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Editorial.

The Definition of Selectivity.

IN an article in this issue Mr. Colebrook discusses this important subject. He distinguishes between selectivity and sharpness of tuning by applying the former term to the variation of response with variation of energising frequency, and the latter term to the variation of response with variation of some electric constant of the circuit. As he points out, it is doubtful if any simple definition of these terms could be formulated which would be applicable to such systems as band pass filters. Difficulties arise with even two tightly coupled circuits with their two resonant frequencies. If one confines one's attention to a simple resonant circuit the matter is relatively plain, and one is therefore somewhat surprised to find that, according to the definitions which he adopts, Mr. Colebrook comes to the conclusion that for current resonance in a simple circuit the selectivity is approximately twice the sharpness of tuning. On examination, however, it is seen that this is because of a definition which is quite arbitrary and of doubtful justification and not because of any essential difference in the quantities defined. If one defined the width as the distance across an object expressed in inches and the breadth as the same distance expressed in centimetres, one would obtain the result that the breadth of the object was 2.54 times its width. As Mr. Colebrook says in paragraph 11, "sharpness of tuning will be expressed in terms of the variable element of the network by means of which the tuning is obtained," but if the tuning is obtained by means of a variable condenser the question arises whether for the variable electric constant one should take the capacity or its square or its square root or some other function of it. The reader may be tempted to say that it is surely the capacity of the condenser which one alters, but this is not so; the root of the capacity is just as fundamental a quantity as the capacity itself, and we can just as well say that we are altering the former as the latter. We are dealing with resonant phenomena and, if one glances through Mr. Colebrook's formulæ, one will see that in such phenomena we are concerned with $\sqrt{C}$ rather than with C. We suggest that sharpness of tuning should therefore be expressed in terms of that property of the variable element which has a linear relation to the resonant frequency of the circuit, that is to say, $\sqrt{C}$ or $\sqrt{L}$ rather than a property like C or L, which has a more complex relation to the frequency. We think that if Mr. Colebrook modifies his suggestion along these lines, the highly undesirable anomaly of the selectivity being twice the sharpness of tuning will disappear.

G. W. O. H.

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Measurement of Wavelengths of Broadcasting Stations.

An Account of the Work of the Brussels Checking Station of the U.I.R.

By R. Braillard and E. Divoire.

IN a former article*, the authors explained to the readers of this journal the reasons why the application of the wavelength distribution plan, called "Plan de Genève," had imposed on broadcasting stations the absolute necessity for maintaining most strictly their nominal wavelengths with the greatest accuracy.

A wavemeter, or more exactly a frequency indicator, giving an accuracy of the order of one or two parts in 10,000 had been specially designed for this purpose by the Technical Commission of the International Broadcasting Union. The complete description of this instrument was the principal object of the above-mentioned article.

Since these wavemeters were taken into service, it has been found that it is not entirely sufficient to give each station an accurate and stable meter in order to ensure the success of the wavelength plan. In effect, the narrowness of the frequency band allowed to each station does not in principle permit of any error. Now, in spite of everything there are offenders; on the one hand among adherents of the Union, it has happened that certain stations either are not supplied with so accurate a meter or that the maintenance engineer neglects for one reason or another to make use of it. On the other hand it is evident that the majority of the interferences are caused by those who do not adhere to the Union. These, even though they are only a small minority compared with the adherents, are however one of the principal causes of interferences which are heard in the reception of broadcasting.

Finally, in general, one finds that it is most useful to have a central organisation which can supervise all broadcasting stations and which can seek systematically the cause of interferences, the effects of heterodynes and other anomalies which may appear.

For these different reasons, the International Broadcasting Union decided to set up at the headquarters of its Technical Committee in Brussels a permanent listening and wavelength checking post. We propose to describe below the wavemeter which has been designed with this end in view.

Method of Measurement Adopted.

One had the choice between two methods of measuring wavelengths at a distance, both classic and well known; the method of absorption and the beat method. After some preliminary tests we arrived at the conclusion that the first method, even though it presented, at least at first sight, more convenience and rapidity of operation, did not give the desired guarantees of precision when one was endeavouring to obtain an accuracy of the order of one part in 10,000.

The beat method was therefore adopted. Its principle is well known. The distant signal is received by means of a sensitive and selective receiver†, and is caused to interfere with a local oscillation produced by a heterodyne wavemeter calibrated to the desired accuracy. At the moment of the zero beat, the adjustment of the heterodyne wavemeter indicates the wavelength of the distant station under measurement.

It is easy to see that a number of precautions must be taken to ensure precision in such measurements. Among others it is evident that the error in calibration of the heterodyne wavemeter must be less than the maximum error allowed for the measure-

* "The Exact and Precise Measurement of the Wavelength of Transmitting Stations," *E.W. & W.E.*, June and July, 1927.

† The receiver used at the Brussels Control Station comprises two stages of high-frequency amplification using screened-grid valves, detector and two stages of resistance-coupled low-frequency amplification.

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ment. The following procedure was adopted after one had become assured that the above conditions had largely been fulfilled :—

(1) To use a heterodyne wavemeter which was sufficiently stable for its calibration to remain non-variable during a certain time ; several days or more.

(2) To check the calibration of the apparatus as often as experience should show it to be necessary, by means of extremely accurate apparatus, relying on a primary standard of which the constancy was absolutely certain. This standard in this case is the valve maintained tuning fork of special construction.

It could here be objected that it would have been of interest to have been able to refer each measurement individually to the primary standard, in order to eliminate the errors which could result from unsuspected variation in the secondary standard, *i.e.*, the heterodyne wavemeter. But such a procedure, more exact in principle, would have had the inconvenience of making the operations much slower and much more laborious. Now among the qualities insisted on from the installation were ease and speed of operation, the apparatus eventually having to be put into the hands of operators but little skilled in laboratory measurements. On the other hand, practice having confirmed that accuracy of the results obtained was more than sufficient for the needs of the moment, we confined ourselves to the above considerations.

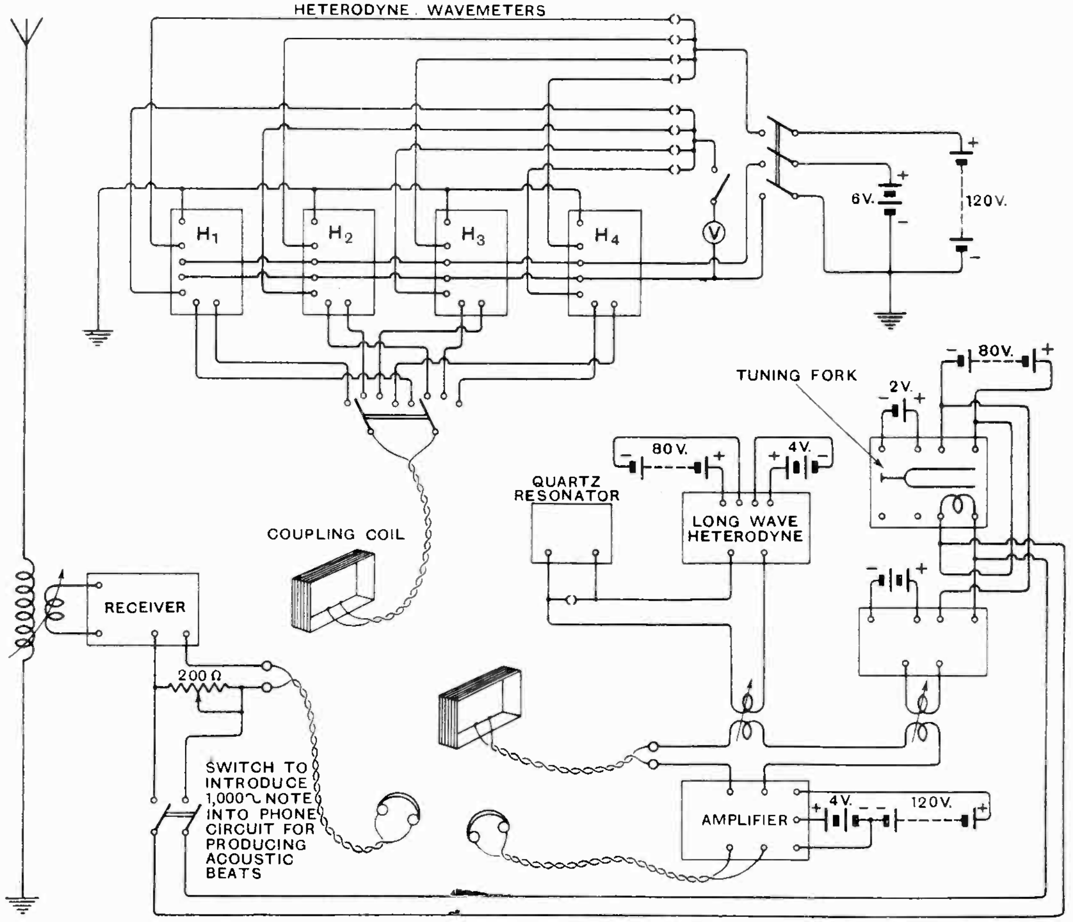

Fig. 1.—*General diagram of connections of the installation.*

We will now examine the result. the final arrangement of which is given in Fig. 1 in a schematic diagram.

Description of the Heterodyne Wavemeter.

To achieve the first of the conditions specified above, the heterodyne wavemeter

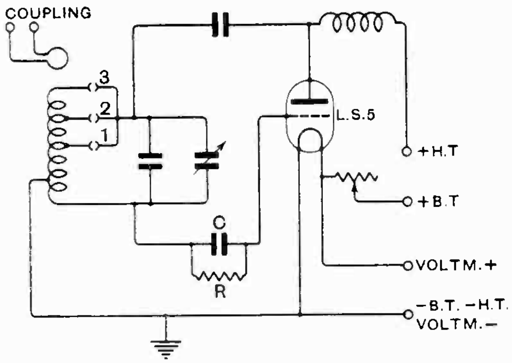

Fig. 2.—*Diagram of connections of the heterodyne wavemeter.*

must be robust and stable, which is assured by the constructional arrangements which we shall describe further on. Further, it should allow measurements of a transmission to be taken easily with an accuracy of the order of one part in 10,000. This condition exacting that the ranges should be sufficiently wide, one was led to foresee the necessity of a "battery" of 4 heterodyne wavemeters, of which each should have three ranges. The total of these 12 ranges cover the 1,000 kilohertz‡ approximately, of the band of frequencies allotted to broadcasting by the Washington Convention (200–545 metres).

To ensure robustness of the instrument, it is constructed on the same principles as were used in the wavemeter of the Technical Committee of the U.I.R. It is composed of particularly stable elements so as not to be susceptible to variations which may be caused by mechanical shock, etc. The metal construction is generally adopted, the volume of insulators being reduced as much as possible. The whole of the components, as well as the valve, are completely enclosed in an aluminium box which serves also as a screen.

‡ 1 kilohertz = 1 kilocycle per second. The term kilohertz, introduced by German professors, has been adopted by the Union Internationale de Radiodiffusion.

The diagram of connections is that of a Hartley circuit with parallel feed (Fig. 2). This circuit has the advantage of giving a fairly constant oscillating energy over a wide extent of frequencies. A plug and socket switch allows the use of three values of inductance. A one-turn coupling coil mounted inside the metal box provides for coupling to external circuits. The variable condenser is of the same type as that of the transmitter wavemeter above mentioned.

The variable condenser ensures, as has been said above, a range of about 100 kilohertz. To obtain ease of adjustment, the condenser is provided with a special slow-motion handle which also provides for insulation between the handle and the moving electrodes. (It should be noted that in effect the moving electrode is not at the potential of the chassis.)

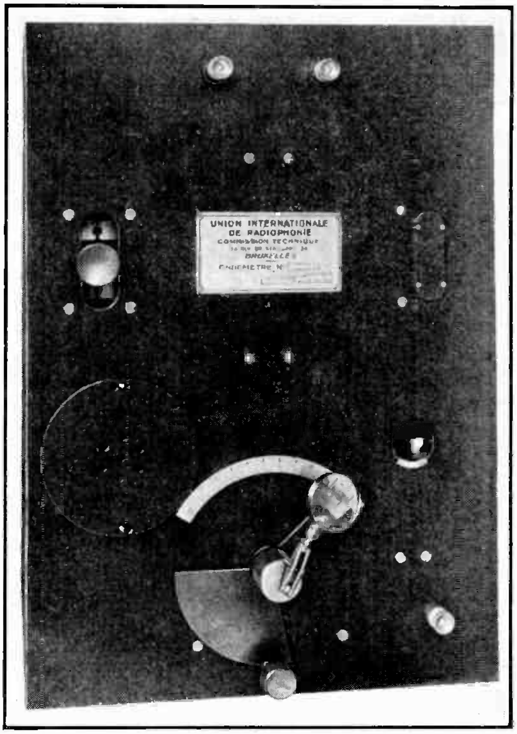

Fig. 3.—*Photograph of wavemeter panel.*

A vernier graduated from 1 to 10 is engraved on the pointer, which allows of reading to 1-10th of a degree or, after a little practice, to 1-20th of a degree. A lens

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mounted on the pointer further assists reading (see Fig. 3).

The scale is divided into 100 degrees corresponding roughly to a range of 100 kilohertz. It follows, therefore, that the scale can be read to 50 hertz.§

A Marconi type LS5 valve is used. This is mounted inside the metal case with the other components, in order to avoid hand capacity effects. It should be mentioned that it was found essential to cover the end of the variable condenser spindle, which necessarily must project from the case, with a metal cap connected to the case. The battery connections are of lead-covered cable, of which the covering is connected to earth. The above-mentioned precautions have completely eliminated frequency variations due to the presence of the observer.

It is further necessary to guarantee the constancy of calibration against inevitable small variations due to changes in low-tension and high-tension battery voltages. It was possible to achieve this by a judicious choice on the one hand of the grid condenser C and of the grid leak R, and on the other hand of the L.T. and H.T. voltages. The value of condenser C is fixed at 0.005 mfd.; its value is not particularly critical. On the contrary the value of R is far from being uncritical.

The curves in Fig. 4 show :—

(*a*) The variation of the calibration of one of the heterodyne wavemeters, expressed in degrees of scale reading of the variable condenser, as a function of the low tension voltage for a high tension voltage of 120 volts.

(*b*) The variation of calibration as a function of the H.T. voltage for a L.T. voltage of 5 volts, the grid leak resistance being 20,000 ohms. (*c*) and (*d*) are similar curves for a grid leak resistance of 100,000 ohms.

Other values than these were tried, but they gave a far from ideal solution.

§ As a matter of fact, in order to conserve the same relative accuracy in reading over the whole band from 200–600 metres, it has been arranged to cover by each of the 12 ranges, a range of which the extent is proportional to the frequency of its middle point. It follows from the calculation of these ranges that throughout the whole extent of the band, one degree of the scale covers $\frac{12}{10,000}$ of the corresponding frequency at the point of graduation.

It will be seen from the curves that the most favourable values are :—

Grid leak resistance of 100,000 ohms.
Anode voltage .... 120 volts.
Filament voltage ...... 5 ,,

It should be noted that with these values, variations of calibration are too small to be evaluated in degrees of the condenser scale.

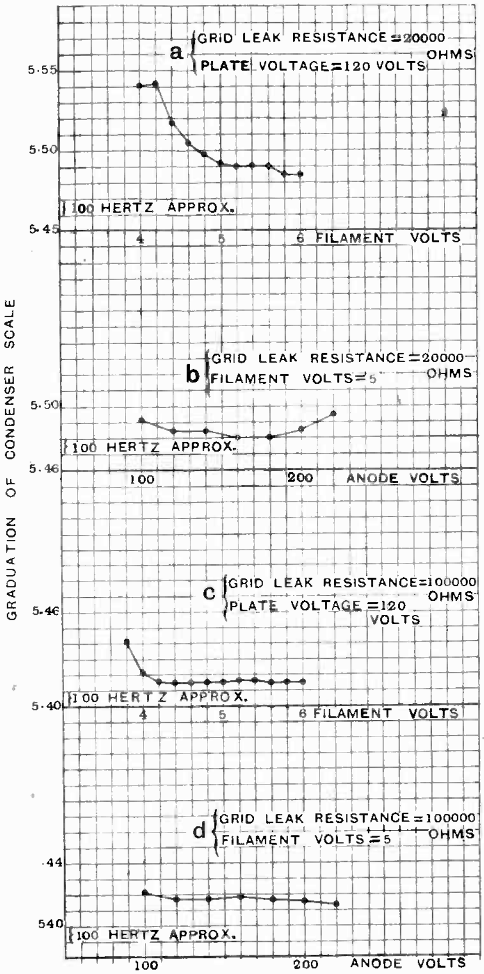

Fig. 4.—*Curves showing the variation of calibration of the heterodyne wavemeter as a function of low-tension and high-tension voltages for a grid leak resistance of* 20,000 *ohms and* 100,000 *ohms.*

The evaluations of differences in frequency were made by ear by listening to a beat between the wave emitted by the heterodyne wavemeter and that of the long wave hetero-

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dyne (see Fig. 1), itself adjusted on to a harmonic of the multivibrator. These beats, even though they were of a very low frequency (of the order of 1 or 2 per second), could be easily appreciated due to the use of an auxiliary current of 1,000 hertz in the manner which we describe in detail further on. It was thus possible to be certain that the calibration did not vary by more than 2 parts in 100,000 for filament voltages between 4.5 and 5.5 volts.

It was further verified that with the values of components and voltages chosen as above, the energy output from the heterodyne wavemeter kept sufficiently constant over the whole extent of the three tuning ranges.

It was also established that the change in impedance of the circuit connected to the terminals of the coupling coil did not cause, by reaction, a change in calibration of the apparatus. It was found that the calibration did not change by more than one or two beats per second in changing over from the coupling turn being open circuited to it being connected to a coupling frame having about 10 turns such as that used in the layout shown in the diagram.

Lastly, desiring to make an estimate of the importance of slow changes in calibration which would result from deformation of the different components, due to changes in atmospheric conditions (temperature, etc.), and inevitable ageing of certain components, insulators, etc., the change in calibration was carefully recorded from day to day for certain particular frequencies.

Below in Fig. 5 will be found the curve showing the variation of calibration, and, as a reference, that of the change in temperature during a period extending from the 31st July to the 19th October, 1928. The frequency used for these observations was 966 kilohertz.

These variations are of the order of one in 10,000, and it is easy to take account of them by applying a correction factor to the measurements on a particular day.

Description of the Calibration Apparatus.

In order to realise the second of the conditions set forth at the beginning of this article, it is necessary to have apparatus which will check the calibration of the heterodyne wavemeters as often as is necessary. This operation should be rapidly and accurately performed.

The general layout shown in Fig. 1 was adopted.

Following a well-known arrangement already described in the article referred to above, the primary standard is a valve-maintained tuning fork which determines the fundamental frequency of a multivibrator. The harmonics of the latter are selected by zero beat method with the aid of a heterodyne called " long-wave heterodyne " in the figure (wavelengths from 1,000 to 3,000 metres approx., frequencies from 300,000 to 100,000 hertz). The harmonics of the latter in turn serve to calibrate the heterodyne wavemeters also by the zero beat method.

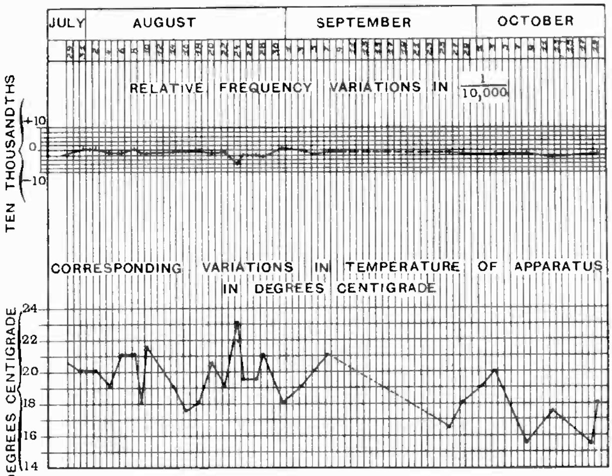

Fig. 5.—*Curves showing the variations in calibration of Range 2 of the heterodyne wavemeter No. 2, for a frequency of 966 kilohertz and variations in temperature.*

The appreciation of the zero beat in both cases is obtained by means of the amplifier shown.

It should be remarked that with constant practice it is often found possible to omit the intermediate operation; that is to say it is possible to observe the beats between the heterodyne wavemeter and the higher harmonics (of the order of 600,000 to 1,000,000) of the multivibrator. Thus one cause of error is avoided.

The valve-maintained tuning fork made by

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Messrs. Sullivan is of Elinvar, a special alloy of which the coefficient of elasticity varies very little with temperature. It was calibrated at the National Physical Laboratory, Teddington, under the direction of Dr. Dye to a frequency of 1,000 hertz with an accuracy of the order of one part in 100,000. The coefficient of variation with temperature is 0.000018 cycles per degree centigrade. (This can be taken into account if necessary.)*

The multivibrator is of the well-known type studied by Abraham and Bloch. The long-wave calibration heterodyne does not contain any special features except perhaps that its variable tuning condenser is provided with a slow-motion dial having a ratio of 1-400th in order that the zero beat point between it and the harmonics of the multivibrator can be found as easily as possible.

A luminous quartz resonator, calibrated specially by the Reichsanstalt at Berlin, is included in the apparatus in order to give a simple method of ascertaining which harmonic of the multivibrator is being used.

The amplifier consists of five stages, resistance coupled (2 high-frequency stages, a detector and two low-frequency stages). Transformer low-frequency amplification was avoided in order to get the best possible response to very low frequencies of the order of only a few cycles per second which are particularly necessary when adjustment to zero beat is being carried out.

Accuracy of Measurements.

The calibration of the heterodyne wavemeters can, with the aid of the installation described, be effected with an accuracy considerably greater than that which actual practice requires. The errors to be considered reduce themselves in effect to the following :—

(*a*) The error in calibration of the tuning fork, equal, as we have seen, to about one part in 100,000.

(*b*) The error in the appreciation of the zero beat between the harmonics of the multivibrator and the fundamental of the long-wave heterodyne. As it is possible easily to reduce this to a value less than one a second, the error is in any case less than one part in 100,000.

(*c*) The error in the appreciation of the zero beat between the harmonics of the multivibrator and the fundamental of the long-wave heterodyne. This is, as above, less than one part in 100,000.

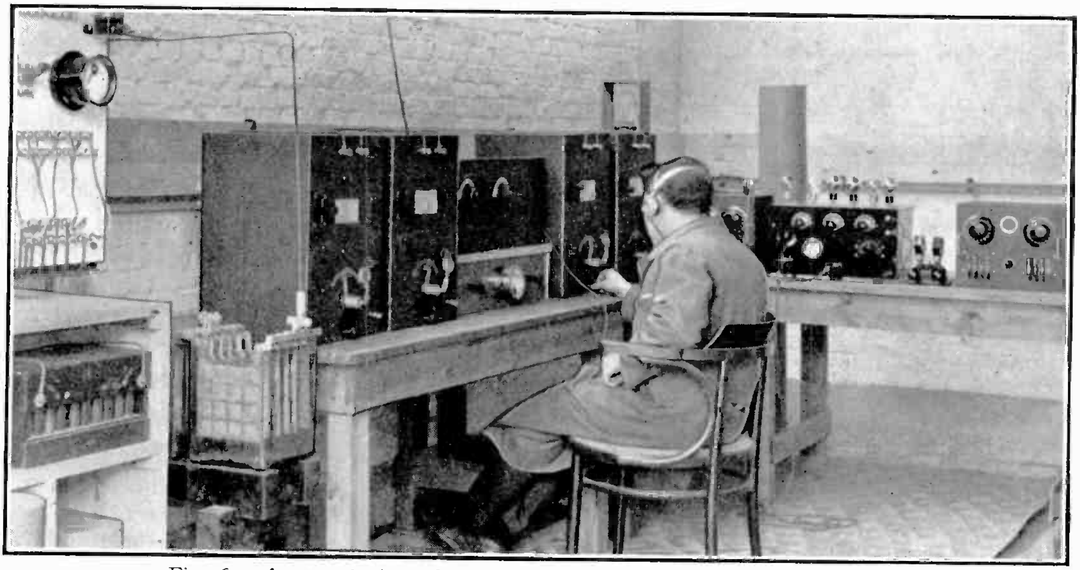

Fig. 6.—*A general view of the laboratory at the Brussels checking station.*

* Some measurements will be undertaken shortly, as a result of an agreement between the U.R.S.I., the Radio Research Board, the National Physical Laboratory and the British Broadcasting Corporation, in order to ascertain that the calibration of such forks does not vary even after a certain lapse of time (December, 1928).

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It is to be noted that, as has been suggested above, one can, with certain practice, observe directly the beat between the fundamental of the heterodyne wavemeter and the harmonics of the multivibrator, and thus eliminate one of the preceding errors.

(*d*) The error of reading the scale of the heterodyne wavemeter, which has been estimated above as one part in 10,000 as a maximum. This error, therefore, preponderates in comparison with the others and they can be, therefore, comparatively neglected.

Let us now evaluate the order of the accuracy which can be obtained in the measurements of broadcast transmitters.

This obviously must first take into account the error in the reading of the scale.

Secondly, the error in appreciating the zero beat with the received current which is under measurement must depend evidently on the intensity of this current. On an average it is found that the zero beat can be estimated to several parts in 100,000.

This error can, however, be reduced in the following way :—

Instead of finding the zero beat between the heterodyne wavemeter and the carrier to be measured, the heterodyne wavemeter is adjusted so as to obtain a beat note of the order of 1,000 cycles on one side of the silent point. It is easy to determine with great accuracy this note of 1,000 cycles by comparing it with the note given by the tuning fork. To this end the switch shown on the left at the bottom of Fig. 1 allows an alternating current of 1,000 hertz, produced by the tuning fork, to be introduced by means of a potentiometer into the telephone circuit of the receiver. The heterodyne wavemeter is then adjusted in order to obtain zero acoustical beat between the two musical notes. A similar procedure is then adopted for the 1,000 hertz beat note on the other side of the silent point on the heterodyne wavemeter.

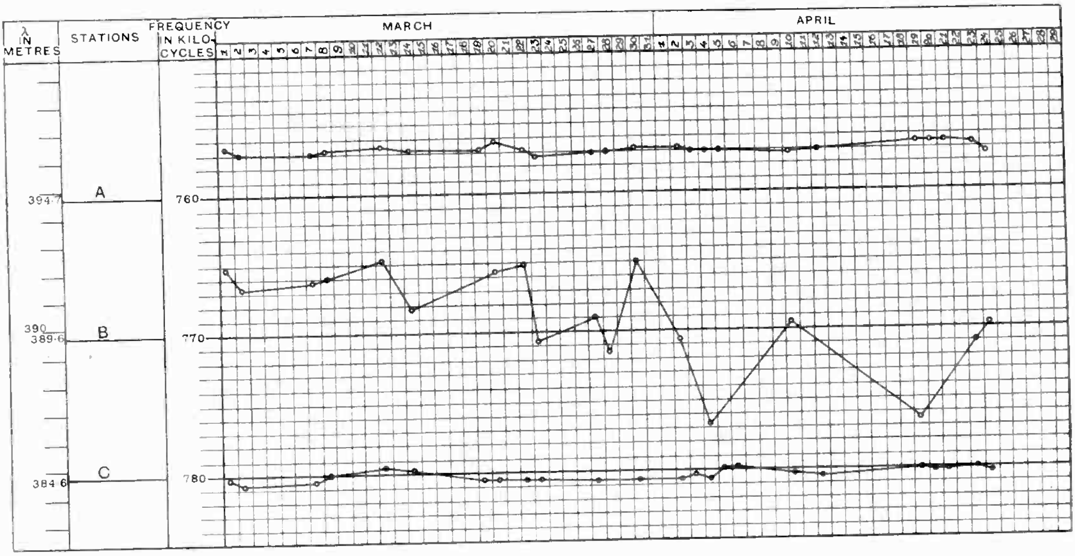

Fig. 7A.—*Summary of the measurements of transmissions taken on 3 stations during the months of March and April,* 1928.

Having thus determined the frequencies $f+1{,}000$ and $f-1{,}000$, the mean of the two readings gives with great accuracy the frequency f which it was required to measure. The error in such a measurement is in this way reduced to considerably less than one in 100,000.

It should be noted again that the reading of the scale gives the principal error.

In general then it can be estimated conservatively that the installation allows the measurement of the wavelengths with an accuracy of the order of one or two parts in 10,000 depending on the particular case.

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The Use of the Apparatus.

Practice has shown that to obtain desired accuracy of results, it was prudent to check against the multivibrator one point on each of the 12 ranges each day; thus 12 correction factors are obtained. With a little practice this operation could be carried out very quickly.

The heterodyne wavemeters have shown themselves to be easily handled, and it is possible for operators not having great skill in laboratory measurements to carry out accurate measurements without difficulty.

At the Brussels Checking Station between 100 and 150 measurements are made daily during a period of about four hours' listening. The accuracy of these measurements makes it possible to follow very closely the fluctuation in the wavelength of certain stations which have shown variations in frequency.

Fig. 7A shows, as an example, a curve giving the day-to-day variation of a station *B*, having stations *A* and *C* on either side of it. One sees how station *A*, in order to keep clear of the variations of *B*, has been obliged to adopt a frequency of approximately 757 kilohertz instead of staying on the frequency nominally assigned to it.

Following intervention by the Brussels checking station, *B* took steps to maintain a constant frequency. The resulting curve in Fig. 7B shows that the efforts made were entirely successful.

Measurement of Scintillation or Variation in the Frequency Due to Modulation (Frequency Modulation).

The method of measurement which makes use of auxiliary low-frequency current described above, has made it possible to observe very simply an annoying phenomenon met with in radio telephony transmitters, and one which it is not always easy for technicians to eliminate. This rapid and irregular variation of carrier frequency, due to modulation of the carrier wave by speech or music, can be compared to a sort of scintillation. The principle of measurement is the following :—

One arranges for an approximately 1,000-hertz beat note between the wave to be observed and the heterodyne wavemeter.

