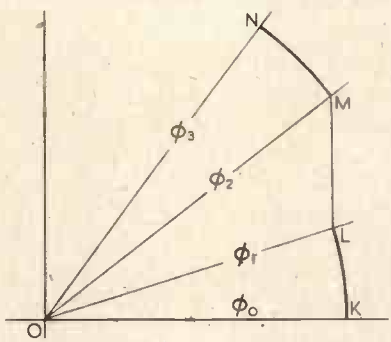

Fig. 7. *Current - voltage locus for the case illustrated in Fig. 4.*

we have a line consisting of several sections of different characteristic impedance and possibly loaded with some shunt or series reactances. As all elements are loss-less, the " load " of any intermediate section of the line which is formed by those parts lying on the " far " side of the cut is always purely reactive—i.e., it can be replaced by a fictitious extension of appropriate length of the section under consideration. (The length of this equivalent extension, say ψ_1, we have learned to find in the preceding discussion.) If we plot the standing wave pattern of voltage and current along this fictitious line, beginning at the open end, then we need only continue this pattern into the section under consideration in order to obtain the wanted current and voltage distribution. This means, that on our diagrams the locus is in each case the corresponding section of an ellipse, plotted between the " ray " angles ψ_1 and $\psi_1 + \psi_s$ where ψ_s is the length of the section under consideration. With the favourable choice of scale for I mentioned above, it will even be a simple circle.

With these preliminary considerations we are now able to determine the current and voltage distribution for those cases which we previously discussed.

Fig. 6 refers to the case of Fig. 2. We have there replotted the web of rays ϕ_1 ϕ_2 ϕ_3 (in a practical

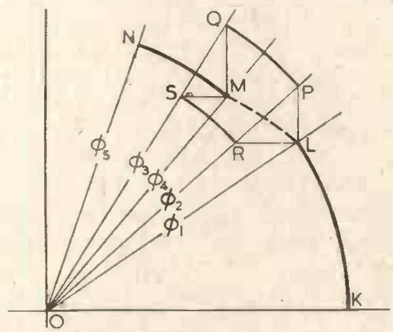

Fig. 8. *Current - voltage locus for the case illustrated in Fig. 3.*

case we would, of course, use the same diagram for the impedance determination as for the plotting of the locus). Let us assume we have made the favourable choice for the I-scale already referred to, then the locus for the first section will be a circular arc which in Fig. 6 is plotted between rays ϕ_0 and ϕ_1 (points K and L). We know that the locus for the second section of the line must be another circular arc, say, $\overline{MN}$, between the rays ϕ_2 ϕ_3, and, furthermore, that the current through both terminals of the inductance Z_L must be the same. This fact is sufficient to determine the position of point M on ray ϕ_2 by plotting a parallel to the X-axis through L; knowing thus M, we can complete the locus.

Fig. 7 gives the locus for the case treated in Fig. 4. The locus consists again of two circular arcs. The second arc is located by the condition that the voltage on both sides of the shunt capacitance must be the same.

Finally, Fig. 8 gives the solution for the problem dealt with in Fig. 3. The locus for the second section can here no longer be a circle if that for the first one has been made a circle (as $Z_{02} \neq Z_{01}$), and as we do not wish to change the current scale in accordance with this change of characteristic impedance. So we plot for this section the U-circular arc PQ and the I-circular arc RS separately, as we did in Fig. 5. These circles allow us to construct the elliptic arc LM. For the completion of the diagram we need actually only its end point M, which, incidentally, must fall on ray ϕ_4, as the locus for the third section must start at ϕ_4 (this means that it would have been sufficient to plot only the U-arc or the I-arc). The circular arc, $\overline{MN}$, for the third section completes the locus.

The examples given should be sufficient to show the handling of the diagram when dealing with analogous cases.

In view of its practical usefulness we shall also give an example of its application to the case of a short-circuited line. Then we have

$$|Z_i| = Z_0 \cdot \tan\psi \text{ and } |Y_i| = Y_0 \cdot \cot\psi \qquad (4)$$

—i.e., we shall read now the impedance on a vertical scale and the admittance on a horizontal scale.

A problem of practical importance is to find the length of line, which tunes exactly to anti-resonance with a given capacitance (e.g., the internal capacitance of a valve oscillator).*

Its solution is illustrated in Fig. 9. Starting at B, we lay off on the admittance axis the admittance Y_c of the given capacitance. The angle ψ formed

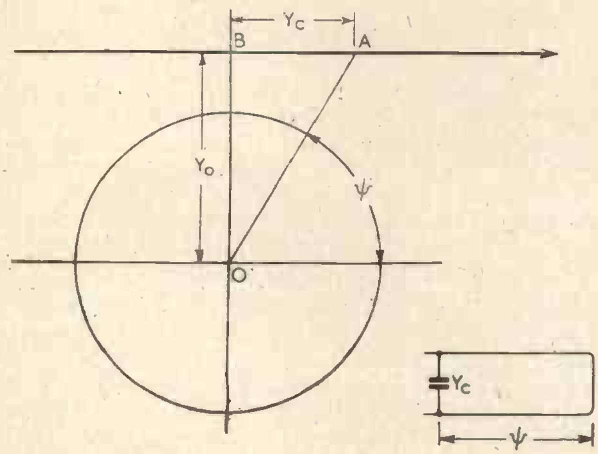

Fig. 9.

by the "ray" OA gives then the electrical length of the line required. If the valve leads are not of negligible length they constitute a transmission line of a characteristic impedance, Z_0', different from that (Z_0) of the line used for tuning (usually $Z_0' > Z_0$). This change in characteristic impedance could be quite easily allowed for in the diagram. We would start by laying off Y_c on the Y_0'-axis, add the angle ψ' possessed by the lead section and then transfer to the Y_0-axis in order to read off the required angle ψ.

* M. R. Gavin, "Triode Oscillators for Ultra-Short Wavelengths" (*Wireless Engineer*, Vol. 16, 1939, p.287.)

II. The "Crank" Diagram

This diagram gives the voltage and current vectors along a loss-less transmission line, if we know these values for one point of the line.

It is based on the resolution of the current and voltage distribution along the line into a forward

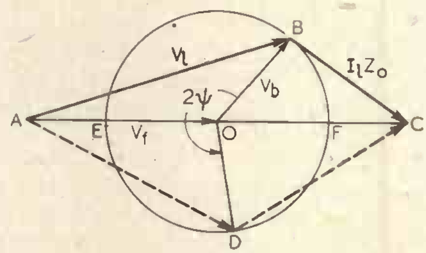

Fig. 10.

and backward travelling wave. As the same basic idea has been used in the graphical method described in the Editorial of the May, 1943, issue of this Journal, the following description of this diagram should be adequate.

The vectors appearing in this diagram (Fig. 10) are all voltage vectors. The current vectors with which we have to deal are all converted into representative voltage vectors by multiplication with Z_0, the characteristic impedance of the line; for shortness we shall continue to speak of them as "current" vectors.

If the voltage and current vectors are known for any one point of the line the diagram is constructed as follows (Fig. 10).

The voltage vector $V_l = \overline{AB}$ and the "current" vector $I_l \cdot Z_0 = \overline{BC}$ are joined as shown. Point O is found midway between A and C and a circle is drawn around O which passes through B. This circle—together with the "base" points A and C—is the locus for all the current and voltage values which are possible along the line.

For instance, at a point of the line which is ψ electrical degrees closer to the load, the new voltage vector will have the magnitude AD and the new "current" vector will have the magnitude DC where D is found by progressing anti-clockwise along the circle by an angle 2ψ. To obtain the true instantaneous position of these vectors we have to rotate the diagram by an angle ψ in opposition to the previous step, 2ψ.

The proof of this proposition follows readily—on considerations given in detail in the Editorial mentioned—if one recognises in $\overline{AO}$ the vector V_f of the forward travelling wave and in $\overline{OB}$ the vector V_b of the backward travelling wave. (The sum, $\overline{AB}$, of these two vectors is evidently the total line voltage, and their difference, $\overline{BC}$, the total line "current".; the angle, 2ψ, is the relative advance of the backward wave against the forward travelling wave as we move ψ electrical degrees closer towards the load.)

The advantage of the diagram of Fig. 10 is that the movement of one point in connection with the two base points gives us all the voltage and current values which we require. Such a circular locus is valid for every homogeneous section of the line. If we meet in passing along the line lumped impedances of any kind connected in series or in shunt we can take these into account by making corresponding additions to the last voltage or current value shown in the diagram—i.e., by a corresponding displacement of either A or C. The locus for the next line section is then a new circle simply drawn with either of the base points shifted to a new position.

Such considerations lead to a solution of the same matching problem, which was dealt with in Prof. Howe's Editorial. (Matching of a load to a transmission line by means of a reactive shunt placed in the neighbourhood of the load.) In

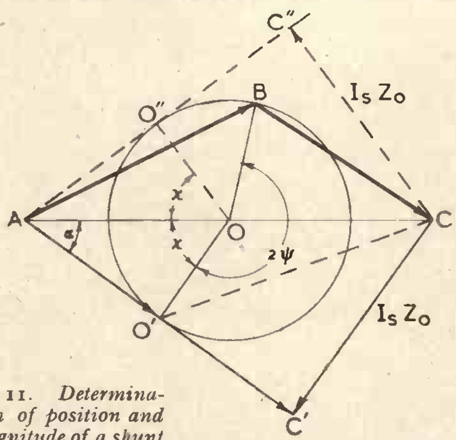

Fig. 11. *Determination of position and magnitude of a shunt which matches a load (taking "current" $\overline{BC}$ at voltage $\overline{AB}$) to a line of characteristic impedance Z_0.*
ψ or $\psi + \chi$ = electrical distance of shunt from load; CC' or CC'' = current taken by shunt.

terms of the present interpretation this solution requires that the current taken by the shunt shifts the base point, C, to a new position, C', which is so situated that the new midpoint, O', coincides with the last point reached in the circular locus. In this case the radius of the new locus will be zero, and there will then be no standing wave left in the new section. If the shunt is loss-less the shift, CC', will have to be normal to the direction of the voltage vector at the shunt position. The solution (found by placing a tangent from A to the circle) is illustrated in Fig. 11.

III. Relations between the two Diagrams

Though the two diagrams here described are obtained by different lines of approach they are not unrelated.

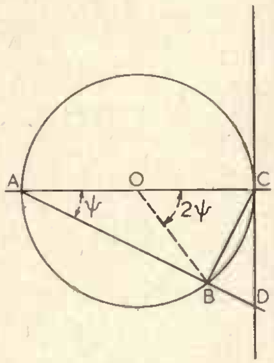

Fig. 12.

In the case of a line with pure standing waves the locus of the "crank" diagram becomes a circle over the base points, AC, as diameter (Fig. 12). In this figure C corresponds to a point with zero current—e.g., to an open-circuited end. We notice that a point, B, on the locus (corresponding to a point of the line ψ electrical degrees closer to the generator end) could in this case be located directly by the angle ψ with its apex at A. The admittance of the open-circuited line cut at this point has the magnitude

$$|Y_i| = \frac{1}{Z_0} \cdot \frac{\overline{CB}}{\overline{AB}}$$

We need now only invert the diagram, with A as centre of inversion, so that the circular locus changes into the straight line passing through CD, in order to arrive at a diagram which is geometrically similar to that shown in Fig. 4.* The triangle, ACD, of the inverted figure is similar to the triangle ABC, and we have

$$\tan \psi = \frac{\overline{CD}}{\overline{AC}} = \frac{\overline{CB}}{\overline{AB}} = Z_0 \cdot |Y_i|$$

in accordance with eqn. (2) of Section I.

In a recent paper read before the Institution of Electrical Engineers, Professor Willis Jackson and Dr. L. G. H. Huxley described two charts which are closely related to the diagrams discussed in this article.

* Fig. 12 shows the diagram of Fig. 4 upside down; if we completed the process of "electrical" inversion, by forming its image in the X-axis. the diagram would also find its correct position.

The "cartesian" form of their chart is obtained if we invert not only the circle shown in Fig. 12, but all the other crank circles which can be drawn inside this largest crank circle, and all the radii passing through O.

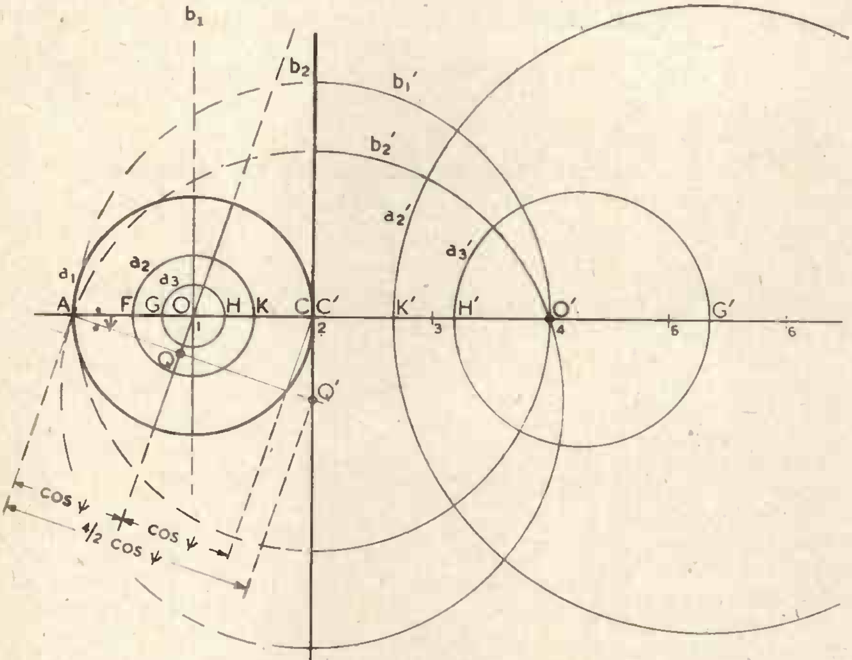

Fig. 13.

The process is illustrated in Fig. 13. The radius of the largest crank circle is there assumed to be unity, the radii of the other crank circles shown are ¼ and ½. The centres of the circles b_1' and b_2' into which the radial lines b_1 and b_2 are transformed are seen to lie on the vertical line through C.

The significance of these transformed diagrams follows from Fig. 14. There we have drawn inside the largest crank circle two loci marked $\beta =$ constant and $|Z_i| =$ constant (for these loci correspond to combinations of line voltage and current either of constant phase difference or of constant ratio of magnitudes). The first of these loci passes through the centre of inversion (A), and also through C. It is therefore inverted into a straight line passing through C, and it is easily seen that the angle between this line and the horizontal axis of the diagram also equals β. The second of these loci is converted into another circle, the midpoint of which is best found by writing down the coordinates of the points R and S at which the original locus intersects the horizontal axis. If $|Z_i| = \lambda Z_0$

then $\overline{AR} = 2\dfrac{\lambda}{1+\lambda}$ $\quad \overline{AS} = 2\left[\dfrac{-\lambda}{1-\lambda}\right]$

Therefore

$$\overline{AR'} = \frac{4}{2}\left[\frac{1+\lambda}{\lambda}\right] \qquad \overline{AS'} = -\frac{4}{2}\left[\frac{1-\lambda}{\lambda}\right]$$

and $\frac{1}{2}[\overline{AR'} + \overline{AS'}] = 2$

Hence the midpoint of the new circle coincides with C and the radius is

$$\overline{AR'} - \overline{AC} = 2/\lambda\,;$$

it need not be calculated, as it can be found by drawing the line ATT'.

It thus follows that the "cartesian" chart gives us the vector of the input admittance. As the loci drawn inside the crank circle can also be interpreted as loci of input admittance, the cartesian chart can also be used as a chart of input impedance; we need only change the line-angle numbers by ± 90 deg.

The second chart contained in the paper referred to is readily identified with our series of crank circles, i.e., it is an inversion of the cartesian form. If we draw on the latter a net of vertical and horizontal lines, corresponding to loci of constant ohmic or reactive input admittance, then we fill by the inversion process the area of the largest crank circle with two additional sets of circular loci (orthogonal to each other) which all pass through A and touch each other there. This is done in the chart of the paper, but needs here no further illustration.

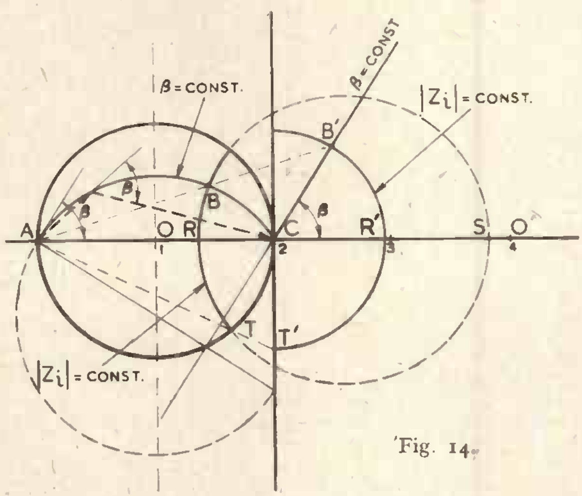

Fig. 14.

TRANSMISSION LINE THEORY *

In Terms of Propagation Characteristics and Reflection Coefficients

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I.

(Radio Department, National Physical Laboratory)

ABSTRACT. The paper gives a systematic presentation of the theory of terminated transmission lines in terms of the propagation characteristics of the lines and the reflection-coefficients of the terminations, starting with the attenuated wave as the basic fact. It is presented in this form for comparison with the usual description in terms of impedances and hyperbolic functions, and it is considered to have some advantages in respect of simplification of formulae and clearness of physical significance.

It is pointed out, incidentally, that the reflection coefficient of a line termination may in some cases slightly exceed unity in magnitude.

Certain limitations of the conception of impedance at very high frequencies, particularly in relation to methods of measurement, are emphasised. It is suggested, in fact, that at very high frequencies the only property of a termination which can be determined with certainty is its reflection coefficient when associated with a particular line.

1. Object

IN transmission-line theory as usually formulated, certain uniformly distributed constants are assigned to the lines, and it is deduced that any periodic electrical condition will be propagated along them as an exponentially attenuated wave. The effects of various kinds of termination are then derived as the result of the formal evaluation of certain undetermined constants and are expressed as more or less complicated formulae in terms of hyperbolic functions. These formulae are not particularly convenient for computation or analysis and moreover they lack what the writer has always regarded as a very desirable feature, that is, a clear and direct physical interpretation. They are not, as a rule, presented in a form which brings out what is, from the practical point of view, the essential feature of any such termination, namely its effect on the waves which are conveyed to it by the transmission lines, the nature and extent of the reflection or absorption of such waves by the termination. The tendency, in fact, is to describe the whole behaviour in terms derived from, and in many respects more appropriate to, ordinary uniform current circuits. There are, of course, some notable exceptions to this general comment. Chipman, for example [1], has described the theory of his measurement circuit in terms of reflection coefficients and propagation constants, and in his recently published book, Hartshorn [2] has emphasised this aspect of the subject. The writer, however, knows of no comprehensive and systematic treatment of the whole subject in these terms. Such a treatment is attempted here. There is, of course, nothing original in it. Indeed it is essentially a return to the analytical methods used in some of the earliest work in this field. (See, for example, Section XLIII of Vol. II of Heaviside's Electrical Papers.) It has, however, given the writer a clearer insight into the subject, and it may be a convenience to other workers to have the matter presented throughout in these terms for comparison with the theory in its more familiar form.

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

2. Basic Assumptions

It is assumed that a sine wave alternating current represented by a vector

$$i = \hat{i}\,\epsilon^{j\omega t} \qquad \text{(1)}$$

is propagated along open or concentric transmission lines of infinite length in the manner represented by

$$i = i_0\epsilon^{-\gamma x}$$

$$\text{where } \gamma = \alpha + j\beta \qquad \text{(2)}$$

and i_0 is a rotating vector which is constant with respect to x, being in fact the value of i when $x = 0$.

The potential difference v between the lines is clearly given as a function of x by

$$-\frac{\partial i}{\partial x} = Yv \qquad \text{(3)}$$

where $Y = G + jB$ is the transverse admittance per unit length. γ and Y are constant complex numbers (or vector operators) which are characteristic of the given transmission line.

In the theory as usually presented, the above results are shown to be a consequence of the assignment of certain uniformly distributed resistive and reactive characteristics to the lines. For the relatively simple case of infinite lines, they could probably be derived directly from the general field equation. For present purposes, this type of propagation is assumed as the basic fact, and it will be shown later that it implies uniformly distributed resistive and reactive characteristics in the lines. The objective of the present paper is, however, primarily practical, and it is not proposed to discuss the fundamental assumptions with any thoroughness.

The complex number γ will be referred to as the propagation constant. The component α is known as the attenuation factor. β is usually known as the wavelength constant, since from (2) it follows that the wavelength λ of the current and voltage waves on the lines is $2\pi/\beta$; ω/β is clearly the velocity of propagation along the lines—it might be called the characteristic velocity.

3. Propagation on Terminated Lines

Consider the system shown in Fig. 1. From (2) and (3)

$$i = i_0\epsilon^{-\gamma x} \quad \ldots \quad (4)$$

$$v = \frac{\gamma}{Y} i_0\epsilon^{-\gamma x} \quad \ldots \quad (5)$$

Putting i_1 and v_1 for the current and voltage at the input end,

$$i_1 = i_0 \quad \ldots \quad (6)$$

$$v_1 = \frac{\gamma}{Y} i_0 \quad \ldots \quad (7)$$

Also $v_1 = e - Z_1 i_1 \quad \ldots \quad (8)$

$$\therefore \quad i_0 = \frac{e}{Z_1 + \gamma/Y} \quad \ldots \quad (9)$$

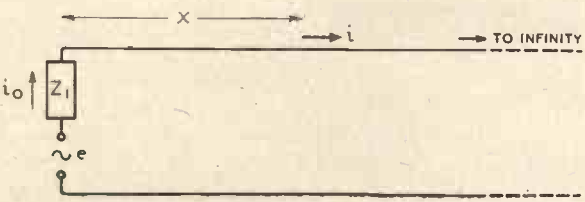

Fig. 1.

This shows, as is otherwise obvious, that the quantity γ/Y is of the nature of an impedance. It is, in fact, the impedance presented by an infinite length of the given transmission line. It is characteristic of the line and is obviously identified with the quantity commonly called the characteristic impedance, and usually written as Z_0. Thus

$$i = \frac{e}{Z_0 + Z_1}\epsilon^{-\gamma x} \quad \ldots \quad (10)$$

and $$v = \frac{Z_0}{Z_0 + Z_1} e\,\epsilon^{-\gamma x} \quad \ldots \quad (11)$$

Now suppose that when the quasi-stationary condition represented by (10) and (11) has been established, the transmission line is suddenly terminated at a point distant l from the source of the waves by a conductor or network as shown in Fig. 2. The current wave cannot travel beyond this point, and must therefore be either absorbed

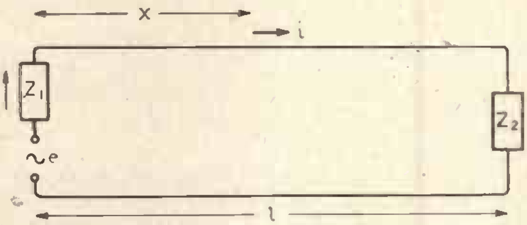

Fig. 2.

or reflected or partly absorbed and partly reflected. All these possibilities are covered by assigning to the termination a reflection coefficient represented by the complex number

$$\rho_2 = |\rho_2|\,\epsilon^{j\theta_2} \quad \ldots \quad (12)$$

which represents a change of amplitude and of phase in the reflected as compared with the incident wave. Calling the incident wave w_0, the introduction of the termination will give rise to a reflected wave w_1, which in turn will be reflected by the input termination, with coefficient ρ_1, giving a further forward wave w_2. This process will continue until a new quasi-stationary condition is established, when the current at any point x can be represented as the sum of two infinite series of forward and reversed waves, i.e.

$$i = (w_0 + w_2 + \ldots) + (w_1 + w_3 + \ldots) \quad (13)$$

The magnitudes of these successive waves are readily determined as follows:

$$w_0 = i_0\epsilon^{-\gamma x} \quad \ldots \quad (14)$$

The first reversed wave will be of the form

$$w_1 = A\epsilon^{\gamma(x-l)} \quad \ldots \quad (15)$$

with the boundary condition at $x = l$

$$w_1 = \rho_2 w_0 \quad \ldots \quad (16)$$

that is $A = \rho_2 i_0\epsilon^{-\gamma l} \quad \ldots \quad (17)$

and $w_1 = \rho_2 i_0\epsilon^{-\gamma 2l}\epsilon^{\gamma x} \quad \ldots \quad (18)$

In this way it is found that

$$w_{2n} = i_0\epsilon^{-\gamma x}(\rho_1\rho_2\epsilon^{-\gamma\cdot 2l})^n;\ n = 0, 1, 2, \text{etc.} \quad (19)$$

$$w_{2m+1} = \rho_2 i_0\epsilon^{-\gamma 2l}\epsilon^{\gamma x}(\rho_1\rho_2\epsilon^{-\gamma 2l})^m;\ m = 0, 1, 2, \text{etc.} \quad \ldots \quad (20)$$

Thus $$i = i_0(\epsilon^{-\gamma x} + \rho_2\epsilon^{-\gamma 2l}\epsilon^{\gamma x})\sum_0^\infty(\rho_1\rho_2\epsilon^{-\gamma 2l})^n \quad \ldots \quad (21)$$

that is $i = i_0 \dfrac{\epsilon^{-\gamma x} + \rho_2 \epsilon^{-\gamma 2l} \epsilon^{\gamma x}}{1 - \rho_1\rho_2 \epsilon^{-\gamma 2l}}$ .. .. (22)

This formula shows that all the forward waves combine into a single forward wave and similarly for the reversed waves. It is also interesting to note that the effect of the summation is merely multiplication by the constant operator

$$(1 - \rho_1\rho_2\epsilon^{-\gamma 2l})^{-1}$$

Thus, the form of the current distribution, which is of the type

$$i = a\epsilon^{-\gamma x} + b\epsilon^{\gamma x} \quad .. \quad .. \quad .. \quad (23)$$

is determined wholly by the first forward and reflected waves, and only these need be considered in finding the way the total resultant varies along the length of the system.

From (3) (and (9)

$$v = v_0 \frac{\epsilon^{-\gamma x} - \rho_2\epsilon^{-\gamma 2l} \epsilon^{\gamma x}}{1 - \rho_1\rho_2\epsilon^{-\gamma 2l}} \quad .. \quad .. \quad (24)$$

where $v_0 = \dfrac{Z_0 e}{Z_0 + Z_1}$ .. .. (25)

4. The Reflection Coefficients in Terms of the Terminal Impedances

From (22) and (24) and (25)

$$v = \frac{Z_0}{Z_0 + Z_1} e \frac{\epsilon^{-\gamma x} - \rho_2\epsilon^{-\gamma 2l}\epsilon^{\gamma x}}{1 - \rho_1\rho_2\epsilon^{-\gamma 2l}} \quad .. \quad (26)$$

$$i = \frac{1}{Z_0 + Z_1} e \frac{\epsilon^{-\gamma x} + \rho^2\epsilon^{-\gamma 2l}\epsilon^{\gamma x}}{1 - \rho_1\rho_2\epsilon^{-\gamma 2l}} \quad .. \quad (27)$$

Therefore

$$v_2 = \frac{Z_0}{Z_0 + Z_1} e\, \epsilon^{-\gamma l} \frac{1 - \rho_2}{1 - \rho_1\rho_2\, \epsilon^{-\gamma 2l}} \quad .. \quad (28)$$

and $i_2 = \dfrac{1}{Z_0 + Z_1} e\, \epsilon^{-\gamma l} \dfrac{1 + \rho_2}{1 - \rho_1\rho_2\epsilon^{-\gamma 2l}}$ .. (29)

But $v_2 = Z_2 i_2$ .. .. (30)

$\therefore \quad Z_2 = Z_0 \dfrac{1 - \rho_2}{1 + \rho_2}$ .. .. (31)

or $\rho_2 = \dfrac{Z_0 - Z_2}{Z_0 + Z_2}$ .. .. (32)

Similarly $\rho_1 = \dfrac{Z_0 - Z_1}{Z_0 + Z_1}$ .. .. (33)

Thus (26) and (27) can be expressed in terms of Z_0 and the reflection coefficients only, that is,

$$i = \frac{e}{2Z_0}(1 + \rho_1) \frac{\epsilon^{-\gamma x} + \rho_2\epsilon^{-\gamma 2l}\epsilon^{\gamma x}}{1 - \rho_1\rho_2\epsilon^{-\gamma 2l}} \quad .. \quad (34)$$

$$v = \frac{e}{2}(1 + \rho_1) \frac{\epsilon^{-\gamma x} - \rho_2\epsilon^{-\gamma 2l}\epsilon^{\gamma x}}{1 - \rho_1\rho_2\epsilon^{-\gamma 2l}} \quad .. \quad (35)$$

These are the basic formulae for terminated transmission lines.

5. Energy Relationships

If $\quad i = \hat{\imath}\, \epsilon^{j\omega t}$ .. .. .. (36)

and $\quad v = \hat{v}\, \epsilon^{j(\omega t - \phi)}$ .. .. .. (37)

be rotating vectors representing the current and potential difference associated with a given conductor, the mean rate of energy consumption in the given conductor is $IV \cos \phi$. Using vector notation, this can be expressed as half the scalar product $(i \,.\, v)$ of the vectors i and v.

Consider an element δx of a transmission line carrying current and voltage waves i and v. The change of potential along the element is $(\partial v/\partial x)\delta x$, and the power consumption is given by half the scalar product of this and the current i. In the same element there is a change of i given by $(\partial i/\partial x)\delta x$. There is therefore a current of this magnitude flowing transversely from the one conductor to the other, that is in the direction of the potential difference v, and associated with a power consumption given by half the scalar product of v and $(\partial i/\partial)\delta x$. Thus

$$\delta P = \tfrac{1}{2}\left(i \,.\, \frac{\partial v}{\partial x}\delta x + v \,.\, \frac{\partial i}{\partial x}\delta x\right) \quad .. \quad .. \quad (38)$$

and in the limit

$$\frac{\partial P}{\partial x} = \tfrac{1}{2}\left(i \,.\, \frac{\partial v}{\partial x} + v \,.\, \frac{\partial i}{\partial x}\right) \quad .. \quad .. \quad (39)$$

$$= \tfrac{1}{2}\frac{\partial}{\partial x}(i \cdot v) \quad .. \quad .. \quad .. \quad (40)$$

Therefore $\quad \partial P = \tfrac{1}{2}\, \partial\, (i \cdot v)$ .. .. .. (41)

and the power consumption in a length of the line between x_1 and x_2 is

$$P = \tfrac{1}{2}\int_{x_1}^{x_2} \partial(i \cdot v) = \tfrac{1}{2}\Big[\ (i \cdot v)\ \Big]_{x_1}^{x_2} \quad .. \quad (42)$$

Further, since the power can be regarded as being transmitted along the line, the power dissipated in any section, e.g. between x_1 and x_2, can be regarded as the difference between the power entering at x_1 and leaving at x_2. It follows that $\tfrac{1}{2}\,(i.v.)$ measures the rate at which energy is *transmitted* across the normal plane at x. It further follows that for given values of i and v, this will be a maximum when i and v are in phase. It will be shown later that this condition obtains when there is no reflection at the receiving end.

