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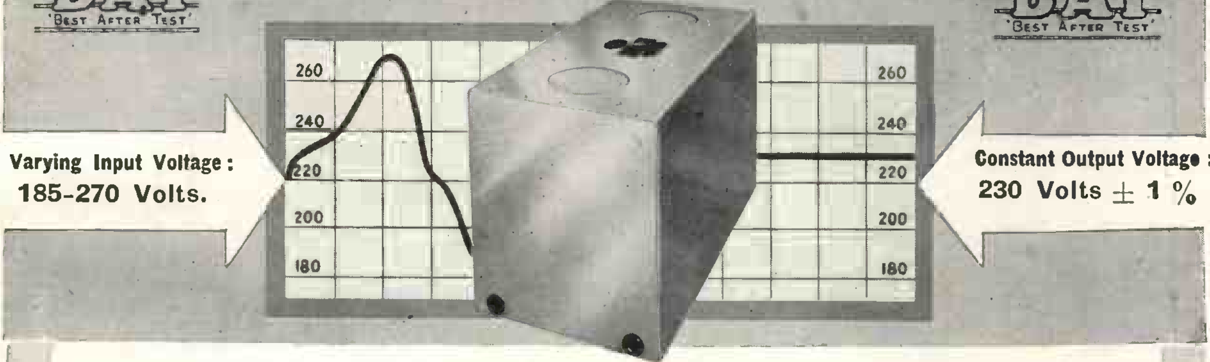

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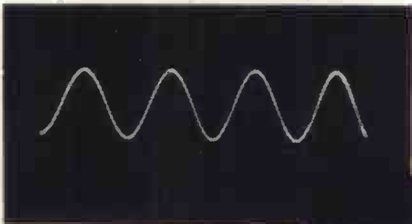

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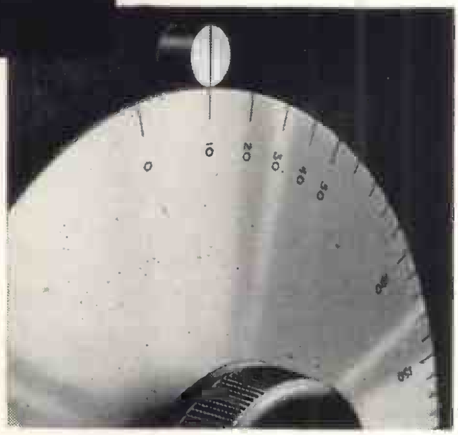

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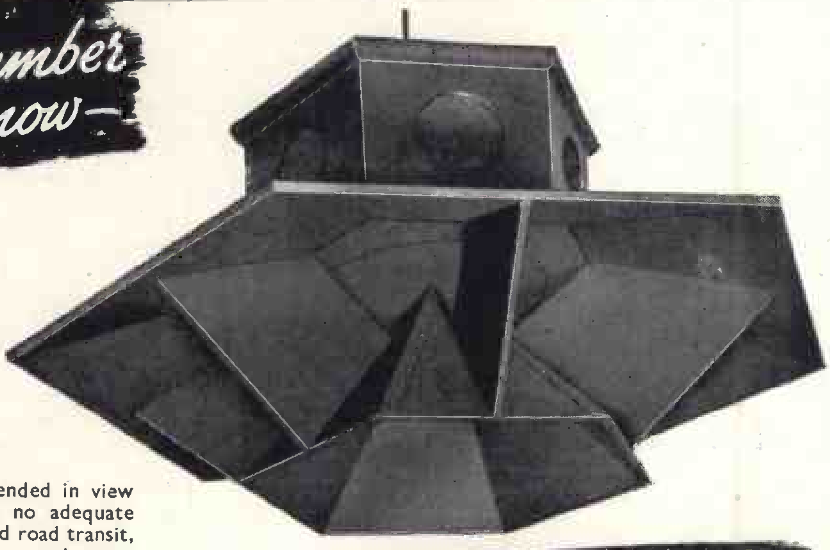

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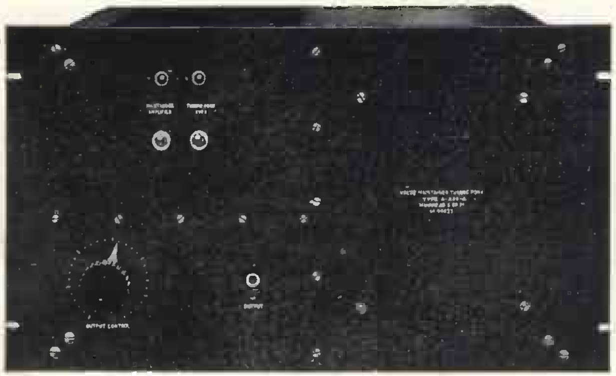


WIRELESS ENGINEER

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

VOL. XXI JUNE, 1944 No. 249

An Interesting Patent Decision

Marconi's W.T.Co. of America *versus* The United States

A DELAYED—very much delayed—action bomb has recently exploded in the United States. The action referred to was a patent action brought against the U.S. Government by the Marconi Co. claiming damages for infringement. The patents in question were No. 763772 (Reissue No. 11913)—the American counterpart of the celebrated British Pat. No. 7777—granted to Marconi in 1904 for improvements in apparatus for wireless telegraphy, No. 609154 granted to Lodge in 1897 and acquired by the Marconi Co. on its extension for another seven years in 1911, and No. 803684, which was the celebrated Fleming patent of 1904 for the diode valve.

The judgment of the Supreme Court is prefaced by a number of interesting pronouncements that really form a summary of the judgment which occupies twenty two pages of the *Official Gazette* of the United States Patent Office issued in November 1943, just over forty-three years after Marconi lodged his patent application. The following are some of these pronouncements.

"A patent specification is merely descriptive or illustrative of an invention, and is not to be read as though it were claims whose function is to exclude from the patent all that is not specifically claimed." "Merely making a known element of a known combination adjustable by a means of adjustment known to the art, when no new or unexpected result is obtained is not invention."

Stone had applied before Marconi for a patent in which the sending and receiving aerials were coupled to tuned circuits, but without stating specifically that the aerials had also to be tuned. In 1902, i.e. after the filing of Marconi's application, in which all the four elements were tuned, Stone was allowed to amend his application by making the aerials tunable, apropos of which "We would ordinarily be slow to recognise amendments made after the filing of Marconi's application and disclosing features shown in that application, but here Stone's letters to Baker, whose authenticity has not been questioned in this case, afford convincing proof that Stone had conceived of the idea of tuning all four circuits prior to the date of Marconi's invention."

"It is well established that as between two inventors priority of invention will be awarded to the one who by satisfying proof can show that he first conceived of the invention." "Commercial success achieved by the later inventor and patentee cannot save his patent from the defence of anticipation by a prior inventor." "Judgment of Court of Claims holding invalid the broad claims of Patent No. 763772 to Marconi for improvements in apparatus for wireless telegraphy, affirmed."

One Claim may be Valid

The Court of Claims had, however, held that one claim, viz. claim 16 of the Marconi patent was not invalid, and it had given judgment against the Government on this claim in the sum of 43,000 dollars. The Government appealed against this finding. The lower Court had "based its holding that claim 16 disclosed patentable invention on its finding that Marconi, by the use of an adjustable condenser in the antenna circuit, disclosed a new and useful method of tuning that circuit. The Government contends that the arrangement of the antenna circuit disclosed by Marconi's specifications—with the condenser shunted around the transformer coil but not around the variable inductance—is such that the condenser cannot increase the wavelength over what it would be without such a condenser, and that it can decrease that wavelength only when adjusted to have a very small capacity. The Government contends, therefore, that its principal function is not that of tuning but of providing 'loose coupling,' The Government does not deny that this precise arrangement is novel and useful, but it contends that its devices do not infringe that precise arrangement, and that claim 16, if more broadly construed so as to cover its apparatus, is invalid because anticipated by the prior art, particularly the patents of Pupin and Fessenden."

"The idea of tuning the antenna circuits involved no patentable invention. It was well known that tuning was achieved by the proper adjustment of either the inductance or the capacity in a circuit, or both. Lodge and Stone had achieved tuning by the use of an adjustable induction coil."

"Moreover the use of an adjustable condenser as a means of tuning was known to the prior art. Pupen in Patent No. 640516 applied for May 28, 1895, and granted January 2, 1900, before Marconi, disclosed the use of an adjustable condenser as a means of tuning a receiving circuit in a system of wired telegraphy. . . . It is true that his patent related not to the radio art but to the art of wired telegraphy, an art which employed much lower frequencies. But so far as we are informed, the principles of resonance, and the methods of achieving it, applicable to the low frequencies used by Pupin are the same as those applicable to the low frequency radio transmission and reception."

"In the present state of the record we do not undertake to determine whether and to what extent these disclosures either anticipate claim 16 of the Marconi patent or require that claim to be so narrowly construed that defendants' accused devices, or some of them, do not infringe Marconi. . . . These are all matters requiring careful consideration by the trial court. In order that the case may receive that consideration, we vacate the judgment as to claim 16 and remand the cause to the Court of Claims for further proceedings in conformity to this opinion."

Surely the situation is almost incredible. In his "Radio-Beam and Broadcast" of 1925, A. H. Morse says of this patent: "It was made the basis of several successful infringement suits, and when it was strengthened by the acquisition of Lodge's 1897 patent, it gave the Marconi Company for a time almost a monopoly of syntonic wireless telegraphy in England and America." Now, more than forty years later, the efforts of the Marconi Company to recover damages for infringement which must have occurred during the last war, if not earlier, are terminated by the Supreme Court finding the patent to have been invalid, with the possible exception of one claim, which is referred back to the lower Court for further consideration. During the interval all the *dramatis personæ* have passed away.

Fleming's Diode Patent declared Invalid

We turn now to the other patent entitled "Instrument for converting alternating electric currents into continuous currents," applied for on April 15, 1905, and granted on November 7, 1905, to the Marconi Company as assignee of Fleming.

"Knowledge disclosed by publication by patentee Fleming more than two years before he filed his application is a bar to any claim for a patent for an invention embodying the published disclosure." The patent was "rendered invalid by an improper disclaimer." "The invalidity of claim 1 would defeat the entire patent unless the invalid portion had been claimed through inadvertence, accident, or mistake, and without any fraudulent or deceptive intention, and was also disclaimed without unreasonable neglect or delay. . . . We think that the Court below was correct in holding that the Fleming patent was invalid because Fleming's claim for more than he had invented was not inadvertent, and his delay in making the disclaimer was unreasonable."

"Claim 37 describes the tube as being used in a system of wireless telegraphy employing oscillations of high frequency. No such limitation was placed on claim 1 as originally claimed, and the specifications already quoted plainly contemplated the use of the claimed device with low as well as high frequency currents. This distinction was eliminated by a disclaimer filed by the Marconi Company November 17, 1915 [i.e. ten years after the granting of the patent] restricting the combination of the elements of claim 1 to a use in connection with high frequency alternating electric currents or electric oscillations of the order employed in Hertzian wave transmission."

"Fleming's paper of 1890 showed his own recognition that his claim of use of his patent for low frequency currents was anticipated by Edison and others. It taxes credulity to suppose, in the face of this publication, that Fleming's claim for the use of the Edison tube with low frequency currents was made through inadvertence, accident or mistake, which is prerequisite to a lawful disclaimer. No explanation or excuse is forthcoming for his claim of invention of a device which he had so often demonstrated to be old in the art, and which he had specifically and consistently attributed to Edison. Nor is any explanation offered for the delay of the patentee—the Marconi Company—in waiting ten years to disclaim the use of the device with low frequency currents and to restrict it to a use with high frequency Hertzian waves which Edison had plainly foreshadowed but not claimed. For ten years the Fleming patent was held out to the public as a monopoly of all its claimed features. That was too long in the absence of any explanation or excuse for the delay, and hence in this case was long enough to invalidate the patent. . . . This improper claim for something not the invention of the patentee rendered the whole patent invalid unless saved by a timely disclaimer which was not made."

Hence this celebrated Fleming patent of 1905, which the Marconi Company applied unsuccessfully to have extended on its expiry in 1919, is now held by the Supreme Court of the United States to have been entirely invalid.

This finding in the Fleming valve case appears to have been unanimous, but in the Marconi case three of the judges dissented in part, their main contention being that Marconi really discovered something that "had eluded the best brains of the time working on the problem of wireless communication." One of the three said "Because a judge of unusual capacity for understanding scientific matters is, by a process of intricate ratiocination, able to demonstrate that anyone could have drawn precisely the inferences that Marconi drew and that Stone hinted at them on paper, the court finds that Marconi's patent was invalid, although nobody except Marconi did in fact draw the right inferences that were embodied into a workable boon for mankind. For me it speaks volumes that it should have taken forty years to reveal the fatal bearing of Stone's relation to Marconi's achievement by a retrospective reading of his application to mean this rather than that. This is for me, and I say it with much diffidence, too easy a transition from what was not to what became."

The same judge animadverted in the following terms upon the administration of the patent law. "The training of Anglo-American judges ill fits them to discharge the duties cast upon them by patent legislation. The scientific attainments of a Lord Moulton are perhaps unique in the annals of the English-speaking judiciary. However, so long as Congress, for the purposes of patentability, makes the determination of originality a judicial function, judges must overcome their scientific incompetence as best they can. But consciousness of their limitations should make them vigilant against importing their own notions of the nature of the creative process into Congressional legislation. . . . Above all, judges must avoid the subtle temptation of taking scientific phenomena out of their contemporaneous setting and reading them with a retrospective eye."

"To find in 1943 that what Marconi did really did not promote the progress of science because it had been anticipated is more than a mirage of hindsight."

This judge appears here to confuse the issue. The Supreme Court was not concerned with what Marconi did—that is beyond question—but with the degree of originality of an invention.

His concluding statement is worthy of note. "I have little doubt, in so far as I am entitled to express an opinion, that the vast transforming forces of technology have rendered obsolete much in our patent law . . . but whatever revamping our patent laws may need, it is the business of Congress to do the revamping. We have neither constitutional authority nor scientific competence for the task."

We cannot help wondering whether a more suitable title for this brief review of the judgment of the Supreme Court would not have been "Alice in Patent Land." G. W. O. H.

Variable-mu or Variable-μ?

WITH further reference to this question, our attention has been drawn to the Paper* in which Ballantine and Snow first described the invention of this special type of valve. The paper is entitled "Reduction of Distortion and Cross-talk in Radio Receivers by Means of Variable-mu Tetrodes." Although the symbol μ never occurs in the paper, and the discussion and diagrams are concerned mainly with the shaping of the $i_a - v_g$ characteristic, i.e., with the variation of the mutual conductance with grid bias, there is little doubt that they used the term variable-mu as meaning variable-μ. This is confirmed by the reference on p. 2122 to the *mu-factor* which they say "decreases continuously as the grid bias increases negatively."

Still further confirmation is obtained from another paper read by Ballantine and Cobb† about a year earlier, on "The Output Characteristics of the Pentode," where, under the heading "Triode with Constant Mu," we read "It will be useful to note here, for future reference, the form taken by (13) in the case of a triode satisfying the Langmuir—van der Bijl relation $\partial e_p/\partial e_g$ (i_p const) $= \mu =$ constant." Hence constant-mu means constant μ and, presumably, variable-mu would mean variable-μ.

This is supported by the fact that they rarely use the term "mutual conductance," preferring the alternative "transconductance." In the earlier paper there are some notes on nomenclature in which they actually deprecate the use of the former term. The significance of the "mu" appears to have undergone a change in crossing the Atlantic.

It is fortunate that the object of designing a valve with a variable mu (mutual conductance) is to endow it with a variable μ (amplification factor), so that either interpretation is equally applicable to the valve, although a student of the Admiralty Handbook would tell you that the object was to endow the valve with a variable *m*.

G. W. O. H.

* *Proc. I.R.E.*, Vol. 18, 1930, p. 2102. † *Ibid.*, p. 450.

LINEARITY CIRCUITS*

By Arthur C. Clarke

CONTENTS

1. Introduction

THE earliest time-base circuit used in television and cathode-ray tube technique consisted essentially of a condenser charging through a resistance from a high potential source of supply. At intervals determined either externally or by the circuit itself the condenser would be quickly discharged and the process would recommence. Thus a saw-tooth wave would be produced with a gradual rise followed by a rapid fall of voltage.

The voltage output of such a circuit does not increase linearly with time but obeys an exponential law. Consequently when it is applied to the horizontally deflecting plates of a cathode-ray tube, the spot moves more rapidly at the beginning of the trace than at the end, and thus the picture or signal is distorted.

Numerous circuits of varying degrees of complexity have been devised to correct the exponential output of such a time base, and to make it a linear function of time. Such circuits are generally known as " linearity circuits " and in this paper an attempt has been made to discuss the theory of their operation and to determine their limitations.

Two lines of attack are employed in the investigation. In the first place certain actual or possible circuits are analysed and found to be incapable of producing perfect correction, though sufficiently satisfactory for many practical purposes. Secondly, an enquiry is made into the types of circuit which would be capable of producing perfectly linear voltages.

In attempting to apply any of the results obtained to practical cases, the following points should be noticed :—

* MS. accepted by the Editor, January, 1944.

(a) Except where otherwise stated it is assumed that any valves act as linear amplifiers.

(b) It is assumed that there is no load on the linearity circuit, e.g. that it is working into a valve with zero admittance.

(c) It is not always desirable for a time base to have a linear output : what is more often required is a *controllable* degree of non-linearity to compensate for distortion in subsequent stages. That, rather than the production of perfect linearity, is the purpose of some of the circuits dealt with in this paper.

The discussion is confined to voltage (electrostatic) time bases. Current (electromagnetic) time bases are not considered, but under suitable conditions low impedance valves may be driven by some of these corrected voltage time bases to produce currents for electromagnetic deflection.

2. Acknowledgment

The author would like to acknowledge his debt to O. S. Puckle's " Time Bases " which appeared during the preparation of this article and enabled him to extend considerably the scope of the original enquiry.

3. Integrating and Differentiating Circuits

3.1.—Fig 1 shows the simplest possible form of time base. E is a source of high potential and S is some electronic switching device such as a gas-filled triode or hard-valve trigger circuit. Although the development of the equations in this section will be found in any textbook dealing with transient phenomena, it is given here for completeness and because it is a particularly simple example of the cases dealt with later.

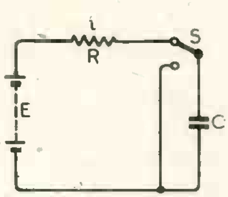


Fig. 1.

The driving voltage E equals the voltages across the resistance and the condenser, i.e.

$$E = iR + \frac{1}{C}\int i\,dt \qquad \ldots \qquad (3.1)$$

Differentiating to remove the integral

$$\frac{1}{C}i + R\frac{di}{dt} = 0$$

$$\therefore \quad \frac{di}{i} = -\frac{1}{CR}dt$$

Integrating,

$$\log i = -\frac{t}{CR} + k$$

When $t = 0$, $k = \log i_0$ where i_0 is the initial current at the moment when the condenser starts to charge. This is obviously E/R since at $t = 0$ there is no charge on the condenser and the full voltage E appears across R.

$$\therefore \quad \log i = -\frac{t}{CR} + \log\frac{E}{R}$$

$$\therefore \quad \log i \cdot \frac{R}{E} = -\frac{t}{CR}$$

$$\text{or} \quad i = \frac{E}{R}\epsilon^{-\frac{t}{CR}} \qquad \ldots \quad \ldots \quad (3.2)$$

To determine the voltage V_c across the condenser at any time it is only necessary to return to Eq. (3.1) from which

$$V_c = E - iR$$

$$= E - E\epsilon^{-\frac{t}{CR}}$$

$$= E\left(1 - \epsilon^{-\frac{t}{CR}}\right) \qquad \ldots \quad \ldots \quad (3.3)$$

When i and V_c are plotted they give the familiar curves in Fig. 2. The shape of the curves depends on the product CR which is known as the "time constant" of the circuit. The smaller CR is, the more rapidly the circuit reaches its final steady state.

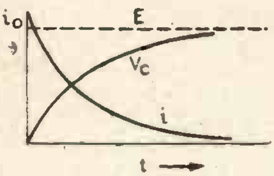


Fig. 2.

Even without mathematics it is obvious that the voltage on the condenser must follow an exponential law. As the condenser charges, the net driving voltage across R decreases and hence the current in the circuit decreases. But the voltage on the condenser is proportional to the integral of current and hence we have a quantity proportional to its own rate of change.

This is the condition which gives rise to an exponential law, whether it be in the case of a cooling body (whose rate of fall of temperature is proportional to its temperature relative to its surroundings) or continuous compound interest, where a sum of money is growing at a rate proportional to itself.

Clearly the only way to prevent an exponential output is to ensure by some means that the charging current is *not* proportional to the driving voltage across R but remains constant. $\frac{1}{C}\int i\,dt$ then equals $\frac{i}{C}t$ and a linear rise is obtained.

Alternatively the exponential rise may be tolerated and an attempt made to remove it in subsequent circuits. If the charging voltage is

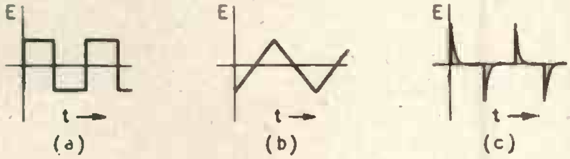


Fig. 3.

very large and the output required is only a small fraction of it, the departure from linearity is small enough to be ignored for many practical purposes. This procedure is sometimes adopted in oscilloscope circuits where high voltages are already available in the C.R.T. supplies. Circuits have also been devised in which fairly low H.T. voltages can be made to behave as very high potential sources by means of negative feedback arrangements. (*See* Section 10.)

3.2. The series condenser-resistance circuit with the output taken across the condenser is known as an integrating circuit since the voltage developed, if sufficiently small, is the approximate integral of the input voltage with respect to time. This follows from the condenser's ability to store charges and will be clear if we consider the case of a square wave applied to the circuit. (Fig. 3a.)

The output is approximately triangular (b), the result of integrating a constant voltage with respect to time.

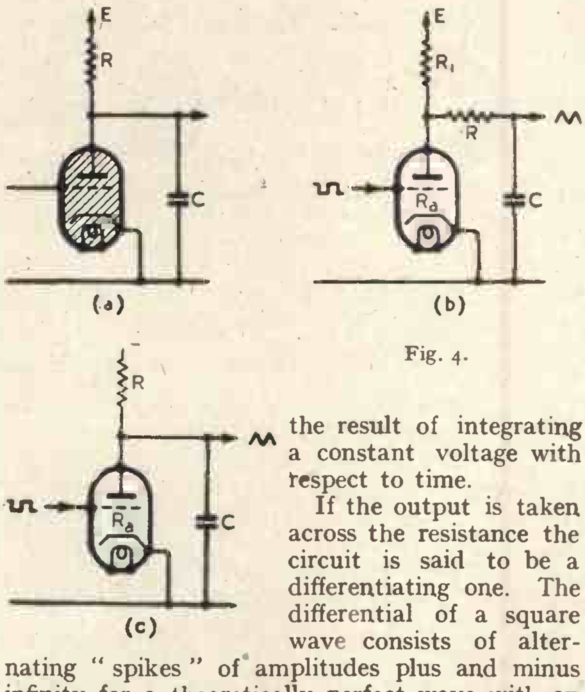


Fig. 4.

If the output is taken across the resistance the circuit is said to be a differentiating one. The differential of a square wave consists of alternating "spikes" of amplitudes plus and minus infinity for a theoretically perfect wave with an instantaneously changing front. In practice pulses with exponential trailing edges (c) are obtained.

The terms differentiating and integrating are used as convenient labels to distinguish between the two types of circuits, even when the values involved are such that the outputs do not approximate to the theoretical triangular waves or narrow spikes.

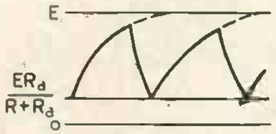


Fig. 5.

4. The Simple Time Base

In practice integrating circuits are used as in Fig. 4 for the production of time bases. In case (a) a gas-filled triode acts as a switch discharging the condenser when the voltage across it has reached a certain value, or on the arrival of a synchronising pulse. The circuit corresponds exactly with Fig. 1, for the gas-filled triode may be assumed to have an infinite resistance when non-ionised and zero resistance when struck.

In (b) the integrating circuit is connected to the anode of a valve into which is fed a square wave or a series of negative pulses sufficient to drive the valve to cut-off. Again the valve may be considered as acting as a switch. When it is conducting the voltage across the circuit will be $\frac{ER_a}{R_1 + R_a}$ where R_a is the D.C. resistance of the valve. When the valve is cut off by the sudden application of the negative wave the condenser will start to charge up towards the line voltage E thus producing a triangular output.

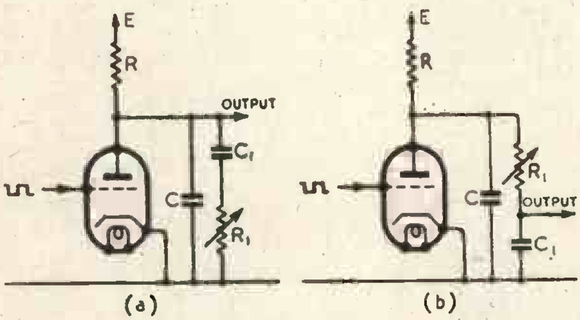


Fig. 6.

There is no need to employ two resistances as in Fig. 4 (b), since the anode load of the valve will complete the integrating circuit—Fig. 4 (c).

When the valve is conducting C will be charged up to $\frac{ER_a}{R + R_a}$ volts which will be nearly zero if R is large and, as is usually the case, the valve is conducting heavily. When the valve is cut off C charges up towards E and the output is a saw-tooth between the limits E and $\frac{ER_a}{R + R_a}$ (Fig. 5).

Whether or not the voltage across C reaches E depends on the duration of the negative wave and the time constant of the circuit. It will be noted that as $R_a \ll R$ the condenser voltage falls back to $\frac{ER_a}{R + R_a}$ very quickly: the time constant on discharging is much shorter than on charging.

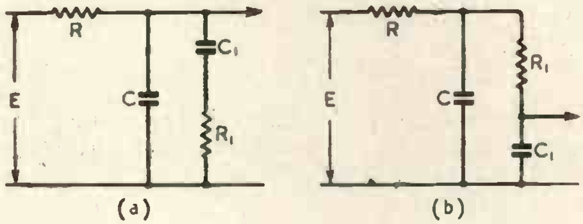


Fig. 7.

For many purposes the valve may be regarded as a pulse or square wave generator of output E driving the integrating circuit and this conception will be used in subsequent analyses.

5. Auxiliary Circuits—Analysis

5.1. A large number of attempts have been made to linearise the output voltage by auxiliary integrating or differentiating circuits and some of the simpler possible arrangements will now be considered. These are not all cases which will necessarily be of practical use but they will serve to demonstrate what happens in the more complicated arrangements.

Regarding the valve in Fig. 6 as a switch with zero D.C. resistance when conducting we may redraw the circuits as shown in Fig. 7 where E is a square wave or pulse generator suddenly applying a voltage E to the circuit at time $t = 0$. If the D.C. resistance of the valve when conducting is R_a, and not zero as assumed, the form of the derived equations is not affected. The only alteration is that E must be replaced by $\frac{ER}{R + R_a}$.

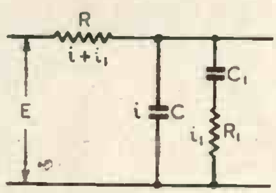


Fig. 8.

5.2. Both circuits may be represented as drawn in Fig. 8.

We have
$$E = (i + i_1)R + \frac{1}{C_1}\int i_1 dt + R_1 i_1 \quad \ldots \ldots (5.1)$$

$$\frac{1}{C}\int idt = \frac{1}{C_1}\int i_1 dt + R_1 i_1 \quad \ldots \quad \ldots \quad (5.2)$$

Differentiating,

$$R\frac{di}{dt} + R\frac{di_1}{dt} + \frac{i_1}{C_1} + R_1\frac{di_1}{dt} = 0 \quad \ldots \quad (5.3)$$

$$\frac{1}{C}i = \frac{1}{C_1}i_1 + R_1\frac{di_1}{dt} \quad \ldots \quad \ldots \quad \ldots \quad (5.4)$$

From (5.4)

$$\frac{di}{dt} = \frac{C}{C_1}\frac{di_1}{dt} + CR_1\frac{d^2i_1}{dt^2}$$

Substituting in (5.3)

$$\frac{RC}{C_1}\frac{di_1}{dt} + CRR_1\frac{d^2i_1}{dt^2} + R\frac{di_1}{dt} + R_1\frac{di_1}{dt} + \frac{i_1}{C} = 0$$

$$\therefore \quad CRR_1\frac{d^2i_1}{dt^2} + \left(R + R_1 + \frac{RC}{C_1}\right)\frac{di_1}{dt} + \frac{1}{C}i_1 = 0$$

$$\therefore \frac{d^2i_1}{dt^2} + \left(\frac{1}{CR} + \frac{1}{CR_1} + \frac{1}{C_1R_1}\right)\frac{di_1}{dt} + \frac{1}{CRC_1R_1}i_1 = 0 \quad \ldots \quad \ldots \quad (5.5)$$

This is a linear second order differential equation of the form :—

$$\frac{d^2i_1}{dt^2} + b\frac{di_1}{dt} + ci_1 = 0$$

The solution of such an equation is

$$i_1 = A\epsilon^{\lambda_1 t} + B\epsilon^{\lambda_2 t} \quad \ldots \quad \ldots \quad \ldots \quad (5.6)$$

where A and B are constants determined by the initial circuit conditions and

$$\lambda_1 = \frac{-b + \sqrt{b^2 - 4c}}{2}$$

$$\lambda_2 = \frac{-b - \sqrt{b^2 - 4c}}{2}$$

In the particular case where $\lambda_1 = \lambda_2 = \lambda$ the solution reduces to

$$i_1 = (A + Bt)\epsilon^{\lambda t} \quad \ldots \quad \ldots \quad \ldots \quad (5.7)$$

5.3. The case where $\lambda_1 \neq \lambda_2$ will be considered first. Since the general solution

$$i_1 = A\epsilon^{\lambda_1 t} + B\epsilon^{\lambda_2 t}$$

must be true for all values of time it will be true when $t = 0$.

Then $(i_1)_0 = A + B$

But when $t = 0$ there can be no current flowing in the C_1R_1 branch as there is no voltage across C. Hence $(i_1)_0 = 0$ and $A = -B$.

$$\therefore \quad i_1 = A(\epsilon^{\lambda_1 t} - \epsilon^{\lambda_2 t}) \quad \ldots \quad \ldots \quad \ldots \quad (5.8)$$

To determine A, we use eqn. (5.4) from which we note that

$$\frac{1}{C}i = \frac{A}{C_1}(\epsilon^{\lambda_1 t} - \epsilon^{\lambda_2 t}) + AR_1(\lambda_1\epsilon^{\lambda_1} - \lambda_2\epsilon^{\lambda_2 t})$$

When $t = 0$ and $i = (i)_0$ we have

$$\frac{1}{C}(i)_0 = AR_1(\lambda_1 - \lambda_2)$$

To find $(i)_0$ we need merely note that at $t = 0$ the full voltage E appears across R since C is uncharged. Hence

$$(i)_0 + (i_1)_0 = \frac{E}{R}$$

but $(i_1)_0 = 0$ and hence $(i)_0 = \frac{E}{R}$ and

$$\frac{E}{CR} = AR_1(\lambda_1 - \lambda_2)$$

$$\therefore \quad A = \frac{E}{CRR_1(\lambda_1 - \lambda_2)}$$

Hence

$$i_1 = \frac{E}{CRR_1(\lambda_1 - \lambda_2)}(\epsilon^{\lambda_1 t} - \epsilon^{\lambda_2 t}) \quad \ldots \quad (5.9)$$

5.4. Before considering the type of output voltage that will be produced by this current it is necessary to investigate the nature of λ_1 and λ_2. They must clearly be negative but they may be unreal.

This would be the case if $4c > b^2$.

Then $$\frac{4}{CRC_1R_1} > \left(\frac{1}{CR} + \frac{1}{CR_1} + \frac{1}{C_1R_1}\right)^2$$

$$\therefore \quad 4\,CRC_1R_1 > (CR + C_1R_1 + C_1R)^2$$

Putting $CR = T$ and $C_1R_1 = T_1$

$$4TT_1 > (T + T_1 + C_1R)^2$$

$$4TT_1 > (T + T_1)^2 + C_1^2R^2 + 2C_1R(T + T_1)$$

$$\therefore \quad 0 > (T - T_1)^2 + C_1^2R^2 + 2C_1R(T + T_1)$$

As all the terms on the right-hand side must be positive, this is impossible and hence $b^2 > 4c$.

Thus λ_1 and λ_2 are real negative quantities and in addition the case $\lambda_1 = \lambda_2$ cannot arise, since b^2 would then equal $4c$. The solution

$$i_1 = (A + Bt)\epsilon^{\lambda t}$$

need not therefore be considered.

5.5. As i_1 in Fig. 8 has been determined we can now consider the type of output voltage it will produce. Taking case (a) of Fig. 7 first the voltage produced is

$$v = i_1R_1 + \frac{1}{C_1}\int i_1 dt$$

$$= AR_1(\epsilon^{\lambda_1 t} - \epsilon^{\lambda_2 t}) + \frac{A}{C_1}\int(\epsilon^{\lambda_1 t} - \epsilon^{\lambda_2 t})\,dt$$

$$= AR_1(\epsilon^{\lambda_1 t} - \epsilon^{\lambda_2 t}) + \frac{A}{C_1}\left(\frac{1}{\lambda_1}\epsilon^{\lambda_1 t} - \frac{1}{\lambda_2}\epsilon^{\lambda_2 t}\right) + K$$

$$= A\left(R_1 + \frac{1}{C_1\lambda_1}\right)\epsilon^{\lambda_1 t} - A\left(R_1 + \frac{1}{C_1\lambda_2}\right)\epsilon^{\lambda_2 t} + K$$

When $t = \infty$ the exponential terms will have vanished and K must therefore be equal to the final output voltage, which is E. Thus the output of the circuit is

$$v = E + A\frac{(R_1C_1\lambda_1+1)}{C_1\lambda_1}\epsilon^{\lambda_1 t} - A\frac{(R_1C_1\lambda_2+1)}{C_1\lambda_2}\epsilon^{\lambda_2 t}$$

$$= E + A'\epsilon^{\lambda_1 t} - A''\epsilon^{\lambda_2 t} \quad \ldots \quad \ldots \quad (5.10)$$

where A' and A'' are constants such that $E + A' = A''$.

5.6. Case (b) of Fig. 7 gives a very similar result. Here

$$v = \frac{1}{C_1}\int i_1\,dt$$

$$= \frac{A}{C_1}\int(\epsilon^{\lambda_1 t} - \epsilon^{\lambda_2 t})\,dt$$

$$= \frac{A}{C_1}\left(\frac{\epsilon^{\lambda_1 t}}{\lambda_1} - \frac{\epsilon^{\lambda_2 t}}{\lambda_2}\right) + K$$

where as before $K = E$.

$$\therefore \quad v = E + \frac{A}{c_1\lambda_1}\epsilon^{\lambda_1 t} - \frac{A}{c_1\lambda_2}\epsilon^{\lambda_2 t} \quad \ldots \quad (5.11)$$

which is of the same form as eqn. (5.10).

5.7. The voltages defined by eqns. (5.10) and (5.11) are not simple exponential functions but are the results of combining exponential curves of different time constants and initial amplitudes.

Examples of such composite functions are shown in Fig. 9. By varying A', A'', λ_1 and λ_2 the output voltage may reach its final value E by an infinite number of routes.

It can be readily shown that no combination of the constants can produce a linear rise. The proof is as follows.