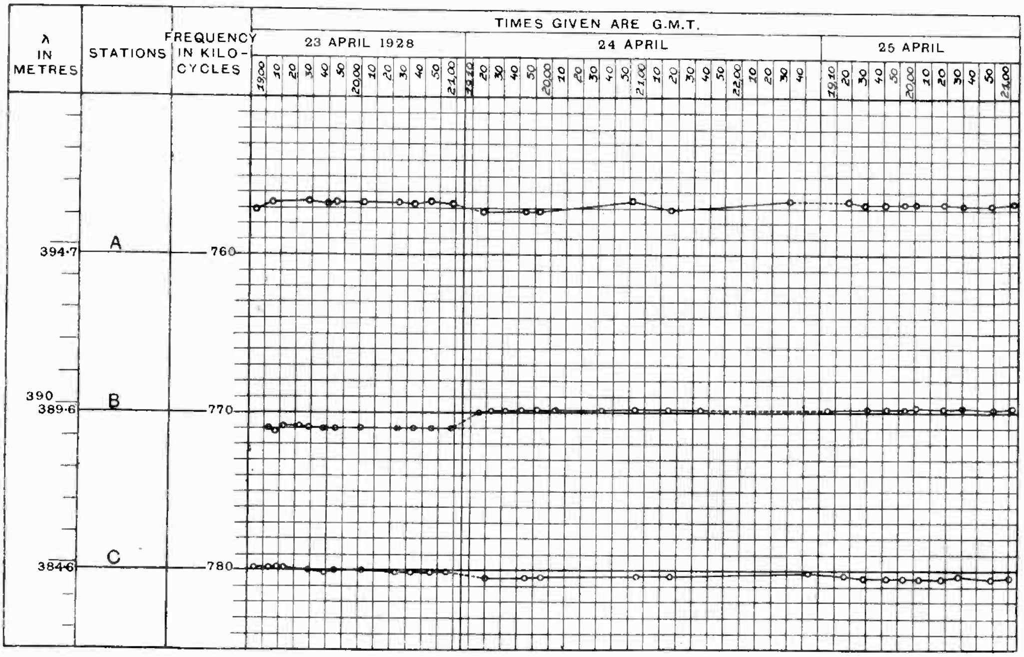

Fig. 7B.—*Summary of measurements for the same stations on the 23rd, 24th and 25th April, after intervention by the Technical Committee.*

This note of approximately 1,000 hertz is caused to beat with the low-frequency note of 1,000 hertz given by the valve-maintained tuning fork as described above.

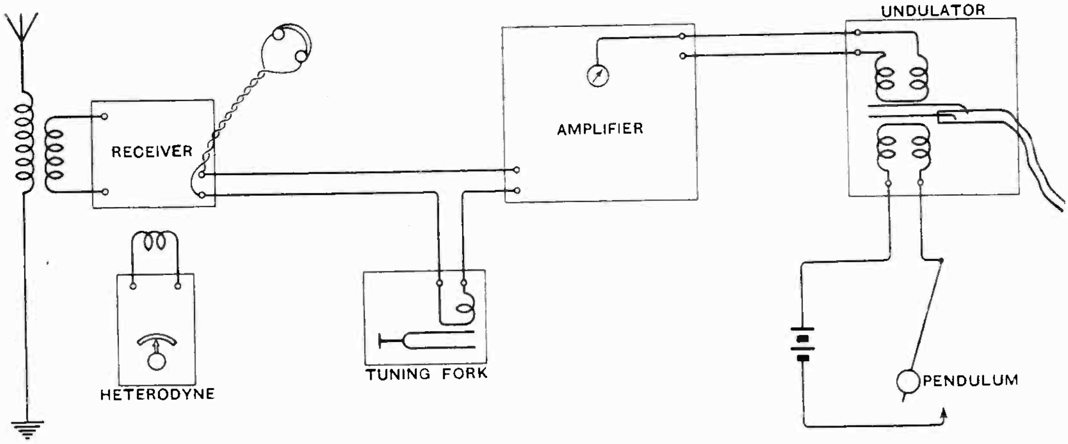

Fig. 8.—*Diagram of connections of the apparatus for recording scintillation (frequency modulation).*

A very low frequency beat is thus obtained, which on this occasion is not reduced to zero, but by a suitable adjustment of the heterodyne wavemeter is arranged to have a value of a few cycles per second. The frequency of the tuning fork being constant, the frequency of the low-frequency beat depends on the value of the beat note between the heterodyne wavemeter and the carrier wave. This latter beat note in its turn depends only on the frequency of the carrier wave, for the calibration of the heterodyne wavemeter remains perfectly constant, in any case during a limited time, thanks to the precautions taken and described above.

Thus by the double-beat method, scintillation (frequency modulation) of a station can be appreciated.

In order to record this very low frequency second beat note at the output of the receiver, it is rectified and amplified by a suitable amplifier for dealing with such low frequencies (see Fig. 8), and connected to a recorder.

The beats of a seconds pendulum are recorded simultaneously on the tape by means of an auxiliary inker.

Fig. 9 shows examples of curves taken by means of this arrangement. It should be noted that stations whose transmission can be registered in such a way are among the better ones. Many stations, however, produce such a marked amount of frequency modulation, that it would not be possible to record on a tape even with the aid of an undulator of very rapid movement, the beats varying from 0 to several hundreds per second.

There is no doubt that such stations occupy a gamut in the band of frequencies allotted to broadcasting much larger than that to which they would normally have a right, and they produce much more serious jamming than one would imagine.

Organisation of Measurements.

The Radio-electric Conference at Prague has entrusted the Belgian Administration with the measurement of the wavelengths of broadcasting stations.

This Administration, in acknowledging the technique and the impartiality of the members of the Technical Commission who have made these measurements for more than two years, has asked the Checking Centre at Brussels to continue its work on an official basis.

The results of the daily measurements of the Checking Centre are sent monthly to the different European administrations through the intermediary of the Belgian Telegraph Administration and the International Telegraph Bureau at Berne.

Besides the Brussels checking station, the Technical Commission of the International Union of Broadcasters has, at the moment, the benefit of the results of measurements taken at the checking stations of

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the B.B.C. (Keston) and the Reichspostzentralamt, Berlin.

Keston is equipped with apparatus in all ways similar to that at Brussels; Berlin uses apparatus specially designed by the technical *personnel* of the Reichspostzentralamt.† Specially organised tests have established the close agreement existing between the several centres in the matter of absolute values of frequency standards. It was particularly useful to be certain of such agreement before conducting the accurate measurements considered indispensable by the Technical Committee.

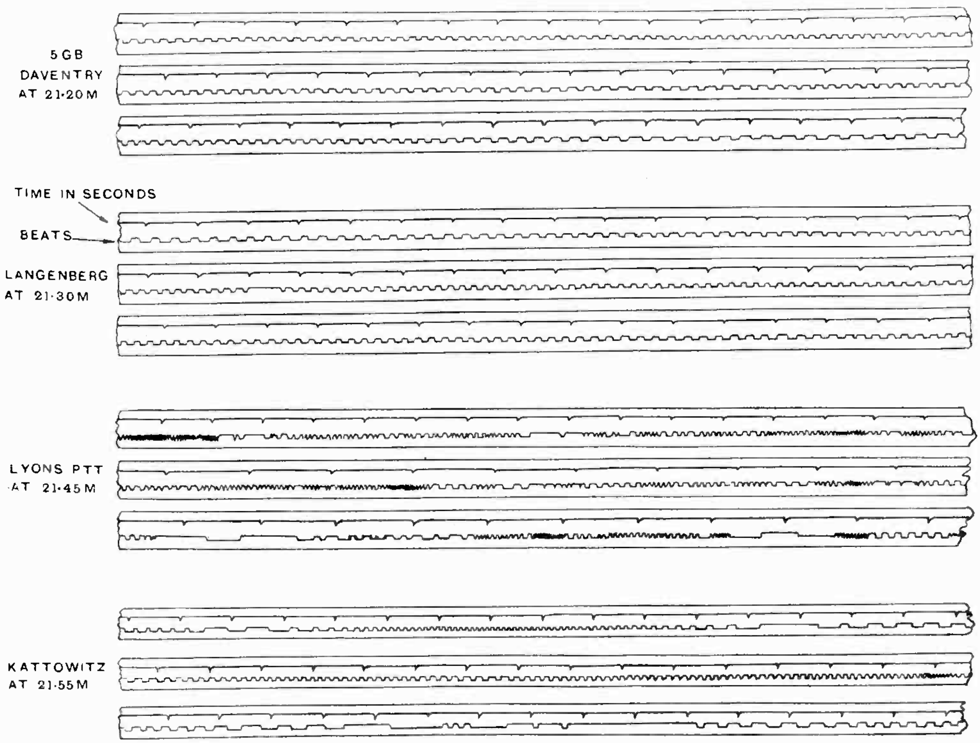

Fig. 9.—*Examples of scintillation records for 4 different stations.*

The three centres exchange the results of their measurements several times a week. Further, it has been found that practically all cases of jamming can be spotted by one or other of these centres. In this manner a close collaboration has been established of which the results appear more and more indispensable. The case represented in Fig. 5 is an example.

There is no doubt that the extension of such methods of control to transmitters in other categories of radioelectric services should be seriously considered from now on.

Although finding itself a relative newcomer in the domain of radio electricity, broadcasting has pointed the way to its seniors in this as in many other directions.

Let us confess, however, that it has been forced to do so by an overwhelming necessity to safeguard its own existence.

But the insistent development of radio communication, the progressive invasion of the whole spectrum of frequencies cannot but result sooner or later in placing other branches of radio in a similar situation. Following the Washington Convention, others more severe will follow, and checking apparatus such as that which we have just described will cease to appear in the eyes of some as a superfluous luxury, but will become, on the contrary, an indispensable auxiliary to a well-conducted service.

† Prague (Radiojournal) will very shortly open an installation of the same model as that at Brussels, and models using identical apparatus are in construction for future centres at Paris, Madrid and Stockholm.

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The Definition of Selectivity.

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

SELECTIVITY is a very important circuit characteristic. There is, however, no universally accepted definition of this term, which is capable of general application to all cases of electrical resonance. Such terms and formulæ as are at present in use have been derived from the theory of the simple series resonant circuit, and are not in a form which makes clear their application to some of the more complex types of resonance which are utilised in wireless practice.

2. Existing terms do not sufficiently clearly distinguish between selectivity, which refers to the variation of the behaviour of a given circuit or network with respect to frequency, and another characteristic which, for want of a better name, can be described as "sharpness of tuning." The latter refers to the variation of the behaviour of the circuit with respect to a variation of some specified element of the circuit, the frequency being kept constant. The behaviour with respect to the variation of a tuning condenser is an example of this.

(In circular No. 74 of the Bureau of Standards, this latter characteristic, *i.e.*, "sharpness of tuning," is described in relation to a simple series resonant circuit and is called alternatively "selectivity" and "sharpness of resonance." In the writer's opinion, however, it is preferable to confine the term "selectivity" to the behaviour of the circuit with respect to frequency variation, since the term suggests the selective behaviour of the circuit with respect to electromotive forces of various frequencies. The term "sharpness of resonance" is not quite suitable, since resonance can be obtained in two ways, either by a variation of the frequency of an applied electromotive force, or by variation of circuit elements, the applied frequency remaining constant. The term "sharpness of resonance" could be applied equally well to either of these, whereas the proposed term "sharpness of tuning" is quite specific).

3. Both "selectivity" and "sharpness" of tuning" are circuit properties, depending only on the electrical constants of the circuit or net work and on the frequency. It is very desirable, however, that these characteristics should be so defined as to take account of the fact that any given network may be associated with a number of different types of resonance. Thus, for instance, in the case of a simple series resonant circuit there will be a current resonance, associated with certain frequency or circuit conditions. The current maximum, however, will not exactly coincide with the maximum potential difference across the inductance with its associated resistance which will occur at a slightly different frequency. Each of these two resonances will have slightly differing selectivities. In the case quoted the differences will in general be negligibly small, but this will not necessarily be so in all cases.

For a complicated network there will obviously be a large number of alternative resonances, depending on the actual electrical quantity concerned. This latter may be any one of a number of branch currents, or the potential difference across any desired component impedance or impedance group. Any definitions of selectivity or sharpness of tuning should therefore be framed in such a way as to take account of these possibilities.

4. For many simple cases there will be a comparatively simple relation between the selectivity and the sharpness of tuning of any given resonance. In fact, assuming for the moment the definitions of these quantities to be as suggested below, the former, in most simple cases (such as that of the series resonant circuit) will be very approximately twice the latter. It should be clearly realised, however, that in a number of cases of considerable practical importance there will be no such simple relationship. Consider, for instance, a network consisting of a condenser-tuned receiving circuit associated with any amplifier having tuned-anode circuits. Taking the resonance of some suitable output quantity, such as the potential difference across the anode impedance of the last valve, then the

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sharpness of tuning of the input circuit will not involve the characteristics of the tuned-anode circuits, since the input frequency remains constant. The selectivity of the whole receiving system will, however, be a totally different quantity, since it will involve the selectivities of all the intermediate circuits. From the point of view of the elimination of interference, the latter will, of course, be the important characteristic.

5. The following proposals are put forward only as a basis for a discussion of the most suitable definitions of selectivity and sharpness of tuning. As a preliminary it will be necessary to consider the term resonance and to define it in a manner which will give a wide generality to its application.

6. Given a certain network of conductors of any character, let A and B be any two simple harmonic alternating electrical quantities of frequency $\omega/2\pi$, the amplitudes $\hat{A}$ and $\hat{B}$ of which are related by an equation

$$\hat{B} = \frac{\hat{A}}{Z}$$

where Z is a function of ω and of the electrical constants of the network. The quantity Z may thus be regarded as a form of generalised impedance connecting the quantity $\hat{A}$ which might be, for example, an electromotive force, with the quantity $\hat{B}$ which might be, say, the current in some particular branch of the network.

7. In general there will be a certain value or values of ω for which Z has a critical value, which may be a maximum or a minimum. This condition can be described as a resonance of Z (or as a resonance of B with respect to A). If ω_r be any such value of ω the critical or resonant condition is specified by

$$\frac{\partial Z}{\partial \omega_r} = 0 \qquad \frac{\partial^2 Z}{\partial \omega_r^2} \neq 0$$

(Z_r will, of course, be a maximum or minimum according as $\partial^2 Z/\partial \omega_r^2$ is negative or positive).

8. The state of resonance being defined by the vanishing of the first differential coefficient, the magnitude of the second would seem to be an appropriate basis for specifying the sharpness of the critical condition, but it should be embodied in a form which involves the ideas of proportional changes of frequency ($\delta\omega/\omega$) and corresponding proportional changes in Z (just as in the analogous case of resolving power in optics, which is expressed in terms of $\delta\lambda/\lambda$).

9. A formulation consistent with the above and consistent with existing ideas on selectivity in the usual simple cases is

$$\text{selectivity} = \omega_r \sqrt{\frac{1}{Z_r} \left| \frac{\partial^2 Z}{\partial \omega_r^2} \right|}$$

(the vertical strokes meaning "magnitude of.")

10. The physical significance of this formula is made clearer by the following :—

$$\omega_r \sqrt{\frac{1}{Z_r} \left| \frac{\partial^2 Z}{\partial \omega_r^2} \right|} = \left(\underset{\delta\omega \to 0}{\text{lt.}} \sqrt{\frac{\delta(Z^2)}{Z^2} \bigg/ \frac{\delta\omega}{\omega}} \right) \omega = \omega_r$$

Of these equivalent formulations that on the left is clearly the form for analytical purposes and that on the right for measurement with R.M.S. measuring instruments.

11. The definition of sharpness of tuning will be identical in form with that of selectivity but will be expressed in terms of the variable element of the network, whatever this may be, by means of which the tuning is obtained. Thus, for example, if the variable element be a condenser of capacity C, the resonant condition is defined by

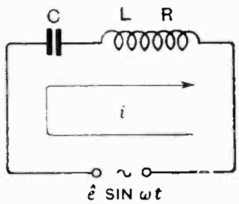
$$\frac{\partial Z}{\partial C_r} = 0 \qquad \frac{\partial^2 Z}{\partial C_r^2} \neq 0$$

and

$$\text{sharpness of tuning} = C_r \sqrt{\frac{1}{Z_r} \left| \frac{\partial^2 Z}{\partial C_r^2} \right|}$$

12. Applications of the above definitions to typical cases are given in an appendix.

13. *Limitations.* The above definitions are probably not applicable to certain types of filter circuit or to combinations of tuned circuits designed so as to have virtually a square topped resonance curve. It is doubtful whether any simple numerical specification could be drawn up which would be usefully applicable both to normal types of resonance and to the special characteristics of band-pass filters and similar circuit combinations.



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APPENDIX.

Deduction of selectivity and sharpness of tuning in some typical cases.

1. *Simple series resonant circuit.*

1.1. *Current resonance.*

Putting $\hat{\imath} = \hat{e}/Z$

$$Z^2 = R^2 + (\omega L - 1/\omega C)^2$$

1.1.1. Selectivity, *i.e.* L, C and R constant, ω variable.

$$2Z\frac{\partial Z}{\partial \omega} = 2(\omega L - 1/\omega C)\,(L + 1/\omega^2 C)$$

$$= 0 \text{ when } \omega L = 1/\omega C.$$

i.e., $$\omega_r = 1\sqrt{LC}.$$

$$\frac{\partial^2 Z}{\partial \omega_r^2} = \frac{4L^2}{R} \text{ and } Z_r = R.$$

Therefore

$$\text{Selectivity} = \omega_r\sqrt{\frac{1}{Z_r}\left|\frac{\delta^2 Z}{\delta \omega_r^2}\right|}$$

$$= 2\sqrt{\frac{L}{CR^2}}.$$

1.1.2. Sharpness of tuning (condenser variation).

In this case ω, L and R are constant and C variable:

$$2Z\frac{\partial Z}{\partial C} = \frac{2(\omega L - 1/\omega C)}{\omega C^2}.$$

Therefore

$$C_r = 1/\omega^2 L \text{ and } Z_r = R$$

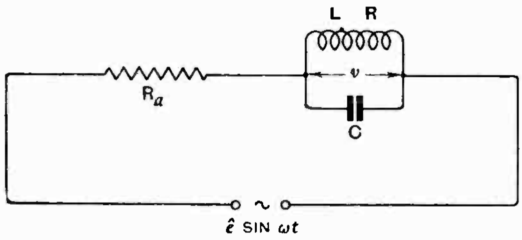
$$\frac{\partial^2 Z}{\partial C_r^2} = \frac{\omega^6 L^4}{R}.$$

Therefore

$$\text{Sharpness of tuning} = C_r\sqrt{\frac{1}{Z_r}\left|\frac{\partial^2 Z}{\partial C_r^2}\right|}$$

$$= \frac{1}{\omega^2 L}\sqrt{\frac{1}{R}\,\frac{\omega^6 L^4}{R}}$$

$$= \frac{\omega L}{R}\left(= \sqrt{\frac{L}{C_r R^2}}\right).$$



1.2. Resonance of potential difference across the condenser.

$$\hat{v} = \frac{\hat{e}}{\omega C\sqrt{R^2 + (\omega L - 1/\omega C)^2}}$$

i.e., $$Z^2 = \omega^2 C^2 R^2 + (\omega^2 LC - 1)^2$$

1.2.1. Selectivity

$$\omega_r^2 = \frac{1}{LC}\left(1 - \frac{1}{2}\,\frac{CR^2}{L}\right)$$

$$Z_r^2 = \frac{CR^2}{L}\left(1 - \frac{1}{4}\,\frac{CR^2}{L}\right)$$

$$\frac{\partial^2 Z}{\partial \omega_r^2} = \frac{4LC}{Z_r}\left(1 - \frac{1}{4}\,\frac{CR^2}{4L}\right)$$

This gives

$$\text{Selectivity} = \frac{2\omega_r L}{R} = 2\sqrt{\frac{L}{CR^2}}\sqrt{1 - \frac{1}{2}\,\frac{CR^2}{L}}$$

Note that ω_r is not quite the same for current and potential resonance.

1.2.2. Sharpness of tuning.

$$C_r = \frac{L}{R^2 + \omega^2 L^2}$$

$$Z_r^2 = \frac{R^2}{R^2 + \omega^2 L^2}$$

$$\frac{\partial^2 Z}{\partial C_r^2} = \frac{\omega^2}{Z_r}(R^2 + \omega^2 L^2)$$

Therefore

$$\text{Sharpness of tuning} = \frac{\omega L}{R} = \sqrt{\frac{L}{C_r R^2} - 1}.$$

2. Another interesting case is that shown in the second Figure, which is an approximation to a tuned anode amplifying circuit.

The resonance to be considered is

$$\hat{v} = \hat{e}/Z$$

The analysis is somewhat lengthy, but can be summarised as follows :—

$$Z^2 = \frac{(R_a + R_0)^2 + X_0^2}{R_0^2 + X_0^2}$$

where $$R_0 = \frac{R}{(1 - \omega^2 LC)^2 + \omega^2 C^2 R^2}$$

$$X_0 = \frac{\omega L(1 - \omega^2 LC) - \omega CR^2}{(1 - \omega^2 LC)^2 + \omega^2 C^2 R^2}$$

2.1. *Selectivity.*

$$\omega_r^2 = \frac{1}{LC}\left\{-\frac{CR^2}{L} + \left(1 + 2\frac{CR^2}{L} - \frac{4R}{R_a}\right)^{\frac{1}{2}}\right\}$$

$$= \frac{1}{LC}\left(1 - \frac{2R}{R_a}\right) \text{ very approximately.}$$

$$\approx \frac{1}{LC} \text{ if } R << R_a.$$

For the approximation $\omega_r^2 = 1/LC$.

$$\text{Selectivity} = \frac{2\omega_r L}{R}\left(\frac{R_a}{R_a + \dfrac{\omega_r^2 L^2}{R}}\right)$$

$$= 2\sqrt{\frac{L}{CR^2}}\left(\frac{R_a}{R_a + L/CR}\right)$$

2.2. Sharpness of tuning.

$$C_r = \frac{L}{R^2 + \omega^2 L^2}$$

and Sharpness of tuning

$$= \frac{\omega L}{R}\left(\frac{R_a}{R_a + \dfrac{R^2 + \omega^2 L^2}{R}}\right)$$

(The formulæ in this case are exact and not approximate.)

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Reduction of Distortion in Anode Rectification.

By *A. G. Warren, M.Sc., M.I.E.E., F.Inst.P.*

SUMMARY.

IT is suggested that, although in modern speakers the frequency response is by no means perfect, the more serious distortion which still persists is due to the presence in the reproduction of alien tones (enharmonic and harmonic). Alien harmonics tend to render the reproduction unduly "stringy," and it is with methods of suppressing them that this article is particularly concerned. In a well-designed set such false harmonics are introduced chiefly during the process of rectification. The general principles of anode rectification are treated and it is shown that the distortion is reduced considerably by increasing the value of the grid swing applied to the rectifier until the sensitivity attains a practically constant value. Although grid swings (peak value) of 2 or 3 volts are commonly advocated it is shown that they are quite inadequate to produce any marked improvement. In treating the theory of rectification it is commonly assumed that a parabolic relation exists between the applied and rectified voltages and it is asserted that, in consequence, distortion is reduced by increase of grid swing. It is shown that this argument is fallacious and that, so long as the relation remains parabolic (which it practically does over the extent of grid swings usually employed), the distortion is unaffected by the magnitude of the grid swing. Fortunately when larger grid swings are used the relation between the applied and rectified potentials deviates considerably from the parabolic form and the reduction of rectification distortion becomes possible. To secure freedom from false harmonics a peak value of grid swing of the order of 10 volts must be employed giving (with an average valve) an L.F. output of about 7 volts. A valve so used gives almost perfect rectification. The subsequent low frequency amplification must be less than that usually adopted. The application of the principles suggested to secure purer reproduction involves a transference of part of the process of amplification from the post-detector to the ante-detector stages.

1. Introduction.

The last two or three years have witnessed enormous strides in the quality of reproduction of broadcast music. Much of the improvement may be directly attributed to the adoption of speakers, such as the "moving-coil," which are capable of reproducing a more comprehensive range of the musical scale. But this, in itself, can account for but a fraction of the advance that has taken place. The output of a modern speaker can be accurately described as a *reproduction*, admittedly imperfect, of the original performance; it has outgrown the stage of music *as played by the loud speaker*. To what is this improvement due? It cannot be attributed solely to the better response to the gamut of musical frequencies; many gramophones, whilst failing to approach the reproduction of a good loud speaker, have a more uniform frequency response. The author would attribute it to the fact that alien sounds have been greatly reduced. A closer approach to the original performance has permitted the faults and the inadequacies of the reproduction to be recognised; recognition has resulted in progress towards correction.

Distortion in reproduction is of three main types:—

(a) *Variation of sensitiveness of the system (speaker or set) to notes of different frequencies.* This is usually manifested by an inadequate reproduction of both the bass and notes of high frequency. Though the effect is much less noticeable with a moving coil speaker than with the earlier diaphragm-horn types, the response is still far from uniform (see McLachlan, *Wireless World*, March 20th, 1927, p. 373). Given, however, some approach to uniformity of response, an approximation to realism of reproduction is possible. A consideration of the conditions obtaining in a concert hall suggests that the quality must change considerably according to the position of the listener; due to reflections and interference the relative intensities of notes of different frequencies must vary greatly from place to place, but the sense of realism is not lost. It appears unnecessary to insist upon too rigid a uniformity of sensitiveness to different

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frequencies. Though it used to be suggested that the reassembly of all frequencies in their correct proportions would result in perfect reproduction, it must be recognised that this condition overlooks the possibility of types of distortion which may be even more serious.

(b) *The introduction of alien harmonics.* The differences of quality between notes of the same pitch, as produced by various instruments, can be attributed to the differences in relative intensity of the various harmonics present. If the relative intensities are preserved, reproduction is natural. Though the quality must suffer through the changing sensitiveness of the speaker to various frequencies, more serious distortion may result through the introduction of ***alien*** harmonics. Their cause is treated more fully later.

(c) *The introduction of alien (enharmonic) tones.* A receiving set or speaker always possesses various possible modes of oscillation—electrical or mechanical. Such modes tend to produce resonance of particular frequencies—the reproduction of certain notes with undue prominence. An effect which may be more distressing is the tendency to the production of transient discordant oscillations, set up particularly in staccato passages or with percussion instruments (see McLachlan, *Wireless World*, 10th October, 1928, p. 497, and 17th October, 1928, p. 539). Such alien tones together with alien harmonics are mainly responsible for "colouration" (loud speaker or gramophone tone).

2. Distortion in the Set.

It is a tribute to the progress which has been made in the speaker itself that each improvement in the set is accompanied by a noticeable improvement in the reproduction. The set has to perform two functions: (*a*) amplification; (*b*) rectification—or the separation of the modulation from its high frequency carrier. For a given frequency no appreciable distortion need occur in amplification so long as the valves are worked well within the straight portions of their characteristics—design must be liberal. The high frequency stages must be designed so that amplification is sensibly constant over a range of 5,000 p.p.s. above and below the frequency of the carrier wave; it is not proposed to consider that problem here, though its practical solution is not difficult. Deviations from rectilinearity of the amplification in the low frequency stages introduce alien harmonics, but this trouble should not arise here. The case is different, however, with rectification. It is commonly acknowledged that rectification introduces distortion, which may sometimes be very considerable, though, under good conditions, particularly with anode rectification, a very fair approach to pure reproduction may be attained. It is well known that the sensitiveness of anode rectification is poor when the signal voltage applied to the grid of the detector is small, and it is generally maintained that with increase of grid voltage not only does the sensitiveness increase but the quality also improves. This is often the case, but the improvement in quality referred to is rarely directly due to the reduction of distortion in rectification. The improvement is usually most noticeable when provision has been made for an increase in high-frequency amplification, ostensibly for the purpose of increasing the efficiency of rectification. The necessity for super-sharp tuning is thereby removed and the higher notes, previously very deficient, begin to reveal themselves. High-frequency circuits too sharply tuned may cause bad distortion. Rectification distortion is quite different and consists in the addition to the output of alien harmonics which are not present in the modulated input. Such harmonics produce an unnatural "stringiness" of tone; their reduction is accompanied by a very noticeable approach to natural reproduction.

The reduction of rectification distortion cannot be accomplished by the use of input grid potentials of the magnitudes usually advocated, 1 or 2 volts R.M.S. Over such a range the distortion is almost constant; often there is a tendency for the distortion to increase slightly with growth of the alternating grid potential. It is shown later, however, that with a properly chosen value of the grid bias it is possible to reduce the distortion almost to the vanishing point by the application of grid potentials much in excess of those usually contemplated.

3. General Principles of Anode Rectification.

Fig. 1 represents the usual connections of an anode rectifier. The condenser C is of

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such a value that its impedance at radio frequency may be assumed negligible, while its impedance is very high to alternating E.M.F.'s at audio frequency. The rectifier would be considered perfect if the alternating potential across DE were an exact replica to scale of the *modulation* of the high frequency carrier wave applied at AB. The supposed characteristic of the valve, when operated with the anode resistance R, is shown in Fig. 2a. At a grid potential V the anode current is I. The application of an alternating potential between A and B causes variations v in grid potential which give rise to variations i in the anode current. The relation between v and i is conveniently drawn to a larger scale in Fig. 2b. On the application of a carrier wave $v = E \sin \omega t$ between A and B the anode current varies

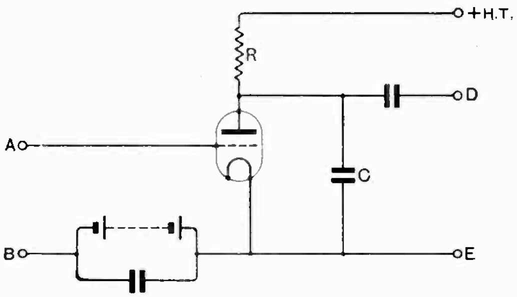

Fig. 1.—*Anode bend rectifier.*

sympathetically. Owing to the curvature of the characteristic the positive excursion of i is greater than the negative (Fig. 2b) and the average value of i becomes positive. That is to say, the receipt of the carrier wave causes an increase i_r (the rectified current) in the direct current flowing through the valve. The high-frequency alternating current flowing through the valve completes its circuit through the condenser C. The potential of the anode therefore falls by an amount $Ri_r = \overline{V}$, the rectified voltage. The relation between the amplitude E of the carrier wave and the consequent rectified voltage $\overline{V}$ may be represented by a curve such as Fig. 3a. Variations e in the amplitude of the carrier wave give rise to variations w in the value of the rectified voltage. These variations are shown to a larger scale in Fig. 3b. The process of transmission involves modulating the carrier wave, or impressing upon it a variation of amplitude, the extent and frequency of the variation being determined by the intensity and frequency of the note being transmitted (Fig. 4). It is such a modulated wave which is applied between A and B. The amplitude varies between $E (1 - m)$ and $E (1 + m)$

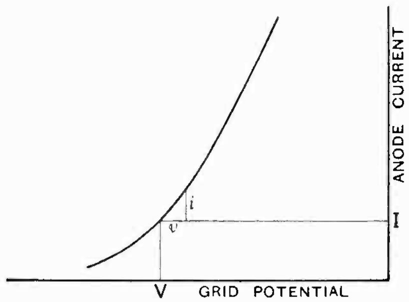

Fig. 2a.—*Relation between grid potential and anode current.*

where m is the fractional modulation (which rarely exceeds 20 per cent.). We may conveniently express the variation in E as

$$e = Em \sin pt \quad \ldots \quad (1)$$

Were the relation between e and w rectilinear, variation in rectified voltage w could be expressed by an equation of the form

$$w = k \sin pt \quad \ldots \quad (2)$$

and with this audio frequency potential available between D and E, distortionless rectification would be achieved. Unfortunately, the relation between w and e is usually more closely represented by a curve such as Fig. 3b. The effect is two-fold.