As an application of the above formulae, consider the case of an infinite line excited by an electromotive force e in series with an impedance Z_1. Then from (10) and (11).

$$i = \frac{\epsilon^{-\gamma x}}{Z_0 + Z_1} e \quad .. \quad .. \quad .. \quad (43)$$

$$v = \frac{Z_0\epsilon^{-\gamma x}}{Z_0 + Z_1} e \quad .. \quad .. \quad .. \quad (44)$$

Then $\frac{1}{2}(i \cdot v) = \frac{R_0}{|Z_0 + Z_1|^2} \epsilon^{-2\alpha x} \frac{\hat{e}^2}{2}$ .. .. (45)

The space rate of dissipation of power is

$$\frac{\partial P}{\partial x} = \frac{R_0}{|Z_0 + Z_1|^2} \frac{\hat{e}^2}{2} - 2\alpha\epsilon^{-2\alpha x} \quad .. \quad .. \quad (46)$$

and the total power dissipated in the line is

$$\left[\tfrac{1}{2}(i \cdot v)\right]_0^\infty = -\frac{R_0}{|Z_0 + Z_1|^2} \frac{\hat{e}^2}{2} \quad .. \quad (47)$$

which is also, as it must be, the input power to the line at $x = 0$.

6. The Distributed Constants of the Line.

From (23) it follows that in general

$$\frac{\partial^2 i}{\partial x^2} = \gamma^2 i \quad .. \quad .. \quad .. \quad (48)$$

Also, from (3) and (9) $-\frac{\partial i}{\partial x} = \frac{\gamma}{Z_0} v$ .. (49)

Thus $\frac{\partial P}{\partial x} = \frac{1}{2}\left(i \cdot \frac{\partial v}{\partial x} + v \cdot \frac{\partial i}{\partial x}\right)$ .. .. (50)

can be put in the form

$$\frac{\partial P}{\partial x} = \tfrac{1}{2}\left\{(i \cdot \gamma Z_0 i) + (v \cdot \frac{\gamma}{Z_0} v)\right\} \quad .. \quad (51)$$

But $i \cdot \gamma Z_0 i = \hat{\imath}^2 \times$ real part of γZ_0 .. (52)

and $v \cdot \frac{\gamma}{Z_0} v = \hat{v}^2 \times$ real part of γ/Z_0 .. (53)

Thus it appears that the real part of γZ_0 is of the nature of a uniformly distributed resistance per unit length of the line, and that the real part of γ/Z_0 is of the nature of a uniformly distributed shunt conductance.

A similar argument about the so-called "imaginary power" (derived from $i.\ jv$) shows that the imaginary parts of γZ_0 and γ/Z_0 must be interpreted as uniformly distributed reactance and susceptances per unit length of the line.

Putting, therefore, $\gamma Z_0 = R + jx$ .. (54)

and $\gamma/Z_0 = G + jB$ .. .. .. (55)

(51) becomes $\frac{\partial P}{\partial x} = \frac{1}{2}(R\,\hat{\imath}^2 + G\hat{v}^2) = RI^2 + GV^2$

the physical significance of which is immediately obvious.

Also $\gamma^2 = (R + jX)(G + jB)$ .. .. (56)

and $Z_0{}^2 = \frac{R + jX}{G + jB}$ .. .. .. (57)

showing, as was to be expected, that the assumed type of propagation implies a uniform distribution of resistive and reactive characteristics along the line. In this formulation, however, they appear as coefficients of the dissipated energy and the stored or oscillating energy, magnetic and electric. It is suggested that these are more satisfactory conceptions than those of uniformly distributed inductance and capacitance.

As far as the practical applications of transmission lines are concerned, however, no great interest attaches to these distributed constants as such, since the behaviour of the lines can be completely described in terms of the characteristic complex constants γ and Z_0 and the reflection coefficients of the terminations. It is only in relation to the design and construction of lines that they are of importance, the application being the control of the values of Z_0 and γ and the minimisation of the parasitic term α.

7. The Nature of the Reflection Coefficient

It has been shown that a termination of impedance Z connected to a line of characteristic impedance Z_0 has a reflection coefficient ρ given by

$$\rho = \frac{Z_0 - Z}{Z_0 + Z} \quad .. \quad .. \quad .. \quad .. \quad (58)$$

It is necessary, however, to call attention to a number of implicit assumptions here—or rather to note certain limitations in the application of this formula.

In the first place, it cannot be assumed that with a line of characteristic impedance Z'_0 the reflection coefficient would necessarily be

$$\rho' = \frac{Z'_0 - Z}{Z'_0 + Z} \quad .. \quad .. \quad .. \quad (59)$$

This will only be true if Z is independent of Z_0, i.e. if there are no interactions between the termination and the line other than those taken account of in the formula, a condition which cannot be satisfied in all cases, particularly at very high frequencies.

Again, it will only be true if Z_0 is independent of Z, or more generally expressed, if the assumptions made with regard to the nature of the line and the propagation along it remain valid as the termination is approached. This point is very clearly made by Heaviside (Electrical Papers, Vol. II, p. 124). "Every theory that ever was made is more or less a paper theory; we must simplify the real conditions to make a theory workable. Now a theory may very closely represent reality (when pursued into numerical detail) through a wide range, and yet go quite wrong at extremes. The justification for making the constants of the circuit independent of its length is that the length is an enormous multiple of the distance between the wires. But if we terminate the circuit somewhere, it is no longer true that the permittance and the inductance per unit length are constants near and at the termination." He goes on to point out that departures from this theory are likely to be considerable only in the immediate neighbourhood of the termination, and moreover that "if the transfer of energy between the circuit and the terminal apparatus be considerable, we may wholly disregard the fact that the circuit changes its nature as the termination is approached."

There is in addition the fundamental difficulty which again becomes acute at very high frequencies, of specifying exactly what is meant by Z. In fact it may be stated that Z is only definite and determined in relation to a given mode of connection to the line. For example, it will be shown later that a length l of line terminated with a reflection coefficient ρ will give, at its input terminals, a reflection coefficient ρ' where

$$\rho' = \rho\epsilon^{-\gamma 2l} \quad \ldots \quad (60)$$

Thus, the mere connection of leads to a terminating impedance may produce a considerable change, at least in phase, of the reflection coefficient, or otherwise expressed, the reflection coefficient, and therefore the apparent value of impedance deduced therefrom, may depend materially on the precise length and arrangement of connecting leads.

It is important to note that these difficulties and limitations are not associated with the reflection coefficient as such, but only with values of impedance deduced from them. Fortunately, it is the reflection coefficient that matters in most cases, and this is in fact the quality that is directly measured in most line measurements. Thus the difficulties are essentially connected with the transference of impedances from one line to another of different physical and electrical constants. This is the basis of the argument for the standardisation of lines and cables (and terminations if possible) as a means of facilitating measurement and design in transmission line systems. In fact, it may be found, particularly at very high frequencies, that behaviour consistent with the simple theory will only be found in the case of terminations which consist of the terminal element itself associated with a certain minimum length of the line with which it is to be used, this length being sufficient to cover the end-effects referred to in the passage quoted from Heaviside.

With the above reservations in mind, we can now consider the nature of the reflection coefficient and its dependence on Z_0 and Z.

Putting

$$Z = |Z|\epsilon^{j\theta}; \quad Z_0 = |Z_0|\epsilon^{j\theta_0}; \quad \rho = |\rho|\epsilon^{j\phi} \quad (61)$$

$$\rho = \frac{1 - \eta\,\epsilon^{j(\theta-\theta_0)}}{1 + \eta\,\epsilon^{j(\theta-\theta_0)}}; \quad \eta = \left|\frac{Z}{Z_0}\right| \quad \ldots \quad (62)$$

and

$$|\rho|^2 = \frac{(1+\eta^2) - 2\eta\cos(\theta-\theta_0)}{(1+\eta^2) + 2\eta\cos(\theta-\theta_0)} \quad \ldots \quad (63)$$

Now θ can have any value, positive or negative, numerically equal to or less than $\pi/2$. If θ_0 could have the same range of values, $\theta - \theta_0$ could have any value between 0 and $\pm\pi$. Thus, for $\theta = \pi/2$ and $\theta_0 = -\pi/2$.

$$|\rho| = \frac{1+\eta}{1-\eta} \quad \ldots \quad \ldots \quad \ldots \quad (64)$$

and since η may be equal to 1, $|\rho|$ could have any value up to infinity.

In fact, however, θ_0 is limited to a range of very small positive and negative values. If the limits of θ_0 are $\pm\alpha_0$ then the limits of $\theta - \theta_0$ are $\pm(\pi/2 + \alpha_0)$ and the corresponding limits of $|\rho|^2$ are

$$|\rho|^2 = \frac{\dfrac{1+\eta^2}{2\eta} \pm \sin\alpha_0}{\dfrac{1+\eta^2}{2\eta} \mp \sin\alpha_0} \quad \ldots \quad (65)$$

Now $(1+\eta^2)/2\eta$, η being a positive number, has a lower limit of 1 when $\eta = 1$. Thus the maximum value of η is

$$|\rho|^2 = \frac{1+\sin\alpha_0}{1-\sin\alpha_0} \quad \ldots \quad \ldots \quad (66)$$

or

$$|\rho| \approx (1 + \alpha_0) \quad \ldots \quad \ldots \quad \ldots \quad (67)$$

It is interesting to note that $|\rho|$ can actually exceed unity. It is a point of academic rather than practical interest, for α_0 is usually less than 0.02 radians, and for most practical purposes Z_0 can be regarded as a pure resistance and the limits of $|\rho|$ as 0 and 1.

It should be noted that if $Z_0 = R_0$, $|\rho|$ is unity for any purely reactive termination, while the phase angle ϕ is zero for any purely resistive termination.

Finally, ρ is zero when $Z = Z_0$.

8. Deductions from the General Formulae for Terminated Lines

The general formulae are

$$i = \frac{e}{2Z_0}(1+\rho_1)\frac{\epsilon^{-\gamma x} + \rho_2\epsilon^{-\gamma 2l}\epsilon^{\gamma x}}{1 - \rho_1\rho_2\epsilon^{-\gamma 2l}} \quad \ldots \quad (68)$$

$$v = \frac{e}{2}(1+\rho_1)\frac{\epsilon^{-\gamma x} - \rho_2\epsilon^{-\gamma 2l}\epsilon^{\gamma x}}{1 - \rho_1\rho_2\epsilon^{-\gamma 2l}} \quad \ldots \quad (69)$$

(*a*) For $\rho_2 = 0$, i.e. $Z_2 = Z_0$.

$$i = \frac{e}{2Z_0}(1+\rho_1)\,\epsilon^{-\gamma x} \quad \ldots \quad \ldots \quad (70)$$

which obviously represents a single forward wave only.

(*b*) For $\rho_1 = 0$, i.e. $Z_1 = Z_0$.

$$i = \frac{e}{2Z_0}(\epsilon^{-\gamma x} + \rho_2\epsilon^{-\gamma 2l}\epsilon^{\gamma x}) \quad \ldots \quad \ldots \quad (71)$$

which represents a single reflection only, at the receiving end.

(*c*) *The reflection-coefficient of a terminated line.* For $Z_1 = 0$, i.e. for $\rho_1 = 1$.

$$i = \frac{e}{Z_0}\frac{1 + \rho_2\epsilon^{-\gamma 2l}}{1 - \rho_2\epsilon^{-\gamma \gamma l}} \quad \ldots \quad (72)$$

i.e. the sending-end impedance Z_s is given by

$$Z_s = Z_0\frac{1 - \rho_2\epsilon^{-\gamma 2l}}{1 + \rho_2\epsilon^{-\gamma 2l}} \quad \ldots \quad (73)$$

i.e.

$$\frac{Z_s}{Z_0} = \frac{1 - \rho_s}{1 + \rho_s} \quad \ldots \quad (74)$$

where $\rho_s = \rho_2\epsilon^{-\gamma 2l}$ .. .. .. (75)

This shows how the phase-angle of a reflector can be controlled by the addition of a suitable length of line. As already pointed out, it emphasises the fact that the mere connection of leads to a reflector may materially affect its reflection coefficient.

From (73) it follows that the reflection coefficients of closed and open lines of length l (i.e. $\rho_2 = 1$ and -1 respectively) are

$$\rho_{sc} = \epsilon^{-\gamma 2l} \quad \text{and} \quad \rho_{s0} = -\epsilon^{-\gamma 2l} \quad \ldots \quad (76)$$

9. Resonance

For lines with zero impedance at the input end, the sending end current is

$$i_1 = \frac{e}{Z_0}\frac{1 - \rho\epsilon^{-\gamma 2l}}{1 + \rho\epsilon^{-\gamma 2l}} \quad \ldots \quad (77)$$

Let ρ, the terminal reflection coefficient, be due to a capacitance C, that is

$$\rho = \frac{Z_0 - 1/j\omega c}{Z_0 + 1/j\omega c} \approx \frac{R_0 - 1/j\omega c}{R_0 + 1/j\omega c} = \epsilon^{2j\theta} \quad (78)$$

where $\tan\theta = 1/\omega CR_0$ .. .. .. (79)

$$\therefore \quad i_1 = \frac{e}{Z_0}\frac{1 + \epsilon^{-2\alpha l}\epsilon^{-j(2\beta l - 2\theta)}}{1 - \epsilon^{-2\alpha l}\epsilon^{-j(2\beta l - 2\theta)}} \quad \ldots \quad (80)$$

The condition of resonance is

$$\epsilon^{-j(2\beta l - 2\theta)} = 1 \quad \ldots \quad (81)$$

that is $2\beta l - 2\theta = 2n\pi$; $n = 0, 1, 2$, etc. (82)

or $\beta l - \theta = n\pi$

If C is ∞, giving in effect a short-circuited end,

$$\theta = 0, \text{ and } \beta l = \frac{2\pi l}{\lambda} = n\pi, \text{ or } l = \frac{n\lambda}{2} \quad \ldots \quad (83)$$

In general, however,

$$l = \frac{n\lambda}{2}\left(1 + \frac{\theta}{n\pi}\right); \tan\theta = \frac{1}{\omega CR_0} = \frac{\lambda}{2\pi c_0}\frac{1}{CR_0} \quad \ldots \quad (84)$$

where c_0 is the characteristic velocity of the lines. Thus, for given values of λ and C, l can readily be calculated. A case which sometimes arises, however, is that l is fixed and C variable, and it is desired to find the tuning range for a given variation of C. This problem is solved as follows. From (82), for $n = 1$

$$\frac{2\pi l}{\lambda} = \pi + \theta \quad \ldots \quad (85)$$

$$\tan\frac{2\pi l}{\lambda} = \tan\theta = \frac{\lambda}{2\pi l}\frac{1}{c_0}\frac{l}{CR_0} \quad \ldots \quad (86)$$

that is

$$\frac{1}{c_0}\frac{l}{CR_0} = \frac{2\pi l}{\lambda}\tan\frac{2\pi l}{\lambda} \quad \ldots \quad (87)$$

Thus, for a given value of C, $2\pi l/\lambda$ can be determined from a curve showing $\theta \tan\theta$ as a function of θ.

The quarter-wave or voltage resonance conditions can be similarly derived. From

$$v_2 = e\,\epsilon^{-\gamma l}\frac{1 - \rho}{1 - \rho\epsilon^{-\gamma 2l}} \quad \ldots \quad (88)$$

v_2 being the voltage across the receiving end termination. Assuming this to be a small capacitance C,

$$v_2 = e\,\epsilon^{-\gamma l}\frac{1 - \epsilon^{j2\theta}}{1 - \epsilon^{-2\alpha l}\epsilon^{-j(2\beta - 2\theta)}} \quad \ldots \quad (89)$$

and as a function of $2\beta l - 2\theta$ this reaches a maximum when $2\beta l - 2\theta = 2n\pi$ $n = 0, 1, 2$ .. (90)

that is $\beta l - \theta = n\pi$

If C is very small, approximating to an open circuit, $\theta \to \pi/2$

and

$$\beta l = (2n + 1)\pi/2 \quad \text{or} \quad l = (2n + 1)\frac{\lambda}{4} \quad (91)$$

For the general case, the equation (84) and (87) apply, but the values of θ are in the region of $\pi/2$, whereas in the former case they are in the region of zero.

10. Measurement of the Characteristic Constants

The quantities γ and Z_0 are usually determined by measuring the input impedance of a length of the line with the far end open and short-circuited. From (74), the sending-end impedances Z_{sc} and Z_{so} corresponding to the closed and open ends are

$$Z_{sc} = Z_0\frac{1 - \epsilon^{-\gamma 2l}}{1 + \epsilon^{-\gamma 2l}} \quad \ldots \quad (92)$$

and

$$Z_{so} = Z_0\frac{1 + \epsilon^{-\gamma 2l}}{1 - \epsilon^{-\gamma 2l}} \quad \ldots \quad (93)$$

whence

$$Z_{sc}\,Z_{so} = Z^2_0 \quad \ldots \quad (94)$$

The detail of this method is described in various publications, and it is well known that there are advantages in selecting certain special cases for measurement. A continuous variation of l is not in general practicable, at least in the case of concentric lines, but the various special conditions suitable for measurement can be obtained by variation of frequency. For example, when

$$2\beta = (4n + 1)\pi/2, \ n = 0, 1, 2 \ldots$$

$$Z_{so} = Z_0 \frac{1 - j\epsilon^{-2al}}{1 + j\epsilon^{-2al}} \quad \ldots \quad (95)$$

and $$Z_{sc} = Z_0 \frac{1 + j\epsilon^{-2al}}{1 - j\epsilon^{-2al}} \quad \ldots \quad (96)$$

Neglecting the small phase angle of Z_0

$$|Z_{sc}| = |Z_{so}| = |Z_0| \quad \ldots \quad (97)$$

and $$Z_{sc}/Z_{so} = \epsilon^{j4\theta}; \ \tan \phi = \epsilon^{-2al} \quad \ldots \quad (98)$$

and similarly for $2\beta l = (4n - 1)\pi/2$.

Another useful special case is

$$2\beta l = (2n + 1)\pi \quad \ldots \quad (99)$$

when $$Z_{so} = Z_0 \frac{1 - \epsilon^{-2al}}{1 + \epsilon^{-2al}} \quad \ldots \quad (100)$$

and $$Z_{sc} = Z_0 \frac{1 + \epsilon^{-2al}}{1 - \epsilon^{-2al}} \quad \ldots \quad (101)$$

that is Z_{so} and Z_{sc} are substantially non-reactive. Z_{so} being very small and Z_{sc} being very large. Similarly for $2\beta l = (2n - 1)\pi$.

11. Measurement of the Reflection-Coefficients of Termination

In the previous section, it was indicated how the characteristics of transmission lines can be determined by measurements on lines having terminations of known reflection-coefficients, i.e. $+1$ and -1, corresponding to closed and open ends. Similarly, the characteristics of a transmission line being known, either by measurement as described, or by calculation, the reflection-coefficients of given terminations can be determined by measurements on terminated lines. Many such methods of measurement have been described in current literature. Their success or otherwise is largely a matter of experimental, and particularly constructional, detail. Such detail will not be discussed here. For present purposes it will be sufficient to describe the essential features of these methods in terms of the theory as here presented:
(4)

(a) *Voltage Distribution Methods.*

The variation of voltage along the length of a transmission line terminated by a reflector depends only on the propagation constant of the line and the reflection-coefficient of the termination. The measurement of this variation is therefore the most direct method of measuring an unknown reflection coefficient.

In (35) put $\rho_1 = 1, \ \rho_2 = |\rho| \, \epsilon^{j\theta}, \ \gamma = j\beta$ (that is, the attenuation is assumed to be negligible) and let x be the distance measured from the unknown termination. Then

$$v = \frac{e\,\epsilon^{-j\beta}(l - x)}{1 - |\rho|\epsilon^{-j(2\beta l - \theta)}} \left\{1 - |\rho|\epsilon^{-j(\beta \cdot 2x - \theta)}\right\} \quad (102)$$

The quantity in brackets varies between maximum and minimum values $1 + |\rho|$ and $1 - |\rho|$, and $|\rho|$ can therefore be determined from

$$\left|\frac{v \text{ max.}}{v \text{ min.}}\right| = \frac{1 + |\rho|}{1 - |\rho|} \quad \ldots \quad (103)$$

The maximum and minimum values correspond to values of x given by

$$\beta \cdot 2x - \theta = \pi, 3\pi, \text{etc.} \quad \ldots \quad (104)$$

and $$\beta \cdot 2x - \theta = 0, 2\pi\ 4\pi, \text{etc.}$$

and θ can obviously be determined by comparison of these values of x with those corresponding to a short-circuit termination. Alternatively, if v be measured at

$$x = \lambda/4 \text{ and } \lambda/2$$

$$\frac{v(\lambda/4)}{v(\lambda/2)} = \frac{1 + |\rho|\,\epsilon^{j\theta}}{1 - |\rho|\,\epsilon^{j\theta}} \quad \ldots \quad (105)$$

that is $$\left|\frac{v(\lambda/4)}{v(\lambda/2)}\right|^2 = \frac{a + \cos\theta}{a - \cos\theta}; \quad a = \frac{1 + |\rho|^2}{2|\rho|} \quad (106)$$

from which θ can be determined, $|\rho|$ being known.

An advantage of this method is that only relative values of voltage are required. An obvious practical requirement is that the method of measurement of relative voltage shall not affect the distribution of voltage.

(b) *Resonance Methods*

Most of the other methods now in use may be described as resonance methods, since they depend on the resonance properties of lines. In general the phase angle of the reflection coefficient of an unknown termination is determined from the changes in line-length required to give resonance, as compared with a short circuit or other known termination, while the magnitude of the reflection coefficient is deduced from the width of the resonance curve as a function of line length.

The current resonance method described by Chipman [1] may be taken as an example. Essentially the arrangement is that shown in Fig. 2, with Z_1 as the unknown impedance and Z_2 as a termination embodying a current measuring element, e.g. a thermo-junction. The length l is variable.

From (34), with $x = l$.

$$i_2 = \frac{e}{2Z_0}(1 + \rho_1)(1 + \rho_2)F(l) \quad \ldots \quad (107)$$

where $F(l) = \frac{\epsilon^{-\alpha l}\epsilon^{-j\beta l}}{1 - a\epsilon^{j\theta}}$ .. .. .. (108)

$$a = |\rho_1\rho_2|\epsilon^{-2\alpha l} \quad \rho_1 = |\rho_1|\epsilon^{j\theta_1}$$
$$\theta = 2\beta l - (\theta_1 + \theta_2) \quad \rho_2 = |\rho_2|\epsilon^{j\theta_2} \quad \text{.. .. (109)}$$

As a function of l, $F(l)$ is a maximum when

$$\theta = 2\beta l - (\theta_1 + \theta_2) = 2n\pi \;;\; n = 1, 2, \text{ etc.} \quad \text{.. .. (110)}$$

for example for $n = 1$,

$$\frac{\theta_1 + \theta_2}{2} = \beta l - \pi \quad \text{.. .. .. (111)}$$

As in all resonance methods, it is very desirable that the line used should be of very low resistance, i.e., of negligible attenuation. In what follows it will be assumed that the variation of $\epsilon^{-\alpha l}$, and therefore of a, with l, is not significant.

At resonance, when $\theta = 0$, or $2n\pi$.

$$|F(l)|^2 \propto 1/(1 - a)^2 \quad \text{.. .. .. (112)}$$

and for any other value of l, i.e. of ϕ

$$|F(l)|^2 \propto 1/(1 + a^2 - 2a \cos \phi) \quad \text{.. (113)}$$

Thus, if l is adjusted to the usual " half-resonance " condition,

$$1 + a^2 - 2a \cos \phi = 2(1 - a)^2 \quad \text{.. .. (114)}$$

i.e. $$\cos \phi = \frac{(1 + a^2) - 2(1 - a)^2}{2a} = f(a) \quad \text{.. (115)}$$

There will be two values of l on either side of any resonance condition for which the above relation is satisfied, e.g. for $n = 1$.

$$2\beta l_1 - (\theta_1 + \theta_2) = 2\pi + \psi \quad \text{.. .. (116)}$$
$$2\beta l_2 - (\theta_1 + \theta_2) = 2\pi - \psi \quad \text{.. .. (117)}$$

i.e. $$\psi = \beta \delta l \quad \text{.. .. (118)}$$

and $$\cos \psi = \cos \phi = \cos(\beta \,.\, \delta l) = f(a) \quad \text{.. (119)}$$

Thus $f(a)$ and therefore a, are known in terms of δl, and $(\theta_1 + \theta_2)$ and $|\rho_1\rho_2|\epsilon^{-2\alpha l}$ are therefore known. By repeating the process with $|\rho_1|$ and θ_1 equal to 1 and 0 respectively, with the short-circuited, $|\rho_2|$ and θ_2 are known.

12. Conclusion

It has been shown that the approximate theory of the behaviour of terminated transmission lines can be fully described in terms of propagation characteristics and reflection coefficients. It is not suggested that this will in all cases lead to simplification of analysis. In fact it seems likely that cases in which a multiplicity of line circuits is involved are somewhat more simply analysed in terms of effective line and termination impedance. It is suggested, however, that in general the treatment described has considerable practical and theoretical advantages, one of which is enhanced clearness of physical interpretation.

The work described above was carried out as part of the programme of the Radio Research Board, to whom this paper was first circulated as a confidential report in February, 1941. It is now published by permission of the Department of Scientific and Industrial Research.

The author wishes to acknowledge his indebtedness to Mr. Ward of the Radio Department, National Physical Laboratory, in connection with that part of the paper which deals with the interpretation of impedance measurements by means of lines and the case for the standardisation of line impedances.

REFERENCES

[1] Chipman, R. A., " A Resonance Curve Method for the Absolute Measurement of Impedance at Frequencies of the Order of 300 Mc/s." *Journ. Applied Phys.*, 1939, Vol. 10, p. 27.

[2] Hartshorn, L., " Radio Frequency Measurements." Chapman and Hall, 1940.

[3] Jones, T. I., " The Measurement of the Characteristics of Concentric Cables at Frequencies between 1 and 100 Mc/s." *Journ. I.E.E.*, 1942, Vol. 89, Pt. 111, p. 213.

[4] Hempel, W., " On the Application of a Line as a Measuring Instrument in the Region of Decimetre Waves." *E.N.T.*, 1937, Vol. 14, p. 33

The Industry

INSULATING materials are now being made by De La Rue Insulation Ltd., with offices at Brighton Road, Sutton, Surrey, and showrooms at Imperial House, Regent Street, London, W.1. The new firm absorbs the Laminated Division of De La Rue Plastics Ltd., Hammans Industries Ltd., and its associated companies.

A new catalogue of the measuring and test instruments manufactured by Taylor Electrical Instruments Ltd., 419–424, Montrose Avenue, Slough, Bucks, has been produced, and will be sent on request.

Particulars have been received of the " Microtimer," an instrument for the accurate measurement of short time intervals, made by R. K. Dundas Ltd., The Airport, Portsmouth. The range is from 1 millisecond to 1 second, and possible applications include the timing of relays, contact breakers, fuses and stroboscopes. The operation of the instrument involves the measurement of the voltage developed across a condenser after charging at constant current for the period of time to be measured.

A handbook outlining the principles underlying the design of components with rubber-to-metal bonded joints has been prepared by the T. B. Andre Rubber Co. Ltd., Kingston By-Pass, Surbiton, Surrey. The title is " Elastomeric Engineering " and copies will be sent on request.

A joint meeting of the North Western Branch of the Institution of Electronics and the Manchester and District Branch of the Institute of Physics will be held at the Reynolds' Hall, College of Technology, Manchester, at 7 o'clock on April 14th, when Dr. D. Gabor will lecture on " Electron Beams." Tickets are available from Leslie F. Berry, 14, Heywood Avenue, Austerlands, Oldham.

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.

"Temperature Coefficient of Capacitance"

To the Editor, "Wireless Engineer."

SIR,—I was much interested in the article in the February issue of *Wireless Engineer*, entitled "Temperature Coefficient of Capacitance," by W. Schick.

The author's most striking contribution to the subject is summarised in his Fig. 3, showing a temperature/time curve relating to a typical test. This is completed within fifteen minutes, operations being between 20° C. and 50° C. The conventional method is to take hours over a test of this nature, in order to ensure a steady thermal state ; the process is made practical by testing a number of condensers at a time, using a selector switch ; if a high-grade ceramic switch is not available, there is no reason for not mounting it outside the chamber.

But to revert to the author's procedure, more details of his results would be appreciated ; in particular, comparison of results obtained on the same specimen, on a 15 minutes and, say, a ten-hour basis would be of value. His claim that stability of capacitance indicates thermal equilibrium may not necessarily apply ; one can only say that the rate of change with time of the capacitance is then equal to zero, which is not the same thing owing to "overshooting."

The author repeatedly falls into the not uncommon error that the temperature coefficient of a beat oscillation is independent of the temperature coefficient of the beating frequencies, if each beating frequency has the same temperature coefficient. This is true for zero beat only. In general, if two oscillations of frequency p and q produce a difference component $(p \sim q)$, and if k (with a suitable suffix) denotes the temperature coefficient, then

$$k_{(p \sim q)} = \frac{p\,k_p - q\,k_q}{p - q},$$

so if $k_p = k_q$,

$$k_{(p \sim q)} \begin{cases} = k_p - k_q & \text{if } p \neq q \\ = 0 & \text{if } p = q \end{cases}$$

In any case, providing stability is not too poor, this is immaterial here as the author followed the procedure of checking against a standard condenser, not shown in his Fig. 2.