5.8. If a linear rise is to be produced it is necessary to satisfy the equation

$$A\epsilon^{at} + B\epsilon^{bt} = kt$$

Expanding

$$A\left(1 + at + \frac{a^2t^2}{2} + \frac{a^3t^3}{3!}\ldots\ldots\right)$$

$$+ B\left(1 + bt + \frac{b^2t^2}{2} + \frac{b^3t^3}{3!}\ldots\ldots\right) = kt$$

Equating coefficients

$$A + B = 0$$

$$Aa + Bb = k$$

$$Aa^2 + Bb^2 = 0$$

This can only be true if $A = -B$, $a = b$, in which case the original function vanishes completely, giving us the helpful result that a linear output can be obtained only if it is infinitely small.

Nevertheless the presence of an auxiliary circuit may produce a slight improvement in linearity at the beginning of the voltage rise, as shown in Fig. 9 where the dotted lines indicate the shape of the exponential curves which would rise to 70% of the final voltage in the same time as the composite function.

Thus by varying C_1 and R_1 the linearity of the output may be controlled to a certain extent. The degree of control depends in a complex manner on the circuit parameters and the duration of the applied square wave.

It is not profitable to carry the general analysis further than this and to attempt to find values of C_1 and R_1 which give the "most linear" rise as they will vary with the amplitude of output required. However much the initial slope of the curve be altered, it is bound eventually to make an asymptotic approach to E and so will have to depart from the linear condition.

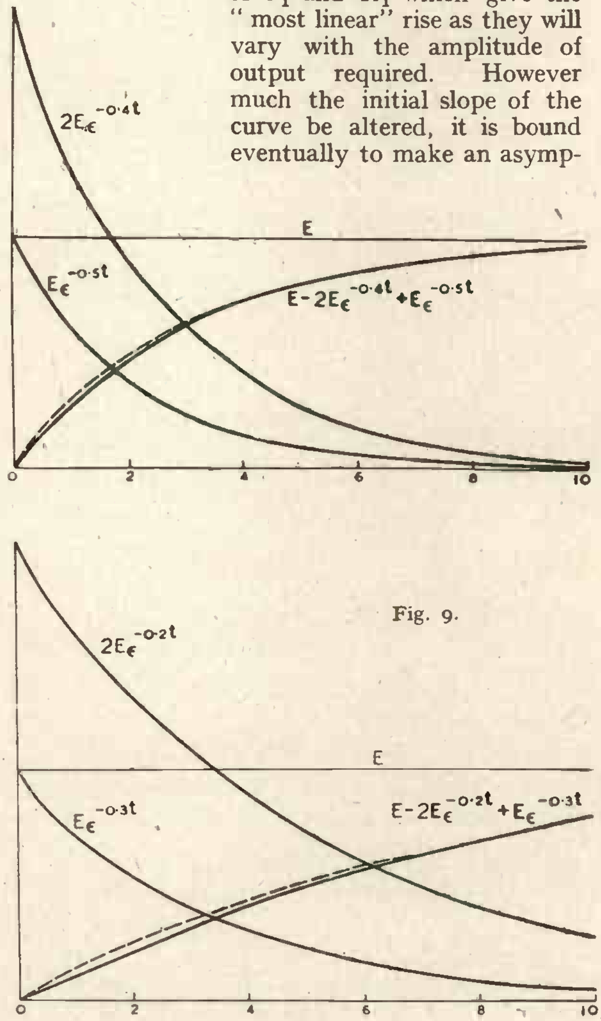


Fig. 9.

6. Auxiliary Circuits—Further Analysis

6.1. A slightly different type of circuit may be constructed in which the integrating circuit precedes the valve and the correcting circuit follows it, as shown in Fig. 10.

This differs from the cases in Fig. 6 because the two circuits are isolated from each other by the valve and so can be considered independently.

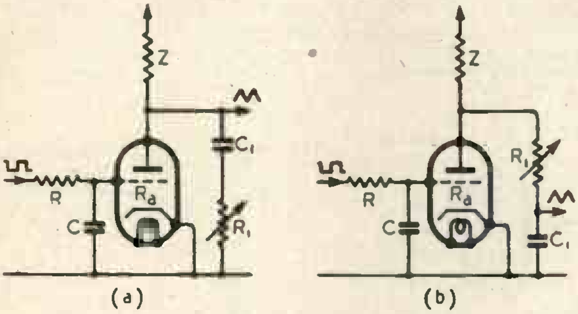


Fig. 10.

The valve and integrating circuit can be regarded as an exponential wave generator driving the correcting circuit and the usual valve equivalent circuit (Fig. 11) can be employed. A further simplification can be obtained by the use of Thévenin's Theorem* which results in the circuits shown in Fig. 12.

Here, $e = \frac{vZ}{Z + R_a}$ and $R' = \frac{R_a Z}{Z + R_a}$

Now v and hence e is an exponential wave and we may write

$$e = E(1 - \epsilon^{-\lambda t})$$

where $\lambda = \frac{1}{CR}$

Then

$$e = i(R_1 + R') + \frac{1}{C_1}\int i\,dt$$

$$\therefore \quad E(1 - \epsilon^{-\lambda t}) = i(R_1 + R') + \frac{1}{C_1}\int i\,dt$$

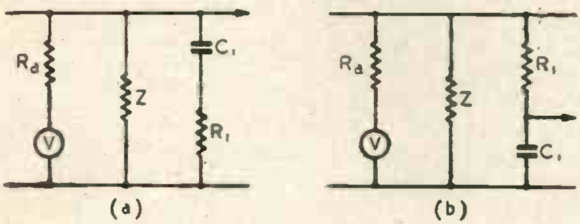


Fig. 11.

Differentiating,

$$E\lambda\epsilon^{-\lambda t} = (R_1 + R')\frac{di}{dt} + \frac{i}{C_1}$$

$$\therefore \quad \frac{di}{dt} + \frac{1}{(R_1 + R')C_1}\,i = \frac{E\lambda\epsilon^{-\lambda t}}{R_1 + R'} \quad \ldots \quad (6.1)$$

* Often so-called but originally due to Helmholtz.—Ed.

This is a linear first order differential equation of the form

$$\frac{di}{dt} + ai = b\,.\,f(t)$$

and may be solved by multiplying by an integrating factor, which in this case is ϵ^{at}

$$\therefore \quad \epsilon^{at}\frac{di}{dt} + \epsilon^{at}ai = b\epsilon^{(a-\lambda)t}$$

$$\therefore \quad \frac{d}{dt}(i\epsilon^{at}) = b\epsilon^{(a-\lambda)}$$

$$\therefore \quad i\epsilon^{at} = b\int \epsilon^{(a-\lambda)t}\,dt$$

$$= \frac{b}{a-\lambda}\epsilon^{(a-\lambda)t} + K$$

$$\therefore \quad i = \frac{b}{a-\lambda}\epsilon^{-\lambda t} + K\epsilon^{-at}$$

To determine K we put $i = i_0$ when $t = 0$ and thus

$$i_0 = \frac{b}{a-\lambda} + K$$

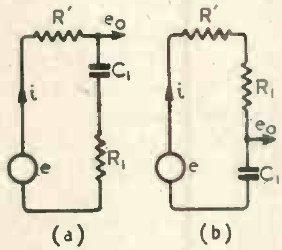


Fig. 12.

But i_0 is zero since when $t = 0$, the driving voltage e is also zero.

$$\therefore \quad K = -\frac{b}{a-\lambda}$$

Thus we have

$$i = \frac{b}{a-\lambda}(\epsilon^{-\lambda t} - \epsilon^{-at}) \quad \ldots \quad \ldots \quad (6.2)$$

where $a = \frac{1}{C_1(R_1 + R')}$ and $b = \frac{E\lambda}{R_1 + R'}$

The output voltage e_0 is given by

$$R_1 i + \frac{1}{C_1}\int i\,dt \quad \ldots \quad \ldots \quad \ldots \quad (6.3)$$

in case (a) and by

$$\frac{1}{C_1}\int i\,dt \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6.4)$$

in case (b).

Considering eqn. (6.3) first we have

$$e_0 = \frac{bR_1}{a-\lambda}(\epsilon^{-\lambda t} - \epsilon^{-at}) + \frac{1}{C_1}\frac{b}{a-\lambda}\left[\int \epsilon^{-\lambda t}dt - \int \epsilon^{-at}dt\right]$$

$$= \frac{b}{a-\lambda}\left[R_1(\epsilon^{-\lambda t} - \epsilon^{-at}) + \frac{1}{C_1}\left(-\frac{1}{\lambda}\epsilon^{-\lambda t} + \frac{1}{a}\epsilon^{-at}\right)\right] + K$$

$$= K + A'\epsilon^{-\lambda t} + A''\epsilon^{-at} \quad \ldots \quad \ldots \quad (6.5)$$

Eqn. (6.4) gives a precisely similar result on integration: both functions are of the type discussed in Sections 5.6 and 5.7 and the same conclusions apply to them. The auxiliary circuits can vary and to some extent improve the linearity of the output, but cannot completely correct the charging characteristic of the original integrating circuit.

6.2. In all the above cases no account has been taken of the steady charge which will accumulate on C. This is a constant term which will disappear when the initial circuit equations are differentiated and so does not affect the form of the solution.

7. Auxiliary Circuits—Conclusions

7.1. The above discussions can be generalised to cover all possible correcting circuits using valves acting purely as linear amplifiers and working into condenser-resistance networks. *Once an exponential wave had been produced any subsequent linear circuits can only differentiate or integrate it—and the differential or integral of an exponential function is still exponential.*

7.2. Similar arguments apply when the circuit contains inductances, as in the case of Blumlein's time-base in which the condenser is charged through a resistance and inductance in series. The inductance limits the initial charging current and so the voltage across the condenser is nearly linear with respect to time, being actually the rising front of a damped sine wave. It is clear that no finite number of inductances can be combined in any linear circuit to produce a perfect sawtooth. Each LC circuit would contribute its characteristic frequency, but the linear sawtooth requires an *infinite* number of frequencies for its production.

8. Valves in Linearity Circuits

A number of important circuits have been devised in which valves are used to improve the linearity of the time base. The valve may be used for three purposes—

(a) as a constant-current device
(b) to provide negative feedback
(c) as a non-linear amplifier.

In cases (a) and (b) the valve may also be regarded as acting as a non-linear device by behaving, for example, as a non-ohmic resistance.

9. Constant-Current Devices

One of the most important cases is that of the constant-current pentode which may be used to replace the resistance through which the condenser charges (Fig. 13). If the voltage across the pentode is not allowed to fall below "A" the current remains substantially constant and the condenser may charge up to 80–90 per cent. of the supply voltage before non-linearity becomes noticeable. The pentode behaves as though it has a very high A.C. or slope resistance—$\frac{dV_a}{dI_a}$—while its D.C. or static resistance, V_a/I_a, is relatively small and so it passes a considerable current.

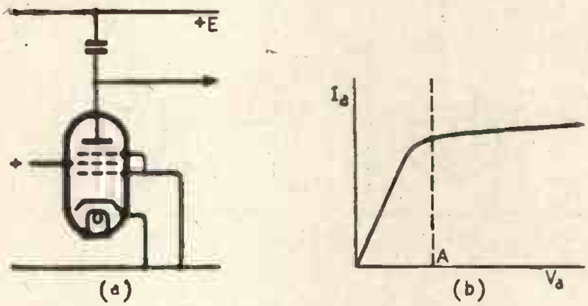


Fig. 13.

Results may be still further improved by the use of a cathode resistance to produce negative feedback. Feedback is also employed in Bedford's circuit (*see* Section 11).

10. Cathode-Follower Time Base

The cathode-follower time base (Fig. 14) uses negative feedback to produce constant current operation with an ordinary triode. In a cathode-follower a negative signal produces a slightly smaller negative output, a positive signal a slightly smaller positive output. Thus the potential difference between grid and cathode is almost constant whatever excursions the two electrodes make. Accordingly in the circuit of Fig. 14 a nearly constant current must flow through R, and hence C must charge up at a linear rate.

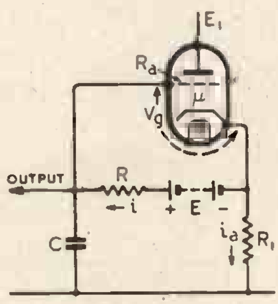


Fig. 14.

The general circuits equations are:

$$V_g = E - iR \quad \ldots \quad (10.1)$$

$$E = i(R + R_1) - i_a R_1 + \frac{1}{C}\int idt \quad \ldots \quad (10.2)$$

$$i_a = \frac{E_1 + \mu V_g}{R_a + R_1} \quad \ldots \quad (10.3)$$

From (10.1) and (10.3)

$$i_a = \frac{E_1 + \mu E - \mu iR}{R_a + R_1} \quad \ldots \quad (10.4)$$

From (10.2)

$$(R + R_1)\frac{di}{dt} - R_1\frac{di_a}{dt} + \frac{i}{C} = 0$$

$$\therefore \quad (R + R_1)\frac{di}{dt} + \frac{\mu RR_1}{R_a + R_1}\frac{di}{dt} + \frac{i}{C} = 0$$

$$\therefore \quad \left[R + R_1 + \frac{\mu RR_1}{R_a + R_1}\right]\frac{di}{dt} + \frac{i}{C} = 0$$

This is of the form

$$a\frac{di}{dt} + \frac{i}{C} = 0$$

which has the solution [*see* equation (3.2)]

$$i = I\,\epsilon^{-\frac{t}{ac}}$$

To find I put $t = 0$. Then from (10.2) and (10.4), if the initial value of i is i_0,

$$E = i_0 (R + R_1) - i_a R_1$$

$$\therefore \quad i_0 (R + R_1) - \left(\frac{E_1 + \mu E - \mu i_0 R}{R_a + R_1}\right) R_1 = E$$

$$\therefore \quad i_0\left(R + R_1 + \frac{\mu RR_1}{R_a + R_1}\right) = E + \frac{E_1 + \mu E}{R_a + R_1}\cdot R_1$$

$$\therefore \quad i_0\left[(R + R_1)(R_a + R_1) + \mu RR_1\right] = E(R_a + R_1) + R_1(E_1 + \mu E)$$

$$\therefore \quad i = \frac{E(R_a + R_1) + R_1(E_1 + \mu E)}{(R + R_1)(R_a + R_1) + \mu RR_1}\,\epsilon^{-\frac{t}{ac}} \qquad \text{(10.5)}$$

where $a = \dfrac{(R + R_1)(R_a + R_1) + \mu RR_1}{R_a + R_1}$

This somewhat unwieldy expression may be simplified for the case when $R_1 = R_a$

Then

$$i = \frac{2ER_a + R_a(E_1 + \mu E)}{2R_a(R + R_a) + \mu RR_a}\,\epsilon^{-\frac{t}{ac}}$$

$$= \frac{2E + E_1 + \mu E}{2(R + R_a) + \mu R}\,\epsilon^{-\frac{t}{ac}}$$

where a has now reduced to $R + R_a + \mu R/2$

Now the output of the time base circuit is the voltage across C which is $\frac{1}{C}\int idt$

$$= \frac{1}{C}\cdot\frac{E + \mu E/2 + E_1/2}{R + R_a + \mu R/2}\int \epsilon^{-\frac{t}{ac}}\,dt$$

$$= -\left[E + \frac{\mu E}{2} + \frac{E_1}{2}\right]\epsilon^{-\frac{t}{ac}} + K$$

When $t = 0$ this expression equals zero.

Hence $K = E + \dfrac{\mu E}{2} + \dfrac{E_1}{2}$ and the output voltage equals

$$\left(E + \frac{\mu E}{2} + \frac{E_1}{2}\right)(1 - \epsilon^{-\frac{t}{ac}}) \qquad \text{(10.6)}$$

Comparing this result with eqn. (3.3) it will be seen that the condenser appears to be charging from a source of e.m.f. $E + \mu E/2 + E_1/2$. As μ may be very high, the effective charging voltage can thus be several hundred times E.

11. Bedford's Circuit.

11.1. Bedford has designed a useful circuit in which a variable degree of linearity may be obtained by feedback. The charging pentode V_1 has its cathode connected to a tapping A on the cathode resistance of the amplifying valve V_2. As the voltage at the anode of V_1 falls, so will that at the grid of V_2 and hence at A. Thus the voltage across the pentode tends to remain constant, producing an improvement in linearity. By varying the position of A, the output voltage may be made to follow an infinite variety of curves and nonlinearity of any subsequent stages may be corrected.

It might be thought that by a proper choice of resistances and tapping points perfect linearity could be obtained, but as will be shown in the following analysis, this is not the case.

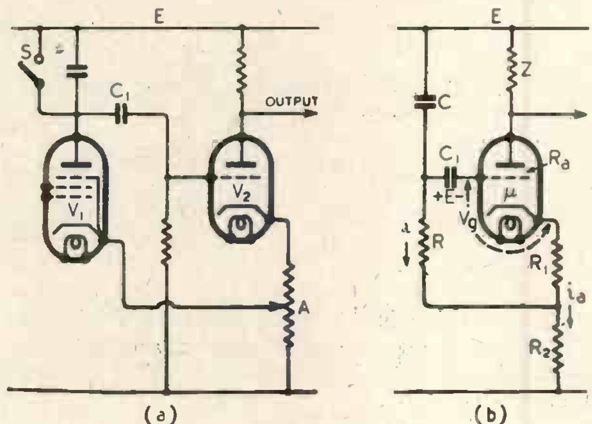


Fig. 15.

The circuit has been redrawn in Fig. 15 (b) with the pentode V_1 regarded as a simple resistance. If the time constant of the coupling circuit is long compared with the repetition period the condenser C_1 may be regarded as carrying a constant voltage equal to that of the supply.

The circuit equations are then

$$i_a = \frac{E + \mu V_g}{Z + R_a + R_1 + R_2} = \frac{E + \mu V_g}{Z_1} \qquad \text{(11.1)}$$

$$iR = i_a R_1 + E + V_g \qquad \text{(11.2)}$$

$$\frac{1}{C}\int idt + iR + (i + i_a)R_2 = E \qquad \text{(11.3)}$$

From (11.1)

$$i_a Z_1 = E + \mu V_g$$

$$\therefore \quad V_g = \frac{i_a Z_1 - E}{\mu}$$

From (11.2)

$$i = E\frac{(\mu - 1)}{\mu R} + \frac{(\mu R_1 + Z_1)}{\mu R} i_a$$

From (11.3)

$$\frac{i}{C} + \frac{Rdi}{dt} + \left(\frac{di}{dt} + \frac{di_a}{dt}\right) R_2 = 0$$

$$\therefore \quad (R + R_2)\frac{di}{dt} + R_2\frac{di_a}{dt} + \frac{i}{C} = 0$$

$$\therefore \quad (R + R_2)\frac{(\mu R_1 + Z_1)}{\mu R}\frac{di_a}{dt} + R_2\frac{di_a}{dt} + \frac{E}{\mu CR}(\mu - 1) + \frac{\mu R_1 + Z_1}{\mu CR} i_a = 0$$

$$\therefore \quad [C(R + R_2)(\mu R_1 + Z_1) + \mu CRR_2]\frac{di_a}{dt} + (\mu R_1 + Z_1)i_a = E(1 - \mu) \quad (11.4)$$

This is of the form

$$a\frac{di_a}{dt} + b\,i_a = c \quad \ldots \quad \ldots \quad \ldots \quad (11.5)$$

For i_a to be a linear function of time equation (11.5) must reduce to

$$a\frac{di_a}{dt} = c$$

Hence $b = \mu R_1 + Z_1 = 0$

or $$\mu = -\frac{Z_1}{R_1}$$

This condition is not physically realisable as it implies that a negative signal on the grid increases the anode current. The meaning of the solution is as follows.

Since $i_a = \dfrac{E + \mu V_g}{Z_1}$ the voltage across R_1 is

$$i_a R_1 = \frac{ER_1}{Z_1} + \frac{\mu V_g R_1}{Z_1} = \frac{ER_1}{Z_1} - V_g$$

if the above hypothetical condition were possible.

Thus

$$i_a R_1 + V_g = \frac{ER_1}{Z_1} = \text{a constant.}$$

But $i_a R_1 + V_g$ is the voltage across R, so this is the condition for a constant charging current.

11.2. It is also instructive to consider the circuit by the familiar *reductio ad absurdum* method of Euclid. Let us suppose that a perfectly linear output is being produced by the triode. Then V_g and i_a must both be linear with respect to time. Hence the voltage across R must be linear and so must be the current i through it which is charging C. The voltage across the condenser, which is obtained by integrating the current i with respect to time, is therefore proportional to t^2 and so is not linear but parabolic.

We thus have three voltages V_C, V_R and V_{R2}, two of which are linear and one of which is parabolic, adding up to a constant voltage E. This is obviously impossible except in the special and practically unrealisable case discussed in Section 11.1.

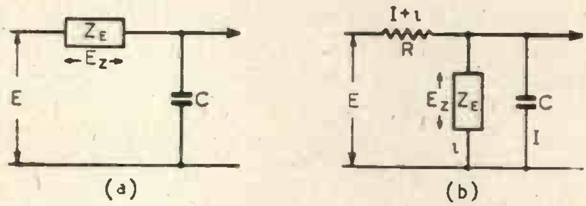


Fig. 16.

In practice, since R is not an ohmic resistance but a constant current pentode contributing its share to the linearity of the circuit, an almost perfect sawtooth output can be obtained. The main disadvantage of the circuit is that it requires four valves, allowing for two in the switching circuit.

We have seen that none of the circuits so far considered are capable, even in theory, of generating perfectly linear outputs. We will now approach the problem from the reverse direction and, assuming that such outputs are available, will discuss the types of circuits that must have produced them, with a view to seeing if any of them are physically realisable.

12. Non-Linear Impedance

A number of resistors employed in electrical engineering, such as "Metrosil" and other surge-arresting materials, do not obey Ohm's Law except over small ranges but have non-linear current-voltage characteristics. This raises the question: what must be the characteristic of a resistance employed in an integrating circuit if it is to produce a linear output?

There are two possible simple circuit arrangements, series and parallel, as shown in Fig. 16. The requirements of both circuits are that the resistance Z vary with the voltage E_Z across it in such a way that the current charging the condenser remains constant. We will assume that the value of the resistance is Z_E when the voltage across it is E_Z.

In case (a) the resistance of Z must obviously be directly proportional to the voltage across it, since it is required to pass a constant current. A resistance obeying the law $Z_E = kE_Z$, even over a limited range, does not seem very likely to be realised in practice. The commercial non-linear resistors obey laws of the form $Z_E = kE_Z^{-4}$ and only depart from linearity at fairly high voltages. However, it would be rash to assume that no substance could be found to obey this direct proportionality law over a voltage range which would make it useful for commercial television purposes.

In case (b) we have

$$E = (I + i)R + iZ_E$$

where I is a constant which must equal E/R, from a consideration of the initial conditions when there is no charge across the condenser.

Thus

$$E = (\frac{E}{R} + i)\,R + iZ_E.$$

Whence

$$Z_E = -R.$$

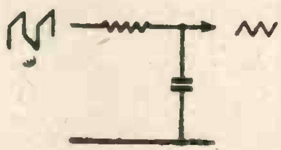


Fig. 17.

Although negative resistances independent of frequency may be realised in practice, for example in the case of the transitron, they require valve circuits, and it does not appear profitable to pursue the parallel circuit case any further.

13. The Integrating Amplifier

It has so far been assumed that the input to the integrating circuit is a constant voltage or a square wave. If, however, the input voltage is rising steadily at the correct rate, it may force a constant current through the circuit and so produce a perfectly triangular output across the condenser.

The required input voltage may clearly be obtained by taking an ordinary integrating circuit driven by a square wave and feeding the output back into the circuit. The input may then be regarded as a square wave surmounted by a triangular wave. The square wave component will produce the constant current through the resistance and the triangular component will appear across the condenser. Clearly the theoretical gain of the feedback loop should be unity.

This is the principle of the integrating amplifier of Beale and Stansfield which consists of a two-stage amplifier with an integrating circuit between the stages (Fig. 18).

Although it would appear that the circuit is liable to go into self-oscillation, according to Puckle there is no danger of this occurring in normal use owing to the fact that gain at low frequencies is reduced in the RC couplings between

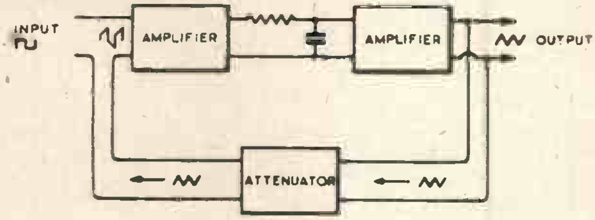


Fig. 18.

the stages. With proper adjustment of the feedback an almost perfectly linear output may be obtained.

14. The Logarithmic Amplifier

14.1. We will conclude this paper by investigating the case of the non-linear valve amplifier. It has already been mentioned that linearity circuits are usually employed to correct for distortion in subsequent stages so that the ultimate result on the face of the cathode-ray tube is a linear trace. Amplifying valves with curved characteristics may be deliberately used to produce a linear output from an exponential input and the gain law of such a valve will now be considered.

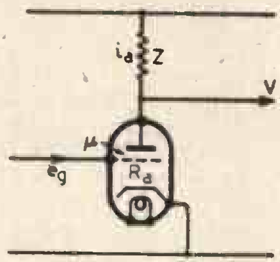


Fig. 19.

14.2. In the circuit of Fig. 19 e_g is the input which is assumed to be of exponential form. The output voltage V is assumed to be linear and the amplification factor μ is therefore a function of e_g which is to be determined.

The circuit equations are

$$V = i_a Z = \frac{\mu e_g Z}{Z + R_a} = \mu e_g Z_1, \text{ say.}$$

$$e_g = E(1 - \epsilon^{-\lambda t})$$

$$\mu = \phi\,(e_g)$$

$$V = kt$$

where k and λ are constants.

Then $kt = \mu e_g Z_1$

$$\therefore \quad \mu = \frac{kt}{e_g Z_1} \quad \ldots \quad \ldots \quad \ldots \quad (14.1)$$

Now $1 - \frac{e_g}{E} = \epsilon^{-\lambda}$.

$$\therefore \quad \lambda t = -\log \frac{E - e_g}{E} = \log \frac{E}{E - e_g}$$

$$\therefore \quad t = \frac{1}{\lambda} \log \frac{E}{E - e_g} \quad \ldots \quad \ldots \quad (14.2)$$

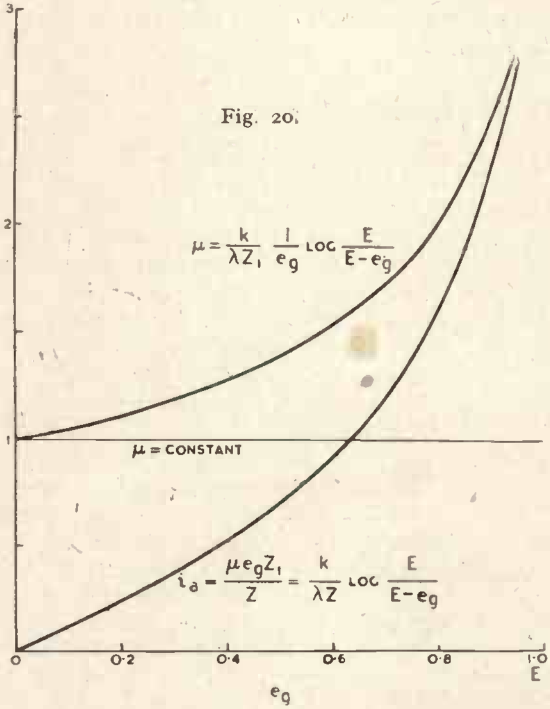
Hence from (14.1)

$$\mu = \frac{k}{\lambda Z_1} \frac{1}{e_g} \log \frac{E}{E - e_g} \quad \ldots \quad \ldots \quad (14.3)$$

Now $\quad i_a = \mu e_g \frac{Z_1}{Z}$

Therefore from (14.3)

$$i_a = \frac{k}{\lambda Z} \log \frac{E}{E - e_g} \quad \ldots \quad \ldots \quad (14.4)$$



14.3. In Fig. 20 μ and i_a have been plotted against e_g. Since eqn. (14.3) becomes indeterminate when $e_g = O$, we must write

$$\mu = -\frac{k}{\lambda Z_1} \frac{1}{e_g} \log \left(1 - \frac{e_g}{E}\right)$$

$$= -\frac{k}{\lambda Z_1} \frac{1}{e_g} \left[-\frac{e_g}{E} - \tfrac{1}{2}\left(\frac{e_g}{E}\right)^2 - \tfrac{1}{3}\left(\frac{e_g}{E}\right)^3 \ldots \right]$$

$$= \frac{k}{\lambda E Z_1} \quad \text{when } e_g = 0$$

This quantity has been put equal to unity in drawing the curves in Fig. 20.

Although the scales used in Fig. 20 are quite arbitrary, since the constants k, λ, Z, Z_1, and E may have any value, the required shape of the valve characteristic is clearly brought out. The $i_a - v_g$ curve is very similar to that of the ordinary variable-mu or super-control valve.

It would thus appear that by careful choice of the circuit constants a useful improvement in linearity might be obtained by employing a variable-mu amplifier or a valve with a similar logarithmic characteristic. This use of a non-linear amplifier was suggested by Bedford and Stevens (British Patent 474623), and a similar idea has been used by Jenkins (*see* Puckle, p. 85).

When television sets are mass-produced, it might be well worth while to design special valves for the amplification of exponental time-bases, if none of the existing types could be found with the required logarithmic characteristic.

The Cathode Ray Oscillograph in Industry

By W. Wilson, D.Sc., M.I.E.E. Published by Chapman & Hall, 11, Henrietta Street, London, W.C.2. Pp. 148: Figs. 156. Price 12s. 6d.

The use of the oscillograph, first as a tool in electrical engineering laboratories, and later for more specialised work in a wide variety of industries, has been increasing rapidly in the past decade. This book sets out to describe in a practical style many of these applications for the benefit of those engaged in industries where problems, which the oscillograph can help to solve are encountered.

The opening chapters are devoted to a description of two typical oscillographs, employing a glass cathode-ray tube and a continuously evacuated metal tube respectively, and to their accessory circuits. Time bases, which come under this heading, occupy less than eight pages, power units a page and a half, and amplifiers about the same space, so it is obvious that the treatment is not very full. After a chapter describing several typical commercial oscillographs, we come to the applications.

These are dealt with in chapters in the following logical arrangement: tests requiring only single deflection readings; tests requiring two deflections at right angles (differential tests); tests requiring a repeating time base; tests requiring a single-sweep time base; tests involving independent bases other than time; and tests in which one of the variables is mechanical pressure.

The electron microscope is, as the author points out, a cathode-ray tube with a highly developed focusing arrangement in which the image does not oscillate, and he therefore devotes an interesting chapter to it.

The value of a four-page appendix on the characteristics of thermionic valves is doubtful, and the same remark applies to the few pages devoted to photo-cells, oscillators and piezo-crystals. Some reference to text-books on these subjects would be of greater use to those sufficiently interested to require the information.

In general, however, the book is interesting and informative. It is well illustrated; and should be of considerable help to those who have little knowledge of the capabilities of modern oscillographs.

There is a slip of the pen on page 14, where it is stated that the focus of a soft tube can be adjusted by means of the *anode* temperature. W. E. M.

DEFLECTED ELECTRON BEAMS*

By J. H. Owen Harries, A.M.I.E.E.

(*Electronics Department, Rediffusion Ltd., London*)

Introduction

IN electron beam valves there are only two possible methods of modulating the beam. One is by changing the number of electrons travelling in the beam; and the other is by accelerating or decelerating them. In the latter case, the acceleration or deceleration may be either in the direction of the initial velocity of the electrons, which method is generally referred to as "velocity modulation" (Bibs. [1, 2, 3, 4, 5]), or it may be in another direction. If this latter direction is transverse to the initial direction of the electrons in the beam, the valve in which this method is used is usually referred to as a "deflection" valve (Bibs. [6, 7, 8]).

This paper is concerned with the theory of these latter valves.

The principal questions which are answered by this paper are as follows :—

(a) What trajectories are described by the electrons when deflected by a transverse electric field?

(b) What is the amplitude and phase of the deflection with respect to the deflecting voltage at any point inside, or outside, the deflecting field, at any given frequency?

(c) What power is required transversely to deflect a beam of given power-carrying capacity; i.e. of any given value of the product of beam-current and beam voltage?

(d) What power output efficiency can be expected if (c) is taken into account? Has a deflection valve a low or a high input impedance at very high frequencies?

(e) Is it best in practice to apply the deflecting field along the whole length of the beam or along a part only?

It will be interesting at first to consider a purely theoretical case of transverse deflection which cannot be realised in practice; but which, because of its simplicity, will assist in visualising the more complex practical problem.

1. Deflection in an Infinitely Long Deflecting Field

A theoretical deflecting system is postulated which has the following characteristics :—

(a) Deflection plates of infinite extent in the x direction and of infinite width.

LIST OF PRINCIPAL SYMBOLS USED

e = electronic charge.
m = mass of an electron.
E = deflection voltage.
v_y = the velocity in the transverse direction.
v_x = the velocity in the longitudinal direction.
v_0 = the entering velocity.
E_b = the (anode) voltage accelerating the electrons to an initial velocity v_o.
i_d = instantaneous value of the transverse displacement current.
I_d = the maximum value of this current.
t_o = the entrance time.
t = the time.
$\tau = t - t_o$ = the transit time in the deflection field itself.
τ_0 = the transit time past one half period of sine shaped variation of electric field along the x axis.
l = length measured along an infinite transverse field.
d = distance across the deflecting field = the distance between the deflecting plates.
I_0 = electron beam current.
y = the transverse deflection of an electron.
$\mathbf{y}$ = the vector value of y.
$\mathbf{Y}$ = the maximum value of the vector value.
$\frac{1}{\mathbf{Z}} = \frac{1}{\mathbf{R}} + j\frac{1}{\mathbf{X}}$ = the complex deflection coefficient.
W = the power output.
W_b = the d.c. power input.
W_d = the power used to deflect the beam.
λ = the wavelength in centimetres.
f = the frequency.
Q = the frequency dependent part of the expression for y_{max} in a sine shaped field.
S = deflection sensitivity = $\frac{E}{y_{max}}$
ϕ = deflection angle at the point of exit from the deflection field.
T = transit time through the "throw" of the beam from the deflection field to the point of measurement of deflection.
l_0 = the total length of the electron beam from the entrance point to the point at which the deflection is measured outside the field.
l_1 = length of a sine shaped deflection field.
$X = l_0 - l_1$.
η_d = the ratio of deflection power to total beam power in the case of a valve having a "throw" L.

* MS. accepted by the Editor, March 1944.

(b) The plates are spaced by a distance d in the y direction.

(c) The system is maintained at a mean potential such that electrons entering on the x axis midway between the plates have an entering velocity of v_0.

(d) The plates oscillate in potential in "push-pull" fashion about a mean potential which is taken as the zero of the system.

(e) No circuit or radiation losses are considered.

(f) The effect of space charge on the longitudinal velocity is neglected. This is not a serious matter, for, unless the space current is so unworkably near the maximum space-charge saturated value as adversely to affect beam focus, calculation shows the variation of velocity to be a small matter compared with other necessary approximations.

(g) Since the electrons enter at a point on the axis about which the system is symmetric, and which is of zero potential whatever the value of the deflection potential E, entrance fields need not be considered.

The arrangement is shown in Fig. 1.