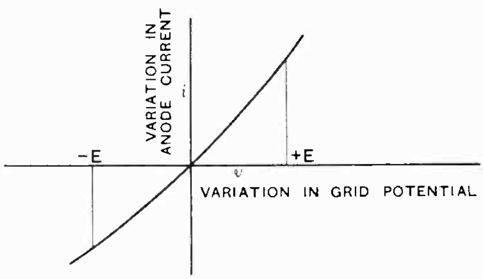

Fig. 2b.—*Relation between changes in grid potential and changes in anode current.*

In the first place modulation itself causes a further change in the anode potential and current, of small magnitude and importance; in the second place a sinusoidal variation of e does not result in a truly sinusoidal varia-

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tion in w. The nature of the distortion thus introduced is illustrated in Fig. 5. The result is that the potential between D and E involves not only the true note of frequency $f = p/2\pi$ but also false audio components of frequency $2f$, $3f$, $4f$, etc.

It is proposed to examine later this distortion more carefully and to consider how it may be reduced.

4. Sensitivity of a Rectifier.

In practice the actual value of the rectified voltage produced as the result of applying a definite high-frequency wave to the grid is not of immediate importance. The sensitivity is measured by the relative magnitude of the *low-frequency alternating potential* to which the *modulation* gives rise. As has just been indicated, if the modulation is considerable, the low-frequency output is not of a simple sinusoidal form for a simple

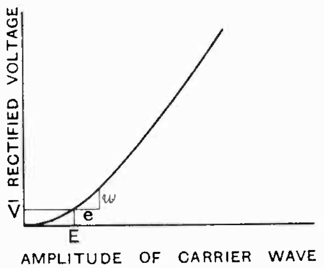

Fig. 3a.—*Relation between rectified voltage and amplitude of carrier wave.*

harmonic modulation. For small modulations, however, the low-frequency output is a pure replica of the modulation. Referring to Fig. 3a, a modulation $Em \sin pt$ of peak value e gives rise to a low-frequency alternating potential of peak value w. The sensitivity s may therefore be defined as

$$s = \frac{w}{e} = \frac{d\bar{V}}{dE} \quad \ldots \quad \ldots \quad (3)$$

Reference to curves given later (particularly Fig. 9) shows that the sensitivity increases towards a definite maximum limiting value. Distortion persists until this limiting value is approached.

5. Expression of Characteristic Curve.

In Fig. 2a is represented the relation between the anode current through a valve and the grid potential under certain defined conditions. From it Fig. 2b is deduced, expressing the relation between changes in anode current and changes in grid potential. Similarly Figs. 3a and 3b are drawn for

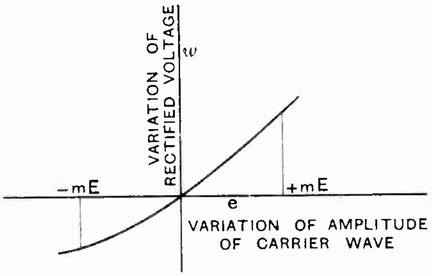

Fig. 3b.—*Relation between changes in amplitude of carrier wave and variation of rectified voltage.*

the amplitude of the carrier wave and the rectified potential. Curves of the general form of 2b and 3b are particularly important in studying rectification, and it is desired to express such a characteristic in general form. Fig. 6 represents such a characteristic; we wish to obtain an expression for y for any value of x. At the origin the rate of increase of y with respect to x, denoted by $\frac{dy}{dx}$, is represented by the slope of the tangent; this slope we may call b. For very small values of x the tangent approximates closely to the curve and the equation

$$y = bx \text{ or } y = x\frac{dy}{dx} \quad \ldots \quad \ldots \quad (4)$$

gives a sufficiently accurate value for y.

Fig. 4a.—*Carrier wave.*

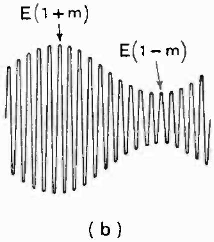

Fig. 4b.—*Modulated carrier wave.*

As x increases, however, the deviation of the curve from its tangent grows, and account must be taken of the fact that, not only has the curve a slope $\frac{dy}{dx}$, but the slope is changing.

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The rate of change of slope, written $\frac{d^2y}{dx^2}$, we will denote by c. More exact expression requires that we must also take account of the fact that the rate of change of slope $\frac{d^2y}{dx^2}$ may itself be changing. The rate of change of $\frac{d^2y}{dx^2}$ is written $\frac{d^3y}{dx^3}$; its numerical value we will suppose to be c. And so on: in our search for accuracy we have arrived at the relations

$$\frac{dy}{dx} = b, \frac{d^2y}{dx^2} = c, \frac{d^3y}{dx^3} = d, \frac{d^4y}{dx^4} = f, \text{ etc.} \quad (5)$$

These relations lead us, by integration, to the equation

$$y = bx + \frac{cx^2}{\underline{|2}} + \frac{dx^3}{\underline{|3}} + \quad \text{etc.} \ldots \quad (6)$$

$$\text{or } y = x\frac{dy}{dx} + \frac{x^2}{\underline{|2}}\frac{d^2y}{dx^2} + \frac{x^3}{\underline{|3}}\frac{d^3y}{dx^3} + \quad \text{etc.} \quad (6a)$$

This is a particular case of Maclaurin's theorem. We see that a very small portion of the curve in the neighbourhood of the origin may be represented by its tangent $y = bx$; a more extended portion is approximated to with accuracy by the parabola $y = bx + \frac{1}{2}cx^2$;

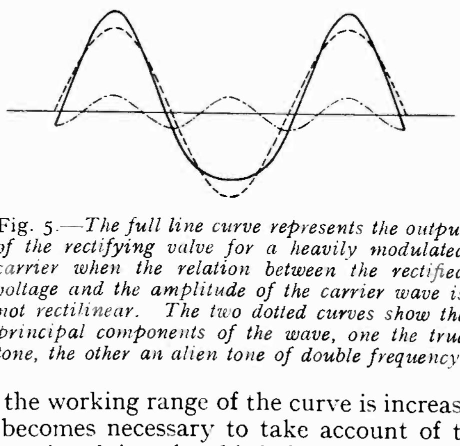

Fig. 5.—*The full line curve represents the output of the rectifying valve for a heavily modulated carrier when the relation between the rectified voltage and the amplitude of the carrier wave is not rectilinear. The two dotted curves show the principal components of the wave, one the true tone, the other an alien tone of double frequency.*

as the working range of the curve is increased it becomes necessary to take account of the terms involving the third, fourth and higher powers of x.

6. Rectified Current Due to Carrier Wave.

Applied to Fig. 2b equation (6) becomes

$$i = bv + \frac{cv^2}{\underline{|2}} + \frac{dv^3}{\underline{|3}} + \quad \text{etc.} \ldots \quad (7)$$

If the carrier wave potential applied to the grid be expressed as

$$v = E \sin \omega t \quad \ldots \quad \ldots \quad (8)$$

then $(i)_a$, the *average* value of i, becomes

$$(i)_a = b(v)_a + \frac{c}{2}(v^2)_a + \frac{d}{6}(v^3)_a + \frac{f}{24}(v^4)_a + \text{ etc.} \quad \ldots \quad (9)$$

Now the average value of any odd power of

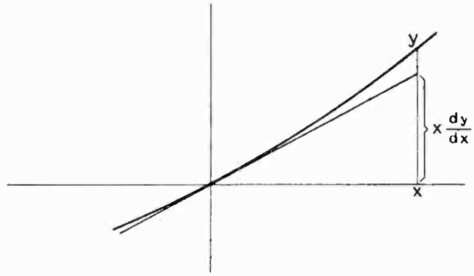

Fig. 6.—*For small values of x the tangent is a sufficient approximation to the curve and y may be assumed equal to x* $\frac{dy}{dx}$. *As x increases it becomes necessary to allow for the fact that* $\frac{dy}{dx}$ *is changing.*

a sine function over a complete period is zero. The average value of $\sin^2 \omega t$ is $\frac{1}{2}$ and of $\sin^4 \omega t$ is $\frac{3}{8}$. Hence the rectified current i_r is given by

$$i_r = (i)_a = \frac{cE^2}{4} + \frac{fE^4}{64} + \quad \text{etc.} \ldots \quad (10)$$

For small values of the applied voltage all terms are negligible except the first and we then have

$$i_r = \frac{cE^2}{4} \quad \ldots \quad \ldots (10a)$$

and the rectified voltage

$$\overline{V} = \frac{RcE^2}{4} \quad \ldots \quad \ldots \quad (10b)$$

It is seen that the efficiency of rectification increases rapidly with the signal voltage applied to the grid. The parabolic variation of the rectified current or voltage, represented by equations (10*a*) and (10*b*), is well known and is usually assumed as the basis of investigation of anode rectification (see *Wireless World*, 25th January, 1928, p. 90; 31st March, 1928, p. 311; 1st August, 1928, p. 129). It is shown later that this relation

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does not describe the nature of the rectification sufficiently when the grid voltage is considerable.

7. Effect of Modulating the Carrier Wave.

Applied to Fig. 3b equation (6*a*) becomes

$$w = e\frac{dw}{de} + \frac{e^2}{\underline{2}}\frac{d^2w}{de^2} + \frac{e^3}{\underline{3}}\frac{d^3w}{de^3} + \frac{e^4}{\underline{4}}\frac{d^4w}{de^4} + \text{ etc.} \quad .. \quad (11)$$

$$\text{or } w = e\frac{dV}{dE} + \frac{e^2}{\underline{2}}\frac{d^2V}{dE^2} + \frac{e^3}{\underline{3}}\frac{d^3V}{dE^3} + \frac{e^4}{\underline{4}}\frac{d^4V}{dE^4} + \text{ etc.} \quad (11a)$$

If the fractional modulation is m, we have

$$e = Em \sin pt \quad .. \quad .. \quad (1)$$

Let us now examine the separate terms in equation (11*a*). Successively, they are of diminishing magnitude; if the modulation is reasonably small, only the first two terms are of any importance. The first term $e\frac{dV}{dE}$ clearly represents a variation of the same frequency as the modulation, and, if it were the only appreciable term, there would be no distortion. The second term is proportional to $\sin^2 pt$, but

$$\sin^2 pt = (1 - \cos 2pt)/2 \quad .. \quad (12)$$

Hence this second term introduces a false oscillation of twice the true frequency. In addition there is a change in the rectified potential due to the curvature of the e/w characteristic. Again, the third term is proportional to $\sin^3 pt$, but

$$\sin^3 pt = (3 \sin pt - \sin 3pt)/4 \quad .. \quad (13)$$

This term, therefore, represents a modification of the magnitude of the fundamental tone, together with a false tone of three times the true frequency. Continuing this process we find that w may consist of the true note together with false notes of 2, 3, 4, etc., times the frequency of the fundamental.

8. Nature of the Distortion when the Rectification Curve is Parabolic.

We saw that when the grid swing is small the rectification curve is parabolic and can be expressed by

$$V = \frac{RcE^2}{4} \quad .. \quad .. \quad (10b)$$

$$\text{whence} \quad \left.\begin{array}{l} \dfrac{dV}{dE} = \dfrac{RcE}{2}, \dfrac{d^2V}{dE^2} = \dfrac{Rc}{2}, \\ \dfrac{d^3V}{dE^3} = \dfrac{d^4V}{dE^4}, \text{ etc.} = 0 \end{array}\right\} \quad .. \quad (14)$$

$$\text{whence} \quad w = e\frac{RcE}{2} + e^2\frac{Rc}{4} \quad .. \quad .. \quad (15)$$

$$\text{giving us} \quad w = \frac{RcE^2}{4}(2m \sin pt + m^2 \sin^2 pt)$$

or

$$w = \frac{RcE^2}{8}(4m \sin pt + m^2 - m^2 \cos 2pt) \quad (16)$$

We see, therefore, that there is a second harmonic whose magnitude is $m/4$ times the magnitude of the fundamental. *The relative intensity of this false second harmonic is independent of the amplitude of the carrier wave*; a result which is not generally appreciated. If the modulation is 20 per cent. the false second harmonic is 5 per cent. of the fundamental, of sufficient magnitude to change definitely the quality of the note. In addition we see from equation (16) that, due to modulation, there is a change in the rectified potential of magnitude $Rcm^2E^2/8$. This change is of little importance: it affects slightly the transient "attack"; further, it is sufficient to enable the modulation to be estimated if care is exercised in reading the anode current.

9. Modification of Distortion by Increase of Grid Swing.

From what has been done it is clear that, so long as the valve characteristic is definitely curved, distortion is inseparable from rectification, the distortion being greatest on loud notes, and therefore then most objectionable. It is clear also that, for distortion to be small, all terms in equation (11*a*) should be small relative to the first; that is to say, the rectified voltage should bear a practically rectilinear relation to the grid swing. The double frequency term arises from the fact that, for small grid swings at least, the rectified voltage is proportional to the square of the grid swing (see equations (10*b*), (14), (15), (16)). It has been pointed out (see, for instance, *Wireless World*, 2nd May, 1928, p. 464) that the ideal characteristic consists of two straight lines (Fig. 7), the rectification point being B. For such a characteristic, having this sudden change at

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B, the rectified voltage $\bar{V} = ke$. From such an ideal curve the usual valve characteristic differs considerably—or at least appears to do so (it is really a question of scale).

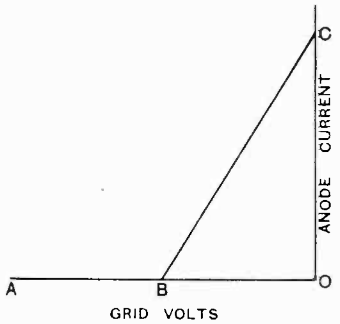

Fig. 7.—*Ideal characteristic for rectification (after McLachlan).*

If we consider the actual characteristic shown in Fig. 8 for a valve with a high anode voltage and large grid bias, we see that it consists of a well curved portion PQ together with portions RQ and PS which do not deviate greatly from the straight lines AB and BC. If the actual grid bias employed be represented by OB and the grid swing does not exceed a few volts, the rectification curve is practically parabolic and distortion occurs of the magnitude indicated in equation (16). If, however, we consider larger grid swings, sweeping over the greater portion of the characteristic as shown, it is clear that the

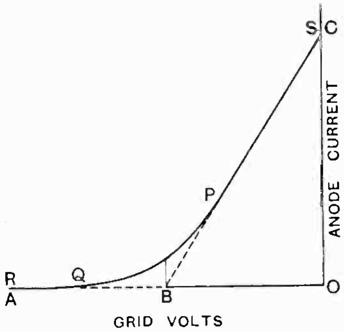

Fig. 8.—*Characteristic of rectifying valve. It is seen that as grid swing increases the effective deviation from the ideal A B C diminishes.*

effective deviation of the characteristic from the ideal ABC becomes less the greater the grid swing employed. If indeed the valve would permit of very large grid swings being employed (the bias being suitably high) the deviation would become almost negligible. Under such circumstances distortion would practically disappear.

10. Magnitude of Rectified Voltage.

Consideration of Figs. 7 and 8 shows that the ideal characteristic ABC is, for a given "slope," the most sensitive rectifier, and further that, with such a characteristic, the sensitivity is constant; that is to say, the rectified voltage is proportional to the grid swing. The slope of the characteristic is $M/(R + A)$, where M is the amplification factor of the valve, R the anode resistance, and A the valve impedance. The change in anode potential when the grid becomes one

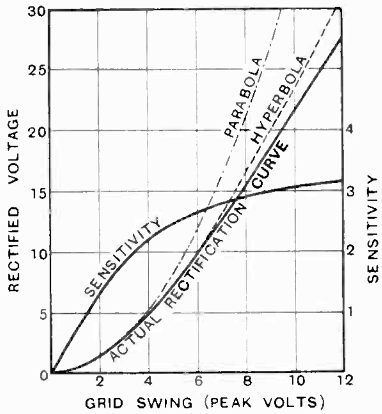

Fig. 9.—*Rectification curve for PM3 valve, R = 130,000 ohms, voltage about 190. The parabola most closely approximating to the curve for small values of the grid swing is also shown. The general features of the curve are more nearly those of an hyperbola, which is also shown. It is seen that for small grid swings the sensitivity is practically proportional to the swing. As the swing increases, however, the sensitivity approaches a limiting value.*

volt less negative is $MR/(R + A)$. It is easy to show that, if the rectification point is B, the rectified voltage is equal to the maximum change in anode voltage divided by π. We have, therefore, the sensitivity

$$s = \frac{M}{\pi} \cdot \frac{R}{R + A} \quad \cdots \quad \cdots (17)$$

Hence the sensitivity cannot exceed $0.318M$. For the particular valve treated later, $R = 130{,}000$, $A = 17{,}000$ and $M = 11.75$. Had this valve possessed the ideal characteristic the sensitivity would have been

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3.31. The ideal rectification curve is shown in Fig. 15. The actual rectification curve (treated more fully later) is given in Fig. 9. It is seen that the actual sensitivity grows steadily from zero over the range for which the curve is plotted, the slope attaining a value of 3.15 for a grid swing (peak) of 12 volts, only 5 per cent. less than the slope of Fig. 15, the rectification curve derived from the ideal characteristic.

11. Actual Form of Rectification Curve.

It is found in practice that for a grid swing of a few volts the deviation of the rectification curve from the parabolic form is small. As, however, the grid swing is increased the departure from the square law becomes marked until, ultimately, the increase in the rectified voltage becomes little more than proportional to the increase in grid swing. These characteristics would be expected in view of the considerations put forward in the previous section. Were the relation between the rectified voltage and the grid swing truly rectilinear over the extent of the modulation, distortion would be absent; in practice the relation becomes sufficiently rectilinear for distortion to be much reduced. Fig. 9 shows an actual rectification curve (the method of obtaining it is given later) and on the figure is shown also the parabola to which it approximates for small values of the grid swing.

12. General Expression for the Distortion.

It has been pointed out that in general the modulation is sufficiently small for all terms in equation (11a) to be neglected except the first two. Under these circumstances the only distortion of any moment is the double frequency note. Its amplitude divided by the amplitude of the true note may be taken as a *measure of the distortion*. The amplitude of the double frequency note is $E^2m^2\dfrac{d^2V}{dE^2} \div 4$ and of the true note $EM\dfrac{dV}{dE}$. The distortion may, therefore, be represented by the ratio

$$\rho = \frac{Em}{4}\frac{d^2V}{dE^2}\bigg/\frac{dV}{dE} \quad \ldots \quad \ldots (18)$$

For a parabolic rectification curve this ratio is equal to $m/4$ for all values of E.

13. Hyperbolic Rectification Curve.

The characteristics of the practical rectification curve have already been described in section 11. They resemble more closely the features of an hyperbola than a parabola. Fig. 9 shows an hyperbola which represents the rectification fairly closely. The general equation to an hyperbola is

$$\frac{V}{b} + 1 = \sqrt{1 + \frac{E^2}{a^2}} \quad \ldots (19)$$

For the case shown in Fig. 9 the values of the constants are $a = 6.6$, $b = 28.75$.

From equation (19) we obtain

$$\frac{dV}{dE} = \frac{b}{a}\cdot\frac{E}{\sqrt{a^2 + E^2}}$$

$$\frac{d^2V}{dE^2} = \frac{ab}{(a^2 + E^2)^{3/2}}$$

whence $$\frac{Em}{4}\frac{d^2V}{dE^2}\bigg/\frac{dV}{dE} = \frac{m}{4}\cdot\frac{a^2}{a^2 + E^2} \quad \ldots (20)$$

The expression given in this equation shows how the distortion varies with E for a hyperbolic rectification curve. For small values of E the distortion is the same as that when the relation is parabolic, but as E becomes comparable with a the distortion falls considerably (Fig. 10).

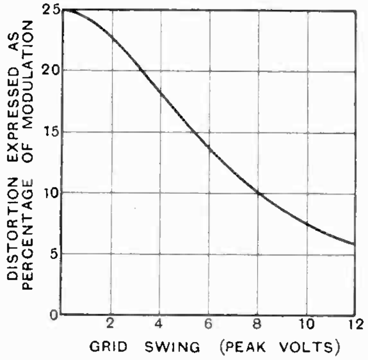

Fig. 10.—*Showing reduction of distortion with increasing grid swing—hyperbolic rectification curve (see* Fig. 9).

14. Determination of Rectification Curve.

A complete investigation of the best conditions of operation for any particular valve involves an accurate determination of the rectification curve. If means are available this may be determined directly

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(see Sowerby, *The Wireless World*, March 21st, 1928, p. 309). Commonly, however, the experimenter is not in a position to effect the determination in this manner. He often has, however, sufficient apparatus available to determine the grid-volts/anode-current characteristic of the valve (with the working anode resistance) with accuracy; from this characteristic the rectification curve may be deduced. An interesting method is given by Barclay in *E.W. & W.E.*, 27th August, 1927, p. 459. The writer has applied this method to a parabolic characteristic and found it surprisingly accurate. It appears, however, to be unsuitable to the type of characteristic which is most desired from the point of view of rectification—a curve of the form of Fig. 8. For such a curve there seems to be no satisfactory alternative to actual calculation; if this is carried out in a systematic tabular form it need not involve excessive labour. Referring to Figs. 2a and 2b it is seen that it is desired to determine the value of i_r when v oscillates harmonically between the limits $-E$ and $+E$. This is clearly equal to the "time average" of i as v passes from $-E$ to $+E$. This can be determined by measuring i at a number of convenient equally time-spaced intervals and obtaining the mean. It is sufficient to measure at each 10 electrical degrees, that is to say from $E \sin -85$ deg., $E \sin -75$ deg., etc., to $E \sin +85$ deg.

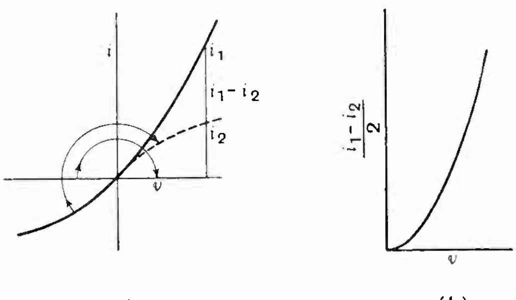

Fig. 11.

There is an obvious simplification; corresponding to each positive value of i (which we may call i_1) with v positive there is a complementary negative value of i (which we may call i_2—numerically less than i_1) for an equal negative value of v. The time average of i is therefore equal to the time average of $(i_1 - i_2)/2$ reckoned between $v = 0$ and $v = E$. It is convenient to plot this curve to a larger scale. Its derivation is illustrated by Fig. 11 ((a) and (b)). Fig. 11(a) is obtained by plotting i_2 below i_1 (swinging the third quadrant of Fig. 2b into the first). From a curve of the form of Fig. 11(b), drawn for any particular value

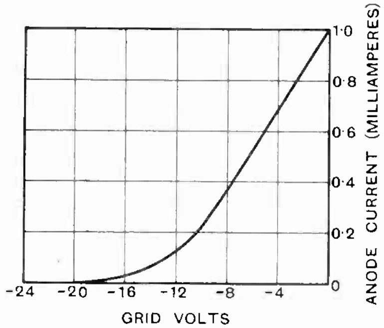

Fig. 12.—*Characteristic for PM3 with anode resistance of* 130,000 *ohms.*

of the grid bias, values of $(i_1 - i_2)/2$ for each 10 deg. from 5 deg. to 85 deg. may be tabulated for various values of e and the corresponding values of i_r thus determined. Fig. 12 gives the characteristic for a P.M.3 with a series resistance of 130,000 ohms, at a potential of about 190 volts, Fig. 13 the deduced curve for $(i_1 - i_2)/2$ when the grid bias is 12 volts. The table given is that part of the actual table prepared which relates to $E = 5$ volts.

TABLE.

θ Deg.	$E \sin \theta$.	$(i_1 - i_2)/2$.
5	0.436	.0009
15	1.294	.0081
25	2.113	.0230
35	2.868	.0406
45	3.535	.0600
55	4.096	.0762
65	4.532	.0940
75	4.830	.1007
85	4.981	.1050
	Total	.5085

giving $i_r = .5085/9 = .0565$ mA.

whence $\bar{V} = 130{,}000 \times .0565/1{,}000 =$ 7.345 volts.

Repeating for various values of E the rectification curve is obtained, shown for the conditions cited in Fig. 9.

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15. Derivation of Distortion from Rectification Curve.

The rectification curve having been obtained the curves representing $\frac{d\bar{V}}{dE}$ and $\frac{d^2\bar{V}}{dE^2}$ are readily deduced (see Appendix). For a P.M.3, under conditions already cited, these curves were determined, and in Fig. 14 is shown the deduced curve of distortion. It is seen that for small grid swings the distortion is practically uninfluenced by the magnitude of the swing, but with swings of the order of 5 to 10 peak volts the distortion is reduced very considerably. Two features of this curve are of particular interest. In the first place the distortion for large values of the grid swing is less than it would be were the rectification curve of the form of the hyperbola shown in Fig. 9. This is due to the fact that the actual rectification curve approaches a straight line more closely than the hyperbola does when the grid swing is great. In the second place it is noticed

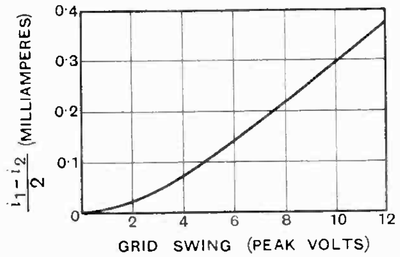

Fig. 13.—*Curve deduced from* Fig. 12 *in the manner indicated in* Fig. 11 ((a) *and* (b)). *Grid bias* 12 *volts.*

that for small grid swings the distortion actually increases slightly. This is due to the fact that the rectification curve in the neighbourhood of the origin is even more sharply curved than a parabola, the rectified voltage being proportional to rather more than the square of the grid swing.

16. Choice of Grid Bias.

A consideration of the ideal characteristic curve illustrated in Fig. 7 reveals the fact that were the grid bias not properly chosen grave distortion might occur. With correct adjustment of the bias to the point B the rectification curve is a straight line PT (Fig. 15). If the bias is incorrectly adjusted no rectification occurs until the grid swing is sufficiently great to sweep past the point B. The curve $PQRS$ of Fig. 15 has been drawn for a grid bias of 14 volts, the correct bias (corresponding to the point B—Fig. 7) being

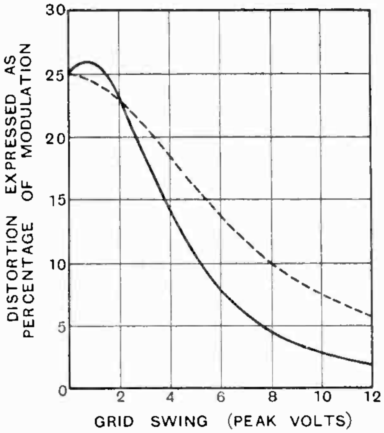

Fig. 14.—*Showing reduction of distortion with increasing grid swing, grid bias* 12 *volts. The full curve shows the actual distortion; the dotted curve is the distortion calculated for a hyperbolic rectification curve* (*see* Figs. 9 *and* 10).

12½ volts. The rectification curve consists of two portions PQ and QRS, the portion RS being practically linear. For grid swings of 4 to 10 volts peak distortion is negligible. Below 4 volts distortion is felt. With a grid swing of 1½ peak volts the distortion would be very bad indeed.

These considerations indicate the desirability of fixing the grid bias so that the sharply curved portion of the characteristic (Fig. 8) is near the middle of the swing. This is practically the point where $\frac{d^2i}{dv^2}$ has its maximum value. If the grid swing is small we have seen that the rectified voltage is expressed by

$$\bar{V} = \frac{RE^2c}{4} = \frac{RE^2}{4} \cdot \frac{d^2i}{dv^2} \quad \text{.. (9c)}$$

The correct value of the grid bias for minimum distortion is therefore the same as that for maximum sensitiveness to weak signals. It is clear that so long as the grid swing is sufficiently great very exact adjustment of the bias is not essential. In any case the fixing of the bias is a simple matter in practice.

The effect of various values of the bias is shown in Fig. 16. As the bias is increased

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from 9 to 11 volts the improvement is progressive. Further increase to 12 volts increases the distortion for grid swings below 4 volts. For large grid swings the higher bias is better. Maximum sensitiveness for this rectifier is obtained with a grid bias between 11 and 12 volts, and it is seen that this bias is also approximately that which gives minimum distortion. The point so obtained is not in the centre of the sharply curved portion but rather towards the straight part of the characteristic. Calculations have been included only for one particular valve, but examination of a considerable number of valves of different constants indicates that the results are almost equally applicable to them. There is a tendency for the curved portion of the characteristic to be rather shorter for valves of a high amplification factor, and for such valves a smaller grid swing may be employed, giving roughly (taking into account the increased amplification) the same low frequency output. There are, however, other objections to the use of valves having too high an amplification factor when the best quality is sought and it is desirable to use a valve whose

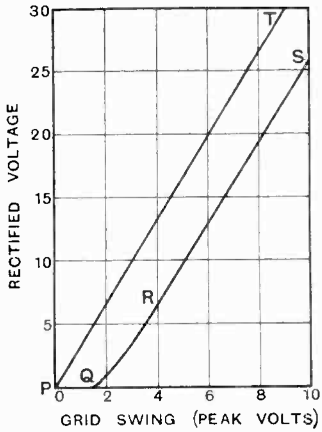

Fig. 15.—*Rectification curves corresponding to ideal characteristic of* Fig. 7. *PT is drawn for the correct grid bias of* $12\frac{1}{2}$ *volts* (*B*, Fig. 7), *PQRS for a grid bias of* 14 *volts. If the grid swing exceeds* 4 *volts in the latter case, the distortion is small. With a grid swing of* $1\frac{1}{2}$ *volts the distortion is great. When the grid bias is correctly adjusted rectification is distortionless for all values of the grid swing.*

amplification factor is not greater than 15. For such valves, with grid swings of 2 or 3 peak volts, the distortion is not much less than with very small swings. As the grid swing increases to 10 volts peak and above, the distortion is reduced to quite a small value. If we assume that we have to legislate

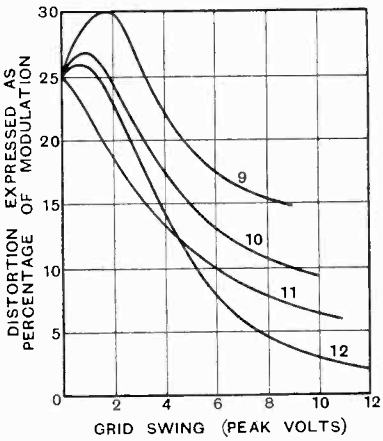

Fig. 16.—*Showing variation of the distortion characteristic with the grid bias. The corresponding grid bias (in volts) is indicated on each curve.*

for a grid swing due to carrier wave alone of 10 volts peak, and that the maximum modulation is 20 per cent., it is clear that the grid bias must be at least 12 volts if the grid is never to become positive. Of course a high anode potential is necessary; that is usually available. The author has yet to find a valve by a reliable maker which will not stand up to an anode potential of 200 volts under anode rectification conditions.