The choice of the oscillator circuits is not, therefore, of great importance except inasmuch as loss factor and changes therein may affect frequency ; information on this point, with special reference to the transitron circuit would be appreciated.

With regard to the "correction" for lead inductance, this is surely unnecessary for the temperature coefficient, providing $\frac{\omega_0}{2\pi}$, the frequency of resonance (lead and condenser), is well above $\frac{\omega}{2\pi}$, the frequency of measurement. The correction term $\left(1 - \frac{\omega^2}{\omega_0^2}\right)$ must then be applied equally to the capacitance and the capacitance change, and cancels out in arriving at the coefficient.

In any case, may I point out that the circuit arrangement for measuring minute capacitance changes need hardly be more complicated than that of a well-shielded radio-frequency bridge ; in fact, if the latter is of a really good commercial type and provided with a stable supply and a sensitive detector such as a well-screened set, the following method may be adopted : it rests on the equivalence of the series and the parallel $C - R$ circuits (Fig. 1) providing the following relations are observed at the frequency $\frac{\omega}{2\pi}$:

$$\left.\begin{aligned} R_s &= \frac{R_p}{1 + Q^2} \\ C_s &= C_p \cdot \frac{1 + Q^2}{Q^2} \end{aligned}\right\} \quad \ldots \quad (1)$$

where the "goodness factor" $Q = \omega\, C_p\, R_p = 1/\omega C_s R_s$. Hence, if $Q < 1$, C_p will be magnified into C_s, $\left(1 + \frac{1}{Q^2}\right)$ times, and similarly for small changes ΔC_p in C_p. However, as both C_p and ΔC_p are equally magnified, the degree of magnification of ΔC_p is limited by practical considerations.

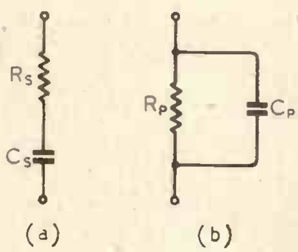

Fig. 1.

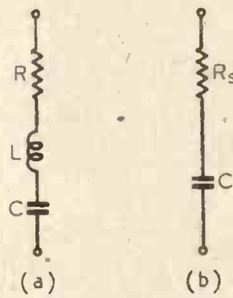

Fig. 2.

This difficulty may be overcome by resonating the test capacitor of capacitance C with a coil of inductance L. Fig. 2 (a) shows a simple series circuit represented by series parameters, R being contributed by the coil and condenser and an additional resistor if required. The equivalent series circuit of Fig. 2 (b) has the parameters

$$\left.\begin{aligned} R_s &= R \\ C_s &= C/1 - \omega^2 LC \end{aligned}\right\} \quad \ldots \quad (2)$$

while the equivalent parallel circuit, Fig. 1 (b), has the capacitance

$$C_p = \frac{C\,(1 - \omega^2 LC)}{(1 - \omega^2 LC)^2 + (\omega RC)^2}$$

on substituting eqn. (2) in (1).

An increment ΔC in C will thus increase C_p to

$$C_p + \Delta C_p = \frac{(C + \Delta C)\,(1 - \omega^2 L\overline{C + \Delta C})}{(1 - \omega^2 L\,\overline{C + \Delta C})^2 + (\omega C R_s)^2}$$

In practice, L, C and ω would be adjusted to resonate approximately ; hence, if

$\Delta C \ll C$, and $(1 - \omega^2 LC) \ll 1$, then

$C_p \doteqdot 0$ and

$$\Delta C_p \doteqdot -\frac{\Delta C}{(\omega C R_s)^2} \doteqdot -\Delta C \cdot Q^2$$

Since 0.1 pF may readily be observed with a standard air condenser, capacitance changes of 5.10^{-6} pF ($= 5.10^{-18}$ F) are detectable. (For $Q \doteqdot 316$).

Thus, if the test condenser be placed in the position of C in Fig. 2 (a) and this forms one arm of the bridge (Fig. 3), the latter would be completed by the equal ratio arms R_b R_b, say, and a finely adjustable resistance arm R_N,

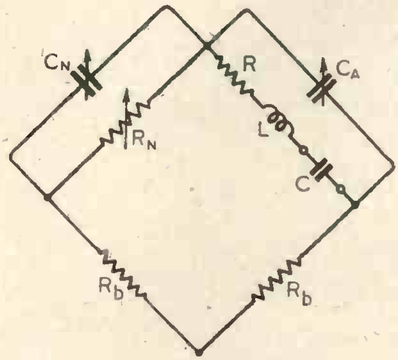

Fig. 3.

preferably of constant inductance. The balancing condenser C_N could always be maintained across this arm by providing a small auxiliary condenser C_A across the " unknown " arm.

As an example of the procedure, C_N and C_A would be set to be equal, at some convenient value; balance would then be obtained by adjusting R_N and, say, a second auxiliary condenser across C.

Changes in C will then require a readjustment of both C_N and R_N; then $\Delta C = \frac{C_N - C'_N}{Q^2}$, C'_N being the new setting for balance.

While the slight readjustment required on R_N is an inconvenience, this will provide a check on changes in the loss factor. Moreover, the only addition required to convert almost any simple r.f. bridge to that of Fig. 3, is a very stable and fairly " high Q " coil. The values of C and Q are obtained from the initial balance adjustment, and another one with L shorted. The self capacitance of L may be made harmless, or corrected for in the usual way.

The scheme of providing a standard reference condenser for the initial value of C can still be employed.

T. J. Rehfisch.

London, E.C.1.

Transversely Deflected Electron Beams

To the Editor, " Wireless Engineer "

Sir,—Dr. Gabor, in his article entitled " Power Loss in Deflecting Condensers " (*Wireless Engineer*, March, 1944, Vol. 21, No. 246, pp. 115 to 116), has added yet another to the many attempts made to calculate the power needed transversely to deflect a beam of electrons.

Dr. Gabor's equation (10) for the " transit power " used to deflect the beam can become negative; that is, according to him, the beam can give power to, as well as take power from, the deflecting field. In the circumstances posed by Dr. Gabor, this involves a violation of the principle of conservation of energy. Corresponding errors exist in his " trajectory " and " beam " equations.

To make this clear, consider an electric field in a three dimensional space bounded by conductors. The field must satisfy the Laplacian equation of a scaler potential if it is an electrostatic or quasi-stationary field; or, alternatively, it must satisfy the equations for a vector field having curl, if it is due to " standing " electromagnetic waves in a resonant cavity.

Assume co-ordinates x, y and z; let a beam of electrons enter in the x direction at a point A on the boundary of the field, and leave the field at a point B also on the boundary. It will be assumed that apertures, which are too small appreciably to affect the field, exist in the conductors to allow of this. The existence of the field will involve the flow of energy in the boundary conductors; i.e. in a circuit external to the field. If, as postulated, the field is totally enclosed, loss by radiation will not exist.

Let N electrons when they enter the field at the point A have components of entrance velocity v_{xo}, v_{yo}, v_{zo}. When the electrons exit from the field (and the point of exit will vary with the trajectory of the electrons within the field), the exit components of velocity can be denoted by v_x, v_y, v_z.

The system can be looked upon as having three " channels " of energy flowing in or out of it, from or to the external world. Energy flowing into the system will be looked upon as positive; energy flowing out of it, as negative.

First energy channel : The beam supplies to the system an amount of energy—

$$W_{\text{in}} = \tfrac{1}{2}Nm\,(v_{xo}^2 + v_{yo}^2 + v_{zo}^2) \qquad (1)$$

This flow of energy is always positive.

Second energy channel : The beam when it leaves the system withdraws energy equal to—

$$W_{\text{out}} = \tfrac{1}{2}Nm\,(v_x^2 + v_y^2 + v_z^2) \qquad (2)$$

I am not in this analysis considering the return of electrons to the field from outside; therefore this energy is always negative.

Third energy channel : The energy flowing into or out of the system to or from the beam via the field is equal to

$$W_o = W_{\text{out}} - W_{\text{in}} \qquad (3)$$

from the principle of conservation of energy.

Since this energy flows via the field, and the field itself is maintained by the flow of current in the conducting boundaries, a transmission loss of energy W_R is involved in this third energy channel. It may be referred to as the " resistive loss " of the system, because it is the loss due to the resistance of the boundary conductors or deflection circuit.

The total energy which is transmitted through the third channel is then

$$W = W_o + W_R \qquad (4)$$

The system, therefore, can deliver energy to the outside world via this channel (i.e. via the field and deflecting circuit) only if W_o is negative and numerically greater than W_R.

These relationships are not satisfied by Dr. Gabor's analysis.

We may note, in passing, that the beam always requires a positive input of energy transversely to deflect it if v_{yo} and v_{zo} are zero, because the beam " deflection energy " can be written

$$W_b = \tfrac{1}{2}Nm\,(v_y^2 + v_z^2) \qquad (5)$$

Two specific applications of the above equations are relevant :—

Case 1 : Let the field in the cavity be such that

$$v_x = v_{xo}$$
$$v_z = v_{zo} = 0$$
$$v_{yo} = 0$$
$$v_y \neq 0$$

that is; the electric force in the field is everywhere transverse to the x axis, and the beam enters along that axis. This infers a vector field having curl; it cannot be a lamellar field having scalar potential. An example of such a field is that within a cubical resonant cavity at the lowest frequency of resonance. The variation of field intensity across one dimension of the cube is a sine function.

We have

$$W_{in} = \tfrac{1}{2}Nm\, v_{xo}^2 = \tfrac{1}{2}Nm\, v_x^2$$

The field will tend transversely to deflect the beam in the y direction. The exit velocity v_y will vary according to the transit time of the electrons within the field, the magnitude of the field, and the frequency at which it is varying.

We have

$$W_{out} = \tfrac{1}{2}Nm\,(v_{xo}^2 + v_y^2)$$

Equation (3) then becomes—

$$W_o = \tfrac{1}{2}Nm\, v_y^2$$

and, because it is positive, indicates a flow of energy into the system. Clearly, if the field conditions and trajectory of the beam are such that at a given instant v_y = zero, W_o will be zero also at that instant; but there is no possibility of the flow of energy W_o becoming negative. If it did, we would be taking more energy out of the system than is being put into it.

From (4) the total flow of energy into the system via the third channel is $W = \tfrac{1}{2}Nm\, v_y^2 + W_R$ and is positive.

Case 2 : Consider next a field which has an x-directed as well as a y-directed component, then clearly v_x will not equal v_{xo}. This field is not necessarily a vector field having curl; it may be a lamellar field possessing scalar potential.

The equations for such a field, and for the trajectories and exit velocities of the beam, are often intractable from the analytical standpoint. The energy relations are, however, just as simple as before. Consider the case where v_x has a value which is not equal to v_{xo}; and v_{yo} and v_{zo} are both zero,—then :

$$W_{in} = \tfrac{1}{2}Nm\, v_{xo}^2$$

and

$$W_{out} = \tfrac{1}{2}Nm\,(v_x^2 + v_y^2 + v_z^2)$$

This latter energy may be less than W_{in}; hence from equation (3) W_o is then negative, and the beam will give out this amount of energy. The energy W travelling out of the system as a whole via the field is obtainable from (4).

Dr. Gabor's analysis : Dr. Gabor's equations (8), (9) and (10) are recognisable as those of a purely imaginary system consisting of a pair of deflection plates of infinite extent in the x as well as in the z direction. The beam can never leave such a system (unless it strikes the deflection plates, which is not contemplated in Dr. Gabor's analysis), and therefore no energy is taken from the system. The deflecting circuit losses are neglected, and no radiation losses are considered. Therefore, referring to my equations, W_{out} is non-existent, and W_R is neglected. According to these assumptions, the movement of the electrons between the imaginary infinite deflection plates can involve no energy, and any " transit power " conception is meaningless. Moreover, no such field as this one exists, or can exist, in nature. The equations are therefore meaningless on this account also.

Dr. Gabor, however, interprets these equations by stating that they represent an actual " deflection condenser," having plates of length L such that, using his terminology, $L = \dfrac{\tau v_o}{\omega}$, subject to a slight correction in the length L. This is untrue, for the field equations will not be satisfied if the field is suddenly terminated at L, or in its neighbourhood. A field cannot abruptly terminate. It must end according to the properties of fields. If it does so, the conditions of my Case (2) above will hold, and (again using Dr. Gabor's symbols), $\dfrac{\omega L}{v_o}$ cannot be put equal to τ, as Dr. Gabor puts it, because the velocity of the beam will change in passing through the field. In fact this change of velocity is the direct measure of the flow of energy W_o from the beam and out of the system, and cannot possibly be ignored because it is itself a measure of the very " transit power " Dr. Gabor is endeavouring to compute. In fact, using my symbols and neglecting transverse velocities, $W_o = \tfrac{1}{2}Nm\,(v_x^2 - v_{xo}^2)$. In short, any transference of energy from the electron beam to the circuit can clearly only occur by causing the beam to exit with less than its entrance velocity. Any addition to its velocity represents a flow of energy into the system and is added to that of the beam.

On the other hand, if the field visualised by Dr. Gabor is actually such that v_x is practically equal to v_o (as he in fact assumes), then my Case (1) above applies, and, contrary to Dr. Gabor's equation (10), no energy can be withdrawn via the field. Moreover, Dr. Gabor is wrong if he applies the Laplacian equation for a scalar potential to such a field. This Laplacian can only be applied to a lamellar field having a scalar potential, not to a vector field having curl. Such a field does not exist between the plates of a condenser as the term is usually understood—" deflecting " or otherwise. Dr. Gabor's analysis is therefore meaningless.

An analysis based on the considerations set out in this letter is included in a paper on transversely deflected electron beams which has already been accepted for publication in *Wireless Engineer*. Pending its publication, it may be of interest to quote the following two equations for the specific case of the vector field in a cubical resonant cavity such as that exemplified above in my Case (1). There can, of course, be no general case for a deflection field, because there are an infinite number of electrodes and field configurations which can be used; but in practice, it is found that this particular vector field shape can, by utilising the principles of harmonic analysis, be made to cover a wide range of practical applications.

The expression for the deflection power in this instance is

$$P_d = \frac{4{\cdot}4 \times 10^{14}\, E^2 I_o}{d^2\omega^2}\left[\frac{\dfrac{2\pi}{\omega\tau}}{1 - \dfrac{\pi^2}{\omega^2\tau^2}}\right]^2 \cos^2\frac{\omega\tau}{2}\ \text{(watts)} \quad (6)$$

where τ = the transit time across the resonator. This expression is never negative.

An expression for the ratio of the power used to deflect the beam to the power carried by the beam is

$$\eta_d = \frac{\tan^2\phi_{max}}{2} \quad \ldots \quad (7)$$

where ϕ_{max} is the maximum angle of deflection at which the beam leaves the field. This relationship is of value to the designer. It enables him to find the proportion of total beam power which is used to deflect the beam in terms of the geometry of the valve he is designing.

OWEN HARRIES.

London, S.W.18.

Wireless Patents

A Summary of Recently Accepted Specifications

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

ACOUSTICS AND AUDIO-FREQUENCY CIRCUITS AND APPARATUS

557 083.—Frame aerial with an auxiliary earthing device for reducing noise due to variations induced by the power supply between the chassis of the receiver and earth.

Marconi's W.T. Co. (assignees of L. E. Barton). Convention date (U.S.A.) 25th March, 1941.

AERIALS AND AERIAL SYSTEMS

557 942.—Short-wave aerial, of the closed-loop type, designed to have a broad frequency-response characteristic.

Standard Telephones and Cables (assignees of A. Alford). Convention date (U.S.A.) 12th April, 1941.

DIRECTIONAL WIRELESS

557 359.—Balanced condenser circuit for indicating the approach path in a radio blind-landing system using overlapping beams.

Standard Telephones and Cables; V. J. Terry; and T. F. S. Hargreaves. Application date 14th April, 1942.

557 385.—Radio directional system used, in combination with the earth's magnetic field, to maintain an aircraft on a pre-determined course.

Bendix Aviation Corp. Convention date (U.S.A.) 7th May, 1941.

557 563.—Short-wave radio-navigational system in which the transmitted wave is amplitude modulated with a slight frequency swing, and the received wave is heterodyned at the mean frequency of the swing.

Standard Telephones and Cables; C. W. Earp; and C. E. Strong. Application date 22nd May, 1942.

557 870.—Directional system in which a rotating radio beam is arranged to indicate the approach path, both in elevation and azimuth, to an aeroplane when making a blind landing.

H. Hughes and Son; D. O. Sproule; and A. J. Hughes. Application date 5th June, 1941.

557 903.—Radio-navigational system in which radio beams are transmitted in timed sequence to indicate in azimuth and elevation a blind-landing path for an aeroplane.

H. Hughes and Son; D. O. Sproule; and A. J. Hughes. Application date 5th June, 1941.

RECEIVING CIRCUITS AND APPARATUS

(*See also under Television*)

557 147.—Radio receiver in which the input circuit is constantly varied over a given searching range by a motor which is automatically operated by an incoming signal to keep the circuits in tune.

E. K. Cole and A. W. Martin. Application date 30th June, 1942.

557 155.—Automatic cathode- and grid-biasing arrangement for equalising the currents fed by two valves to a common output circuit.

Standard Telephones and Cables (assignees of R. R. Blair). Convention date (U.S.A.) 18th October, 1941.

557 163.—Preventing disturbances due to voltage fluctuations between the cathode and heating filament of a short-wave mixer valve when the cathode is coupled to an unearthed point.

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

557 225.—Radio telegraph receiver in which the automatic volume control is adjusted during a "marking" period and is held during the succeeding "spacing" period.

Creed and Co. and F. P. Mason. Application date 8th May, 1942.

557 362.—Selective switching arrangement for improving the overall signal-to-noise ratio in an anti-fading system of diversity reception.

Marconi's W.T. Co. and G. T. McDonald. Application date 15th April, 1942.

557 469.—Construction and arrangement of screening cans or hoods for valves or inductance coils.

Re-diffusion; G. B. Ringham; and P. A. Tiller. Application date 17th July, 1942.

557 648.—Preventing fading by a diversity reception system utilising loop and vertical aerials, spaced apart, with general and selective gain-control circuits.

Marconi's W.T. Co. (assignees of G. L. Beers). Convention date (U.S.A.) 30th August, 1941.

557 852.—Selective relay responsive only to definite pulses, such as those used for a radio distress signal.

Standard Telephones and Cables; G. C. Hartley; L. P. Lowry; and F. H. Bray. Application date 4th June, 1942.

557 862.—Visual tuning indicator consisting of an incandescent electric lamp combined with a Thermistor device having a resistance which varies with temperature.

Standard Telephones and Cables and D. M. Ambrose. Application date 5th June, 1942.

557 864.—Radio receiver in which the aerial coupling includes a Thermistor device having a variable temperature-resistance coefficient for the purpose of A.V.C.

Standard Telephones and Cables; C. T. Scully; and L. W. Houghton. Application date 5th June, 1942.

558 003.—Wireless receiver and selective relays for the remote control, say, of a motor target boat.

The British Power Boat Co. and F. P. Parfitt. Application date 18th March, 1942.

558 036.—Valve circuit in which "kinetic grid current" is utilised, say, to detect or convert frequency-modulated signals into equivalent variations in amplitude.

J. A. Sargrove. Application date 28th March, 1942.

558 253.—Push-pull mixing circuit with small input damping for the reception of decimetre waves.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 5th June, 1941.

558 265.—Arrangement of the component parts on the chassis of a set so as to facilitate inspection and repair.

Stratton and Co. and H. A. J. Laughton. Application date 24th June, 1942.

558 266.—Arrangement and assembly of the component parts or units of a set to facilitate the rapid installation or interchange of the equipment, say, from a road vehicle to an aeroplane.

Stratton and Co. and H. A. J. Laughton. Application date 24th June, 1942.

558 311.—Submarine cable system with an auxiliary A.C. source for regulating, from the shore end, the gain of intermediate repeaters.

Standard Telephones and Cables (assignees of M. K. Zinn). Convention date (U.S.A.) 31st October, 1941.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

557 367.—Television scanning circuit in which the deflection coils of the cathode-ray tube form part of a transmission line impedance which is purely resistive to the applied saw-tooth frequency.

The British Thomson-Houston Co. Convention date (U.S.A.) 10th May, 1941.

557 837.—Arrangement of rotating screens or discs for projecting television pictures in solid relief.

J. L. Baird. Application date 4th March, 1942.

557 992.—Optical arrangement for projecting three images side by side on a photo-electric mosaic, for coloured television.

J. L. Baird. Application date 11th July, 1942.

558 163.—Relaxation oscillation generator in which a Thermistor (i.e. a device having a variable temperature coefficient of resistance) is utilised to produce saw-toothed waves of constant slope.

Standard Telephones and Cables; P. K. Chatterjea; and D. M. Ambrose. Application date 19th June, 1942.

558 241.—Preventing distortion effects in a television receiver of the kind in which the picture is viewed from the same face of the fluorescent screen as that traversed by the scanning beam.

Cinema-Television (communicated by C. S. Szegho). Application date 13th August, 1942.

TRANSMITTING CIRCUITS AND APPARATUS

(See also under Television)

557 148.—Valve oscillation generator in which negative transconductance is controlled by a parallel-tuned circuit between anode and cathode, and a series-tuned circuit between anode and grid.

Standard Telephones and Cables (assignees of W. P. Mason). Convention date (U.S.A.) 26th November, 1941.

557 388.—Selective switching and relay device for the remote control of a radio transmitter.

Re-diffusion and J. B. McC. Clifton. Application date 15th May, 1942.

557 507.—Frequency-modulating system in which a fixed phase-shift is included in the feed-back system in order to stabilise the carrier and prevent "drift."

Marconi's W.T. Co. (assignees of E. S. Winlund). Convention date (U.S.A.) 26th September, 1941.

557 889.—Frequency-modulation system in which a transmission line of predetermined electrical length is utilised to multiply a given phase shift.

Marconi's W.T. Co. (communicated by The Radio Corporation of America). Application date 7th July, 1942.

557 984.—Framework for housing a radio transmitter and designed for compact stowage when dismounted.

Marconi's W.T. Co. and F. R. Page. Application date 10th June, 1942.

558 224.—Telegraphic transmitter wherein the output voltage from a keying valve over-rides a separate biasing potential which is independently applied to the control grid of an amplifier valve.

Standard Telephones and Cables and A. J. Maddock. Application date 19th June, 1942.

558 246.—Ganged arrangement of piezo-electric crystals for the local or remote tuning control of a radio transmitter over a wide band of frequencies.

P. Stein. Application date 22nd August, 1942.

558 260.—System of automatic frequency control for telegraphic transmitters utilising one frequency for marking and a different frequency for spacing.

Marconi's W.T. Co. (communicated by The Radio Corporation of America). Application date 12th June, 1942.

SIGNALLING SYSTEMS OF DISTINCTIVE TYPE

557 440.—Signalling system in which a carrier wave of varying frequency is modulated and then passed through frequency-discriminating and "scrambling" circuits to ensure secrecy.

Re-diffussion and P. Adorjan. Application date 7th August, 1942.

557 452.—Multiplex system wherein telephone signals are transmitted on a single side-band, and telegraph signals on the carrier frequency.

S. N. Watson and T. Worswick. Application date 17th April, 1942.

557 670.—Stabilising the operation of a valve oscillation generator which is subject to intermittent short-circuiting, e.g. by switching the load on and off.

Standard Telephones and Cables (assignees of L. A. Meacham). Convention date (U.S.A.) 19th November, 1941.

557 863.—Selective relay including a cold-cathode tube for generating pulsed signals of predetermined duration.

Standard Telephones and Cables and F. H. Bray. Application date 5th June, 1942.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

557 128.—Construction and operation of a frequency-dividing tube utilising a velocity-modulated electron stream.

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

557 242.—Arrangement of the cathode sleeve and mica spacers for the electrode assembly of an electron discharge tube.

Marconi's W.T. Co. (assignees of A. B. Dickenson). Convention date (U.S.A.) 29th April, 1941.

557 287.—Thermionic frequency converter in which a constantly rotating beam of electrons is swept over a series of segmental anodes.

Bendix Aviation Corp. Convention date (U.S.A.) 20th June, 1940.

557 529.—Method of, and apparatus for, applying attachment tabs to the fine filament wires of thermionic valves.

Marconi's W.T. Co. (assignees of B. W. Kinyon). Convention date (U.S.A.) 20th May, 1941.

557 548.—Unitary assembly of the electrodes forming the gun of a cathode-ray tube.

Standard Telephones and Cables (communicated by Western Electric Co. Inc.). Application date 10th April, 1942.

557 735.—Construction of a grid electrode, particularly suitable for securing velocity-modulation effects in an electron discharge tube.
Standard Telephones and Cables (assignees of R. L. Vance). Convention date (U.S.A.) 28th June, 1941.

558 095.—Electron multiplier in which a predetermined capacitance coupling between selected electrodes is ensured by the provision of auxiliary plates mounted inside the tube.
F. J. G. van den Bosch ; H. S. Molyneux-Ffennell ; and Vacuum-Science Products. Application date 13th February, 1942.

558 109.—Electron multiplier in which a normally external coupling or circuit impedance is arranged inside the tube.
F. J. G. van den Bosch ; H. S. Molyneux-Ffennell ; and Vacuum-Science Products. Application date 13th February, 1942.

558 143.—Electron discharge tube in which the electron stream is caused to traverse a set of velocity-modulating electrodes more than once.
Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 6th February, 1942.

SUBSIDIARY APPARATUS AND MATERIALS

557 105.—Rectifier arranged to operate as an "on-off" switch in a circuit carrying radio-frequency currents.
Marconi's W.T. Co. and B. van Ryn. Application date 2nd April, 1942.

557 112.—Rotary frequency converter in which the ratio between input and output can be varied, both in magnitude and frequency, without altering the relative speed of the stator and rotor.
B. Schwarz. Application date 5th June, 1942.

557 135.—Spring-controlled mounting for preventing the subsequent movement, due to vibration, of a preset or trimming condenser.
The Mullard Radio Valve Co. and C. E. Maitland. Application date 27th March, 1942.

557 172.—Series arrangement of cathode-loaded gas-filled relays operating as an impulse counter, or frequency divider.
The British Thomson-Houston Co. (communicated by the General Electric Co.). Application date 6th May, 1942.

557 342.—Wheatstone-bridge circuit including an element whose resistance varies with the applied voltage arranged to develop an alternating or oscillatory current from a D.C. source.
R. J. Stevens. Application date 13th August, 1942.

557 489.—Assemblage and composition of resistance elements having a high temperature coefficient.
Standard Telephones and Cables ; H. Wolfson ; and S. C. Shepard. Application date 19th May, 1942.

557 516.—Means for minimising initial "sputtering" when starting-up a gas-filled rectifier or discharge lamp.
The British Thomson-Houston Co. Convention date U.S.A.) 21st February, 1941.

557 541.—" Thermistor " element with a high temperature coefficient of resistance and fitted with extended arms which serve as a dipole to detect the presence of centimetre waves.
Standard Telephones and Cables ; H. Wolfson ; and S. C. Shepard. Application date 22nd May 1942.

557 559.—Construction and arrangement of a Thermistor device having a high temperature-coefficient of resistance.
Standard Telephones and Cables ; H. Wolfson ; and S. C. Shepard. Application date 22nd May, 1942.

557 615.—Thermionic valve relay adapted to give a remote indication of the presence of moisture, say, in the gap between insulated electrodes.
The British Thomson-Houston Co. ; H. R. Ruff ; and R. F. Weston. Application date 28th August, 1941.

557 704.—Composition of the powdered-iron cores of inductances, particularly for handling frequencies above 3 megacycles.
J. M. Blair. Application date 27th May, 1942.

557 709.—Circuit arrangement of Thermistors, or indirectly-heated devices having a positive or negative temperature-coefficient of resistance, for taking a constant current from a variable source of voltage.
Standard Telephones and Cables and L. W. Houghton. Application date 29th May, 1942.

557 711.—Multi-valve switching circuit to enable several wave forms to be observed simultaneously on a cathode-ray oscillograph.
Standard Telephones and Cables ; E. M. S. McWhirter ; and R. H. Dunn. Application date 29th May, 1942.

557 712.—Inter-coupled triple-valve circuit for generating three-phase high-frequency currents, particularly for testing purposes.
Standard Telephones and Cables ; E. M. S. McWhirter ; and R. H. Dunn. Application date 29th May, 1942.

557 713.—Construction of fixed condensers in which alternate layers are set at right-angles to each other.
Standard Telephones and Cables ; J. A. Leno ; and J. H. Fearon. Application date 29th May, 1942.

557 749.—Process for increasing the magnetic properties, say, of Nickel-aluminium-iron alloys, capable of being hardened by precipitation.
Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 14th October, 1941.

557 801.—Valve circuit comprising a negative-resistance device for amplifying direct or slowly-varying currents.
Standard Telephones and Cables (communicated by International Standard Electric Corporation). Application date 4th December, 1942.

557 838.—Composition and arrangement of the powdered-iron cores for high-frequency inductances.
W. J. Polydoroff. Convention date (U.S.A.) 5th May, 1941.

557 955.—Arrangement for protecting a Thermistor (i.e. a device having a variable temperature coefficient of resistance) from damage due to excessive voltage.
Standard Telephones and Cables (assignees of J. H. Bollman). Convention date (U.S.A.) 26th December, 1941.

558 027.—Static frequency converter or divider, including a non-linear reactance and two conversion paths in out-of-phase relation.
Telephone Manufacturing Co. and B. Drake, Application date 27th August, 1942.

558 114.—Valve holder with upwardly-extending lugs which act as spring clips or contacts.
Carr Fastener Co. and G. Wagstaff. Application date 19th May, 1942.

GOODS FOR EXPORT

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

Abstracts and References

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For the information of new readers it is pointed out that the length of an abstract is not necessarily an indication of the importance attached to the work concerned. An important paper in English, in a journal likely to be readily accessible, may be dealt with by a square-bracketed addition to the title, while a paper of similar importance in German or Russian may be given a long abstract. In addition to these factors of difficulty of language and accessibility, the nature of the work has, of course, a great influence on the useful length of its abstract.

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PROPAGATION OF WAVES

1100. ON THE ENERGY DISTRIBUTION IN THE NEAR FIELD OF ELECTROMAGNETIC RADIATORS, IN PARTICULAR IN FRONT OF DIAPHRAGMS AND REFLECTORS [treated by Acoustical Methods].—Born. (*See* 1193.)