Consider an electron which enters the deflection field on the axis of symmetry; then the electric intensity in the x direction is zero, and $\frac{d^2x}{dt^2}$ is zero; but

$$\frac{d^2y}{dt^2} = \frac{eE}{dm} \quad \ldots \quad (1)$$

Let the instantaneous voltage vary as $E\epsilon^{j\omega}$

then $$\frac{d^2y}{dt^2} = \frac{eE\epsilon^{j\omega t}}{dm} \quad \ldots \quad (1.1)$$

Integrating between the limits of an entrance time t_0 and the time t, the velocity of the electrons in the y direction at the time t is

$$\frac{dy}{dt} = v_y = \frac{eE}{j\omega dm}\{\epsilon^{j\omega t} - \epsilon^{j\omega t_0}\} \quad \ldots \quad (2)$$

It may be proved (by, for instance, the means suggested by Ramo (Bib. [13]),) that the instantaneous displacement current produced in a circuit connecting the two deflecting plates, due to one electron between them, is

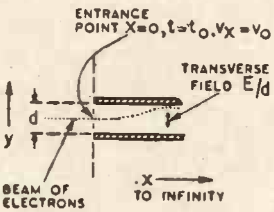


Fig. 1. *Theoretical electron beam deflection system with infinitely long deflection plates*

$$i_d = \frac{e}{d} v_v \quad \ldots \quad (3)$$

If there are N electrons entering between the plates per second, the beam current $I_0 = Ne\,v_x$.

The total instantaneous displacement current induced along a length l of field is

$$i_d = \frac{Ne}{d}\int_{x=0}^{x=l} v_y \,.\, dx$$

But the beam current $I_0 = Ne\,v_x$ and the above equation can be written

$$i_d = \frac{I_0}{dv_x}\int_{x=0}^{x=l} v_y \,.\, dx$$

but, in the case of the integrals used,

$$1/v_x \int_{x=0}^{x=l} v_y \,.\, dx = \int_{\tau=0}^{\tau} v_y \,.\, d\tau$$

Therefore $$i_d = \frac{I_0}{d}\int_0^{\tau} v_y \,.\, d\tau$$

To obtain an "equivalent electrical circuit" which specifies the theoretical performance of the electrons between the plates, one may proceed as follows:—

Equation (3) may, from the above, be re-written as

$$i_d = \frac{I_0 eE\epsilon^{j\omega t}}{d^2\omega^2 m}\{\epsilon^{-j\omega\tau} + j\omega\tau\epsilon^{-j\omega\tau} - 1\} \quad \ldots \quad (3.1)$$

and

$$\frac{1}{\mathbf{Z}_d} = \frac{I_0 e}{d^2\omega^2 m}\{\epsilon^{-j\omega\tau} + j\omega\tau\epsilon^{-j\omega\tau} - 1\} \quad \ldots \quad (4)$$

where $\mathbf{Z}_d$ = the equivalent impedance,

$\frac{1}{\mathbf{Z}_d}$ is a complex quantity varying in sign with the transit time τ.

Equation (4) may be written in terms of circular measure:

$$\frac{1}{\mathbf{Z}_d} = \frac{1}{R_d} + j\frac{1}{X_d} = \frac{I_0 e}{d^2\omega^2 m}\{\omega\tau\sin\omega\tau + \cos\omega\tau - 1 + j(\omega\tau\cos\omega\tau - \sin\omega\tau)\} \quad \ldots \quad (4.1)$$

The function in brackets will be designated Φ_0. The real and imaginary parts are plotted in Fig. 2.

To convert (4.1) to practical units, note that $\frac{I_0 e}{d^2\omega^2 m}\Phi_0$ becomes $\frac{1.76 \times 10^{15} I_0}{d^2\omega^2}\Phi_0$ in these units (mhos).

Clearly, as one considers sections of the system from the entrance point to points x_1, x_2, etc. (which equal $\tau_1 v_x$, $\tau_2 v_x$, etc.), the beam can be looked upon as a transverse current flow having a phase and magnitude which varies with x. At the same time, the velocity of the electrons in the x direction remains constant and equal to the entrance velocity v_0. Therefore the x-directed energy of the beam is not altered. Energy is not withdrawn from the beam, therefore energy is not given to the deflection plate circuit. This is what could be anticipated for this theoretical case, because no effects of deflection circuit losses have been included in expressions (3) and (3.1) for transverse displacement current, and electron radiation losses have been ignored.

Note that equations (4) and (4.1) do *not* mean that if the plates are terminated at $x = l = \tau v_x$, the valve input will represent a reactance $j\dfrac{1}{X_d}$ and a resistance $1/R_d$ across the deflection plates. If the plates are terminated at a point $x = l$, then an exit part of the field is inferred which represents the return of the field to zero conditions outside the plates. It is, among other things, the neglect of such an end part of the field, and a confusion of thought about equation (4.1) (in looking upon $1/\mathbf{Z}_d$ incorrectly as the impedance presented by the valve to an actual external deflection circuit), which caused errors in certain early analyses (Bibs. [9, 10, 11]). The author has dealt with this question in greater detail in a recent comm nication (Bib. [12]).

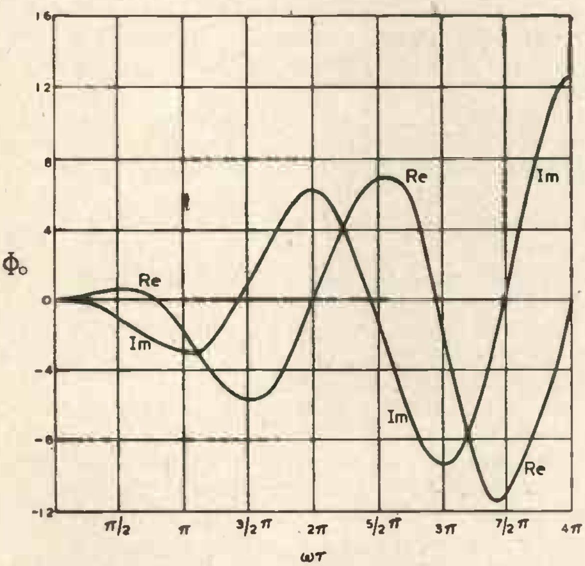


Fig. 2. *The frequency dependent part of the expression for vector displacement of the electron beam in an infinitely long transverse field as a function of the transit angle.*

Returning to the theoretical infinitely long field, with its loss-free deflection of the beam, it is important to examine the displacement of the electrons in the beam in the y dimension.

Referring again to equation (2), and integrating this with respect to t, and remembering that $y = 0$ when $t = t_0$, the following expression is

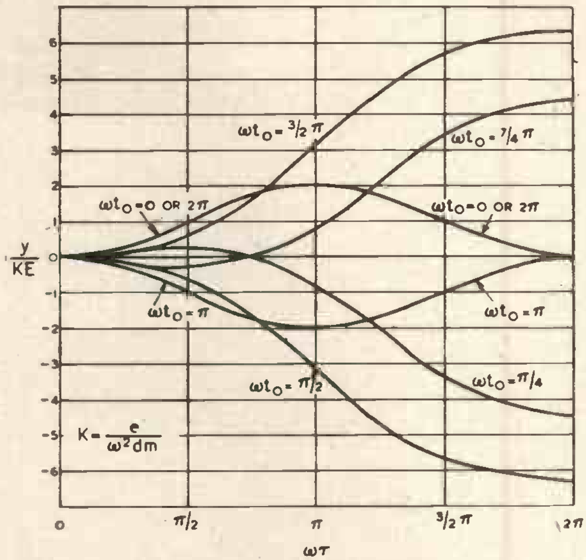


Fig. 3. *Tracks of electrons between infinitely long deflection plates as a function of the transit angle.*

arrived at for the displacement vector $\mathbf{y}$ of an electron at a time t :—

$$\mathbf{y} = \frac{eE}{\omega^2 dm}\{\epsilon^{j\omega t_0} + j\omega\tau\epsilon^{j\omega t_0} - \epsilon^{j\omega t}\} \quad .. \quad (5)$$

Taking advantage of the useful property of $\epsilon^{j\theta}$ which causes the real part of this equation to be the result of successively integrating,

$$\frac{d^2y}{dt^2} = \frac{eE}{dm}\cos\omega t$$

the displacement of any one electron may be expressed, as a function of τ, by the real part of (5), thus

$$y = \frac{eE}{\omega^2 dm}\{\cos\omega t_0 - \omega\tau\sin\omega t_0 - \cos(\omega t + \omega\tau)\} \quad .. \quad .. \quad (6)$$

A plot of this equation against $\omega\tau$ is the track of an electron entering at a given entrance angle ωt_0. A few typical tracks for different entrance angles are plotted in Fig. 3, and are of interest. (In reading this graph, remember that ωt itself is a function of $\omega\tau$, because $\omega t = \omega t_0 + \omega\tau$).

In practical units

$$\frac{eE}{\omega^2 dm} \quad \text{becomes} \quad \frac{1.76 \times 10^{15}E}{\omega^2 d}.$$

Returning to the rotating vector $\mathbf{y}$ of equation (5), it is of interest to find the relative phase and magnitude of the voltage and of the deflection.

(5) may be written

$$y = \frac{eE\epsilon^{j\omega t}}{\omega^2 dm}\{\epsilon^{-j\omega\tau} + j\omega\tau\epsilon^{-j\omega\tau} - 1\} \quad .. \quad (7)$$

The desired information will be given by a study of a quantity such that if multiplied by the maximum voltage it will give the corresponding deflection for a given value of the transit angle $\omega\tau$. Such a quantity is found as follows :—

From (7)

$$\frac{Y}{E} = \frac{e}{\omega^2 dm}\{\epsilon^{-j\omega\tau} + j\omega\tau\epsilon^{-j\omega\tau} - 1\} \quad .. \quad (8)$$

where Y = the maximum value of the deflection and

$$\frac{\mathbf{Y}}{\mathbf{E}} = \frac{1}{\mathbf{Z}} = \frac{1}{R} + j\frac{1}{X}.$$

$1/\mathbf{Z}$ may be called the deflection coefficient by analogy with the deflection susceptance $1/\mathbf{Z}_d$.

Equation (8) may be written as

$$1/\mathbf{Z} = \frac{e}{\omega^2 dm}\{\omega\tau \sin\omega\tau + \cos\omega\tau - 1 + j(\omega\tau\cos\omega\tau - \sin\omega\tau)\} \quad .. \quad (8.1)$$

Note that $\frac{e}{\omega^2 dm}$ becomes $\frac{5.274 \times 10^{17}}{\omega^2 d}$ in practical units.

The bracketed part of $\frac{1}{\mathbf{Z}}$ is the function Φ_0 already plotted in Fig. 2.

The function Φ_0 therefore represents the dynamic, or frequency-dependent, performance of the system.

If the plates are terminated at a certain point, and at this point the deflection is very small, and end-effects in the path of the beam are therefore negligible, we may derive equations applicable to the deflection of an electron beam in the ordinary cathode-ray oscilloscope at the point where the beam leaves the deflection plates.

The tangent to the angle ϕ made by the beam, as it leaves the deflection field at a point x_1, with the x axis of the system is $\frac{dy}{dx}$.

The "sensitivity" of the beam is proportional to this tangent at the point x_1 plus the actual displacement y at that point.

Utilising equation (2)

$$\frac{dy}{dt}\cdot\frac{dt}{dx} = \frac{dy}{dx} = \frac{eE}{j\omega m d v_x}\left\{\epsilon^{j\omega t} - \epsilon^{j\omega t_0}\right\} \quad (9)$$

which may be written

$$\tan\phi = \frac{dy}{dx} = \frac{eE}{\omega m d v_x}\left\{j\epsilon^{j\omega t_0} - j\epsilon^{j\omega t}\right\} \quad (10)$$

or in circular measure, utilising the propertie $\epsilon^{j\theta}$ again,

$$\tan\phi = \frac{eE}{\omega m d v_x}\left\{\sin(\omega t_0 + \omega\tau) - \sin\omega t_0\right\} \quad (10.1)$$

By the use of half-angles, equation (10) may also be written

$$\tan\phi = \frac{2eE}{v_x m d\omega}\left\{\cos\left(\omega t_0 + \frac{\omega\tau}{2}\right)\sin\frac{\omega\tau}{2}\right\} \quad (10.2)$$

The maximum value of tan ϕ is the maximum for this part of the "sensitivity," and the expression is at a maximum when $\cos\left(\omega t_0 + \frac{\omega\tau}{2}\right)$ = unity,

$$\tan\phi_{max} = \frac{2eE}{v_x\omega m d}\sin\frac{\omega\tau}{2} \quad .. \quad .. \quad (11)$$

From this the standard formula for ultra-dynamic sensitivity of a cathode ray oscilloscope may readily be obtained. Neglecting the very small deflection at x_1, the deflection of the beam on a screen at a distance L from x_1, is $L \tan\phi_{max}$.

2. A Generalised Deflection Field Shape.

1. *Introduction*.—The preceding analysis is simple, but does not correspond to physical reality, because there can be no such thing as a valve having an infinitely long deflecting field. Various authors have considered approximations to the field shapes at the end of a pair of deflection plates of finite length in a cathode ray oscilloscope (Bib. [10, 11]).

There can be no general case for the field; because clearly there are an infinite number of different boundary conditions and electrode configurations which can be used.

A useful method of attack, which has been utilised by the author in investigating certain physical problems of actual deflection valves, assumes that the field varies as a periodic function along the length of the deflecting electrode, and that the field is terminated at one of the points where that function is zero. "End effects" are then non-existent. Any shape of this function can be represented by the sum of sine and cosine functions in accordance with the principle of harmonic analysis. In practice, a pure sine function gives quite a reasonable approximation to many actual field shapes. The effect of departures in practical apparatus from this pure sine shape will be to alter the values of such quantities as transit times from those calculated; but the general physical effects are unaltered. For instance, deflecting fields are of particular interest when they are produced at very high frequencies inside resonant cavities. The vector field along the beam path in such a resonant cavity often approximates very closely to a sine function. Thus, in the case of a cubical resonant cavity, when oscillating at the "fundamental" mode, the variations of intensity of the field across one dimension of the cube is a sine function. In the case of a circular disc shaped resonant cavity, the variation across a diameter is a Bessel function $J_0(x)$ of zero order (Bib. [14, 15]). For most purposes, this latter function may be looked upon

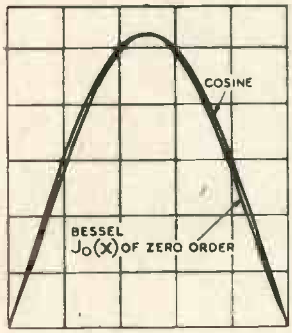


Fig. 4 (left). *A comparison between a cosine and a Bessel function $J_0(x)$ of zero order.*

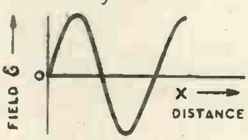


Fig. 5 (below). *A "sine-shaped" deflection field.*

as a good approximation to a sine function (*see* comparison in Fig. 4).

The present analysis is therefore concerned with the consideration of what may be called a "sine shaped field" like that illustrated in Fig. 5, in which $\mathcal{E}$ is the maximum instantaneous value of the transverse field, and x is the distance along the field in the initial direction of the electrons.

It will be realised that since a field of this kind possesses curl, it cannot also possess scalar potential. Nevertheless we may refer to a quantity

$$\int_0^d \mathcal{E}y \, . \, dy$$

which is the integral of the field in the y direction along the distance d across the deflecting field. In this paper this quantity will be referred to as the deflection voltage E. E will be evaluated at the maximum with respect to both time and distance along the x axis of the field.

The following are the principal assumptions made :—

(a) The system is supposed to be maintained at a mean potential such that electrons entering on the x axis midway between the plates have an entering velocity of $v_0 = v_x$.

(b) The system oscillates in potential in "push-pull" fashion about a mean potential which is taken as zero.

(c) The effect of space charge on the longitudinal velocity is neglected.

(d) The width of the beam in the direction of deflection is small compared with the distance across the deflecting field.

(e) The field is terminated at a point where the function representing its variation along the x axis is zero.

2. *Deflection in a "sine shaped" field.*—The transit time past one half period of field variation along the x axis of the field may be indicated by τ_0. If $t - t_0 = \tau =$ the transit time in the deflection field, then the variation of field along the x axis may be represented by the function : $\frac{E}{d} \sin \frac{\pi\tau}{\tau_0}$

The equation of motion becomes

$$\frac{d^2y}{dt^2} = \frac{eE}{dm} \cos \omega t \sin \pi\, \tau/\tau_0 \qquad \text{(12)}$$

Integrating between the limits of t_0 to t, and remembering that $\frac{dy}{dt} = v_y = 0$ when $t = t_0$; and also expressing the time factors as angles.

$$\frac{dy}{dt} = v_y = \frac{eE}{2dm\omega}\left\{\frac{\cos(\omega t_0 + \omega\tau - \pi\,\tau/\tau_0)}{1 - \pi/\omega\tau_0} - \frac{\cos(\omega t_0 + \omega\tau + \pi\,\tau/\tau_0)}{1 + \pi/\omega\tau_0} - C\cos\omega t_0\right\} \qquad \text{(13)}$$

A further integration gives the deflection y at a time t. y is zero when $t = t_0$.

$$y = \frac{eE}{2md\omega^2}\left\{\frac{\sin(\omega t_0 + \omega\tau - \pi\,\tau/\tau_0)}{(1 - \pi/\omega\tau_0)^2} - \frac{\sin(\omega t_0 + \omega\tau + \pi\,\tau/\tau_0)}{(1 + \pi/\omega\tau_0)^2} - C\omega\tau\cos\omega t_0 - 2A\sin\omega t_0\right\} \qquad \text{(14)}$$

In the above two equations

$$A = \frac{\dfrac{2\pi}{\omega\tau_0}}{\left(1 - \dfrac{\pi^2}{\omega^2\tau_0^2}\right)^2} \quad \text{and} \quad B = \frac{1 + \dfrac{\pi^2}{\omega^2\tau_0^2}}{\left(1 - \dfrac{\pi^2}{\omega^2\tau_0^2}\right)^2}$$

which together with $C = \dfrac{\dfrac{2\pi}{\omega\tau_0}}{1 - \dfrac{\pi^2}{\omega^2\tau_0^2}}$

are factors common to relevant systems of equations. A graph of A, B, and C is shown in Fig. 6. A tends to equal C, and B to equal unity, at large values of $\omega\tau_0$.

The ratio $\tau/\tau_0 = a$ is the distance travelled along the x axis in terms of half sine periods of field variation along that axis.

Equation (14) shows the instantaneous deflection of a single electron. To find the maximum deflection of the beam it is necessary to maximise (14) :

$$y_{\max} = \frac{eE}{2md\omega^2}\sqrt{\left[\frac{1}{(1-\pi/\omega\tau_0)^4} + \frac{1}{(1+\pi/\omega\tau_0)^4} + 4A^2 + C^2\omega^2\tau_0^2a^2 - \frac{2\cos 2\pi a}{\left(1-\frac{\pi^2}{\omega^2\tau_0^2}\right)^2} - \frac{4A\cos(\omega\tau_0 a - \pi a)}{(1-\pi/\omega\tau_0)^2} + \frac{4A\cos(\omega\tau_0 a + \pi a)}{(1+\pi/\omega\tau_0)^2} - \frac{2C\omega\tau_0 a \sin(\omega\tau_0 a - \pi a)}{(1-\pi/\omega\tau_0)^2} + \frac{2C\omega\tau_0 a\sin(\omega\tau_0 a + \pi a)}{(1+\pi/\omega\tau_0)^2}\right]} \quad .. \quad (15)$$

If the surd expression is designated by Q, this equation becomes

$$y_{\max} = \frac{eE}{2md\omega^2}Q \quad .. \quad .. \quad .. \quad (15.1)$$

Remember that $\omega\tau = \omega\tau_0 a$.

If y or $y_{\max}$ are to be calculated using practical units, the term outside the brackets in (14) and outside the square root in (15) becomes $8.8 \times 10^{14}\, E/d\omega^2$ and E is then in volts.

An important question is the relative phase of the deflection and of the deflection voltage.

The method already exemplified in Section 1, equation (8) will be used.

Equation (12) may be written in vector form as

$$\frac{d^2y}{dt^2} = \frac{eE}{2mdj}\{\epsilon^{j(\omega t+\pi a)} - \epsilon^{j(\omega t - \pi a)}\} \quad .. \quad (16)$$

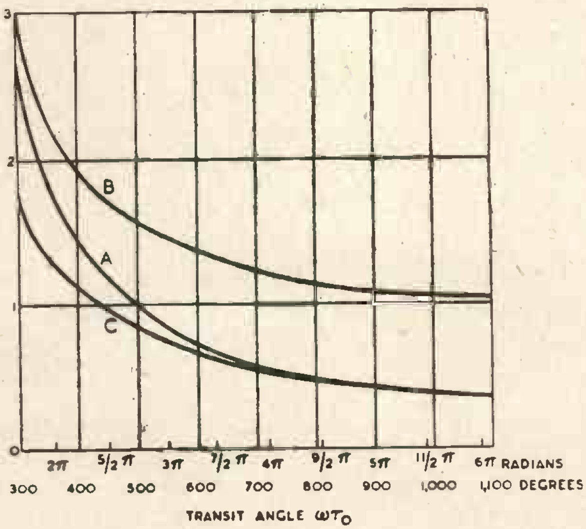


Fig. 6. *Graph of functions A, B and C.*

Successive integration yields for the vector displacement

$$\mathbf{y} = \frac{eE\epsilon^{j\omega t}}{2md\omega^2}\left\{\frac{j\epsilon^{j\pi a}}{(1+\pi/\omega\tau_0)^2} - \frac{j\epsilon^{-j\pi a}}{(1-\pi/\omega\tau_0)^2} + 2Aj\epsilon^{-j\omega\tau_0 a} - a\omega\tau_0 C\epsilon^{-j\omega\tau_0 a}\right\} \quad .. \quad (17)$$

The "deflection coefficient" is a complex number:

$$\frac{\mathbf{Y}}{E} = \frac{1}{\mathbf{Z}} = \frac{e}{2md\omega^2}\left\{\frac{j\epsilon^{j\pi a}}{(1+\pi/\omega\tau_0)^2} - \frac{j\epsilon^{-j\pi a}}{(1-\pi/\omega\tau_0)^2} + 2Aj\epsilon^{-j\omega\tau_0 a} - a\omega\tau_0 C\epsilon^{-j\omega\tau_0 a}\right\} \quad .. \quad (18)$$

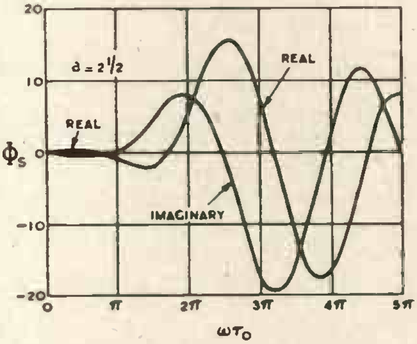


Fig. 7.—*A typical graph of the real and imaginary parts of the deflection coefficient in a "sine shaped" deflection field. a = 2½.*

The imaginary and real parts of (18) are respectively

$$j\frac{1}{\mathbf{X}} = \frac{je}{md\omega^2}\left\{A(\cos\omega\tau_0 a - \cos\pi a) + \tfrac{1}{2}C(a\omega\tau_0\sin\omega\tau_0 a)\right\} \quad .. \quad (18.1)$$

and

$$\frac{1}{\mathbf{R}} = \frac{e}{md\omega^2}\left\{(A\sin\omega\tau_0 a - B\sin\pi a - \tfrac{1}{2}C(a\omega\tau_0\cos a\omega\tau_0)\right\} \quad .. \quad (18.2)$$

If E is in practical units the terms outside the brackets become, respectively,

$$j\frac{1.76 \times 10^{15}}{d\omega^2} \quad \text{and} \quad \frac{1.76\times 10^{15}}{d\omega^2}$$

The case when $\omega\tau_0 = \pi$.

If the equation of motion (12) is integrated as it stands, and then the value $\omega\tau_0 = \pi$ substituted the result becomes indefinite. This numerical difficulty may be overcome by making the substitution before integration is performed. The real and imaginary parts of the deflection coefficient are then

$$\frac{1}{\mathbf{R}} = \frac{e}{md\omega^2}\left\{-\tfrac{1}{4}\sin a\pi + \frac{a\pi}{4}\cos a\pi + \frac{a^2\pi^2}{4}\sin a\pi\right\}$$

and

$$j\frac{1}{\mathbf{X}} = j\frac{e}{md\omega^2}\left\{-\frac{a\pi}{4}\sin a\pi + \frac{a^2\pi^2}{4}\cos a\pi\right\} \quad (14.1)$$

Fig. 7 shows a typical function of the real and imaginary parts of the deflection coefficient for a "sine shaped" field. The deflection is evaluated at a point $2\frac{1}{2}$ half-periods along the field in the x direction.

3. *Deductions from the above equations.*—It will be observed that any desired relative phase between 0 and 2π may be arranged to exist between the instantaneous displacement of the beam, and the instantaneous value of the electric field, at any point along the path of the beam, because this phase angle is itself a function of the total transit angle $a\omega\tau_0$ from the entrance point to the point where the phase is evaluated.

Corresponding to any such phase angle there exists an infinite number of total transit angles. In an actual deflection valve, each transit angle refers, of course, to a given accelerating voltage E_b, corresponding to a value of the initial velocity of the electrons.

For example, if $a = \frac{1}{2}$, a phase difference of π will exist between the deflection and the deflection voltage, at a point half-way along the first half-sine wave shape of deflection voltage, at an infinite number of different accelerating voltages. If the total length l of the deflection field is, for example, 7.6 centimetres, and the wavelength of operation is 10 centimetres, the accelerating voltages will range from 41,000 volts downwards. Thus: 41,000, 9,600, 4,120, 2,325, 1,495, 1,035, 750, 590, 456, 370, etc.

The values of these voltages will vary, of course, with the shape of the function of voltage along the x axis of the deflecting field. For any such shape there will, however, exist a choice of various voltages at which the same phase change may be obtained. Operation of the valve at one of these different accelerating voltages may be referred to as "operating at the 1st, 2nd, or 3rd, and so on, transit angles." Thus, in the above example, the "first transit angle" of the beam will be that produced by a potential of 41,000 volts, and the "second" by a potential of 9,600 volts.

Figs. 8 (a) and 8 (b) show respectively a "cinematograph" type of graph showing beam profiles for the first and second transit angles respectively in the case of the example above. It will be observed that, in this particular case, the deflection at the point where $a = \frac{1}{2}$ is only slightly less for the second transit angle than for the first. The "snaking" of the beam at appreciable transit angles may be observed.

4. *Approximate Relationships.*—It may be shown from equations (18.1) and (18.2) that certain terms tend to zero when $\omega\tau_0$ becomes large. In these circumstances approximate formulae are obtainable. For instance, at large values of transit angle,

$$Q \simeq 2(1 + a\pi) \quad \ldots \quad \ldots \quad \ldots \quad (18.3)$$

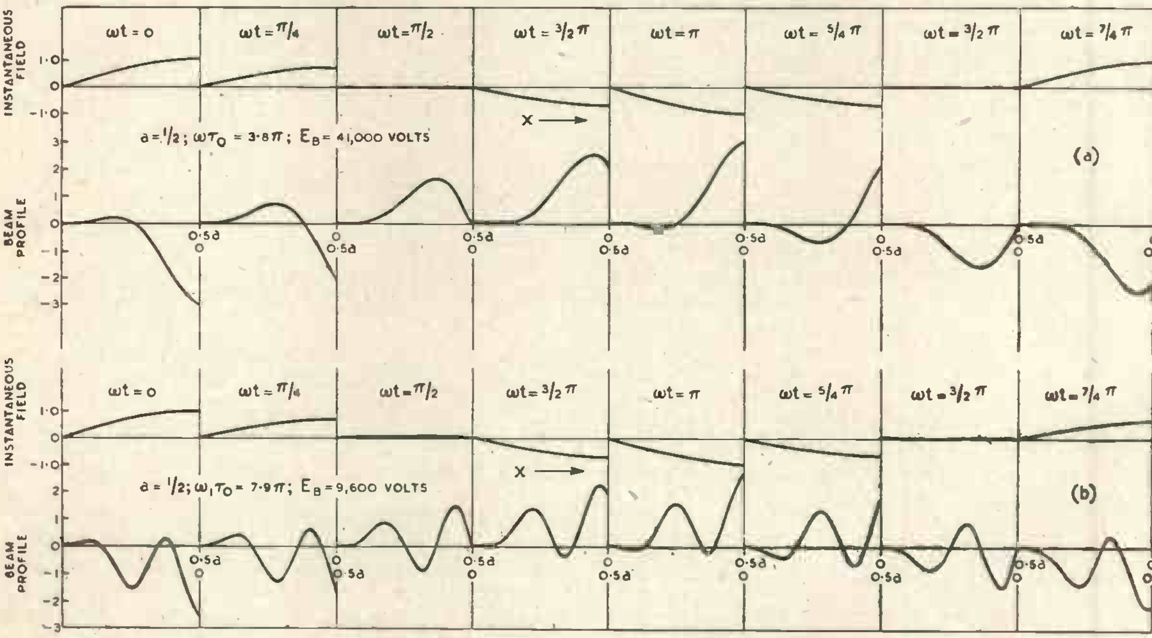


Fig. 8. *Examples of beam profiles and instantaneous "sine-shaped" deflection field values at vdrious points on the deflection field cycle.*

The deflection sensitivity is, from (15.1),

$S = \frac{y_{max}}{E} = \frac{e}{2md\omega^2}Q$, and from (18.3) this also tends to equal $\frac{e}{md\omega^2}(1 + a\pi)$, which at first sight gives the impression that the deflection sensitivity can be increased indefinitely by increasing the number of half periods of deflection field along the length of the beam. This is indeed true if the field length l_1 is increased to do this; but, in practice, the total length of the beam is limited by such factors as those of "electron optical" design and by space charge considerations. One can, of course, produce standing waves of deflection field along its length, and may then look upon the relationship between a and a fixed value of l_1

as $$a \simeq \frac{2l_1}{\lambda}$$

Then $$S \simeq \frac{e\lambda^2}{4mdc^2\pi^2}\left(1 + \frac{2l_1\pi}{\lambda}\right) \quad \ldots \quad \ldots \quad (18.4)$$

Clearly, for a given construction and beam length, decreasing λ (to increase a) will not help to improve the deflection sensitivity. Indeed, the contrary is the case.

5. *Power used to deflect the beam.*—An electron leaving the boundary of a transverse field will have a transverse energy which is withdrawn from the field. The average rate of loss of energy is the deflection power used.

Let there be N electrons leaving the boundary of a transverse field per second. The transverse energy of each electron will be $\frac{1}{2}mv_y^2$. During an interval of time $\delta\tau$ the number of electrons leaving is $N\delta\tau$. The work done by the deflection field is

$$\frac{Nm}{2}\int_0^\tau v_y^2 d\tau.$$

But the beam current is Ne; and therefore the work done may be written in terms of this current

as $$\frac{I_0 m}{2e}\int_0^\tau v_y^2 \,.\, d\tau$$

In the case of present interest, v_y is a periodic function of time, i.e. of ωt_0 in equation (13).

The deflection power is the average energy expended per period and equals

$$W_d = \frac{I_0 m}{4\pi e}\int_0^{2\pi} v_y^2 \,.\, d(\omega t_0) \quad \ldots \quad \ldots \quad (19)$$

Substituting (13) for (v_y) in (19), and integrating, results in a general expression for deflection power:

$$W_d = \frac{I_0 e E^2}{8md^2\omega^2}\left\{\frac{\cos 2\pi a}{1 - \frac{\pi^2}{\omega^2\tau_0^2}} + B + \frac{C^2}{2} - C\left[\frac{\cos(\omega\tau - \pi a)}{1 - \pi/\omega\tau_0} - \frac{\cos(\omega\tau + \pi a)}{1 + \pi/\omega\tau_0}\right]\right\} \quad \ldots \quad \ldots \quad (20)$$

The power required will vary with a.

This expression for deflection power is never negative. This follows readily from physical considerations. The kinetic energy in the beam is due to the movement of the electrons in the x direction. The analysis is concerned only with electric fields transverse to this movement. These fields can have no effect upon the x-directed velocity, and therefore no effect upon the x-directed energy of the beam of electrons, and energy therefore cannot be transferred from the beam to the transverse electric field. Of course there is no reason why the transverse field should not cause the beam to enter another x-directed field so arranged and of such relative phase and magnitude as to withdraw energy from the beam; but this effect is not considered in the present analysis, and has nothing to do with the transverse field as such.

Equation (20) reduces to the following special cases. All are expressed in practical units (watts).

Case I. If $a = 1, 3, 5$, etc.

$$W_d = \frac{4.4 \times 10^{14}E^2 I_0 C^2}{d^2\omega^2} \,.\, \cos^2\frac{\omega\tau_0 a}{2} \quad (20.1)p$$

Case II. If $a = 2, 4, 6$, etc.

$$W_d = \frac{4.4 \times 10^{14}E^2 I_0 C^2}{d^2\omega^2} \,.\, \sin^2\frac{\omega\tau_0 a}{2} \quad (20.2)p$$

Case III. If $a = \frac{1}{2}, 2\frac{1}{2}, 4\frac{1}{2}$, etc.

$$W_d = \frac{4.4 \times 10^{14}E^2 I_0}{\omega^2 d^2}\left[\frac{1}{1 - \frac{\pi^2}{\omega^2\tau_0^2}}\right]^2\left(1 + \frac{\pi^2}{\omega^2\tau_0^2} - \frac{2\pi}{\omega\tau_0}\sin\omega\tau_0 a\right) \quad \ldots \quad \ldots \quad (20.3)p$$

Case IV. If $a = 1\frac{1}{2}, 3\frac{1}{2}, 5\frac{1}{2}$, etc.

$$W_d = \frac{4.4 \times 10^{14}E^2 I_0}{\omega^2 d^2}\left[\frac{1}{(1 - \frac{\pi^2}{\omega^2\tau_0^2}}\right]^2\left(1 + \frac{\pi^2}{\omega^2\tau_0^2} + \frac{2\pi}{\omega\tau_0}\sin\omega\tau_0 a\right) \quad \ldots \quad \ldots \quad (20.4)p$$

To express these equations in terms of wavelength, substitute $1.24 \times 10^{-8}\lambda^2$ for $\frac{4.4 \times 10^{14}}{\omega^2}$.

In order to answer question (d) in the Introduction to this paper, and to determine whether in fact a deflection valve will be useful as an amplifier, it is necessary to determine what power is required to deflect the beam in comparison with that obtainable from it.

Clearly the power output obtainable from the valve cannot exceed the initial power in the beam $W_b = I_0 E_b$.

The output power will in fact be less than W_b. The valve can be useful as an amplifier only if the power required to deflect the beam $W_d \ll W_b$.

Writing (15.1) in terms of wavelength in centimetres, and in practical units, gives

$$y_{max} = \frac{2.5 \times 10^{-8} EQ\lambda^2}{d} \quad \ldots \quad \ldots \quad (21)p$$

Assuming that the centre of the beam is to move a distance equal to half the distance between the deflecting electrodes, $y_{max} = \frac{1}{2}d$. From (21)p

$$d = \sqrt{5 \times 10^{-8} EQ\lambda^2} \quad \ldots \quad \ldots \quad (22)p$$

The deflection power is calculable from (20.1, 2, 3 or 4)p by substituting $5 \times 10^{-8} EQ\lambda^2$ for d^2.

Calculations show that, even if the deflection voltage E is equal to the total anode voltage E_b of the valve, W_d is not more than about 1 per cent. of the total power in the beam. In other words, a high input impedance may be expected, and the power amplifying efficiency of a transverse control valve should be satisfactory.