It has been seen that the sensitiveness of rectification is but little affected by the value of the anode resistance so long as it is several times the impedance of the valve. There is therefore no difficulty in forcing the bend of the characteristic towards the left so that rectification is obtained with a sufficiently great grid bias. For instance, if it is found that greatest sensitiveness is obtained when the grid bias is 9 volts, a reduction of the anode resistance will shift the characteristic so that the grid bias has to be increased.

17. Conclusion.

It is usual in considering the design of a set to decide the grid swing necessary on the output valve and to calculate backwards to determine the requisite low-frequency amplification to be employed in view of the

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anticipated signal strength at the grid of the rectifier. The author would suggest that when the best quality is desired both the output grid voltage and the grid swing of the rectifier should be fixed and both high-frequency and low-frequency amplification then designed to suit. It has been seen that when the grid voltage sweeps well over the straight portions of the characteristic the sensitivity approaches 0.318M. Using a valve whose M value is 12 with a 20 per cent. modulation on a grid swing of 10 volts, the peak value of the low-frequency potential is rather lower than $12 \times 2 \times 0.318 = 7.64$ volts. The probable potential (peak) would be about 7 volts. It is clear that this is sufficient to load a pentode fully without further amplification. Commonly a transformer is used with a rectifier output of not more than 2 volts. The author finds that the quality is definitely improved by omitting the transformer and increasing the rectifier output. In the previous section it was pointed out that it is desirable to aim at roughly the same rectifier output, whatever the M value of the rectifier employed. A suggested value for that output is not less than 7 volts peak on a 20 per cent. modulation. If the final stage consists of an ordinary triode working on a grid bias of 30 volts the intermediate stage should give an amplification of 4. The author uses a valve of M value 7 for this stage and makes use of only one half its amplification. The full amplification is available when weak signals are being received; the quality is then not likely to be too good.

It is seen that the perfection of a rectifier is determined entirely by the form of the characteristic. In this respect, so long as the grid swing is sufficiently great, no other arrangement can surpass an anode-bend rectifier. A good deal has been written of late respecting the diode rectifier. Its characteristics must be generally the same as those of the anode-bend detector; when the damping which it introduces is remembered it is clear that its behaviour must compare poorly with that of the more conventional arrangement when properly designed.

APPENDIX.

A Note on the Differentiation of Curves.

It is usually considered that the differentiation of an experimental curve admits of errors which may be considerable; a second differentiation may result in these errors being greatly magnified. The errors arise in two distinct ways :—

(*a*) Errors of observation and plotting.

(*b*) Subsequent errors in determining the slope of the curve; these arise chiefly owing to the curve not being correctly drawn between the observed points (even if the observed points themselves are accurate).

If a curve is correctly drawn (for instance, if an hyperbola is calculated and plotted for a large number of points) it is surprising how accurately its slope at any point may be determined by the simple process of drawing the tangent at that point. When, however, the number of observed points is limited, considerable errors may be introduced in the slope of the curve in plotting, particularly when the curvature is great. Methods of plotting should therefore aim at (i) eliminating errors of observation as far as possible,

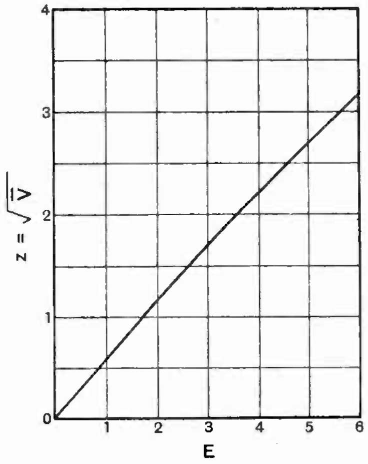

Fig. 17.—*This curve represents another way of graphing the relation represented in* Fig. 9 *by the lower part of the hyperbola. From such a curve, approximating as it does to a straight line,* $\frac{dV}{dE}$ *can be determined with much greater accuracy than it can from the original hyperbola.*

(ii) graphing the curve in such a way that deviations from its true form (due to bad draughtsmanship) are likely to be but small.

When any relation can be expressed in such a way that its graph is a straight line, or approximately a straight line, both these

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aims are achieved. Not only is it then possible to measure the slope with considerable accuracy, but the slope so measured is likely to approximate very closely to the slope of the true curve imagined prepared from theoretically perfect observations.

If we consider as an example the rectification curve of Fig. 9, this approximates to a rectilinear form when E exceeds 6 volts. For this range errors of graphing are likely to be small and the slope and rate of change of slope can be determined with very reasonable accuracy. When, however, we consider the lower part of the curve conditions are different: the rate of change of slope is considerable; errors of plotting are less obvious, and direct measurement from the curve as drawn is open to inaccuracy. The relation may, however, be expressed in a graph which is more or less rectilinear by plotting $z = \sqrt{\bar{V}}$ against E instead of $\bar{V}$ against E. This curve is shown in Fig. 17; its slope $\frac{dz}{dE}$ can be determined with accuracy.

But we have $\bar{V} = z^2$

therefore $$\frac{d\bar{V}}{dE} = 2z\frac{dz}{dE}$$

Hence $\frac{d\bar{V}}{dE}$ is readily calculated from the values of $\frac{dz}{dE}$. For this range the relation between $\frac{d\bar{V}}{dE}$ and E is approximately rectilinear, and errors of measurement are largely eliminated by plotting. The determination of $\frac{d^2\bar{V}}{dE^2}$ from $\frac{d\bar{V}}{dE}$ over this range presents no difficulties.

As a check upon this, and the direct, methods of calculation, the hyperbola

$$\frac{\bar{V}}{28.75} + 1 = \sqrt{1 + \frac{E^2}{(6.6)^2}}$$

was plotted for values of $E = 1, 2, 3, 4, 5, 6$. The values of $\frac{d\bar{V}}{dE}$ determined directly from the curve exhibited an average error of 1.8 per cent. and a maximum error of 3.3 per cent. When, however, the curve connecting z and E was used, the average error in the values of $\frac{d\bar{V}}{dE}$ was reduced to 0.44 per cent., the maximum error being 1.1 per cent.

Correspondence.

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

Push-Pull Amplification.

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

SIR,—It was with interest that I read Mr. Aughtie's article on Push-Pull Amplification in this month's *E.W. & W.E.*, because about a year ago I hit upon exactly the same scheme.

The suggestion was made to several of my friends, and in several cases the arrangement is still in use with very satisfactory results. The advantages claimed by Mr. Aughtie do not seem to include those which seem to me to be the most important, namely: (1) Back-coupling through the H.T. supply is eliminated with respect to *both* stages of L.F. (2) The H.T. for all four L.F. valves may be taken direct from D.C. mains without smoothing. For reasons which I have pointed out elsewhere, mains noises are not reproduced. (3) The wave from distortion due to characteristic curvature is cancelled out in the output stage. Unfortunately this last point does not apply to the first pair of valves, because the input to V_2 (Mr. Aughtie's figures) has already passed through one additional distorting stage.

This fact should be added to the reasons why a completely silent point cannot be attained, and it seems to me to be of more importance in this respect than those given by Mr. Aughtie. I was never able to achieve perfect silence even with a single frequency input, and the weird noises I got did not suggest anything quite so simple as a phase displacement, as this ought to produce a pure tone.

The arrangement I use is slightly different from either of Mr. Aughtie's suggested forms, both of which I rejected. The potentiometer grid leak has the disadvantages he mentions, while I never succeeded in obtaining a reliable anode resistance which would carry an appreciable anode current and in which a continuously variable tapping could be provided. The difficulty is easily surmounted, however. I simply connect a high resistance potentiometer between the two anodes V_1 and V_2 and take the slider to the grid of V_2 through the usual condenser. As the potentiometer is

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connected between two points of equal D.C. potential, it is only called upon to carry a small A.C., and therefore one of the many potentiometers sold as volume controls is quite satisfactory.

Stratford-on-Avon. P. G. DAVIDSON.

Frequency Modulation.

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

SIR,—Following Mr. Holmblad's and Mr. Makey's letters in the *E.W. & W.E.* issues of May and July, I would like to submit the following remarks regarding the frequency band width of an alternating "carrier" current of constant amplitude, the frequency of which is alternately varied between two values ω_1 and ω_2 under the action of a modulating vibration of frequency m, the frequency difference $k = \omega_2 - \omega_1$ being proportional to the amplitude of the modulating vibration.

The frequency m being small with respect to the carrier frequency, there will generally be at least one frequency value ω_3 of the carrier current, comprised between ω_1 and ω_2, which is an exact multiple of the frequency m. The frequency of the carrier current varying, during every cycle of the modulating vibration, from the lower value ω_1 to the higher value ω_2 and back to the value ω_1, the carrier current goes through the frequency value ω_3 *twice* during every cycle of the modulating vibration and may be considered every time to assume this frequency value ω_3 for a short period of time, covering say 3 or 4 cycles of the carrier current. The carrier current thus comprises a component current of frequency ω_3, flowing in the circuit $2m$ times per second and for but a few cycles every time, and having hence an amplitude which is modulated at the fundamental frequency $2m$ between zero and the constant maximum amplitude of the actual carrier current. The frequency band width of this ω_3 frequency component is thus at least equal to $4m$ cycles (and is, in fact, much greater, since this ω_3 frequency current is very far from being sinusoidally modulated at the frequency $2m$).

The same remarks apply as well to all other components the respective frequencies of which, comprised between ω_1 and ω_2, are exact multiples of the frequency m. And they may be considered as approximately applying to the other intermediate frequency components of the carrier current—and in particular to the components of frequencies $\omega_2 - a$ and $\omega_1 + a$ differing from the extreme values ω_1 and ω_2 by as small an amount a as desired.

It follows that the *minimum* value of the frequency band width of the constant-amplitude, frequency-modulated carrier current is approximately equal to

$$[(\omega_2 - a) + 2m] - [(\omega_1 + a) - 2m]$$
$$= \omega_2 - \omega_1 - 2a + 4m = k - 2a + 4m.$$

Expressed in words, and neglecting the small factor $2a$, the minimum value of the frequency band width is equal to the frequency variation k (proportional to the modulating amplitude) plus four times the modulating frequency m.

This is more than twice the frequency band width of an ordinary amplitude-modulated, constant frequency carrier current, for the same modulating vibration.

A mathematical formulation of the above remarks is an extremely easy matter, but is not carried out here in order not unduly to lengthen this note.

Briefly summarising and picturising the above, a frequency-modulated, constant amplitude transmitting set may be thought of as replaced by a multiplicity of heavily damped spark transmitters having respectively frequencies comprised between ω_1 and ω_2, and operating successively in a given order at a rate of $2m$ sparks per second.

Paris. H. LAUER.

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

SIR,—Mr. G. H. Makey, in his criticism of my letter on the above subject, attempts to show that I am in error in my conception of the frequency modulation system. Unfortunately the formula Mr. Makey arrives at in his letter cannot be correct, since it is the expression for a wave of which the frequency is oscillating between steadily increasing limits.

As already pointed out in my first letter, the "instantaneous" cyclic frequency of a wave given by the expression

$$i = A \sin [f(t)] \quad \ldots \quad (1)$$

may be determined by differentiating $f(t)$ with regard to the time. This may easily be shown: The "instantaneous" frequency is in fact nothing but a measure for the momentary variation of the angle with regard to the time, *i.e.*, the momentary angular velocity; if for instance, the angle be constant ($i = A \sin \omega$), the frequency is zero; if the angle be increasing linearly ($i = A \sin \omega t$), the frequency is constant (ω), and so on.

The expression given by Mr. Makey is

$$i = A \sin (\omega t + k \cdot t \cdot \sin mt) \quad \ldots \quad (2)$$

Differentiating the angle with regard to the time we get the instantaneous frequency

$$n = \omega + k \sin mt + m.k.t.\cos mt \quad \ldots \quad (3)$$

which is oscillating between steadily increasing limits.

As shown above, the expression (2) is not a periodic function of time, and consequently it cannot be expanded in fourier series.

My pessimism with regard to frequency modulation does not seem to be shared, however, by everybody, judging from the number of patents described in *E.W. & W.E.* since my first letter.

N. E. HOLMBLAD.

Copenhagen.

Moving Coil Loud Speakers.

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

SIR,—In the article on M.C. Speakers (*E.W. & W.E.*, July, 1929) Mr. Cosens cites a motional capacity of 0.74 mfd. which he attributes to Mr. L. E. T. Branch. So far as I am aware, the *equivalent* electric circuit, the term "motional capacity" and data pertaining thereto were first given by me in *The Wireless World*, 23rd March, 1927. The figure 0.74 mfd. was taken by Mr. Branch—with reference—from this article. In this and other articles

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(*Handbook on Loud Speakers*, completed June, 1926, and published March, 1927, also *W.W.*, 13th April, 21st Sept., 1927, 11th, 18th, 25th July, 8th Aug., 10th, 17th October, 28th November, 1928, and 10th April, 1929), I have given a good deal of data pertaining to the performance and design of M.C. Speakers. The mathematical analysis—formulated early in 1926 prior to the instalment of the speaker I designed for the Science Museum—being beyond the scope of *W.W.*, was published in the Supplementary issue of the *Phil. Mag.*, June, 1929. Due to delay in publication, Mr. Cosens has unfortunately repeated part of my *Phil. Mag.* Paper.

I think the term "adherent" air is a misnomer. The added mass is caused by divergence of the waves from the disc, and not by air "adhering" thereto. Rayleigh's nomenclature ought to stand, viz., "accession to inertia." I introduced the question of accession to inertia in my *W.W.* article 30th March, 1927, and in my book on Loud Speakers, pp. 64, 65. These publications antedate by two years the references cited by Mr. Cosens.

I have been alive to lack of diaphragm rigidity since 1926. In January, 1927, I filed a patent (now 288713) in which the "break-up" of a diaphragm is used in a reed-driven speaker (natural frequency 2,600 ∼), now known as the "Amplion Lion." During vibration the radiation from alternate areas is of opposite sign and a degree of neutralisation occurs. This, together with diaphragm attenuation results in the diaphragm contributing very little to the radiation above about 8,000 ∼ (see L.S., chap. 4 and p. 56, also *W.W.*, 10th, 17th July, 1929). The effect of transients in various speakers is shown in the records given in *W.W.*, 10th April, 1929. I think the upper register in M.C. Speakers is partly due to concertina action of coil and diaphragm, i.e., the elasticity of the neck of the coil. (*W.W.*, p. 542, 17th October, 1928, also 10th April, 1929.)

Neither Mr. Cosens' Paper nor my *Phil. Mag.* Paper can purport to be an orthodox theory of the M.C. Speaker. Owing to (1) inadequate rigidity of the complete system thereby giving natural frequencies well within the audible register, (2) the shape of the diaphragm and its complex radiation properties which are accentuated by its concavity and convexity, (3) the velocity down the diaphragm being less than that of sound in air, the problem would appear to present grave analytical difficulties. Nevertheless, with Mr. Butterworth's unique mathematical powers the solution is almost a foregone conclusion.

N. W. McLachlan.

London,
July, 1929.

On the Writing of Scientific Papers.

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

Sir,—As a teacher of "Wireless," I am tempted, by Mr. Colebrooke's recent article on the writing of scientific papers, to draw attention to a subject on which authors are extremely apt to mislead students.

I refer to the relation between the electric and magnetic fields of a wireless wave. Although this problem has been clearly discussed by Dellinger, Moullin, and many others, the old fallacies about these fields and particularly about their effects on loops and open aerials are astonishingly persistent.

It is therefore specially unfortunate that scientific papers by the most eminent authorities should not infrequently include ambiguous statements, which are liable to encourage and prolong the life of these ancient heresies.

Here are a few examples :—

"Since the aerial responds to E_z, and the loop to H_x." (Professor Appleton, *Journal I.E.E.*, Vol. 66, p. 874.)

"One responds to the electric, the other to the magnetic oscillation." (Sir Oliver Lodge, *Modern Wireless*, Vol. I., No. 1, p. 9.)

"We may also use the oscillatory magnetic force in the wave as a method of receiving signals." (J. A. Ratcliffe, *The Physical Principles of Wireless*, p. 55.)

"The Nodes" (of the electric and magnetic fields) "will be situated in different places according to which of these fields is under consideration." (R. H. Barfield, *Journal I.E.E.*, Vol. 67, p. 787.)

"The states of maximum and minimum strain" (of the electric and magnetic fields) "are not simultaneous." (Capt. Eckersley and Mr. Howe, *Journal I.E.E.*, Vol. 67, p. 788.)

To varying extents all these statements are ambiguous and misleading to the uninitiated. So I feel justified in saying that if a special plea for care on this subject could be added to your general advocacy of attention to the arrangement and composition of papers, many teachers would be grateful, in addition to

F. C. Curtis,
Captain, R. Signals.

Book Review.

Concerning High-frequency Stabilisation by Piezo-electric Oscillators. A 12-page brochure issued by Adam Hilger, Ltd.

Messrs. Hilger have a world-wide reputation for the manufacture of optical instruments of the highest class and for the accurate working of glass and quartz in connection therewith. They are therefore well equipped for the closely allied problem of the construction of piezo-electric oscillators and resonators. The brochure received deals only with the former, a separate brochure being issued dealing with resonators. The first five pages are devoted to an historical and general account of the subject, with several references to original papers. This is followed by a description of the mounting devised by the firm and a discussion of its advantages and of the precautions to be adopted in its use. The crystal plate is placed between two brass electrodes in a glass tube, the whole being enclosed in an ebonite case about 2in. diameter and 1in. high. The length of the glass tube is carefully adjusted so as to ensure the proper air-gap between the crystal and the upper electrode.

The brochure will prove of interest to anyone who has to manipulate piezo-electric oscillators.

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Abstracts and References.

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PROPAGATION OF WAVES.

DOUBLE AND MULTIPLE SIGNALS WITH SHORT WAVES. SHORT RANGE ECHOES WITH SHORT WAVES.—E. Quäck and H. Mögel. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 791–823 and 824–829.)

English version of the paper and supplement dealt with in June Abstracts, pp. 322 and 323.

EXPERIMENTELLE UNTERSUCHUNGEN DER VERÄNDERUNG DER DIELEKTRIZITÄTSKONSTANTEN EINES SEHR VERDÜNNTEN GASES DURCH ELEKTRONEN (Experimental Investigations of the Alteration of the Dielectric Constant of a Very Rarified Gas by Electrons).—L. Bergmann and W. Düring. (*Ann. der Phys.*, 7th May, 1929, 5th Series, V. 1, No. 8, pp. 1041–1068.)

After sketching the theory of the Heaviside layer, the writers refer to the investigations of Eccles, Salpeter, Larmor, Lassen and Elias on the dielectric constant and conductivity of an ionised gas traversed by electric waves. These all lead to the same main result—a diminution of the dielectric constant which increases with increasing ionisation, and an absorption of the passing wave owing to the conductivity of the ionised gas. The Larmor equations differ slightly from those of the other workers, owing to different assumptions, but are fundamentally the same. They then describe the experimental investigations of van der Pol (2nd Drude method) giving the resulting curve for a wavelength of 150 cm., and point out that the greater part of this allows little to be learned of the dielectric constant, but that one portion definitely shows a diminution—though only qualitatively. They then describe the experiment of Gutton and Clément (who also used the effect of the ionisation on a condenser, but in a different way). These workers found a diminution of dielectric constant, in the case of small ionic densities, but for great densities they found an increase of the constant—contrary to the Eccles theory. This discrepancy they explained on the idea that at great densities the ions suffer not only the frictional force of Eccles' theory but also a mutual attraction, and are bound in a state of equilibrium. Rybner, however (March Abstracts, p. 146), points out that the elastic force thus postulated for an explanation of the increase of dielectric constant is not necessary, since the apparent increase may be due to the apparatus used by Gutton and Clément.

The writers, considering that a decision can only be made by a new test with improved apparatus, to give quantitative instead of only qualitative results, have now made such a test, avoiding the difficulties of the former experiments by the use of highly rarified gas. This plan practically eliminates the frictional effect. They also avoid the complication of the presence of both ions and electrons, dealing only with electrons, using the same 2nd Drude method and obtaining the electrons from a hot cathode; an auxiliary electrode (grid) being employed to destroy the space charge. The vacuum was so high that the electron free paths were large in comparison with their oscillation amplitudes in the electrical oscillating field (this is the case at a pressure of $1-2 \times 10^{-5}$ mm.) Wavelengths used ranged from 100 to 240 cms.

Results showed that the presence of electrons produced a diminution of dielectric constant which increased with increasing density of electrons. So far as quantitative measurements were possible, the absolute value of the constant agreed with theory. Dispersion (the effects on gradually increasing wavelengths, keeping a constant electron density) was also investigated and the results agreed with theory.

ÜBER DIE EIGENSCHWINGUNG FREIER ELEKTRONEN IN EINEM KONSTANTEN MAGNETFELD (The Natural Vibration of Free Electrons in a Constant Magnetic Field). — S. Benner. (*Naturwiss.*, 15th February, 1929, V. 17, pp. 120–121.)

When free electrons move in a constant magnetic field, they describe spirals round the lines of force. The number of turns of spiral traversed in unit time is independent of the electron speed when this is small, and depends only on the charge e, the mass m, and the field strength H; it is $eH/2\pi m$. But if in addition to the magnetic field an alternating electric field perpendicular to this acts on the electrons, the latter fall into strong oscillation due to a form of resonance, when the frequency of this field is nearly equal to the rotation-period of the electrons. The dielectric constant and the conductivity of the space are strongly altered by

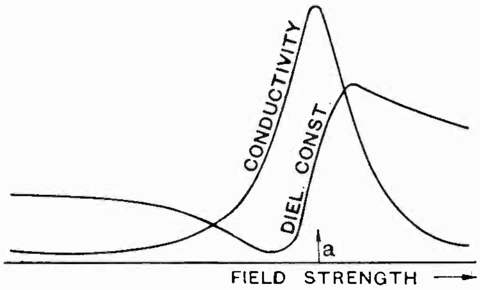

Fig. 1.—*Theoretical.*

a change in the frequency of the field: or, on the other hand, the field may be kept at a constant frequency and the electron rotation-period can be varied by varying the strength of the magnetic field. Fig. 1 shows the theoretical curves which should be obtained by such a process. Appleton and Barnett, Nichols and Schelleng, and later Pedersen, have based on this effect a theory of the Heaviside layer: the present writer has now carried out experiments to test this. A cylindrical oscillator valve (Schott, Type *N*) was paralleled with a variable condenser to form an oscillating circuit in which the anode/grid capacity was effective. A weak field between filament and grid drove electrons across the space between grid and anode. The valve was surrounded by a co-axial magnetising coil. The resonance curve of the system was plotted for a constant frequency and varying field-strengths, and from this the changes in decrement and capacity were calculated. Fig. 2 gives the results for a 7.9 m. wavelength.

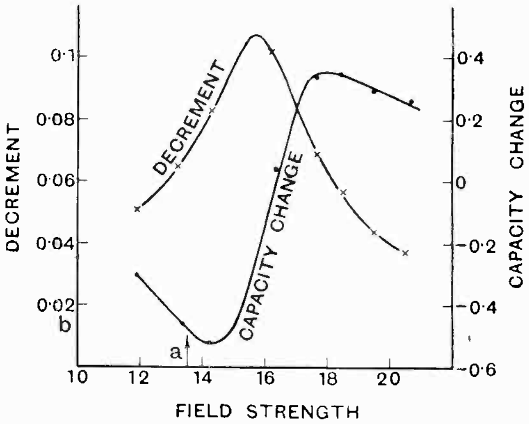

Fig. 2.—*Experimental. a. Field strength at which the electron frequency = field frequency. b. Decrement for cold cathode.*

The shape of the curves is the same as that demanded by theory, but they are slightly displaced towards the region of higher field strength (see positions relative to *a*). This is probably due to one condition of the theory not being fulfilled—that the free paths should be small compared with the distance between the electrodes. It would be expected that the discrepancy would be smaller with smaller electron-speeds and higher frequencies; this seems to be indicated by preliminary tests. More exact tests, with a gas pressure of about 0.05 mm., are being prepared.

LE RÔLE DES ÉLECTRONS LIBRES DANS LA PROPAGATION DES ONDES COURTES (The Part Played by the Free Electrons in the Propagation of Short Waves).—J. Granier. (*QST Franç.*, June, 1929, pp. 6–11.)

An article written round excerpts from recent letters and papers (dealt with in these Abstracts) by Störmer, Fabry, Ponte and Rocard, and Bureau.

MEASUREMENTS OF THE HEIGHT OF THE KENNELLY-HEAVISIDE LAYER.—G. W. Kenrick and C. K. Jen. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 711–733.)

Authors' summary:—In this paper we have sought to offer some further contribution to the Kennelly-Heaviside layer problem; first in the form of experimental data showing clearly evidence of the diurnal cycle in layer height, and secondly, in the form of a discussion of methods for the interpretation of group time and phase retardation experiments and the problem of determining the relationship between the "virtual" and "true" heights. Methods of successive approximation for arriving at the "true" height, from group time or phase retardation measurements, are also discussed and applied. Close accord is found between the results of these methods and the approximation used by Schelleng in a recent paper. The results shown in Fig. 16 also indicate the necessity for further experiments in the important frequency range from 1 to 4 megacycles where no data are available.

THE PROPAGATION OF ELECTROMAGNETIC WAVES IN A STRATIFIED MEDIUM.—D. R. Hartree. (*Proc. Camb. Phil. Soc.*, No. 1, 1929, V. 25, pp. 97–120.)

Author's summary:—The equations of propagation of electromagnetic waves in a stratified medium (*i.e.*, a medium in which the refractive index is a function of one Cartesian co-ordinate only—in practice the height) are obtained first from Maxwell's equations for a material medium, and secondly from the treatment of the refracted wave as the sum of the incident wave and the wavelets scattered by the particles of the medium. The equations for the propagation in the presence of an external magnetic field are also derived by a simple extension of the second method.

The significance of a reflection coefficient for a layer of stratified medium is discussed and a general formula for the reflection coefficient is found in terms of any two independent solutions of the equations of propagation in a given stratified medium.

Three special cases are worked out, for waves with the electric field in the plane of incidence, viz.:

(1) A finite, sharply bounded, medium which is "totally reflecting" at the given angle of incidence.

(2) Two media of different refractive index with a transition layer in which μ^2 varies linearly from the value in one to the value in the other.

(3) A layer in which μ^2 is a minimum at a certain height and increases linearly to 1 above and below, at the same rate.

For cases (2) and (3) curves are drawn showing the variation of reflection coefficient with thickness of the stratified layer.

Case (3) may be of some importance as a first approximation to the conditions in the Heaviside layer.

CHUTE D'UN GAZ LOURD DANS UN GAZ LÉGER. STABILITÉ DE L'OZONE DANS LA HAUTE ATMOSPHÈRE. (The Sinking of a Heavy Gas in a Light Gas. Stability of Ozone in the Upper Atmosphere).—Y. Rocard. (*Comptes Rendus*, 22nd May, 1929, V. 188, pp. 1336–1338.)

The author's calculations lead him to the conclusion that if the light gas is taken as being nitrogen, the rate of sinking of the ozone is 22 m. per day;

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if hydrogen, the rate is 17 m. per day. In either case, the ozone is practically stable, and any fluctuations in the height of the ozone layer must be due either to the causes which create and destroy it or to general motion of the atmosphere.

Ozone Due to Particles.—F. E. Fowle. (*Sci. News-Letter*, 1st June, 1929, p. 342.)

Of two layers of ozone in the earth's atmosphere, one (probably due to ultra-violet light) shows an annual period of change, depending on the position of the earth in its orbit; the other (perhaps due to the emission of particles shot out from the sun) shows a close relationship to sun-spots; probably, when these are at their minimum number, this second layer is absent entirely, though the observations have not continued long enough to ascertain this.

Note on Earth Reflection of Ultra Short Radio Waves.—E. H. Lange. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 745–751.)

Author's summary:—"In analytical investigations of the resultant pattern of electric intensity about an antenna, for the longer waves, the earth in the vicinity of the antenna has generally been considered as a perfect conductor. At sufficiently high frequencies, the reflected waves may differ considerably in magnitude and phase from perfectly reflected waves. The resultant distribution of electric intensity about an ultra short antenna depends upon the nature of the reflecting surface. Some computations and curves are given for the reflection coefficients and phase angles for various surface conditions, in conjunction with a horizontal ultra short antenna. Theoretical polar diagrams have been computed for various heights of horizontal antenna above the surface."

These polar diagrams agree well, in general form, with the experimentally observed distributions given by Yagi for waves of about 2.6 m. length (Abstracts, 1928, V. 5, p. 519).

Geographical Influences and Radio Waves.—R. Bureau. (*Nature*, 4th May, 1929, V. 123, p. 695.)

Summary of a paper in the *Revue Scientifique* for 23rd March, which would appear to cover much the same ground as the *Comptes Rendus* paper referred to in May Abstracts, page 262. Points mentioned here are:—apart from what happens in the upper atmosphere, important effects are produced in the troposphere, which is about six miles in height, and in the lower layers of the stratosphere. Contrary to expectation, direct experiment has shown that the surface which separates the stratosphere from the troposphere has little, if any, effect on the propagation of waves. It is found that short waves, whether entering or leaving France, have very different properties, which depend on their direction of propagation. Waves coming from the Caribbean Sea, Panama, and the Gulf of Mexico suffer little attenuation. On the other hand it is, if not impossible, at least very difficult to get signals from the North-East of the United States and from Newfoundland. Signals given by a 200-watt emitter on the Atlantic coast of Morocco seem never to reach Central or Eastern Europe, though they can be heard in other directions for thousands of miles. The radio waves seem to have difficulty in passing through the surface of separation between a mass of cold air and a mass of warm air. The lines which separate the audible zones from the zones of silence often coincide very closely with the meteorological lines separating masses of cold and warm air.

Enkele Opmerkingen over de Analogie tusschen Mechanische en Golfuitbreidungsproblemen (Remarks on the Analogy between Mechanical and Wave-propagation Problems).—W. de Groot. (*Physica*, May, 1929, V. 9, No. 5, pp. 175–180.)

Author's summary:—It is shown that the Schrödinger expression for the dispersion of material waves,

$$u = \frac{h\omega}{\sqrt{2M(h\omega - V(x, y, z))}},$$

is the only one for which the velocity of wave-groups of any desired frequency can be represented by the motion of a particle in a potential field independent of frequency. It is therefore pointed out that in considering any dispersion law it may be useful to bring the dispersion formula, in a small frequency-range, into the Schrödinger form.

Über die achsensymmetrischen elektromagnetischen Wellen mit axialer Fortpflanzungsrichtung (On Axially-symmetrical Electromagnetic Waves Propagated in a Direction Parallel to the Axis).—N. S. Japolsky. (*Zeitschr. f. Phys.*, 21st March, 1929, V. 54, No. 1/2, pp. 108–122.)