1101. SOME THEOREMS RELATING TO THE EVALUATION OF POTENTIALS AND CHARGES INDUCED ON CONDUCTORS PLACED IN A GIVEN EXTERNAL ELECTRIC FIELD.—G. A. Grünberg. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 10th March 1943, Vol. 38, No. 7, pp. 203–205: in English.) For other work *see* 740 of March.

1102. DEVELOPMENT OF ELECTROMAGNETIC THEORY FOR NON-HOMOGENEOUS SPACES [with Implications regarding Velocity of Light, etc.].—B. Liebowitz. (*Phys. Review*, 1st/15th Nov. 1943, Vol. 64, No. 9/10, pp. 294–301.)

"It is well known that any attempt by usual methods to extend classical electromagnetic theory to non-homogeneous spaces meets with the difficulty of wave equations which contain more than one component of the electromagnetic vectors or potentials. It is shown here that this difficulty can be overcome, so far as deriving separated wave equations is concerned, by introducing a Riemannian space whose line element $ds^2 = h^2 (du_1^2 + du_2^2 + du_3^2)$ is adjusted to the variable inductivity ϵ by means of the formula $h^2 = 1/\epsilon$ . . . The wave equations which are derived have essential singularities both at the origin and at infinity, for any reasonable choice of h . . ." Applied to atomic phenomena, the theory shows that "every atom can conceivably be endowed with a permanent system of electromagnetic wave fields which will not radiate itself away—a conception which was impossible under the old restrictions."

1103. RECTANGULAR & CIRCULAR WAVE-GUIDE NOMOGRAMS.—F. C. Everett. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 24–25: Sept. 1943, No. 9, pp. 86–87.)

1104. AEROANALYSIS [Air Mass & Front Analysis] AND VERY-HIGH-FREQUENCY TECHNIQUES: OUR GROWING KNOWLEDGE OF CONDITIONS IN THE LOWER ATMOSPHERE.—H. M. French. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 11–16 and 102, 104.)

In the series mentioned in 735 of March. Principles of aeroanalysis: radiosonde design: applications to v.h.f. development: forecasting transmitting conditions.

1105. RADIO WEATHER-FORECASTING [System of Observation of Variation in Signal Strength from a Number of V.H.F. Transmitters (F.M. Broadcasting Stations, W.E.R.S. Transmitters, etc.) plotted on Regional Map keyed by means of Rectangular Coordinates].—P. Ferrell, Jr. (*Radio* [New York], Aug. 1943, p. 32 onwards.) Mentioned in 1104, above.

1106. SOME FUNDAMENTAL QUESTIONS IN IONOSPHERIC RESEARCH [True & Apparent Height of the Ionised Layer (and the Calculations of Rawer and of Booker & Seaton): Total & Partial Reflection: the Cloud-like Structure of the Anomalous E Layer].—J. A. W. Zenneck. (*Alta Frequenza*, Oct. 1942, Vol. 11, No. 10, pp. 460–462: summary, from *Forschungen u. Fortschritte*, Jan. 1942.)

1107. POLARISATION OF THE LINES IN THE NIGHT-SKY LUMINESCENCE SPECTRUM AND IN THE SPECTRUM OF NORTHERN LIGHTS.—V. L. Ginsburg. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 20th March 1943, Vol. 38, No. 8, pp. 237–240: in English.) *See* also 1108, below.

1108. ON THE ANOMALIES IN THE POLARISATION OF TWILIGHT.—V. L. Ginsburg. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 30th March 1943, Vol. 38, No. 9, pp. 301–303: in English.)

"Within the last years Khvostikov and others carried out measurements on the polarisation of twilight at the zenith . . . It was found that the dependence of the degree of polarisation upon the height of the sun is no monotonic one, but shows several maxima and minima. The position of these maxima and minima, as well as the rest of details in the shape of the curve, vary according to the day; the first deep minimum, however, lies invariably within the region of 75–100 km. It has been suggested that polarisation anomalies are directly associated with the presence in the stratosphere of ionised layers, and that the decrease in the polarisation of light scattered by these layers is due to a sharp increase in the anisotropy of the ions, as compared to neutral particles. The author finds this interpretation unacceptable": he gives his reasons, among which is the calculation that the light scattered by the ions of the E layer makes up no more than about one ten-thousandth of the total light scattered in this region.

Among the points discussed, "it should be noted that in the course of the twilight there may take place redistribution of density in the atmosphere (pulsating atmosphere), changes in the density gradient [" for instance, the gradient of electron concentration in the F layer is known to vary sharply during twilight. This process may be not only a static one, but a dynamic as well, *i.e.* it may prove to be connected with redistribution of the density of the atmosphere"], air streams, etc. Dynamical processes of this kind must tell upon changes in the polarisation and in the intensity of the light scattered. Moreover, polarisation may be affected by meteoric dust, which may be present in considerable amounts at altitudes around 100–150 km . . . In the course of the day, polarisation processes are strongly dependent on the solar activity and on the conditions of illumination of the given region of earth surface by the sun. There is no reason to suppose that these factors play a less important part during twilight. As the state of the ionosphere is also dependent on solar radiation, the existence of a correlation between polarisation and the state of the ionosphere is quite natural. The rotation of the polarisation plane at high altitudes, which has been observed by Rosenberg, as well as its rotation during solar eclipses, stand in need of special explanation and further experimental study. . . The possibility of the rotation observed being due to fluorescent luminescence of the atmosphere, excited either by solar radiation or by electronic impact, cannot yet be rejected" [" the rotation of the plane of fluorescence polarisation may be due to the influence of the terrestrial magnetic field, and to disturbances of normal illumination conditions (changes in the direction of the sun's rays as a result of refraction, etc.)"].

1109. LIGHT OF THE NIGHT SKY [Hypothesis of Process explaining Excitation & Observed Intensity of Green Radiation and Excitation of the N_2 Bands], *and* NATURE OF ACTIVE NITROGEN.—S. K. Mitra. (*Sci. & Culture* [Calcutta], July 1943, Vol. 9, No. 1, pp. 46–48 : pp. 49–50.)

(i) Chapman's hypothesis based on a three-body collision process is invalidated by the proof that the light of the night sky originates at great heights (much greater than 100 km, and it may be as much as 500 km; Elvey & Farnsworth, 2955 of 1943 and 750 of March), namely in the F region: on account of the extremely low pressure here, three-body collisions must be very rare. The reaction proposed by the present writer is $N_2^+ (X') + O^- \rightarrow N^2$ (excited) $+ O$ (excited): "this is a reaction involving electron transfer, and its efficiency is high if the energy released on recombination is wholly taken up as potential energy of excitation by the reaction products", and it is shown how it would produce the observed results. The possibility is also suggested of an additional, weak reaction in which the products would be $N_2O \rightarrow NO + N$: this would explain the reported (but by no means certain) occurrence of the β and γ bands of NO and the atomic nitrogen line λ3467. Ghosh (1110, below) has estimated the number of transitions $O(^1S_0) \rightarrow O(^1D_2)$ which would occur on the above hypothesis, in a column of 1 cm² cross-section: he finds a value of the order of 6×10^8 transitions per second: "this may be compared with the estimate of 1.8×10^8 per second made by Rayleigh from measurements of the absolute intensity of the green radiation".

(ii) "No satisfactory hypothesis has yet been offered of the nature of active nitrogen. A remarkable feature of active nitrogen is the persistence of the glow, which under favourable circumstances may continue for several hours. Another remarkable fact about active nitrogen is that its spectrum does not show any new lines or bands which could be ascribed to some hitherto unknown modification of nitrogen. It will be shown in the present note that the observed properties of active nitrogen can be satisfactorily explained if active nitrogen is assumed to be the positive ions of nitrogen molecule in the $N_2^+ (X')$ state . . ." The action in a discharge tube is first discussed (a three-body collision process is involved) and then the writer deals with the fact that the production of the after-glow is facilitated by the presence of a little oxygen or of some gas which readily takes up electrons to give negative ions. "The explanation of this is simple: with negative ions (M^-) present, three-body collision is not necessary . . . the process is one of electron transfer similar to that causing the night-sky luminescence described in a separate note" (*see* i, above).

1110. A COMPARISON OF THE VARIATIONS OF NIGHT-SKY LUMINESCENCE AND OF REGION-F ELECTRON DENSITY AT NIGHT.—S. N. Ghosh. (*Sci. & Culture* [Calcutta], Oct. 1943, Vol. 9, No. 4, pp. 170–172.)

Supplementary to Mitra's paper, 1109, above. The writer points out that Mitra's identification of the F region as the luminescent layer might lead to the expectation of a correlation between the night variations of the F-region electron density (as obtained by radio measurements) and the intensity variations of the light of the night sky; whereas in fact there is little similarity, the intensity of the light remaining fairly constant throughout the night and diminishing by only about 20% of its evening value (Elvey, *Astrophys. Journ.*, referred to in 750 of March). He goes on, however, to explain that such a correlation would actually be surprising, since the electron-density variations given by ionospheric measurements are those occurring in the region of maximum ionisation and give no information on the variations of the total number of electrons present in a column of the ionised region: this number, indeed, may quite possibly remain constant, the density at the region of max. ionisation merely increasing owing to the contraction, due to cooling, of the layer as a whole. Moreover, for recombination according to the proposed reaction it is shown that in a vertical column of the ionised region with a parabolic gradient of ion density the decay in the total number of electrons will be far less than the decay in the density in the region of max. ionisation.

The remainder of the paper deals with the calculations mentioned by Mitra, above. At the end, the writer discusses certain abnormal nights on which the evening intensity of the light is much higher than the average, falling later by a large fraction of its evening value (Elvey, *loc. cit.*): if, as is plausible, it is assumed that on such nights the electron density also is abnormally high, the phenomenon fits in with eqn. A, just obtained. On the other hand, "we are not yet in a position to offer any explanation" of certain nights on which the light intensity, after decreasing to a minimum towards midnight, rises again (Elvey, *loc. cit.*)

1111. Absorption Spectrum of N_2 in the Extreme Ultra-Violet.—R. E. Worley. (*Phys. Review*, 1st/15th Oct. 1943, Vol. 64, No. 7/8, pp. 207–224.)

1112. A Note on the Mesotron Temperature Coefficient [and the Results as determined from Spatial-Average & Mass-Average Temperatures and Temperatures *at* Various Levels].—F. A. Benedetto. (*Phys. Review*, 1st/15th Nov. 1943, Vol. 64, No. 9/10, pp. 317–318.) Following on 1887 of 1942.

1113. Intensity of High-Energy Electrons and Photons at 10 000 Feet.—W. E. Hazen. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, p. 187 : summary only.)

1114. The Multiple Production of Secondary Cosmic-Ray Particles in the Lower Atmosphere [Sea Level to 14 000 Feet], *and* Absorption Curve and Production of Slow Cosmic-Ray Protons at Low Altitude.—V. H. Regener. (*Phys. Review*, 1st/15th Oct. 1943, Vol. 64, No. 7/8, pp. 250–252 : pp. 252–253.)

1115. Note on Large Cosmic-Ray Bursts in an Unshielded Ionisation Chamber [found to coincide with Extensive Auger Showers as detected by Geiger–Müller Counters : Largest Burst estimated as originating from Electron or Photon of at least 10^{16} eV Energy at Top of Atmosphere : etc.].—R. E. Lapp. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, pp. 129–130.)

1116. Committee on Coordination of Cosmic-Ray Investigations.—J. A. Fleming. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 215–216.)

1117. A Note on Fluctuations in the Cosmic Radiation observed in Connection with Magnetic Storms [Observations of Forbush, Hess, and others (2942 of 1942, 2064 of 1943 ; ref. " 1 " & 643 of 1942) and Duperier (2279 of 1942, 1374 of 1943) : Writer's Own Results].—S. A. Korff. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 217–218.)

" Such large changes, if real, are obviously important. It is suggested that, as a part of any long-period programme of cosmic-ray investigation, the average cosmic-ray intensity be determined each hour, in order to reveal other such abrupt fluctuations, should they occur."

1118. Aurora, Radio Fade-Out, and Magnetic Storm of August 28th–31st, 1943.—H. T. Stetson : R. G. Ferris. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 251–252.)

1119. Remarkable Auroral Forms, Meanook Observatory, Polar Year, 1932–33.—E. H. Vestine. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 233–236.)

The writer concludes :—" The 28-day interval between the displays of Feb. 26th and March 26th, and the 26-day interval between the displays of March 26th and April 21st, may suggest recurrence of weakly penetrating solar particles from some active area of emission on the Sun. The fluctuations in the display of March 26th are suggestive of rapid oscillations of air in the upper atmosphere, perhaps occasioning the geomagnetic micropulsations accompanying the display, as well as the regular fluctuations of similar period in the luminosity of the auroral arc."

1120. The Properties of Solar Prominences as related to Type.—E. Pettit. (*Sci. Abstracts*, Sec. A, Nov. 1943, Vol. 46, No. 551, p. 211.) For other recent work *see* 3258 of 1943.

1121. Predictions for the Coming Sunspot-Cycle [" beginning Very Probably before 1945 " : likely to be Interesting by reason of Its High Maximum and of the Rapid Increase & Slow Decrease of Spot Numbers (Table 1)].—W. Gleissberg. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, p. 243–244.)

" While the methods of Waldmeier and of Stewart permit us only to predict the remaining course of the *current* spot-cycle from its initial course, my method enables us to predict the behaviour of the *coming* spot-cycle . . ." From Istanbul. A Mount Wilson note on p. 245 mentions that minimum sunspot-activity had not yet been reached in Sept. 1943 ; during the third quarter of 1943, 29 spot-groups were observed, only two of which belonged to the new cycle : *cf.* 3261 of 1943.

1122. Systematic Fluctuations of the Characteristics of Sunspot Cycles.—W. Gleissberg. (*Sci. Abstracts*, Sec. A, Nov. 1943, Vol. 46, No. 551, p. 211.)

1123. 1944 : Sunspot-Minimum Year : Effects on Wireless Communication.—T. W. Bennington. (*Wireless World*, Feb. 1944, Vol. 50, No. 2, pp. 34–36.)

1124. The Sun's Spottedness as a Possible Factor in Terrestrial Pressure.—I. I. Schell. (*Sci. Abstracts*, Sec. A, Nov. 1943, Vol. 46, No. 551, p. 224.) *See* also 2297 of 1943.

1125. Solar Gas and Radiation may determine Weather [" Close Agreement " between Observations of Abundance of Calcium-Gas Clouds and Daily Variations in Solar Radiation].—C. G. Abbot. (*Sci. News Letter*, 27th Nov. 1943, Vol. 44, No. 22, p. 344.) For previous work *see*, for example, 13, 291, 650, 1596 & 1827 of 1941, and 3191 of 1942.

1126. Mean *K*-Indices from Twenty-One Magnetic Observatories and Five Quiet and Five Disturbed Days for 1942, *and* American Magnetic Character-Figures, Three-Hour Range Indices, and Mean *K*-Indices, for July to September, 1943.—H. F. Johnston. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 219–227 : pp. 228–231.)

1127. List of Geomagnetic Observatories and Thesaurus of Values : III.—J. A. Fleming & W. E. Scott. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 237–242.)

1128. Summary of the Year's Work, to June 30th, 1943, Department of Terrestrial Magnetism, Carnegie Institution of Washington.—J. A. Fleming. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 207–213.)

1129. Some Early Contributions to the History of Geomagnetism : V—The Shadow Instrument, by Pedro Nunes (1537) : VI—Mercator's Letter on the Existence of an Earth's Magnetic Pole (1546).—H. D. Harradon. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 197–199 : pp. 200–202.)

1130. Integral Photometry of the Solar Corona of Sept. 21st, 1941, in Different Parts of

THE SPECTRUM.—N. N. Sytinskaya. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, 30th Jan. 1943, Vol. 38, No. 2/3, pp. 75–77: in English.)

1131. EFFECT OF LINE ABSORPTION ON THE DETERMINATION OF THE TEMPERATURE OF THE INNER CORONA [and the Question of the Validity of Schwarzschild's Hypothesis of Its Electronic Nature].—V. Hase. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, 10th March 1943, Vol. 38, No. 7, pp. 193–196: in English.)

1132. CONSTITUTION OF THE SOLAR CORONA [New Theory]. —H. Alfvén. (*Nature*, 8th Jan. 1944, Vol. 153, No. 3871, p. 59.) Note on the paper dealt with in 1625 of 1943.

1133. ON A STELLAR MODEL BUILT IN COMPLETE ACCORDANCE WITH BETHE'S FORMULA OF ENERGY-GENERATION [and Comparison with Model of Sun worked out by Blanch, Bethe, & others].—N. R. Sen & U. R. Burman. (*Phys. Review*, 1st/15th Nov. 1943, Vol. 64, No. 9/10, p. 317.)

1134. DIFFUSE REFLECTION OF LIGHT BY A FOGGY MEDIUM.—V. A. Ambartsumian. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, 20th March 1943, Vol. 38, No. 8, pp. 229–232: in English.) A summary was referred to in 756 of March.

1135. ABSORPTION OF LIGHT BY SMALL DROPS OF WATER. —R. Ruedy. (*Canadian Journ. of Res.*, Oct. 1943, Vol. 21, No. 10, Sec. A, pp. 79–88.)

1136. ON THE PROBLEM OF LIGHT PROPAGATION IN THE SEA.—E. S. Kuznetzov. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, 10th Jan. 1943, Vol. 38, No. 1, pp. 10–13: in English.)

1137. A NOTE ON THE POLARISATION OF A PLANE-POLARISED WAVE AFTER TRANSMISSION THROUGH A SYSTEM OF CENTRED REFRACTING SURFACES, AND SOME EFFECTS AT THE FOCUS.—H. H. Hopkins. (*Proc. Phys. Soc.*, 1st Jan. 1944, Vol. 56, Part 1, No. 313, pp. 48–51.)

"It is perhaps worthy of note that eqn. 10 contains the interesting suggestion that near the focal plane the light disturbance is plane-polarised in a direction identical with that of the incident wave, no matter what the aperture or the conditions of transmission."

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

1138. THE DETERMINATION OF VERTICAL VELOCITIES IN THUNDERSTORMS.—C. E. Buell. (*Sci. Abstracts*, Sec. A, Nov. 1943, Vol. 46, No. 551, p. 224.)

1139. TOWNSEND CURRENTS IN NON-UNIFORM ELECTRIC FIELDS.—P. L. Morton. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, p. 187: summary only.)

1140. APPARENT FAILURE OF THE MEEK CRITERION FOR STREAMER FORMATION.—L. H. Fisher. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, p. 187: summary only.)

1141. THE CHANNEL OF THE SPARK DISCHARGE [Simultaneous Measurements of Luminous Channel & Discharge Current: Discharge in Air attempts to establish Channel where Density has a Constant Value of 10^3 A/cm^2: Disagreement with the Meek & Loeb Recombination Theory and Pilot-Streamer Mechanism].—J. W. Flowers. (*Phys. Review*, 1st/15th Oct. 1943, Vol. 64, No. 7/8, pp. 225–235.)

1142. RESULTS OF MAGNETIC RECORDING OF LIGHTNING CURRENTS BY THE POWER COMBINES OF THE U.S.S.R. DURING THE PERIOD OF 1937–1940.—I. S. Stekol'nikov & A. A. Lamdon. (*Journ. of Tech. Phys.* [in Russian], No. 4/5, Vol. 12, 1942, pp. 204–210.)

Over 1000 measurements of the amplitudes of lightning currents were made by means of ferromagnetic recorders in various parts of the U.S.S.R. during 1937–1940. The results are analysed and it is shown that only in 1% of cases does the current amplitude exceed 140–150 kA, and that it greatly depends on the conductivity of the soil and the protecting circuits.

1143. APPLICATION OF LIGHTNING-PROTECTIVE DEVICES IN WARTIME.—I. W. Gross. (*Elec. Engineering*, April 1943, Vol. 62, No. 4, Transactions pp. 173–175.) A summary was dealt with in 2655 of 1943.

1144. ON THE RADON-CONTENT OF THE ATMOSPHERE AND THE RADIUM-CONTENT OF RIVER-WATER.—V. F. Hess. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, pp. 203–206.)

PROPERTIES OF CIRCUITS

1145. VERY HIGH-FREQUENCY TUBES AND WAVE GUIDES: TYPES AND USES DISCUSSED [with Illustrations of University of Illinois Apparatus].—R. G. Peters. (*Communications*, July 1943, Vol. 23, No. 7, pp. 30 and 93..95.)

1146. RECTANGULAR & CIRCULAR WAVE-GUIDE NOMOGRAMS.—Everett. (*See* 1103, above.)

1147. RESONANT-LINE DESIGN FOR COMPACTNESS, RIGIDITY, AND TEMPERATURE-COMPENSATION [using Expansion of Polystyrene Base].—(*Communications*, July 1943, Vol. 23, No. 7, p. 44.)

1148. CHARACTERISTICS OF RESONANT TRANSMISSION LINES [in Graphical Form].—J. B. Epperson. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 139 and 140.) The reference sheet gives voltage, current, and resistance along resonant lines, together with the equivalent resonant circuit at quarter-wave sections and the reactance for other lengths as open or shorted lines. For corrections *see* December issue, p. 232.

1149. ELEMENTARY THEORY OF SPHERICAL CAVITY RESONATORS EXCITED BY A HERTZ DIPOLE.—F. De Simoni. (*Alta Frequenza*, April 1943, Vol. 12, No. 4, pp. 163–182.)

Although Owe Berg, in his paper dealt with in 1843 of 1941, considers his theory of the spherical cavity resonator to be elementary, the present writer has the opinion that the mathematical development is rather laborious and not always as rigorous as it should be. He has therefore treated the problem anew and has developed a really elementary mathematical theory starting from the Maxwell–Hertz equations of the electromagnetic field surrounding a simple Hertz dipole, and leading, with the help of the potential vector Π, to the calculation of the lowest possible resonance frequency (eqn. 27: longest wavelength $\lambda = 2.29a$, where a is the internal radius of the sphere); of the decrement b of the natural oscillations (eqn. 30: $b = 8.536 \cdot 10^7 \cdot 1/\lambda \cdot \sqrt{\rho\mu/\lambda}$, where the resistivity ρ is expressed in ohms per mm^2/m and λ in centimetres: curves of Figs. 3 and 4 show b as a function of λ, for a fixed ρ, and of ρ, for a fixed λ, respectively ; μ being taken as unity, as it practically is for commercial copper) ; and of the factor of loss Q (eqn. 31 : $Q = 1.10 \,.\, 10^3 \sqrt{\lambda/\rho\mu}$: Fig. 5 shows Q as a function of λ for resonators made of commercial copper). The paper ends with a comparison of the author's results with those of Owe Berg. *See* also Bargellini, 1150, below.

1150. CAVITY RESONATORS IN DECIMETRIC-WAVE TRIODE GENERATORS.—Bargellini. (*See* 1173.)

1151. CALCULATION OF ELECTROLYTIC-TROUGH POTENTIOMETERS BY THE METHOD OF CONFORMAL REPRESENTATION [particularly Potentiometers with Linear Variation of Attenuation, for H.F. or Acoustic Applications, consisting of Curved Electrodes & Water-Container with Profiles based on Equipotential Lines & Lines of Flux (according to Equation 17) : Calculation & Experimental Verification : Advantages].—G. B. Madella. (*Alta Frequenza*, March 1943, Vol. 12, No. 3, pp. 114–133.)

An English summary will be found at the end of the journal. In the model described the height of the electrolyte was adjusted to give a total resistance of 5000 ohms : the frequency used was 1 kc/s, the voltage about 10 v. The departure from linearity was not more than 0.15 db over a range of 54 db.

1152. DESIGN OF TWO-TERMINAL BALANCING NETWORKS [*e.g.* for Open-Wire Line, Spiral-Four Cable (361 of January), etc.].—K. G. Van Wynen. (*Bell S. Tech. Journ.*, Oct. 1943, Vol. 22, No. 3, pp. 278–292.)

"This paper describes a simple graphical method for designing a two-terminal network [with the minimum number of elements] which will simulate a given line impedance to such a degree that return losses of the order of 25 db or better will be readily obtained. The method is particularly useful in those problems in which a reasonably accurate balancing network is adequate, but a high degree of precision is not required. . . . A solution can frequently be obtained in a fraction of an hour."

1153. ADJUSTMENT OF TRANSMISSION-LINE LOAD FOR MINIMUM LOSS.—Andrew. (*See* 1199.)

1154. MATCHING : PART I—MAXIMUM POWER AND MINIMUM DISTORTION AT AUDIO FREQUENCIES : PART II—AERIAL AND INTER-VALVE COUPLINGS AT RADIO FREQUENCIES.—S. W. Amos. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, pp. 6–8 : Feb. 1944, No. 2, pp. 47–49.) For previous work *see* 2655 of 1942 and 422, 2370, & 2966 of 1943.

1155. TUNED TRANSFORMERS [and Universal Performance Curves] : PART II [with Selectivity Curves for Single Tuned Circuit & Two Coupled Tuned Circuits : Checking the Calculated Results].—J. E. Maynard. (*Gen. Elec. Review*, Nov. 1943, Vol. 46, No. 11, pp. 606–609.) Concluding 416 of February.

1156. TRANSFORMER SCREENING : SUGGESTIONS FOR IMPROVEMENT [Frequent Ineffectiveness of Conventional Screen : Need for Proper Screening of All Instrument & Testing Transformers : Experiments on Extra Screening : Tests on Suppression of Mains-Borne Interference by Mains-Transformer Screening, and Need for Further Work].—T. A. Ledward. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, pp. 15–18.)

1157. AUDIO-FREQUENCY GENERATOR : RESISTANCE–CAPACITY TUNING WITH WIEN BRIDGE FEEDBACK CIRCUIT [with Details of Model covering 30 c/s–14 kc/s in Four Ranges : with 9 English-Language References].—S. K. Lewer. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, pp. 2–5.) For typographical errors *see* February issue, No. 2, p. 57.

1158. SOME PROPERTIES OF A SPECIAL TYPE OF ELECTRICAL PULSE [the Exponential Recurrent Pulse].—F. F. Roberts & J. C. Simmonds. (*Phil. Mag.*, Dec. 1943, Vol. 34, No. 239, pp. 823–827.)

"Repeated pulses of current and voltage are being used to an increasing extent in various types of electrical apparatus, and papers have appeared which give details of the Fourier analyses of a number of recurrent pulse wave-forms (465 & 480 of 1943). Other writers have shown how the Fourier integral may be employed to determine the frequency spectrum corresponding to most practical pulse shapes independently of the pulse repetition frequency (1319 of 1943). A very interesting type of pulse shape, however, does not appear to have been considered before. This pulse is described below and some of its properties are given." A valve is taken whose grid-voltage/anode-current characteristic is assumed to be represented by $I = Az^{Bv}$, which is approximately true for many valves, especially certain high-slope pentodes. Recurrent pulses will occur if a large alternating voltage is applied to the control grid, together with a negative bias V such that practically no anode current flows in the absence of the alternating voltage : the latter is assumed to be sinusoidal, so that the grid voltage $v = E \cos pt - V$. Substitution of this value for v in the equation for I gives $I = Ae^{-BV} . e^{BE \cos pt}$: the first factor is clearly a constant for a given valve and given operating conditions, while the second factor determines wave-form and also affects the amplitude, for the peak of the pulse occurs when cos pt is unity, and the peak amplitude is then $\hat{I} = Ae^{B(E-V)}$. The ratio instantaneous-current/peak-current, $I/\hat{I}$, is therefore $e^{BE(\cos pt - 1)}$, and is dependent only on the valve constant B and the applied alternating voltage.

A number of wave-forms derived from this last equation, for various values of BE, are shown in Fig. 1 : since, for suitable valves, B lies between 5 and 10, quite narrow pulses can be obtained without excessive voltages being applied to the control grid. The frequency components of such exponential pulses are calculated, and illustrations are given of the ease with which these pulses can be manipulated mathematically (superposition of two wave-forms : multiplication of two wave-forms, as in a suitable modulation circuit : "different types of demodulation processes may be analysed with the help of eqn. 21, and the effects of the frequency response of the intermediate transmission path can readily be allowed for, by expansion of the wave-form by eqn. 18 into its frequency components").

1159. THE FREQUENCY-DEPENDENCE OF THE GROUP PATH TIME IN RESONANCE AMPLIFIERS [for Image Transmission, Pulse Measurements, etc.].—Schaffstein. (*See* 1253.)

1160. CAUSES OF THE CURRENT AND VOLTAGE FLUCTUATIONS [in Amplifier Circuits].—C. J. Bakker. (*Alta Frequenza*, Jan. 1943, Vol. 12, No. 1, pp. 40–42.) Long summary, in Italian : a German summary was referred to in 2321 of 1943.

1161. THE DESIGN OF A CATHODE-RAY-TUBE AMPLIFIER.—B. M. Hadfield. (*Electronic Eng:g*, Nov. 1943, Vol. 16, No. 189, pp. 226–229.)

"In a recent article (544 of February) describing a c.r. oscillograph equipment in general outline, only a brief reference could be made to two major points in the specific design. These were (a) the minimum ratio between the amplifier and tube supply voltages, and (b) the design of the amplifiers by a novel method known as the limiting-gain principle. The purpose of this article is to deal with these points in detail and in as general a manner as possible, because they constitute the basis of design of such equipment as distinct from the mere formulation of the circuit arrangements. The amplifier design method is also of great use when applied to all types of valve amplifiers ".

1162. DESIGN CONSIDERATIONS FOR GROUP [Multi-Channel] AMPLIFIERS FOR CARRIER-FREQUENCY TELEPHONY.—P. Fedi. (*Alta Frequenza*, Jan. 1943, Vol. 12, No. 1, pp. 26–35.)

Author's summary :—" After brief considerations on the advantages presented by the use of multi-channel amplifiers compared with the employment of a separate amplifier for each channel, it is shown that the principal parameter to be considered in the design calculations is the non-linear distortion. The troubles due to this are examined, namely the generation of harmonics of the amplified frequencies and cross-talk between the channels; the equations giving the amplitude relation between the two phenomena are derived; and the special importance is brought out of non-linear distortion of the third order when the carrier frequency is transmitted. Finally, measurements [on an amplifier built in the S.A.F.A.R. laboratories, with a frequency range of 6 600–18 000 c/s and a maximum output around 1.6 w] are reported which show that the theory developed is in good agreement with practical results ".