6. *The effect of a magnetic field in a resonant cavity.*—Any resonant cavity has a magnetic field orthogonal to the electrical field. In a simple cubical resonator operating at the "fundamental wavelength," the magnetic field varies along the x-axis approximately as a cosine function, and the acceleration is therefore

$$\frac{d^2 y_m}{dt^2} = -p \cos \pi a \cos(\omega t + \pi/2) \quad \ldots \quad (23)$$

where $p = \frac{e}{m} V_x \kappa \mathcal{E}$

and κ expresses the relationship between the maximum value of the magnetic field H and the maximum value of the electric field $\mathcal{E}$. That is, $H = \kappa \mathcal{E}$.

The acceleration due to the electric field alone is

$$\frac{d^2 y}{dt^2} = q \cos \omega t \sin \pi a$$

where $q = \frac{e\mathcal{E}}{m}$

These two equations may be written in vector form, combined, and integrated. A result is the following expression for the deflection coefficient for a beam travelling through a resonator:

The real part

$$\frac{1}{\boldsymbol{R}_m} = \frac{1}{2\omega^2}\left\{ -\sin \pi a \left[\frac{2q\left[1 + \frac{\pi^2}{\omega^2 \tau_0^2}\right] - \frac{4\pi p}{\omega \tau_0}}{\left(1 - \frac{\pi^2}{\omega^2 \tau_0^2}\right)^2} \right] - w\tau_0 a \cos \omega \tau_0 a \left[qC - \frac{2p}{1 - \frac{\pi^2}{\omega^2 \tau_0^2}} \right] + \sin \omega \tau_0 a [2qA - 2pB] \right\} \quad (24.1)$$

The imaginary part is

$$\frac{1}{\boldsymbol{X}_m} = \frac{j}{2\omega^2}\left\{ \cos \pi a \left[\frac{2p\left[1 + \frac{\pi^2}{\omega^2 \tau_0^2}\right] - \frac{4\pi q}{\omega \tau_0}}{\left(1 - \frac{\pi^2}{\omega^2 \tau_0^2}\right)^2} \right] + \omega \tau_0 a \sin \omega \tau_0 a \left[qC - \frac{2p}{1 - \frac{\pi^2}{\omega^2 \tau_0^2}} \right] + \cos \omega \tau_0 a \, [2qA - 2pB] \right\} \quad \ldots \quad (24.2)$$

This is clearly an equation of the same general kind as that for the electric field alone.

7. *Deflection outside the deflection field: "Throw."*—In the preceding analysis, deflection values and phase have been considered at points within the deflection field itself. A more usual practical arrangement consists (as in the usual cathode ray oscilloscope) of a deflection field followed by a "field-free" space through which the beam travels before reaching the point at which the deflection is measured. This space may be referred to as the "throw" L of the beam.

If the total length of the beam is l_0, then $l_0 - L = l_1$.

Let the transit angle along the length of the "throw" L be ωT. The deflection of the beam will be equal to $L \tan \phi$. As already explained in Section 1,

$$\tan \phi = \frac{dy}{dx} = \frac{v_y}{v_x} = \frac{dy}{dt} \cdot \frac{dt}{dx}$$

Integrating equation (16) and dividing it by v_x,

$$\tan \boldsymbol{\Phi} = \frac{eE}{2md\omega v_x}\left\{ \frac{\epsilon^{j(\omega t - \pi a)} - \epsilon^{j\omega t_0}}{1 - \pi/\omega\tau_0} - \frac{\epsilon^{j(\omega t + \pi a)} - \epsilon^{j\omega t_0}}{1 + \pi/\omega\tau_0} \right\} \quad \ldots \quad \ldots \quad (25)$$

The time t will increase by T when the electrons travel along the "throw," and the displacement at the end of the length L is therefore equal to the vector

$$\mathbf{L} \tan \boldsymbol{\Phi} = \frac{LeE\epsilon^{j\omega(t+T)}}{2md\omega v_x}\left\{ \frac{\epsilon^{-j\pi a} - \epsilon^{-j\omega\tau_0 a}}{1 - \pi/\omega\tau_0} - \frac{\epsilon^{j\pi a} - \epsilon^{-j\omega\tau_0 a}}{1 + \pi/\omega\tau_0} \right\} \quad \ldots \quad \ldots \quad (26)$$

The real and imaginary parts of the maximum value of $\mathbf{L} \tan \boldsymbol{\Phi}$ are

$$\text{REAL } L \tan \phi_{max} = \frac{LeEC}{2md\omega v_x}\left\{ \cos \pi a - \cos \omega \tau_0 a \right\}$$

$$\text{IMAG. } L \tan \phi_{max} = j\frac{LeEC}{2md\omega v_x}\left\{ \sin \omega \tau_0 a - \frac{\omega \tau_0}{\pi} \sin \pi a \right\} \quad \ldots \quad \ldots \quad (27)$$

From (27) the magnitude of the deflection of the end of the "throw" L is

$$L \tan \phi_{max} = \frac{LeEC}{2md\omega v_x}\sqrt{1 - 2\cos a\omega\tau_0 \cos \pi a + \cos^2 a\pi - \frac{2\omega\tau_0}{\pi}\sin a\omega\tau_0 \sin \pi a + \left(\frac{\omega\tau_0}{\pi}\right)^2 \sin^2 \pi a} \quad (28)$$

In view of assumption (*e*) of Section 2 of this paper, fractional values of a are not of interest. The last two terms under the square root therefore become equal to zero.

Two formulae are therefore derivable from (28) for the magnitude of the deflection at the end of a "throw":—

For $a = 1, 3, 5$, etc.

$$L \tan \phi_{max} = \frac{LeE}{md\omega v_x}\left\{C \cos \frac{a\omega\tau_0}{2}\right\} \quad .. \quad (29.1)$$

For $a = 2, 4, 6$, etc.

$$L \tan \phi_{max} = \frac{LeE}{md\omega v_x}\left\{C \sin \frac{a\omega\tau_0}{2}\right\} \quad .. \quad (29.2)$$

The condition of $a = 1$ is likely to be the most usual.

The function in brackets in equation (29.1) is plotted in Fig. 9 for values of $\omega\tau_0$ up to 7π. It

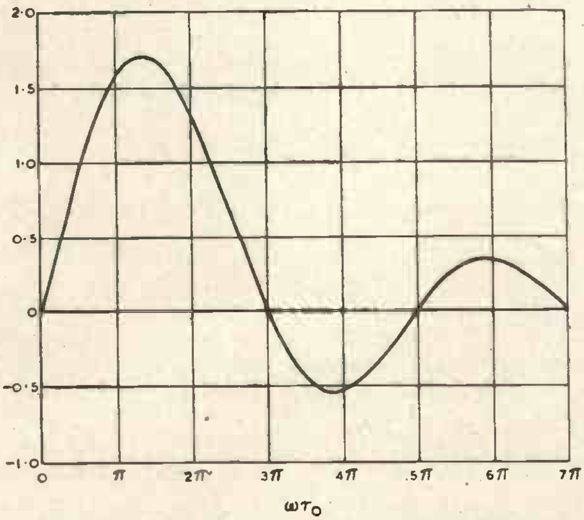


Fig. 9. *The magnitude of the frequency dependent part of the expression for beam displacement at the end of "beam throw" L with a "sine-shaped" deflection field.* $a = 1$.

will be observed that its maximum occurs at $\omega\tau_0 = 1.4\pi$, and subsequent minimum and maximum values in the neighbourhood of 4π, 6π, etc. It tends to zero as $\omega\tau_0$ increases. Assuming the transit angle $\omega\tau_0$ is adjusted so that the term in brackets has the maximum value of 1.7 (Fig. 9), (29.1) may be re-written in practical units as

$$L \tan \phi_{max} = \frac{2.68 \times 10^{-4} LE\lambda}{d E_b^{\frac{1}{2}}} \quad .. \quad (29.3)p$$

Deflection will be obtained at each of the maximum and minima of the curve of Fig. 9, i.e. at a decreasing series of accelerating voltages. In practical units for $a = 1$

$$E_b = \left(\frac{10^3 l_1 \pi}{\omega\tau_0\lambda}\right)^2 \quad .. \quad .. \quad .. \quad (30)p$$

We have therefore again a decreasing series of anode voltages, for any given phase angle between deflection voltage and deflection, each of which correspond to a value of $\omega\tau_0$.

Calculation shows that the deflection of the beam at the point of exit from the deflection field is very small, and may be neglected in comparison with $L \tan \phi_{max}$, provided that l_1 is small compared with l_0.

8. *The effect of "throw" on sensitivity.*—Let $\omega T = \phi_T$.

Then, in (28), the term

$$\frac{LeE}{md\omega v_x} = \frac{\phi_T eE}{md\omega^2}$$

It will be found that $Q/2$ in equation (15.1) is usually of much the same order of magnitude as C times the surd expression in equation (28). Therefore, generally speaking, the deflection obtainable for a given deflection field E/d can be made greater in valves in which a "throw" is employed, than in those in which it is omitted, by the factor ϕ_T. The question of whether a "throw" is best used or not in any given case introduces, however, practical questions of design which are outside the scope of this paper.

9. *Deflection power ratio.*—The deflection power, in the case of a valve having a "throw," may, of course, be calculated by equation (20) as already stated; but another relationship is available for the ratio between the deflection power and the d.c. power carried by the beam.

The ratio between the instantaneous value of the transverse energy $\frac{1}{2}mv_y^2$ and the x-directed energy $\frac{1}{2}mv_x^2$ is $\frac{v_y^2}{v_x^2}$. The average value of the transverse energy is $\frac{1}{4}mv_{y\,max}^2$.

Therefore, the ratio between the power used to deflect the beam and the power carried by the beam is

$$\eta_d = \frac{W_d}{W_b} = \frac{\tan^2 \phi_{max}}{2} \quad .. \quad .. \quad (31)$$

This relationship is of considerable value to the designer. It enables him to find the proportion of the total beam power which is used to deflect the beam in terms of the geometry of the valve he is designing. A graph of values of η_d as a function of tan ϕ_{max} is shown in Fig. 10.

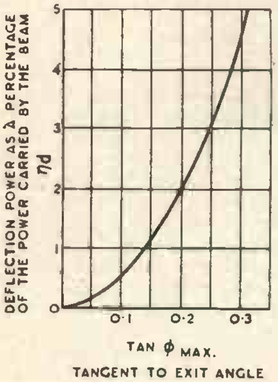


Fig. 10. *The ratio η_d between the power W_d required to deflect the beam, and the power $I_0E_b = W_b$ carried by the beam as a function of the tangent to the exit angle ϕ_{max} of the beam from the deflection field in a valve having a "throw" L. The magnitude of the deflection = L* tan ϕ_{max}.

10. *A numerical example.*—Consider a valve having the following parameters :—

"Throw" $L = 2.5$ centimetres.

Peak deflection volts $E = 2500$ volts.

Wavelength $\lambda = 5$ centimetres.

Distance across the deflection field $d = 0.4$ cm.

$a = 1$.

Length of deflection field $l_1 = 0.5$ cm.

Transit angle $= 1.4\pi$.

From equation (30), writing 1.4π for $\omega\tau_0$, we have an anode voltage of approximately 5000 volts. From equation (29.3), the magnitude of the deflection $L \tan \phi_{max} = 0.3$ cm.

Tan ϕ_{max} is 0.12, and from equation (31) and Fig. 10, the power used to deflect the beam is about 0.7 per cent. of the total power carried by the beam.

11. *Conclusions.*—It is clear from this analysis that the input mechanism of deflection valves is satisfactory for the purposes of voltage and power amplification.

The questions posed at the beginning of this paper may be answered as follows :—

(a) The trajectories described by the electrons in the beam are obtainable from the equations stated.

(b) The relative phase and amplitude of the deflection of the beam with respect to the deflecting voltages are available from the equations.

(c) The power required transversely to deflect a beam of electrons in a typical valve can be of the order of only one per cent. of the power W_b in the beam, even when the deflection voltage E is as high as the accelerating voltage E_b. In other words, a deflection valve can have a high input impedance. This is the case even at extremely high frequencies.

(d) Deflection sensitivity is usually best obtained in practice by providing a "field-free throw" of the beam from the deflection field to the point where the deflection is required.

12. *Acknowledgment.*—The author wishes to express his thanks to Rediffusion Ltd. for permission to publish this paper.

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Books Received

Radio Technology. By B. F. Weller. Written with a view to providing "a good technical background for people already engaged in various branches of radio engineering who would like a clearer understanding of their everyday work," this book is intended as an intermediate between elementary manuals and full-size standard textbooks. The author in his preface states that he has "tried to write a book for engineers from the standpoint of practical radio technology. For that reason it will be seen that far more space has been given to practical considerations of transmitter, receiver and aerial design rather than to matters of more academic interest." Much greater space has been devoted to transmitters and power amplifiers than is usual in genera text books. Pp. 358 + viii. Figs. 113. Price 21s. Chapman & Hall, Ltd., 11, Henrietta St,. London, W.C.2.

Plastics—Scientific and Technological. By H. Ronald Fleck, M.Sc. A critical survey of the literature and a correlation of scattered data on the properties and manufacture of plastics is given in this book, which should be of value both to chemists in the plastics industry and to those whose professional duties necessitate a knowledge of the science of plastics. The fifteen chapters deal progressively with the chemistry, manufacture and physical properties of plastic materials. A twenty-page alphabetical index is included. Pp. 325+li. Figs. 80. Price 25s. Temple Press, Ltd., Bowling Green Lane, London, E.C.1.

Worked Radio Calculations. By Alfred T. Witts. Some three hundred worked formulae of the type met with in radio servicing and wireless operators' courses are given in this book. Several examples are included for each formula and explanatory notes have been reduced to a minimum. An index to the graded practical examples is included for ease of reference. Pp. 126. Figs. 60. Price 6s. 6d. Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2.

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.

"A Note on Frequency Modulation"

To the Editor, "Wireless Engineer."

SIR,—The article by F. M. Colebrook in the March issue (p. 112) rightly stresses the importance of undesirable frequency modulation in amplitude-modulated ultra-short-wave signal generators. In early experiments on F.M. receiver problems I found such a generator quite useful for providing a F.M. signal! The following observations on the article may be of interest to those engaged in A.M. or F.M. ultra-short-wave developments. The undesirable F.M is only of consequence in an A.M. receiver because of attenuation and/or phase distortion in the receiver itself. If both forms of distortion are zero over a range from $f_c - f_d - f_m$ to $f_c + f_d + f_m$, F.M. has no effect on output, which is the same as for the "pure" A.M. In the above, f_c, f_d and f_m are the carrier, deviation due to F.M., and modulating frequencies respectively. Colebrook in his section 2 appears to lay undue stress upon the difference between the sine and cosine forms of the modulation in the two F.M. waves represented by $e_1 = \hat{e}_0 \sin (\omega t + m \sin pt)$ and $e_2 = \hat{e}_0 \sin (\omega t + m \cos pt)$, where $m = \frac{2\pi f_d}{p} = \frac{f_d}{f_m}$. The only real difference between the two waves is that the reference points are separated by 90° in time as shown by Figs. 1(a) and (b). There is no change in the position of the loci of the resultants of the constituent sideband pairs—the really important feature of F.M.—and odd order sideband pairs ($f_c \pm (2n - 1)f_m$) have resultants at 90° to the carrier and even order pairs ($f_c \pm 2nf_m$) have resultants in line with the carrier.

With simultaneous A.M. and F.M. the phase relationship of the two modulations is important, but the fact that the sine or cosine form of F.M. is used has significance only in so far as it indicates its relationship to the A.M. Thus there is no real difference, except in the time reference point, between $e_3 = \hat{e}_0 (1 + k \sin pt) \sin (\omega t + m \sin pt)$ and $e_4 = \hat{e}_0 (1 + k \cos pt) \sin (\omega t + m \cos pt)$, but both are different from $e_5 = \hat{e}_0 (1 + k \cos pt) \sin (\omega t + m \sin pt)$, which is also different from $e_6 = \hat{e}_0 (1 - k \cos pt) \sin (\omega t + m \sin pt)$. The differences are best indicated by means of the oscillating vector representation in Figs. 2(a) and 2(b). The vector locus of Fig. 2(a) represents e_3 and e_4, the reference point for $t = 0$ is A for e_3 and B for e_4. Note that the instantaneous frequency for e_3 is $f_c + f_d \cos pt$ and for e_4 is $f_c - f_d \sin pt$, and direction of vector rotation is as shown by the arrows, anticlockwise direction indicating an instantaneous frequency greater than f_c and *vice versa*. Fig. 2(a) shows that amplitude change is symmetrical, i.e., is the same for increasing as for decreasing carrier frequency; hence upper and lower sidebands of a given pair have equal amplitudes, i.e., the frequency spectrum is symmetrical as regards amplitude and phase. Fig. 2(b) gives the vector representation of e_5, and also e_6. The reference point is C for e_5; amplitude and instantaneous frequency are maximum and vector direction is shown by the arrow. For e_6 the reference point is D; amplitude is minimum and instantaneous frequency a maximum. Amplitude change is now asymmetrical; when the instantaneous carrier frequency is greater than f_c, amplitude is greater than $\hat{e}_0$ for the e_5 wave, and the upper frequency sideband is therefore greater than the lower of the same pair. The converse is true of the e_6 wave. To complete the picture the representation of $e_7 = \hat{e}_0 (1 - k \sin pt) \sin (\omega t + m \sin pt)$—reference point at F for $t = 0$—is given

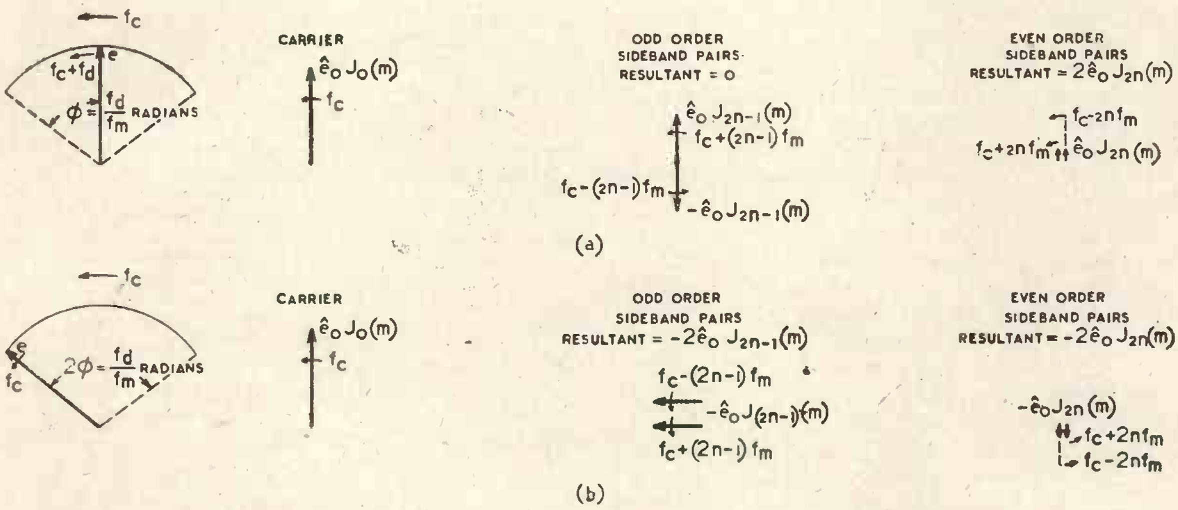


Fig. 1. (a) *Vector representation of* $e_1 = \hat{e}_0 \sin (\omega t + \frac{f_d}{f_m} \sin pt)$ *at* $t = 0$. (b) *Vector representation of* $e_2 = \hat{e}_0 \sin (\omega t + \frac{f_d}{f_m} \cos pt)$ *at* $t = 0$.

in Fig. 2(c). Like the e_3 wave it has a frequency spectrum symmetrical in amplitude and phase. All the waves from e_3 to e_7 produce the same output, except for a time phase displacement, if applied to an A.M. receiver having zero attenuation and phase distortion over the range $f_c - f_d - f_m$ to $f_c + f_d + f_m$. The output for the e_3 wave is the same as for the e_4 whatever may be the attenuation or phase characteristics of the A.M. receiver, but the results for the e_3, e_5, e_6, and e_7 waves will generally differ from each other, and will be determined by the attenuation or phase change over the pass range.

Colebrook suggests the master oscillator—buffer amplifier as a possible solution of the problem of preventing frequency modulation, but it must not be forgotten that A.M. of a buffer amplifier can still produce phase modulation of the carrier. This effect could probably be reduced, however, by keeping to a low modulating frequency, thereby reducing the effective f_d due to the phase modulation.

Chelmsford. K. R. STURLEY.

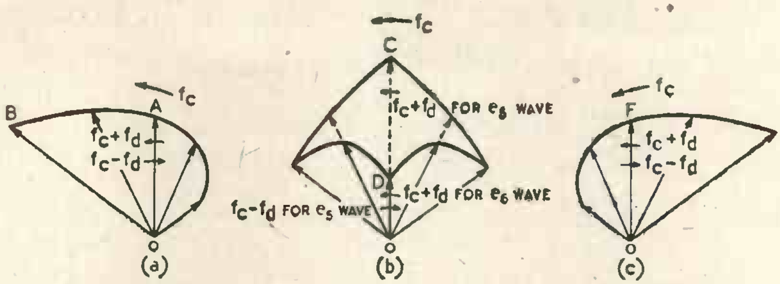


Fig. 2. *Vector representation of simultaneous amplitude and frequency modulation by a sinusoidal modulating voltage.*

(a) $e_3 = \hat{e}_0\ (1 + k \sin pt) \sin (\omega t + m \sin pt)$ *reference point A at* $t = 0$, *or* $e_4 = \hat{e}_0(1 + k \cos pt) \sin (\omega t + m \cos pt)$ *reference point B at* $t = 0$.

(b) $e_5 = \hat{e}_0\ (1 + k \cos pt) \sin (\omega t + m \sin pt)$ *reference point C at* $t = 0$, *or* $e_6 = \hat{e}_0(1 - k \cos pt) \sin (\omega t + m \sin pt)$ *reference point D at* $t = 0$.

(c) $e_7 = \hat{e}_0\ (1 - k \sin pt) \sin (\omega t + m \sin pt)$ *reference point F at* $t = 0$.

NOTE.—*In Fig.* 2(a) *OA is also vector position of* e_3 *when* $t = \frac{\pi}{p}$ *and its frequency is then* $f_c - f_d$.

In Fig. 2(b) *OD is also vector position of* e_5 *when* $t = \frac{\pi}{p}$ *and its frequency is then* $f_c - f_d$.

"Power Loss in Deflecting Condensers"

To the Editor, "Wireless Engineer"

SIR,—I entirely agree with Mr. Rodda's letter in the May issue of *Wireless Engineer.* His expression for the transit power as the wattmetric product of the induced currents and the electrode potentials, and my equation (3) are mathematically equivalent in the frequency range in which the vector potential can be neglected. This is proved in a general way in my paper on Energy Conversion. I regret that my remark to the effect that the subject is in need of clear general principles might have given the impression that I thought Mr. Rodda's principles were in need of clarification.

Regarding Mr. Benham's letter in the same issue he and I agree up to his equation (c), which is equivalent to my equation (4). The meaning of $\dot{\phi}$ in this specialised equation follows without ambiguity from the process by which it was derived from the general equations (b) or (3). $\dot{\phi}$ is the partial derivative with respect to time of the potential at a point (x, Y) occupied by the central ray of the beam at a given instant. The rule is therefore: differentiate the expression $\phi\ (x, y, t)$ partially with respect to t, substitute $y = Y(x, t)$, introduce this into equations (4) or (c), integrate over x, and average over a full cycle of t. There is therefore no need for experimenting with different interpretations, as Mr. Benham does. I plead guilty to the charge of brevity, and to having used the symbol y both for the co-ordinate, which specifies the field, and for the dependent variable $Y\ (x, t)$ which specifies the position of the beam. The final result is Recknagel's formula, and there is no error of sign.

As regards Mr. Harries' second letter, in the same issue, as he does not substantiate his sweeping statements that my "mathematical operations . . . do not apply to any fields at all", and my "derivation of the expression for transit power . . . is wrong", I regret that I am not in a position to give a reply.

Rugby. D. GABOR.

"Characteristic Impedance of Transmission Lines"

To the Editor, "Wireless Engineer."

SIR,—Equation (8) of this paper (*Wireless Engineer*, May, 1944, p. 225), viz.:—

$$C = \frac{1}{2 \log_\epsilon \left(1 + \frac{2\pi h}{a}\right)} \text{ e.s.u./cm.} \qquad (8)$$

is stated to be "a formula for the capacitance per unit length between two plates of width a and separation h." It is, however, derived from equation (7) and, therefore, applies to the same physical arrangement as (7), i.e., to a thin strip of width a parallel to an infinite plane and separated from it by a distance h.

The corresponding formula for the case of two strips of width a separated by a distance b is

$$C = \frac{1}{4 \log_\epsilon \left(1 + \frac{\pi b}{a}\right)} \text{ e.s.u./cm.}$$

Redbourn, Herts. C. F. BROCKELSBY.

PARALLEL TRANSMISSION LINES*

The Relation Between Their Mutual Inductance and Mutual Capacitances

By A. Bloch, Dr.-Ing., M.Sc., F.Inst.P.

(Research Laboratories of The General Electric Company, Limited, England)

At high frequencies the inductance L and the capacitance C of a transmission line obey the simple relation $L \cdot C = \frac{1}{c^2}$ .. .. (1)

where c is the velocity of electromagnetic waves in a space filled with the dielectric of the line.† Hence a determination of the capacitance of the line fixes also the value of its inductance and with this the value of its characteristic impedance.

$$Z_0 = \sqrt{\frac{L}{C}} = \frac{1}{c \cdot C} \ddagger$$

The purpose of this short note is to show in an elementary manner that not only self inductances but also mutual inductances can be deduced from electrostatic considerations. The Figure shows a pair of conductors a, b, which form line 1 and another pair of conductors c, d, which form line 2 parallel to line 1. The mutual inductance between these two lines is defined by $i_1 \cdot L_{12} = \Phi_2$ .. (2)

where i_1 denotes the current flowing in line 1 and Φ_2 the flux which is in this case linked with the currentless line 2.

(everything referred to unit length of line.)

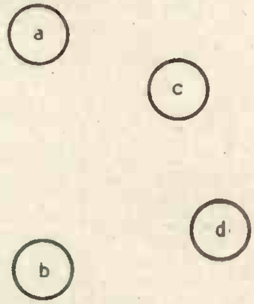
We have further $i_1 \cdot L_{11} = \Phi_1$ .. .. (3)

where L_{11} is the self inductance of line 1 in the presence of the open-circuited line 2 (in this case only the bodies of the conductors c and d act as obstacles to the lines of flux).

From (2) and (3) follows

$$L_{12} = L_{11} \cdot \frac{\Phi_2}{\Phi_1} \quad \text{.. .. .. (4)}$$

To evaluate the ratio Φ_2/Φ_1 we would have to pass a current i_1 through line 1 and count the number of flux lines passing between a and b and those passing between the open circuited conductors c and d. Now, exactly the same pattern of lines would be obtained as equipotential lines in an electrostatic experiment, in which we produce a potential difference E_1 between the conductors a and b and in which we have the conductors c and d isolated.



This follows easily from the fact that both patterns are obtainable (as graphical solutions of Laplace's differential equation) by covering in well-known fashion the area between the conductors with a square net, making the boundaries of all of the conductors coincident with some of the lines of this net (which are equipotential lines in one case and streamlines in the other.)

The number of equipotential lines passing between a and b is a measure of the potential difference E_1 and the number passing between c and d, a measure of the potential difference E_2 which exists in these circumstances between c and d.

$$\text{Thus} \quad L_{12} = L_{11} \cdot \frac{E_2}{E_1} \quad \text{.. .. .. (5)}$$

L_{11} can here be obtained by a capacitance determination according to eqn. (1). The ratio E_2/E_1 can be calculated once the mutual capacitances between the various conductors are known. If calculation is to be replaced by an experiment (electrostatic or in an electrolytic trough) it is, of course, just as well to determine this ratio by direct measurement.

If we use Maxwell's "coefficients of electric induction" then we can describe the electrostatic relations between line charges and line voltages by the following set of equations:

$$\begin{aligned} E_1 &= K_{11} \cdot Q_1 + K_{12} \cdot Q_2 \\ E_2 &= K_{21} \cdot Q_1 + K_{22} \cdot Q_2 \end{aligned} \quad \text{.. .. (6)}$$

---

* MS. accepted by the Editor, December 1943.

† This relation, of course, also applies at lower frequencies if we are allowed to neglect the magnetic field inside the conductor.

‡ The determination of the characteristic impedance of a line from its capacitance does not actually need the intermediate concept of its inductance. If we apply unit voltage to the beginning of an infinite line the current has to charge afresh in each second a length of line equal to c and the amount of electricity required in each second for doing so is $c.C$, which means that the source of EMF sees under these circumstances an admittance $c.C$.

where the K_{ik} are the coefficients referred to and where Q_1 denotes the charge per unit length on conductor a ($-Q_1$ on b) and Q_2 a possible charge per unit length on conductor c ($-Q_2$ on d).

The result of the electrostatic experiment mentioned above is then expressible in the simple form $\frac{E_2}{E_1} = \frac{K_{22}}{K_{11}}$ .. .. (7)

Hence we have $\frac{L_{22}}{L_{11}} = \frac{K_{22}}{K_{11}}$ .. .. (8)

i.e., the coefficients of magnetic induction are simply proportional to the coefficients of electric induction. This relationship is sometimes mentioned in treatises on travelling waves (usually without proof and with a slightly different definition for the coefficients K_{ik} and L_{ik}, this difference being immaterial for the present purpose).*

* The only publication known to the author where a proof is given is K. W. Wagner, *Electrotechnische Zeitschrift*, 1914, Vol. 35, p. 639.

Wireless Patents

A Summary of Recently Accepted Specifications

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

DIRECTIONAL WIRELESS

559 062.—Indicator for distinguishing the dots from the dashes in a radio-navigational system of the overlapping-beam type.

Standard Telephones and Cables; C. W. Earp; and J. D. Weston. Application date, 28th July, 1942.

RECEIVING CIRCUITS AND APPARATUS

(*See also under Television*)

559 078.—Means for more effectively utilising the H.T. supply to a multi-stage arrangement of amplifiers wherein the anode of one valve is coupled both to the cathode and grid of a succeeding valve.

E. L. C. White. Application date, 13th May, 1942.

559 161.—Frequency detector of the cycle-counter type, adapted for receiving frequency-modulated signals.

Standard Telephones and Cables (assignees of J. R. Pierce). Convention date (U.S.A.), 29th May, 1941.

559 218.—Push-pull limiter or "muting" and gain-control system, of short-time-constant, particularly for frequency-modulated signals.

Hazeltine Corporation (assignees of L. F. Curtis). Convention date (U.S.A.), 28th October, 1941.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

559 005.—Television transmitter, for operation by a cinema film, with means for re-inserting the D.C. or "background" component of the picture.

Marconi's W. T. Co. (assignees of A. C. Schroeder). Convention date (U.S.A.), 31st January, 1941.

559 065.—Optical projection system for television pictures provided with means for correcting spherical aberration and other errors.

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

559 070.—Preventing undesired reflection effects in an optical projection system for television pictures.

Marconi's W.T. Co. (communicated by Radio Corporation of America). Application date, 28th August, 1942.

559 112.—Synchronising the colour discs or filters used for producing television pictures in natural colour.

Marconi's W.T. Co. (assignees of G. L. Grundmann). Convention date (U.S.A.), 28th June, 1941.

559 214.—Optical system associated with a cathode-ray tube for projecting large-sized television pictures on to a theatre screen.

Marconi's W.T. Co. (assignees of D. W. Epstein; I. G. Maloff; and F. H. Nicoll). Convention date (U.S.A.), 31st July, 1941.

TRANSMITTING CIRCUITS AND APPARATUS

(*See also under Television*)

559 095.—Power amplifier with expansion control for feeding a transmitting aerial or like load.

D. L. Hings. Application date, 21st August, 1942.

559 151.—Discharge tube in which two rotating beams of electrons are utilised to produce a time delay, e.g., for "clipping" the initial signals so as to prevent "singing" in telephone systems.

Standard Telephones and Cables (assignees of N. I. Hall). Convention date (U.S.A.), 22nd May, 1941.

559 243.—Aircraft wireless transmitter arranged to be automatically modulated in accordance with the height or direction of flight of the craft in which it is installed.

Square D. Co. Convention date (U.S.A.), 5th February, 1941.

SIGNALLING SYSTEMS OF DISTINCTIVE TYPE

558 933.—Push-pull pentode circuit for measuring the phase of an impulse voltage relatively to a standard voltage of the same frequency.

Marconi's W.T. Co. (assignees of L. E. Norton). Convention date (U.S.A.), 31st October, 1941.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

559 057.—Construction and electrode assembly of a high-powered discharge tube of the de-mountable type.

Standard Telephones and Cables (assignees of C. V. Litton). Convention date (U.S.A.), 7th August, 1941.

559 316.—Means for supporting the fluorescent screen of a cathode-ray tube so as to obviate the effect of negative charges due to the scanning beam.

Cinema-Television (communicated by C. S. Szegho). Application date, 14th September, 1942.

Waste Paper.—The increasing part played by paper in the production of weapons of war is traced in an exhibition sponsored by the Waste Paper Recovery Association at Marble Arch, London, W.1.

Abstracts and References

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

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.

PROPAGATION OF WAVES

1844. THE FIELD-LINE DIAGRAM OF THE MAGNETIC MODE OF OSCILLATION IN THE CYLINDRICAL GUIDE OF CIRCULAR CROSS-SECTION.—E. Ledinegg. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, pp. 38–44.)

"In a recent paper by Borgnis (1818 of 1943) the properties of a cylindrical guide of circular cross-section excited in *H*-type oscillations were investigated. It was pointed out that in addition to the electric fundamental oscillation E_{001} (Borgnis, 3874 of 1939) the magnetic fundamental oscillation (H_{111} type) possesses special interest; the two named types of oscillation alternate, according to the condition $l/D \gtreqless 1$, in the property of possessing the longest resonance wavelength of all possible natural oscillations. As an extension to the paper first mentioned, the geometrical properties of the magnetic type of oscillation will be examined here. Above all, the paper will discuss the course of the field lines of the *H* type which appear as the solution of the differential equations $[d\mathfrak{s}, \mathfrak{H}] = 0$, $[d\mathfrak{s}, \mathfrak{E}] = 0$. The exact knowledge of the field lines is, apart from purely theoretical interest, of importance for instance in problems which are not directly amenable to strict calculation: for example, coupling problems between two guides, where it is particularly important to know the current lines on the surfaces of the sheath."

Author's summary:—"The equations of the magnetic and electric field lines of the magnetic fundamental oscillation of the cylindrical guide with circular cross-section are set up and discussed [use being made of the results of the writer's previous work (4 of 1943) combined with Borgnis's second paper quoted above]. The representation of the magnetic field lines as the penetration-product of coaxial cylinders ('*H*-cylinders') and bodies of rotation ('*H*-rotation bodies') furnishes a clear spatial picture of the course of the field lines [for the definition of the "*H*-cylinder" *see* p. 39, r-h column. "The $\mathfrak{H}$ vectors must thus lie in planes, parallel to the z axis, for which the $\mathfrak{E}$ lines represent orthogonal trajectories. Since the latter are independent of z, it follows that on every cylinder which is built up from eqn. 4 over an arbitrary orthogonal trajectory ($z = 0$), an infinite number of lines of magnetic force must lie. These cylinders are known for shortness as *H*-cylinders"; their differential equation is given in eqn. 5. For the unequivocal determination of the *H* lines a further differential equation is required: this is eqn. 7. The geometrical interpretation of this equation is discussed with the help of Fig. 2: "since the multiple-solution nature of eqn. 7 is representable in the form $z = z(r)$, independent of ϕ, the *H* lines of force must lie on coaxial rotation-bodies generated by the $z = z(r)$ curves in rotating about the cylinder axis." It is these "*H*-rotation bodies" that give, by their penetration curves with the "*H*-cylinders," the actual lines of magnetic force: *see* Fig. 5].