Many workers have dealt with axially-symmetrical waves propagated radially—*i.e.*, perpendicularly to the axis of symmetry. The writer now deals with those waves propagated axially which he terms "axial waves," limiting his treatment to waves in an isotropic homogeneous medium. The paper is divided into the following sections:—Introduction; ordinary and "equi-phase" cylindrical co-ordinates; the general expression for the Maxwell differential equations and its application to axial waves; the differential equations of simple harmonic cylindrical waves, and their integration; the calculation of the radial complex factors; the transition from cylindrical to conical waves; concluding remarks on the importance of these waves.

Über die Frequenzänderung des Lichtes durch Variation des Optischen Weges (On the Frequency Change of Light Due to Variation of Optical Path).—S. Levy. (*Zeitschr. f. Phys.*, 11th May, 1929, V. 54, No. 9/10, pp. 674–675.)

The writer takes as an example the passage of a ray of monochromatic light through a Kerr cell supplied with periodically varying potential, and investigates the consequent frequency difference between the two components (the waves parallel to and perpendicular to the electric field). The bearing of this result on Rupp's experiment on the modulation of a light ray is discussed (Abstracts, 1928, V. 5, p. 587.)

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SUR LA CONSTANCE DE LA VITESSE DE LA LUMIÈRE (On the Constancy of the Velocity of Light). —P. Salet. (*Comptes Rendus*, 10th June, 1929, V. 188, pp. 1539–1540.)

"The study of double or variable stars has shown that the velocity of light is—so far as can be observed—independent of wavelength (dispersion in space) and of the motion of the source (ballistic theory). The question arises whether it may be modified by other causes, notably the attraction of the source. In the case of a Newtonian attraction, light proceeding from a star with velocity *c* would quickly assume a slightly smaller velocity. The loss of velocity, about proportional to the ratio mass/radius of the star, would amount to 0.7 km. per sec. for the sun, and would change with the spectral type." The writer suggests that observations on double spectroscopic stars would furnish a test as to the existence of such variation.

A METHOD OF EXPLORING THE ATMOSPHERE BY THE HELP OF DISTURBANCES OF ELECTROMAGNETIC FIELD AT THE PASSAGE OF THE TWILIGHT BAND.—J. Lugeon. (*See* under "Atmospherics.")

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

SUR L'ORAGE MAGNÉTIQUE DU 7 AU 8 JUILLET 1928 ET LES PHÉNOMÈNES CONNEXES (The Magnetic Storm of 7th–8th July, 1928, and its Associated Phenomena).—Ch. Maurain. (*L'Onde Élec.*, April, 1929, V. 8, pp. 170–172.)

Information from various sources, sent to the writer as a result of his former note on this storm (Abstracts, 1928, V. 5, p. 638), is given here. At Spitzbergen, variations of 5 degrees in the magnetic declination were noted, and reception of short waves (30 m.) showed great weakening or complete cessation, whereas 600 m. and 9–18 thousand metre waves showed no weakening. A few sunspot and polar aurora observations are included.

SUR L'ORIGINE DE CERTAINS PARASITES (On the Origin of Certain Atmospherics).—Ch. Maurain. (*L'Onde Élec.*, April, 1929, V. 8, pp. 131–134.)

Author's summary :—"The similarity between the diurnal variation of the earth's magnetic agitation and the diurnal variation of one category of atmospherics [nocturnal] suggests the idea of a relation between the two phenomena. A recent work of T. L. Eckersley shows such a relation ["whistlers"—January Abstracts, p. 38]. The diurnal and annual variations of storms, on the other hand, are similar to those of a second category of atmospheric ["afternoon" atmospherics] which would appear to originate in storm-phenomena; the comparison of storm frequency charts with charts of these atmospherics would be capable of throwing light on the range of the latter, which is much disputed. . . ."

The writer supports Bureau (*ibid.*, 1926, p. 301) in his rejection of "certain interpretations supposing, without sufficient proofs, that a certain atmospheric is the result of a certain atmospheric discharge at some more or less great distance"; but he considers that Bureau does not pay sufficient attention to the relation between storm phenomena (of which lightning is one manifestation) and atmospherics. He quotes a table of storm statistics giving, for the whole of France, the average proportion of storms per month taken over 33 years, showing the enormous increase in summer (15.6 to 19.02 as compared with 1.04 in January), and compares this with Bureau's statement that in temperate regions the afternoon atmospherics are always more prominent in summer than in winter.

SUR L'ORIGINE DE CERTAINS PARASITES.—R. Bureau. (*Ibid.*, pp. 134–142.)

A reply to the above. The writer agrees that the afternoon or "stagnant" atmospherics are, like storms, an effect of stormy meteorological conditions, but he lays stress on the point that they are *not* an effect of "storms strictly so-called"—*i.e.*, lightning flashes.

As regards nocturnal atmospherics, on the other hand, he disagrees with Maurain. Even if he admits the possibility of a relation between atmospherics and magnetism, he insists that the relation is not a simple one and that in all cases a vigorous meteorological action is superimposed on it. He gives four principal reasons for this belief :—(1) the nocturnal atmospherics disappear above the layers of inversion (an effect noted by Lugeon and recently confirmed by the writer by comparison of the records of Mt. Valérien and St. Cyr); (2) the amplitude and number of these atmospherics are very variable; this variation is in close relation with the meteorological situation (records are given, taken at St. Cyr in December, 1928); (3) magnetic storms do not appear to be accompanied by a "recrudescence" of atmospherics: in particular he cites the storms of 26th January, 1926 and 7th July, 1928; and (4) the minimum of atmospherics takes place about 8 o'clock in winter, but in summer it occurs earlier and always about sun-rise. Maurain and Eblé have themselves shown that the daily minimum of magnetic disturbance is displaced in the opposite sense and approaches mid-day in summer.

The last part of the paper is devoted to an exposition of how all three classes of atmospherics can ultimately be attributed to meteorological factors—the vertical thermal instability of the atmosphere and the convection currents resulting from it. When the atmosphere is stratified in a stable way and, in consequence, there is no exchange between the various superposed layers, the distribution of potential is equally stable and there is no cause for the existence of appreciable horizontal gradients between two points on the same level. Such a condition, free from atmospherics, is formed in spring and autumn in the masses of tropical air in temperate regions. When, however, vertical ascending and descending movements set in, particles of air from very different levels find themselves at every moment brought to the same level and very close to each other; thus at every point, at every instant, comparatively high horizontal electric gradients are formed. This effect is the stronger, the weaker the horizontal currents. In the case of a turbulence of uniformly distributed movements of small amplitude, discharges would

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be fairly small but very numerous and almost continuous (nocturnal atmospherics); in the case where powerful movements occur alternately up and down (stormy Cu. Nb., strong cold fronts) there would be more violent discharges, perceptible over quite extended regions but grouped irregularly in time ("cold front" atmospherics). The writer concludes by remarking that observations of the aerial-earth current or of the "whistlers" mentioned by Eckersley should give valuable information on the variations of vertical electric gradient, just as observations of atmospherics give information on the horizontal gradients.

A Method of Exploring the Atmosphere by the help of the Disturbances of Electromagnetic Field at the passage of the Twilight Band.—J. Lugeon. (*Comptes Rendus*, 22nd April, 1929, V. 188, pp. 1114–1116.)

In anti-cyclones in particular, stratified zones of inversion of temperature exist at a mean altitude which varies from a maximum exceeding 2,500 metres in August, to a minimum of some 700 metres in February over the Swiss plateau. Though this layer is thermally stable, its electric state has a very important daily variation which is the direct product of solar radiation. This variation produces at dawn a very rapid diminution or disappearance of atmospherics, while re-establishment of the régime of nocturnal atmospherics in the evening occurs more slowly. The layer thus possesses a nocturnal post-twilight electromagnetic inertia which seems to be a function of the variation of diurnal illumination and to a certain extent of the intensity of this radiation, which itself depends on the purity and temperature of air masses above the layer. If frontal cirrus or the margin of a cloud system cut off the solar rays for an instant, atmospherics will begin more rapidly after sunset, but they will be weaker than in cases where the sky remained clear throughout the day. The examination of the diagram of atmospheric disturbance thus permits the detection, from under the sea of mist, of the presence of clouds above it invisible to the eye. These conclusions apply specially to local atmospherics, but they refer also to distant atmospherics which have marked directional properties and which continue unchanged into the daylight phase in contradistinction to the local atmospherics.

With the help of curves recording the frequency of incidence of atmospherics, there can be calculated the height and thickness of the sea of mist and of all other stratified cloud ceilings possessing the same electromagnetic properties, as for example certain cirrus layers, some dry haze layers, ionised regions, and the so-called Heaviside layer. At the precise instant when the rays of the rising sun penetrate one of these screens, there is produced on the diagram a very sharply marked maximum (due to the screen acting also as a source of local atmospherics), followed by a progressive diminution in frequency and in intensity of atmospherics. The analysis of numerous special cases of the last nocturnal maximum of atmospherics thus allows a diagnosis to be made, not only of the troposphere but also of the stratosphere, and a calculation of the altitude of the Heaviside layer. This layer, whose thickness would appear to be between 5 and 30 km., seems to be subject to a true tide independent of its daily oscillation with a period lying between 9 and 12 days. The amplitude of this tide seems to vary somewhat slowly between the altitudes of 70 and 150 km. The author finds evidence of one layer varying between the heights of 250 and 750 km. He finds also a peculiarity in the record during the morning astronomical twilight which he interprets as implying the existence of a thick layer of inversion of temperature oscillating between the altitudes of 31 and 62 km., probably the ozone layer, where—according to recent experiments on the propagation of sound waves—the temperature would appear to reach that of the human body.

Houlton Observations on the Direction of Atmospherics.—A. E. Harper and S. W. Dean. (*Sci. News-Letter*, 25th May, 1929, V. 15, pp. 327–328.)

Addresses to the I.R.E. "It is sometimes assumed that static is of relatively local origin and is rapidly attenuated along its path. This theory seemed to us rather untenable, since simultaneous records have been made of static crashes at Hawaii, New York, and Germany. We believe that for receiving in Maine the most important source of static is thunderstorms in the U.S. and Canada, after which we put thunderstorms in other portions of the globe. In addition to actual thunderstorms we find static accompanying weather disturbances such as electrified clouds, etc., which have not reached the point of producing audible thunder. As a working hypothesis it may be assumed that such static is produced on the southeast edge of an advancing low-pressure area, especially if precipitation occurs. This condition when accompanied by up-rushing winds, according to Dr. W. J. Humphreys of the U.S. Weather Bureau, tends to produce a thunderstorm. Therefore in the absence of other data, thunderstorm charts would be the most logical index of the location of static sources. This theory seems to be strengthened by our Houlton measurements."

From cathode ray oscillograph records, places as far remote from Maine as Florida, Africa, a position at sea off Argentine, Southern Mexico, Ecuador and Brazil are all responsible for some of the static that interferes with the telephone service. All these are recognised as great thunderstorm centres.

S. W. Dean mentioned that in the summer the effects of near-by disturbances usually overshadow these distant sources. A low-pressure area seems to produce more atmospherics when it is moving rapidly. When it is more or less stationary or quiescent it produces few atmospherics. In the summer, low-pressure areas produce many more atmospherics when over land than after they pass out to sea, but in cool weather the reverse is sometimes true. He then dealt with the prediction of approaching storms by observations on atmospherics. "It would seem that as few as three stations, one on the north Atlantic coast, one on the south Atlantic coast, and one in the middle west, would cover the eastern part of North America and the western part of the Atlantic Ocean fairly well. Our experience indicates that such a system might be helpful in the location of storms in northern

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Canada, the Atlantic, the Gulf of Mexico, and the West Indies, as well as those in the eastern half of the United States."

DISTRIBUTION OF TEMPERATURE IN THE FIRST 25 KILOMETRES OVER THE EARTH.—K. R. Ramanathan. (*Nature*, 1st June, 1929, V. 123, pp. 834–835.)

The writer gives a diagram showing the probable distribution (using all the data now available) of isotherms in the atmosphere up to 25 km., in summer and winter over the Northern Hemisphere. He summarises the principal features; gives a second diagram illustrating the seasonal variation of temperature of the tropopause at Batavia and Agra, and quotes Bemmelen's figures for the variation of height of the tropopause over Batavia, similar to that occurring over Agra but displaced by about 6 months. "The lower temperatures and greater heights of the tropopause in summer are presumably due to the stronger convection in the troposphere in that season. The persistent increase of temperature with height for at least 5 km. above the tropopause in the tropics finds a natural explanation if we assume that the tropopause marks the lower limit of the ozone layer in the atmosphere."

THE IMPORTANCE OF LINES OF EQUAL ENTROPY IN ATMOSPHERIC PHYSICS.—Napier Shaw. (*Nature*, 15th June, 1929, V. 123, p. 906.)

Referring to Ramanathan's letter (see above) the writer mentions the desirability of a corresponding diagram, embodying all the data available, of the lines of equal entropy: pointing out the important influence of entropy on convection and therefore on weather:—"it is entropy which decides the equilibrium position of a sample of air, whether it will rise or sink or stop where it is. . . Circulation along an isentropic surface can take place without any communication of heat, no matter whether the controlling surface be horizontal or vertical at the position of the sample. . . ."

THE MOTION OF IONS IN CONSTANT FIELDS.—Leigh Page. (*Phys. Review*, April, 1929, V. 33, pp. 553–558.)

Author's abstract:—It is shown that the effect of constant electrical or gravitational force F on ions passing through a constant magnetic field H is to cause the circular or helical ion paths to advance in a direction at right angles to both F and H with the constant velocity $u = c\,[\mathbf{F} \times \mathbf{H}]/eH^2$. Ion paths relative to a rotating earth are discussed on the assumption that the earth's field is purely magnetic relative to the inertial system of the centre of the earth. The essential features of the theory are shown to be unaltered if the constant mass of the classical theory is replaced by the variable mass of the relativity theory.

SONDAGES DE PRESSION ET DE TEMPÉRATURE PAR RADIOTÉLÉGRAPHIE (Pressure and Temperature Soundings by Radiotelegraphy).—R. Bureau. (*Comptes Rendus*, 10th June, 1929, V. 188, pp. 1565–1566.)

A description of the writer's use of automatic transmission by wireless of the readings of a barometer and a thermometer carried in an exploring balloon in its ascent into the stratosphere.

In the case of a thermometer with a range from +20 to −60°C., the error is less than 0.7°, and this can be reduced by reducing the range of temperature. The system gives a valuable saving of time over other methods (aircraft, ordinary sounding balloons) for the analysis of meteorological conditions and for forecasting weather. The readings are given by the length of the signal dashes compared with the intervening spaces.

NEW EVIDENCE OF THE ACTION OF SUNLIGHT ON AURORA RAYS.—C. Störmer. (*Nature*, 8th June, 1929, V. 123, pp. 868–869.)

Further work on the subject referred to in April Abstracts, p. 204. A new phenomenon has been observed, certain of the high sun-lit rays having extensions in the dark zone, the connecting portion (beginning at the sunlight boundary and extending downwards a little way) being invisible.

THE SUN'S RADIAL MAGNETIC GRADIENT AND ATMOSPHERE.—Ross Gunn. (*Phys. Review*, April, 1929, V. 33, pp. 614–620.)

Theory of the radial magnetic gradient of the sun based on the diamagnetic effect produced by ions spiralling about the impressed magnetic field. Ionic densities estimated from magnetic data.

AN ELECTROMAGNETIC EFFECT OF IMPORTANCE IN SOLAR AND TERRESTRIAL MAGNETISM.—Ross Gunn. (*Phys. Review*, May, 1929, V. 33, pp. 832–836.)

Author's summary:—"*The thermal motions of ions in an inhomogeneous magnetic field give rise to a systematic ion drift.* A study of the motions of ions executing long free paths and spiralling about an inhomogeneous impressed magnetic field has shown that a systematic drift is imposed which is oppositely directed for the positive and negative ions. The resulting drift velocity is proportional to the component of the magnetic gradient that is perpendicular to the magnetic field itself. Under the conditions of radial symmetry and a closed circuit a current flows which is in such a direction as to reduce the inhomogeneity of the impressed field and to increase the total flux enclosed by the current circuit. This increase in the flux enclosed by the circuit shows that the phenomena may be regenerative. Certain applications to the sun's atmosphere, sunspots and the permanent magnetic field of the sun and earth are suggested."

One of these applications leads to the supposition of the existence in the sun's atmosphere of *westward* currents which, if not compensated, would greatly increase the apparent magnetic moment of the sun; using available data and certain assumptions, the calculated magnetic moment of the westward current sheet turns out to be about the same as would be computed for a sun represented by a uniformly magnetised sphere of polar strength 50 gauss; suggesting that the permanent magnetic field of the sun and earth is due to similar phenomena taking place probably in the interior where the free paths of the ions are short. "The ion density selected for the above calculation seems too low by

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one or two orders of magnitude and we are led to believe that diamagnetism and perhaps *eastward* currents play an important part in solar magnetism, since the larger densities would lead to values of the magnetic moment which were much too large." It is suggested that the eastward gravitational current dealt with by Chapman and the westward "magnetic gradient" current here described would largely neutralise each other, since a calculation of the latter—using Chapman's data—gives a velocity of drift of both ions approximately equal to Chapman's value for the gravitational drift velocity.

EFFECT OF THE EARTH'S MAGNETIC AND ELECTRIC FIELDS ON ION PATHS IN THE UPPER ATMOSPHERE.—Leigh Page. (*Phys. Review*, May, 1929, V. 33, pp. 823–831.)

Author's summary :—"It is shown that the lines of force of the earth's magnetic field can be treated as if rotating with the earth in so far as the calculation of ion paths is concerned only if there exist positive charges over the poles accompanied by negative charges over the equator. The earth would have a total charge of –72 coulombs although observers on the earth would be aware of no electric field. Assuming that the earth is an uncharged, conducting, uniformly magnetised sphere, rotating about its magnetic axis with angular velocity Ω, it is shown that ion paths progress to the west, the velocity of progression increasing with altitude so as to approach the limiting value $-\Omega \times r$ which measures the progression that would exist if the earth's field were solely magnetic relative to observers who do not partake of the rotation. The earth would have an *apparent* charge of $+72$ coulombs although actually uncharged. It is shown that a uniformly distributed charge q on the earth merely changes the value of the limiting westward velocity found above, increasing the westward progression if q is positive, and decreasing it if q is negative."

PROPERTIES OF CIRCUITS.

ÜBER DIE MAXIMALLEISTUNGEN VON SCHUTZNETZLEISTUNGSRÖHREN (On the maximum Output of Screen-Grid Power-amplifier Valves).—H. Bartels. (*E.N.T.*, May, 1929, V. 6, pp. 182–193.)

Further development of the work referred to in July Abstracts, p. 388. By calculation and from experimentally measured characteristic curves of screen-grid power-amplifier valves, the writer shows that for equal anode loads and approximately equal battery voltages the attainable A.C. output for the screen-grid valve is equal to that of the corresponding single-grid valve. For powers of several watts and over, the single-grid valve is preferable ["the screen-grid valve is more sensitive to mechanical shocks. . . . If screen-grid valves are to be used it would seem more advantageous to employ them in the earlier stages as voltage amplifiers"]: for smaller powers [*e.g.*, where the audion valve controls the power valve directly] the screen-grid valve may be advantageously used for the sake of its saving in grid potential [especially when, for as small grid-voltages as possible and for a given type of loud-speaker, it is desired to maintain a constant ratio of grid voltage to anode current.] Finally it is shown that quite generally the highest obtainable ratio of A.C. output to the maximum anode load has the limiting value 0.5 for all types of valves and all methods of loading.

DETECTION CHARACTERISTICS OF SCREEN-GRID AND SPACE-CHARGE-GRID TUBES.—F. E. Terman and B. Dysart. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 830–833.)

A paper giving data on the grid-leak detection characteristics of four-electrode valves, in continuation of a similar study of triodes (May Abstracts, p. 273). Results are expressed in terms of the detector voltage constant v as a function of grid resistance, and are obtained from bridge measurements of dynamic grid resistance at grid voltages that differ slightly. It is found that the rectifying properties of the grid circuit for the four-electrode valve, used in screen-grid or space-charge-grid connection, are about the same in character and magnitude as in triodes with the same type of filament. The rectifying action in the grid circuit is largely independent of the voltages of filament, plate and second grid when compared at the same grid resistance. The space-charge-grid-leak-condenser detector is superior to the screen-grid and most triode grid-leak-condenser detectors, in that the space-charge-grid valve retains its full rectifying powers at adjustments which give full reproduction of the high notes.

VERSTÄRKUNGSMESSUNGEN AM RÜCKGEKOPPELTEN WIDERSTANDSVERSTÄRKER. KONSTRUKTION EINES KOMPENSIERTEN VERSTÄRKERS MIT GERADER FREQUENZKURVE (Amplification Measurements on the Reactively-coupled Resistance Amplifier. Construction of a Compensated Amplifier with Straight-line Frequency Characteristic).—H. G. Baerwald. (*Arch. f. Elektrot.*, 8th May, 1929, V. 22, No. 1, pp. 81–103.)

A resistance amplifier with strong reaction by ohmic resistance is neither linear nor independent of frequency in its working. Investigations (such as those described in this paper) into the frequency-dependence of such an amplifier must be based, therefore, on keeping the output voltage constant and measuring the various inputs. The constant output voltage was chosen so large that the amplifier worked as an "amplifier limiter" (L. B. Turner). Various precautions necessary for the measuring process are described—*e.g.*, the neutralisation of interfering stray voltages, screening, etc.—and the probable errors are discussed. The next section deals with the experimental and theoretical investigation of the "uncompensated" resistance amplifier and its behaviour; theoretical and experimental curves agree well. "Quasi-resonance" (involving capacitive and ohmic elements only, without inductance) is discussed, and its dependence on the reaction-amplification constant.

The above work leads up to the development of a "compensated" amplifier with a straight line characteristic (in the case in point) between 3,000 and 35,000 cycles per sec. The lower limit can be reduced without difficulty. A 2-valve amplifier on

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this design allows a reaction-amplification of 73 (*i.e.*, an absolute amplification of about 8,500) with practically complete frequency-independence, compared with a value of about 9 for the amplifier without compensation. The compensation is obtained by the use of a complex reaction resistance made up of (adjustable) ohmic resistances in series and parallel with an inductance. The parallel connection was apparently necessary because H.F. oscillations were set up by the series inductance-resistance arrangement; this trouble was stopped by the parallel (several thousand ohms) resistance.

THE PROBLEM OF "TURN-OVER."—M. Reed. (*E.W. & W.E.*, June, 1929, V. 6, pp. 310–315.)

Under certain conditions the value of the current obtained in the plate circuit of a rectifying tube, for a given A.C. input, is not the same if the connections to the input of the rectifier are reversed. The ratio of the two values of the plate current is known as the "turn-over," and the conditions under which it is obtained are here considered and the results applied to the case of the ordinary valve-voltmeter and to the valve-voltmeter using the "slide-back" principle. It is shown that (1) in both types there will be an error due to "turn-over" if the applied voltage wave contains suitable harmonics and if the equation of the rectifier characteristic is at least a cubic; (2) the error will become less as the value of the negative grid bias on the rectifier is decreased; (3) to avoid error due to "turn-over" it would be necessary (*a*) to make the input free from harmonics; (*b*) to employ two valves to form a balanced rectifier; (*c*) to employ a rectifier whose characteristic can be expressed by a quadratic over the operating portion; or (*d*) to determine the value of the grid bias so that the operating point is in a region where the rectifier characteristic can be expressed by a quadratic, and to arrange that the input to the rectifier is such that the grid swing does not go beyond this region.

EINE BEOBACHTUNG BEI VERSUCHEN ZUR BESTIMMUNG DER FREQUENZMODULATION VON RUNDFUNKSENDERN (A Point Noticed in Tests to determine the Frequency Modulation of Broadcasting Transmitters).—F. Gerth and W. Scheppmann. (*E.T.Z.*, 16th May, 1929, V. 50, p. 722.)

It was found, by a slow repetition of the modulation characteristic, that an oscillating audion close to the transmitter gave a marked change in heterodyne note between the points of maximum and minimum aerial current—in the case in point, a total frequency change of 0.3 per thousand being found. The same effect was noticed with the same receiver at a distance of 10 km., when used with a vertical aerial; but when used with a closed oscillating circuit, no such frequency change was found. The conclusion is that the effect of strong signals on the oscillating audion is to alter its natural frequency by displacing the working point on the curve; for successful measurements, therefore, care must be taken not to load such a receiver heavily; loosely coupled circuits or—better still—a quartz controlled oscillator are recommended. Tuning the whole receiver to a high harmonic would also give accurate results.

FREQUENCY MULTIPLICATION BY SHOCK EXCITATION.—E. A. Guillemin and P. T. Rumsey. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 629–651.)

Authors' summary:—The fundamental principles involved in the theory of frequency multiplication by means of iron-core coupled circuits are briefly reviewed from the standpoint of Fourier analysis as well as that of recurring transients. Oscillograms and figures illustrating the effect of transformer inductance and shock duration upon wave form are given. Oscillations of the first and second kind are discussed in their relation to the analogous arc circuit problem. Efficiency and power output are considered in their dependence upon primary and secondary current amplitude, and the conditions for smoothest wave form and maximum efficiency are pointed out.

TRANSFORMERS AS BAND PASS FILTERS.—E. K. Sandeman. (*Elec. Communication*, April, 1929, V. 7, pp. 282–292.)

PRINCIPLES OF GRID-LEAK GRID-CONDENSER DETECTION (F. E. Terman): Discussion.—(*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 752–754.)

The paper was dealt with in January Abstracts, p. 41. Polydoroff argues from Terman's conclusions that for the best results the detector constants should be adjustable, and mentions that he has found a very practical method of control of detector load to be the use of the old variable grid-leak. The variable leak (15,000 to 500,000 ohms) is in parallel with a fixed 2-megohm resistance. When "off," the variable leak leaves the detector adjusted to maximum sensitivity for weak signals, with its 2-megohm leak; while for louder signals it can be suitably adjusted to give the best results.

TRANSMISSION.

THE SHORT-WAVE LIMIT OF MAGNETRON OSCILLATIONS.—K. Okabe. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 652–659.)

The writer explains the process in the magnetron as follows:—when the magnetic field is greater than the critical value, the anode current is cut off and there is an accumulation of charges near the anode and cathode. The accumulation of charges near the anode is the true seat of oscillatory phenomena. As soon as the conditions become such that a negative resistance is possible, the accumulated charges begin to be dispersed or discharged and the state of negative resistance disappears until a further accumulation of charges occurs. The time required for such accumulation after the preceding discharge is approximately equal to the time t taken by an electron to travel from the cathode to the region near the anode where the charge density is greatest. The period T of the resulting oscillations will be $T = t + t'$ where t' represents the time required for the electronic discharge. We have at present no way of estimating t', but since the process is alternating, the writer considers it not unreasonable to assume that t' is approximately equal to t. From this he arrives at an equation for

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the wavelength $\lambda = \frac{2\pi c^2 m}{eH} = \frac{10650}{H}$ cm., whereas experimentally $\lambda = \frac{13000}{H}$ cm.

The former equation was a simplification made by assuming the radius of the cathode to be extremely small, which would account for the difference of about 20 per cent. between theory and experiment.

Theoretically, therefore, if H could be raised to 20,000 gauss a wavelength of 6.5 mm. would be obtained. But there is another condition to be complied with:—the maximum oscillation (generally) occurs in the neighbourhood of the critical field strength, and consequently the following relation should exist—

$$\text{anode radius } r_a = \sqrt{\frac{8mc^2}{H^2e} \cdot V_a} = \frac{6.7}{H}\sqrt{V_a} \text{ cm.}$$

Now assuming an anode voltage of 10,000, the anode radius would work out at 0.34 mm., and it is doubtful whether such conditions could be fulfilled. But it would appear that the practical lower limit of wavelength is of the order of a few millimeters. The shortest actually produced so far is 5.6 cm. (neglecting harmonics).

A STUDY OF THE THREE-ELECTRODE VACUUM-TUBE OSCILLATOR.—CONDITIONS FOR MAXIMUM CURRENT.—E. T. Cho. (*Phil. Mag.*, June, 1929, V. 7, No. 46, pp. 1038–1049.)

This study is confined to the "tuned-grid" circuit. Experimental results plotted as curves bring out the fact that there is a simple relation of the inductance L to the capacity C of the tuned grid-circuit, when the constants of the oscillating circuit have been adjusted to give the largest possible current. This relation depends upon the filament and plate potentials and the resistance of the circuit, thus:—L/C varies as $1/E_f$, as R, and as E_p; or $L = hRE_pC/E_f$, where h is a constant which for the valve used (type 201 A) was about 50. The value of C is much larger than that usually employed in practice (the results apply for maximum current and not necessarily for maximum power or efficiency). Another relation found experimentally is that if M is the mutual inductance between L and the anode-circuit reaction-coil, for maximum current M/L is a constant; this holds good for circuit tuning from 50 to 1,600 metres. The average value found for this constant is 3.3. Theoretically, it is shown that the ratio M/L for maximum current should equal about half the amplification constant, *i.e.*, for the particular valve used, it should equal about 4.5.

SHORT WAVE GENERATION.—(German Patent 471524, Žácek, published 14th February, 1929.)

Žácek's 1924 patent using the effect of a magnetic field on the electrons as they emerge from the cathode: this field is parallel to the cathode and causes the electrons to describe spiral-shaped curves round the cathode, in planes perpendicular to the field. The resulting oscillations depend for their frequency on the strength of field, the electrode voltages and the electrode distances.

SUR LES ONDES DE 10 À 20 CENTIMÈTRES (10–20 cm. Waves).—G. Beauvais. (*Bull. d. l. Soc. franç. d. Élec.*, May, 1929, V. 9, pp. 503–510.)

See June Abstracts, p. 326. In the present article diagrams are given of the Pierret transmitter and receiver circuits, of the super-regenerative receiver used in the writer's tests, and of the Pierret circuit adapted to telephony.

TELEGRAPHY CONTROL WITH VALVE IDLE LOAD.—(German Patent 471895, Telefunken, published 19th February, 1929.)

The grid circuit of the transmitting valve contains a resistance which is also included in the grid circuit of the valve forming the idle load. The change of transmitting valve grid-current, when the anode supply is connected by closing the key, thus affects the grid of the idle-load valve and prevents it from taking its load.

L'ALIMENTATION DES POSTES ÉMETTEURS RADIOÉLECTRIQUES À BORD DES AVIONS (Current Supply for Aircraft Radio Transmitters).—J. Morel. (*L'Industrie Élec.*, 25th February, 1929; summary in *Génie Civil*, 8th June, 1929, V. 94, p. 563.)

RECEPTION.

DIE APERIODISCHE VERSTÄRKUNG VON RUNDFUNKWELLEN (The Aperiodic Amplification of Broadcast Waves).—M. v. Ardenne. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, pp. 166–175.)