1163. APPLICATION OF NEGATIVE FEEDBACK TO DESIGN PRINCIPLES [including as Illustrations the Broad Design of a Three-Stage R.F. Amplifier (50 db Gain over a 20 : 1 Frequency Range) and a Four-Stage Audio Amplifier for a 100 kW Transmitter].—S. Hill. (*Journ. British I.R.E.*, Sept/Oct. 1943, Vol. 3, No. 6, pp. 252–267 : Discussions pp.267–275.) A summary was referred to in 2104 of 1943.

1164. HISTORIC FIRSTS : THE NEGATIVE-FEEDBACK AMPLIFIER.—H. S. Black. (*Bell Lab. Record*, Dec. 1943, Vol. 22, No. 4, p. 173.)

1165. EFFECT OF FEEDBACK ON IMPEDANCE.—R. B. Blackman. (*Bell S. Tech. Journ.*, Oct. 1943, Vol. 22, No. 3, pp. 269–277.)

" Relations between impedance and feedback were derived by Black and others for a number of specific feedback-amplifier configurations. In some cases these relations turned out to be very simple. For the most part, however, these relations were so complicated that they defied reduction to a common form." This was due to difficulties which are avoided by the method of derivation now used. Illustrative examples are given of some of the uses to which the general relationship may be put. Two of the examples illustrate the use of feedback to magnify (series feedback) or to reduce (shunt feedback) the impedance of a network. This impedance, however, will be correspondingly sensitive to changes in the characteristics of the vacuum tubes. A third example (bridge-type feedback) of the use of the relationship shows that feedback may also be used to make the impedance of a network less sensitive to such changes.

1166. FORMULAS FOR THE CALCULATION OF THE INDUCTANCE OF LINEAR CONDUCTORS OF STRUCTURAL SHAPE.—T. J. Higgins. (*Elec. Engineering*, Feb. 1943, Vol. 62, No. 2, Transactions pp. 53–57.)

1167. RADIO DATA CHARTS : INDUCTANCE, CAPACITY, AND FREQUENCY : No. 13—MEDIUM WAVE : No. 14 — INTERMEDIATE - FREQUENCY RANGE. — J. McG. Sowerby. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, pp. 10–11 : Feb. 1944, No. 2, pp. 50–52.)

1168. A RECIPROCAL SLIDE RULE FOR PARALLEL RESISTORS.—R. C. Paine. (*Communications*, July 1943, Vol. 23, No. 7, pp. 16–17 and 86, 91.)

1169. BRIDGE VOLTAGE REGULATORS [*e.g.* to give Constant Current of 100 mA at 12 V : the Use of Barretters or Electronic Semiconductors : Greatly Increased Efficiency of Regulation by Use of Two Bridge Regulators in Series].—C. Morton. (*Journ. of Scient. Instr.*, Jan. 1944, Vol. 21, No. 1, pp. 15–17.)

In a particular regulator described, the power consumption was only one-tenth of that of a bridge regulator of similar power output using metal-filament lamps instead of barretter filaments.

1170. ELECTRONIC UNIT FOR ACCURATE TIMING OF SWITCHING OPERATIONS IN RAPID AND ADJUSTABLE SEQUENCE [where Rapid Repetition is Not Needed (Minute or Two required before Cycle can be Repeated)].—F. O. Mason & K. Goldschmidt. (*Journ. of Scient. Instr* , Dec. 1943, Vol. 20, No. 12, pp. 192–194.)

The unit described will trip four separate circuits in a time sequence pre-selected for each individual relay to within $\pm$ 1% over a continuously variable range from approximately 10^{-4} to 10^{-1} second, with provision for extending the time range. For other circuits (" generally these are very complicated, partly because rapid repetition of the sequence is required ") *see* 1634 of 1941. The present paper is based on E.R.A. Report G/XT95.

1171. THE FUNDAMENTAL CIRCUITS OF CONTACTLESS CONTROLLING AND SELECTING SYSTEMS.—N. A. Livshits, N. N. Klyuev, & A. P. Manovtsev. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 25–36.)

The disadvantages of electro-mechanical devices used in controlling and selecting systems are pointed out and a number of suitable valve circuits free from relays or moving parts are proposed. The circuits discussed are designed to perform the following functions : self-locking at the beginning of the signal impulse, self-locking at the end of the signal impulse, selection of signals lasting a predetermined time interval, self-releasing after a predetermined time interval, maintaining the voltage level of signal impulses, and selecting current impulses of different directions.

1172. THE APPLICATION OF THE THEORY OF FOUR-POLE NETWORKS TO THE ANALYSIS OF COMPLEX MAGNETIC CIRCUITS.—V. I. Kovalenkov. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 9–14.)

The theory of four-pole networks can be applied to the design of magnetic circuits if (1) the dimensions of the air gaps are such that a linear relationship between H and B can be assumed, and (2) the configuration of the magnetic circuit is such that the circuit approximates to a two-conductor electric line. It is shown that in practice condition (1) holds good with sufficient accuracy, while with respect to condition (2) the difficulty can be obviated by determining the flux Φ and tension U_m at the ends of the circuit, without considering the processes taking place intermediately. A number of particular cases are then discussed and formulae are derived (top of page 14) for determining Φ and U_m for any complex magnetic circuit, uniform or non-uniform. The importance of the " tertiary parameters " A, B, and C (top of page 11) of a magnetic circuit is emphasised, and methods for measuring these are indicated.

TRANSMISSION

1173. **Cavity Resonators in Decimetric-Wave Triode Generators** [Theoretical & Experimental Investigation of the Application, to Negative-Grid Triode Generators, of Cavity Resonators such as are used in Velocity-Modulated Generators : the Increase in Efficiency at Voltages above the Normal Voltage for the Valve, and the Use of Pulse Excitation (500 per Second, Length 4–300 Microseconds)].—P. L. Bargellini. (*Alta Frequenza*, April 1943, Vol. 12, No. 4, pp. 183–212.)

From the Florence laboratories of FIVRE (Fabbrica Italiana Valvole Radio-Elettriche) : the various triodes employed (singly or in parallel or push-pull pairs, always in the negative-grid connection : *cf.* Carrara, 1174, below) were of this firm's make, particularly successful being the Type T 800A, with external water-cooled anode capable of dissipating 800 w (wavelength 92 cm). The resonators chiefly used were of the " quasi-spherical " shape (sphere with two re-entrant truncated cones) : in some cases (Figs. 25, 26) a frequency adjustment (*e.g.* between 340 and 460 Mc/s) was provided by a sliding rod. For production purposes it would be necessary to select materials such as would reduce the losses to a minimum and avoid cavity-frequency changes due to volume variations with temperature. A point mentioned in a footnote is that the natural frequency of the resonator with its valves mounted is considerably lower than that of the free resonator. " This disadvantage, liable to put a definite limit on the construction of oscillators beyond a certain frequency, has recently been removed by a new arrangement (Magneti-Marelli patent No. 3944, applied for 9/11/1942) which points out a promising path."

Figs. 27, 28 show, for two types of valve (and in the latter case for four types of circuit), the drop in conversion efficiency as the frequency increases from about 100 Mc/s to 400 Mc/s and over. Such a drop must be largely due to the transit time of the electrons, and measurements were therefore carried out on the efficiencies resulting from a diminution of these transit times by the employment of higher accelerating voltages than usual. To avoid exceeding the max. anode dissipation laid down for the valves in question, the anode voltage was applied in practically rectangular pulses following each other at a rate of 500 per second (Fig. 29 shows the principle of the pulse-generating equipment). Figs. 32, 33 show the increase in efficiency, as the anode voltage is increased from 1000 to 5000 v, of cavity-generators with two types of valve, while Figs. 34, 35 show the same for the same valves in transmission-line circuits : taking as an example the 62 cm curve of Fig. 32, the efficiency increases from 20% at 1000 v to 33% at 3500 v.

Regarding the measurement of efficiencies, the writer discusses on pp. 206–209 the difficulties encountered in employing, for the pulse-excitation tests, the lamp-and-photocell method used in the case of normal (or slightly over-normal) anode voltages. These were overcome by replacing the lamp load by a radiating dipole with its coupling adjusted to give the identical plate and grid currents as before (so that it could be assumed that the power taken by the dipole was the same as that previously absorbed in the lamp) and measuring the power received by a second dipole at a fixed distance, by means of a small (3-watt) lamp working with a photocell/microammeter combination. In his final pages the writer compares the measured increases in efficiency (with increased anode voltages) with those theoretically obtainable, and the reason for falling short of the latter. This reason, involving the losses in the oscillatory circuit, brings out the superiority of the cavity oscillators over the transmission-line type.

1174. **Decimetric-Wave Oscillators with Negative-Grid Triodes.**—N. Carrara. (*Alta Frequenza*, May 1943, Vol. 12, No. 5, pp. 219–247.)

Report on the writer's researches, in which De Simoni (1149, above) and Bargellini (1173, above) have collaborated. They were prompted by the fact that while the retarding-field valve and the magnetron have lately fallen into disfavour (largely because they lend themselves badly to amplitude modulation—except possibly the Lüdi magnetron, ref. " 3 "), the remaining method, velocity modulation, requires several (and high) supply voltages and as a result " is not well suited to certain special and important applications ".

Considering first the requirements of a triode for negative-grid decimetric-wave generation, the writer points out that reducing the electrode spacings, in order to reduce the transit times, leads to an increase in the inter-electrode capacitances, and that if this disadvantage is countered by reducing the surface area of the electrodes the tendency is to get over-heating, which may lead to dangerous secondary emission, especially from the grid. Either, therefore, radiating fins must be provided, or secondary emission must be hindered by coating the electrodes with a substance such as zirconium. A diminution of transit time by raising the anode voltage is then considered ; this is naturally bound up with the use of an intermittent excitation by pulses, which however may follow one another so quickly as to produce no serious disturbance to an eventual modulation (*cf.* Bargellini, *loc. cit.*). Assuming a normal efficiency of 20%, the use of an anode voltage nine times the normal, in an impulsive régime, would lead to an efficiency almost doubled and an output almost trebled, while the applied power would be multiplied only by 1.33. A footnote on pp. 224–225 deals with the synchronising action between a high harmonic of the rectangular pulse and the natural frequency of the oscillator in the non-impulsive régime : there is always one harmonic close enough in frequency to produce this synchronisation, which makes itself evident (apart from direct oscillographic observation) in reception. It is to it that one owes the possibility of frequency-transformation with ordinary superheterodyne arrangements.

After summing up the points to be observed in the design of such triodes, the writer passes on to the oscillatory circuits, parallel-wire, coaxial-line, and cavity types. He then gives a long analysis of the action of the oscillator composed of a Lecher-wire system driven by a single negative-grid triode, and of a similar system with two triodes in push-pull : three versions of the latter arrangement are considered, all symmetrical (Figs. 14, 15, 18), and on pp. 245–246 the writer compares them and gives his reasons (theoretical and from experience) for preferring the " double square " type of Fig. 14.

Finally, cavity-resonator generators are considered, but only very briefly in view of Bargellini's paper, above.

1175. **Design Precautions for Oscillators using Filament-Type Acorns** [Oscillation may Continue after Filament Voltage has been Removed, unless Plate Voltage also is Cut Off].—(*Communications*, July 1943, Vol. 23, No. 7, p. 91.) Particularly with exceptionally well-designed circuits.

1176. **Crystal Holder Design** [with Description & Discussion of Eight Varieties of Mounting, each with Distinct Advantages for Certain Applications].—L. A. Elbl. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 134–138.)

RECEPTION

1177. THE DIODE AS A MIXING-VALVE IN THE FIELD OF DECIMETRIC WAVES.—M. J. O. Strutt & A. van der Ziel. (*Alta Frequenza*, Oct. 1942, Vol. 11, No. 10, pp. 457–460: long illustrated summary of the paper dealt with in 2362 of 1943.)

1178. SUPER-REGENERATION: ITS THEORY OF OPERATION [Non-Mathematical Treatment based on Negative-Resistance Phenomenon: Effects of Changes in Quenching Frequency & Voltage on Sensitivity, Selectivity, & Fidelity, leading to Suggestions for Optimum Adjustments].—L. S. Fox. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 17–19.) Based on an R.C.A. report by Grimes & Barden, presumably that dealt with in 1934 Abstracts, p. 267.

1179. AN ULTRA-HIGH-FREQUENCY RECEIVER COMBINING SUPER-REGENERATION AND SUPERHETERODYNE ACTION.—(*Communications*, July 1943, Vol. 23, No. 7, p. 44.)

1180. FREQUENCY-MODULATION RECEIVER DESIGN [Account of Step-by-Step Development of Satisfactory Receiver (for New York Fire Department) from Basic Unit found Deficient in Over-All Gain, Limiting, Oscillator Stability, Inter-Channel Noise Suppression ("Squelching") and Audio Fidelity].—L. Pressman. (*Communications*, July 1943, Vol. 23, No. 7, pp. 13–15 and 66, 76..79, 92, 93.)

1181. DUAL-CHANNEL RECEIVERS FOR MOBILE AND FIXED OPERATION [primarily for New York Fire Department, for Mobile Units requiring Communication with both Police (2.45 Mc/s) & Fire (1.63 Mc/s) Departments, either Simultaneously or Alternatively: Triode Portions of Two Triode–Hexode Converters combine to form Common Push-Pull Crystal Oscillator: Pilot-Light System: etc.].—A. H. Meyerson. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 56–58 and 103.)

1182. AUTOMATIC BIAS FOR BATTERY TUBES [in Transceivers & Transmitter–Receivers: Elimination of the "C" Battery for Output-Valve Grid Bias].—L. S. Fox. (*QST*, Dec. 1943, Vol. 27, No. 12, p. 62.)

1183. "SUPERHET–STRAIGHT" SWITCHING: CATHODE-FOLLOWER METHOD CALLING FOR FEW CIRCUIT ALTERATIONS [No Extra Valves & No Switching in R.F. Leads: for Improved Quality on the "Home" Programme].—P. A. Shears. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, pp. 24–25.) The article also describes a method ("superior to that of long screened leads") by which gramophone concerts can be relayed to other receivers in the same building: and ends with a description of the writer's improved (treble, middle, bass) tone control.

1184. "AMERICAN MIDGETS" [Notice of Booklet on Their Circuits & Upkeep].—(*Wireless World*, Feb. 1944, Vol. 50, No. 2, p. 52.)

1185. "CLASSIFIED RADIO RECEIVER DIAGRAMS" [Book Review].—E. M. Squire. (*Electronic Eng:g*, Nov. 1943, Vol. 16, No. 189, p. 262.) "Might be considered a companion volume to the author's 'Radio Receiver Circuits Handbook', which gave comprehensive notes on the theory of various basic circuits . . ."

1186. EXPERIMENTS ON THE REDUCTION OF MAINS-BORNE INTERFERENCE BY SUITABLE SCREENING OF THE MAINS TRANSFORMER.—Ledward. (In paper dealt with in 1156, above.)

1187. EFFECT OF RADIO FREQUENCIES OF A POWER SYSTEM ON RADIO-RECEIVING SYSTEMS.—C. V. Aggers, W. E. Pakala, & W. A. Stickel. (*Elec. Engineering*, April 1943, Vol. 62, No. 4, Transactions pp. 169–172.) A summary was dealt with in 2708 of 1943.

1188. RURAL ELECTRIFICATION ENGINEERING AND ELECTROAGRICULTURAL ENGINEERING [including a Note on Radio Interference Problems in Rural Areas].—M. M. Samuels. (*Elec. Engineering*, April 1943, Vol. 62, No. 4, Transactions pp. 193–197.)

"As 'telephone interference' was changed to 'telephone coordination' by cooperative efforts of utility engineers and telephone engineers, so should 'radio interference' be changed into 'radio coordination' by cooperative efforts of the engineers of the electric utilities, the broadcasting companies, and the radio manufacturers."

1189. INDUSTRIAL INTERFERENCE WITH SHORT-WAVE RECEPTION [Present Position: No Steps taken to ensure Non-Radiation from Appliances: *Now* is the Time for Regulations, for Post-War Production, especially of Electric Razors].—"Diallist." (*Wireless World*, Jan. 1944, Vol. 50, No. 1, p. 30.)

1190. SPARKING OF TRAMCARS AND ITS PREVENTION.—Ya. I. Frenkel. (*Journ. of Tech. Phys.* [in Russian], No. 4/5, Vol. 12, 1942, pp. 171–184.)

The separation of the trolley-collector from the trolley-wire causes sparking, and in its turn is caused mainly by two factors, the oscillation of the collector due to friction with the wire and the oscillation of the wire due to the pressure of the collector. It is therefore suggested that in order to decrease sparking the pressure of the collector should be reduced and the natural frequencies of the wire and collector made equal. A mathematical analysis of the oscillatory movements involved is given, proving the validity of the suggestions made.

1191. AIRCRAFT RADIO-NOISE FILTERS.—C. W. Frick & S. W. Zimmerman. (*Communications*, July 1943, Vol. 23, No. 7, pp. 32..42 and 75.) Already dealt with in 88 of January.

1192. EUROPE'S 213 MILLION LISTENERS: COMPARATIVE FIGURES OF RADIO DENSITY IN 1942 [U.I.R. Data].—(*Wireless World*, Jan. 1944, Vol. 50, No. 1, p. 18.)

AERIALS AND AERIAL SYSTEMS

1193. ON THE ENERGY DISTRIBUTION IN THE NEAR FIELD OF ELECTROMAGNETIC RADIATORS, IN PARTICULAR IN FRONT OF DIAPHRAGMS AND REFLECTORS [treated by Acoustical Methods].—H. Born. (*Hochf:tech. u. Elek:akus.*, July 1943, Vol. 62, No. 1, pp. 20–23.)

"Already in many cases comparisons have been made between the phenomena of electromagnetic oscillations and those of acoustics [*cf.*, for example, 2702 of 1941]. The possibility of such comparisons is due to the common wave nature of the two types of oscillation. In the present paper the object is to point out further analogies which will enable a solution to be found on acoustical lines to certain complex interference phenomena in electromagnetic radiation fields, which hitherto could only be dealt with by actual measurements."

From Rayleigh's integral for the velocity potential, Backhaus & Trendelenburg ("On the directional action of piston diaphragms," *Zeitschr. f. tech. Phys.*, Vol. 7, 1926, p. 630) obtained, on certain simplifying assumptions, the simple relation $J = \sin^2 k/2 . [\sqrt{R^2 + z^2} - z]$ for the energy distribution along the central normal of a disc-shaped vibrator excited co-phasally with over-all equal amplitude: here J is the intensity at the point z, R the radius of the radiating surface, $k = 2\pi/\lambda$, and z is the distance of the point of observation from the radiator. It is this formula, together with the expressions of eqns. 3 and 4 derived from it for the positions of the individual maxima and minima of the relative energy density, that the present writer applies to the electromagnetic radiation fields dealt with experimentally by other workers without their arriving at a satisfactory quantitative treatment of the energy distributions.

He deals first with Erler's "Investigations on diaphragms with centimetric waves" (670 of 1941), where energy distributions along the central normal are reported which display striking similarities to the corresponding acoustical results. His experimental conditions were very favourable for the present purposes, the diaphragms being "irradiated," from a suitable distance, by a dipole lying at the focus of a large parabolic reflector, so that co-phasal excitation of the aperture was ensured. Erler's experimental results (broken-line curves) and the calculations by the Backhaus–Trendelenburg formula (full-line curves) are compared in Figs. 1a, b, c for a 7 cm wave and three different aperture ratios, R/λ = 4.3, 3.4, and 1.7. In all three cases there is good agreement, especially in the positions of the maxima and minima: such differences as occur between the curves are explained by the fact that the formula is valid only for the central normal, whereas Erler's receiver had an appreciable surface.

Erler himself tried to represent his curves mathematically by means of a formula used in the treatment of Fresnel diffraction at circular diaphragms: he succeeded only for the last maximum, and even there only approximately. But when an oversight made by him is corrected, the formula he used gives, for a practically parallel radiation, $J = E . \sin^2 \pi/\lambda . R^2/2z$, which agrees with the Backhaus–Trendelenburg formula for the case where z is much greater than R.

As an example in which the conditions are less perfect, in the investigation of the near field of reflectors or similar surface radiators where such a uniform irradiation cannot be ensured, the writer considers Bach's paper "Investigations in the near field of paraboloid-of-revolution reflectors" (2758 of 1939). Again there is satisfactory agreement between the measured results and those given by the Backhaus–Trendelenburg formula (Fig. 2 : λ = 14.2 cm). In both the cases dealt with above the energy distribution considered is that in a non-absorbing medium, air; but the question of energy distribution in a medium possessing damping is also of practical interest, and the writer next deals with the experiments of Pätzold & Osswald (dipoles under water, using reflectors: λ = 107 cm: 3276 of 1940) and of Pätzold (2621 of 1941: electrolytes and biological tissues, λ = 58 and 430 cm). In view of the conditions under which these measurements were made, the agreement between measured and calculated values must be considered satisfactory (Fig. 3): the formula here used, for a medium possessing damping, is given in eqn. 9, taking the place of the one previously employed: for details (in connection with supersonic waves) *see* Born, *Zeitschr. f. Phys.*, Vol. 120, 1943, p. 383 onwards. In connection with the discussion of these last results, mention is made of a paper on the distant field of parabolic reflectors, by Esau & Scheffers, *Luftfahrtforschung*, Vol. 3, 1942, p. 169 onwards.

1194. On the Radiation Impedance of Aerials.—D. Graffi. (*Alta Frequenza*, Jan. 1943, Vol. 12, No. 1, pp. 3–25.)

"In a recent paper [dealt with in 2663 of 1942] Gori has notably deepened and made more precise the concepts of self and mutual radiation impedance of multiple radiating systems [for short and ultra-short waves], and in particular has brought into prominence the facts that: (a) there can be no radiation on the part of a conductor without there being a corresponding (apparent) alteration of the reactive parameters of the conductor, defined in the non-radiating régime; and (b) in comparing the feeding of multiple systems it is essential to take into consideration the resistances and reactances of coupling between the radiating elements which compose the systems. In general, such resistances and reactances do not have equal reciprocal values.

"The importance of these results has led to an investigation as to whether it is not possible to establish them by a different method, by which eventually they could be extended. Such a process is actually possible, and though rather more complicated than that developed by Gori, has nevertheless the advantage of providing an energetic interpretation of the reactive parameters of an aerial, capable of a wide generalisation."

Author's summary:—"After establishing in a precise form the relations between the impressed electromotive forces and the electrical currents, both for a single aerial and for a system of aerials in the stationary-wave régime, an energetic expression is determined for the self and mutual impedances of the aerials. By means of an application of the reciprocity theorem, the non-mutuality of the resistances and reactances of coupling is confirmed and generalised."

1195. A Lecher-Wire System suitable for the Direct Measurement of the Impedance of Aerials.—Williams. (*See* paper dealt with in 1255, below.)

1196. Measurement of Antenna Impedance: a Simple Method of determining Antenna and Transmission-Line Operating Conditions [from Measurements of Standing-Wave Ratio on Feeding Line: Use of Tuning Stubs: Open-Circuited *versus* Short-Circuited Stubs: etc.].—H. E. Stewart. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 30–35.) For Carter's paper, referred to here, *see* 2345 of 1939.

1197. Transmission Lines as Reactors in Antenna Construction: Supplementary Diagrams.—V. J. Andrew. (*Communications*, July 1943, Vol. 23, No. 7, pp. 84–85.) Following on 2384 of 1943.

1198. Characteristics of Resonant Transmission Lines [in Graphical Form].—Epperson. (*See* 1148.)

1199. Adjustment of Transmission-Line Load for Minimum Loss.—V. J. Andrew. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 26 and 101.) Including (as an alternative method) two loss-factor graphs for a 70-ohm line, each circle showing the range of resistance and reactance in the termination, for a particular factor of normal-line-loss increase.

1200. The Design of Antenna Arrays by Fourier Analysis: a Discussion of Practical Methods of calculating Antenna Arrays when the Desired Radiation Pattern is Known.—N. Marchand. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 16–18, 20, 21, and 76, 78.)

1201. An Electromechanical Calculator for Directional-Antenna Patterns.—C. E. Smith & E. L. Gove. (*Elec. Engineering*, Feb. 1943, Vol. 62, No. 2, Transactions pp. 78–83.) The full paper, a summary of which was dealt with in 2722 of 1943.

1202. Data Sheets Nos. 54 & 55 : Aerial Characteristics : III—Effect of Ground Losses on Polar Characteristics : *also* No. 56 : Aerial Characteristics : IV—Effect of Ground Losses on Field Strength.—(*Electronic Eng:g*, Nov. 1943, Vol. 16, No. 189, pp. 241–244 : Dec. 1943, No. 190, pp. 285–288.) For I & II *see* 3379 of 1943.

1203. Directive Aerials : Comparative Merits of Different Types [Opening Paper to Wireless Section, I.E.E., Discussion].—J. A. Smale. (*Elec. Review*, 28th Jan. 1944, Vol. 134, No. 3453, pp. 119–120.)

1204. The Effect of an Exponential Current Distribution on the Radiating Properties of the Rhombic Aerial.—E. G. Hoffmann. (*Hochf: tech. u. Elek:akus.*, July 1943, Vol. 62, No. 1, pp. 15–20.)

In previous theoretical investigations of this type of aerial, the aerial current has been assumed to be a progressive undamped sine wave. The present writer investigates the effect of assuming, instead, an exponentially damped aerial current. It is found that the radiation diagram remains practically unchanged. The damping shows its effect in reducing, for a constant input current, the amplitude of the field strength, and in converting the null points which occur with the undamped current distribution into radiation minima. But for a damping $e^{-2\beta a} = J_e/J_0 = 0.5$ these minima are so small that they are not visible in the diagrams plotted in Figs. 2–4. On the other hand, for a simple long-wire aerial in the form of a straight wire Jachnow has shown the reduction of the maxima and the conversion of null points into minima (1050 of 1942) : in his case the minima are considerably larger in comparison with the maxima than they are in the rhombic aerial.

For the undamped progressive wave the field-distribution maxima are easily determined, but for the exponentially damped current-distribution the corresponding equations have no such simple and workable form. The writer confines himself to deriving eqn. 10 for the elevation of the principal lobe. This shows that the longer the rhombic aerial is (and consequently the higher the damping), the more the elevation of the principal lobe sinks compared with that of the undamped aerial.

1205. Transmitter Installation in a Low Land Area [and Its Special Problems : the 5 kW Installation at WSJS].—P. F. Hedrick. (*Communications*, July 1943, Vol. 23, No. 7, pp. 18–19.) Including the switching from day to night aerial-patterns.

1206. Frame-Aerial Construction : Directional Reception with Standard Broadcast Sets [using a Symmetrical Balanced Circuit].—R. E. Stace. (*Wireless World*, Feb. 1944, Vol. 50, No. 2, pp. 56–57.)

VALVES AND THERMIONICS

1207. The Diode as a Mixing-Valve in the Field of Decimetric Waves.—Strutt & van der Ziel. (*See* 1177.)

1208. Very-High-Frequency Tubes and Wave Guides : Types and Uses Discussed [with Illustrations of University of Illinois Apparatus].—R. G. Peters. (*Communications*, July 1943, Vol. 23, No. 7, pp. 30 and 93..95.)

1209. Some Technological Problems in the Development of a New Series of Transmitting Valves [for Ultra-Short Waves].—E. G. Dorgelo. (*Alta Frequenza*, Jan. 1943, Vol. 12, No. 1, pp. 56–58.) Long Italian summary, with diagrams, of the Philips Company's paper dealt with in 1098 of 1943.

1210. Technological Problems relative to the Construction of Valves [Transmitting, for Short & Ultra-Short Waves : Metal *versus* Glass : Abolition of Valve-Base, and Its Advantages : etc.].—Th. P. Tromp. (*Rev. tech. Philips*, Nov. 1941, Vol. 6, No. 11, p. 317 onwards : long summary in *Alta Frequenza*, March 1943, Vol. 12, No. 3, pp. 149–151.) The paper dealt with in 1109 of 1943.

1211. Design Precautions for Oscillators using Filament-Type Acorns.—(*See* 1175.)

1212. Tubes for High-Power Short-Wave Broadcast Stations : Their Characteristics and Use.—G. Chevigny. (*Elec. Communication*, No. 3, Vol. 21, 1943, pp. 143–156.) Already dealt with in 3010 of 1943.

1213. Physics and the Static Characteristics of Hard-Vacuum Valves.—J. H. Fremlin. (*Elec. Communication*, No. 3, Vol. 21, 1943, pp. 167–173.)

Already dealt with in 3399 of 1943. "I have tried to show some of the improvements resulting from the application of the next approximation to reality, and I am looking forward with some interest, not unmixed with apprehension, to the time when this has been sufficiently well worked out to justify the consideration of some of the really very well established non-particulate properties of the electrons themselves."

1214. The Input Admittance of Vacuum Tubes [and the Positive, Negative, or Zero Value of the Input Conductance : Discussion of Vector Diagrams & Equivalent Circuits].—P. K. Hudson. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 54 and 102, 108.)

1215. Measurement of the Energy Distribution and Directions of Secondary Electrons [by the Retarding-Field Method and the Methods employing a Transverse & a Longitudinal Magnetic Field].—R. Kollath. (*Arch. f. Tech. Messen*, Sept. 1941, Part 123, V63–2, Sheet T118 : long summary, with diagrams, in *Alta Frequenza*, Jan. 1943, Vol. 12, No. 1, pp. 42–45.) *See* also 2134/5 of 1941.

1216. Electronic Tubes : How They Work [illustrated by Discussion of the Gas-Filled FG-57 Thyratron : Article intended for Industrial Users of Electronic Devices].—(*Gen. Elec. Review*, Nov. 1943, Vol. 46, No. 11, pp. 612–617.)

1217. Before the Diode [Extract from "The Saga of the Vacuum Tube" : Developments prior to the Discovery of the Edison Effect & the Fleming Diode].—G. F. J. Tyne. (*Electronic Eng:g*, Dec. 1943, Vol. 16, No. 190, pp. 273–276.)

1218. A Ham-Made Free-Point Tube Tester [for Tests on Emission, Transconductance, etc.].—H. M. French. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 56–58 and 106.)

"The very fact that economy dictated the use of salvaged tip jacks in place of rotary switches resulted in a design which has made possible many un-anticipated uses of the instrument" (*e.g.* as valve voltmeter).

ACOUSTICS AND AUDIO-FREQUENCIES

1219. On the Energy Distribution in the Near Field of Electromagnetic Radiators, in particular in front of Diaphragms and Reflectors [treated by Acoustical Methods].—Born. (*See* 1193.)