"The harmonics of the magnetic type are discussed with some examples [Figs. 7 a, b], and the *H*-cylinders and *H*-rotation bodies are given, from which the shape of the field lines can be derived directly. On the basis of a general differential-geometrical law it is shown that for cylinder surfaces in general, closed by plane plates, the *E* field is perpendicular to the *H* field, so that the *E* lines are orthogonal trajectories of the *H*-cylinders. All *H*-cylinders (considered as metallically covered) oscillate with the cylindrical guide at the same frequency. Finally it is shown that the work which has to be done against the electromagnetic field in deforming into any arbitrary *H*-cylinder is zero when averaged over time."

1845. WAVE GUIDE WITH RECTANGULAR CROSS-SECTION FOR VERY SHORT ELECTRIC WAVES.—W. Ilberg & others. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 95, Fig. 13.)

A Telefunken patent, D.R.P.732 423, applied for 4/10/40. The shorter side walls of the "rectangular" hollow guide *H* are formed by the curved walls of the "guard-tube" *R*, which are (at any rate at these points) metallic or metallised.

1846. ON A BOUNDARY-VALUE PROBLEM OF THE WAVE EQUATION IN CYLINDRICAL COORDINATES.—Oberhettinger. (*See* 1929.)

1847. The Theory of the Spherical Wave excited at a Finite Distance from the Surface of Demarcation of Two Media, for Finite Refractive Indices [Completely General Theory on Assumption of Validity of Fresnel's Reflection Formulae for Plane Elementary Waves].—M. Krüger. (*Zeitschr. f. Phys.*, 10th Aug. 1943, Vol. 121, No. 5/8, pp. 377–437.) *See* also Ott, 18 of 1943, whose treatment, however, "cannot be regarded as a general solution of the problem."

1848. Research on the Physics of the Stratosphere, at the Kaiser Wilhelm Gesellschaft, 1942/3.—E. Regener & others. (*Naturwiss.*, 5th Nov. 1943, Vol. 31, No. 45/46, p. 513: in a report on the activities of this institution.)

"Further work on the constitution and physical properties of the stratosphere. In the foreground stand optical problems of the stratosphere and investigations on the cosmic radiations." No details are given: on p. 527 a paper by Prof. Regener, on "the ozone layer and atmospheric turbulence," is announced as about to appear in *Meteorol. Z.* *See* also 2075, below.

1849. Banded Meson Spectrum and the Rossi Second Maximum.—S. V. C. Aiya. (*Nature*, 25th March 1944, Vol. 153, No. 3882, p. 375.)

"Such a drop in the meson absorption curve has not so far been reported by anybody to my knowledge; but its appearance in this experiment is due to the use of the counter arrangement based on Bhabha's method, which is such as to bring out any existing discontinuities. The interpretation of this experiment, together with the results of further experiments now in progress, will be given in a paper with Prof. Bhabha."

1850. What do Spectrum-Analytical Investigations say as to the Constitution of the Upper Atmosphere?—R. Penndorf. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, pp. 87–88.) A longish summary, by Zenneck, of the paper dealt with in 8 of 1943: it includes some of the tables.

1851. The Band Spectrum of Nitrogen: New Singlet Systems [and Additional Data & Information on the Singlet Systems reported by van der Ziel and by Kaplan].—A. G. Gaydon. (*Proc. Roy. Soc.*, Series A, 1st March 1944, Vol. 182, No. 990, pp. 286–301.)

1852. The Band Spectrum of N_2: Weak Systems in the Visible Region, *and* The Band Spectrum of NO: the Gamma and Epsilon Systems.—A. G. Gaydon. (*Proc. Phys. Soc.*, 1st March 1944, Vol. 56, Part 2, No. 314, pp. 85–95: pp. 95–103.)

1853. "Clouds and Weather Phenomena" [Second Edition, Revised: Book Review].—C. J. P. Cave. (*Nature*, 26th Feb. 1944, Vol. 153, No. 3878, p. 237.) Reviewed by D. Brunt. "One of the most satisfying books which have appeared in the field of meteorology for many years."

1854. The Thermal Effect of Diffusion [Chapman's "Thermal Flux of Diffusion"].—L. Waldmann. (*Zeitschr. f. Phys.*, 24th Aug. 1943, Vol. 121, No. 9/10, pp. 501–522.)

The diffusion current in a mixture of gases is made up of two components, the ordinary current depending on concentration conditions and the thermal diffusion current, proportional to the temperature gradient. On this analogy it may be supposed that the thermal flux also consists of two components, proportional respectively to the temperature gradient and the concentration gradient. This was shown theoretically to be the case, by Chapman and Enskog, both in 1917, but since then the subject has been neglected. The present writer now shows that the effect must be universal and capable of being measured: preliminary experiments (ref. "1") qualitatively confirm the theory.

1855. Ionospheric Measurements during the Solar Eclipse of April 7th, 1940.—L. V. Berkner & S. L. Seaton. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, pp. 59–61.) Long summary, with diagrams, from *Trans. of 1940 of Am. Geophys. Union*, pp. 311–314.

1856. Origin of the Solar System [Letter prompted by Criticisms of Alfvén's Theory].—A. Hunter: Alfvén. (*Nature*, 26th Feb. 1944, Vol. 153, No. 3878, pp. 255–256.)

1857. Interstellar Calcium Clouds [Note on Spectrograms in *Astrophys. Journ.*, 1943, p. 105: Evidence strongly suggests that Interstellar Calcium occurs to a Great Extent in Discrete Clouds, each with Its Own Small Peculiar Motion but with Little Internal Turbulence: etc.].—(*Nature*, 11th March 1944, Vol. 153, No. 3880, p. 319.)

1858. Hydrogen Content of the Sun and of Stars of Small Masses.—N. R. Sen & U. Burman. (*Nature*, 5th Feb. 1944, Vol. 153, No. 3875, pp. 166–167.) *See* also 1133 of April.

1859. On the Presence of Phosphorus in the Solar Atmosphere [Data at present available indicate Its Presence].—K. N. Rao. (*Indian Journ. of Phys.*, Aug. 1943, Vol. 17, Part 4, pp. 197–203.) *See* also 2298 of 1943.

1860. Measuring the Distance of the Sun from the Earth [R.I. Discourse].—H. Spencer Jones. (*Nature*, 12th Feb. 1944, Vol. 153, No. 3876, pp. 181–187.)

1861. Some Facts on the Propagation of Hertzian Waves in Geological Conductors.—V. Fritsch. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, pp. 50–59.)

"Certain tests are here reported which show that Hertzian waves can penetrate even thick mountain layers, and that the range is dependent not only on the geoelectrical properties of the mountain but also on the frequency of the field.

"The necessity, in cases of mine disasters, of maintaining a communication link which is not dependent on destructible wire lines has led to the development of mine wireless. For the closer study of the foundations for such systems, a long series of tests has been carried out during the past year in the Tyrolese mines. Above everything else, these tests were to determine what wavelength gave the best ranges. They supplement the researches undertaken in the last ten years partly by other radio-technicians and partly by myself. The work now considered was carried out in close collaboration with, and at the request of, the C. Lorenz Company of Berlin."

The writer's previous tests, of which "the most important" were those dealt with in 39 of 1939 and back references and in Reference "3", had already shown that quite considerable ranges were obtainable underground. Signals were received under a covering of as much as 500 m. Even in these early tests the marked influence of the transmitter frequency was realised. With wavelengths above 100 m a reasonable agreeement was found between observed results and those of modern "extinction" theory, but the relations became much more complicated for wavelengths below 100 m. At first, as the frequency increased, the range diminished; but in the 40 m band an increase appeared. There seemed, also, to be a "dead zone" in the region of the 100 m wave. The three workers mentioned in references "5" to "7" and also Petrowsky, 1933 Abstracts, p. 519, and Doborzynski (1712 of 1936 [and 4311 of 1938]), agree in finding that the ranges obtained underground considerably exceed those hitherto calculated in the technical literature. The writer considers that this apparent discrepancy between theory and experiment is not due to any fault in the theory, but to the use of incorrect values for the electrical properties of the geological conductors, the conductivity and dielectric constant often being measured on small samples which, as recent experience has shown, generally differ in their properties from the natural mass: in particular, the conductivity of these samples—always taken from the surface layers—is often higher than the mean value for the natural mass.

He deals first with the suggestion sometimes made that the larger ranges obtained are due to the propagation of the waves along air-filled galleries and shafts, or to the action of metal ropes, pipes, etc. This idea is opposed on several grounds, theoretical and practical (p. 51), and was finally disproved by the writer's latest tests (Figs. 1–3): in Fig. 1, for example, the transmitter in the bottom gallery was well received in an upper gallery separated by about 500 m of solid dolomite, whereas it was inaudible outside the mouth of the upper gallery, from which it was screened by a thick layer of clay having high attenuation. If the signals had travelled in the air of the bottom gallery and round to the receiver, they would have been louder just outside the upper gallery than along it.

The main body of the recent tests includes measurements made on the 1000 m, broadcasting, and short-wave bands, and (very cursorily) on the 5 m band. The geoelectrical conditions are not dealt with in detail, since they are given in a paper which is being printed in *Beitr. z. angew. Geophysik.* Table 1, however, gives some resistances (measured on a wavelength of 1000 m in the case of dry granite, and otherwise presumably on 300 m) of various masses, and the dielectric constants and extinction coefficients calculated from these and from the known porosity of the materials. For instance, for dry granite the resistance (given in "ohms per cm") is 10^{10}, $\epsilon = 10$, and $\gamma = 0.0000015$; for "rock with natural moisture" the values are 10^5–10^6, 13, and 0.128–0.015, while for moist clay they are 10^3, 40, and 1.28. Table 2 gives the "practical" ranges (5 μv/m for an aerial power of 10 w) calculated from these values: they are, for the above cases, 7×10^6 m, 800–100 m, and 10 m respectively. Thus a quite thin layer of clay (or still more of humus) will affect the range more than a hill of several hundred metres' thickness.

Author's summary:—"Ranges underground up to 1700 m were obtained, but the observations suggest that possible ranges of 2 to 3 km can be obtained in practice. In dry, low-porosity rock ranges from several hundred to a thousand kilometres are possible. The extinction, and hence the range, depends chiefly on the moisture-content of the rock. For this reason, tectonic deformations are always of great importance for wave propagation. They may considerably reduce ranges by their high extinction, or on the other hand may considerably increase them by guiding the field [*cf.* Howell, 81 of January]. An important factor is the angle at which the field is incident.

"The influence of the frequency is also very marked. It has continually been observed, up to the present, that a wave-band exists between short and broadcasting wavelengths on which no underground transmission is possible. In the long-wave region the extinction decreases with increasing wavelength. At a wavelength shorter than 100 m this regular behaviour can no longer be observed. Conditions in this wavelength region are more complicated [*see* earlier in this abstract] and the ranges are several times the calculated values. The frequency-dependence of extinction seems to be different for different geological conductors.

"The application of the experimental material now available offers new methods both to mine wireless technique and also to radio prospecting." For Japanese measurements on absorption, etc., in rocks, *see* 4196 of 1940 and back reference.

1862. The Electromagnetic Processes taking place along a Symmetrical Group of Conductors.—V. I. Kovalenkov. (*Automatics & Telemechanics* [in Russian], No. 3, 1941, pp. 7–14.)

The operation is discussed of a symmetrical group of n conductors (Fig. 1) of which m conductors act as a transmission line and the remaining $(n - m)$ conductors have voltages and currents induced in them from this line. It is shown that there are two electromagnetic waves propagating along the group of conductors, of which the first propagates between the active and passive conductors (inter-phase wave) and the other between all conductors and earth (earth wave). On the basis of this analysis an artificial line is suggested (Fig. 5) imitating the active line in the group of conductors.

1863. On the Development of a General Theory of the Transmission of Electromagnetic Energy along Wires.—V. I. Kovalenkov. (*Automatics & Telemechanics* [in Russian], No. 4/5, 1941, pp. 5–18.)

The development of the theory of transmission is briefly surveyed. It is pointed out that in this, as in any other branch of technical science, theory develops through stages of differentiation and of solving special problems towards a broad generalisation of the results obtained. It is suggested that the present task is to evolve a general theory of an active multipolar circuit network, *i.e.* of a group of parallel conductors of which some or all are active. The present state of this theory is discussed and it is shown that a steady electromagnetic wave on a line forming part of the group of conductors is a resultant of a series of component electromagnetic waves. The latter depend on the number of the conductors of the group and on the type of termination. It is important from both the practical and theoretical points of view that methods should be evolved for determining the component waves. It is pointed out that the theory discussed deals with stabilised processes only and that further study will be required to cover transient processes.

1864. On the General Theory of the Transmission of Electrical Energy along Lines.—V. A. D'yakov & V. I. Ivanov. (*Automatics & Telemechanics* [in Russian], No. 4/5, 1941, pp. 19–22.)

With reference to Kovalankov's paper, 1863, above, the importance is emphasised of pooling knowledge gained in various branches of electrical engineering regarding the transmission of electrical energy, and of developing a general theory of transmission. The following factors are briefly discussed:—(1) The number of conductors; (2) the types of e.m.f. applied to a group of conductors; (3) the impedances of the transmitting and receiving apparatus, and (4) the asymmetry of the conductors. Some of the possible steps in the development of a general theory are also indicated, as for example the derivation of formulae for determining the voltages and currents on the line in terms of its secondary parameters, the determination of tertiary parameters of an equivalent four-pole circuit network, the investigation (with the aid of a model) of the solutions of differential equations representing the processes taking place on the line, etc.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

1865. Lightning Surges transferred from One Circuit to Another through Transformers [Theoretical & Experimental Investigation].—P. L. Bellaschi. (*Elec. Engineering*, Dec. 1943, Vol. 62, No. 12, Transactions pp. 731–738.)

1866. The Course of the Potential at a Condenser at the End of an Overhead Line struck by Lightning [Calculation on Assumption of Quasi-stationary Régime].—K. Berger & J. Giaro. (*Bull. Assoc. Suisse des Élec.*, 12th Jan. 1944, Vol. 35, No. 1, pp. 14–26 : in German.)

1867. Guiding Principles for the Introduction of Surge Arresters in Overhead-Line Systems.—W. Siemer. (*E.T.Z.*, 18th Nov. 1943, Vol. 64, No. 45/46, pp. 601–607.)

1868. Lightning Arresters housed in Transparent Plastic Cases [used by Army : Neon-Tube Glow indicates Satisfactory Connection between Aerials & Ground].—(*Sci. News Letter*, 5th Feb. 1944, Vol. 45, No. 6, p. 96.)

PROPERTIES OF CIRCUITS

1869. The Field-Line Diagram of the Magnetic Mode of Oscillation in the Cylindrical Guide of Circular Cross-Section.—Ledinegg. (*See* 1844.)

1870. The Plotting of Electromagnetic Fields [in Cavity Resonators, etc.] by means of "Test Bodies."—G. Goubau. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, pp. 73–76.)

In a paper on the electromagnetic cavities used, for instance, in u.s.w. frequency stabilisation, Müller has given a method of determining the field distribution inside such a cavity : *see* end of 1379 of 1940. This consisted in introducing small "test bodies" and measuring the change in natural frequency or input impedance which they cause. The method gives the values of the electric and magnetic field strengths and also, if the shapes of the test bodies are suitably chosen, the directions of the fields. It assumes, however, that the damping losses are negligible and that consequently the electric and magnetic fields are in themselves of the same phase everywhere, and $\pi/2$ out of phase with each other. It is shown theoretically in the present paper that the "test body" method can be adapted for application to arbitrarily strongly damped systems, and also to radiating systems; further, that besides the amplitude and the direction, the phase of the field components can be determined simultaneously from the change in the input impedance. The only assumption that must be made is the linearity and isotropy of the medium of which the system is composed.

For the calculation of the impedance change at the point of excitation, produced by the introduction of a composite test body made up of a conducting and a non-conducting part, the writer starts from Maxwell's equations connecting the field magnitudes $\mathfrak{E}_1$, $\mathfrak{H}_1$, $\mathfrak{E}_2$, $\mathfrak{H}_2$ for the bounded space (Fig. 1) when this is completely filled with the ambient dielectric and when it contains also the test body. Up to eqn. 11 no restrictions are placed on the form and dimensions of the test body, but after that point the dimensions are assumed to be small enough (*i.e.* the volume δV in Fig. 1, which is filled by the composite test body when this is introduced into the cavity, is assumed to be small enough) for the undistorted field $\mathfrak{E}_1$, $\mathfrak{H}_1$ within δV to be considered as homogeneous and ϵ_1, μ_1 also as constant. Ultimately it is found that the impedance change $\delta\mathfrak{R}$ produced by the introduction of the test body can be represented by the total electric and magnetic moments $\mathfrak{M}_e = \mathfrak{M}_e' + \mathfrak{M}_e''$ and $\mathfrak{M}_h = \mathfrak{M}_h' + \mathfrak{M}_h''$ induced in the test body by the $\mathfrak{E}_1$, $\mathfrak{H}_1$ field, so that from eqns. 12a, b, 15, and 17 the impedance change is given by eqn. 18 . . .

$$\delta\mathfrak{R} = j\omega/J_1^2 \cdot \{-\mathfrak{E}_1 \cdot \mathfrak{M}_e + \mathfrak{H}_1 \cdot \mathfrak{M}_h\} .$$

In the above, $\mathfrak{M}_e'$ and $\mathfrak{M}_h'$ represent the electric and magnetic moments induced in the non-conducting component of the composite test body, while $\mathfrak{M}_e''$ and $\mathfrak{M}_h''$ represent the corresponding moments induced in the conducting component. Eqn. 18 can also be transformed into a power relation, eqn. 19 ; this, for a loss-free cavity with $\phi_h = 0$, $\phi_e = \pm\,\pi/2$, reduces to eqn. 20, the equation given by Müller for those simpler conditions.

Section III deals with the application of eqn. 18 to the plotting of fields. The easiest part is the measurement of electric-field distribution, for this can be done with a dielectric test body, which leaves the magnetic field undisturbed so that the equation reduces to

$$\delta\mathfrak{R} = -\,j\omega/J_1^2 \cdot \mathfrak{E}_1 \cdot \mathfrak{M}_e .$$

If the electric field swings everywhere in one direction only (that is, if no rotating field is present) amplitude and phase can be determined by the use of a spherical test body, $\mathfrak{M}_e$ for which is given by eqn. 22 : the working formula for the impedance change $\delta\mathfrak{R}$ thus becomes eqn. 23. The field direction can be found with a non-spherical test body such as an ellipsoid : the impedance change becomes a maximum when the axis of this body coincides with the direction of the field. A rotating field can also be dealt with by the ellipsoid, the impedance changes being measured for three mutually perpendicular directions of its axis, and the field components in these three directions being calculated from the values obtained. "The same results as are obtained with a dielectric solid-of-revolution are given by a cylindrical piece of wire. If the thickness is sufficiently small compared to the length, the influence of the magnetic induction may be neglected."

The distribution of the magnetic field cannot be plotted as simply as that of the electric field, since no non-conductor exists with a permeability much different from unity. Only a metallic test body can therefore be used, and such a body has an electric moment as well as a magnetic. To eliminate this, it is necessary to measure beforehand the electric field by means of a dielectric test body ; it is also necessary to know how the magnetic *and* electric moment induced in the metallic test body varies with the direction of the field—" this can be determined theoretically or experimentally."

The field distribution for a conductor is more simple to plot than for a cavity, since the need for a direction-determination is avoided completely in the case of the electric field and partially in that of the magnetic field. A hemispherical or hemiellipsoidal test body can be employed. It is mentioned that the test bodies need not always be so small that the field is homogeneous : for instance, to find the field distribution about a straight wire, ring-shaped test bodies may be used : formulae for the impedance change for such bodies, of the dielectric and the conducting types, are given.

Finally, the accuracy of the method is briefly discussed: This depends on the accuracy of the impedance measurements, and above all on the constancy of the frequency. Theoretically the method is applicable to the radiation field of an aerial. Practically, the question is whether the effect of the test body (which in this case would certainly have to be of larger dimensions, perhaps a half-wave aerial) would be sufficiently great. "The practical limits of the method must be decided by experiment."

1871. TRANSMISSION-LINE PROBLEMS AND THE IMPEDANCE CIRCLE DIAGRAM [Transmission Lines in Micro-Wave Engineering, for Interconnection & as Circuit Elements: Analysis of Their Behaviour greatly facilitated by Circle-Diagram Technique: Its Fundamental Equations: Non-Reflecting Terminations, and a "Widespread Misunderstanding": etc.].—Willis Jackson & L. G. H. Huxley. (*Nature*, 11th March 1944, Vol. 153, No. 3880, p. 319: summary of I.E.E. paper.)

1872. EQUIVALENT T AND PI SECTIONS FOR THE QUARTER-WAVELENGTH LINE.—C. G. Brennecke. (*Proc. I.R.E.*, Jan. 1944, Vol. 32, No. 1, pp. 15–17.)

Instead of the usual application of the general transmission-line equations to the special conditions of the case, the quarter-wavelength line may be represented by a lumped reactive network "of simple structure and interesting behaviour, which behaviour may then also be expected of the line."

For any smooth transmission line, an equivalent T section of the symmetrical form of Fig. 1 may be constructed if the values of the branch impedances are chosen according to the equations $Z_1/2 = Z_0 \tanh \theta/2$ and $Z_2 = Z_0/\sinh \theta$, where $Z_0 = \sqrt{z/y}$ and $\theta = \sqrt{zy}\, l$; Z_0 being the characteristic impedance, θ the "electrical length" of the line in hyperbolic radians, z the series impedance per unit length, l the length of the line, and y the transverse admittance per unit length. For the corresponding equivalent pi section (Fig. 4) the conditions are $Z_1 = Z_0 \sinh \theta$ and $2Z_2 = Z_0 \coth \theta/2$.

Now at ultra-high frequencies, where the series resistance and the transverse conductance of the line become negligible compared with the series reactance and transverse susceptance respectively, Z_0 may be written as $\sqrt{L/C}$, where L is the inductance and C the capacitance between wires, each per unit length. Further, the real part of θ represents attenuation and may thus be neglected, while the quadrature term represents phase rotation, and for a quarter-wavelength line must be $\pi/2$. Thus for such a line the above equations become $Z_1/2 = \mathrm{j}\sqrt{L/C}$ and $Z_2 = -\mathrm{j}\sqrt{L/C}$ for the T section, and $Z_1 = \mathrm{j}\sqrt{L/C}$ and $2Z_2 = -\mathrm{j}\sqrt{L/C}$ for the pi section, so that the two equivalent sections take the form of Fig. 2 and Fig. 5 respectively.

Such a section (and therefore the quarter-wavelength line it represents) will act as an impedance transformer, giving a perfect match between resistances and a conjugate match between impedances whose phase angles are the same: it will also invert an impedance, making it appear as a constant times its own admittance. "For want of a better name" the two types are called the "inverting T section" and the "inverting pi section." Since individual circuit considerations often require the use of a matching section with capacitive input and output, the "inverting pi section" may be of more general use than its T equivalent. "It may be that a similar representation of other high-frequency lines, stubs, and antenna feeders by equivalent pi or T sections will lead to a better appreciation of their potential applications."

1873. METHOD OF COUNTERING THE FALLING-OFF OF THE EFFECTIVE RESISTANCE OF AN ULTRA-HIGH-FREQUENCY VALVE DUE TO THE INDUCTION CURRENT FLOWING TO THE CONTROL GRID.—Philips Company. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 95, Fig. 11.)

Swiss Patent 221 470, applied for 1/5/41. "Between the control grid 16 and the anode 19 an auxiliary grid 17 is introduced, whose alternating voltage is in opposed phase to the control-grid voltage, from the fact that the auxiliary electrode is connected to the control grid through the resonant circuit 13, 14, 15 tuned to the working frequency. The energy given up to the electron stream by the control grid is balanced out by the energy taken from it by the auxiliary electrode."

1874. ULTIMATE BAND-WIDTHS IN HIGH-GAIN MULTI-STAGE VIDEO AMPLIFIERS [and the Question of Shunt Peaking].—MacLean. (*See* 1990.)

1875. A FREQUENCY DOUBLER FOR HIGH-FREQUENCY OSCILLATIONS.—Philips Company. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 93, Fig. 5.)

French Patent 874 733, priority 15/8/40. "The fundamental frequency is fed to the input circuit consisting of a Lecher system 2, 3 tuned to it, and this system is connected to two equivalent electrodes (*e.g.* the grids) of the two valves T_1, T_2, of which two other equivalent electrodes (*e.g.* the cathodes) are connected together. The output circuit, consisting of the Lecher system 4, 5, tuned to the harmonic, lies between the point of junction of the two electrodes and the middle point of a potential divider, formed in the case illustrated by the grid/anode capacitances.

1876. FREQUENCY MULTIPLICATION WITHOUT THE USE OF TUNED RESONANT CIRCUITS.—Philips Company. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 93, Fig. 3.)

Swiss Patent 221 471, applied for 2/5/41. The fundamental oscillation is applied in push-pull to two control grids 9, 11 whose working points lie on the straight parts of the corresponding anode-current/grid-voltage characteristics; the harmonic is taken off the anode 19.

1877. CIRCUIT ARRANGEMENT FOR LINEARISING THE ANODE-CURRENT CHARACTERISTIC OF A MULTI-ELECTRODE VALVE.—W. Jacobi & L. Grassl. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 62.)

A Siemens & Halske patent, D.R.P.730 675. To linearise the anode-current characteristic L (Fig. 3), the bias U_s of a positive auxiliary grid (screen grid) is so controlled, as in curve 6, that it falls off on both sides of the working point A. This is accomplished for region I (to the right of the working point) by a series resistance in the s.g. circuit, and for region II (to the left of the working point) by a controlled discharge gap (auxiliary valve) in parallel with the screen-grid/cathode gap.

1878. NEUTRALISATION OF SCREEN-GRID TUBES TO IMPROVE THE STABILITY OF INTERMEDIATE-FREQUENCY AMPLIFIERS.—Hultberg. (*See* 1918.)

1879. RADIO DATA CHARTS: No. 15—I.F. TRANSFORMER DESIGN.—J. McG. Sowerby. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 82–85.)

1880. A STUDY OF THE PERFORMANCE OF VARIOUS COMMON RESISTANCE-AMPLIFIER STAGES [including the "Cathode-Amplifier" Stage (36 of 1943, and *cf.* 410/11 of February)].—R. Wunderlich. (*E.N.T.*, Jan. 1943, Vol. 20, No. 1, p. 1 onwards.) With 8 diagrams.

1881. New Contrast-Expansion Circuit: Applying the Principle of the Cathode Follower [Objections to Usual Circuits with Lamps or Variable-Mu Valves: Suggested Circuit & Its Several Advantages].—M. O. Felix. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 92–93.)

Results of tests on this at present untried circuit are invited.

1882. The Development of the Push-Pull System [from about 1880 onwards].—D. McNicol. (*Communications*, Nov. 1943, Vol. 23, No. 11, pp. 17–19 and 110..112: to be contd.)

1883. Response of a Linear Rectifier to Signal and Noise.—W. R. Bennett. (*Journ. Acous. Soc. Am.*, Jan. 1944, Vol. 15, No. 3, pp. 164–172.)

From the Bell Telephone Laboratories. I.—Direct-current component of output, for input of sinusoidal signal with superposed random noise. The probability density function of signal voltage is found (eqn. 3): the corresponding probability density for the noise voltage is well known and is given in eqn. 4. The distribution of occurrence of the resultant instantaneous amplitudes of the combined noise and signal voltages is then computed by the rules of mathematical probability (eqn. 7). The assumption that the rectifier is linear then leads directly to an integral (eqn. 9) which yields the average current obtained from the rectifier (eqn. 10: eqn. 11 gives the ascending series for signal power small compared with noise power, eqn. 12 the asymptotic series available when the signal is large).

II.—Spectrum of output, by use of multiple Fourier series. "The response of the rectifier is thus seen to consist of all orders of modulation products of signal and noise. In a typical case of interest the band of input frequencies is relatively narrow and centered about a high frequency, while the output band includes only low frequencies. In such a case the important components in the output are the beats between signal and noise components and between noise components. The d.c. component is present in the output only if the pass band of the system actually includes zero frequency; we have already computed its value in Section I, but we will derive it again by the method used here, as a check" [eqn. 30, identical with eqn. 10]. The writer then calculates the spectra of the energy resulting from beats between signal and noise inputs (eqns. 38, 39) and between individual noise components (eqns. 41–45). "The products just considered give a fair approximation for the problem of detection of a r.f. band of signal and noise followed by audio amplification. Certain other products should also be added to obtain higher accuracy." This is done in Fig. 4, where curve *A* shows, as fractions of the limiting value when the mean signal input power is made indefinitely large compared with the mean input noise power, the calculated noise power (signal/noise and noise/noise components) when noise and signal are applied in a relatively narrow r.f. band; while curve *B* is obtained from curve *A* by adding the contributions from fourth- and sixth-order products. It is seen that this inclusion of the higher-order products improves the agreement between the calculated results and the experimental values of F. C. Williams (1364 of 1937), shown as circles; though the value of the intercept is unaffected by them. Williams gives the intercept (at zero signal power) as 35%, while the theoretical value deduced here is $\pi/8$, or 39.27%. The writer stresses that his analysis applies strictly to purely resistive networks, whereas the conventional radio detector circuit (used by Williams) introduces a reactive element. Ragazzini's approximate solution (390 of 1943) would give an intercept of 50%.

1884. Analysis of Rectifier Circuits [giving Essential Formulae in Systematic & Unified Form for Engineers: with Characteristic Curves].—E. F. Christensen & others. (*Elec. Engineering*, Dec. 1943, Vol. 62, No. 12, p. 546: summary only.)

1885. Replacement of Grid-Bias Batteries by Glow-Discharge-Lamp Circuits, for Amplifier Valves used for D.C. Voltage Stabilisation.—A. Sasse. (*Funk*, No. 5/6, 1943, p. 57 onwards.)

1886. Analysis and Characteristics of Vacuum-Tube Thyratron Phase-Control Circuit.—S. C. Coroniti. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, pp. 653–656.)

"By substituting a vacuum tube for the resistance in the *RC* component of a phase-control circuit such as Fig. 1, a small grid voltage can be made to control effectively large electrical power" (Fig. 2). It is shown that the effective phase angle between the plate/cathode and grid/cathode voltages is influenced by the direct rectified current flowing through the control valve. The effect of the thyratron grid resistance on the stability of operation is discussed, and curves are given to illustrate the degree of control by various types of valve: the degree of control can be varied by careful selection here (Fig. 8).

1887. Investigation of Multiple-Regulation Systems with the Help of the Operational Calculus.—A. Leonhard. (*Elektrot. u. Masch:bau*, 9th July 1943, Vol. 61, No. 27/28, p. 329 onwards.)

1888. On an Expression, valid at All Frequencies, for the Resistance of an Air-Cored Solenoid.—P. Pellé. (*Rev. Gén. de l'Élec.*, Feb. 1943, Vol. 52, No. 2, p. 57 onwards.)

1889. The Influence of Losses on the Properties of Electrical Networks.—J. F. Schouten & J. W. Klüte. (*Philips Tech. Rundschau*, 1942: long illustrated summary, in German, in *Bull. Assoc. Suisse des Élec.*, 22nd Sept. 1943, Vol. 34, No. 19, pp. 578–580.)

The original paper was referred to in 1396 of 1943. The two methods there mentioned are (A) the theoretical process named by the writers "the method of the perpendicular derivatives," from the geometrical representation (not dealt with in the summary) of the Cauchy–Riemannian equations used, and (B) the "soap-bubble-film" or "rubber-membrane" method based on the Laplacian equations derived from the same C.–R. equations.

(A). If the impedance of an ideal inductance is given by $Z = \mathrm{j}\omega L$, that of an inductance with losses is represented by $Z = R + \mathrm{j}\omega L$: similarly, if the ideal condenser admittance is $Y = \mathrm{j}\omega C$, that for a condenser with losses is $Y = G + \mathrm{j}\omega C$. Introducing the loss equivalent of the coil $\rho = R/L$ and that of the condenser $\gamma = G/C$, we obtain $Z = (\rho + \mathrm{j}\omega)L$ and $Y = (\gamma + \mathrm{j}\omega)C$. Making, for the moment, the assumption that $\rho = \gamma = k$, we have $Z = (k + \mathrm{j}\omega)L$ and $Y = (k + \mathrm{j}\omega)C$. Then if we know any property whatever of the ideal network as a function of the argument $(\mathrm{j}\omega)$—for example the propagation constant $\eta = \alpha + \mathrm{j}\beta$—we need only replace the argument $(\mathrm{j}\omega)$ throughout by the expression $(k + \mathrm{j}\omega)$ in order to obtain the property of the network with losses. Thus if $\eta_0 = f(\mathrm{j}\omega)$, then $\eta_k = f(k + \mathrm{j}\omega)$. If $f(\ldots)$ is an analytical function of the argument, the Cauchy–Riemann equations ($\partial\alpha/\partial k = \partial\beta/\partial\omega$; $\partial\beta/\partial k = -\partial\alpha/\partial\omega$) are valid. If k is small, we can develop α and β for a given ω into a Taylor's series in k, and break off after the second term; obtaining finally, with the help of the above C.–R. equations, the results $\alpha(k) = \alpha(0) + k \,.\, \partial\beta(0)/\partial\omega$ and $\beta(k) = \beta(0) - k \,.\, \partial\alpha(0)/\partial\omega$, so that the actual attenuation equivalent is greater than the ideal by the term $k \cdot \partial\beta(0)/\partial\omega$, and the actual phase constant is smaller than the ideal by the term $k \cdot \partial\alpha(0)/\partial\omega$. Both the supplementary terms are easy to calculate when the properties of the ideal network are known.

The objection to the above method lies in its assumption that $\gamma = \rho$, which is hardly ever true; generally ρ is much larger than γ. If in this case we put $k = \frac{1}{2}(\rho + \gamma)$, the above results are considered to hold good to a first approximation; the neglected inequality of γ and ρ only produces a slight displacement of frequency. The writers illustrate the application of the method by the calculation of a simple (basic-type) low-pass filter (Fig. 1): by further examples not given in the summary, including a low-pass filter of the transformed type, they show that it can be applied successfully also to networks with complicated α and β characteristics.

(B). From the Cauchy–Riemann equations already given, two Laplacian differential equations are obtained: $\partial^2\alpha/\partial k^2 + \partial^2\alpha/\partial\omega^2 = 0$ and $\partial^2\beta/\partial k^2 + \partial^2\beta/\partial\omega^2 = 0$. For small values of the differential quotients $\partial\alpha/\partial k$, etc., it can be shown that the differential equation of the "soap-bubble film" ("minimum surface"), and also that of the rubber membrane, are practically the same as the Laplacian equations. Here, as with the latter, the solution for the interior of a closed space curve is determined unequivocally by the values of the function at the edges, so that if the edge curves are known, the $\alpha(k,\omega)$ and $\beta(k,\omega)$ surfaces can be represented by soap-film or rubber membrane. As, however, the assumption of slight slopes for the α and β surfaces is hardly fulfilled, an exact picture is not to be expected, but only a general idea. The method is illustrated by application to the same basic-type low-pass filter as before: Figs. 2, 4 show rubber-membrane models, while Fig. 3 shows the soap-film model corresponding to Fig. 2. "The original paper contains, besides further interesting examples of the application of this model method, some brief remarks on the internal connection between attenuation equivalent and phase constant."