The author considers that for frame-aerial reception, the average necessary R.F. amplification lies between five and ten thousand. Four triode stages are needed for this, and if tuned amplifiers are used (*i.e.*, 5 tuned circuits) adjustment becomes complicated or the apparatus expensive (gang control): moreover, loss of quality is probable owing to too much selectivity. Screen-grid valves, with their 25–40 amplifications between 200–600 m., get over some but not all of this difficulty. Aperiodic amplifiers solve it completely. Such amplifiers, capable of useful amplification in the wave-range named, were known in 1927; but the valves of those days, when thus used, had certain failings (too high a current-consumption in the space-charge circuit, and L.F. disturbances due to L.F. amplification accompanying the R.F. amplification). The writer therefore deals with the design of up-to-date aperiodic amplifiers for the latest valves.

Discussing the choice between resistance, choke, and transformer coupling, he concludes that for the sake of obtaining independence of frequency over the wide range in question, without reducing the amplification per stage by having to choose a valve with low internal resistance, resistance coupling is preferable. The rest of the paper, therefore, deals with this type only. Treating first the preliminary calculation of a single stage, the writer compares his mathematical results with data of the recently-developed Loewe 2 H.F. single-grid valve, showing how well these valves fit in with the best conditions for the wavelengths in question.

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Two possible methods for obtaining the greatest possible amplification are given as (a) diminution of the effective capacity and (b) increase of the valve constant. One way of accomplishing (a) is to design so that the electrode and internal structure capacities are kept small—as can be done so successfully in multiple valves; the other way is to keep down the effective capacity by eliminating (by compensation) the apparent capacity due to anode reaction—a plan which was unfavourably criticised in a former work (Abstracts, 1928, V. 5, pp. 402 and 466). As regards (b), attempts have been made to use high-emitting cathodes by employing several filaments in parallel, but this plan is bound to increase the inter-electrode capacities. Indirectly heated cathodes, however, work well in multiple valves. The rest of the paper deals with combination of units into a cascade, starting with general considerations and going on to the use of the 2 H.F. multiple valves previously referred to. In this new type the makers have given up the space-charge grid, partly because the full advantage is not obtained in H.F. resistance-coupled amplifiers, partly because of the smaller capacity of the single-grid system.

RADIO FREQUENCY TRANSFORMERS AS APPLIED TO SCREEN-GRID VALVES.—S. Butterworth. (*E.W. & W.E.*, June, 1929, V. 6, pp. 293–299.)

When the screen-grid valve was introduced it was hoped that the inter-electrode capacity would be reduced to such a value that efficient recording circuits could be employed to give stable systems having high magnifications, without the need for the "somewhat delicate operation" of neutrodyning. By using screen-grid valves of a special construction, Hull and Williams reduced the capacity to 0.006 $\mu\mu$F. as compared with the 2 $\mu\mu$F. or more of the ordinary triode; but the commercial screen-grid valve usually has a value of 0.05 to 0.1 $\mu\mu$F. (*cf.* Bligh, these Abstracts, under "Valves"). The writer therefore sets out to find how to make the best use of R.F. transformers while accepting capacities of this order, and without the use of neutrodyning (see Sowerby, June Abstracts, p. 329).

His investigation leads to the conclusion that the best method is to use a transformer in which the primary turns are reduced until the requisite stability is attained. The transformer ratio required will vary inversely as the square root of the frequency of instability, while the expected magnification will vary in like manner. For multi-stage amplification, the procedure indicated can be applied; but in this case the writer is inclined to prefer the plan of interleaving transformer- with resistance-capacity-coupling, so as to reduce the possibility of instability owing to capacity coupling between the tuned circuits.

MORE AMPLIFICATION FROM SCREEN-GRID VALVES.—(*Wireless World*, 12th June, 1929, V. 24, p. 623.)

In a recent article under this heading (June Abstracts, p. 329) figures were given for the theoretical amplification attainable on the broadcast band using the Cosmos AC/S valve in conjunction with a special tuned circuit of high dynamic resistance. These figures were based on measurements made on an advance sample of the valve, which appears to have been by no means up to the standard of those now on the market; with these, an amplification of well over 500 times has been actually measured, with no assistance from reaction, at 300 m.

THE DESIGN OF H.F. TRANSFORMERS: PART I.—THE ESSENTIAL THEORY CONCERNING THE INTERDEPENDENCE OF VALVE AND TRANSFORMER. PART II.—SOME EXPERIMENTAL DATA.—A. L. M. Sowerby. (*Wireless World*, 29th May and 12th June, 1929, V. 24, pp. 548–552 and 617–621.)

"In conclusion, we may say that the simple theory of the high frequency transformer presented in the first of these articles is well borne out in practice at every point at which it has been tested by experiment, and that the inaccuracies imported into it by the simplifying assumption of infinitely close coupling are negligible, at least with the type of winding adopted. We may, therefore, use the equation $n = \sqrt{\frac{R}{R_0}}$ for determining the ratio for any transformer of which the secondary characteristics are known. Having found the ratio n, either by calculation or by the method of measurement described, we can take $A = \frac{1}{2}\mu n$ as a reliable estimate of the amplification to be expected from the stage when transformer-coupling is used in a high-frequency amplifier."

IMPROVING DETECTOR EFFICIENCY.—W. B. Medlam.—(*Wireless World*, 22nd May, 1929, V. 24, pp. 524–528.)

It is generally considered that an anode-bend detector has but a slight reaction on the R.F. input circuit to which it is coupled, assuming that the operating conditions are such that there is no grid current. Attention is here drawn, however, to the load due to R.F. feed-back through the anode-grid capacity of the valve, which may reduce the signal voltage, under certain working conditions, by more than fifty per cent. Suggested remedies are:—(1) the use of a centre-tapped input circuit and a neutralising condenser; (2) a series tuned circuit (tuned to the carrier frequency) connected across the external anode lead, serving to exclude H.F. potentials from the 1st L.F. amplifier grid; this means an additional tuning control but is very effective; and (3) the use of a pentode, with its excellent rectifying properties; no details are given as to this solution.

A SELECTIVE 8-VALVE RECEIVER FOR MEDIUM AND LONG-WAVE TELEGRAPHY.—F. M. Colebrook. (*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 177–183.)

Author's abstract:—"The receiver here described was designed for the Metrology Department of the National Physical Laboratory, for the reception and recording of time signals on wavelengths ranging from 1,500 to 20,000 metres. The principal requirements were: (a) comparative ease of manipulation; (b) sufficient sensitivity and selectivity for the signal operation of a relay for

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recording purposes. The latter requirement is a severe one as far as the long-wave range is concerned. The receiver consists of four separate parts: (*a*) aerial tuning and coupling unit; (*b*) 4-valve amplifier (2 radio-frequency amplifying stages, detector, and 1 audio-frequency amplifying stage); (*c*) local oscillator; (*d*) selective audio-frequency amplifier. A detailed description is given of each of these parts."

As set up at the National Physical Laboratory, with a single wire aerial some 50 ft. high and 130 ft. long, the receiver gives Annapolis (NSS) without difficulty, an anode-current change of about 1 to 1½ mA. being obtained.

DER SABA-KURZWELLEN-EMPFÄNGER (The "Saba" Short Wave Receiver).—H. Gunther. (*Rad., B., F., f. Alle*, June, 1929, pp. 280–288.)

A three-valve receiver with five interchangeable coils giving wave-ranges of 13–25, 25–45, 40–90, 200–440 and 440–950 metres.

BROADCAST RECEIVERS—PHILIPS TYPE 2802. A FOUR-VALVE SET FROM 10 TO 2,400 METRES. —(*Wireless World*, 22nd May, 1929, V. 24, pp. 542–543.)

THE MODERN PORTABLE, A REVIEW OF CURRENT COMMERCIAL PRACTICE. REPRESENTATIVE PORTABLES REVIEWED. BUYERS' GUIDE TO PORTABLE SETS.—(*Wireless World*, 5th June, 1929, V. 24.)

SUPER-REGENERATION WITH A PUSH-PULL OSCILLATOR.—L. D. Inskeep. (*QST*, May, 1929, V. 13, p. 45.)

The writer recommends the use of the push-pull oscillator described, as reducing the characteristic background roar.

MISE SOUS ÉCRAN DES BOBINES CYLINDRIQUES (Screening of Cylindrical Coils).—M. v. Ardenne. (Short summary in *L'Onde Élec.*, April, 1929, p. 31A, from *Funk.*, January, 1929.)

The construction of Faraday cages round the windings of a receiver is here considered. In practice, for broadcast wavelengths, a copper cage of diameter twice that of the coil might be used, a suitable thickness being 0.4—0.6 mm.

AERIALS AND AERIAL SYSTEMS.

ÜBER DIE RICHTCHARAKTERISTIK VON IN EINER EBENE ANGEORDNETEN STRAHLERN (On the Directional Characteristics of Radiators arranged in a Plane).—H. Stenzel. (*E.N.T.*, May, 1929, V. 6, pp. 165–181.)

Author's summary:—"The directional behaviour of periodically radiating systems is investigated. Such effects have long been known and investigated in optics under the title of diffraction. Recently they have played a rôle in acoustics (loud-speaker technique) and electricity (short waves). Special progress has also been made in submarine sound technique, for directive transmission (acoustic sounding) and reception (acoustic D.F.). Whereas in optics the chief considerations are the number and distance apart of principal maxima, here the chief rôle is played by the shape of the directional characteristic.

"It is shown in Section I that the directive sharpness, *i.e.*, the course of the main part of the characteristic, can be determined even for radiators distributed quite arbitrarily in the plane. For the determination of the complete characteristic, the arrangement of the radiators must be given in detail. Section II shows that for simple radiators of continuous form (straight line, circle, and circular plane) the characteristics can be determined very simply. Section III investigates the characteristics of individual radiators ('point-formed') distributed at regular intervals along a straight line or a circle, and optimum conditions for intervals and number of radiators are given. Finally, Section IV investigates the 'artificial' characteristic formed if the radiator system remains fixed but each radiator undergoes a corresponding varying phase-displacement. The optimum conditions, in this case, take another form. The important superiority of the circular-system over the straight-line system [in the matter of secondary maxima] is here brought out clearly."

The writer's investigation of the "artificial" characteristics of single circle-shaped systems shows that secondary maxima can only be kept small by arranging for a comparatively slight sharpness of directivity. For great sharpness, the secondary maximum will attain a value of 0.4. But he shows how this disadvantage can be removed by the use of two (or more) concentric circles, or (to a smaller extent) by a central radiator at the mid-point of the single circle. With inner and outer circles of diameter d_1 and d_2 given by $d_1/\lambda = 0.56$ and $d_2/\lambda = 1.28$, the space characteristic shows no sign of a secondary maximum, since this is less than one per cent. of the main maximum. The intensity of each concentric system is suitably proportioned; *e.g.*, for the single 8-radiator circle and extra mid-point radiator, the latter is given an amplitude eight times as great as that of each radiator in the circle.

NEUE RAHMENKONSTRUKTIONEN (New Designs of Frame Aerials).—M. v. Ardenne. (*Rad., B., F., f. Alle*, June, 1929, pp. 247–252.)

The sharpening of the directional properties of frame aerials, by a suppression of the open aerial effect, can be attained by the use of symmetrical arrangements, by compensation, or by screening. The present paper deals with the last method. The enclosing of the frame aerial by a metal tube (*e.g.*, as used by Telefunken—chiefly for protection against the weather) is impracticable for broadcasting purposes since for this wave-band the losses reduce the available voltage to a sixth of that given by an unscreened frame. The new construction gives large spacing between frame and screen, instead of the 0.5—1.0 cm. gap formerly used, and this gives excellent results, when combined with leads which are also screened, and with circuits which introduce no earth connection to the winding and also no connection to the screening. But even so, measurements showed that such screening by metal plate caused a considerable increase of damping, even when the plate was made of material of

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low conductivity. A marked improvement, however, was found when the screen was made of a number of separate wires (30 to 100 per cent. of the number of turns in the actual winding). Like the metal plate screening, this screen of wires was interrupted at one point (centre of bottom section), each separate turn being broken at this point by an insulator. At a point opposite to this break, the screen wires were connected together by a cross wire which led to earth or to the receiver-screening. The possible use of the recently-introduced insulated and screened types of wire, for the simple construction of screened frames, is discussed: certain types would introduce too much self-capacity to be applicable to the broadcast waveband, but others would appear very suitable.

The paper then deals with the degree of directivity attainable with such screened frames, and the causes limiting this. Among these are the fluctuations in the direction of the incoming waves. All things considered, it should be possible to cut down the voltage produced by a local station—say 8 km. away—to about 1.5 per cent. of its maximum value. If the local station is very close, a frame which not only rotates but also tilts is of advantage. Such a mounting is also useful even at greater distances if the receiving apparatus as a whole possesses an open aerial effect, as it enables phase conditions to be obtained which can compensate for the effect and increase the sharpness of directivity.

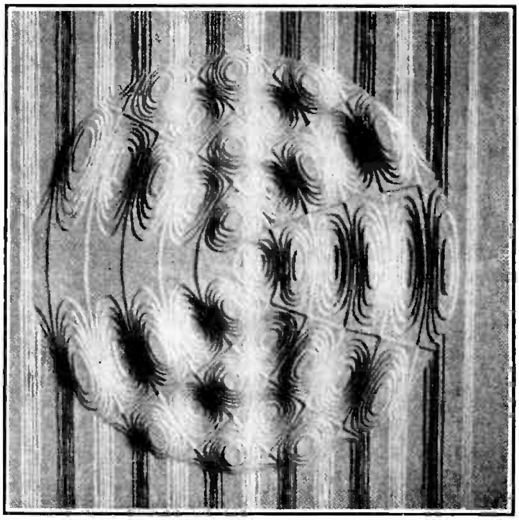
BEITRAG ZUR BESCHREIBUNG DES INTERFERENZGEBIETES IN DER NÄHE VON EMPFANGS-ANTENNEN (A Contribution to the Characterisation of the Interference Zone in the Neighbourhood of a Receiving Aerial).—M. Dieckmann. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, pp. 161–166.)

An investigation of the field round a receiving aerial due to the combined effects of an in-coming wave-train and of the re-radiated waves from the receiving aerial. Since the electric field-vector, the magnetic field-vector, and the direction of propagation form a system of directions beyond the scope of the ordinary methods of representation, the writer uses photographs of plastic modelling to illustrate the effects described; hillocks representing electric field-strengths directed from beneath to above the plane of the paper, and hollows representing those in the reverse direction. Each relief model of one group of four represents the instantaneous state at different moments separated by intervals of one eighth of a period. These models therefore do not represent what would be found by electrical measuring instruments, since these record not the instantaneous but the integral values. Moreover, in these models it is assumed that the re-radiated circles of waves do not decrease in amplitude as they get further from the aerial; and—on the assumption that the aerial is tuned and without resistance—this constant amplitude is taken as equal to that of the in-coming waves.

On these assumptions, the formation of maxima and minima (large hillocks and large hollows) and of null values where the two sets of waves neutralise each other (flat surface) is shown. These null points form two separate groups of parabolas with a common focus at the foot of the aerial. One of these groups lies open to the direction of the transmitter, and its parabolas are changing their position and form from moment to moment, moving—increasing always in parameter—in the direction of propagation of the in-coming train. Each time that the innermost one reaches a parameter length equal to λ, a new parabola is formed on the joining-line between the stations. At this moment, the field along this line is uniformly null, as is seen by the flat surface of the model here reproduced where the distant transmitter lies to the left, and the receiving aerial can be seen as a raised point at the centre of the model.

The second group of parabolas remains constant in position and shape; their parameters are $\lambda/4$, $5\lambda/4$, $9\lambda/4$ . . . up to λ, and their intersections with the joining-line between the stations mark the nodes of the standing waves.

The next model represents the integral, instead of the instantaneous, values—as would be given by a measuring instrument. The next shows an



Model for the instant t/8 before the passage of a wave-crest.

instantaneous record similar to the first four but with the assumptions that the secondary waves vary in amplitude as the reciprocal of their distance from the aerial, and that the aerial has a radiation- but no internal resistance. Lastly, the decrease of the field distortion by the secondary waves, when the aerial is given an internal resistance as well, is shown by diagram.

It is to be noted that in all the above models the pure radiation field only has been considered, to the exclusion of the induction field; and the fact has also been neglected that the energy of the secondary rays is derived from the primary field.

VALVES AND THERMIONICS.

MEASUREMENTS OF THE GRID-ANODE CAPACITY OF SCREEN-GRID VALVES.—N. R. Bligh. (*E.W. & W.E.*, June 1929, V. 6, pp. 299–300.)

The valves tested were of the types S 625 and S 215. Measurements were made with filaments

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cold. The average figure obtained for the first type was 0.022 and for the second type 0.014 $\mu\mu$F.

Determination of the Charge of Positive Thermions from Measurements of Shot Effect.—N. H. Williams and W. S. Huxford. (*Phys. Review*, May, 1929, V. 33, pp. 773–788.)

Authors' abstract :—Several new types of current fluctuations have been studied with special reference to the possible effects of both positive ions and electrons, and the influence of space charge. An emitter of positive potassium ions is described which has proved suitable for shot effect measurements. Results indicate that the discharge may be properly controlled and temperature limited currents obtained, giving a value for the $K+$ion equal in magnitude to the electron charge. Values resulting from an extensive series of electron charge determinations confirm the precision and expediency of several new methods which have been introduced into the experimental procedure. A detailed description is given of a simple and direct method of determining the shot circuit impedance.

Methoden zur Beseitigung des Mikrophoneffektes in Verstärkerröhren (Methods for the Elimination of the Microphone Effect in Amplifier Valves).—M. v. Ardenne. (*Zeitschr. f. tech. Phys.*, May, 1929, V. 10, pp. 185–187.)

"The avoidance of the disturbing noises which are caused by every external shock to modern amplifier valves with light, stretched filaments, has become a serious task" (reaction from the loudspeaker is here referred to, but work in the neighbourhood of motors—in aircraft—is mentioned later). The writer deals first with the damping of filament-vibration by mechanical design, or the arrangement—by the same means—that the natural period of vibration should be above or below the troublesome zone. Damping by electrical means is next treated ; unluckily the eddy-current effects produced by the current in the filament are too small. Reduction of the *effect* of filament-vibration, by increasing the distance between filament and the other electrodes, leads to a decrease of amplification ; such special valves should only be used in the first stage of a cascade. The rest of the paper deals not with the avoidance of vibration currents but with their neutralisation, according to the plans due to the writer and to Schlesinger. A constant magnetic field is produced either by a permanent magnet or by an electromagnet traversed by the filament current, and the vibrations of the filament produce in the latter L.F. induced currents which superpose themselves on the filament current, from which they can be separated by a small transformer. After one stage of amplification (if necessary) this L.F. is then adjusted in phase and used to oppose the direct disturbance due to the filament-vibration. One objection to this plan is the two-fold dependency of the neutralisation on the filament temperature, which changes (a) the filament period, thus upsetting the adjustment of the phase-regulating circuit, and (b) the amplification of the valves. This objection does not hold for those receivers which work under constant conditions of supply.

Recherches et Essais sur les Lampes de T.S.F. (Tests and Experiments on Wireless Valves). —A. Kiroloff. (*QST Franç.*, May and June, 1929, pp. 50–55 and 18–22.)

The May instalment of the series referred to in December, 1928 and July, 1929, Abstracts, deals with detector valves and various attempts to improve their working, such as the use of a "getter" (the question of the appearance of an "auto-current" is briefly discussed, together with Malarov's tests on the relation between the points at which this appears and the detector-action) and the use of special valves with multiple plates and grids to obtain double rectification, with increased efficiency. By a suitable modification of circuit, the ordinary two-grid valve can be used for this purpose ; the author's circuit for this is given, together with an apparently more satisfactory one using a pair of valves (but here the second valve appears to lack a filament). Improvement of detection by the aid of a heterodyne oscillator is illustrated by two circuits, and the special "organ of detection" due to Fromy is shown. The rest of the paper is devoted to various types of double-grid valve and their special circuits, including Blondel's design and the Frenotron where the inner grid is replaced by a small plate.

The June instalment deals with A.C.-heated valves (Bathenod's use of three-phase current is mentioned) and valves for short waves ; regarding the latter, the use of quartz for plate and grid supports is referred to, and also the advantage of symmetry and the need for a very good vacuum.

Dependence of Electron Emission from Metals upon Field Strengths and Temperatures.—R. A. Millikan and C. C. Lauritsen. (*Phys. Review*, April, 1929, V. 33, pp. 598–604.)

"This paper contains a full presentation of the reasons for believing, contrary to results recently obtained elsewhere (*cf.* de Bruyne, January Abstracts, p. 44) that field currents are only independent of temperature up to about 1100°K., and that at that temperature the energy of thermal agitation begins to assist the fields appreciably in causing the escape of electrons from metals. The precise form of function describing this dependence is not accurately determinable experimentally, but the form originally suggested by us fits the facts of observation thus far known satisfactorily ; not better, however, than does the theoretical form suggested by Houston."

Eine neue Lautsprecherröhre (A New Loud-Speaker Valve).—Telefunken Company. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, p. 183.)

Details and curve of the RE 114, with acid filament (3.8—4 v., 0.15 A.). Anode voltage 40–150 v. Slope 1.4 mA./v., $1/\mu$ = 20 per cent. ; internal resistance 3500 ohms, emission 40 mA. ; average anode current consumption 7 mA.

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THE DEVELOPMENT OF THE OXIDE-COATED FILAMENT.—B. Hodgson, L. S. Harley and O. S. Pratt. (*Journ. I.E.E.*, June, 1929, V. 67, pp. 762–771.)

The full paper (with discussion) extracts of which were dealt with in April Abstracts, p. 212.

DIRECTIONAL WIRELESS.

DIE UNMITTELBARE MESSUNG VON ENTFERNUNGEN DURCH ELEKTRISCHE WELLEN (Direct Measurement of Distances by Electric Waves).—W. Burstyn. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, pp. 181–183.)

The method described is accurate only for distances up to a few kilometres, but that is enough for the primary object—the avoidance of collision or stranding for ships in fog. It depends on the fact that at short distances (*e.g.*, distances less than $\lambda/5$) radiation departs from the linear law. The paper begins by deriving, from the Hertz dipole equations, formulæ for the peak values of the electric and magnetic field strengths in dependence on wavelength and distance. These formulæ are, respectively :—

$$E = \frac{4\pi^2 Is}{\lambda^2} \cdot \frac{\sqrt{1 - u^2 + u^4}}{u^3} \text{ and } H = \frac{4\pi^2 Is}{\lambda^2} \cdot \frac{\sqrt{1 + u^2}}{u^2},$$

where S is the length of the dipole and

$$u = \frac{2\pi}{\lambda} \times \text{distance}.$$

These formulæ can be applied unchanged to aerials with good earths, and their use (or the use of curves derived from them) enables the distance to be estimated or measured by the comparison of the strength of two waves of very different wavelength. One method of procedure is as follows :—The transmitter sends out, interlaced, the letter *a* on a 20 km. wave and the letter *n* on a 1 km. wave. To ensure that the two sets of signals should give the same heterodyne note, the short wave is controlled by the 20th harmonic of the long wave and "is modulated in time with this." The receiver, with a vertical aerial, is tuned to both waves : aural reception is by heterodyne, by a wave near 20 km., the long wave being heterodyned directly, the short wave after rectification ; the same valves are used for both, so that filament-fluctuations, etc., affect both waves equally.

The relations between transmitter and receiver are so chosen that at a distance of about 3 km. ($u = 1$ for the long wave) both waves are of equal strength. At greater distances the short wave signals are stronger, at smaller distances the long wave signals : the ratios being :—at 5 km., 0.8 ; at 3 km., 1.0 ; at 2.5 km., 1.25 ; at 2 km., 1.8 ; and at 1.5 km., 3.5. Thus as the distance decreases, the listener will hear first only the letter *n* ; then the gaps will be filled with a weaker note gradually strengthening, until at 3 km. an unbroken dash is heard ; after that, the warning signal *a* becomes more and more prominent. Estimates of the distance can be obtained by a calibrated shunt to weaken the long wave signals, adjusted so as to merge the two sets of signals into a long dash. These aural estimates are liable to an error, at 3 km., of 20% at most. A direct-reading method, independent of the ear, is also possible ; in this case long dashes or continuous transmission on both waves is employed, and a crossed-coil indicating instrument at the receiving end.

If the magnetic component is made use of instead of the electric, by the employment of a frame aerial, the increase of the *a* signal over the *n* signal takes place over a longer distance-change. Another method still is to compare the electric and magnetic components of a single (long-wave) transmission ; or to measure the phase-displacement of the two components $\left(\tan \phi = \frac{1}{u^3}\right)$, a frame and a vertical aerial being used in combination. But the first method is the simplest and most reliable, and any discrepancy due to the differing attenuation of the long and the short waves is negligible over the short distances in question, particularly over sea.

NOUVELLES CARTES AÉRIENNES POUR L'EMPLOI DE LA T.S.F. EN NAVIGATION (New Aerial Charts for the Use of Wireless in Navigation).—L. Kahn. (*L'Onde Élec.*, March, 1929, V. 8, pp. 87–102.)

The writer's new type of chart is particularly designed for use in aircraft, for quick and direct reading of the great circle course. Calculations by spherical geometry are entirely inadmissible, and the various attempts at simplification by gnomonic projection (Hilleret, Germain, and Gernez charts—*cf.* Abstracts, 1928, V. 5, p. 402) have certain defects. The Favé chart, in which the great circles are projected on to a Mercator planisphere, is probably better, but for use in the aeroplane itself even this is too cumbersome and complex. The new plan is to have separate charts for each route. Each chart is derived from a band of the earth's surface whose centre line is the great circle between the two places, the band being opened out flat and the chart deformed as is done in a planisphere map : thus the great circle itself is neither stretched nor twisted, and the angles are preserved. Each chart, in fact, resembles in its properties a band of a planisphere close to the equator. A section of the paper shows how the scheme can be utilised for astronomical bearings at sea.

ÉTUDES DES RADIOPHARES POUR AÉRONEFS PAR LE "BUREAU DES STANDARDS" (The Bureau of Standards Development of Radio Beacons for Aircraft). (*L'Onde Élec.*, April, 1929, V. 8, pp. 143–159.)

A survey, up to November, 1928, of the work on "equi-signal radio beacons" to which several references have been made in these Abstracts. The present paper includes diagrams of connection of the transmitting and receiving systems.

FIELD INTENSITY CHARACTERISTICS OF DOUBLE MODULATION TYPE OF DIRECTIVE RADIO BEACON.—H. Pratt. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 873–878.)

An investigation of the field intensity characteristic patterns under varying conditions, when both carrier waves are modulated (for the visual

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2-reed indicator—Abstracts, 1928, V. 5, p. 582). The condition where the two carrier voltages supplied to the aerial system have the same amplitude and are in phase is found to be the most favourable, leading to two courses only.

DIRECT-READING DIRECTION FINDER. (German Patent 471633, Rempe, pub. 14th February, 1929.)

Waves received on a directional aerial are rectified and used as the exciting current of a small dynamo, whose output voltage is indicated by a suitable instrument and serves as a measure of the direction of the in-coming waves.

PORTABLE DIRECTION FINDER: WIDE RANGE COMBINED WITH SENSITIVITY AND ACCURACY.—R. L. Smith-Rose and E. L. Hatcher. (*Wireless World*, 12th June, 1929, V. 24, pp. 614–616.)

A seven-valve supersonic heterodyne receiver is employed, and the working wavelength range extends from 40 to 3,000 metres. Transportability is improved compared with earlier models.

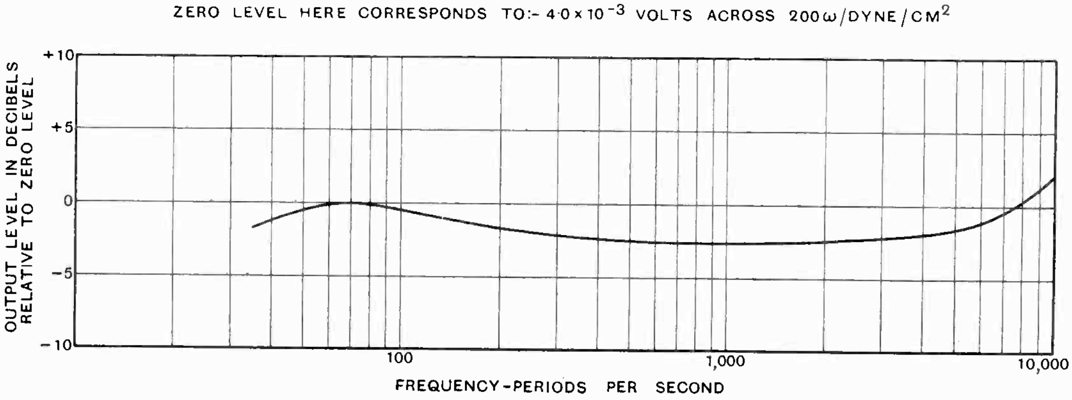
COMPULSORY D.F. ON SHIPS. (*Wireless World*, 12th June, 1929, V. 24, p. 623.)

Eighteen nations have signed the new convention for the safety of life at sea, among the provisions of which is a clause making compulsory the fitting of D.F. apparatus on all passenger ships of 5,000 tons gross and upwards.

ACOUSTICS AND AUDIO-FREQUENCIES.

A SOLUTION OF THE PROBLEM OF THE BROADCASTING MICROPHONE.—A. H. Reeves. (*Elec. Communication*, April, 1929, V. 7, pp. 258–265.)

In their search for the perfect microphone the International Standard Electrical Corporation has reverted to the "MS.1670" condenser-microphone (Wente) but with a new circuit which greatly reduces background noise (an improvement of 14–24 decibels in speech/noise ratio); the essential principle being the utilisation of the capacity changes to alter the tuning of an inductance-capacity circuit coupled weakly to a R.F. oscillator circuit just out of tune with it. The resulting modulated carrier wave is then rectified. Among the several advantages of this method, over the earlier plan of direct amplification of the L.F. fluctuations due to the microphone, perhaps one of the greatest is the elimination of high (15 megohms) resistances with their resulting "thermal agitation" noises (Abstracts, 1928, V. 5, p. 581) and noises due to irregular leakage. As regards output volume, the new combination, with an average speaker 5 feet from the microphone, gives an output level of minus 20 decibels. (As zero level corresponds to 5.9 mw., this corresponds to a maximum instantaneous peak power of 0.059 mw.). The frequency characteristic reproduced below shows that up to 8,000 cycles the characteristic lies within $\pm 1\frac{1}{2}$ decibels, and above that there is a small rise "which is an asset rather than otherwise, owing to the deficiencies of receiving apparatus." No background noise can be detected under conditions of normal operation in the studio, and no overloading could be detected under conditions which caused blasting with a high quality diaphragmless carbon microphone.



Overall characteristic of equipment.

VOLTAGE SURGES IN AUDIO-FREQUENCY APPARATUS.—E. M. Fisher. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 841–848.)