1220. Speech-Scrambling Methods [for Secrecy: Frequency-Inverter Circuit and Band-Splitting Methods].—Roberts. (*See* 1362.)

1221. Piezoelectric Surgical Probe.—Ostroumov & Lepeshinskaya. (*See* 1470.)

1222. A Differential Microphone: Basic Principles of the New Noise-Proof Signal Corps Lip Microphone [Type T-45].—F. C. Beekley. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 36–38.)

1223. Portable Communication System for Divers.—D. W. Gellerup. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 60 and 104, 108.) *See* also 837 of March.

1224. A Tone Selector for Radio Alert Systems [operated by 1000 c/s Tone: Development of Resonant-Reed (as used in Frequency Meters) Circuit to replace Sharply Tuned Filter].—H. E. Adams. (*Communications*, July 1943, Vol. 23, No. 7, pp. 20 and 87.)

1225. Future of the Disc [*Wireless World* Brains Trust, continued from 473 of February].—L. E. C. Hughes: D. W. Aldous. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, pp. 8–9.)

(i) Cost of sound-film compared with discs: advantage of playing discs outwards instead of inwards: "we are committed to discs" (with reasons): home recording the solution of the cry for long playing-times: need for international standardisation of cutting-stylus dimensions and groove-spacing (rendering mechanical tracking possible): etc. (ii) Improvements and modifications in disc recording: the embossing or burnishing system, with constant groove-speed (30 minutes' music on one side of 12-inch disc: Griffin, 4317 of 1940): the technically successful Duo-Trac film-recording method: Cricks' survey of sound-on-film *versus* disc (2687 of 1942): etc. For a letter from Wm. H. Jarvis, vigorously supporting the possibilities of film records, and quoting his own experiences with Duo-Trac strips, *see* February issue, No. 2, p. 60.

1226. Defects in Direct Disc Recording [Table from New Book, "Manual of Direct Disc Recording"].—D. W. Aldous. (*Electronic Eng:g*, Nov. 1943, Vol. 16, No. 189, pp. 233–235.)

1227. "That which Carries the Pick-Up": the Term "Pick-Up Arm" is Short & Complete.—R. W. Lowden. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, pp. 26–27.) Prompted by the correspondence referred to in 3428 of 1943. For a plea (on original grounds) for the retention of "tone arm," *see* H. Morgan, Feb. issue, No. 2, p. 60.

1228. Voice recorded on Hair-Like Wire [66 Minutes of Continuous Speech on 11 500 Feet of Steel Wire on Doughnut-Size Spool: for Aircraft, etc.].—M. Camras. (*Gen. Elec. Review*, Dec. 1943, Vol. 46, No. 12, p. 694.) Developed at the Armour Research Foundation.

1229. Synthetic Reverberation [with the "Reverberstat"].—J. K. Hilliard. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 62 and 108.) *See* 3442 of 1943.

1230. Synthetic Sound [and Its Possibilities: the Work of Previous Experimenters: a Patent by the Writer].—C. C. Buckle. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, p. 26.) Prompted by a "Free Grid" paragraph on "Ersatz Run Riot." *Cf.* 1933 Abstracts, p. 332, r-h column (two items); 1059 of 1936; 180, 1038, 2244 of 1937; 1495, 3987 of 1939; 654/5, 1061, 1064 of 1940; 3388, 3391 of 1941. The present writer mentions particularly the work by Moholy-Nagy.

1231. On the Nature of the Sound Field obtained when Music is reproduced by a System of Distributed Radiators.—L. D. Rosenberg. (*Journ. of Tech. Phys.* [in Russian], No. 4/5, Vol. 12, 1942, pp. 211–219.)

Following on the work dealt with in 835 of March. Since speech and music occupy an intermediate position between periodic and non-periodic sound radiation, the method of calculating sound fields depends entirely on the "degree of coherence" (*i.e.* approximation to periodicity) of the matter radiated. The structure of speech and music in this respect has not yet been exhaustively studied, but there are reasons for supposing that interference is not prominent when speech or music are reproduced by a system of distributed radiators (*i.e.* the degree of coherence is low) and that therefore the energy summation method can be used. This is fully confirmed by experiments reported in the present paper. *See* also 1232, below.

1232. A Method for calculating the Sound Fields of Distributed Systems of Radiators operating Indoors.—L. D. Rosenberg. (*Journ. of Tech. Phys.* [in Russian], No. 4/5, Vol. 12, 1942, pp. 220–248.)

In a previous paper (835 of March) a method was indicated in which the source of sound is replaced by fictitious sources representing reflections from the inner surface of the room. The results so obtained are the more accurate, the more uniform the distribution of the real sources. The practical applications of the method will be considered in later papers, while in the present work the fields of the fictitious sources are discussed under the following headings:—(1) The field of a point source located between two parallel absorbing planes; (2) the field of a point source located between two mutually perpendicular pairs of parallel absorbing planes; (3) the case of a sound receiver (observer) outside the plane of fictitious sources; (4) the field of sources distributed in a space enclosed by absorbing surfaces; (5) isotropic absorption; and (6) the field of sources distributed in a medium with a double anisotropy of damping.

1233. Compensating Audio Amplifier for Three Channels [(i) Broad Resonance Point around 12 kc/s, (ii) Low Gain, Uniform Response 200–5000 c/s, (iii) Resonance Point adjustable between 40 & 150 c/s: an Electronic Equaliser for Outside Broadcasts, Disc-Recording, etc.].—W. L. Widlar. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 28–29 and 111.) With provision for correct phase relations.

1234. U.S. SHORT-WAVE BROADCAST CONTROL CENTRE [Office of War Information Radio Headquarters]. (*See* 1364.)

1235. MUSIC IN INDUSTRY [and Its Effect on Production: Investigation with Cooperation of Muzak, Inc., and R.C.A.].—H. Burris-Meyer. (*Scient. American*, Dec. 1943, Vol. 169, No. 6, pp. 262–264.) *Cf.* 491 of February.

1236. MUSICAL TASTE [More of the Correspondence referred to in 452 of February].—P. B. Fellgett. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, p. 27.)

1237. RELATION BETWEEN DISSONANCE AND CONTEXT.—R. W. Pickford. (*Nature*, 15th Jan. 1944, Vol. 153, No. 3872, p. 85.) For previous correspondence *see* 493 of February.

1238. REMEDIES FOR UNPLEASANT NOISES [Summary of Report].—C. P. McCord & J. D. Goodell. (*Science*, 5th Nov. 1943, Vol. 98, No. 2549, Supp. pp.10 and 12.) "The public needs to be convinced that noise is unnecessary."

1239. HEARING AIDS: ESTABLISHING A BASIS OF COMPARISON.—C. M. R. Balbi: T. S. Littler. (*Elec. Review*, 3rd Dec. 1943, Vol. 133, No. 3445, p. 754.) Summaries of I.E.E. papers. *See* also *Electrician*, 10th Dec. 1943, Vol. 131, No. 3419, p. 579.

1240. INCIDENCE OF DEAFNESS [Some Data as to Numbers: with an Editorial Note quoting Further Figures].—G. W. Lilburn. (*Wireless World*, Feb. 1944, Vol. 50, No. 2, pp. 60–61.)

1241. AN IMPROVED LOW-FREQUENCY ANALYSER.—Grey Walter. (*See* 1473.)

1242. AUDIO-FREQUENCY GENERATOR: RESISTANCE–CAPACITY TUNING WITH WIEN BRIDGE FEEDBACK CIRCUIT [with Details of Model covering 30 c/s–14 kc/s in Four Ranges].—Lewer. (*See* 1157.)

1243. A TWO-PHASE BEAT-FREQUENCY OSCILLATOR FOR AUDIO-FREQUENCIES [and Its Many Uses].—G. B. Madella. (*Alta Frequenza*, May 1943, Vol. 12, No. 5, pp. 248–254.)

For the measurement of phase differences (Fig. 3), the rapid determination of impedances (Madella, 1244, below, and Fig. 5), the plotting of the transmission characteristics of four-terminal networks (Fig. 6), the measurement of non-linear distortion (Fig. 7), and other purposes, great use can be made of an apparatus which will provide two sinusoidal voltages, of precisely equal frequencies, whose phase relation can be adjusted at will, without any dependence on the frequency. The Franke generator provides such a source, but has the usual disadvantages of rotating machines, especially with respect to wave-form and restriction of frequency-range. On the other hand the alternative method, consisting in the use of any kind of generator combined with some suitable phase-shifting device, has the defect that the behaviour of such a phase-shifting organ is necessarily dependent to a greater or lesser extent on the working frequency, so that satisfactory calibration over a wide frequency range is impossible.

The writer has therefore developed the present apparatus, to cover the range 5 c/s to 25 kc/s: this range can easily be extended. The principle is shown in Fig. 1: two independent oscillators, the one of fixed frequency and the other of variable, are used: both high-frequency voltages are taken to two independent non-linear organs ("modulators A and B"), but the voltage from the fixed-frequency oscillator, before it reaches "modulator A", has its phase regulated in the "phase-shifter A", giving a displacement β. The two l.f. voltages on the far side of the two "modulators" will now be $v_u = V_u \cos [(\omega_1 - \omega_2)t + \phi_1 - \phi_2]$ and $v'_u = V_u \cos [(\omega_1 - \omega_2)t + \phi_1 - \phi_2 - \beta]$, having a phase difference β which can be maintained constant throughout the frequency changes made by varying ω_2.

Since the phase-shifter works on a fixed frequency, its design is not difficult. In a first model it took the form of the bridge circuit of Fig. 2, but this, though conveniently simple, did not give a large enough range of phase-variation. This could be remedied by introducing a second phase-shifter (shown dotted in Fig. 1) adjusted simultaneously with the first and producing an opposite phase-shift in front of "modulator B"; or by introducing, at the output of the original phase-shifter, a frequency-multiplication, which would multiply the phase-variations. Actually, however, the bridge circuit was finally replaced by a crossed-coil variometer (like a radio-goniometer) fed with two currents exactly in quadrature. Since the rotating field was not perfectly circular, the output voltage did not keep completely constant, and it was found desirable to introduce an amplitude limiter between the phase-shifter and "modulator A". The second phase-shifter was retained to act as a vernier, its range being made to cover only a few degrees.

1244. METHOD FOR THE RAPID MEASUREMENT OF ELECTRICAL IMPEDANCES AT AUDIO-FREQUENCIES [for Inductive & Capacitive Impedances: particularly suitable for plotting Impedance Diagrams: using a Special Two-Phase Beat-Frequency Oscillator (1243, above) and a Differential Valve-Voltmeter as Zero-Indicator, alternating (by Manual Switching or Electronic Commutator) with a Cathode-Ray Oscillograph].—G. B. Madella. (*Alta Frequenza*, Oct. 1942, Vol. 11, No. 10, pp. 435–441.)

A special circuit (Fig. 3) is used for the differential valve-voltmeter, to allow it to act as a sensitive zero-indicator and yet to be protected against over-loading. As examples of the use of the apparatus, specimen diagrams are shown for the impedance of a piezoelectric loudspeaker and the input impedance of a band-pass filter.

1245. AUDIO AND MEASURING FACILITIES FOR THE C.B.S. INTERNATIONAL BROADCAST STATIONS.—H. A. Chinn. (*Elec. Communication*, No. 3, Vol. 21, 1943, pp. 174–179.) For these stations *see* Romander, 3177 of 1943.

1246. CALCULATION OF ELECTROLYTIC-TROUGH POTENTIOMETERS BY THE METHOD OF CONFORMAL REPRESENTATION.—Madella. (*See* 1151.)

1247. AN AUDIO-FREQUENCY OUTPUT-POWER METER.—Savelli. (*See* 1267.)

1248. USE OF SUPERSONIC WAVES TO HOMOGENIZE MILK [so that Cream will Not Separate Out], TO PRODUCE SPECIAL, ULTRA-FINE-GRAINED PHOTOGRAPHIC EMULSIONS, ETC.—K. Sollner. (*Science*, 17th Sept. 1943, Vol. 98, No. 2542, Supp. p. 12: summary only.)

1249. APPLICATIONS OF SUPERSONICS IN METALLURGY.—(*Journ. of Scient. Instr.*, Dec. 1943, Vol. 20, No. 12, p. 200.) Note on an abstract of a German paper, evidently that dealt with in 2569 of 1943.

PHOTOTELEGRAPHY AND TELEVISION

1250. STANDARDS FOR TELEVISION : ENSURING AN EARLY POST-WAR START [Editorial : the Cossor Scheme].—(*Wireless World*, Jan. 1944, Vol. 50, No. 1, p. 1.) *See* 616 of February, and 1251, below.

1251. "PERFECT" TELEVISION : JUSTIFYING 525-LINE DEFINITION [*Wireless World* Brains Trust].—D. A. Bell. (*Wireless World*, Feb. 1944, Vol. 50, No. 2, pp. 58–59.)

1252. LIGHT RELAYS [Light Valves, Modulators].—Tager. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 37–52.)

A comprehensive classification of these devices is given in respect of the methods of modulation and the physical phenomena underlying their operation, and a chart illustrating this is shown (Fig. 1). The requirements imposed on them are discussed, and the main types suitable for practical purposes are described.

1253. THE FREQUENCY-DEPENDENCE OF THE GROUP PATH TIME IN RESONANCE AMPLIFIERS [for Image Transmission, Pulse Measurements, etc.].—G. Schaffstein. (*Hochf:tech. u. Elek:akus.*, July 1943, Vol. 62, No. 1, pp. 6–14.)

A knowledge of the group path time and its frequency characteristic is of little importance in connection with the transmission of speech or music, where a path-time difference would have to be more than 10 msecs to cause trouble—a value not nearly reached even in a multi-stage h.f. amplifier ; but it attains considerable significance in the cases named above : *cf.* Strecker, 447 of 1941 ; Ring, 4465 [and 213] of 1938 ; and Küpfmüller & Mayer, 1978 of 1939, all in connection with television amplifiers and cables.

Author's summary :—"For a single-stage amplifier with a parallel *LC* circuit as anode resistance, the group path time is calculated as a function of the 'rationalised' detuning Ω [the values for $\Omega = \pm 1$ correspond to a 45° detuning]. By limiting the treatment to the region close to the resonance point, the expression for the group path time can be analysed into two factors, one of which contains only the circuit data [which vary from case to case] while the other is exclusively a function of the rationalised detuning [the whole expression is the approximation $\tau \approx (2/d\omega_0) \cdot (d\phi/d\Omega) = -(2/d\omega_0) \cdot 1/(1+\Omega^2)$, d being the circuit damping]. The resultant group path time for a multi-stage amplifier is obtained by addition of the individual path times. The relations for coupled circuits are derived from those for the decoupled and mutually detuned circuits. The experimental circuit used for measuring the frequency-dependence of the path times is described [Fig. 5 : Figs. 6 & 7 show the two types of phase-shifter used, the one inductive and the other resistive, and Fig. 8 gives the circuit for calibrating them]. Good agreement was found between the measured and calculated values.

"For a multi-stage amplifier with an approximately rectangular amplification characteristic [Schienemann, 2016 of 1939], the frequency-dependence of the group path time is calculated, and represented in curves, for a number of circuits ranging from 1 to 10. Although the amplification in the transmission band remains practically constant, the path-time curves show marked humps. As is shown by an example, path-time errors (phase distortion) may thus be produced in television if the amplification characteristic of the h.f. amplifier is nearly rectangular.

"By a suitable selection of circuit data it can be arranged that the path time, instead of the amplification, remains practically constant over the transmission band [the circuits must be mutually detuned by a smaller amount than was necessary to give the rectangular amplification curve. This, naturally, tends to narrow the pass-band of the h.f. amplifier, but by increasing the damping d of the circuits the transmission band, referred to *absolute* detunings, can be kept constant. Thus the curve "f" of Fig. 12a shows that for a seven-circuit amplifier the value of $d\phi/d\Omega$, and therefore the group path time, remains practically constant up to detunings of $\Omega = \pm 2$. The amplification at these points (Fig. 12b, curve "f") is only half that at the symmetrical frequency, but the result is of practical importance for h.f. amplifiers specially intended for path-time or phase measurement, where a drop in amplification is less serious than a change of path time]. This is shown by some calculated curves : measurements on a three-stage h.f. amplifier [Figs. 13 a, b] confirm the calculated results."

MEASUREMENTS AND STANDARDS

1254. A DISCUSSION OF THE SENSITIVITY OF A METHOD FOR MEASURING IMPEDANCE BY MEANS OF TRANSMISSION LINES : SUGGESTIONS FOR APPLICATION TO THE INVESTIGATION OF LIQUIDS AT ULTRA-HIGH FREQUENCIES.—D. Rogers. (*Proc. Phys. Soc.*, 1st Jan. 1944, Vol. 56, Part 1, No. 313, pp. 1–8.)

The method discussed is that of Flint & Williams (780 of 1942 : for a later paper *see* 1255, below) : it "gives good results for most impedances, but in its original form it has been found to be rather insensitive for the determination of impedances with large phase angles." The reasons for this are found and two practical methods of improving the sensitivity and widening the range of applicability of the method are given : the first, using a concentric line, is relatively simple in procedure and gives both the dielectric constant and the losses directly, but has the disadvantage of requiring a greater quantity of liquid than the other methods : the second, in which only a part of the concentric line is filled with the liquid, is only applicable when the losses are negligible.

1255. A NEW METHOD FOR THE MEASUREMENT OF IMPEDANCE AT ULTRA-HIGH FREQUENCIES USING A SYSTEM OF LECHER WIRES [eliminating Many of the Disadvantages of Previous Lecher-Wire Methods : Application to Measurements, at about 150 Mc/s, on Carbon Resistors, Valve Capacitances, & Liquids : Suitability for Direct Impedance-Measurements on Aerials].—G. Williams. (*Proc. Phys. Soc.*, 1st Jan. 1944, Vol. 56, Part 1, No. 313, pp. 63–72.)

To eliminate errors due to fluctuations in the oscillator power output, Flint & Williams modified the ordinary Lecher-wire method so that the unknown impedance was determined from the ratios of the currents flowing in two bridges (780 of 1942 : *cf.* 1254, above). This method, while giving good results, has the disadvantage that the impedance of the current meter in the fixed bridge has to be measured in a subsidiary experiment. The present method avoids this objection : the unknown impedance is connected across the end of the wires and the ratios of the currents flowing in two other bridges located at various points on the wires (in practice taking the form of a tandem bridge with the spacing fixed at a critical value) are used for its calculation.

1256. MEASUREMENT OF ANTENNA IMPEDANCE : A SIMPLE METHOD OF DETERMINING ANTENNA AND TRANSMISSION-LINE OPERATING CONDITIONS.—Stewart. (*See* 1196.)

1257. A TWO-PHASE BEAT-FREQUENCY OSCILLATOR FOR AUDIO-FREQUENCIES [and Its Many Uses], *and*

METHOD FOR THE RAPID MEASUREMENT OF ELECTRICAL IMPEDANCES AT AUDIO FREQUENCIES.—Madella. (*See* 1243 & 1244.)

1258. MEASURING SMALL INDUCTANCES: AN INSTRUMENT FOR THE RAPID MEASUREMENT OF THE INDUCTANCE AND SELF-CAPACITANCE OF COILS FROM 1 TO 1000 μH [based on the Two-Frequency Resonance Method].—R. F. Blackwell & D. J. Becker. (*Wireless World*, Feb. 1944, Vol. 50, No. 2, pp. 37–40.) From Murphy Radio, Ltd.

1259. "DOUBLE T" BRIDGE FOR THE MEASUREMENT OF LOSS ANGLES OF DIELECTRICS [Ordinary Bridges, used at High Frequencies for This Purpose, require Screened Transformers, Wagner Earth, etc: Difficulties avoided by Use of Bridge composed of Two Paralleled T Sections (*c.f.* Tuttle, 1549 of 1940): Derivation of Optimum Conditions for Measurement of Power Factor, for a Given Frequency & Capacitance-Range: Design of Bridge for 1 Mc/s Frequency, Test Capacitance 50–250 μμF, Unknown Resistance not less than 10^5 Ohms].—N. Carrara. (*Alta Frequenza*, Feb. 1943, Vol. 12, No. 2, pp. 66–77.)

1260. THE MEASUREMENT OF THE RESIDUAL PARAMETERS OF VARIABLE AIR CONDENSERS [in "Q"-Meters).—J. C. Simmonds. (*Phil. Mag.*, Dec. 1943, Vol. 34, No. 239, pp. 833–837.)

In many magnification meters, now in quite general use for power-factor measurements on condensers and dielectric specimens, the tuning condenser is not of the highest quality and serious errors may result from its residual inductance and resistance. "A method of measuring the residual parameters of a variable condenser has been described by Sinclair (1897 of 1936), and this method can frequently be used to determine the parameters of the tuning condenser used in the 'Q'-meter. When this can be done it is, of course, an easy matter to apply corrections to the results of measurements so that greater accuracy is obtained." It is shown that the required observations can be made on the Q-meter itself, the only additional equipment being a fairly small unknown fixed condenser.

1261. CAPACITANCE AND DISSIPATION-FACTOR CORRECTION [for Stray Capacitance & Leakage Resistance of Instrument & Leads: New Formulae suited to Slide-Rule or Mental Calculation].—G. Shombert, Jr. (*Elec. Engineering*, Feb. 1943, Vol. 62, No. 2, pp. 85–86.)

1262. MEASUREMENTS IN RADIO EXPERIMENTAL WORK [Lecture to Radio Society of Great Britain].—R. L. Smith-Rose. (*Nature*, 8th Jan. 1944, Vol. 153, No. 3871, p. 50: summary only.)

1263. PHOTOELECTRIC POTENTIOMETER RECORDER [0.2 mV Full Scale (at Max. Sensitivity): takes less than 10^{-12} Watt: Balance in less than ½ Second: Many Applications].—D. F. Hang. (*Gen. Elec. Review*, Nov. 1943, Vol. 46, No. 11, pp. 623–625.)

1264. A NEW ELECTRONIC STABILISER AND REGULATOR FOR D.C. VOLTAGES, *and* THE USE OF A SIMPLE A.C. POTENTIOMETER FOR THE PRECISION TESTING OF INSTRUMENT TRANSFORMERS [Discussion of Two Papers].—A. Glynne. (*Electrician*, 28th Jan. 1944, Vol. 132, No. 3426, pp. 79–81.) For previous work *see* 1957 of 1943, and for the Eindhoven stabiliser mentioned *see* 817 & 2077 of 1942.

1265. CALCULATION OF ELECTROLYTIC-TROUGH POTENTIOMETERS BY THE METHOD OF CONFORMAL REPRESENTATION.—Madella. (*See* 1151.)

1266. CIRCUIT FOR THE MEASUREMENT OF THE ROOT-MEAN-SQUARE VALUES OF ALTERNATING VOLTAGES BY MEANS OF THERMIONIC VALVES.—G. B. Madella. (*Alta Frequenza*, Feb. 1943, Vol. 12, No. 2, pp. 78–81.)

A letter prompted by Francini's paper (719 of 1943) on the use of negative-transconductance valves. The usual triode/microammeter combination for measuring r.m.s. values (Fig. 1), in which conditions are so arranged that the working part of the plate-current/grid-voltage characteristic is approximately parabolic, has the one great defect of instability, in the form of zero-drift due to small variations in the supply voltage or the valve characteristics. A certain amount of improvement is obtained by compensation by a second triode whose control grid is kept free from any alternating voltage (Fig. 2), but this arrangement involves an extra valve, taking no direct part in the measuring process, and having to be selected carefully to match the working valve.

A marked advantage is gained by arranging that the compensation is effected in the working valve itself: this can be done by applying the alternating voltage to a grid which, while leaving the total valve current unchanged, modifies its distribution among the various electrodes. If the working point is chosen so that such a controlling action follows a square law, and the circuit of Fig. 3 is employed (pentode connected to give a differential negative transconductance), the differential current through the microammeter is practically proportional to the square of the r.m.s. value of the unknown voltage, and is influenced to a relatively small degree by variations of the cathode emission, as is seen from curve "a" of Fig. 4. By the modification shown in Fig. 5, the first grid may be used to introduce a negative feedback with respect to the total current, and this renders the circuit still more stable, as is seen in curve "b" of Fig. 4. Fig. 7 shows the curve of zero-drift of such an arrangement, from the moment of switching-on the filament to the end of 30 minutes: after less than 10 minutes the drift practically disappears. Continuous observation over 6 hours showed a variation of the differential current always less than 1 μA. The frequency characteristic was found to be practically flat from 50 c/s to 40 kc/s (variation less than 0.05 db). It is well to connect a suitable condenser across the microammeter, to prevent the latter from being traversed by too large an a.c. component. The type 89 valve was found to be particularly suitable for the circuit.

1267. AN AUDIO-FREQUENCY OUTPUT-POWER METER.—V. Savelli. (*Alta Frequenza*, March 1943, Vol. 12, No. 3, pp. 156–160.)

Instruments based on the scheme of Fig. 1, where impedance matching depends on the use of a multi-tapping transformer, are liable to large errors over a range of frequencies: "one instrument made by a well-known American firm is stated by the makers to have an error of 30% in the indication of power, and of 20% in impedance indications, over the range 20 c/s to 10 kc/s. The apparatus now described uses a different principle (Italian patent applied for), giving more exact results over a wide range of frequencies. The circuit is seen in Fig. 2: the impedance across the input terminals "1", "2" is composed of a resistance R_1 variable in steps by the slider "3", which is rigidly connected to another slider "4" (leading to the indicating instrument) running over the same resistance in such a way that the resistance

R_2 between slider " 4 " and terminal " 2 " always fulfils the relation $R_2/\sqrt{R_1}$ = constant. Such a condition is easily satisfied if R_1 and R_2 vary in steps: the " sliders " take the form of rotating contact-arms.

If the generator whose output P into a load R_1 is to be measured is connected across " 1 " and " 2 ", and if I is the current in R_1 (and hence also in R_2) and V the voltage between " 2 " and " 4 ", then $P = R_1I^2$ and $V = R_2I = \sqrt{P} . R_2/\sqrt{R_1}$. But from the above condition $R_2/\sqrt{R_1}$ is a constant, so that V is proportional to $\sqrt{P}$ and is independent of R_1 and R_2; that is, of the position of the double slider. Therefore if a voltmeter of sufficiently high impedance is used as the indicating instrument across " 2 " and " 4 ", its scale can be calibrated directly in units of power. In the apparatus described and illustrated it takes the form of a two-stage amplifier, with strong negative feedback (about 20 db) to stabilise it against fluctuations, combined with a rectifier-type voltmeter. The apparatus has five ranges, the first scale division on the lowest range corresponding to 50 μw and the highest range ending at 10 w. The input impedance can be varied in 40 steps from 2.5 to 20.000 ohms. The response curve is flat (Fig. 5) from about 30 c/s to 10 kc/s, after which it falls as a result of the shape of the characteristic of the rectifier-type voltmeter.

1268. TERMINAL CORRECTIONS FOR TEMPERATURE TESTS ON SHORT CONDUCTORS [Comment on Letter dealt with in 2789 of 1943].—F. Bauer & J. J. Taylor: Goodwin. (*Elec. Engineering*, Feb. 1943, Vol. 62, No. 2, pp. 83–84.)

1269. AN A.C.-OPERATED VACUUM-TUBE VOLTMETER [for Wide Range of Voltage & Frequency: using Diode Rectifier and A.C.-Operated Triode Amplifier: requires No Voltage Regulator: costs 25 Dollars to construct].—J. N. Thurston. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 102–104 and 224..232.)

" The careful reader will discern that there is more to Mr. Thurston's article than the description of a highly useful and inexpensive voltmeter. The use of tubes with an a.c. source of plate supply has wide application in many industrial devices, particularly if a tube so used is reasonably free from line voltage variations which, laboratory investigation has shown, is the case ": Editorial Note.

1270. A HAM-MADE FREE-POINT TUBE TESTER [for Tests on Emission, Transconductance, etc.].—French. (*See* 1218.)

1271. RESEARCH ON MATERIALS AND PROCESSES [and Some Testing Equipments (*e.g.* " Greenness " Tester for Synthetic Resin)].—(*Met.-Vick. Gazette*, Oct. 1943, Vol. 20, No. 342, pp. 233–236.)

1272. INSULATION TESTING OF ELECTRIC WINDINGS [Equipment consisting of Repeating-Type Surge Generator, Cathode-Ray Oscillograph, & Synchronously Driven Switch].—C. M. Foust & N. Rohats. (*Elec. Engineering*, April 1943, Vol. 62, No. 4, Transactions pp. 203–206.) A summary was referred to in 2772 of 1943.

1273. NEW MODEL " ROTOBRIDGE " MASS-PRODUCTION CIRCUIT-TESTER [One Circuit per Second].—(*Gen. Elec. Review*, Nov. 1943, Vol. 46, No. 11, p. 638.) *See* also 152 of January and back reference.

1274. TELEGRAPH-TRANSMISSION MEASURING SET [for determining the Distortion in Teletypewriter Pulses: the Type 118 C 1 Set].—W. T. Rea. (*Bell Lab. Record*, Dec. 1943, Vol. 22, No. 4, pp. 174–178.)

1275. DUST-CORED COILS: METHODS OF MEASUREMENT.—Welsby. (*See* 1348.)

1276. A NEW METHOD OF MEASURING THE INCLINATION OF THE EARTH'S MAGNETIC FIELD [based on Increase in Impedance, due to Skin Effect, in Nickel–Iron Wires when Axial Component of Field is Decreased: the " All-Magnetic Square " Bridge].—E. P. Harrison & E. Hamilton Smith. (*Proc. Phys. Soc.*, 1st Jan. 1944, Vol. 56, Part 1, No. 313, pp. 31–47.)

If a suitably heat-treated 26 s.w.g. wire of the permalloy range, 9 inches long, carries an a.f. current, the change of impedance for a field-change from 0 to 0.2 oersted may be as large as 18% (1226 of 1937). The present design, using four carefully assembled matched wires, is twice as sensitive as its immediate forerunner, the bridge with two magnetic arms (magnetic repeater compass, Brit. Patent), and has various other advantages. The device will find the meridian plane, the magnetic north, and the dip. For other previous work *see* 2103 of 1938 and 699 of 1939.

1277. USE AND MISUSE OF THE SALT-SPRAY TEST AS APPLIED TO ELECTRODEPOSITED METALLIC FINISHES.—C. H. Sample. (*Engineering*, 26th Nov. 1943, Vol. 156, No. 4063, p. 426: summary only.)