1890. On the Equivalent Diagram of a Bridge Connection with Non-Ideal Differential Transformer [Auto-Transformer & Two-Winding Transformer: Diagrams taking into account the Leakage, Leak Inductance, etc., Neglected in Simple Equivalent Diagrams but often Not Negligible, particularly in Wide-Band Working: Simplified Diagrams obtained by treating High, Medium, & Low Frequencies separately: Experimental Confirmation: Relation between Attenuation in Stop Direction & Attenuation Distortions in Pass Direction: Application to Double-Fork Neutraliser].—A. Dold & G. Kalckhoff. (*T.F.T.*, Aug. 1943, Vol. 32, No. 8, pp. 173–180.)

1891. Corrections to "Networks with Predetermined Network Matrices" [1537 of May and *T.F.T.*, July 1943, Vol. 32, No. 7, p. 144 onwards].—W. Bader. (*T.F.T.*, Aug. 1943, Vol. 32, No. 8, p. 180.) A large number of author's corrections which escaped attention owing to difficult working conditions.

1892. Correction to Equation in "Radio Engineers' Handbook" and in "Network Theory, Filters, and Equalisers."—F. E. Terman. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, p. 656.) The correction was wrongly given in the note referred to in 776 of March. For a review of the book *see* 977 of March.

1893. "Method for the Solution of Transient Circuits whose Steady State can be written by Millman's Network Theorem": Correction to Equation.—N. E. Polster: Millman. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, p. 656.) *See* 779 of March.

1894. The Calculation of Transient Processes in Simple Circuits with Voltage-Dependent Resistances.—H. Meyer. (*Brown–Boveri Mitteil.*, Nov./Dec. 1942: short summary, in German, in *Bull. Assoc. Suisse des Élec.*, 3rd Nov. 1943, Vol. 34, No. 22, p. S.43.)

1895. Practical Calculation of Electrical Transients on Power Systems [Method of "Zeros & Slopes" based on Heaviside Expansion Theorem].—R. D. Evans & R. L. Witzke. (*Elec. Engineering*, Nov. 1943, Vol. 62, No. 11, Transactions pp. 690–696.)

1896. A Method for determining the Normal Modes of Foster's Reactance Networks [Method of finding the Zeros of a Rational Function having Alternate Zeros & Poles, if Poles are known, and *vice versa*: Advantage over Other Methods: Application to Other Circuits & to Other Rational Functions].—W. R. Le Page. (*Elec. Engineering*, Nov. 1943, Vol. 62, No. 11, Transactions pp. 674–678.) A summary was referred to in 2681 of 1943. *Cf.* Maa, 3302 of 1943.

1897. Deriving the Parameters of Filters.—C. R. Burrows. (*Elec. Engineering*, Nov. 1943, Vol. 62, No. 11, p. 516.)

"It is very disappointing to have such authorities as Schelkunoff, Slater, and Terman publish the well-written books they recently have and still base their derivation of the parameters of the ladder-type filter on the full section as done by Campbell, the inventor of this type of filter, when the half section is so superior pedagogically", as indicated in this letter.

1898. The Determination of the Shape of a Repetition Signal at the Output of a Band-Pass Filter.—P. N. Ramlau. (*Automatics & Telemechanics* [in Russian], No. 3, 1941, pp. 43–48.)

A mathematical analysis is given of the transmission of a repetition signal through a communication channel. It is assumed that the signal consists of a number of impulses and that the communication channel has the attenuation characteristics of an ideal band-pass filter. Methods are indicated for calculating the shape of the signal at the output of the channel.

1899. Quartz Crystals with Adjustable Frequency ["Vario-Crystals"].—Zobel. (*See* 1996.)

1900. On the Design of Screening [with Nomogram].—K. Nentwig. (*E.T.Z.*, 11th March 1943, Vol. 64, No. 9/10, p. 128 onwards.)

TRANSMISSION

1901. The Ultra-High-Frequency Oscillations and Their Generation [Survey for the Practical Man, neglecting Some of the Latest Developments, but including Habicht's Work on Push-Pull "Triplet" Systems of Lecher Wires, compressed into Spirals & Rolls ("Wirbelspule," primarily for Medical Oscillators, 2–8 m wavelengths)].—G. Lohrmann. (*Bull. Assoc. Suisse des Élec.*, 20th Oct. & 3rd Nov. 1943, Vol. 34, Nos. 21 & 22, pp. 649–652 & 686–690: in German.)

1902. Generator for Ultra-Short Waves.—" Patelhold " Patent Company. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 93, Fig. 4.)

Swiss Patent 222 091, applied for 10/11/41. " A resonator composed of two coaxial cylinders closed on both sides contains two double grids 5, 6, arranged diametrically and near a potential antinode: the first is used for velocity-modulation, the second for the balancing-out of energy. The inner tube acts as the drift tube, and may contain a hollow cylinder 11 for additional velocity-modulation. The removal of energy is accomplished by the probe 12."

1903. Arrangement for the Protection of Ultra-Short-Wave Transmitters or Receivers against Mechanical or Weather Effects.—W. Kleinsteuber. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 95, Fig. 12.)

A Julius Pintsch patent, D.R.P.731 177. The apparatus, sunk below ground, is covered by a plate 6 which is very transparent to u.s. waves and whose thickness, in order to avoid attenuation or reflection of the beam 3, is made equal to $N \cdot \lambda/2 \cdot 1/\sqrt{n^2 - \sin^2\delta}$, where N is a whole number, λ the wavelength in air, n the index of refraction of the plate material, and δ the inclination of the ray direction to the normal to the plate.

1904. Arrangement for Keying a High-Frequency Feeder.—K. Schmid. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 63.)

A Telefunken patent, D.R.P.731 060. " For keying a h.f. line connecting a transmitter to its load, a tie-line [stub] is used having a length of about $\lambda/8$ and terminated by an oscillatory circuit which is so detuned, inductively and capacitively, in the keying rhythm, that its reactance in both key positions is equal to the characteristic impedance of the tie-line."

1905. Arrangement for Single-Sideband Transmission.—K. Küpfmüller. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 61.)

A Siemens & Halske patent, D.R.P.730 416, applied for 15/11/40. " To make the frequency requirements for the transmission of telegraphic and television signals, etc., only about half as great as in ordinary alternating-current telegraphy, the carrier frequency is displaced from the middle of the transmitted frequency band. The transient process can then be resolved into a rapid and a slow component, the latter being suppressed."

1906. Crystals of Quartz [Survey of Development].—Mason. (*See* 1995.)

1907. Quartz Crystals with Adjustable Frequency [" Vario-Crystals "].—Zobel. (*See* 1996.)

1908. Matching: III—Transmitter Aerial Couplings.—S. W. Amos. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 86–87.) For previous parts *see* 1154 of April.

RECEPTION

1909. Receiving Method with a Magnetic-Field Valve worked at Electron-Rotation Resonance.—H. Jungfer. (*E.T.Z.*, 18th Nov. 1943, Vol. 64, No. 45/46, p. 610.) Summary of the paper dealt with in 441 of February.

1910. Arrangement for the Protection of Ultra-Short-Wave Transmitters or Receivers against Mechanical or Weather Effects.—Kleinsteuber. (See 1903.)

1911. Receiver for Frequency-Modulated Waves [Low Noise Voltage obtained by making the Derived Modulation Voltage control the Receiver Band Width so that Small-Frequency-Deviation Signals are received with a Narrow Band Width and Large-Deviation Signals with a Broad Band Width].—E. H. Plump. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 63.) A Siemens & Halske patent, D.R.P.731 416.

1912. Response of a Linear Rectifier to Signal and Noise.—Bennett. (*See* 1883.)

1913. The Rectifying Property of Carborundum [Experimental Investigation paying Special Attention to the Great Difference between the Green & Black Types and the Avoidance of Two Contacts in Series—Points neglected even in Recent Researches].—J. T. Kendall. (*Proc. Phys. Soc.*, 1st March 1944, Vol. 56, Part 2, No. 314, pp. 123–129.)

From the Met.-Vick. laboratories. The writer's results with the two types confirm the findings of Gokhberg and of Losev that from the direction of rectification the green must be classified as an " excess " semiconductor and the black as a " defect " semiconductor [sometimes called " reduction " and " oxidation " semiconductors respectively; the former gives a negative Hall constant, and increases its conductivity on reduction, which produces " excess " metal atoms whose valency electrons become available for current conduction: the latter type, on the other hand, gives a positive Hall constant and its conductivity increases with increasing oxygen: *see* Hartmann, 697 of 1937 and back reference. For Wilson's book, referred to in the present paper in this connection, *see* 806 of 1940].

Regarding the second point, several recent workers have simply clamped their crystals in metal electrodes and measured the over-all rectification. " If there is no volume rectification this simply gives the difference between the rectification at the two contacts, and the results can become very misleading. As shown below, even a soldered contact does not have under all conditions a resistance small compared with that of a cat's-whisker contact." Fairweather (1242 of 1943) avoids this difficulty, but his method is comparatively insensitive, especially for small voltages. The present writer uses a special fused carbon contact with an exceedingly low resistance.

His measurements show that " all the rectification takes place at the contact surface, and that any volume rectification (if it exists) is a second-order effect." In his final theoretical discussion he states that the cause of the " excess "- and " defect "- semiconductor natures of the two types of carborundum is obscure: " carborundum is certainly an ' impurity ' semiconductor, but the identity of the impurities is not known." Discussion of various " barrier-layer " theories of contact rectification leads to the conclusion that the current theories do not apply satisfactorily to carborundum: a possible solution may be found in Losev's work, which indicated that while the bulk of the crystal may have " defect " conductivity, the outer layer will have " excess " conductivity, the " barrier layer " occurring at the junction. " It does seem necessary to postulate some sort of *physical* barrier layer, for the formation of an *electrical* barrier seems ruled out by the apparently instantaneous response of the carborundum rectifier to short impulses."

1914. The Subscriber's Auxiliary Unit for High-Frequency Telephone-Network Broadcasting.—Werthmüller. (*See* 2056.)

1915. INDUSTRIAL INTERFERENCE : THE CHANCE THAT IS BEING MISSED.—"Diallist." (*Wireless World*, March 1944, Vol. 50, No. 3, p. 94.)

Supplement (prompted by I.E.E. address by Chairman of Installations Section) to the argument dealt with in 1189 of April. ". . . . twenty-four different appliances intended to be plugged-in to wall sockets. And, of these, nine at any rate are well-known causes of interference," while even the long list makes no mention of many sure-to-be-popular appliances, notorious as interferers, such as the shaver, the egg-whisk, and the cocktail shaker. The exceptional nature of the present opportunity is stressed.

1916. USKON RUBBER [Synthetic Material with Volume Resistivities down to 5000 Ohms/cm³ : as Dissipator of Static Charges, etc.].—U.S. Rubber Company. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, p. 380.)

1917. ON THE OCCURRENCE OF ACOUSTICAL FEEDBACK IN SHORT-WAVE RECEPTION WITH HETERODYNE RECEIVERS, AND POSSIBILITIES OF HINDERING IT [Mechanical & Electrical Influences on Capacitance-Fluctuations of the Variable Condenser : Production of a Frequency-Modulated Oscillation in Oscillator : etc.].—W. Piltz. (*E.N.T.*, Jan. 1943, Vol. 20, No. 1, p. 17 onwards : short summary in *Bull. Assoc. Suisse des Élec.*, 6th Oct. 1943, Vol. 34, No. 20, p. S.41.)

1918. NEUTRALISATION OF SCREEN-GRID TUBES TO IMPROVE THE STABILITY OF INTERMEDIATE-FREQUENCY AMPLIFIERS.—C. A. Hultberg. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, pp. 663–665.)

"The original s.g. tube, by virtue of its low grid/plate capacitance, was intended to eliminate the need for neutralisation. Subsequent improvements in tubes and circuits has brought about such high possible gain-levels that even the small grid/plate capacitances again provide sufficient [wrongly printed "insufficient"] reaction to make the application of Hazeltine's principles [published when s.g. valves were not available] advantageous." Practical means for injecting the necessary phase-opposed voltage are described and a few of the limitations outlined. "The advantage of much less frequency shift with automatic frequency control or manual gain control, plus greater ease of production alignment, is very noticeable when several narrow-pass-band stages are cascaded", and "in numerous applications it is felt that the increased stability obtainable more than justifies the inclusion of the additional circuit components required".

1919. RADIO DATA CHARTS : NO 15—I.F. TRANSFORMER DESIGN.—J. McG. Sowerby. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 82–85.)

1920. DESIGN CALCULATIONS OF THE THREE-POINT-BALANCE CIRCUIT FOR THE TRACKING IN SUPERHETERODYNE RECEIVERS : PART II.—K. Fränz. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, pp. 44–50.)

"The process given in an earlier work (3575 of 1942 [and 3369 of 1943—translation]) for the systematic calculation of tracking, which gave tracking curves of the type of Fig. 1 in which the four maximum percentage errors (two at the ends and two in the interior of the reception band) are equal, is here extended. Curves are now given for the convenient calculation of the tracking error and for the design of the usual circuit according to Fig. 2 for h.f. variations v_h and oscillator-frequency variations v_o conforming to $1.2 \leqq v_h \leqq 3.8$ and $1 \leqq v_o \leqq v_h$ [the "h.f. variation" v_h is the ratio of the frequencies at the beginning and end of the scale]. In this way practically all receivers are covered in which the oscillator frequency ω_o lies above the resonance frequency ω_h of the h.f. circuits.

"The curves are also applied to the calculation of three-point balancing circuits which depart from the most commonly used circuit of Fig. 2 : for example, the circuit of Fig. 3, which contains supernumerary trimming condensers (*i.e.* more than are necessary for the obtaining of three-point tracking) but which gives an exact tracking at three points and no more than three : and that of Fig. 4, with no supernumerary condensers. When the usual circuit of Fig. 2 leads to trimmer values which though possible in themselves are for some reason inconvenient, circuit 3 and its variants may provide a way out of the difficulty. They might be used, for instance, when circuit 2 offers little chance of introducing temperature-compensation, or when the taking into account of various unavoidable circuit capacitances makes it necessary to use a more complicated equivalent circuit. Finally, an extension of the calculating process is given which enables the hitherto excluded limiting case of $v_o = 1$ to be dealt with in the numerical calculations of the curve material".

It is pointed out at the end of the paper that in the tracking of receivers calculated by these formulae, contrary to the older methods, the actual "variation" of the oscillator circuit coincides with its nominal variation, while the h.f. circuit is to be detuned, in the initial and end positions of the variable condenser, by the amount of the tracking errors taken from the curves of Fig. 5 ; negatively for the initial frequency (variable condenser at its minimum) and positively for the end frequency (variable condenser at its maximum). "Negative" detuning means that the signal frequency is smaller than the resonance frequency.

As already mentioned, the present paper covers receivers in which the oscillator frequency is higher than that of the h.f. circuits. The less common case when this is reversed will be dealt with in a supplement.

1921. RECEIVER WHOSE LOW-FREQUENCY STAGES ARE USED FOR GRAMOPHONE REPRODUCTION.—H. Wilke. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 95.)

A Telefunken patent, D.R.P.732 752, applied for 28/3/40. "A voltage negative-feedback is provided which simply produces the desired frequency characteristic for gramophone reproduction (bass reinforcement) and is made ineffective for broadcast reproduction : it works with a voltage divider (for the amplified alternating voltage) which contains the pick-up connected between control grid and cathode. The bass reinforcement can thus be regulated without affecting the amplification of the higher frequencies : the connection described for the pick-up produces an equalising effect on its resonance peaks."

1922. SERVICEMEN'S ORGANISATION [Need for Institute or Society, and Creation of "Their Own Standards"].—S. Goldstein. (*Wireless World*, March 1944, Vol. 50, No. 3, p. 75.)

AERIALS AND AERIAL SYSTEMS

1923. THE PLOTTING OF ELECTROMAGNETIC FIELDS BY MEANS OF "TEST BODIES."—Goubau. (*See* 1870.)

1924. CORRECTION TO "THE SOLID-CORE COAXIAL CABLE AS A HIGH-FREQUENCY LINE".—L. Rohde. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 64.) *See* 814 of March. The 6 lines under Fig. 13 should precede the 10 lines between Figs. 12 and 13.

1925. Double Lines for Decimetric Waves.—E. Missler. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 63.)

A Telefunken patent, D.R.P.730 730, applied for 11/12/40. "To avoid reflection at bends, the spacing at those points is so altered, compared with the straight parts, that the characteristic impedance remains the same. In the case of coaxial lines the inner conductor is bent more sharply than the axis of the line, and is displaced outwards".

1926. Arrangement for Eliminating the Effect of Sheath Waves in Ultra-Short-Wave Installations.—H. Schuster. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 63.)

A Fernseh Company patent, D.R.P.731 313. In Fig. 6 the screened line linking the dipole to the receiver has its inner conductor 2 connected to a point 3 on the dipole, between a potential node and antinode, while the sheath 4 is connected to a potential node on the dipole through a lead 5 whose electrical length equals a whole multiple of $\lambda/2$.

1927. Group-Radiator Arrangement for Ultra-Short Waves.—J. Pintsch Company. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 63.)

D.R.P.731 417, applied for 23/8/39. "The box-shaped cavity radiators (Fig. 7, which is printed upside-down), with their adjacent walls touching, are coupled to the coaxial feeder 6 by the slots 2, and are coupled electrically to each other by the windows 9 in the common walls, so that all the radiators oscillate with the same amplitude".

1928. Antenna Arrays around Cylinders [for the Broadcasting of Ultra-Short Waves: the Effect of the "Support" (Empire State Building Mooring Mast, Chrysler Building Spire, etc.), for Arrays of Vertical Dipoles and of Horizontal Dipoles with Axes on Circumference of Circle or pointing Radially Outwards].—P. S. Carter. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, pp. 671–693.)

Including many diagrams showing calculated horizontal and vertical radiator patterns; tabulated formulae for arrays of all three types, with various numbers of elements and fed in several different ways; and a rigorous solution of Maxwell's equations for a dipole near a long perfectly conducting cylinder (using the reciprocity theorem to avoid infinite integrals in the terms of the Fourier–Bessel series). A final section deals with the case of a dielectric cylinder, and briefly with that of a cylinder with a complex dielectric constant. Among the various practical points brought out is that although a nearly circular horizontal pattern may be obtained even from arrays of considerable radius, by using a sufficient number of units, the radiation at high angles to the horizon increases greatly with increase in radius: to avoid this waste of energy it becomes necessary to use two or more tiers. *Cf.* Oberhettinger, 1929, below.

1929. On a Boundary-Value Problem of the Wave Equation in Cylindrical Coordinates [Contribution to the Problem of the Effect of a Metallic Surface on the Field due to a Source of Electromagnetic Radiation near the Surface].—F. Oberhettinger. (*Ann. der Physik*, 26th June 1943, Vol. 43, No. 1/2, pp. 136–160.)

Cf. Carter, 1928, above. The paper deals with the radiation field excited by an elementary dipole oscillating parallel to the axis of an infinitely long metal cylinder of circular cross-section. Two very different types of reflected wave are obtained, according to whether the dipole is inside or outside the cylinder: for the former case *see* also Buchholz, 2402 of 1941, and Weyrich's paper therein quoted. In the present work, Part I investigates the case of the internal dipole, on the basis of a formula (originating from Poincaré) by which the reflected field is calculated from the currents flowing along the cylindrical shell. The current and field distributions can here be represented explicitly by cylindrical and trigonometrical functions. It is first shown (eqn. 21) that the current distribution on the cylinder surface, due to the dipole, is made up from a sum of undamped current waves, flowing along the shell in both directions, and a sum of exponentially decaying components along the shell. Finally, eqn. 23 for A_{z2} gives the vector potential for the secondary field. By the addition of this expression to the expression for the primary field, A_{z1} in eqn. 10, the resultant field $A_z = A_{z1} + A_{z2}$ in the internal space is fully determined.

Part II deals in a similar way with the dipole outside the cylinder, and eqn. 28 gives the current distribution and eqn. 32 the resultant field, both in integral form. The solution obtained in the form of eqn. 32 is not so convenient for numerical evaluation as the final equation for the internal dipole, eqn. 23, which took the form of a series of terms of products and quotients of tabulated functions. But eqn. 32 can, at any rate for large values of the distance R of the point of observation from the cylinder and dipole, be developed into an asymptotic series, the first term of which provides an approximate representation of the field. Figs. 6–9 show the calculated horizontal radiation patterns for a dipole at a distance a from a cylinder of radius λ, when $a = 5\lambda/4$, $3\lambda/2$, $7\lambda/4$, and 2λ respectively.

1930. Antenna Theory and Experiment [Comparison of Formulae: Discussion of the Local Capacitance between the Input Terminals].—S. A. Schelkunoff. (*Journ. Applied Phys.*, Jan. 1944, Vol. 15, No. 1, pp. 54–60.)

"During the past ten years several approximate formulas for the input impedance of antennas have been obtained by: (1) Siegel & Labus, for cylindrical antennas [1934 Abstracts, p. 502]; (2) Hallén, for cylindrical antennas [2763 of 1939]; (3) Chu & Stratton, for spheroidal antennas [1888 of 1941 (Part III)]; (4) Schelkunoff, for antennas of any shape [1049 of 1942, and book (2295 of 1943)]. The work of Hallén has been extended by King & Blake, who published sets of impedance curves and tables [423 of 1943: the reference also includes Harrison's paper, 2720 of 1943], and obtained an explicit formula for the maximum resistance in the vicinity of $l = \lambda/2$, where l is the length of a vertical antenna just above ground.

"There is substantial disagreement between some of these formulas, and while it is possible and legitimate to express opinions on the relative goodness of various methods of approximation, experiment will have to play an important rôle in the decision for some time to come. . . . I can only say that in my judgment the method which I presented in references 4 and 5 [*loc. cit.*: based on approximate calculations of characteristic wave functions] will yield more accurate results than can be obtained from Hallén's formula, and that the experimental evidence, meagre though it is, supports my conclusion. . . ." But Hallén's basic idea of using an integral equation for solving the antenna problem, used in conjunction with the method based on characteristic wave functions, may yield valuable information. "But first of all Hallén's method of successive approximations has to be revised; one such revision is given in the following paper by Miss Marion C. Gray" [1931, below].

1931. A Modification of Hallén's Solution of the Antenna Problem.—Marion C. Gray. (*Journ. Applied Phys.*, Jan. 1944, Vol. 15, No. 1, pp. 61–65.)

Supplementary to Schelkunoff's paper, 1930, above. "It is shown that the introduction of a variable parameter $Z(z)$ in place of Hallén's $\Omega = \log(4l^2/a^2)$ modifies the numerical results considerably, and leads to much better agreement with experimental evidence"; it is pointed out that the series for $I(z)$ is still an asymptotic series, and it is conceivable that a different choice of parameter would prove even better.

1932. Typographical Corrections to "The Distribution of Current along a Symmetrical Centre-Driven Antenna" [817 of March].—King & Harrison. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, p. 697.)

1933. The Radiation Field of a Symmetrical Centre-Driven Antenna of Finite Cross-Section [or of Vertical Base-Driven Antennas over a Highly Conducting Plane].—C. W. Harrison, Jr., & R. King. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, pp. 693–697.)

This is the paper referred to in 2721 of 1943: it is a sequel to 1932, above. The present approach to the problem of determining accurately the distant field of such aerials, of unknown "effective" cross-section, is "first, to plot the observed distribution of current as measured, for example, using a wavemeter; and second, by a judicious application of the formulas for the current distribution in moderately thick cylindrical antennas, to obtain curves for the square root of the sum of the squares of the quadrature components of the current in antennas of several different radii. Then, by a curve-fitting process, an estimate of the 'effective' antenna cross-section is made in terms of an approximate equivalent circular cross-section (whether the actual cross-section be triangular, square, etc.). In this way one has achieved the desired end, namely that of obtaining satisfactory approximations for the quadrature components of the current in the actual antenna." The fields obtained in this paper apply exactly only to an aerial over a perfectly conducting earth: in the case of an imperfect earth the effects of the quadrature components of the radial currents flowing along the surface of the earth must be superimposed (Strutt, 1929 Abstracts, p. 329).

1934. The Receiving Antenna, *and* The Receiving Antenna in a Plane-Polarised Field of Arbitrary Orientation.—R. King & C. W. Harrison, Jr. (*Proc. I.R.E.*, Jan. 1944, Vol. 32, No. 1, pp. 18–34: pp. 35–49.)

(i) Authors' summary:—"After a discussion of the general problem of coupled antennas, the distribution of current in a centre-loaded receiving antenna with its axis in the plane of a linearly polarised electric field is derived. Distribution curves are shown for a wide range of lengths, thicknesses, and load impedances. A simple 'equivalent' circuit is obtained for the loaded antenna, for determining the current in the load. The 'effective length' for a receiving antenna is defined, and curves are shown for a wide range of lengths and several thicknesses. An expression for the power transferred to a matched load is derived, and curves for computing it are given for antennas over the same range of lengths and thicknesses. Optimum conditions are discussed."

(ii) Sequel to (i): "it also has an important bearing on the determination of the distant electric field of linear radiators of non-vanishing radius as analysed in two recent papers (1932 & 1933, above)." The analysis in (i) is extended to include arbitrary orientation with respect to a linearly or elliptically polarised field: thus bringing in "the highly important problem of a receiving antenna immersed in an electric field which is the resultant of one component due directly to the retarded action of currents in the transmitting antenna and of a second component due to the retarded action of periodically moving electrons in the ionosphere." The final two sections deal with the reciprocal theorem and the distant field of driven aerials, and an approximate method of determining the complex "effective length" of a receiving aerial.

1935. The Principle of Reciprocity in Antenna Theory.—M. S. Neiman. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, pp. 666–671.)

"The principle of reciprocity enables us to obtain all the characteristics of receiving antennas from the known characteristics of the transmitting ones, avoiding involved direct computing, and in a very simple manner," and gives "a convenient criterion for evaluating and explaining the peculiarities of receiving-aerial construction as compared with that of transmitting antennas, and *vice versa*." The formulae obtained show that in the case of strong interference (long, medium, and fairly short waves, where the required signal intensity is determined by the interference level and the receiver's amplifying capacity cannot be fully employed), the highest possible directivity is of equal importance in the transmitting and receiving aerials, the efficiency of the transmitting aerial is of considerable importance, whereas that of the receiving aerial, and its "coefficient of exploitation" (the ratio of the useful power taken from the aerial to the greatest useful power which it can give out to a correctly chosen load impedance) have no significance. On the other hand, for weak interference (very short and ultra-short waves, where the useful sensitivity of the receiver is limited by internal noises), while both directivities are again of equal importance, the efficiency and coefficient of exploitation of the receiving aerial are just as important as the efficiency of the transmitting aerial.

It is mentioned in passing that with strong interference, in certain cases, sharpness of directivity may be more important for the receiving than for the transmitting aerial (especially when steps can be taken to provide for "dead zones"). The additional way of selection furnished by a difference in the planes of polarisation is not dealt with. A final section deals with various non-linearities which may play a part in the performance of aerials.

1936. Matching: III—Transmitter Aerial Couplings.—S. W. Amos. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 86–87.) For previous parts *see* 1154 of April.

1937. The Use of High-Frequency Currents for Indicating the State of Icing on Overhead Lines.—E. A. Karpovich. (*Automatics & Telemechanics* [in Russian], No. 3, 1941, pp. 139–149.)

The theory and practice of using the change in the attenuation of an overhead line as an indication of the state of icing on it are surveyed. The survey is based mainly on foreign sources, although some results of observation carried out in Russia are also reported.

1938. The Strain on Overhead Communication-Lines under Ice Loading [with Table for Wires of Various Materials, Thicknesses, etc.].—W. Weiken. (*T.F.T.*, Aug. 1943, Vol. 32, No. 8, pp. 171–173.)

1939. Limiting and Breaking Spans of Ice-Loaded Overhead Telephone Wires, *and* The Heating

OF AERIALS FOR DE-ICING [without Damage to the Mechanical Properties].—K. Machens: Editorial. (*Europ. Fernsprechdienst*, 1942 : *E.T.Z.*, 11th March 1943, Vol. 64, No. 9/10, p. 129 onwards: short summaries in *Bull. Assoc. Suisse des Élec.*, 8th Sept. 1943, Vol. 34, No. 18, p. S.36.)

1940. PLYWOOD TUBES ["Plytube," for Aerial Masts, etc.].—Plymold Corporation. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, pp. 380–381.)

VALVES AND THERMIONICS

1941. MAGNETRON FOR THE SIMULTANEOUS GENERATION OF TWO OR MORE FREQUENCIES.—O. Schwede. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 61.)

D.R.P.730 246, applied for 2/6/39. "The resonant systems consist of short tubular lines, radial to the cathode K (Fig. 1) and closed at one end: they are tuned, some to the fundamental oscillation and some to the higher-frequency oscillation which is to be 'coupled out,' and form sectors of a composite metal body, their open ends acting as the anode segments A_1, A_2": the sketches help to make this explanation intelligible.

1942. ON THE BEHAVIOUR OF ELECTRON CURRENTS IN LONGITUDINAL ELECTRIC FIELDS.—H. W. König. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, pp. 76–86.)

"In many cases of practical application the flow of electrons may be considered, with good approximation, as plane. In such a flow, by the choice of a suitable system of coordinates, all field magnitudes except the magnetic field strength become dependent only on time and on one single coordinate of place. For this reason such processes can be described in a comparatively clear manner, particularly if each point in space is considered to have allocated to it only electrons of 'unequivocal' velocity, so that overtaking and reversing effects are excluded. Such an electron-flow is here spoken of, for short, as 'unequivocal.'

"It is the object of the present work to investigate the behaviour of an 'unequivocal', plane electron-flow, starting from the fundamental equations and omitting negligible terms only at those points where their omission seems necessary for the further development of the calculation or desirable in the interest of lucidity. The treatment of the problem—in contrast to Müller's work (1933 Abstracts, pp. 443–444)—is undertaken from the standpoint of 'local' considerations, as exemplified in Euler's equations of hydro-mechanics. To limit the length of the paper, elementary intermediate steps in the calculation are passed over, while more space is devoted to the physical interpretation of the results."

Author's summary:—"Starting with the fundamental equations [defining the electromagnetic field in the presence of charge-carriers: for the three vectors involved (the electric and magnetic field strengths and the carrier velocity) there are available the two Lorentz field equations and the law of force. Representing the specific charge of the carrier by k, these three equations may be written $\epsilon_o \,.\, \partial\mathfrak{E}/\partial t + e_o \mathfrak{v} \operatorname{div} \mathfrak{F} = \operatorname{rot} \mathfrak{H}$, $-\mu_o \,.\, \partial\mathfrak{H}/\partial t = \operatorname{rot} \mathfrak{E}$, and $\partial\mathfrak{v}/\partial t = k\{\mathfrak{E} + \mu_o[\mathfrak{v}\mathfrak{H}]\}$, if the mass variability is neglected], the differential equations of a plane electron flow are derived [eqn. 2 for E and v], and from these [by a technique given by Courant & Hilbert] its general integral is obtained [eqn. 18]. In this there appear two arbitrary functions, whose determination involves the taking into account of two boundary conditions. They require that at a point of discontinuity in the flow, due to the introduction therein of an ideal electrode (grid), the velocity and density of the charged particles suffer a uniform transition.

"The electric field strength F and velocity u appear in the solution as functions of the phase angle $\phi = \omega t$ and of a parameter ψ which is linked to the 'virtual' path-time angle $z = \omega x/v_o$ [so termed to distinguish it from the actual path-time angle $\psi - \psi_o$: top of p. 81], and also to the phase angle, by the 'path-time equation' [eqn. 23]. The quantity ψ represents in every case the actual path-time angle. The investigation of the 'path-time equation' as to the unequivocal nature of its solution with respect to ψ leads to the condition of the 'unequivocal' electron flow.

"As an example of application, an arrangement is considered in which a pure electron current I_o has superposed on it an alternating current $I \sin \phi$. The condition for 'unequivocal' flow leads to a relation between the current modulation $p = I/I_o$, the d.c. field strength at the point of entry of the electrons, and the 'virtual' path-time angle z, while the flow is subjected to the alternating field. This relation is closely connected with the position of the branching-point of the Riemann surface [Fig. 6] associated with the inversion function of the path-time equation.

"With the help of Lagrange's inversion law [ref. "5", and eqns. 45, 46] the path-time equation is solved, and from the power-series representation thus obtained a rapidly converging series of functions [eqns. 56, 58] is derived by a series-transformation process [p. 83, r-h column]. With the help of this rapidly converging series the potential at the electron path and the efficiency of the energy conversion are determined. In a particular numerical example an efficiency between 12 and 15% is found". Similar values are given by Müller & Rostas and by Kleinsteuber (406 & 1010 of 1942 : 3229 of 1942): "the calculations given in these papers differ from the present work chiefly in neglecting the space charge". The paper comes from the valve laboratory of the "Werner" Works for radio apparatus, of Siemens & Halske.

1943. THEORETICAL LIMITATION TO TRANSCONDUCTANCE IN CERTAIN TYPES OF VACUUM TUBES [where Space-Charge Effects play No Important Part ("Deflection" and "Stopping-Potential" Valves using Electric or Magnetic Control): Limits imposed by Thermal-Velocity Distribution].—J. R. Pierce. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, pp. 657–663.)

Among various points brought out, the transconductance of a deflection tube cannot be increased indefinitely by the use of electron-optical means for amplifying the deflection: except for aberrations, the limiting transconductance of such a tube is quite independent of the nature of the fields between the deflection region and the cut-off edge: from the point of view of gain and band-width, magnetic control is definitely inferior to electric, for any operating voltages likely to be encountered: for the special stopping-potential valve of Fig. 8, the calculated limiting transconductance (inserting plausible values into eqn. 37) is $g_m = 563\,000 \times 10^{-6}$ mho; of the three main reasons "why such startling values will not be attained in actual tubes" the most important is probably the effects of aberration, mis-alignment, variation of contact potential over the electrodes and of potential over the grids, in making the location and shape of the "sorting surface" vary throughout the beam.

1944. ON SPATIALLY PERIODIC DISTRIBUTIONS OF FREE-FALLING IONS AND ELECTRONS.—W. O. Schumann. (*Zeitschr. f. Phys.*, 1st Oct. 1943, Vol. 121, No. 11/12, pp. 629–646.)

"If, into a high-vacuum space, there enter on one side ions and on the other side electrons, it is well known that according to the values of the current-densities, entrance velocities, and applied voltages, very varied distributions of field strength, carrier densities, etc., may be formed in the space." Well-known examples are the case of the Langmuir "double-layer" and the positive-charge layer in front of the cathode, also dealt with by Langmuir. "If the phenomena are investigated for somewhat more general conditions, the interesting result is found that spatially periodic distributions are also possible: these are described in the following pages". For other recent work by the same writer *see* 785/6 of March.

1945. Calculation of Grid Control in Electronic Valves by means of an Equivalent Representation.—F. W. Gundlach. (*Arch. f. Elektrot.*, 31st Oct. 1943, Vol. 37, No. 10, pp. 463–477.)

"In the theoretical treatment of the processes in grid-controlled valves it is in general customary to replace the discharge space, divided up by the grid, by two diode gaps in series. This method can be applied with success whenever the grid structure is not important for the functioning of the valve; that is, when electron-optical effects at the bars of the grid do not seriously influence the distribution of flow. If space-charge or transit-time effects, or both together, appear in the valves, the dividing of the discharge space into equivalent diodes is the only serviceable solution, since at present it is only for diode gaps that the behaviour of the electron flow has been solved mathematically.

"The equivalent-diodes procedure is specially popular, in the literature, for the case where a space-charge cathode faces a grid and, beyond this, other electrodes. When it is merely a matter of calculating the magnitude of the cathode current, a large number of possible solutions are available for determining, from the geometrical dimensions of the valve and from the applied voltages, the electrode spacing and effective voltage for the equivalent diode (cathode/grid equivalent surface): *cf.* Benham, 148 [and 1388] of 1939, and Scheel, 1443 of 1935, and the literature references therein. When, on the other hand, the transit-time relations of the electrons have also to be reproduced correctly in this equivalent diode, there is only one possibility of solution. The same is true when space-charge effects between two grids have to be calculated, or when the equivalent-diodes diagram has to represent correctly also the individual component capacitances between various grids.