Transient voltages of over 2,000 are shown to occur across the secondary when the normal plate current of a high inductance audio-frequency transformer is opened. A type 201 A valve, without departing from recommended values of grid and plate voltages, gave secondary surges approaching 2,500 v.—which would jump a gap of 3/16 inch. The use of the larger valves now quite common makes possible even higher transients in coupling and output transformers (*cf.* Sims on the Pentode, March Abstracts, p. 152). Except perhaps in testing, the ordinary radio set does not as a rule have the plate circuit opened: but pulling a valve out of its socket with the filament "on," or plugging loud-speakers in, might easily cause transients of the magnitudes observed—as might

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also a small surge as the "B" eliminator voltage builds up. Under such a stress, some transformers flash across internally—thus giving an indication of why transformers sometimes "go noisy." A small safety-gap is suggested as a protection. The paper is illustrated by a number of oscillograms showing that these transients are oscillations of definite frequency and magnitude, depending on the primary current, inductance, and secondary distributed capacity. The manner of breaking the circuit has a minor influence.

The oscillograms were taken by an "inverted valve" arrangement, which forms with an oscillograph a means of recording which is rapid and at the same time uses practically no energy. The functions of grid and plate are reversed, the grid being made positive so that it draws a current large enough to work an oscillograph. Any negative voltage applied to the plate then has an effect on the grid current equivalent to reducing the grid voltage by $1/\mu$ times as much as that of the plate. As the transients are oscillatory, a negative plate bias is applied to keep the plate from going positive when the oscillation is reversed.

A NEW MOVING COIL LOUD SPEAKER.—(*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 197–198.)

In the conventional m.c. loud-speaker "the cone itself is suspended by means of a small flexible paper web at the apex and an annular strip of material at the edge. It is in the latter that the chief defect . . . originates . . . If the material of the ring is loose, the cone movement will not be axial. It is well known that the currents in the coil cause forces which tend to tilt the coil as well as propelling it axially, and if this can occur the coil will touch the faces of the magnet poles. Hence arises a necessity for a wider air-gap in the magnetic system, which in turn means a heavier magnet and field winding, with increased energy consumption. If, on the other hand, the supporting material is stretched to avoid sagging, the natural period of vibration of the cone as a whole is raised into the range of audible frequencies, and the result is generally a marked resonance at some point between 40 and 80 cycles with a sharp cut-off below. . . ."

The article then describes and illustrates the Marconiphone m.c. loud-speaker, due to Round, in which the cone is supported by two paper webs on a stout brass spindle which screws into the centre pole of the magnet. "At the edge there is merely a thin strip of soft felt, which does not support or restrain the cone in any manner. The weight is taken by the larger paper spider, which cannot sag, yet permits of absolutely free axial motion."

THE VOGT ELECTROSTATIC LOUD SPEAKER.—(*Wireless World*, 29th May, 1929, V. 24, pp. 553–556.)

An illustrated article from a Berlin correspondent giving technical details of a new and improved type with differential movement. Polarising voltage is from 500–700 v. To avoid danger, the loud-speaker, receiver, amplifier and battery eliminator are all built into one case. The writer suggests a method of connection (in which the polarising voltage is applied to the central membrane, the front plate being at earth potential and the back plate carrying the signal voltage) which he says would decrease very considerably the danger of receiving serious shocks from the plates of the loud-speaker.

DESIGN DATA FOR THE MOVING COIL: SOME NOTES ON THE MOST EFFICIENT COIL AND ITS CORRECT DESIGN.—L. E. T. Branch. (*Wireless World*, 29th May, 1929, V. 24, pp. 561–564.)

AN ALL-ELECTRIC AMPLIFIER: HIGH QUALITY REPRODUCTION OF GRAMOPHONE RECORDS. PART I.—A. P. Castellain. (*Wireless World*, 19th June, 1929, V. 24, pp. 634–637.)

THE TRANSMISSION OF SOUND THROUGH PARTITIONS. II.—VIBRATING PARTITIONS.—A. H. Davis and T. S. Littler. (*Phil. Mag.*, June, 1929, V. 7, No. 46, pp. 1050–1062.)

GESCHWINDIGKEITSMESSUNGEN MIT ERHITZTEN DRÄHTEN IN STEHENDEN LUFTWELLEN (Velocity Measurements with Heated Wires in Stationary Air Waves).—G. Goldbaum and E. Waetzmann. (*Zeitschr. f. Phys.*, 4th April, 1929, V. 54, No. 3/4, pp. 179–189.)

The periodic and the constant cooling effects produced on heated wires by the velocity-amplitudes in a sound field were measured relatively along stationary air-waves of various periods. Tests between 100 and 1000 cycles per sec. lead the authors to doubt whether the constant cooling effect can give absolute measurements of sound intensity, the curves showing (for constant velocity-amplitudes) a decrease of (constant) cooling-effect which *increases* with increasing frequency.

PHOTOTELEGRAPHY AND TELEVISION.

DER FERNSEHER TELEFUNKEN-KAROLUS (The Telefunken-Karolus Television Apparatus).—(*E.T.Z.*, 23rd May, 1929, V. 50, p. 761.)

Report of a recent demonstration, with photographs of the transmitting and receiving cabinets. The reproduction is on a screen 30 × 30 cm., but for smaller types of receiver this would be reduced to 10 or 15 cm. length of sides. The number of elements is 2,500, but "this could easily be increased." The report speaks of the results as comparable in quality with the early cinematograph pictures. It is not definitely stated whether transmission was by wireless. Karolus said that difficulties in transmission could be overcome by the use of a 50 m. wave, though at first only for a broadcast range of at most 50 km.

LA TÉLÉVISION OU TRANSMISSION À DISTANCE DES IMAGES ANIMÉES (Television, or Transmission to a Distance of Animated Pictures).——Belus. (*La Tech. Moderne*, 1st March, 1929, V. 21, pp. 129–133.)

FACSIMILE PICTURE TRANSMISSION: DISCUSSION.—V. Zworykin and others. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 895–898.)

Discussion on the paper referred to in June Abstracts, p. 334. Among the various points arising

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are the following :—the author says that he has thoroughly tried introducing the A.C. component by supplying A.C. to the photoelectric cell, instead of by the present method of interrupting the light : the trouble is that with the high frequency necessary (at least 3000 cycles) the capacity leakage of the cell is relatively large. Ballentine says that the G.E.C. finds the major problem to be the "getting across and through the ether" of short-wave high-speed signals. The author describes his synchronising arrangement ; the tuning fork is driven by a valve and a resistance is included in the grid circuit of this. Every time the correcting impulse comes to the terminals of the resistance it changes slightly the oscillation of the valve, and this corrects the fork. This is sufficient to correct the fork if the frequency difference between the two forks does not exceed about 1 beat in 20 seconds. One lumen gives about 20 micro-amperes through 0.5 megohm, with a cæsium cell ; the latter was found to be about 100 times as sensitive as a potassium cell. 64 lines per inch are used ; the author agrees that for fine detail the G.E.C. practice of 100 is better ; he has seen systems in Europe using 130, but considers that anything above 100 is waste of time and of band-width. Ranger however points out that with 120 lines to the inch a whole line can be missed through fading, etc., without preventing the reception of a perfectly legible type-written copy. He has certain criticisms to make of the author's pick-up system, and then advocates relieving the "poor link through space" of the extra duty of synchronisation ; pointing out that the Radio Corporation maintains separate tuning forks on opposite sides of the Continent, within 2 parts in a million, and the drift in the picture is not noticeable.

Der Bildtelegraph System Siemens-Karolus-Telefunken (The S.K.T. Picture Telegraphy System).—P. Arendt. (*E.T.Z.*, 23rd May, 1929, V. 50, pp. 744–748.)

A description illustrated by photographs of the latest results, of the components used in the apparatus, and of the complete apparatus.

A New Sférograph Transmitter.—L. Chauveau. (*Rev. Gén. de l'Élec.*, 4th May, 1929, V. 25, pp. 674–675.)

This differs from the transmitter previously described (Abstracts, 1928, V. 5, p. 649) : a photoelectric cell is inside the drum, and is illuminated by a small source of light, outside the drum, travelling parallel to the axis of the latter.

Der gegenwärtige Stand der Bildtelegraphie. V.—Das hochwertige Bélin-Verfahren (The Present State of Picture Telegraphy. V.—The Improved Bélin System).—F. Noack (*Rad., B., F., f. Alle*, June, 1929, pp. 261–264.)

Continuation of the series dealt with in May and June Abstracts.

Where it is necessary to compete in speed with other systems, the new Bélin apparatus has abandoned the potassium bichromate relief method of transmission and uses—like the Lorenz-Korn system—an optical method which is here described and illustrated, together with the receiving apparatus. The most interesting point about the latter is perhaps the use of an "absorption prism" which, working in conjunction with a mirror-galvanometer, controls the light reaching the photographic paper.

La Phototélégraphie d'Amateur (Amateur Phototelegraphy).—R. Mesny. (*Bull. d. l. Soc. franç. d. Élec.*, May, 1929, V. 9, pp. 511–524.)

Photoelectric Cells.—(German Patent 472485, Siemens-Shuckert, published 28th February, 1929.)

Cells independent of temperature are made by mixing the photoelectrically active material with material of higher melting point such as barium.

Photoelectric Cells and Methods of Coupling to Vacuum Tubes.—T. P. Dewhirst. (*QST*, June, 1929, V. 13, pp. 17–20.)

Among the circuits given are :—a good circuit for general television work ; circuits (which can be used for working relays) enabling the same battery to be used to supply voltage to the triode anode and to the photoelectric cell ; a circuit (where a linear frequency response is not essential) giving an enormous gain by the use of a screen-grid valve.

Light Control for Picture Telegraphy, etc.—(German Patents 471160, Telefunken, published 8th February, 1929 ; 471720, Karolus, published 18th February, 1929.)

(1) In the control of polarised light by an anisotropic substance, the resultant effect depends not only on double refraction but also on rotation of polarisation : the latter prevents the obtaining of complete darkness by the use of crossed Nichols. This difficulty is overcome by the use of a second anisotropic substance ; *e.g.*, a right-handed quartz succeeding a left-handed quartz ; only the latter being excited electrically. (2) This is the Karolus 1924 patent on the use of the Kerr cell.

Kniffe beim Bildfunkempfang ("Tips" for Wireless Picture Reception).—*Rad., B., F., f. Alle*, June, 1929, pp. 252–254.)

A table is given showing 15 common symptoms of trouble, their causes and their remedies.

MEASUREMENTS AND STANDARDS.

Sur un nouvel Emploi des Quartz piézo-électriques (A New Use for Piezoelectric Quartz).—G. Siadbei. (*Comptes Rendus*, 27th May, 1929, V. 188, pp. 1390–1391.)

A method of using piezoelectric control for chronometry is suggested which should lead to an accuracy of time-keeping "unknown by any other method." Two pieces of quartz cut from the same plate are stuck together and trimmed in one piece so that their dimensions are exactly the same : on separation, one piece is lightly polished so that its thickness is diminished to such an extent that the difference in frequency of the two pieces produces

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a beat with a period about 1 second. Plates about 1 mm. thick, with a frequency round 3 million, have the advantage of using very small amounts of electrical energy with a correspondingly smaller tendency to heating up. The two oscillators formed from these plates are kept at a suitable distance, and by means of coupling coils apply their variations of potential to the two grids of a tetrode: the plate current of this is therefore modulated by the beat frequency, and can be used in various ways to control a chronometer or—for phototelegraphy, etc.—a phonic motor (in the latter case a more suitable beat frequency would be chosen).

The only disturbing factor is the effect of temperature-change. A change of 1 degree causes, according to Meissner, a change of 0.6 in a million; to Powers, 5; and to Cady, about 20. Such changes would produce a 24 hour error of 0.0516, 0.432 and 1.728 second respectively. A thermostat control which would keep the temperature constant within 1/100 or even 1/1000 of a degree, and a rigorous selection of quartz with small temperature coefficient, would enable a remarkable constancy of time-keeping to be obtained. Without the complication of thermostatic control, merely by the fairly rough registration of the temperature changes, corrections can easily be made since the frequency variation is strictly a linear function of the temperature.

Étude Préliminaire d'un Diapason de Quartz dans un Vide Élevé (Preliminary Study of a Quartz Tuning-Fork in a High Vacuum).—Holweck and Lejay. (*Comptes Rendus*, 10th June, 1929, V. 188, pp. 1541–1543.)

This apparatus is similar in principle to that used by Wertenstein (*Phil. Mag.*, July, 1928) in his viscosity manometer. An elastic system, oscillating at right angles to its own plane, is formed by a sharp *V* of two quartz threads, 0.2 mm. in diameter and 15 cms. long. The two extremities of the *V* are fused to a solid quartz fork with a thick stem which supports the whole system. The angle of the *V* carried a small quartz ball, and the whole "may be prolonged by a thread, providing easy observation and an adjustment of period by gradual shortening." The whole, which behaves like a flexible blade fixed at one extremity, is enclosed in an air-tight container of glass or quartz, the thick stem of the quartz fork being pinched or fused to the interior of the envelope. With this envelope highly exhausted, if a shock is given to the whole system the time taken for the amplitude of the vibrations to die down to one half is several hours (provided that the whole apparatus is fixed very rigidly to a very solid mount, so that the losses in the support are reduced as much as possible. These are the only losses to be considered, those due to the elastic viscosity of the quartz and to friction with the gas being negligible).

The frequency is considered likely to be remarkably constant, reasons for this being given and preliminary experimental verification quoted. More accurate measurements than those given (which showed an accuracy of about 1 ten-thousandth of a second in two seconds) must await the making of a second similar apparatus. Various applications are outlined. It is suggested that the vibrations could be maintained by an arrangement using the pressure of light.

Measurement of the Frequencies of Distant Radio Transmitting Stations.—G. Pession and T. Gorio. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 734–744.)

English version of the Italian paper referred to in Abstracts, 1928, V. 5, p. 643. Regarding the tuning fork controlling the multivibrator, the writers say: ". . . we reached the conclusion that in measurements requiring a high degree of precision (1 to 5 parts in 100,000) it is necessary to calibrate the tuning fork each time before the measurement and to maintain an absolute constancy of temperature." The method adopted is to combine the fork current with that of a small Siemens 100-toothed induction alternator and to record, through a chronograph, the beats thus formed, the number of revolutions, and the frequency of the alternator together with the time furnished by a pendulum of the Astronomical Observatory. A stroboscopic arrangement is used for the rough adjustment of alternator speed, which need not be kept absolutely constant.

A Direct Reading Frequency Bridge for the Audio Range, based on Hay's Bridge Circuit.—C. I. Soucy and B. de F. Bayly. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 834–840.)

"The bridge is portable, simple to construct, and makes use of external connection—for the variable resistances—to two standard decade non-inductive resistance boxes. Its operation is convenient and permits of a precision of balance of 0.1% with a probable error of less than about 0.25%."

The range is about 50–5,000 cycles. The method depends on the fact that in the Hay bridge for inductance measurement, the equation for the inductance is nearly independent of frequency, but the equation for the resistance of the inductive coil is dependent on frequency and a variable resistance; therefore by introducing a variable resistance in series with the inductance, an arrangement is obtained in which the frequency is determined directly in terms of this variable resistance. A very similar bridge was described by Kurokawa and Hoashi in *J.I.E.E., Japan*, No. 437, pp. 1132–1138.

Constancy of Oscillator Frequency. (*Elec. Times*, 6th June, 1929, pp. 921–922.)

After a short description of various valve generator circuits, including the Hartley and Colpitt's circuits, and a reference to electro-mechanical methods of keeping the frequency constant, the paper devotes itself to purely electrical methods of frequency stabilisation, dealing first with Horton's arrangement used on the Trans-atlantic telephone service (*Bell Tech. Journ.*, July, 1924); then with the B.B.C. "Master Oscillator" (Eckersley, *Journ. I.E.E.*, May, 1928) as used at 5GB; Fromy's oscillator (*L'Onde Élec.*, Sept., 1925) based on the idea of avoiding phase differences by segregating the tuned circuit from both grid and anode; and lastly Colebrook's Modulating Wavemeter circuit (*E.W. & W.E.*,

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Dec., 1927). The following claims for the various methods are quoted:—Horton: H.T. Voltage change from 100 to 150 V. causes 0.04% frequency change; filament current change from 1.1 to 1.4 A. causes 0.03% frequency change; changes in frequency from changes of load impedance are negligible. B.B.C. "Master Oscillator," no results given. Fromy: on 300 kc., a variation of 1 in 100,000 as filament voltage is varied between 4.75 and 6 v., while the variation is much less than this over a region 5 to 5.5 V. Changes of anode voltage give rise to frequency variations of the same order of magnitude. "Without any very special care the attainment of at least 1 in 50,000 is very easy, but the disadvantage of four coils and three condensers" (which may be "ganged" if they and the coils are suitably chosen) "is considerable both from the obvious point of view of economy and also from the difficulty of obtaining well-matched components to ensure the maximum frequency stability." Colebrook: a frequency stability of better than 1 in 1,000 is claimed for filament variations of 1.5 to 2 V. and H.T. variations of 30–70 V. The modulating property is of great advantage in working with a non-oscillating receiver, and in helping to "grope" for tune even if it is cut off later to permit the final working to be done with heterodyne. The four circuits are shown in the diagrams given below.

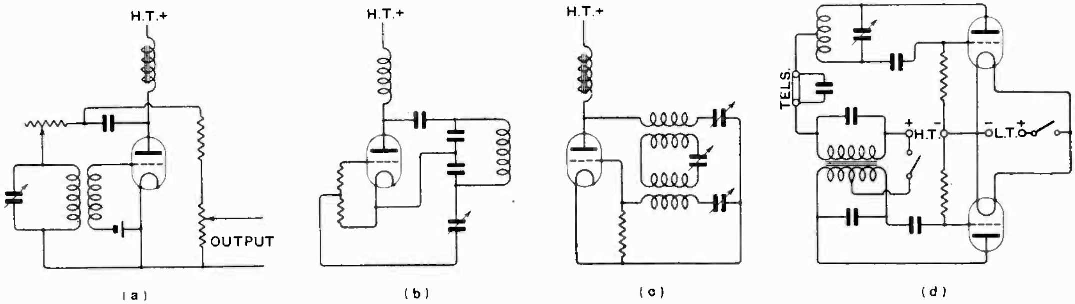
(which may contain helium) connected in series with the crystal. Sensitivity can be increased by an auxiliary voltage permanently across the electrodes of the glow-tube.

Piezoelectric Control of Low Frequency Oscillations. (German Patent 471630, Radio Corp. New York, pub. 15th February, 1929.)

For slow oscillations the crystal is allowed to vibrate like a prong of a tuning fork: three electrodes are used, a pair (of the same polarity) one on each side of the fixed end, and the third (of opposite polarity) opposite this fixed end, so that the lines of force run from the sides to the end.

Piezoelectric Patents.—(American, 1696626, Crossly; 1692074, Burtes; 1688713, Hund. German, 469208, Radiofrequenz.)

(1) For the prevention of frequency variation and of too much load on the crystal, a grid bias is provided; two ways of doing this are shown. (2) Damaging sparking between crystal and electrodes is prevented by interposing a separating layer, non-hygroscopic, free from organic particles and highly insulating, such as water-glass. (3) A coupling is formed through the crystal between grid and anode circuits, one crystal electrode going to the grid and the other to a metal ring which



(a) *Horton's Oscillator*; (b) *B.B.C. Master Oscillator*; (c) *Fromy's Oscillator*; (d) *Colebrook's Modulating Wavemeter.*

encircles, without touching, part of a helix in the anode circuit. (4) The audio-frequency currents which accompany the luminous charges on a piezoelectric crystal in a more or less evacuated container, when the crystal is excited by a H.F. alternating field, are used as an indication of resonance between the field and the natural frequency of the crystal.

Multivibrator Circuit using Four-electrode Valve. (German Patent 472128, Philips' Co., published 23rd February, 1929.)

The number of valves used in a multivibrator circuit can be halved by using two-grid valves instead of triodes. A periodically discharging condenser (2,000 cm. to 1 microfarad) is connected across the two grids, one of which goes—through a resistance of about one megohm—to the cathode, the other—through a resistance of a few thousand ohms—to a point in the anode circuit.

Piezoelectric Glow Resonance Indicator. (German Patent 471631, Telefunken, pub. 18th February, 1929.)

The ordinary piezoelectric glow resonators give very faint glow and moreover their wavelength can only be changed after removing the crystal from its exhausted container. According to this invention, the glow is provided by a special glow-tube

Internationale Vergleichungen von Frequenznormalen für elektrische Schwingungen (International Comparisons of Frequency Standards for Electrical Oscillations). —E. Giebe and A. Scheibe. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, pp. 176–180.)

An analysis of the 1926–27 international comparison of frequencies, together with some later results (1927–28) with some Bureau of Standards quartz resonators with thermostatic control and with some German piezoelectric "glow" resonators

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(in a mixture of neon and helium at a few mm. pressure). These latter have a much smaller temperature coefficient than the quartz oscillators and can therefore be used without thermostatic control. They seem to give about as good a constancy as the temperature-controlled oscillators, their average deviation being of the order of $\pm 0.4 \times 10^{-4}$ cycles per sec.

PIEZOELECTRIC WAVE CONTROL. (French Patent 648687, Soc. le Matr. Anon., pub. 12th December, 1928.)

Instead of using several crystals in series (to avoid overloading), several pairs of electrodes are used at different points of the same crystal: these pairs are connected in series, alternating from one side of the crystal to the other.

DIE ABHÄNGIGKEIT DER PIEZOELEKTRISCHEN KONSTANTE BEI QUARTZ VON DER TEMPERATUR (The Temperature-variation of the Piezoelectric Constant of Quartz).—A. Andreeff, V. Fréederiksz and I. Kazarnowsky. (*Zeitschr. f. Phys.*, 27th April, 1929, V. 54, No. 7/8, pp. 477–483.)

The investigation was by the method of electrical oscillations and extended to the range 15 to 500° C. It was found that the piezoelectric modulus decreased very little with rising temperature (a maximum of 12% in the whole range named). The authors are not yet convinced that even this change is a true temperature variation of the modulus. The results contradict those of other workers who employed only electrostatic methods. It is mentioned that above 500° C. no resonance curve could be plotted, but oscillations could be detected up to 575°. Above this point all attempts to set the quartz in oscillation failed.

A PORTABLE RADIO INTENSITY-MEASURING APPARATUS FOR HIGH FREQUENCIES.—J. Hollingworth and R. Naismith. (*E.W. & W.E.*, June, 1929, V. 6, pp. 316–318.)

Abstract of the I.E.E. paper. The instrument described is capable of measuring field intensities of 10 to 10,000 microvolts/metre in a waverange 25–66 metres. It can be carried in a light car, its weight (without batteries) being about 60 lbs. The receiver includes a detector valve and a retroactive tuning control valve, with one stage of L.F. amplification and an extra stage (L.F. rectifier) for galvanometer working. A separate heterodyne is used to obtain the audio-frequency. An open aerial is used, connected to earth through a high resistance; its height is kept well below a quarter wavelength. Local injection of signals is obtained by an attenuator, a resistance potential divider being adopted after a condenser potential divider had proved unsatisfactory.

RADIO RECEIVER TESTING EQUIPMENT.—K. W. Jarvis. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 664–710.)

A long article on methods and apparatus of the Crosley Radio Corporation. Among the apparatus may be mentioned a "distortometer" enabling the distortion and overload of the output to be directly measured.

THE PROBLEM OF "TURN-OVER" AS APPLIED TO VALVE-VOLTMETERS.—M. Reed. (*See under* "Properties of Circuits.")

VACUUM-TUBE VOLTMETER DESIGN.—H. R. Lubcke. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 864–872.)

Author's summary :—It is shown that for every input range and meter a set of optimum conditions exist, which insure maximum readability, economy, and minimum operating current. Equations are developed (and illustrated with several examples) for the rapid design of a meter for a predetermined range. Optimum conditions are imposed. The dependence of the range secured upon plate circuit impedance is shown and its variation with frequency explained. The procedure for eliminating frequency error up to and including radio frequencies is illustrated.

THE USE OF THE ELECTRON TUBE PEAK VOLTMETER FOR THE MEASUREMENT OF MODULATION.—C. B. Jolliffe. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 660–663.)

Nelson and Conrad have each patented methods of measuring the degree of modulation, but both systems have the disadvantage of measuring the amplitude of the audio-frequency current before it is impressed on the R.F. current. An oscillograph is the ideal means but is expensive and not readily portable. The thermionic peak voltmeter described by van der Bijl may conveniently be used to measure the modulation of a R.F. current whose maximum value for complete modulation varies between the limits zero and twice the maximum unmodulated R.F. current. If the peak value of the R.F. current is measured without modulation, and then the modulation is applied and the peak value again measured, then the percentage modulation $= \frac{(I_{\text{mod.}} - I_r) \times 100}{I_r}$. Accuracy by this method appears to be to within about 4%.

DIE BESTIMMUNG DER BRAUCHBARKEIT VON SPULEN (The Determination of the Serviceability of Coils).—H. Kottas. (*Rad. f. Alle*, May, 1929, pp. 201–208.)

A method is described of comparing the merits of different coils, for various wavelengths. The coil is connected between grid and anode of a Hartley circuit, and a tapping lead from the earthed end of the filament is connected to each turn, one after the other: for each position, the circuit condenser is adjusted to the point where oscillations just break off. A curve is thus plotted, and from the area of this curve the "serviceability" of the coil for that particular wavelength is deduced.

SUBSIDIARY APPARATUS AND MATERIALS.

AUTOMATIC BATTERY CHARGING.—O. Gramisch. (*Elektrot. u. Masch:bau*, 10th March, 1929, V. 47, pp. 201–202.)

An automatic make-and-break depending on voltage is unsatisfactory for the purpose, since the voltage curve towards the end of the charge is practically horizontal. In the course of the article

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the writer recommends the "Pöhler interrupter," a combination of a relay dependent on voltage and a timing-mechanism; the relay comes into action at the voltage where intense formation of gas takes place—a point where the voltage rises very rapidly.

A Barretter with Long Life.—(French Patent 653087, Thomson-Houston Co., published 16th March, 1929.)

Iron wire ballast resistances, even when enclosed in hydrogen at low pressure, have lives of only about 1000 hours owing to evaporation of the iron. The present invention uses a nickel wire in series with an iron wire, in an atmosphere of hydrogen or helium at from 1–10 mm. pressure. The ballast-action of the nickel wire begins at a temperature 100° C. lower than that at which the iron wire ballast-action begins, and ends just where this begins. The life is said to be 40–50 times as great as that of an iron resistance in hydrogen.

Zernike Thermopile.—(*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 202–203.)

A new thermopile of 8 elements of improved Bismuth alloys giving an E.M.F. of 120 microvolts per degree Celsius. The usual disadvantages of such elements, high resistance and slow response, are compensated here by making the wires extremely short. The instrument is so shielded that it possesses great insensitivity to outside disturbances. Resistance is 20 ohms, and the position of equilibrium is attained within 3 seconds after radiation falls on the pile.

The Use of Wollaston Strip for Suspensions.—D. W. Dye. (*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 203–204.)

Cathode-ray Oscillograph with Rapid Automatic Starter.—W. Krug. (*E.T.Z.*, 9th May, 1929, V. 50, pp. 681–685.)

In an article on the recording of surges, the writer mentions the successful development of a pre-deflecting arrangement (*cf.* Berger, Abstracts, 1928, V. 5, p. 525) which allows the oscillograph to be set working automatically with a lag of only 10^{-9} to 10^{-8} sec. The method allows the ray pre-deflection and the time-axis pre-deflection to be accomplished with one pair only of time-axis plates. Details are promised in a later paper.

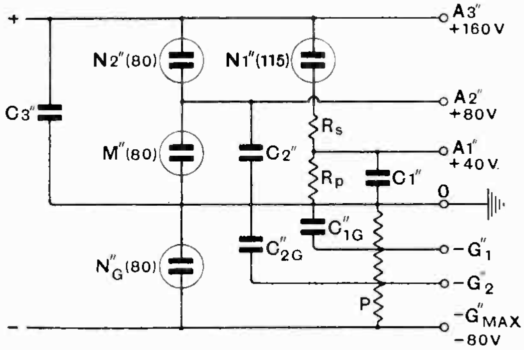
Lightning Surges on Medium Voltage Power Networks, recorded by Cathode-ray Oscillograph.—K. Berger. (*Bull. de l'Assoc. Suisse des Élec.*, 7th June, 1929, V. 20, pp. 321–338.)

Logarithmic Scale for Beat-Frequency Oscillator.—E. R. Meissner. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 879–881.)

The equation is developed governing the shape of plates for a condenser which, when used in a beat-frequency oscillator, would give a logarithmic frequency scale—so that it would be possible to set (say) a 90 cycle frequency to the same number of significant figures as 900 or 9000.

Glimmstrecken-Spannungsteiler für Netzanschluss der Anoden- und Gitterspannungen (Glow-discharge-gap Voltage-dividers for Mains Supply of Anode and Grid Voltages).—L. Körös. (*E.T.Z.*, 30th May, 1929, V. 50, pp. 786–788.)

The employment of ohmic resistances, as voltage-dividers and series resistances in mains eliminators for anode and grid supply, leads to voltage fluctua-



tions, oscillation and distortion, owing to the effect of change of load. Schröter has patented a method of avoiding such voltage fluctuations by the use of a glow-discharge tube in a parallel connection, but the writer points out objections to this plan (*e.g.*, the impossibility of making the grid voltages independent of the fluctuations) and advocates instead the substitution of similar tubes for the usual ohmic resistances.

The diagram reproduced above shows such an arrangement to provide three constant anode voltages and tappings for constant grid biases. The figures in brackets against the glow-discharge tubes represent their working voltages. The tubes N_2'', M'' and N_G'' are always sufficiently loaded to prevent oscillation through the condensers. To prevent oscillations from the tube N_1'', which has to supply the anode circuit of the audion valve taking a comparatively small current, the resistance R_s is introduced, of value 2500–3000 ohms. The tubes incidentally act as indicators, taking the place of milliammeters, since any fluctuations of brightness can be observed.

Cold Cathode Rectification.—A. E. Shaw. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 849–863.)

Author's summary:—Asymmetric conductivity in a gas between two electrodes can be accomplished without the use of a hot cathode, if the relative areas of the electrodes are widely different. This paper presents the results of an investigation of the discharge phenomena and asymmetric conductivity in a cold cathode rectifier tube containing two anodes and one cathode, when utilising: (1) one anode and one cathode; (2) two anodes and one cathode; and (3) two anodes and one cathode and a low-pass filter circuit. The electrodes are situated in a gaseous atmosphere of helium and neon at 20 mm. Hg. pressure.

A theoretical explanation of the asymmetric

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conductivity is considered ; (1) for the initial state of asymmetry ; and (2) for the limiting state of asymmetry, the former referring to the phenomena of ionisation by collision and the latter to the theory of normal cathode current densities.

Typical static characteristic curves are shown, from which can be anticipated the asymmetry shown by the oscillograph records.