1278. RECENT BRITISH STANDARD SPECIFICATIONS.—(*Journ. of Scient. Instr.*, Jan. 1944, Vol. 21, No. 1, p. 19.)

1279. STANDARD-FREQUENCY TRANSMISSIONS [from WWV: 24-Hour Service].—Nat. Bureau of Standards. (*Wireless World*, Feb. 1944, Vol. 50, No. 2, p. 59.) *See* also 3478 of 1943.

1280. FREQUENCY MEASUREMENT IN THE WERS: A SIMPLIFIED STABLE OSCILLATOR–MONITOR FOR THE 112-MC/S BAND [RCA-9002 Valve as Ultra-Audion Oscillator with Folded Line tuned with Small Variable Condenser].—P. Bliss. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 23–25.)

1281. CRYSTAL HOLDER DESIGN [with Description & Discussion of Eight Varieties of Mounting, each with Distinct Advantages for Certain Applications].—L. A. Elbl. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 134–138.)

1282. THE USE OF X-RAYS FOR DETERMINING THE ORIENTATION OF QUARTZ CRYSTALS.—W. L. Bond & Elizabeth J. Armstrong. (*Bell S. Tech. Journ.*, Oct. 1943, Vol. 22, No. 3, pp. 293–337.)

Chapter III of the series dealt with in 3350 of 1943. Production of X-rays for this purpose: detection (heat effects, fluorescence, photographic effects, ionisation of gases): precautions against physiological effects: diffraction: naming of atomic planes: X-ray goniometry: choice of atomic plane for checking the orientation of a given face: determination of orientation of an atomic plane with respect to the plate-edges, given its Miller–Bravais indices: determination of angles between X-rays and faces of finished plate: use of Laue photographs (and the " back-reflection Laue camera "): X-ray checks of slabs in course of manufacturing.

1283. RAW QUARTZ, ITS IMPERFECTIONS AND INSPECTION [Source, Size, Shape: Colour: Twinning: Cracks: Inclusions (Bubbles, Needles, Phantoms, Veils, etc.): the " Inspectoscope " (Improved Form of Inspection Tank): the Immersion " Refractoscope ": Photographic Study of Interior Defects: Effect of Interior Imperfections on Finished

Plates], *and* AN INTERFEROMETRIC PROCEDURE FOR THE EXAMINATION OF CRYSTAL SURFACES.—G. W. Willard: S. Tolansky. (*Bell S. Tech. Journ.*, Oct. 1943, Vol. 22, No. 3, pp. 338–361: Abstract 1450, below.)

1284. SYNCHRONISING ELECTRIC CLOCKS [Reply to Davies's Letter, 537 of February].—H. Morgan: Davies. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, p. 26.)

SUBSIDIARY APPARATUS AND MATERIALS

1285. REMARKS ON THE DEVELOPMENTS OF RECENT CATHODE-RAY OSCILLOGRAPHS [for Frequencies up to 500 Mc/s].—Pieplow. (*Alta Frequenza*, Oct. 1942, Vol. 11, No. 10, pp. 462–464.) Illustrated summary of the paper dealt with (from another summary) in 502 & 2776 of 1942.

1286. WAR EMERGENCY BRITISH STANDARD CODE OF PRACTICE RELATING TO CATHODE-RAY TUBES AND THEIR APPLICATION TO VARIOUS PURPOSES [Notice of Leaflet].—British Standards Institution. (*Wireless World*, Feb. 1944, Vol. 50, No. 2, p. 40.)

1287. THE DESIGN OF A CATHODE-RAY-TUBE AMPLIFIER [on the Limiting-Gain Principle].—Hadfield. (*See* 1161.)

1288. MULTIPLE ELECTRONIC COMMUTATORS FOR CATHODE-RAY OSCILLOGRAPHS [Survey of Previous Types of Electronic Commutator, mostly limited to the Switching of Two Phenomena: Investigation of Switching with Sinusoidal Voltage, and the Conditions necessary to give a Clear Image of *n* Signals (Choice of Frequency of Commutation, Effect of Time of Transit of Ray from One Trace to Another, Circuit for Extinction of Transit-Trace): Principle & Design of a Triple Electronic Commutator (Figs. 11, 12): Applications, including to Transient Phenomena].—Ioppolo. (*Alta Frequenza*, Oct. 1942, Vol. 11, No. 10, pp. 442–455.)

1289. THE ELECTRON MICROSCOPE AND ITS APPLICATION TO ENGINEERING PROBLEMS.—Quarrell. (*Engineer*, 24th & 31st Dec. 1943, Vol. 176, Nos. 4589 & 4590, pp. 499–502 & 526–528.)

1290. NEW MICROTOME AND SECTIONING METHOD FOR ELECTRON MICROSCOPY.—O'Brien & McKinley. (*Science*, 19th Nov. 1943, Vol. 98, No. 2551, pp. 455–456.) Giving the section-thicknesses of 0.1μ necessary for good results.

1291. THE ELECTRON MICROSCOPE IN AN X-RAY DIFFRACTION LABORATORY [and Its Special Powers & Limitations], *and* RECENT DEVELOPMENTS IN THE ELECTRON MICROSCOPE [Effect of Electron-Gun Focusing on Specimen Illumination: Resolving Power with & without a Limiting Aperture: Distortion & Its Reduction: etc.].—Clark & Baylor: Zworykin & Hillier. (*Phys. Review*, 1st/15th Nov. 1943, Vol. 64, No. 9/10, pp. 314–315: pp. 315–316: summaries only.)

1292. ON MICROANALYSIS BY ELECTRONS [Development of Instrument tentatively named "Electron Microanalyser" for Elemental Analysis of Extremely Small Regions of Electron-Microscope Specimens: converted into Electron-Microscope of Shadow Type (by turning off the Deflecting Field and adjusting the Electron Probe) for Location & Identification of the Region].—Hillier. (*Phys. Review*, 1st/15th Nov. 1943, Vol. 64, No. 9/10, pp. 318–319.) Prompted by the work of Ruthemann, 1566 of 1940, 517 of 1942, and 1293, below.

1293. ELECTRON RETARDATION AT RÖNTGEN LEVEL [and the Velocity Spectrum of 7.5 ekV Electrons after Passing through a Very Thin Collodion Film].—Ruthemann. (*Naturwiss.*, 27th Feb. 1942, Vol. 30, No. 9/10, p. 145.)

1294. THE MEASURED CHARACTERISTICS OF SOME ELECTROSTATIC ELECTRON LENSES [Operating Characteristics of Nine Lenses of the Three Basic Types, presented in Form of Object-Distance/Image-Distance Curve Families (1142 & 2464 of 1942): Satisfactory Approximate Formula for Lateral Magnification: etc.].—Spangenberg & Field. (*Elec. Communication*, No. 3, Vol. 21, 1943, pp. 194–204.)

1295. GENERAL THEORY OF THE FOCUSING ACTION OF ELECTROSTATIC AND MAGNETIC FIELDS: III—THREE-DIMENSIONAL (TWISTED) TRAJECTORIES IN THE PRESENCE OF BOTH AN ELECTROSTATIC AND A MAGNETIC FIELD.—Grünberg. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 30th Jan. 1943, Vol. 38, No. 2/3, pp. 78–81: in English.)

"To sum up, the method suggested in the present work affords the possibility for dealing in the most general way with problems in which the focusing of electron and ion beams of any desired type is considered. By using it it is also possible to decide to what extent such focusing beams are arbitrary and to establish the character of electrostatic and magnetic fields necessary for their creation. . . ."

1296. OPTIMUM CONDITIONS FOR APERTURES OF MAGNETIC ELECTRON LENSES OF THE FIELD FORM $H(Z) = H_0/\{1 + (Z/a)^2\}$.—Marton & Hutter. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, p. 186: summary only.)

1297. THE VALIDITY OF LENS EQUATION AND MAGNIFICATION FORMULA OF LIGHT OPTICS FOR ELECTRON LENSES.—Hutter. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, p. 186: summary only.)

1298. ON LIMITING THE RAYS IN OPTICAL APPARATUS HAVING AT LEAST ONE INFINITELY SMALL DIAPHRAGM.—Shesmintsev. (*Journ. of Tech. Phys.* [in Russian], No. 4/5, Vol. 12, 1942, pp. 195–203.)

To select paraxial rays at least two diaphragms are required. The optical laws of Gauss are, however, applicable only to the case when the apertures in the diaphragms are infinitely small. This paper discusses the aberrations introduced when the aperture in one or the other diaphragm is finite.

1299. ELECTROMAGNET POLEPIECES AND CONDENSERS WITH SPECIAL SHAPES [Note reporting Progress in devising & testing Electric & Magnetic Fields such that $\partial H/\partial s$ or $\partial H^2/\partial s$ is Constant over a Certain Distance or throughout a Small Volume: with a Note on the Gerlach–Stern Polepieces].—Davy. (*Phil. Mag.*, Dec. 1943, Vol. 34, No. 239, pp. 803–810.) In connection with molecular-beam researches, magnetic-susceptibility measurements, etc. For a previous paper *see* 219 of 1943.

1300. THE SHAPE OF BETATRON POLE FACES [Correct Shape, necessary for Focusing of Electron Beam, determined by Calculation].—Bartlett: Kerst. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, p. 185.) For the "Betatron" *see* 153 (and 3114) of 1943.

1301. An Automatic Flow Switch for Water-Cooled Apparatus [Simple Protecting Device formed of Two U-Tubes].—Gouley. (*Science*, 8th Oct. 1943, Vol. 98, No. 2545, p. 330.)

1302. Luminescence of [Electrolytic-] Valve Metals during Electrolytic Oxidation [Investigation of Production Mechanism of "Anodic" & "Cathodic Flash"].—Anderson. (*Journ. Applied Phys.*, Nov. 1943, Vol. 14, No. 11, pp. 601–609.)

These and previous experiments suggest that the origin of this luminescence is similar to that of the luminescence in the semiconductor sulphide phosphors, and is a property of the (excess-semiconductor) oxide coating formed on the metal. The phosphoroscope constructed to measure the decay rates photographically is described.

1303. Aircraft Electric Power Supply System [Progress made with Light-Weight Power Transformers & Selenium Rectifiers in A.C., D.C. Aircraft Systems].—Yarmack. (*Elec. Communication*, No. 3, Vol. 21, 1943, pp. 159–166.)

1304. Aircraft Inverter Construction [Rotary Types only].—Button. (*Elec. Engineering*, Sept. 1943, Vol. 62, No. 9, Transactions pp. 598–602.)

1305. Generator Brushes [for Use at High Altitudes].—Stackpole Carbon. (*Gen. Elec. Review*, Nov. 1943, Vol. 46, No. 11, pp. 637–638.)

1306. Contribution to the Working-Life Law of Electrical Machines [Extension of the Work dealt with in 3739 of 1942].—Büssing. (*Arch. f. Elektrot.*, 31st Dec. 1942, Vol. 36, No. 12, pp. 735–742.)

1307. Copper Metallurgy [Some Problems of Concern to the Electrical-Machinery Designer].—Parker. (*Gen. Elec. Review*, Dec. 1943, Vol. 46, No. 12, pp. 663–666.)

1308. Reclaiming Used Flashlight Batteries [provided that Sufficient Moisture remains in the Electrolyte: by Re-charging Them like Accumulators, followed by a 6-Hours' Voltage-Stabilising Period].—Kennedy. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 148, 152, 154: summary in *Electronic Eng:g*, Dec. 1943, Vol. 16, No. 190, p. 302.) *Cf.* Broadbent, 1193 of 1941.

1309. A Method of Rejuvenating Electrolytic Condensers [Successful in 90% of Wet-Type Condensers].—(*QST*, Dec. 1943, Vol. 27, No. 12, p. 63.)

1310. How to Maintain Capacitors [Rules for Periodic Inspection & Testing of Power Capacitors].—General Electric. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 105 and 106.)

1311. Progress in the Construction of Mica Condensers [with Comparative Table for 1935 & 1940].—Ebinger & Linder. (*Alta Frequenza*, March 1943, Vol. 12, No. 3, pp. 152–154.) Long summary of the paper dealt with in 564 of February.

1312. Canada Now Produces Low-Power-Factor Mica.—(*Sci. Abstracts*, Sec. A, Nov. 1943, Vol. 46, No. 551, p. 224.)

1313. Synthetic Elastomer: Styraloy 22, a New Thermoplastic [suitable for Ignition Cable, L.F. Coaxial Cable, etc.].—Dow Chemical. (*Review Scient. Instr.*, Nov. 1943, Vol. 14, No. 11, p. 343.)

1314. The Polymerisation of Styrene, and Some Concepts of the Electrical Properties of Plastics.—Warner. (*Elec. Communication*, No. 3, Vol. 21, 1943, pp. 180–193.)

Polymerisation of pure styrene by heat: molecular-weight dependence on temperature of polymerisation: chain initiation and chain propagation: chain termination: experimental technique: observations on the dielectric properties of dielectrics: electronic polarisations: atomic, dipole, and interfacial polarisations: circular-arc method of expressing dielectric phenomena (1323, below): Eyring rate theory and dielectric phenomena: dielectric behaviour of extremely low-loss material: importance of dielectric loss in transmission-line theory.

1315. "Handbook of Engineering Plastics" [Book Review].—Warburton Brown. (*Engineering*, 3rd Dec. 1943, Vol. 156, No. 4064, p. 444.)

1316. "Synthetic Resins and Allied Plastics" [Book Review].—Morrell (Edited by). (*Nature*, 9th Oct. 1943, Vol. 152, No. 3858, p. 398.)

1317. "The New Chemical Formulary, Vol. VI" [Book Review].—Bennett (Edited by). (*Communications*, July 1943, Vol. 23, No. 7, p. 53.) "In view of the activities of chemists in radio to-day, this reference book takes on added significance. . . ."

1318. Control of the Insect Enemies of Lac.—Negi. (*Nature*, 27th Nov. 1943, Vol. 152, No. 3865, p. 639: summary only.)

1319. Resistor-Coil Coating [Low-Loss Vitreous "Lectraseel," protecting against Corrosion and "Highly Resistant to Thermal Shock"].—(*Scient. American*, Dec. 1943, Vol. 169, No. 6, p. 285.)

1320. Glass Fibres Now Available in Seven Basic Types.—Owens-Corning Fiberglas. (*Scient. American*, Dec. 1943, Vol. 169, No. 6, p. 281.)

1321. Glass Structure according to Infra-Red Absorption Spectra [Measurements on 10μ Films].—Gerlovin. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 10th Feb. 1943, Vol. 38, No. 4, pp. 126–127: in English.)

"Thus it is seen that the glass has crystalline properties which are gradually fading away as its composition is becoming more complex and the quantity and mass of metal oxides are increased." For a later paper, on the relation between chemical composition and glass transmission in the infra-red, *see* issue of 28th February, No. 5/6, pp. 170–172.

1322. On the Electrification of Dielectrics by Friction [Treatment of Dielectrics as Electronic Semiconductors at Low Temperatures leads to Conclusion (contrary to Widely Accepted Belief based on Results of Owen & others) that Local Heating due to Friction is Necessary].—Frenkel. (*Journ. of Phys.* [of USSR], No. 1, Vol. 5, 1941, pp. 25–29: in English.)

1323. Circular-Arc Method of expressing Dielectric Phenomena.—Cole & Cole. (In paper in *Journ. Chem. Physics*, Vols. 9 & 10, 1941 & 1942, pp. 341 & 98 onwards.) Discussed in Warner's paper, 1314 above; *cf.* also 2833/5 of 1941, and Kauzmann, 1250 of 1943.

1324. CONDUCTION OF ELECTRICITY IN HIGHLY INSULATING LIQUIDS [Measurements on Natural Conductivity and That induced by Gamma Rays: Confirmation of Plumley's Theory, 3508 of 1941].—Pao. (*Phys. Review*, 1st/15th Aug. 1943, Vol. 64, No. 3/4, pp. 60–74.)

1325. THE ELECTRIC BREAKDOWN AND CUMULATIVE IONISATION [Breakdown interpreted as Abrupt Transition from Lower to Upper Branch of *S*-like Current/Field-Strength Curve: etc.].—Davydov. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, pp. 156–158.)

1326. CORONA SUPPRESSION IN HIGH-VOLTAGE MACHINES [Use of "Coronox" Semiconducting Paint].—Westinghouse. (*Engineering*, 17th Dec. 1943, Vol. 156, No. 4066, p. 488.) *See* also 1964 of 1943.

1327. CORONA IN GASES AT LOW PRESSURES [2 cm Hg downwards: Results with Various Impure Gases: Occurrence & Non-Occurrence of Streamers].—Craggs & Meek. (*Phys. Review*, 1st/15th Oct. 1943, Vol. 64, No. 7/8, pp. 249–250.)

1328. PAPERS ON THE SPARK DISCHARGE.—Morton: Fisher: Flowers. (*See* 1139/41.)

1329. INFRA-RED INDUSTRIAL LAMPS [and the Uses of Infra-Red Heating in Wartime: Some Typical Equipments].—(*Met.-Vick. Gazette*, Oct. 1943, Vol. 20, No. 342, pp. 226–229.) *Cf.*, for example, 579 of February and back reference.

1330. BRIDGE VOLTAGE REGULATORS [Use of Barretters or Electronic Semiconductors, and of Two Bridge Regulators in Series].—Morton. (*See* 1169.)

1331. DISCUSSION ON "A NEW ELECTRONIC STABILISER AND REGULATOR FOR D.C. VOLTAGES."—Glynne. (*See* 1264.)

1332. ELECTRONIC UNIT FOR ACCURATE TIMING OF SWITCHING OPERATIONS IN RAPID AND ADJUSTABLE SEQUENCE.—Mason & Goldschmidt. (*See* 1170.)

1333. THERMO-RELAYS.—Sotskov. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 53–72.)

Thermo-relays are discussed under two main headings: (1) those utilising dimensional changes with temperature and (2) those using changes in electrical parameters. Under the first heading relays in which different components absorb different amounts of radiated energy are also considered. Under the second heading are included relays in which a coil is pulled into or pushed out of a cylinder and relays with a variable resistance (for example a copper-oxide rectifier). The theory of each of the above types is discussed in detail and formulae are derived necessary for design work.

1334. THE OPERATING TIME OF IMPULSE RELAYS.—Vitenberg. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 73–83.)

A general formula (6) determining the operating time of an impulse relay is written down and the mathematical difficulties involved in the use of this formula are pointed out. Accordingly a simplified method is proposed and a number of numerical examples are given.

1335. THE INDUCTANCE OF A RELAY CARRYING A CONSTANT CURRENT.—Vitenberg. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 85–94.)

In calculating the operating time of a relay it is necessary to know the dynamic inductance of the relay, *i.e.* the inductance when the current is growing and the armature moving. In view of the difficulties in determining the dynamic inductance it is normal in practice to use the static inductance. A method for calculating this, with the magnetic reluctance of iron taken into account, is proposed and a number of numerical examples are given.

1336. NOMOGRAMS FOR THE DESIGN OF THE WINDINGS OF TELEPHONE RELAYS.—Vitenberg. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 135–137.)

To ensure the most economical use of copper, nomograms have been prepared for various types of windings showing the relationships berween the number of turns, depth of winding, wire diameter, and winding resistance.

1337. ON DESIGNING THE SHAPE OF THE POLES OF INDUCTIVE AND ELECTROMAGNETIC RELAYS OF THE DYNAMOMETER TYPE.—Ponomarenko. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 95–102.)

The characteristic of a dynamometric relay is determined mainly by the couple, which is a function of the magnetic field in the air gap. The field in its turn depends on the air gap and the pole shape. The field is represented by a Laplace equation (1), and in the present paper a method is proposed for designing the shape of the poles on the basis of a solution of this equation.

1338. THE MAGNETIC FIELD IN A CIRCULAR IRON CORE AT THE BREAKING OF THE CIRCUIT.—Oygenzikht. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 103–108.)

When a relay circuit is broken an important rôle is played by the Foucault currents appearing in the core of the relay and delaying the decrease in the magnetic flux which holds the armature. In this paper a mathematical analysis is given of the variation of the magnetic field under these conditions.

1339. A RATIONAL CONSTRUCTION OF THE ELECTROMAGNETS FOR REGULATORS AND RELAYS.—Eliseev. (*Automatics & Telemechanics* [in Russian], No. 2, 1941, pp. 109–130.)

The operation of relays and of various types of continuous regulators employing electromagnets is discussed in detail, with a number of graphs. On the basis of this discussion, a method is proposed for designing electromagnets with a view to effecting full use of their energy. Tables 2 and 3 are prepared, for d.c. and a.c. electromagnets respectively, giving the design formulae depending on the type of operation required, and various constructions of electromagnets with corresponding constants are shown in Fig. 8. The suspension of the armature is considered separately. The law of similitude for electromagnets is also discussed. In conclusion, a complete design of a d.c. electromagnet for a carbon-pile regulator is given.

1340. GRAPHIC SOLUTION OF DESIGN PROBLEMS INVOLVING SENSITIVE RELAYS [Proposed System of Curves helps both Users & Designers of Relays].—Fisher. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 125–127 and 310, 311.)

1341. THE INFLUENCE OF THE MAGNETIC VISCOSITY ON THE SPEED OF CHANGE OF MAGNETISATION IN IRON.—Telesnin. (*Journ. of Phys.* [of USSR], No. 4, Vol. 5, 1941, pp. 213–229: in German.)

1342. THE APPLICATION OF THE THEORY OF FOUR-POLE NETWORKS TO THE ANALYSIS OF COMPLEX MAGNETIC CIRCUITS.—Kovalenkov. (*See* 1172.)

1343. The Design, by the Method of Successive Integration, of Magnets assembled after Magnetisation.—Razumovski. (*Izvestiya Elektroprom. Slab. Toka*, No. 12, 1940, pp. 61–64.)

The method of successive integration for calculating the magnetic induction of a magnetic circuit is applied to the case of a circuit made up of previously magnetised components. As an illustration of the method, a horseshoe magnet with a short-circuiting armature (Fig. 1) is considered. Referring to a previous work (232 of January) considerable differences are pointed out between the magnetic properties of the systems under consideration and those of systems magnetised after assembly and then stabilised by partial demagnetisation. Experimental curves are plotted, generally confirming the theoretical calculations.

1344. Modern Magnetic Materials, with Special Reference to Permanent Magnets and High-Permeability Alloys.—Sowter & Tyrrell. (*Journ. British I.R.E.*, Sept./Oct. 1943, Vol. 3, No. 6, pp. 226–238: Discussion pp. 238–249.) Among the materials discussed (with curves and tables) are Ticonal 44/44 and 42/50 and the "soft" alloys Permendur (first in order of saturation flux density), Mumetal, and Radiometal.

1345. Iron–Aluminium Alloy for Transformer Cores.—Siegel. (*Sci. & Culture* [Calcutta], July 1943, Vol. 9, No. 1, p. 34.) Summary of the paper, on Westinghouse researches, referred to in 2846 of 1943.

1346. The Production of Magnetic Laminations [Nickel–Iron & Silicon–Steel for Transformers, Inductors, etc., particularly for Telecommunications].—Carter. (*P.O. Elec. Eng. Journ.*, Oct. 1943, Vol. 36, Part 3, pp. 65–70.)

1347. "Metallkeramik . . ." [Preparation of Metallic Bodies from Metal Powders: Sintering & Powder-Metal Technique: Book Review].—Skaupy. (*Zeitschr. f. tech. Phys.*, No. 6, Vol. 24, 1943, pp. 147–148.) A third edition, covering the important developments in the last twelve years.

1348. Dust-Cored Coils: Part IV—Equi-Q Charts: Conclusion, Part V—Methods of Measurement.—Welsby. (*Electronic Eng:g*, Nov. 1943, Vol. 16, No. 189, pp. 230–232: Dec. 1943, No. 190, pp. 281–284.) For previous parts (errata in which are corrected on p. 284) *see* 3559 of 1943; and for the writer's paper on the measurement of loss coefficients *see* 1201 of 1943.

1349. Toroidal Winding Machines [for Wire or Tape].—Planer. (*Journ. of Scient. Instr.*, Dec. 1943, Vol. 20, No. 12, pp. 185–189.)

"The few sources of foreign manufacturers of such machines have become inaccessible, and literature on the principles and design of machines is to the writer's knowledge practically non-existent. The winding of toroidal coils by hand, which is still common practice, is both slow and unreliable. It is felt therefore that a discussion of the fundamental principles involved in the design and operation of automatic winding machines will be of interest in the present emergency. In particular, a simple graphical method is developed describing the characteristics of machines of this type." The principles may also be applied to the winding of variable toroidal resistances and adjustable auto-transformers, the taping and wrapping of rings of wire, tubing, pneumatic tyres, etc. Similar problems are involved in the protecting of joins in cables. The writer concludes: "A machine employing this principle allows winding speeds for small toroidal coils up to approximately 250 turns per minute."

1350. Circular Slide-Wire Rheostat–Potentiometer.—Ohmite Mfg Company. (*Review Scient. Instr.*, Sept. 1943, Vol. 14, No. 9, p. 280.)

1351. Corrugated Ribbon Resistors [Heavy-Duty "Corrib" Resistors, ranging from 0.04 to 70 Ohms, Max. Rating 1500 W].—Ohmite Mfg Company. (*Review Scient. Instr.*, Sept. 1943, Vol. 14, No. 9, p. 280.)

1352. Carbon Resistors: Properties of the Various Types [Carbon-Composition Rod and Film, "Cracked" Carbon Film: Aging, Loading, Moisture, Temperature & Voltage Coefficients, Noise: etc.].—Burkett. (*Wireless World*, Jan. 1944, Vol. 50, No. 1, pp. 12–14.)

1353. Solderless Splicing Terminal [with Four-Point "Knife-Switch" Wiping Action].—(*Gen. Elec. Review*, Dec. 1943, Vol. 46, No. 12, p. 695: *see* also Advt., p. 667.)

1354. Fuse Mounting [New Littelfuse Extractor Post, with Anti-Vibration Side Terminals].—Littelfuse, Inc. (*Review Scient. Inst.*, Oct. 1943, Vol. 14, No. 10, p. 324.)

1355. A Simple Glass-Blowing Machine [for Inexpert Use in the Laboratory].—Phillips. (*Journ. of Scient. Instr.*, Jan. 1944, Vol. 21, No. 1, pp. 17–18.)

STATIONS, DESIGN AND OPERATION

1356. New Designs in F.M: Improved Performance from Two-Way Frequency-Modulation Radio Equipment that is designed to Save Critical Materials.—Du Val. (*Gen. Elec. Review*, Nov. 1943, Vol. 46, No. 11, pp. 631–634.)

1357. Frequency Modulation and Ultra-High Frequencies: a Revealing Study of Its Early History [from Ehret's 1902 Patent, through R.C.A. Tests on 9 & 18 Mc/s (2962 of 1936, Crosby), to Present Day (with F.M. Station Listings)].—Guy. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 30..36 and 79, 84, 85.)

1358. Mobile Communications for Surface Line Maintenance [Latest Application of the 30–40 Mc/s Band, with Frequency Modulation: for Messages regarding Disabled Transportation, Altercations with Passengers, Trolley-Feeder Trouble, etc.].—Phillips. (*Communications*, July 1943, Vol. 23, No. 7, pp. 46–47 and 50, 90.)

1359. A Transceiver for Mobile WERS Work [with Some Innovations in Circuit & Construction: Defects of Common Audio Volume Control for Transmitting & Receiving eliminated by Use of Dual Triode as Audio Mixer: etc.].—Bradley. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 48–50.)

1360. Aircraft-Radio Maintenance [General Lines, and a Number of Typical Case Histories].—McKee. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 64..69 and 103.) By the Supervisor of Aircraft Radio, Eastern Air Lines, Inc.

1361. The Saga of the 299 : an Amateur-Type Transmitter goes to War [Signal Corps Mobile Unit, SCR-299, embodying the Hallicrafters HT-4 Transmitter].—Read. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 44–47 and 98, 100.) " They have operated over distances of 2300 miles and have given satisfactory performance at all intermediate distances . . ."

1362. Speech-Scrambling Methods [Description of Frequency-Inverter Circuit (and Finished Instrument) : Discussion of Several Band-Splitting Methods which combine with Inversion to give even Greater Privacy (Simple Band Splitting, Transposition, Attenuation, or Phase Shift in Band Splitting, Variable Inverting Frequency)].—Roberts. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 108–111 and 270..278.). From the Sperry Gyroscope Company.

1363. Symposium on the Telefunken Single-Sideband Transoceanic Link.—Hahn & others. (*Alta Frequenza*, Feb. 1943, Vol. 12, No. 2, pp. 82–106.) Long summary, with diagrams, of the papers referred to in 224 of 1943.

1364. U.S. Short-Wave Broadcast Control Centre [Office of War Information Radio Headquarters, New York City, to handle 20 Programmes simultaneously, despatching them to 40 Short-Wave Transmitters].—(*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 114–117 and 301..303.)

1365. Audio and Measuring Facilities for the C.B.S. International Broadcast Stations.—Chinn. (*Elec. Communication*, No. 3, Vol. 21, 1943, pp. 174–179.) For these stations *see* Romander, 3177 of 1943.

1366. Moving a 50-kW Transmitter without Loss of Air Time [Removal of WJZ from Bound Brook to Lodi, N.J.].—(*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 100–101 and 184..188.)

1367. Installing a Transmitter under Wartime Conditions [Experiences at WKBN].—Wilkens. (*Communications*, Aug. 1943, Vol. 23, No. 8, pp. 40..48 and 110.)

1368. Transmitter Installation in a Low Land Area [and Its Special Problems : the 5 kW Installation at WSJS].—Hedrick. (*Communications*, July 1943, Vol. 23, No. 7, pp. 18–19.) Including the switching from day to night aerial-patterns.

1369. Frequency Allocations : Need for an Interim International Plan : Anarchy on the Ultra-Short Waves [Editorial].—(*Wireless World*, Feb. 1944, Vol. 50, No. 2, p. 33.)

1370. Competitive Broadcasting [should be Avoided like the Plague : Soaring Artists' Fees].—Baggs. (*Wireless World*, Feb. 1944, Vol. 50, No. 2, p. 61.)

GENERAL PHYSICAL ARTICLES

1371. Some Theorems relating to the Evaluation of Potentials and Charges induced on Conductors placed in a Given External Electric Field.—Grünberg. (*See* 1101.)

1372. Development of Electromagnetic Theory for Non-Homogeneous Spaces [with Implications regarding Velocity of Light. etc.].—Liebowitz. (*See* 1102.)