"The following considerations will show that it is possible to replace the grid of a valve by equivalent planes in such a way that the transit-time and field relations remain correct. The procedure also enables a particularly simple calculation of the penetration coefficient (durchgriff), agreeing in its results with the values known from the literature. With the help of this equivalent-diagram representation (numerical values for which are given in the case of grid designs in specially frequent use) space-charge and transit-time effects can readily be surveyed, as will be seen from two examples": a footnote mentions that Llewellyn's paper, 552 of 1936, deals with the transit-time problems in grid-controlled triodes with the assistance of a similar, but simplified, equivalent-diagram representation.

Author's summary:—"A plane grid may be represented as equivalent to two electron-transparent planes arranged parallel to each other at a distance d_g, conductively linked to each other and connected through a capacitance C_g to the grid terminal. The values of C_g and d_g depend simply on the geometrical construction of the grid and are independent of its environment so long as the neighbouring electrodes do not come too close to it. Similarly, a cylindrical grid may be replaced by two coaxial conducting cylindrical surfaces, and a spherical grid by two concentric conducting spherical surfaces.

"For plane grids with [round] parallel bars, for plane meshed grids, and for cylindrical [round-] bar grids, values for C_g and d_g are given [in both the first two cases it is seen from eqns. 9 and 13 for d_g that the value of d_g is such that the volume between the two conducting planes equals twice the volume of the whole amount of wire used in constructing the actual grid. In the first case, eqn. 11 for C_g can be written as at the top of p. 469, showing that C_g may be regarded as a cylindrical condenser in series with a parallel-plate condenser; in a rough physical interpretation the former may be taken as representing the capacitance between the grid bars and the mid-plane of the grid, the latter as representing the capacitance between the mid-plane of the grid and the equivalent surfaces. In the case of the plane meshed grid there is a second cylindrical condenser in parallel with the first, due to the bars in the other direction. For the more complex case of the cylindrical grid *see* pp. 471–472]. The diode gaps formed from the conducting equivalent surfaces of the grid and from the metallic surfaces of cathode and anode, represent—in the absence of any electron currents—capacitances which, together with the equivalent grid capacitance C_g, form the electrostatic equivalent diagram of the valve. From this equivalent diagram it is possible to derive all the component capacitances between the electrode terminals, and also the value of the 'durchgriff.' The voltages on the equivalent surfaces are the effective voltages acting on the grid.

"If, on the other hand, the diode gaps are traversed by electrons, they represent complex resistances. The effective voltages then coincide no longer with the electrostatic values, but they can be obtained by elementary calculation from the equivalent-diagram representation, as is shown for the [plane-electrode] triode in two examples" [pp. 474–477, the second example dealing with ultra-high frequencies].

1946. The Plotting of Potential Fields in the Electrolytic Trough.—R. Strigel. (*Bull. Assoc. Suisse des Élec.*, 15th Dec. 1943, Vol. 34, No. 25, p. S.51: short summary, in German, from *Arch. f. Tech. Messen*, Feb. 1943, Vol. 13, Part 140.)

1947. The Surveying of Electrostatic Fields [by the Toepler Method of Striae (Schlieren Method): Determination of Field Strength with the help of a Glow-Discharge Tube: the Making Visible of the Field Picture in an Insulating Liquid: Field Shape determined with the help of a Membrane: Field Picture made Visible by Pulses of Very Short Duration].—R. Strigel. (*Bull. Assoc. Suisse des Élec.*, 15th Dec. 1943, Vol. 34, No. 25, pp S.51–52: short summary, in German, from *Arch. f. Tech. Messen*, June 1943, Vol. 13, Part 144.)

1948. Negative Ions in Cathode-Ray Tubes, and Their Connection with the Oxide-Cathode Mechanism.—Schaefer & Walcher. (*See* 2003.)

1949. Spectrographic Determination of Thorium in Tungsten Filament Wire [over Range from 1.0% to 2.0%: Development of Method & Routine Control Analyses].—S. L. Parsons. (*Journ. Opt. Soc. Am.*, Dec. 1943, Vol. 33, No. 12, pp. 659–662.) From Sylvania Products, Inc. Chemical analysis is rather slow owing to the difficulty of putting tungsten into solution.

1950. New Tungsten Process [Crystalline Tungsten obtained directly from Ore by Electrolytic Process].—C. G. Fink & C. C Ma. (*Sci. News Letter*, 22nd Jan. 1944, Vol. 45, No. 4, p. 52.)

1951. THERMAL AND ELECTRICAL CONDUCTIVITIES OF TUNGSTEN AND TANTALUM.—Cox. (*Phys. Review*, 1st/15th Oct. 1943, Vol. 64, No. 7/8, pp. 241–247.)

1952. ZIRCONIUM [Applications & Production: the Philips Process for Ductile Zirconium].—Foote Mineral. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, pp. 379–380.) Apart from its employment as a getter, its low secondary emission suggests a considerable use for valve grids. Other applications are mentioned. For a Japanese paper on the metal *see* 1696 of 1942: and *cf.* 829 of March.

1953. ON THE MIGRATION OF INERT GASES THROUGH METALS [Investigation prompted by Recent Observations of the Taking-Up of These Gases by the Glow-Discharge Cathode].—W. Lumpe & R. Seeliger. (*Zeitschr. f. Phys.*, 24th Aug. 1943, Vol. 121, No. 9/10, pp. 546–559.)

1954. THE ACTIVATION OF THE PALLADIUM [Wire] SURFACE BY MEANS OF THE GLOW DISCHARGE.—R. Ulbrich. (*Zeitschr. f. Phys.*, 19th Aug. 1943, Vol. 121, No. 5/8, pp. 351–376.)

DIRECTIONAL WIRELESS

1955. ARRANGEMENT FOR THE SIMULTANEOUS DETECTION AND LOCATION IN SPACE OF SEVERAL THREE-DIMENSIONAL MOVING OBJECTS.—E. Montù. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 96.)

D.R.P.731 799, with priority of 31/1/36. "The equipment, which works on the re-radiation principle, includes two directional receivers continuously rotated on two axes at right angles to each other, in combination with two cathode-ray tubes in each of which the ray scans its screen in parallel lines once in every half-revolution of its particular receiver, so that every line corresponds to a definite angular region of the rotation of that receiver. By means of intensity modulation of the cathode rays, only those parts of the lines which are scanned during the reception of radiation are made visible. A mirror arrangement combines the two screens into a single image, in which the two scanning directions are at right angles to each other and each object located has corresponding to it a 'line cross' defined by space coordinates. Alternatively, both cathode rays may scan a common screen in directions at right angles to each other".

1956. METHOD AND EQUIPMENT FOR DETERMINING THE EXACT D.F. MINIMUM.—G. Guanella. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 96.)

Swiss Patent 221 970. "For obtaining the exact d.f. minimum by the comparison of two signal-magnitudes, the first signal, dependent on direction and requiring to be adjusted to a minimum, is combined with a second signal, also direction-dependent and obtained from the same point in such a way that it reaches a maximum as the first signal passes through its minimum, and is small for waves coming in laterally to the bearing direction. From these combined signals a control magnitude is derived which corresponds to the mean value (in time) of the product of both signal-magnitudes, and thus to small bearing errors in size and sign, while being little influenced by laterally incident disturbing waves such as would falsify the minimum. The two signal-magnitudes may be derived from two frame aerials or goniometer coils at right angles, rotatable about a common axis; for obtaining the correcting magnitude the two signals may be intermodulated with each other or taken to a wattmeter system".

1957. DIRECTION-FINDING AERIAL SYSTEM [Frame Aerial having, Symmetrically along Its Winding-Axis, a Dipole whose Capacitance is Increased by "Stars" of Wires at the Ends, which upset the Magnetic Field less than End Discs].—F. Bergtold. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 63, Fig. 5.) A Telefunken patent, D.R.P.730 798.

1958. GONIOMETER [Design & Arrangement of Field & Search Coils to give Specially Small Dimensions for Whole Instrument].—R. Lüderitz. (*Hochf:tech. u. Elek:akus.*, Aug. 1943, Vol. 62, No. 2, p. 64, Fig. 10.) A Telefunken patent, D.R.P.731 418.

1959. "PRINCIPLES OF AERONAUTICAL RADIO ENGINEERING" [Book Review].—P. C. Sandretto. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 79–81.) A previous review was referred to in 1899 of 1943.

ACOUSTICS AND AUDIO-FREQUENCIES

1960. SOUND STROBOSCOPE [Patent for Acoustical Counterpart of the Stroboscope].—L. M. Kurtz. (*Journ. Acous. Soc. Am.*, Jan. 1944, Vol. 15, No. 3, pp. 196–197.) Assigned to the General Electric Company.

1961. ON THE MODE OF ACTION OF THE ROCHELLE-SALT TORSIONAL STRIP IN THE DIRECT AND THE RECIPROCAL PIEZOELECTRIC EFFECTS.—H. Keller. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, pp. 66–73.)

A previous paper (75 of 1943: for other work by the same writer *see* 2393 of 1942 and 1138 of 1943) dealt with the flexural strip. Like this, the torsional strip in its most commonly employed form is made up of two plates of similar dimensions and similar crystallographic orientations. Its most important technical application is in sound pick-ups and sound recorders (*see* 1962, below), but it should also be useful in measuring technique for the investigation of torsional vibrations.

The writer begins by giving the appropriate part of Voigt's theory of the torsional elasticity of a crystal cylinder and the assumptions made in order to apply it to the present problem. The application then follows. Owing to the symmetrical properties of the hemihedral group of the rhombic crystal system and to the elongated cross-section of the double plates in question (for a fair amount of capacitance is desirable in order to avoid too high a reactance, and this capacitance is proportional to B/D, the breadth/thickness ratio of the combined strip), simplified elastic relations are obtained by the satisfactory approximation which is established between the elastic behaviour of the parallelepiped torsional strip and the more easily analysed cylinder of elliptical cross-section.

The treatment in the main part of the paper is confined to the case where the torsional axis is parallel to the crystallographic axis c (Figs. 2, 3), but in the final section it is shown that the alternative case, where it is parallel to the other crystallographic axis b, can be dealt with similarly and will yield similar results. Even the changes in the indices of the elastic and piezoelectric parameters which would seem to be called for by the rotation of the coordinate system are shown to be unnecessary, so that the formulae originally obtained apply to both the possible orientations. Where these latter do differ, however, is in mechanical strength, for the crystallographic plane {001} of the Rochelle-salt crystal is a "preferred" plane of splitting; in general, therefore, it is advisable to keep this plane parallel to the longest dimension of the torsional strip.

1962. NEW PIEZOELECTRIC DEVICES OF INTEREST TO THE MOTION-PICTURE INDUSTRY, *and* NEW MOTION-PICTURE APPARATUS : A NEW RECORDING MACHINE COMBINING DISC RECORDING AND MAGNETIC RECORDING, WITH SHORT REFERENCE TO THE PRESENT STATUS OF EACH.—A. L. Williams : S. J. Begun. (*Journ. Soc. Mot. Pic. Eng.*, Vol. 32, 1939, p. 552 onwards : Vol. 35, 1940, p. 507 onwards.) Referred to in 1961, above.

1963. A MULTIPLE-PLATE DOUBLE-PYRAMID CRYSTAL SYSTEM WITH LINEAR CHARACTERISTIC, FOR SOUND RECORDING AND REPRODUCTION.—E. Burkhardt. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 96, Fig. 15.) An A.E.G. patent, D.R.P.732 899. The double hollow pyramid is built from triangular plates so arranged that they act together in tending to flatten or sharpen the pyramids.

1964. DYNAMIC LOUDSPEAKER WITH METALLIC VIBRATING ELEMENT [Removal of Heat from Metallic-Tube Element improved by Extending the Middle and/or Outer Poles with Non-Magnetic Highly Conductive Metal, to equal the Length of the Tube].—S. Sawade. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 96.) A Telefunken patent, D.R.P.732 959, applied for 28/7/40.

1965. CONTROL ORGAN FOR COMPRESSED-AIR LOUDSPEAKER [Air Path divided into Long, Narrow Channels by Aerodynamically Designed Partitions whose Shape is varied by the Modulation].—O. Vierling. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 96.) D.R.P.733 305, applied for 14/5/39.

1966. IMPROVED LOUDSPEAKER INSTALLATION AT LIVERPOOL STREET [with Automatic Adjustment of Volume of Loudspeaker Groups in relation to Noise Level in Their Vicinity].—Central Rediffusion Services. (*Engineer*, 18th Feb. 1944, Vol. 177, No. 4597, p. 138 : *Engineering*, 18th Feb. 1944, Vol. 157, No. 4075, p. 140.) *See* also *Wireless World*, March 1944, Vol. 50, No. 3, pp. 73–74.

1967. NEW TYPE OF ANNULAR SOUND DISTRIBUTOR GIVING UNIFORM DISTRIBUTION OVER HORIZONTAL PLANE OF 360° & VERTICAL PLANE OF ABOUT 40° [Loudspeaker "combining Molecular Reflection & Collision instead of Collision Alone"].—Langevin Company. (*Gen. Elec. Review*, Jan. 1944, Vol. 47, No. 1, p. 61.)

1968. METHOD OF REDUCING THE ACOUSTIC FEEDBACK BETWEEN MICROPHONE AND LOUDSPEAKER.—L. Bialk & G. Stephanus. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, p. 94.)

A Telefunken patent, D.R.P.732 247, applied for 26/4/41. The sound field existing in the room is represented optically (for example on the screen of a c.r. tube) by the use of a note-frequency spectrometer. This frequency/sound-pressure curve is scanned and made to yield, by photoelectric means combined with a synchronously varied note generator, a control voltage for reducing the resonance peaks by introducing the necessary amounts of damping into the transmission path.

1969. TWO-WAY-WORKING INTERCOMMUNICATION INSTALLATION WITH LOUDSPEAKERS, AS A COMPONENT OF MODERN BUSINESS ORGANISATION [Description of the "Vivavox" System, by which Conversation is possible at Considerable Distances from Microphone/Loudspeaker Units].—(*Schweizer Arch. f. angew. Wiss. u. Tech.*, Nov. 1943, Vol. 9, No. 11, Supplement pp. 13–16.)

1970. RECORDING AND REPRODUCTION OF SOUND [I.E.E. Wireless Section Discussion].—G. F. Dutton & others. (*Electrician*, 3rd March 1944, Vol. 132, No. 3431, p. 182 : summary only.) For a longer summary see *Wireless World*, April 1944, Vol. 50, No. 4, pp. 114–115.

1971. ON A DEFORMATION OF THE MERCURY-VAPOUR DIRECT-CURRENT HIGH-PRESSURE ARC BY A SUPERPOSED ALTERNATING CURRENT.—Koch. (*See* 2110.)

1972. EXIT THE "TONE-ARM" [and Editorial Preference for Lowden's "Pick-Up Arm" over All Other Suggestions].—(*Wireless World*, March 1944, Vol. 50, No. 3, pp. 74–75.) A letter from A. C. Robb, and an Editorial note closing the correspondence dealt with in 1227 of April.

1973. "MANUAL OF DIRECT DISC RECORDING" [Book Review].—D. W. Aldous. (*Wireless World*, March 1944, Vol. 50, No. 3, p. 85.) This is the book referred to in 1226 of April.

1974. RECEIVER WHOSE LOW-FREQUENCY STAGES ARE USED FOR GRAMOPHONE REPRODUCTION.—Wilke. (*See* 1921.)

1975. NEW CONTRAST-EXPANSION CIRCUIT : APPLYING THE PRINCIPLE OF THE CATHODE FOLLOWER.—Felix. (*See* 1881.)

1976. WHAT IS SYNTHETIC SOUND ? [*Wireless World* Brains Trust Discussion, prompted by 1230 of April].—H. W. Page : Editor. (*Wireless World*, March 1944, Vol. 50, No. 3, p. 91.)

1977. EXPERIMENTS ON DR. POHLMAN'S MECHANICAL HEARING AIDS [the Diaphragm-Rod Prosthesis & the Acoustic Probe].—K. Lowy & N. Gross : Pohlman. (*Journ. Acous. Soc. Am.*, Jan. 1944, Vol. 15, No. 3, pp. 160–163.) Using the same technique (measurements of the electrical potential in cats) as in the investigation of the pellet type of artificial drum (2702 of 1942).

1978. EAR DEFENDERS [Account of Development & Testing of 50 Types, leading to Three Final Recommended Models, All using Neoprene, One having Pressure Equalising Insert].—N. A. Watson & V. O. Knudsen. (*Journ. Acous. Soc. Am.*, Vol. 15, No. 3, pp. 153–159.)

1979. THE GROWING APPRECIATION OF MUSIC AND ITS EFFECT UPON THE CHOICE OF MUSIC IN INDUSTRY.—A. Pepinsky. (*Journ. Acous. Soc. Am.*, Jan. 1944, Vol. 15, No. 3, pp. 176–179.) *Cf.* 3063 of 1943.

1980. SOME EXPERIMENTS ON AN "ELEPHANT" BELL [Design giving Auditory Impression of a Much Lower Pitch than the Size and Actual Component Frequencies would appear Capable of Producing].—H. D. Brailsford. (*Journ. Acous. Soc. Am.*, Jan. 1944, Vol. 15, No. 3, pp. 180–187.)

1981. A MACHINE FOR HARMONIC SYNTHESIS [Simple Ink-Recording Apparatus with Oil-Filled Cylinders having Cam-Driven Pistons].—A. Shilton. (*Proc. Phys. Soc.*, 1st March 1944, Vol. 56, Part 2, No. 314, pp. 130–132.)

1982. THE PERMEABILITY OF DYNAMO SHEET-IRON TYPE IV AT NOTE FREQUENCIES.—Feldtkeller. (*See* 2043.)

1983. THE PROBLEM OF REDUCTION OF VIBRATIONS BY USE OF MATERIALS OF HIGH DAMPING CAPACITY [and Methods reconciling High Damping with High Mechanical Quality].—A. Gemant. (*Journ. Applied Phys.*, Jan. 1944, Vol. 15, No. 1, pp. 33–42.)

1984. THE SOUND FIELD OF A RADIATOR IN A LAYER OF MEDIUM WITH ACOUSTICALLY "SOFT" AND ACOUSTICALLY "HARD" BOUNDARIES [*e.g.* Water Medium bounded by Air & Hard Ground respectively].—H. Stenzel. (*Ann. der Physik*, 26th June 1943, Vol. 43, No. 1/2, pp. 1–31.)

Author's summary:—"Using the method given by R. Weyrich in a paper on the propagation of electromagnetic waves (1928 Abstracts, p. 516), the present work derives general formulae for the sound field of a radiator in a layer of medium bounded by two planes, which may be either acoustically hard or soft. For the calculation of the near field on the axis of symmetry the general formulae are not competent [eqns. 14 a–d, which are generally valid so long as r, one of the cylindrical coordinates of the point of observation, is not zero: when it is zero, the formulae fail owing to the Hankel function H_0^1 $(k_\nu r)$ becoming infinite] and a special investigation is necessary [using the mirror-image principle: section 2].

"As a practical example, the case of a thick layer of medium is first worked out, only a single, acoustically soft boundary being considered [radiator below the surface of deep water, so that the influence of the ground boundary can be neglected and only that of the "soft" air boundary taken into account]; the sound field is represented graphically for the cases where the depth of the radiator below the surface is $d = \lambda_0/2$, λ_0, $3\lambda_0/2$, and $2\lambda_0$ [Figs. 5–8]. Next, the sound field along the axis of symmetry is calculated for a shallow layer of medium (depth $h = \lambda_0/2$, λ_0, $3\lambda_0/2$, $2\lambda_0$, and $10\lambda_0$) for a radiator at a distance $z_1 = 0.9h$ from the acoustically hard ground, the upper boundary being soft. The results are represented graphically [Figs. 10, 9, 11, 12 (incorrect caption), and 13]. Finally, the formulae are derived for the radiated acoustical output in the case of a soft upper boundary and a hard lower boundary, and are illustrated by individual examples". On the assumption that for the four depths of water $h = \lambda_0/2 \ldots 2\lambda_0$ the radiator gives out the same power, four different factors are obtained (p. 30) by which the numerical values given in Figs. 9–12 must be multiplied in order to yield the true sound-pressure amplitudes in dynes/cm².

The author's summary does not mention that pp. 23–27 leave the near fields hitherto treated and deal with the calculation of the distant fields in the case of deep and shallow water. A footnote also refers to previous work on this problem by Tamm (1985, below).

1985. PAPER ON A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE DISTANT FIELD OF A SOUND RADIATOR IN A WATER LAYER.—K. Tamm. (*Akust. Zeitschr.*, Vol. 6, 1941, p. 16 onwards.) Referred to in 1984, above.

1986. ON THE PROBLEM OF THE MEASUREMENT OF ABSORPTION IN THE SUPERSONIC REGION.—H. Born. (*Zeitschr. f. Phys.*, Vol. 120, 1943, p. 383 onwards.) For corrections to typographical errors in some of the equations *see* issue of 1st Oct. 1943, Vol. 121, No. 11/12, p. 754.

1987. THE THEORY OF THE SPHERICAL WAVE EXCITED AT A FINITE DISTANCE FROM THE SURFACE OF DEMARCATION OF TWO MEDIA, FOR FINITE REFRACTIVE INDICES.—Krüger. (*See* 1847.)

PHOTOTELEGRAPHY AND TELEVISION

1988. CIRCUIT PROBLEMS OF TELEVISION [Address to the Fryburg Conference of the S.E.V., with Special Attention to Recent Researches at the École Polytechnique Fédérale and to the Practical Development of the A.F.I.F. (Division for Industrial Research) Large Screen Projector (embodying the "Eidophor" Liquid-Surface Light-Control Device)].—W. Amrein: Fischer. (*Bull. Assoc. Suisse des Élec.*, 15th Dec. 1943, Vol. 34, No. 25, pp. 751–768: in German.)

For the theoretical aspects of this projector *see* Fischer & others, 1165 of 1943 and back references. The present paper deals also with the practical side, and stresses the possibility which this development offers of halving the required frequency-band.

1989. TELEVISION RELAY NETWORK [Unattended Relay Stations spaced 20–50 Miles will provide National Network, and open up New Era in International Communications, "through Development of Trunk Lines over Such Vast Areas as Russia and China"].—R. R. Beal. (*Proc. I.R.E.*, Dec. 1943, Vol. 31, No. 12, pp. 58A..62A.) Predictions by the assistant to the vice-president in charge of RCA Laboratories.

1990. ULTIMATE BAND-WIDTHS IN HIGH-GAIN MULTI-STAGE VIDEO AMPLIFIERS [and the Question of Shunt Peaking: the $k = \frac{1}{2}$ *versus* $k = 0.414$ Argument].—W. R. MacLean. (*Proc. I.R.E.*, Jan. 1944, Vol. 32, No. 1, pp. 12–15.)

"It is often said that gain and band-width are exchangeable. That is true from a certain point of view for a single-stage amplifier, but the implication is that the loss in gain may be made up by using more stages. Yet if this is done, each stage must be better. Is this a limitation? Is there an optimum number of stages, or does the band-width increase indefinitely with the number of stages? In the following, such a problem is posed and analysed for two simple cases".

MEASUREMENTS AND STANDARDS

1991. ELECTRICAL AND MECHANICAL PROBLEMS IN THE CONSTRUCTION OF A SIGNAL GENERATOR FOR FREQUENCIES UP TO 300 Mc/s.—R. Otto. (*Siemens-Z.*, Oct./Dec. 1942, Vol. 22, No. 4, p. 126 onwards: short summary, in German, in *Bull. Assoc. Suisse des Élec.*, 6th Oct. 1943, Vol. 34, No. 20, p. S. 41.)

1992. A LECHER-WIRE SYSTEM WITH TUNING OVER A WIDE FREQUENCY-BAND [*e.g.* 60–200 Mc/s].—Philips Company. (*Hochf:tech. u. Elek:akus.*, Sept. 1943, Vol. 62, No. 3, pp. 95, 96, Fig. 14.) The Lecher system is bridged at one point at least by a condenser 13, and the short-circuiting bridge 12 is slid away from this on both sides.

1993. THE "KEYED" WAVEMETER, A NEW FORM OF ABSORPTION WAVEMETER.—H. J. Wilhelmy. (*Arch. f. Tech. Messen*, June 1943, Vol. 13, Part 144, V3614-7, Sheet T68 onwards.) The German word is "Tastwellenmesser," which might also give the impression of "feeling about for the right point."

1994. ULTRA-HIGH-FREQUENCY WAVEMETER: RANGE 70–270 Mc/s, WITH QUARTZ CRYSTAL FREQUENCY STANDARD.—A. H. Beattie & L. Knight. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 66–69.) From the Murphy laboratories. If the external signal is strong, the effective range is up to 810 Mc/s.

1995. Crystals of Quartz [Survey of Development, including the Specification of "Cuts" and the Bell Laboratories' Work on the Reduction of Temperature Effects: the *AT*, *BT*, & *GT* Cuts].—W. P. Mason. (*Bell Lab. Record*, Feb. 1944, Vol. 22, No. 6, pp. 282–289.)

1996. Quartz Crystals of Adjustable Frequency ["Vario-Crystals"].—A. Zobel. (*T.F.T.*, Aug. 1943, Vol. 32, No. 8, pp. 167–170.)

From the Steeg & Reuter laboratories, Bad Homburg. The adjustment of the frequency of a crystal through its temperature coefficient is ruled out for most practical purposes by the delay necessary to allow the crystal to take up its new temperature: this is particularly the case when a quick change of frequency is necessary. In the "vario-crystals" here described, for the frequency region between 500 and 4000 kc/s, the adjustment of frequency (*e.g.* from 3000.0 kc/s to 3010.5 kc/s) is obtained by varying the gap between one surface of a circular-plate crystal and its electrode, the second electrode being at a small constant distance from the other surface. The horizontal crystal (excited in the "thickness" mode) is held at three points along the edge of its middle plane, one of the three grips being springy so as to prevent additional damping due to the holder. The lower electrode is fixed (by a threaded shank and nut) with as small an air gap as possible: actually the size of this gap provides a way of adjusting to a required range of frequency-variation for the unit, since for a given total air gap $d_1 + d_2$ the frequency-variation is the greater, the smaller the fixed gap d_1. The upper electrode is adjustable through one complete turn of the external knob, which corresponds to an air-gap variation of 0.45 mm: the amount of rotation is read off a circular scale, marked in degrees or calibrated to read directly in kilocycles/second. This electrode is in electrical connection with a guard ring surrounding the crystal and protecting it against electrostatic effects. The non-metallic parts of the plug-in container are of ceramic material.

The paper begins by deriving the equivalent circuit of the "vario-crystal," and its equations. For series resonance the frequency-variation is obtained from the pair of equations of eqn. 8, by subtracting one from the other: once the constant A_s is found numerically, the variations for any combinations of air gap are thus given. For the *Y*-cut plate ($\delta = 90°$), which is of particular interest for these investigations (*see* below), A_s is calculated for a particular 2 Mc/s plate, and the top curve of Fig. 4 shows the frequency-variation as a function of the air gap (varying from 0.01 to 0.45 mm), for series resonance: measured values are shown by the small circles, and the agreement is excellent.

For parallel resonance the corresponding relations are given by eqn. 10, and the lower curve of Fig. 4 shows the calculated results and (small crosses) the measured values, after the new constant A_p had been found by numerous measurements on a particular Pierce circuit with a known value of C_3, the parallel capacitance. The attainable frequency-variation for parallel resonance is always about 40% smaller than for series resonance, so that whenever the largest possible variation is desired the crystal should always be excited in series resonance.

The final section III deals with the use of crystals of various cuts. The largest frequency-variation obtained was given by the *Y* cut already mentioned: this value (at around 4 Mc/s) was 5.2×10^{-3} in series resonance. Over the whole range of frequency considered (500–4000 kc/s) the values increased with increasing frequency, from 2×10^{-3} up to the above figure. The temperature-independent variant of the *Y* cut (with $\delta = 125°$ instead of 90°) gave only about half these variations.

1997. On the Mode of Action of the Rochelle-Salt Torsional Strip in the Direct and Reciprocal Piezoelectric Effects.—H. Keller. (*See* 1961.)

1998. Study of a Diode-Voltmeter for All Frequencies.—J. Heuskin. (*Bull. Soc. belg. Élec.*, 1942: short summary in *Bull. Assoc. Suisse des Élec.*, 8th Sept. 1943, Vol. 34, No. 18, p. S.35.)

1999. Electrostatic "Induction" Voltmeter.—H. Schwenkhagen. (*Elektr.-Wirtsch.*, 1943: short summary in *Bull. Assoc. Suisse des Élec.*, 8th Sept. 1943, Vol. 34, No. 18, p. S.35.)

2000. Measuring Instruments with Suppressed Lower End Readings.—W. Oesinghaus. (*Arch. f. Tech. Messen*, Jan. 1943, Part 139, J015-7: with 4 diagrams.) *See* also 540 of February.

2001. Heat Capacity of Fine Wires [Ballistic Method of examining Specific Heat of Alloys of Rare Metals, using Condenser Discharge].—B. Kurrelmeyer & others. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, pp. 349–355.)

2002. The Construction and Use of Climate-Test Rooms for Communication Apparatus.—C. Marsch. (*E.T.Z.*, 23rd Sept. 1943, Vol. 64, No. 37/38, p. 507 onwards.)

SUBSIDIARY APPARATUS AND MATERIALS

2003. Negative Ions [producing "Black Spot"] in Cathode-Ray Tubes, and Their Connection with the Oxide-Cathode Mechanism.—Schaefer & Walcher. (*Zeitschr. f. Phys.*, 1st Oct. 1943, Vol. 121, No. 11/12, pp. 679–701.)

Bachman & Carnahan (3692 of 1938) have already made a mass-spectrographic investigation of the ion beam, using a constant magnetic field of such an intensity that the beam focused on the screen was split into its components. The latter destroyed the screen at their various points of impact, and by subsequent uniform irradiation of the screen by electrons these destroyed spots were made visible and were photographed. "This method has the disadvantages that neither could the intensities of the individual components be measured, nor their variation with time be followed continuously. In order to form conclusions as to the origin and mechanism of formation of the ions—and thus as to their eventual elimination—it is necessary to investigate the intensity of the various ion-beam components, their behaviour with respect to time, and their dependence on external influences. The following work was undertaken to clear up these questions": a Faraday-cage and electrometer combination was used for measurement, the various components being deflected in turn, by a magnetic field, through the 48° necessary for them to pass through the final slit and enter the cage. The actual ion emission at the cathode was estimated (by tests with electrons) to be about four times as large as the cage-measured current, owing to the losses in the lens and at the diaphragms.

The four cathodes tested were of the paste, barium-acid, and tungsten-hairpin types. Much the most intensive ions from the paste cathode (Fig. 4) were the H, OH, CH_1, CH_2, C_2, and O_2 ions, and (in a fresh cathode) the Cl ions: these last fell in a few hours from very high initial values to below the limit of measurement. The many other ions present (OH_2, Na, C_2H & C_2H_2, Ca, CaO, Ni, etc.) were weaker by an order of magnitude. The Ni ion only appeared when the cathode was old, the Ca ion only when it was new. The intensities of the ion currents from the tungsten cathode were (apart from the H-ion current) about 100 times smaller than those from the paste and acid types, for equal electron emissions : " this observation will later on allow us to draw conclusions as to the origin and production of the ions".

The sharpness of the images formed by the negative ions leads to the conclusion that they have one single place of origin. For most of them this is the substance of the cathode ; only for the OH ions the gas space is an additional source, since OH_2 molecules from this reach the cathode surface and are emitted again as negative OH ions. The relation between the O_2^- emission and the electron emission of the cathode was investigated during the activating process, and the results were interpreted by the following conception of the " forming " process :— the cathode activation consists in the Ba^+ ions, by thermal dissociation in the BaO, leaving their regular place in the BaO lattice and being adsorbed at preferred positions, where they assume the character of an electron-delivering " point of disturbance ". As regards the transport of the negative ions from their place of origin in the cathode substance to the cathode surface, it is deduced that while the O^-, OH^-, and Cl^- ions migrate electrolytically through the BaO crystallite to the cathode surface, for the CH^- and C_2^- ions there must occur (from their behaviour) a surface migration along the crystallite boundary surfaces to the cathode surface : this surface migration is unhindered only so long as the surface is not covered with adsorbed O_2^- ions (example of the mutual interaction of the ion currents, discussed in section 9). Section 7 deals with the well-known " poisoning " phenomenon and also with a newly encountered variant of this, due to the action, for instance, of hydrocarbon ions (Fig. 8).

2004. CONTRIBUTIONS TO THE THEORY OF THE ELECTRICAL DEFLECTION OF ELECTRON-RAY BEAMS : IV—SUPPLEMENTARY REMARKS ON II AND III [3091 of 1941 : the Question of " Ellipse " & " Ellipse-like " Aberration Curves] AND THE RELATION BETWEEN THE ABERRATION EQUATIONS FOR CROSSED ELECTRICAL DEFLECTION SYSTEMS FOUND IN III AND THOSE DERIVED BY WENDT [1732 of 1942].—Picht. (*Ann. der Physik*, 26th June 1943, Vol. 43, No. 1/2, pp. 53–72.)

2005. IMAGE FORMATION AND RESOLVING POWER OF THE ELECTRON MICROSCOPE FROM THE STANDPOINT OF WAVE MECHANICS.—Glaser. (*Zeitschr. f. Phys.*, 1st Oct. 1943, Vol. 121, No. 11/12, pp. 647–666.)

Author's summary :—" The electron intensity in the image plane is calculated wave-mechanically, and on the basis of the formula thus obtained for the intensity of the electron current, the resolving power of the supermicroscope is estimated correctly for the first time."

2006. THE TRANSMISSION TYPE OF ELECTRON MICROSCOPE AND ITS OPTICS [Survey of Basic Theory, with Special Emphasis on Limitations of Resolving Power].—Marton & Hutter. (*Proc. I.R.E.*, Jan. 1944, Vol. 32, No. 1, pp. 3–12.)

Apart from the inherent limitations, factors such as aperture defects and, to some extent, chromatic aberrations can be reduced by developing better lenses. " The mathematical problem of the improvement of lenses is difficult but not entirely unpromising. In the second part of this paper we intend to show how, coupled with experimental methods, serious progress may be expected in spite of such limitations as saturation of the pole pieces of magnetic lenses and cold emission in electrostatic lenses. . . " For other recent work *see* 545 of February and 1296 of April.

2007. SECONDARY IMAGES IN THE ELECTRON-MICROSCOPIC EXAMINATION OF CRYSTALLINE MATERIALS.—Boersch. (*Zeitschr. f. Phys.*, 1st Oct. 1943, Vol. 121, No. 11/12, pp. 746–753.)

This recently observed effect is explained as the result of crystal-lattice interference (it will therefore be frequent only in the higher range of voltages, say above 40 ekv, where more interferences occur) and of non-ideal image-formation. It is stated that the measurement of the spacing between the primary and secondary images provides a method of investigating, on electron-diffraction lines, very small regions of an object which is simultaneously imaged electron-microscopically [*cf.* Prebus, 181 of January, and Hillier, 1292 of April]. Up to the present the smallest regions examined successfully had diameters of about 200 A.U., compared with about 5000 A.U. for the shadow-microscopic and diffraction method dealt with in 3075 of 1942.

2008. CONTRIBUTION TO THE [Optical] PROBLEM OF THE DETERMINATION OF THE SIZE AND SHAPE OF ULTRAMICROSCOPIC PARTICLES [Definition of the " Visibility Function " : Application to Objects of Various Shapes : Objects far beyond Limits of Resolution : Diffraction at a Double Slit with Finite Slit-Breadth].—Hanke. (*Zeitschr. f. Phys.*, 10th Aug. 1943, Vol. 121, No. 5/8, pp. 438–458.)

2009. GAUSSIAN OPTICS AND GAUSSIAN BRACKETS.—Herzberger. (*Journ. Opt. Soc. Am.*, Dec. 1943, Vol. 33, No. 12, pp. 651–655.)

" It appears to have escaped Gauss's attention, however, that the so-called ' Gaussian brackets ' [recursion formulae developed by Euler], originally a purely mathematical concept, can be highly useful in handling problems of Gaussian optics. . . ."

2010. THE INFLUENCE OF THE SPACE CHARGE ON THE IMAGE-FORMING PROPERTIES OF MAGNETIC SECTOR-FIELDS [with Application to the Design of Mass Spectrographs, especially for the Separation of Isotopes].—Walcher. (*Zeitschr. f. Phys.*, 1st Oct. 1943, Vol. 121, No. 11/12, pp. 719–728.) Extension of Herzog's theory of ion-optical cylinder-lenses and prisms, to take into account the space-charge effects which become serious in instruments using large ion currents.

2011. ON SPATIALLY PERIODIC DISTRIBUTIONS OF FREE-FALLING IONS AND ELECTRONS.—Schumann. (*See* 1944.)

2012. THE PLOTTING OF POTENTIAL FIELDS IN THE ELECTROLYTIC TROUGH.—Strigel. (*See* 1946.)

2013. THE SURVEYING OF ELECTROSTATIC FIELDS [by the Toepler Method of Striae (Schlieren Method)].—Strigel. (*See* 1947.)

2014. RIDENOUR–LAMPSON IONISATION-GAUGE CONTROL AND INDICATOR, USING " MAGIC EYE " 6E5 TUBE TO REPLACE EXPENSIVE & HIGH-PRIORITY MICROAMMETER.—(*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, pp. 377–378.) The smallest current readable is about 5×10^{-8} A.

2015. ZIRCONIUM [Applications & Production : the Philips Process].—Foote Mineral. (*See* 1952.)

2016. New Heat-Resistant Alloy with Low Nickel and Chromium Content.—Harder & Gow. (*Sci. News Letter*, 6th Nov. 1943, Vol. 44, No. 19, p. 297 : *Scient. American*, Dec. 1943, Vol. 169, No. 6, p. 261.)

2017. On the Migration of Inert Gases through Metals.—Lumpe & Seeliger. (*See* 1953.)

2018. "Manual of Laboratory Glass-Blowing" [Book Notice].—Wright. (*Journ. of Scient. Instr.*, Feb. 1944, Vol. 21, No. 2, p. 35.)

2019. Electronically Controlled Dry-Disc Rectifier [eliminating the Two Defects of Selenium Rectifiers—Lack of Fine Voltage Regulation, and only Fair Voltage Regulation under Load: Rectifier Voltage compared against Constant Comparison Voltage, amplified, & used to shift Phase of Reactor-Saturating Thyratrons].—Rosenstein & Barnett. (*Elec. Engineering*, Dec. 1943, Vol. 62, No. 12, p. 546 : summary only.)

2020. The Rectifying Property of Carborundum.—Kendall. (*See* 1913.)

2021. On the Question of the Selective Heating of Small Particles in the Ultra-Short-Wave Condenser Field [Problem of the Inhomogeneous Dielectric].—Schaefer & Schwan. (*See* 2098.)

2022. Relationship between Dielectric Constant of Liquids and Solids and Dipole Moments [Preliminary Communication]. — Jatkar. (*Nature*, 19th Feb. 1944, Vol. 153, No. 3877, p. 222.) *See* also 2023, below.

2023. Dipole Moments of Polyatomic Molecules.—Jatkar. (*Nature*, 11th March 1944, Vol. 153, No. 3880, pp. 316–317.)

"The law of component moments accounts quantitatively for the anomaly of flexible molecules, the ortho, meta, para moments in aromatic compounds . . . on the basis of the regular geometry of the molecules and theoretical values of angles and bond moments. Details will be published elsewhere."

2024. Processes at the External and Internal Boundary Surfaces of Synthetic Materials [and Surface-Leakage Tests as a Basis of Design].—Vieweg & Klingelhöffer. (*Kunststoffe*, July 1943, Vol. 33, No. 7, p. 173 onwards.) For previous work *see* 1514 of 1943.

2025. The Apparent Second-Order [Glass/Liquid] Transition Point of Polystyrene [Discussion of the Situation, with Conclusions confirmed by Experimental Investigation of the Transition Glassy-Polystyrene/Rubbery-Polystyrene].—Alfrey, Goldfinger, & Mark. (*Journ. Applied Phys.*, Dec. 1943, Vol. 14, No. 12, pp. 700–705.)

2026. Flow Properties of Cellulose Esters [and Comparison with Polystyrene & Phenol Fibre].—Frosch. (*Bell Lab. Record*, Feb. 1944, Vol. 22, No. 6, pp. 269–272.)

2027. Carbon Resistors [Supplement to 1352 of April: Polyvinyl-Chloride Sleeves & Their Proper Use].—Burkett. (*Wireless World*, March 1944, Vol. 50, No. 3, p. 75.)

2028. Insulating Pipe for Rectifiers [Water-Cooled Rectifiers insulated from Water Supply by Thermoplastic "Saran"].—(*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 174 and 176.)

2029. Plastic from Sawdust [with only 25% of Resin: High Tensile Strength & Moisture Resistance].—Hardin. (*Sci. News Letter*, 1st Jan. 1944, Vol. 45, No. 1, p. 2.)

2030. Compregnated Wood ["Pluswood," with "Extremely High Mechanical, Structural, & Dielectric Strength"].—Pluswood, Inc. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, p. 381.) *Cf.* a paragraph in the *Times*, 18th April 1944, on a "Dupont," announcement.

2031. Uskon Rubber [Synthetic Material with Volume Resistivities down to 5000 Ohms/cm³ : as Dissipator of Static Charges, etc.].—U.S. Rubber. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, p. 380.)

2032. Rhodesian Mica [unsurpassed for General Hardness & Flatness : etc.].—Perkins. (*Engineering*, 18th Feb. 1944, Vol. 157, No. 4075, p. 140 : paragraph on recent address.)

2033. The Replacement of Mica in High-Frequency Transmitting Condensers by Ceramic Materials.—Dirks. (*Lorenz-Berichte*, Aug. 1942, No. 1/2, p. 2 onwards.) Will be dealt with in July Abstracts.

2034. "Physical Processes in the Drying of Synthetic-Resin Varnishes by [Infra-Red] Irradiation, and Their Utilisation in Practice" [Review of Osram Pamphlet].—Saatmann. (*Bull. Assoc. Suisse des Élec.*, 6th Oct. 1943, Vol. 34, No. 20, p. 621 : in German.) Among other points, Saatmann finds that ordinary incandescent lamps (500–2000 w) give even better results than types specially developed for the purpose.

2035. Contribution to the Evaluation of the Magnetic Circuit of Permanent Magnets.—Fischer. (*Zeitschr. f. tech. Phys.*, No. 7, Vol. 24, 1943, pp. 149–162.)

From the Hartmann & Braun laboratories. Author's summary :—"For the most successful design of permanent magnets the procedure is to make the product BH as large as possible along the permanent-magnetic-state curve, and to know the corresponding ratio H/B. The curve of state for 'permanent' permanent magnets can be represented by a sloping straight line. The optimum relations for this are given. Among other things it is shown that in addition to the permanent-state curve, the magnetisation curve also plays a part in determining the coordinates for the optimum values. The curve of state of 'remanent' permanent magnets is the branch of the magnetisation curve running between remanence and coercive force [for the necessity, in good design, of distinguishing between the "permanent-magnetic" and "remanent-magnetic" states *see*, in particular, section 2, where Breitling's original paper (1735 of 1939) is summarised]. Here, in order to get away from the point-by-point search for the optimum values and to obtain, as in the case of the permanent-state curve, a simple, informative general relation which can be expressed analytically, the replacement of the magnetisation curves by second-order curves (hyperbolas, parabolas, circles, ellipses) is examined. The properties of the substitute curves are compared with those of experimental magnetisation curves, and simple procedures for arriving at the optimum values are given. An already-known approximate method for determining these optimum values, which has proved successful when compared with experimental curves, is confirmed (Watson, 1923). The application and merits of the approximations are shown by numerical examples. The range of application of the circles and parabolas as substitutes is limited, while the hyperbolas cover the whole possible range".

2036. THE COMPLEX PERMEABILITY OF COIL CORES OF LAMINATED IRON.—Feldtkeller & Wilde. (*Elektrot. u. Masch:bau*, Vol. 61, 1943, p. 317 onwards.)

2037. A SIMPLE METHOD FOR CALCULATING COMPLEX PERMEABILITY [from Experimental Data: using the Relation Complex Permeability $= \mu - i\rho' = (A_e + iB_e) \cdot (\mu_1 - i\mu_2)$].—Arkadiev & Polivanov. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 10th Jan. 1943, Vol. 38, No. 1, p. 14: in English.) For previous work *see* reference "3" and 3158 of 1943: and *cf.* Lawrentiew, 2038, below.

2038. MAGNETIC SPECTRUM IN INFRA-LOW FREQUENCY [and a Method of Measuring the Complex Magnetic Permeability $\mu' = \mu - i\rho'$, the Quantity used in Computations of the Course of Magnetisation of a Ferromagnetic Body possessing Magnetic Viscosity in a Weak Sinusoidal Field: 2037, above].—Lawrentiew. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, 20th March 1943, Vol. 38, No. 8, pp. 233–236: in English.)

2039. PAPER ON THE THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE HYSTERESIS IN THE RAYLEIGH REGION OF WEAK MAGNETIC FIELDS.—Kornetzki. (*E.N.T.*, Jan. 1943, Vol. 20, No. 1, p. 10 onwards.)

2040. HIGH-RESISTIVITY INSULATED IRON CORES [of Special Material reducing Leakage Currents, with Their Resultant Noise Troubles, and Likelihood of Coil/Core Breakdown].—Stackpole Carbon. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, p. 378.) For other Stackpole cores *see* 2844 of 1943.

2041. THE USE OF BRIQUETS FORMED FROM METAL GRINDINGS FOR THE SPECTROGRAPHIC ANALYSIS OF STEEL [including Method of obtaining Fine Particles, and Magnetic & Electrostatic Separators for removing Grinding-Wheel Particles].—Nusbaum & others. (*Journ. Opt. Soc. Am.*, Jan. 1944, Vol. 34, No. 1, pp. 33–40.) From General Motors laboratories.

2042. "A COURSE IN POWDER METALLURGY" [Book Review].—Baeza. (*Electronics*, Nov. 1943, Vol. 16, No. 11, pp. 339 and 340.)

2043. THE PERMEABILITY OF DYNAMO SHEET IRON TYPE IV AT NOTE FREQUENCIES.—Feldtkeller. (*T.F.T.*, Aug. 1943, Vol. 32, No. 8, pp. 163–167.)

For Wilde's paper on the use of this material in place of ring cores of compressed powder *see* 1513 of May. Author's summary:—"Results are given of permeability measurements on various coil cores of dynamo sheet iron IV at frequencies between 50 c/s and 10 kc/s and field strengths between 2 and 250 mA/cm. The results are compared with calculations of the permeability made on the basis of idealising assumptions".

The writer discusses in turn the definition and equation of the complex permeability (leading to eqn. 8 for the impedance of the resulting coil); Rayleigh hysteresis (and the representation of the hysteresis loops by parabolic arcs); measurements on 15 cores of the "type IV" sheet from different sources, but all 0.35 mm thick, at 50 c/s where the effect of eddy currents can be neglected (giving three groups each yielding consistent permeability values within the group); the "ideal complex permeability" (obtained by combining Rayleigh's assumptions with those of Wolman in his work on the limiting frequency of eddy-current effects: Abstracts, 1930, p. 228, and 1932, p. 656); and, finally, measurements on three cores taken from the above-mentioned three groups, at the frequencies and field strengths given in the author's summary, and a comparison of the resulting curves (Figs. 7–9) with the calculated curves of Fig. 6.

From this comparison the writer concludes:—"Thus the 'doubling' field strength [top of p. 165] for all three cores increases considerably with increasing frequency; that is, with increasing skin effect, and consequently also from the interior of the sheet to the layers under the surface. Figs. 7–9 can therefore not only serve as the basis for calculating the impedance of coils with cores of 0.35 mm dynamo sheet IV but also provide information as to inhomogeneities in the magnetic properties in the interior of the sheet, leading to the conclusion that in the three cores investigated the permeability partly falls and partly rises from the centre of the sheet to its boundaries, and that the rise of permeability with the field strength decreases from the centre to the boundaries. Thus the surface layers have the better magnetic properties".

2044. "DER GESTEINMAGNETISMUS" [Mineral Magnetism: Its Relations to the Phenomena of Ferromagnetism & to the Earth's Magnetic Field: Book Review].—Haalck. (*Zeitschr. f. tech. Phys.*, No. 6, Vol. 24, 1943, p. 148.) For Herroun & Hallimond's paper on the magnetisation of rocks *see* 1482 of April.

2045. DRAG CUP MOTORS [High-Speed Precision Motors for Quick Starting, Stopping, & Reversal (Radio-Compass Loops, Remote Controls, etc.): No Rubbing Contacts].—(*Electronics*, Oct. 1943, Vol. 16, No. 10, p. 280.)

2046. THE HEATING OF ELECTROMAGNET WINDINGS.—Windred. (*Engineering*, 31st Dec. 1943, Vol. 156, No. 4068, pp. 521–523.)

2047. CONNECTING LINES OF STEEL–COPPER WIRE [with Mechanical & Electrical Data of Felten & Guilleaume "Stakudraht" Wires with 30% Copper].—Goedicke. (*E.T.Z.*, No. 29/30, Vol. 64, 1943, p. 396 onwards: summary, in German, in *Bull. Assoc. Suisse des Élec.*, 20th Oct. 1943, Vol. 34, No. 21, pp. 644–645.) *Cf.* 911 & 2092/3 of 1943.

2048. FIELDS OF APPLICATION AND TYPES OF MACHINE OF ELECTRICAL RESISTANCE WELDING AND HEATING [Illustrated Survey, including the Welding of Fine Wires and Carbon-Point Welding (*cf.* 3564 of 1943)].—Schlatter. (*Bull. Assoc. Suisse des Élec.*, 1st Dec. 1943, Vol. 34, No. 24, pp. 730–742: in German.)

2049. METROVICK "LO-VOLT" SOLDERING IRON.—Metropolitan Vickers. (*Wireless World*, March 1944, Vol. 50, No. 3, p. 87.)

2050. METHODS OF DEPOSITING METALLIC FILMS [Survey of Old & New Techniques: Applications: Literature & Patent References].—Wein. (*Electronics*, Sept. 1943, Vol. 16, No. 9, pp. 110–113 and 248..254.)

2051. PROTECTIVE METAL FINISHES [Note on Symposium dealt with in 2838 of 1943].—(*Electronics*, Sept. 1943, Vol. 16, No. 9, p. 201.)

2052. METAL-COATING PROCESS ["Rapid Electroplating Process, Inc."].—(*Electronics*, Sept. 1943, Vol. 16, No. 9, p. 270.)

2053. Testing and Rating Air Filters [for Industrial Interiors].—Eliason. (*Bell Lab. Record*, April 1943, Vol. 21, No. 8, pp. 243–247.)

STATIONS, DESIGN AND OPERATION

2054. U.S.A. plans Post-War Radio: Plea for a "United Nations Agreement" [on Frequency Allocations].—Bell. (*See* 2078.)

2055. The Belgrade 10 Kilowatt Short-Wave Broadcasting Station.—Heidrich. (*Lorenz-Berichte*, Aug. 1942, No. 1/2, p. 13 onwards.) With 9 illustrations.

2056. The Subscriber's Auxiliary Unit for High-Frequency Telephone-Network Broadcasting ["Straight"-Type Receiver with Input Band-Filter switched to Any of Five Carrier Frequencies: Special Requirements].—Werthmüller. (*Bull. Assoc. Suisse des Élec.*, 20th Oct. 1943, Vol. 34, No. 21, p. 649: summary only, in German.) For networks where, with the conversion to automatic working, the l.f. broadcasting is replaced by h.f.

2057. High-Frequency Telephone-Network Broadcasting [replacing, in 1940, the 1932 Low-Frequency System].—Steiger. (*Bull. Assoc. Suisse des Élec.*, 3rd Nov. 1943, Vol. 34, No. 22, pp. 671–676: in German.) Address to the Berne Conference: *see* also 2056, above.

GENERAL PHYSICAL ARTICLES

2058. A Method of Determining the Potential of a Uniform Double Layer.—Schwarzer. (*Arch. f. Elektrot.*, 31st Oct. 1943, Vol. 37, No. 10, pp. 505–508.)

It is shown that the potential can be determined from the central projection of the double layer on to the surface of a sphere whose centre is the point of observation where the potential is to be measured. The approximate determination of the surface projected, by means of spherical triangles, is given. A direct method of measuring the potential, by replacing the double layer by a photo-electric surface irradiated from a point source at the point of observation, is derived.

2059. The Smallest "Quantum" of Energy [New Measurements by X-Ray Method give Results agreeing with Atomic Theory].—Ohlin. (*Science*, 3rd Dec. 1943, Vol. 98, No. 2553, Supp. p. 10.) From a report in *Nature*.

2060. Electrical Energy of Two Cylindrical Charged Particles [derived by Approximate Debye–Hückel Theory: Existence of a Minimum for a Certain Inter-Particle Distance: may be of Considerable Importance in explaining the Thixotropic Properties of Certain Colloidal Systems].—Dube. (*Indian Journ. of Phys.*, Aug. 1943, Vol. 17, Part 4, pp. 189–192.)

2061. The Impulse-Energy Tensor of Material Particles: Part I—Mesons and Electrons: Part II—Particles of Spin 2 or 3/2.—Chang. (*Proc. Roy. Soc.*, Series A, 1st March 1944, Vol. 182, No. 990, pp. 302–311: pp. 311–318.)

2062. Nuclear Disintegrations produced by Cosmic Rays [Letter on Sinha's Cloud-Chamber Photograph & His Suggested Interpretation: a Hitherto Unknown Process? Creation of New Strongly Ionising Particles].—Goldhaber: Sinha. (*Nature*, 19th Feb. 1944, Vol. 153, No. 3877, pp. 221–222.)

2063. Beta-Decay [Survey].—Konopinski. (*Reviews of Modern Phys.*, Oct. 1943, Vol. 15, No. 4, pp. 209–245.)

2064. Matrix Theory of Correlations in a Lattice: Parts I and II.—Eisenschitz. (*Proc. Roy. Soc.*, Series A, 1st March 1944, Vol. 182, No. 990, pp. 244–259 & 260–269.)

MISCELLANEOUS

2065. Relations between Hypergeometric and Bessel Functions [Appendix to Paper dealing with Linear Rectification of Signal & Noise].—Bennett. (*See* 1883.)

2066. "Tables of Functions with Formulae and Curves" [Book Review].—Jahnke & Emde. (*Proc. Phys. Soc.*, 1st March 1944, Vol. 56, Part 2, No. 314, p. 148.) Previous reviews were referred to in 961 of March: the present one includes the names of the sole British agents and the price.

2067. Table of Fourier Coefficients [encountered in Solutions of Problems in Heat Conduction, Diffusion, and Wave Motion for Domains bounded by Parallel Planes, and in Potential Theory].—Lowan & Laderman. (*Journ. of Math. & Phys.* [of M.I.T.], Sept. 1943, Vol. 22, No. 3, pp. 136–147.)

2068. Seven-Point Lagrangian Integration Formulas.—Blanch & Rhodes. (*Journ. of Math. & Phys.* [of M.I.T.], Dec. 1943, Vol. 22, No. 4, pp. 204–207.)

2069. On a Non-Linear Differential Equation of the Second Order [$\ddot{x} + f(x)\dot{x} + x = e(t)$, where $e(t)$ is continuous & periodic, and $f(x)$ is continuous except possibly at discrete points].—Levinson. (*Journ. of Math. & Phys.* [of M.I.T.], Dec. 1943, Vol. 22, No. 4, pp. 181–187.) For previous work *see* 2161 of 1942 and 626 of February.

2070. Coefficients for Numerical Differentiation with Central Differences.—Salzer. (*Journ. of Math. & Phys.* [of M.I.T.], Sept. 1943, Vol. 22, No. 3, pp. 115–135.)

2071. Table of Coefficients for Inverse Interpolation with Central Differences.—Salzer. (*Journ. of Math. & Phys.* [of M.I.T.], Dec. 1943, Vol. 22, No. 4, pp. 210–224.)

2072. A Machine for Harmonic Synthesis [Simple Ink-Recording Apparatus with Oil-Filled Cylinders having Cam-Driven Pistons].—Shilton. (*Proc. Phys. Soc.*, 1st March 1944, Vol. 56, Part 2, No. 314, pp. 130–132.)

2073. Royal Society Anniversary Address [including the Problem of the Housing of Scientific Societies in London].—Dale. (*Proc. Roy. Soc.*, Series A, 1st March 1944, Vol. 182, No. 990, pp. 217–243.)

2074. Electrical Developments of 1943 [of the General Electric and Its Associated Companies].—Bartlett. (*Gen. Elec. Review*, Jan. 1944, Vol. 47, No. 1, pp. 8–55.)

Mentioning, among endless other items, an insulated-junction-type vacuum thermocouple for use at u.h.f ; the lost-wax process (1787 of May) ; and dri-film for insulators (3549 of 1943 : other uses are being explored energetically).

2075. Report on the Activities of the Kaiser Wilhelm Gesellschaft, 1942/3.—(*Naturwiss.*, 5th Nov. 1943, Vol. 31, No. 45/46, pp. 513–526 : followed by list of papers published or in the press, pp. 526–548.) *See* also Regener, 1848, above. Among physical papers listed is that of Bagge, 2939 of 1943, on the ionosphere.

2076. Visit to the Brown–Boveri Works, Baden.—Brown–Boveri. (*Bull. Assoc. Suisse des Élec.*, 1st Dec. 1943, Vol. 34, No. 24, pp. 742–746 : in German.)

Lectures and demonstrations dealt with, among other things, h.f. filters using synthetic (Rochelle salt) crystals (particularly for multi-channel transmission), simple frequency-modulation methods with glow-discharge tubes for reactance-control, transmission with " time " modulation (speech and music transmitted by pulses of varying length), new gas-filled modulatable valves for medium and high frequencies, decimetric-wave radio links, and microwave transmission of music, using the " Turbator " valve (2352 of 1943).

2077. Organisation of Radio Technical Planning Board and Panels approved by Sponsors.—R.T.P.B. (*Elec. Engineering*, Dec. 1943, Vol. 62, No. 12, pp. 557–558.) *See* 326 of January and 1752 of May.

2078. U.S.A. plans Post-War Radio : Plea for a " United Nations Agreement " [Article on Fly's Paper (1809 of 1943), the Work of " R.T.P.B." (2077, above), and International Problems].—Bell. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 76–77.)

" Will it be necessary to wait until after the war—perhaps two years or more after an armistice—and call a truly international conference, or will the United Nations draw up a wavelength plan this year ? The latter is the only hope if the radio industry is to be converted immediately from war production to the production of civilian requirements in navigational aids as well as broadcasting. . . ." A fairly rough indication of the bands is all that is asked for. Apart from international plans, " Britain has yet to go as far as U.S.A. in preparing to work out its own radio plans, and this must be our next step ".

2079. Research Workers : Their Education and Place in Industry.—Fleming. (*Nature*, 25th March 1944, Vol. 153, No. 3882, pp. 371–372 : summary of Manchester Chamber of Commerce address.)

2080. Scientific and Industrial Research in Great Britain [Leading Article on Recent Articles & Reports, especially the London Chamber of Commerce's Report, 2081, below].—(*Nature*, 11th March 1944, Vol. 153, No. 3880, pp. 293–296.)

2081. Scientific Industrial Research [Leading Article on " Report on Scientific Industrial Research "].—London Chamber of Commerce. (*Engineering*, 4th Feb. 1944, Vol. 157, No. 4073, pp. 91–92.)

2082. Correspondence on the Press and Technology.—Roskill : Chatley : Addison. (*Engineering*, 18th Feb. 1944, Vol. 157, No. 4075, p. 135.)

Prompted by a letter from Prof. Addison, who wonders " why the British don't discuss technology outside of the technical Press, why the technical Press doesn't interest itself in sociology and economics, and why we allow other nations to out-advertise us in the countries where we have influence ".

2083. Practical Education in Wartime.—Swain. (*Elec. Engineering*, Dec. 1943, Vol. 62, No. 12, pp. 534–537.)

" The war of curricula—culture *versus* vocation—goes on. The overlooked truth is that all sound vocational training is, in itself, highly cultural. It is equally true, of course, that certain subjects [those necessary for good citizenship, together with music, art, literature, modern languages, etc.] with little vocational application have such great cultural value as to justify a big place in the curriculum ; but let them hold this place because of something better than a certificate of vocational uselessness ".

2084. Radio Research Institute Proposed.—British Inst. of Radio Engineers. (*Electrician*, 25th Feb. 1944, Vol. 132, No. 3430, p. 166.) For Editorials *see* pp. 156–157 (scope for E.R.A.? need for avoidance of duplication), and *Wireless World*, March 1944, p. 65. *See* also *Nature*, 18th March, p. 338.

2085. Letter on the Formation of the Association of Industrial Scientists at the Shell Development Company.—Taylor. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, p. 377.)

2086. Servicemen's Organisation [Need for Institute or Society, and Creation of " Their Own Standards "].—Goldstein. (*Wireless World*, March 1944, Vol. 50, No. 3, p. 75.)

2087. One Practical Suggestion [for the B.B.C.].—Crossman. (*Wireless World*, March 1944, Vol. 50, No. 3, p. 89 : paragraph from *New Statesman*.)

" So long as the B.B.C. devotes only two programmes to the home listener it should sharply distinguish them, keeping, say, the Forces programme entirely for background noise and devoting the Home Programme entirely to programmes which can only be appreciated if the listener pays attention ".

2088. The Growing Appreciation of Music and Its Effect upon the Choice of Music in Industry.—Pepinsky. (*Journ. Acous. Soc. Am.*, Jan. 1944, Vol. 15, No. 3, pp. 176–179.) *Cf.* 3063 of 1943.

2089. United States Communications in the War [Military, Domestic, & International Communications : Policing the Ether].—(*Elec. Engineering*, Dec. 1943, Vol. 62, No. 12, pp. 521–530.)

2090. " The Foundations of Aviation Automatics " [Book Review].—Rubin & Kheyman. (*Automatics & Telemechanics* [in Russian], No. 3, 1941, pp. 167–169.) Dealing chiefly with the theory and practice of the stabilisation of aeroplanes in space (auto-pilots).

2091. " Principles of Aeronautical Radio Engineering " [Book Review].—Sandretto. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 79–81.) A previous review was referred to in 1899 of 1943.

2092. " Glossary of Terms used in Telecommunication " [Notice of Revised & Enlarged Edition of B.S. 204].—British Standards Institution. (*Electrician*, 25th Feb. 1944, Vol. 132, No. 3430, p. 159.) For a review see *Wireless World*, April 1944, Vol. 50, No. 4, p. 105.

2093. " RADIO DATA CHARTS : REVISED AND EXPANDED THIRD EDITION " [Book Notice].—Beatty, Sowerby. (*Wireless World*, March 1944, Vol. 50, No. 3, p. 77.)

2094. " BASIC RADIO " [Book Review].—Boltz. (*Nature*, 26th Feb. 1944, Vol. 153, No. 3878, p. 237.)

2095. CORRECTION TO EQUATION IN " RADIO ENGINEERS' HANDBOOK " AND IN " NETWORK THEORY, FILTERS, AND EQUALISERS."—Terman. (*See* 1892.)

2096. " EXPERIMENTS IN PRECOGNITIVE TELEPATHY " [Book Review].—Soal & Goldney. (*Nature*, 11th March 1944, Vol. 153, No. 3880, pp. 298–299.) " The experiments here described . . . are some of the most interesting and suggestive hitherto recorded ".

2097. SOME FACTS ON THE PROPAGATION OF HERTZIAN WAVES IN GEOLOGICAL CONDUCTORS [Investigations with Special Reference to Wireless in Mines]. —Fritsch. (*See* 1861.)

2098. ON THE QUESTION OF THE SELECTIVE HEATING OF SMALL PARTICLES IN THE ULTRA-SHORT-WAVE CONDENSER FIELD.—Schaefer & Schwan. (*Ann. der Physik*, 26th June 1943, Vol. 43, No. 1/2, pp. 99–135.)

" The present investigation yields for the first time a complete mathematical theory of the problem as a whole ; that is, of the non-stationary as well as the stationary state. On the basis of the theoretical results here given, and the measurements made on the model system, the temperature relations can now be calculated in advance for systems of arbitrary size and of arbitrary constants. These results confirm everywhere the theoretical and experimental findings already reported by other writers, and at the same time extend them to the non-stationary initial process."

The section subjects are as follows :—A. Formulation of the problem : the present state of knowledge. B. The spatial temperature-distribution in an emulsion of spherical droplets in the stationary régime (mathematical treatment : application to the water-in-oil emulsion : practical carrying-out of the test, on an 11 m wavelength, of selective disintegration by boiling in the water-in-oil emulsion) : the temperature-distributions, in space and in time, in the non-stationary process immediately following the switching-on of the field (mathematical treatment : experimental investigation of the non-stationary temperature distribution in a macroscopic model system, where a water drop is represented by an 8 cm-diameter brass sphere carrying a central heating-element and buried in moist sand in a large cylindrical container furnished with ten probes with thermoelement ends : application to the water-in-oil emulsion : application to other macro- and micro-systems).

2099. HIGH-FREQUENCY HEATING OF LAMINATED MATERIALS.—Jervis. (*BEAMA Journal*, Feb. 1944, Vol. 51, No. 80, p. 63 : summary only.)

2100. MORE ABOUT RADIO HEATING, *and* RADIO HEATING EQUIPMENT : DESIGNING A CLASS " C " PUSH-PULL R.F. GENERATOR.—Langton. (*Wireless World*, March 1944, Vol. 50, No. 3, pp. 70–72 : April, No. 4, pp. 111–114.) (i) Expansion of some of the points dealt with in the survey referred to in 1475 of April. (ii) Major points of design procedure for any value of output.

2101. POSSIBLE APPLICATIONS OF ULTRA-SHORT RADIO WAVES [including Accident-Prevention, De-Infestation, Cooking, etc.].—Mouromtseff. (*Journ. Applied Phys.*, Jan. 1944, Vol. 15, No. 1, pp. 20–21 : short note only.)

2102. IMPROVISED METHODS OF LOCATING A BREAK IN A MULTI-CORED CABLE.—" Diallist." (*Wireless World*, March 1944; Vol. 50, No. 3, pp. 94–95.) Notes on suggestions prompted by 1485 of April.

2103. THE PROBLEM OF REDUCTION OF VIBRATIONS BY USE OF MATERIALS OF HIGH DAMPING CAPACITY.—Gemant. (*See* 1983.)

2104. SOUND STROBOSCOPE [Patent for Acoustical Counterpart of the Stroboscope].—Kurtz. (*Journ. Acous. Soc. Am.*, Jan. 1944, Vol. 15, No. 3, pp. 196–197.) Assigned to the General Electric Company.

2105. THE DU MONT TYPE 244 CYCLOGRAPH FOR DETERMINING DIFFERENCES OR VARIATIONS IN METALLURGICAL PROPERTIES OF METAL PARTS OR STOCK. —Du Mont Laboratories. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, p. 378.) *See* also 1480 of April and 1802 of May.

2106. THE " IDENTOMETER ", FOR IDENTIFICATION OF FERROUS ALLOYS [by Comparison of Thermo-electric Properties].—Dravo Corporation. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, p. 379.)

2107. THE TECHNIQUE OF MICRORADIOGRAPHY [for the Examination of Alloys].—Maddigan. (*Journ. Applied Phys.*, Jan. 1944, Vol. 15, No. 1, pp. 43–54.)

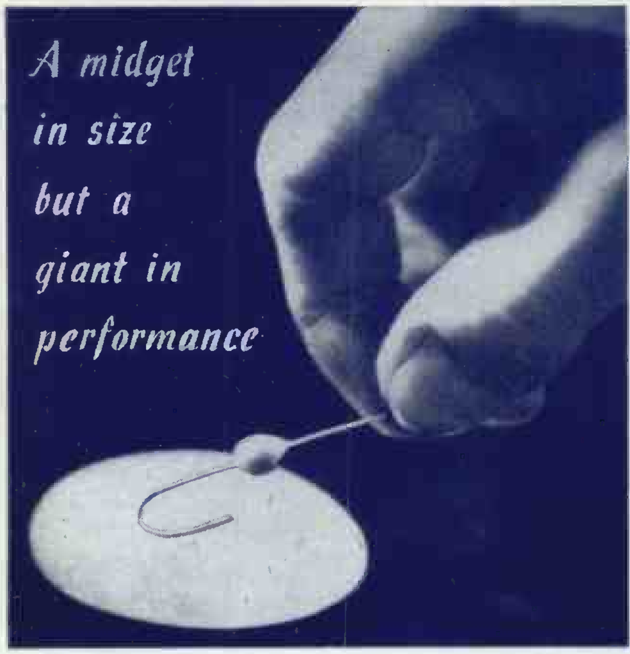
2108. A FAST AND SENSITIVE BOLOMETER AND GALVANOMETER SYSTEM FOR AN INFRA-RED SPECTROMETER [Equipment responding in 0.2 Second to 6×10^{-8} Watt of Radiation from a Slit : Moll Microgalvanometer, Photocells, & Preamplifier mounted on Support employing Large Compression Spring : Effects of Vibration thus reduced to well below those of Brownian Motion].—Baker & Robb. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, pp. 356–359.) *See* also 2109, below.

2109. AN ELECTRODYNAMIC SLIT UNIT FOR AN INFRA-RED DOUBLE MONOCHROMATOR [Constant Energy-Output during Changes in Wavelength, by Control of Slit through Amplifier for Automatic Output Control].—Baker & Robb. (*Review Scient. Instr.*, Dec. 1943, Vol. 14, No. 12, pp. 359–361.) Leading up to pp. 362–367, " High-Speed Automatic Infra-Red Spectrometer " : *see* also 2108, above.

2110. ON A DEFORMATION OF THE MERCURY-VAPOUR DIRECT-CURRENT HIGH-PRESSURE ARC BY A SUPERPOSED ALTERNATING CURRENT [50–16 000 c/s: Observations on Different Types of Lamp, including the " Heraeus Burner "].—Koch. (*Ann. der Physik*, 26th June 1943, Vol. 43, No. 1/2, pp. 91–98.) A footnote mentions that Mangold [for previous work *see* 1537 of 1941] has encountered similar effects with the spherical Osram HgB 500 lamp : he will shortly be reporting on the interpretation of this effect as a resonance oscillation of the gas-filling of the cavity.

2111. NEW INTERFERENCE PHENOMENA WITH NEWTON'S RINGS [by using Multiple Beams instead of the Usual Two].—Tolansky. (*Nature*, 11th March 1944, Vol. 153, No. 3880, pp. 314–315.) *See* also 3271 of 1943, 1450 of April, and 1827 of May.

2112. BRIGHT DIFFRACTION GRATINGS [Latest Technique]. —Babcock. (*Journ. Opt. Soc. Am.*, Jan. 1944, Vol. 34, No. 1, pp. 1–5.)



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