1373. On Dirac's New Method of Field Quantization.—Pauli. (*Reviews of Mod. Phys.*, July 1943, Vol. 15, No. 3, pp. 175–207.)

1374. The External Field of a Radiating Star in General Relativity.—Vaidya. (*Current Science* [Bangalore], June 1943, Vol. 12, No. 6, p. 183.) " Further details and astronomical applications are considered in a paper to be published elsewhere ".

1375. The de Broglie Theory of the Photon in a Geometrical Representation.—Haenzel. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 24, 1943, pp. 87–90.)

1376. The New Statistical Mechanics [Bose–Einstein and Fermi–Dirac Statistics].—Darrow. (*Bell S. Tech. Journ.*, Oct. 1943, Vol. 22, No. 3, pp. 362–392.)

1377. Recently Published American Developments in Physical Science.—Overbeck. (*Journ. of Scient. Instr.*, Jan. 1944, Vol. 21, No. 1, pp. 1–10.)

MISCELLANEOUS

1378. Some Properties of a Special Type of Electrical Pulse [the Exponential Recurrent Pulse].—Roberts & Simmonds. (*See* 1158.)

1379. The Frequencies of Natural Power Oscillations in Interconnected Generating and Distribution Systems.—Rüdenberg. (*Elec. Engineering*, April 1943, Vol. 62, No. 4, p. 172 : summary only.)

1380. A New Method for Grapho-Analytical Integration.—Popov. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 30th March 1943, Vol. 38, No. 9, pp. 286–288 : in English.)

1381. Corrections to " Solution of the Equation $f'x=f(1/x)$ ".—Silberstein. (*Phil. Mag.*, Dec. 1943, Vol. 34, No. 239, p. 850.) *See* 4476 [and 2091] of 1940.

1382. Statistical Methods for Government Departments [Review of Memorandum].—Royal Statistical Society. (*Nature*, 15th Jan. 1944, Vol. 153, No. 3872, pp. 88–89.)

1383. Symposium on Quality Control.—Institution of Mechanical Engineers. (*Engineer*, 24th Dec. 1943, Vol. 176, No. 4589, pp. 507–508 : summaries of three papers.)

1384. A New Industrial Frontier [Increased Speed & Economy of Production resulting from Employment of the Applied Mathematician : the Lag of America behind Europe].—Huddle. (*Scient. American*, Nov. 1943, Vol. 169, No. 5, pp. 211–213 and 235.)

1385. American Science mobilises for Victory.—King. (*Bell S. Tech. Journ.*, Oct. 1943, Vol. 22, No. 3, p. 398 : summary, from *Bell Tel. Magazine*.)

1386. Recently Published American Developments in Physical Science.—Overbeck. (*Journ. of Scient. Instr.*, Jan. 1944, Vol. 21, No. 1, pp. 1–10.)

1387. The I.E.E. Wireless Section's 25th Anniversary : Mr. T. E. Goldup's Inaugural Address [Summary of Parts dealing with Growth of Radio Industry and the Wireless Section, Past & Future].—Goldup. (*Electronic Eng:g*, Nov. 1943, Vol. 16, No. 189, pp. 256 and 258.)

1388. Europe's 213 Million Listeners: Comparative Figures of Radio Density in 1942 [U.I.R. Data]. —(*Wireless World*, Jan. 1944, Vol. 50, No. 1, p. 18.)

1389. Post-War University Education [and the Problems of how Honours Students can acquire a More Balanced & Mature Mental Outlook: the "History of Ideas" Course].—Hardie. (*Nature*, 8th Jan. 1944, Vol. 153, No. 3871, p. 57.) *See* also issue of 29th January, No. 3874, p. 142, for a letter from Maxwell Garnett.

1390. Education for the Public Services [Critical Review of British Association Report].—(*Engineering*, 3rd Dec. 1943, Vol. 156, No. 4064, p. 452.) "As industry and governmental activity becomes more scientific, as it is doing every day, the present practice may tend to weaken as it is realised that the pure administrator is not usually competent to handle highly technical affairs."

1391. Research and Its Utilisation [the Question of "Efficiency": Some Causes leading to a Low Value: the Need for the "Right Type of Man in Charge"].—(*Engineer*, 10th Dec. 1943, Vol. 176, No. 4587, pp. 467–468.) Letter from "Engineer", prompted by the recent "hailstorm of presidential addresses and committee reports."

1392. Science will need Support [Financial Backing, from Private Sources, for Basic Research is a Critical Post-War Problem: and the Problem of finding Suitable Directors of Research].—Taylor. (*Sci. News Letter*, 27th Nov. 1943, Vol. 44, No. 22, p. 339: summary only.)

1393. Science in the New World Order [Leading Article on the Prime Minister's Message to the Royal Society's Meeting in India].—(*Nature*, 15th Jan. 1944, Vol. 153, No. 3872, pp. 63–64.)

1394. "Report on Scientific Research and the Universities in Post-War Britain", *and* "F.B.I. Report on Industry and Research" [Summaries].—Parliamentary & Scientific Committee: Federation of British Industries. (*Journ. of Scient. Instr.*, Dec. 1943, Vol. 20, No. 12, pp. 199–200: p. 200.) *Cf.* 996 & 998 of March.

1395. Industrial Science Looks Ahead.—Sarnoff. (*Science*, 19th Nov. 1943, Vol. 98, No. 2551, pp. 437–442.) Address by the President, R.C.A.

1396. Organisation of Science in the Soviet Union.—Sen. (*Sci. & Culture* [Calcutta], July 1943, Vol. 9, No. 1, pp. 11–18.)

1397. Post-War Organisation of Scientific Research in India [Opening Address at Symposium: the Example of Canada, including the National Research Council and Research Enterprises, Ltd.]. —Ghosh. (*Sci. & Culture* [Calcutta], Oct. 1943, Vol. 9, No. 4, pp. 135–139.) *Cf.* 1004 of March.

1398. The Telecommunication Engineering and Manufacturing Association [Note on Its Formation].—(*Engineer*, 17th Dec. 1943, Vol. 176, No. 4588, p. 494.)

1399. Ways of Conserving Critical Material to aid Wartime Electrical Industry.—A.I.E.E. Committee. (*Elec. Engineering*, April 1943, Vol. 62, No. 4, pp. 181–185.)

1400. Production Aids [Some Examples].—(*Communications*, July & Aug. 1943, Vol. 23, Nos. 7 & 8, pp. 88..91 & 50, 81.) *Cf.*, for example, 300 of January, 573 of February, and 991 of March.

1401. Music in Industry [and Its Effect on Production]. —Burris-Meyer. (*See* 1235.)

1402. Invention in Relation to Industry [Chairman's Address (abridged) to Measurements Section, I.E.E.].—Moss. (*Engineering*, 3rd Dec. 1943, Vol. 156, No. 4064, pp. 444–445.)

1403. Inventions, Patents, and the Engineer [Letter on Crawford's Article, 2890 of 1943].—Harris. (*Elec. Engineering*, April 1943, Vol. 62, No. 4, pp. 186–188.)

1404. Vagaries and Elusiveness of Invention [Response of Edison Medallist: including Stories of the Invention of the Superheterodyne & Super-Regenerative Methods].—Armstrong. (*Elec. Engineering*, April 1943, Vol. 62, No. 4, pp. 149–151.)

1405. Reviving Old Ideas ["a Scheme that proved a Wash-Out in Its Time may Now prove to be the Answer to a Trying Riddle"].—(*Wireless World*, Jan. 1944, Vol. 50, No. 1, p. 5.) From *Radio* [New York].

1406. Before the Diode [Extract from "The Saga of the Vacuum Tube": Developments prior to the Discovery of the Edison Effect & the Fleming Diode].—Tyne. (*Electronic Eng:g*, Dec. 1943, Vol. 16, No. 190, pp. 273–276.)

1407. Workshops for All [Letter welcoming Suggestion in Recent Leading Article].—Dunsheath. (*Engineer*, 24th Dec. 1943, Vol. 176, No. 4589, p. 505.)

1408. Signals Officers in the Making: Technical and Tactical Training in an O.C.T.U.—(*Wireless World*, Feb. 1944, Vol. 50, No. 2, pp. 44–46.)

1409. An Experiment in Training [at Oldham Technical College: for Employment by Admiralty as Junior Laboratory Assistants].—(*Wireless World*, Feb. 1944, Vol. 50, No. 2, p. 49.)

1410. Slide-Films for Training.—Metcalfe. (*Communications*, July 1943, Vol. 23, No. 7, pp. 54–55 and 83, 95.) *See* also 266 of January.

1411. A "Slow-Motion" Oscillator for Class Demonstration [of Phase Relations, etc: Processes slowed down to about ½ Cycle per Second: Two Inter-Valve Transformers & 6 μF Condenser: Ordinary Meters, C.R. Oscillograph if Available].—Bulman. (*Electronic Eng:g*, Dec. 1943, Vol. 16, No. 190, p. 295.)

1412. Radio in the Civil Air Patrol: the Hams Do It Again! [Work with Coastal Patrol].—Stello. (*QST*, Dec. 1943, Vol. 27, No. 12, pp. 20–22.)

1413. The M9 Electrical Gun Director Demonstrated.—(*Bell Lab. Record*, Dec. 1943, Vol. 22, No. 4, pp. 157–167.)

1414. A Signal Corps Report on Enemy Radio Equipment.—Lipp. (*QST*, Dec. 1943, Vol. 27, No. 12, p. 43.)

1415. Controversy [on Shoemakers sticking to Their Lasts: the Need for Designs by Electronic

Engineers].—Campbell Rose. (*Electronic Eng:g*, Dec. 1943, Vol. 16, No. 190, p. 304.) Prompted by the Editorial dealt with in 3629 of 1943. The present writer quotes as illustration a cathode-ray oscillograph "for laboratory use only" which has been out of service six times since it was purchased less than a year ago.

1416. ELECTRONIC APPLICATIONS: A NEW CURRICULUM IN ELECTRICAL ENGINEERING [at M.I.T.].—Gray & Frazier. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 122–124 and 304..309.)

1417. ELECTRONIC TUBES: HOW THEY WORK [illustrated by Discussion of the Gas-filled FG-57 Thyratron: Article intended for Industrial Users of Electronic Devices].—(*Gen. Elec. Review*, Nov. 1943, Vol. 46, No. 11, pp. 612–617.)

1418. THE FACTORS INFLUENCING THE PLATEAU CHARACTERISTICS OF SELF-QUENCHING GEIGER–MÜLLER COUNTERS.—Spatz. (*Phys. Review*, 1st/15th Oct. 1943, Vol. 64, No. 7/8, pp. 236–240.) A summary was referred to in 716 of February.

1419. PHOTOELECTRIC POTENTIOMETER RECORDER [with Many Applications].—Hang. (*See* 1263.)

1420. A PHOTOELECTRIC EXTENSOMETER WITH VERY SMALL WORKING BASE [necessitating Magnification of order of 10 to 50 Thousand: by Change of Light transmitted by Slot mechanically linked to Mobile Base Point].—Lehr & Granacher. (*Journ. Roy. Aeron. Soc.*, Dec. 1943, Vol. 47, No. 396, pp. 683–685: an R.T.P.3 Abstract.)

1421. SUPER-SIGHT WITH PHOTOTUBES [Industrial Photocell-Devices (Paper-Handling Control, Packaging, etc.)].—Marcus. (*Scient. American*, Nov. 1943, Vol. 169, No. 5, pp. 214–216.) On p. 216 there are also notes on the protection of sewing machines for blind seamstresses (385 of January) and the electronic judge for drunken drivers (388 of January).

1422. PHOTOTUBE CONTROL OF PACKAGING MACHINES.—Cockrell. (*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 94–99 and 180, 182.)

1423. COAL-MINE EYES: ELECTRONICS TAKES THE PLACE OF CHILD LABOUR.—(*Scient. American*, Dec. 1943, Vol. 169, No. 6, p. 258.)

1424. PHOTOELECTRIC GRADING OF SUGAR.—Seymour. (*Electrician*, 6th Aug. 1943, Vol. 131, No. 3401, pp. 137–138.)

1425. ELECTRONIC SCALE, DEVELOPED FOR THE BLIND, HAS OTHER APPLICATIONS [*e.g.* to Industrial Process requiring Weighing in the Dark].—Toledo Scale Company. (*Scient. American*, Sept. 1943, Vol. 169, No. 3, p. 105.) *See* also 2922 of 1943.

1426. PHOTOELECTRIC RELAY, ADAPTED TO BATCH WEIGHING, METERING, ETC. [for External Application to Existing Apparatus or Incorporation during Manufacture]. — United Cinephone. (*Scient. American*, Sept. 1943, Vol. 169, No. 3, p. 105.)

1427. ELECTRONIC LOAD-REGULATOR FOR METER TESTING [saves Man-Power & increases Precision of Calibration of Watt-Hour Meters].—Lenahan. (*Electronics*, July 1943, Vol. 16, No. 7, pp. 116–117 and 254,260.) A photoelectric arrangement developed by Westinghouse.

1428. CALIBRATING STOP-VALUES OF LENSES [Failure of Conventional Formula (takes No Account of Type of Glass, Presence of Coating, etc.): Photoelectric Measurement gives Correct Result: Project for Use as National Standard].—Clark. (*Electronics*, July 1943, Vol. 16, No. 7, pp. 186 and 188: summary only.)

1429. ELECTRONIC METHOD FOR THE AUTOMATIC PAINTING OF MURALS AND ENLARGED PAINTINGS ON WALLS, FROM SMALLER ORIGINALS.—Murphy. (*QST*, Aug. 1943, Vol. 27, No. 8, p. 37.) Patent assigned to Western Electric. *Cf.* 3675 of 1940.

1430. THE SENSITIVITY OF INCANDESCENT LAMPS TO SHORT-TIME VOLTAGE FLUCTUATIONS [Objective Measurements (with Photocell & Oscillograph) on Various Types].—Schwabe. (*E.T.Z.*, 20th May 1943, Vol. 64, No. 19/20, p. 275: summary only.)

1431. A METHOD FOR DETERMINING DEPOLARISATION FACTORS IN RAMAN SPECTRA [Recording Monochromator with Ice-Refrigerated Multiplier Phototube & Additional D.C. Amplification: Initial Photocurrent amplified about 10^8-fold].—Rank, Pfister, & Grimm. (*Journ. Opt. Soc. Am.*, Jan. 1943, Vol. 33, No. 1, pp. 31–35.) Further development of 3454 of 1942.

1432. A NULL-READING PHOTOELECTRIC MICRODENSITOMETER.—Baier. (*Sci. Abstracts*, Sec. A, July 1943, Vol. 46, No. 547, p. 134.)

1433. A RECORDING MICROPHOTOMETER FOR THE EXAMINATION OF X-RAY DIFFRACTION FILMS.—Ronnebeck. (*Journ. of Scient. Instr.*, Oct. 1943, Vol. 20, No. 10, pp. 154–161.) With a long bibliography. From I.C.I.

1434. PHOTOELECTRIC FLUORIMETER [Mains Operated, with Vacuum Photocells].—Krebs & Kersten. (*Sci. Abstracts*, Sec. A, July 1943, Vol. 46, No. 547, p. 137.)

1435. A SIMPLE INEXPENSIVE PHOTOELECTRIC HAEMOGLOBINOMETER [Colorimeter unaffected by Variations in Light Source or Photocell Characteristics].—Bell & Guthmann. (*Journ. of Scient. Instr.*, Sept. 1943, Vol. 20, No. 9, pp. 145–146.)

1436. "PHOTOELECTRIC TRISTIMULUS COLORIMETRY WITH THREE FILTERS" [Circular C429, Bureau of Standards].—Hunter. (*Electronics*, Aug. 1943, Vol. 16, No. 8, p. 176: summary only.)

1437. ON THE USE OF SELENIUM PHOTOELEMENTS FOR SYSTEMATIC MEASUREMENTS OF LIGHT [Investigation of the Objections (Variation of Sensitivity with Aging, Sudden Rises in Sensitivity, Inertia, etc.) habitually made against Photoelectric Photometers: Conclusion that They are Unjustified, if Cells of the Right Kind are Properly Used].—Finkelnburg & Schluge. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 24, 1943, pp. 72–75.)

1438. A NEW TYPE OF MICROPHOTOMETER [Improvement on Fürth's Instrument (2896 of 1942 and 2278 of 1943), giving Increased Resolving Power & More Satisfactory Working Conditions].—Pringle: Fürth. (*Nature*, 15th Jan. 1944, Vol. 153, No. 3872, pp. 81–82.)

1439. NEW PRECISION INSTRUMENT FOR MEASURING GLOSS [Aminco–Scott Glossmeter (Goniophotometer)].—American Instrument. (*Journ. Applied Phys.*, Aug. 1943, Vol. 14, No. 8, p. 408.) *Cf.* 2926 of 1943.

1440. FILTER PHOTOMETER [Small Model "Photelometer" for Industrial Use].—Central Scientific. (*Scient. American*, Dec. 1943, Vol. 169, No. 6, p. 285.)

1441. PHOTOELECTRIC CONTACT-PRINTER CONTROL [ensuring that All Prints from a Given Negative shall have Same Density regardless of Lamp-Intensity Variations: Phototube/Thyratron/Guillotine-Shutter Combination].—Penther & Weiske. (*Electronics*, Sept. 1943, Vol. 16, No. 9, pp. 114–115 and 274.)

1442. USE OF THE GENERAL ELECTRIC PHOTOGRAPHIC EXPOSURE-METERS IN WAR.—(*Gen. Elec. Review*, Nov. 1943, Vol. 46, No. 11, p. 635.)

1443. COLOUR-MATCHING IN INDUSTRY, *and* COLOUR-MATCHING: CAMOUFLAGE WORK AIDED BY ELECTRONIC DEVICE [General Electric Recording Spectrophotometer].—Marcus: General Electric. (*Scient. American*, Dec. 1943, Vol. 169, No. 6, pp. 256–258: p. 270.)

1444. TEMPERATURE MEASUREMENT AND CONTROL WITH SOLID PHOTOELECTRIC CELLS [and Comparison of Photoelectric Pyrometers with Optical & Total-Radiation Instruments].—Fogle. (*Sci. Abstracts*, Sec. B, Nov. 1943, Vol. 46, No. 551, p. 195.)

1445. THE WIDE-ANGLE PHOTOELECTRIC SCANNER [with Rotating Pyramid of Mirrors: Improved Results as Industrial Safety or Inspection Device, Door-Opening Control, etc.].—McDowell. (*Sci. News Letter*, 4th Dec. 1943, Vol. 44, No. 23, pp. 358–359.) From General Electric's electronic division.

1446. FROM INVISIBLE TO VISIBLE: NEW MICROSCOPE CONVERTS ULTRA-VIOLET IMAGE TO A PICTURE IN FULL COLOURS.—Brumberg, Gershgorin, & Radchenko. (*Sci. News Letter*, 4th Dec. 1943, Vol. 44, No. 23, p. 355.) From the description in *Nature* (708 of March).

1447. THE ELECTRON MICROSCOPE AND ITS APPLICATION TO ENGINEERING PROBLEMS.—Quarrell. (*Engineer*, 24th & 31st Dec. 1943, Vol. 176, Nos. 4589 & 4590, pp. 499–502 & 526–528.)

1448. ON MICROANALYSIS BY ELECTRONS [Development of the "Electron Microanalyser"].—Hillier. (*See* 1292.)

1449. LIGHT RELAYS [Light Valves, Modulators: Classification and Practical Types].—Tager. (*See* 1252.)

1450. AN INTERFEROMETRIC PROCEDURE FOR THE EXAMINATION OF CRYSTAL SURFACES [Highly Sharpened Fringes permit of Very Great Precision: Cleavage Steps only a Few Molecules in Height can be Measured].—Tolansky. (*Nature*, 18th Dec. 1943, Vol. 152, No. 3868, pp. 722–723.) Further details (including results with quartz) will appear elsewhere. *See* also 3271 of 1943.

1451. NEW SOURCES OF ULTRA-VIOLET LIGHT [and the Use of a New Chemical Coating which transforms Short-Wave Ultra-Violet to Near Ultra-Violet: for Spotlights (Trail-Blazing), etc.].—Beggs. (*Science*, 31st July 1942, Vol. 96, No. 2483, Supp. p. 6.)

1452. FLUORESCENT LAMPS; A SURVEY OF OLD AND RECENT DEVELOPMENTS.—Neumann. (*Electronic Eng:g*, Sept., Oct., Nov., Dec. 1943, Vol. 16, Nos. 187/190, pp. 154–157, 202–205, 247–250, & 300–302.)

1453. A TUNGSTEN-IN-QUARTZ LAMP AND ITS APPLICATIONS IN PHOTOELECTRIC RADIOMETRY.—Stair & Smith. (*Journ. of Res. of Nat. Bur. of Stds.*, June 1943, Vol. 30, No. 6, pp. 449–459.)

1454. "THE THEORY OF THE PHOTOGRAPHIC PROCESS" [Book Review].—Mees. (*Journ. Applied Phys.*, Aug. 1943, Vol. 14, No. 8, pp. 407–408.) Based largely on Kodak Research Laboratories' work.

1455. PHOTOGRAPHIC DEPARTMENT [New Quarters & Equipment produces 14 000 Negatives & nearly 200 000 Prints per Year, with Staff of 15].—Van Horn. (*Bell Lab. Record*, Oct. 1943, Vol. 22, No. 2, pp. 70–77.)

1456. ANOTHER SIMPLE METHOD OF PHOTOGRAPHING BLACK-AND-WHITE DOCUMENTS [Use of Mirror with Reflecting Surface on Top of Glass].—Colquhoun. (*Journ. of Council for Scient. & Indust. Res., Australia*, Aug. 1943, Vol. 16, No. 3, p. 201 and Plate.)

1457. ON SIZE-FREQUENCY DISTRIBUTION IN PHOTOGRAPHIC EMULSIONS.—Silberstein. (*Journ. Opt. Soc. Am.*, Jan. 1943, Vol. 33, No. 1, pp. 35–42.)

1458. AMERICAN STANDARDS FOR PHOTOGRAPHY [Papers, Films, Method of determining Speeds, etc.].—(*Journ. Opt. Soc. Am.*, Aug. 1943, Vol. 33, No. 8, pp. 457–486.)

1459. PHOTOGRAPHY, AN INDUSTRIAL TOOL.—Perry. (*Scient. American*, Dec. 1943, Vol. 169, No. 6, pp. 267–269.) From the du Pont de Nemours Company.

1460. SPECTRAL SENSITIVITY OF THE RETINAL RECEPTORS [Measurements on Dark-Adapted Eyes].—Wright. (*Nature*, 26th June 1943, Vol. 151, No. 3843, pp. 726–727.)

1461. BINOCULAR AND UNIOCULAR THRESHOLD OF VISION.—Pirenne. (*Nature*, 11th Dec. 1943, Vol. 152, Vol. 152, No. 3867, pp. 698–699.)

1462. MAGNITUDE OF THE THRESHOLD OF STEREOSCOPIC VISION AS AFFECTED BY THE PERIOD OF OBSERVATION.—Gassovsky & Nikolskaya. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 10th Jan. 1943, Vol. 38, No. 1, pp. 15–19: in English.)

1463. FACTORS IN HUMAN VISUAL RESOLUTION, *and* SOME ASPECTS OF THE EYE AS AN IMAGE-FORMING MECHANISM.—Walls: Ogle. (*Journ. Opt. Soc. Am.*, Sept. 1943, Vol. 33, No. 9, pp. 487–505; pp. 506–512.)

1464. A SIMPLE METHOD FOR OBTAINING X-RAY PHOTOGRAPHS WITH A VERY SHORT EXPOSURE.—Tsukerman [Zuckerman] & Avdeenko. (*Journ. of Tech. Phys.* [in Russian], No. 4/5, Vol. 12, 1942, pp. 185–194.)

A brief survey is made of the existing methods for obtaining short-exposure X-ray photographs, and a report is given on an experimental investigation. One of the conclusions reached is that a standard X-ray equipment can be so modified as to give, under factory conditions, photographs of simple objects with an exposure of the order of a few microseconds without the use of an impulse generator or a special impulse tube.

1465. Simple X-Ray Unit. "Searchray," for examining Parcels [Anti-Sabotage Unit, with Many Other Applications].—North American Philips. (*Scient. American*, Dec. 1943, Vol. 169, No. 6, p. 276.)

1466. A High-Temperature X-Ray-Analysis Camera [for Studies during Annealing Processes].—Owen. (*Journ. of Scient. Instr.*, Dec. 1943, Vol. 20, No. 12, pp. 190–192.)

1467. The Use of X-Rays for Determining the Orientation of Quartz Crystals, *and* Raw Quartz, Its Imperfections and Inspection [by Optical Devices].—Bond & Armstrong: Willard. (*See* 1282 & 1283.)

1468. An X-Ray Tube using an Electron Gun [giving Great Reduction in Target-Contamination and preventing Space Charge from limiting the Target-Currents available at Low Voltages: Adjustable Focal-Spot Size).—McCue. (*Review Scient. Instr.*, Nov. 1943, Vol. 14, No. 11, pp. 339–341.)

1469. An X-Ray Record [Total Potential of 100 Megavolts attained (with Induction Electron Accelerator)].—General Electric. (*Engineer*, 24th Dec. 1943, Vol. 176, No. 4589, p. 514: paragraph only.) The first few observations indicate that the characteristics of the radiation "differ radically from those with which physicists are familiar."

1470. Piezoelectric Surgical Probe [making Use of the Highly Developed Character of the Ear and the Extremely High Sensitivity (Not Inferior to that of the Sense of Touch) of the Rochelle-Salt Crystal].—Ostroumov & Lepeshinskaya. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 30th Jan. 1943, Vol. 38, No. 2/3, pp. 82–84: in English.)

1471. A Surgeon's Invitation to Physicists [to give "Invaluable Help towards the Solution of Many of the Problems of Surgery"].—Souttar. (*Journ. of Scient. Instr.*, Jan. 1944, Vol. 21, No. 1, p. 20.) Note on recent Bradshaw Lecture to R.C.S.

1472. A Possible New Application of the Wilson Cloud Chamber [Bacteria (0.5–2 Microns) serve as Condensation Nuclei with Small Supersaturations, and *All* can be precipitated, instead of Unknown Percentage as in Most Air-Sampling Methods].—Nielsen. (*Phys. Review*, 1st/15th Sept. 1943, Vol. 64, No. 5/6, p. 187: summary only.)

1473. An Improved Low-Frequency Analyser [Improvement of Apparatus dealt with in 2603 (*see* also 2602 & 3609) of 1943, by Replacement of Mercury Contact & High Resistance (as Charging Circuit for Storage Condenser) by Photoelectric Integrating Circuit: Selenium-Cell/Pentode Combination with Properties very similar to those of a Vacuum Photocell].—Grey Walter. (*Electronic Eng:g*, Nov. 1943, Vol. 16, No. 189, pp. 236–240.)

1474. High-Frequency Therapy: Part III—Electrode Theory and Design: Part IV—The Electric Field in a Dielectric: Part V—Energy Absorption in Biological Media: Part VI—Output-Circuit Theory and Measurement.—Oliphant. (*Electronic Eng:g*, Nov. & Dec. 1943, Vol. 16, Nos. 189 & 190, pp. 252–255 & 296–299: Jan. & Feb. 1944, Vol. 16, Nos. 191 & 192, pp. 338–341 & 382–386: to be contd.) For previous parts *see* 705 of February.

1475. Radio Heating: Industrial Applications of Eddy-Current and Dielectric "Losses" [with Illustrations of Apparatus built by Rediffusion, Ltd.].—(*Wireless World*, Feb. 1944, Vol. 50, No. 2, pp. 41–42.)

1476. The Theory and Practice of Industrial Electronic Heating [Oscillator Theory: Induction-Heating & Dielectric-Heating Theory (and the Precautions necessary in applying the Equations): Equipment & Controls].—Jordan. (*Gen. Elec. Review*, Dec. 1943, Vol. 46, No. 12, pp. 675–683.)

1477. Work Coils for High-Frequency Heating.—(*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 112–113 and 299, 300.)

1478. Applications of Supersonics in Treatment of Milk, etc., and in Metallurgy.—(*See* 1248/9.)

1479. A New Method of Sorting Steels [with Description of Final Electronic Apparatus, with Sensitivity Control: Satisfactory & Rapid Operation].—Brown & Bridle. (*Engineer*, 3rd Dec. 1943, Vol. 176, No. 4586, pp. 442–444.) From Morris Motors, Ltd. *Cf.* 371 of January.

1480. Electronic Means of Checking and Sorting Metals for Depth of Case-Hardening and Other Metallurgical Factors [Use of Du Mont "Cyclograph," a Cathode-Ray Instrument giving Tests on Several Frequencies, Simultaneously or in Succession].—Du Mont Laboratories. (*Scient. American*, Dec. 1943, Vol. 169, No. 6, pp. 285–286.)

1481. A New Method of Measuring the Inclination of the Earth's Magnetic Field [the "All-Magnetic Square" Bridge].—Harrison & Hamilton Smith. (*See* 1276.)

1482. Laboratory Experiments on the Magnetisation of Rocks.—Herroun & Hallimond. (*Terr. Mag. & Atmos. Elec.*, Dec. 1943, Vol. 48, No. 4, p. 232: review of paper in *Proc. Phys. Soc.*)

1483. Design of Multi-Channel Amplifiers for Carrier-Frequency Telephony.—Fedi. (*See* 1162.)

1484. Carrier-Current Transmission at 150–160 kc/s [for Control Purposes, but especially for Voice & Music Transmission: Impedance Matching: Substation Problems: etc.].—Wightman & Lyon. (*Communications*, Aug. & Sept. 1943, Vol. 23, Nos. 8 & 9, pp. 13–15 and 74, 106, 107: pp. 32 and 54..58.) *See* also 247 of January.

1485. Improvised Methods of Locating a Break in Multi-Cored Cables.—"Diallist". (*Wireless World*, Jan. & Feb. 1944, Vol. 50, Nos. 1 & 2, pp. 30 & 62.)

1486. A Tone Selector for Radio Alert Systems.—Adams. (*See* 1224.)

1487. Russian Papers on Control Systems, Relays, etc. (*See* 1333/39.)

1488. The Fundamental Circuits of Contactless Controlling and Selecting Systems.—Livshits & others. (*See* 1171.)

1489. Ignitron Control for Seam-Welding Machines.—British Thomson-Houston. (*Engineering*, 10th Dec. 1943, Vol. 156, No. 4065, pp. 470 and 476–477.)

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