Theoretical expressions are given for degree of asymmetry in half- and full-wave rectification, and data collected with reference to the performance of the rectifiers show that the theoretical values are closely approached by this cold cathode type of tube.

SUR L'EFFICACITÉ DES ÉCRANS ÉLECTROSTATIQUES DISCONTINUS (The Effectiveness of Discontinuous Electrostatic Screens).—P. Bricout. (*Comptes Rendus*, 27th May, 1929, V. 188, pp. 1388–1390.)

A certain number of physical measurements requiring constancy of potential are carried out in metallic enclosures which for experimental reasons cannot be closed completely. The writer investigates the disturbance produced by the discontinuity of the electrostatic screening in a simple case capable of various practical applications. He considers an infinite metallic plane at zero potential. An infinitely long cylindrical wire of radius r is stretched parallel to the plane at a distance a such that r/a is very small (of the order of 1/100 for example). An infinite and infinitely thin metallic plate, parallel to the plane at a distance b ($b < a$) is at zero potential, forming thus an electrostatic screen between plane and wire—which is brought to unity potential. The plate is divided into two parts by a rectilinear gap of breadth $2c$ and unlimited length, whose plane of symmetry passes through the axis of the wire. The writer investigates to what extent the space between plane and plate may be considered as equipotential. To do this, he calculates the potential P on the axis of the gap ; this is an upper limit of potential in the region considered. He finds that $P = \dfrac{\log \frac{2d+c}{2d-c}}{\log \frac{2d}{r}}$, where $d = a - b =$ distance of wire from screen.

NICKEL-IRON ALLOY FOR MAGNETIC CORES.—(German Patent 472623, Felten and Guilleaume Carlswerk, published 4th March, 1929.)

Fine particles of the alloy (containing 5–15 per cent. of nickel) are covered with an insulating layer of acetyl cellulose and are pressed into shape under a pressure not exceeding that of the elastic limit of the alloy.

DER "VARTA-DUPLEX" RADIO-GLEICHRICHTER (The "Varta-Duplex" Rectifying Set for Radio Purposes).—W. Müller. (*Zeitschr. f. Fernmeld:tech.*, 29th April, 1929, V. 10, pp. 55–57.)

An appliance for charging simultaneously both filament and anode accumulators (1 or 2 cells at 1–2 A. and 40 to 60 cells at 80–55 mA.). It includes a rectifying valve with two anodes (one for each type of charging current), an enclosed iron-wire resistance for steadying the 1–2 A. current and a glow-discharge tube which controls the anode battery current.

MAGNETIC ALLOYS OF IRON, NICKEL AND COBALT.—G. W. Elmen. (*Journ. Franklin Inst.*, May, 1929, V. 207, pp. 583–617.)

A full description of the Bell Telephone Laboratories investigations, some of the principal results, and particular applications made.

COOLING OF R.F. IRON-CORED COILS.—(German Patent 470752, Lorenz, published 30th January, 1929.)

For high frequencies the iron core should be run at a very high temperature because of its lower loss at that temperature, whereas the insulated windings should be kept much cooler. According to the invention, a cooling liquid or gas is circulated *between* the iron and the winding.

IMPROVEMENTS IN H.T. INSULATORS.—(French Patent 650934, Verrerie Électrotech., published 12th February, 1929.)

The distribution of potential field in the interior of the insulator is improved by metal coatings on its surface, particularly at the points of contact of the conductors.

DIE ABHÄNGIGKEIT DER DIELEKTRIZITÄTSKONSTANTE TECHNISCHER ISOLIERSTOFFE VON DER FREQUENZ (The Dependence on Frequency of the Dielectric Constant of Commercial Insulating Materials).—P. Böning. (*Zeitschr. f. tech. Phys.*, January, 1929, pp. 20–22.)

An application of the author's ionic absorption theory (Abstracts, 1928, V. 5, p. 523) to frequency-dependence.

ELECTRICAL PRESSBOARDS.—A. R. Dunton and A. W. Muir. (*Electrician*, 10th May, 1929, V. 102, pp. 549–551.)

"Developments which have led to important applications in the manufacture of high-voltage apparatus ; improved electrical characteristics ; manufacturing processes." To be continued.

SURFACE DISCHARGE AND HIGH VOLTAGE INSULATION.—S. Mochizuki. (*Tech. Rep. Tôhoku Imp. Univ., Sendai*, 1929, No. 2, V. 8, pp. 1–30.)

In English. In the study of surface creepage phenomena in the A.C. field, Nishi found that the surface discharge caused short-wave damped oscillations. The present paper investigates this result quantitatively, extending the research to D.C. The oscillations obtained ranged from 7 to 15 m. wavelength ; this wavelength depends on the circuit constants. When a thin layer of air is provided in series with the solid dielectric between the electrodes, much stronger oscillations are obtained than when the electrodes are in close contact with the dielectric. Among the other

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points mentioned, it is deduced that the oscillation current may have considerable effect on the spark-over voltage of insulators connected in parallel, whereas it has no effect on the puncture test of thin varnished cambric.

THE INSULATING POWER OF A VACUUM.—N. W. Tomachewsky. (*Arch. f. Elektrot.*, 7th December, 1928, V. 21, pp. 244–249.)

A German paper covering much the same ground as the Russian paper referred to in April Abstracts, p. 222.

"MYCALEX."—(*A.E.G.*, *Mitteilung.*, December, 1928, p. 629.)

An insulating material of mica and glass, made by compression at a high temperature. Its low coefficient of expansion allows it to sustain sharp rises of temperature; in spite of its great mechanical strength it can be machined. It is unaffected by moisture and its dielectric losses are very small.

THE LOSSES IN LAMINATED INSULATING MATERIALS.—W. Burstyn. (*Rev. Gén. de l'Élec.*, 23rd March, 1929, V. 24, pp. 461–463.)

Long French summary of a German paper. In the subsequent discussion Kirch gives the results of his research on ionisation in dielectrics.

ELECTROTECHNICAL INSULATING MATERIALS.—H. Stäger. (*Kolloid Zeitschr.*, September, 1928, V. 46, pp. 60–66.)

A general theoretical paper.

THE NATURE OF DIELECTRIC LOSSES.—H. Schiller. (*Zeitschr. f. Phys.*, No. 7/8, 1928, V. 50, pp. 577–579.)

A vindication of the author's previous statement—that the conductivity conditions, etc., can be explained by an alteration of the limits of the movement of the ions, together with a simultaneous increase in their mobility caused by the high field strength. Smekal has explained the mechanism of such phenomena.

STATIONS, DESIGN AND OPERATION.

A NEW HIGH POWER RADIO BROADCASTING EQUIPMENT.—D. B. Mirk. (*Elec. Communication*, April, 1929, V. 7, pp. 241–257.)

Illustrated description of the International Standard Electric Corporation's transmitter, recently erected and tested at New Southgate, London: with a maximum input of 180 kw., 100% linear modulation was obtained for an aerial carrier power of 50 kw. Wave-range 280–600 m. Modulation is by choke control, at a level slightly higher than the master oscillator output; then the modulated wave is amplified by three stages of high frequency amplification. Various characteristic curves are given. Overall efficiency is about 20%.

IS THE PRAGUE PLAN SOUND?—J. G. Abrahams. (*Wireless World*, 19th June, 1929, V. 24, pp. 638–640.)

THE OPERATION OF SEVERAL BROADCASTING STATIONS ON THE SAME WAVE-LENGTH.—P. P. Eckersley and A. B. Howe. (*Journ. I.E.E.*, June, 1929, V. 67, pp. 772–789.)

After a short history of the development of single-wavelength broadcasting, the paper discusses the general theory and certain experiments carried out by the B.B.C. to test this and to determine empirical quantities. Two stations were used, 38 miles apart working on 491.8 m. Exact carrier-wave synchronisation was obtained by governing the two transmitters from a common source. It was found that with such exact synchronisation, whenever the strength of one station at a point was 5, or more, times that of the other station, reception was normal. If, on the other hand, there was a difference of carrier frequency greater than 5 cycles per second, signals from the one station had to be at least 10 times as strong as those from the other station if good quality was to be obtained. Finally, if the carrier waves are the same but the modulations are different (*i.e.*, different programmes from the two stations), one station must give signals 100–200 times as strong as the other in order to give good service.

The next section deals with the range of stations sharing wavelengths. As no useful estimate of such range can be made (at any rate if the stations are 100 km. or more apart) without allowing for the presence of a strong indirect ray from the interfering station, and as no complete data as to the measured absolute value of the indirect ray are available, a large part of this section is taken up in obtaining a rough estimate of this value. Ultimately, two graphs are given (for perfect and imperfect synchronisation) for the range of two equal-power stations sharing the same wavelength, at various distances apart. The section ends by a consideration of the effect of a number of stations sharing the same wavelength. It is concluded that the range of a station sharing a wavelength with others will not be seriously decreased after more than 6 or 7 stations share the wavelength, because the probability of the averaging out of the peaks of field strength is greater with more stations.

Section 2 deals with the three general methods available for synchronisation; describes why the B.B.C. adopted (for the four sets now working) the method of independent, carefully adjusted transmitters without any common source of master frequency; and how the constant and common frequency at each station is obtained (Eccles' valve-maintained tuning-fork, with 25 valves for amplification and frequency-multiplication). Results of practical working of the four stations are then discussed; these appear to be good. The authors' conclusions are summarised, and a long discussion follows the paper. In their reply, the authors mention that recent reports of Continental reception of one of the four stations (Bournemouth) suggest that distant service from a group of synchronised stations may be better than from a single station: there may be "a better chance for the receiver to piece together the scattered fragments [from the Heaviside layer] of the original pattern." In the discussion itself, Lucas supports piezo-electric frequency regulation as opposed to tuning-forks. Dye, in defending the latter, suggests that

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other mechanical oscillators require developing. At the N.P.L., electrostatic drive allows the bars to be relieved from the magnetisation which certainly increases the damping. He describes a simple valve circuit consisting of a valve oscillator having a resonant anode circuit and a resonant grid circuit closely coupled and adjusted so that the anode circuit is approximately harmonic to the grid circuit: a cascade of such units should possess very great stability.

TABLEAU DE CONTROLE DES LONGEURS D'ONDE (Wavelength Control Chart).—(*QST Franç.*, May, 1929, pp. 65–78.)

A number of charts representing the wavelength measurements made from January, 1928 to January, 1929 by the Brussels Laboratory of the International Union of Radio-telephony.

T.S.F. ET ÉDUCATION (Wireless and Education).—(*QST Franç.*, May, 1929, pp. 5–9.)

An article based on the report of the Hadow Committee.

AMATEUR STATUS IN BRITAIN.—(*Wireless World*, 19th June, 1929, V. 24, p. 633.)

An editorial on the U.S.A. army-amateur radio organisation (June Abstracts, p. 343) and the lack of any such thing in Britain.

DIE SPRACHE DER AMATEURE (The Language of Amateurs).—R. Wigand. (*Rad., B., F., f. Alle*, June, 1929, pp. 273–277.)

The first list given is the "Amateur Code" giving the German interpretations of English and American abbreviations such as "enuf," "sigs," etc. Then come the Note-quality and Strength of Signal (QSA) codes; and finally the "Q" code with its subdivisions for general, ship, and aircraft traffic.

GENERAL PHYSICAL ARTICLES.

DIE FUNKENSPANNUNG DER LUFT BEI KLEINEM RAUMQUERSCHNITT (Sparking Voltage of Air for Small Cross Section of Gap).—A. Gyemant. (*Naturwiss.*, 22nd February, 1929, V. 17, p. 135.)

The writer has found evidence that a small cross section of available air-gap increases the sparking potential, just as small electrode distance or small duration of strain increases it.

SUR LA DISTRIBUTION SPATIALE DU RAYONNEMENT GAMMA DU RADIUM DANS LES MILIEUX DISPERSIFS LÉGERS (On the Spatial Distribution of the Gamma Radiation of Radium in Light Dispersive Media).—M. Bruzau. (*Ann. de Phys.*, January, 1929, V. 11, pp. 5–140.)

An exhaustive experimental investigation. Among the results, it is found that the secondary radiation of diffusion in the superficial layers of water leads to the observation of an absorption-coefficient less than the true one: measurements at 10 m. depth give the accurate value, but at smaller depths the rays appear more penetrating than they really are. It is suggested that this effect may vitiate some of Millikan's measurements on cosmic rays.

MESSUNGEN ÜBER DAS KURZWELLIGE ENDE DER DURCHDRINGENDEN HOHENSTRAHLUNG (Measurements of the Short Wave End of the Spectrum of the Penetrating Radiation).—E. Regener. (*Naturwiss.*, 15th March, 1929, V. 17, pp. 183–185.)

A preliminary communication on the results of recent tests carried out by the writer with self-registering apparatus.

THE ABSORPTION OF HIGH-FREQUENCY RADIATION.—E. C. Stoner. (*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 841–858.)

Working on the measurements of Ellis and Wooster and of Ahmad, on the gamma rays of *Ra B* and *C*, the author shows that there is agreement within 2 per cent. with calculation provided the Klein-Nishina formula is used, whereas the unmodified Dirac formula gives results 25 per cent. lower than those observed. The effect of filters is considered, and suitable experimental arrangements for more precise tests are briefly discussed. If the Klein-Nishina formula is assumed to hold for the hardest rays, the most penetrating radiation observed by Millikan corresponds to the electron-proton annihilation wavelength, instead of to that of the up-building of the silicon atom as Millikan suggests.

THE TEMPERATURE COEFFICIENT OF GAMMA-RAY ABSORPTION.—L. Bastings. (*Phil. Mag.*, February, 1929, V. 7, No. 42, pp. 337–345.)

The somewhat unexpected existence of a temperature effect on gamma-ray absorption was reported in a letter to *Nature* (p. 51, 1927); it is confirmed here for a number of typical metals, and an intimate connection, if not an agreement (at present unexplained), is found between the linear temperature coefficient of absorption and the mean coefficient of *linear* (not superficial) expansion of the absorber.

ON THE WAVES ASSOCIATED WITH β-RAYS, AND THE RELATION BETWEEN FREE ELECTRONS AND THEIR WAVES.—G. P. Thomson. (*Phil. Mag.*, February, 1929, V. 7, No. 42, pp. 405–417.)

ÜBER DIE ERREGUNG VON REIBUNGSELEKTRIZITÄT ZWISCHEN METALLEN UND NICHTLEITERN IN ABHÄNGIGKEIT VOM DRUCK DES UNGEBENDEN GASES SOWIE VOM ENTGASUNGSZUSTANDE DES METALLES (The Production of Frictional Electricity between Metals and Non-conductors, in dependence on Pressure of Surrounding Gas and on the Outgassed State of the Metal).—W. Kluge. (*Ann. der Phys.*, 2nd January, 1929, 5th Series, V. 1, No. 1, pp. 1–39.)

MODULATION OF LIGHT WAVES.—A. Bramley. (*Journ. Franklin Inst.*, March, 1929, V. 207, pp. 315–321.)

Description of the experiments referred to in

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February Abstracts, p. 114, and discussion of the conclusions to be drawn from them. For H.F. fluctuations in intensity of light waves, by piezo-electric control, see Abstracts, 1928, V. 5, p. 105.

STUDIEN ÜBER DIE ERZEUGUNG VON REIBUNGSELEKTRIZITÄT.—L. Wolf. (*Ann. der Phys.*, 19th January, 1929, 5th Series, V. 1, No. 2, pp. 260–288.)

Six experimental conclusions are given which contradict the assumptions made by Riecke and others in their theories of the production of frictional electricity.

EIN GRÜNDLICHES EXPERIMENT ÜBER DIE KONTAKT THEORIE DER TRIBOELEKTRIZITÄT (A Fundamental Experiment on the Contact Theory of Frictional Electricity).—E. Perucca. (*Zeitschr. f. Phys.*, 12th October, 1928, V. 51, pp. 268–278.)

Support for the contact theory is given by the experimental proof of the production of a potential difference by the contact of two insulating materials: it is true that one was a liquid, but the writer considers that there is no reason why a solid-solid contact should show any substantially different result.

A CRITICISM OF THE ELECTRON THEORY OF METALS. —H. M. Barlow. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 459–470.)

Experiments are described which "prove conclusively that the assembly of free electrons in the interior of a conductor invariably behaves like a perfectly incompressible fluid, and consequently in no way resembles a gas. The fundamental hypothesis of the Sommerfeld theory of conduction cannot, therefore, be maintained."

EXTINCTION OF AN A.C. ARC.—J. Slepian. (*Journ. Am. I.E.E.*, October, 1928, V. 47, pp. 706–710.)

The transition from high conductivity to high resistivity which an A.C. arc undergoes on extinction is studied. Theory, approximate calculations and experimental results are given for the rate of recovery of dielectric strength of the arc space for short arcs.

ON THE INVESTIGATION OF PREDISCHARGES.—Fr. Trey. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 854–857.)

Photographs taken by means of brush-light show that with long sparks—where the electrode distance is much larger than the radius of curvature of the electrodes—the spark track is produced by the *positive* predischarge.

THE ELECTRIC ARC IN GASES AT LOW PRESSURES. —F. H. Newman. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 811–817.)

A type of arc in high vacua was described by the writer in 1926, in which with cold electrodes an arc could be started and maintained provided that an initial electrical discharge was passed between one of the arc electrodes and a third electrode within the discharge-tube; many amperes passed although the pressure was so low that there was practically no luminosity, though the tube walls fluoresced under the cathode ray action. The present paper deals with experiments to investigate the mechanism of this arc and the conditions necessary for its starting.

CONDUCTION OF ELECTRICITY THROUGH GASES. VOL. I.: GENERAL PROPERTIES OF IONS, IONISATION BY HEAT AND LIGHT.—J. J. and G. P. Thomson. (Long review in *Engineer*, 29th March, 1929, V. 147, p. 357.)

THE CORONA DISCHARGE IN NEON.—F. M. Penning. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 632–633.)

Huxley recently found that at the higher pressures the negative discharge (wire cathode) started at a higher P.D. than the positive—which he took as a strong argument against the theory that in corona discharges the electrons are liberated mainly from the cathode by the action of the positive ions.

The writer quotes experiments to show that the effect observed by Huxley is a spurious one occurring only when the gas is not quite pure—that in the pure gas, the starting P.D. is somewhat higher for the positive than for the negative discharge.

HIGH-FREQUENCY DISCHARGES IN HELIUM AND NEON.—R. L. Hayman. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 586–596.)

Measurements of the potentials required to start and maintain H.F. discharges, of various frequencies, in helium and neon at various pressures in cylindrical tubes of various diameters.

HIGH-FREQUENCY DISCHARGES IN GASES.—J. S. Townsend and W. Nethercot. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 600–616.)

An account of experiments to determine the relation between the current and the electromotive force in H.F. discharges, and also in continuous current discharges in the same gas (nitrogen) under the same conditions.

Results fit in well with the Townsend theory of the uniform glow in an electrodeless discharge, according to which the mean value of the electric force in the glow of a H.F. discharge should be the same as the force in the uniform positive column of a continuous current discharge.

MISCELLANEOUS.

DIE MESSUNG DES ELEKTRISCHEN FELDES DES MENSCHEN (The Measurement of the Electric Field of Human Beings).—O. Utesch. (*Zeitschr. des V.D.I.*, 27th April, 1929, V. 73, pp. 575–577.)

A description of the apparatus, methods and some results of the work carried out under the auspices of Sauerbruch and Schumann (Abstracts, 1928, V. 5, pp. 349 and 649; *cf.* also v. Ardenne p. 590.) Oxide-coated filaments were discarded owing to the need for absolutely constant emission, and tungsten double-grid valves were used ex-

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clusively. All attempts to find magnetic fields were fruitless, but electric field changes were recorded (for muscle actions) both by string-galvanometer and by cathode-ray oscillograph. In the latter case records were taken on a strip of silver bromide paper passing continuously over the outside of the fluorescent screen (10 cms. in from 0.06 to 0.1 second).

Physics in Relation to Oil Finding (Part I).—A. O. Rankine. (*Nature*, 4th May, 1929, V. 123, pp. 684–686.)

Geophysical Prospecting: (1) Theoretical Considerations, for Methods using Two Point-shaped Electrodes: by J. N. Hummel; (2) Application of Electric Methods in Practical Geophysics: by E. Pautsch; (3) Modern Instruments and Methods of Seismic Prospecting: by C. A. Heiland.—(*Gerlands Beitr.*, 1928, No. 3/4, V. 20, pp. 281–287; *ibid.*, No. 1/2, V. 20, pp. 85–98; *Am. Inst. Mining and Met. Eng. Tech.*, pub. No. 149, 1928.)

Latitude Determination in Aircraft.—J. Jaumotte, E. Lehay and J. F. Cox. (*Roy. Acad. Belgium*, summarised in *Nature*, 4th May, V. 123, p. 701.)

The magnetic inclination is measured by a telephonic null method depending on the E.M.F. developed in a rotating coil. An accuracy of 10′ is indicated as possible.

Effect of Light on the Eye recorded by Valve Methods.—E. L. Chaffee. (*Scient. Amer.*, May, 1929, p. 451.)

Fine thread electrodes are connected to the retina of an excised eye, and the electrical effects of light stimulation are amplified and passed into a recording galvanometer.

Une Application des Cellules photoélectriques à un Dispositif enregistreur de Trafic urbain (An Application of Photoelectric Cells to the Recording of Urban Traffic).—(*Rev. Gén. de l'Élec.*, 27th April, 1929, V. 25, p. 129B.)

Traffic in the Holland Tunnel joining New York and New Jersey is counted in this manner, the photoelectric impulses being used to work a relay and through this a counting-mechanism.

The Use of X-rays in the Testing of Engineering Materials.—(*Elektrot. u. Masch: bau*, 21st April, 1929, pp. 321–352.)

The whole number is devoted to a series of papers on this subject by various authorities.

La Propriété Scientifique (Scientific "Property").—Fernand-Jacq. (*Rev. Gén. de l'Élec.*, 12th January, 1929, V. 25, pp. 73–78.)

A report of a conference at Geneva on the subject of better legal recognition of the rights which the originator of a scientific discovery should have in those industrial applications which arise from his discovery. *See also* same journal, 6th April, 1929, pp. 545–549.

General Ferrié. (*Rev. Gén. de l'Élec.*, 30th March, 1929, V. 25, pp. 100B–101B.)

The French Minister of War proposes to pass a special law to retain the services of General Ferrié regardless of the age limit.

Une Machine Électrostatique à Courant continu (An Electrostatic D.C. Machine).—H. Chaumat. (*Comptes Rendus*, 3rd June, 1929, V. 188, pp. 1490–1492.)

Continuing his Notes on the subject (*see* July Abstracts, p. 405) the writer now describes schematically a direct current electrostatic machine which (for one set of values) would deliver 0.2 A. at 20,000 V. maximum. It consists of two insulating discs, one fixed and the other rotating very close to it, each carrying metallic sectors and thus bearing a family resemblance to the Wimshurst machine; but here the sectors of each disc are connected to each other. The fixed set is permanently connected to one pole of a source of d.c. (*e.g.*, a dry battery) and to one pole of the output; the other pole of the dry battery ("exciter") goes to a brush which makes momentary contact with the rotating sectors as they pass, while the other pole of the output goes to a second brush which makes momentary contact with the rotating sectors at moments mid-way between the moments of contact with the first brush. Thus the two sets of sectors form a condenser which is being periodically charged from the exciter and whose capacity periodically changes from a maximum (sectors opposite) to a minimum (sectors staggered). The output mentioned above is calculated for 20 sectors per disc, 50 revs. per sec., exciting volts 1,000, capacity (max.) 0.01 microfarad (obtained by several pairs of discs in parallel) and capacity (minimum) one-twentieth of this.

Les Machines Électrostatiques en Fonctionnement sur des Condensateurs (Electrostatic Machines acting on Condensers).—H. Chaumat. (*Comptes Rendus*, 10th June, 1929, V. 188, pp. 1546–1547.)

The electrostatic generator referred to above is here considered in conjunction with a condenser acting as a constant pressure reservoir.

Action exerted by an Oscillating Metallic Circuit on the Germination of Seeds.—G. Mezzadroli and E. Vareton. (*Nature*, 1st June, 1929, V. 123, p. 859.)

Abstract of an Italian paper: the presence of an oscillatory circuit of a single coil 30 cm. in diameter, capable of catching natural cosmic waves* of wavelength about two metres, exerts a favourable influence on the germinating power of seeds, the time of germination being reduced, in some cases, by one half.

* But see Lakhovsky, May Abstracts, pp. 386-387.

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PHOTOELECTRIC CELL AS PROTECTION FOR ELECTRICAL APPARATUS. (French Patent 653217, Cie. Thomson-Houston, pub. 19th March, 1929.)

Transformers, etc., immersed in oil are protected from over-heating by a photoelectric alarm device. When near the dangerous temperature, the oil in a glass tube becomes permeated with gas, which changes the refraction of a beam of light passing transversely through the tube: this change of refraction diverts the beam from a photoelectric cell and gives the warning.

TRAIN WIRELESS. (*Wireless World*, 12th June, 1929, V. 24, p. 622.)

A paragraph announcing the formation of a limited liability company in France, called " Radio-Fer," to exploit the installation of wireless on trains. On the next page is another paragraph, describing the broadcast reception arranged by the McMichael Company on the " Flying Scotsman," when the running commentary on the Derby and wireless pictures of the race were received with the train travelling at over a mile a minute.

ERFAHRUNGEN ÜBER SELBSTTÄTIGE ZUGBEEINFLUSSUNGEN (Trials of Automatic Train Control). (*E.T.Z.*, 30th May, 1929, V. 50, pp. 777–780.)

An article on the different systems used on various railroads in the U.S.A.

A RAPID METHOD FOR DETERMINING THE LIMIT OF ENDURANCE FOR BENDING OF STEELS, BY THE MEASUREMENT OF THE ELECTRICAL RESISTANCE.—S. Ikeda. (*Tech. Rep. Tôhoku Univ.*, No. 2, V. 8, pp. 42–70.)

QUELQUES STATISTIQUES RÉDUCTIBLES ET NON RÉDUCTIBLES À LA LOI DE PROBABILITÉ SIMPLE (Some Statistics reducible and irreducible to the Law of Simple Probability).—R. de M. de Ballore. (*Ann. Soc. Scient. Bruxelles*, V. 48 A, 1928.)

A summary of this paper is given in *L'Onde Élec.*, April, 1929, p. 25A, by P. David, who points out its possible value in the treatment of experimental observations on the propagation of waves.

ON THE WRITING OF SCIENTIFIC PAPERS.—F. M. Colebrook. (*E.W. & W.E.*, June, 1929, V. 6, pp. 301–306.)

" The preparation and the writing of a paper on even the most severely scientific or technical of subjects is a work of art and should be conceived and executed in that spirit ; it should be judged by the same high standards as a work of art, and demands at least as high an endeavour. . . . This æsthetic element . . . can, and should, find expression in all forms of scientific activity—in the devising of experiments, and the designing of apparatus with which to carry them out ; in the analysis of data so obtained, and finally in the exposition of the matter for the benefit of others through the medium of the printed word. In all of these there is scope for that perfect adaptation of means to an end, that ordered harmony of parts and economy of effort that finds an immediate response in the æsthetic part of consciousness. I mean the kind of thing that will on occasion provoke the pleased exclamation ' That's very neat,' even from one who has no interest at all in the immediate object of the work." Among the various points whose importance is urged in the paper are :—the isolation of the essential variables of a problem both in analysis and in the design of experiments ; the attainment of the highest economic degree of generalisation ; the preservation of the " physical anatomy " of a problem in its mathematical formulation ; clarity, to be sought not only in the choice of the individual word but also, and more particularly, in the arrangement of the paper as a whole.

RADIO INTERFERENCE.—J. G. Allen. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 882–891.)

" The radio interference situation is rapidly becoming so serious as to make improvements in both methods of detection and methods of elimination absolutely imperative." Of the interference cases brought during one year to a certain Power company as being due to their supply, the following percentages of true causes were traced :—15% defective receivers and associated apparatus ; 13% miscellaneous ; 30% industrial apparatus ; 25% household appliances ; 17% Light Company's equipment. A figure is given showing aerial and earth conditions " typical of those found in half the homes to-day," twelve different avoidable sources of trouble being indicated.

The most effective method in interference detection is that combining the good features of the intensity method (using substantial and reliable audibility meters of the indicating type, possessing high sensitivity) with the circuit-selection features of the directional method, coupled with extensive experience both in the field and in the laboratory. Progress should be made in more thorough filter design study, with special attention to draining the noises from power lines, trolley wires, feeders and telephone lines ; and in the manufacture of " interference proof " electrical appliances.

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Some Recent Patents.

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.

TELEVISION SYSTEMS.

Convention date (U.S.A.), 6th April, 1927. No. 302238.

A television system is described, the novelty of which lies in the feature that the field scanned at the receiving station is evenly illuminated over its whole area. A subordinate feature is that the field is at least as large as the picture to be viewed, the instantaneous intensity of illumination being varied in accordance with the tone value of the exposed elemental area of the picture at any instant.

No. 288237 of the same Convention date. Here a system for translating space-variations of light intensity into time-variations of electric-current energy is characterised by the provision of a network circuit having an attenuation factor designed to correct for the distortion arising from the fact that the light-aperture in the rotating scanning disc has finite dimensions instead of being a mere point.

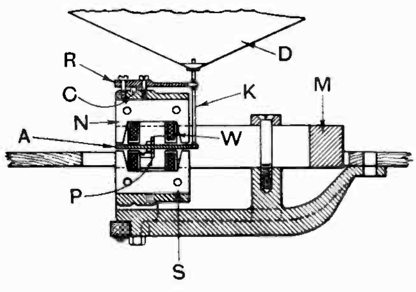
No. 288238 of the same Convention date. The object is scanned by a beam of intense light which is moved rapidly so as to give a cyclic point-by-point exploration, the reflected ray being received directly on a light-sensitive cell of large aperture, without having to pass through any obstruction, such as a condensing lens.

Patents issued to Electrical Research Products Inc.

LOUD SPEAKERS.

Application date, 8th November, 1927. No. 305614.

A balanced armature A is pivoted centrally on a blade P mounted across the centre of the gapped pole-pieces N, S of a magnet M. The armature is rocked about the blade P under the influence of currents flowing in the coil windings W. A thin rod K connects one end of the armature to a stiff



No. 305614.

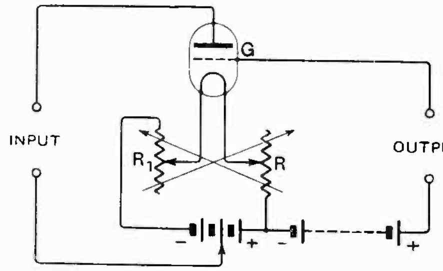
reed R having a very high natural period of vibration, preferably exceeding 10,000 cycles per second. The reed is forced by two screws against a rod C resting in a groove or notch formed in a rigid part of the mounting, this arrangement allowing the reed to be correctly centred. The loud speaker diaphragm D is mounted on the rod K at a point beyond its connection to the reed R. Owing to the reed control being located at a point outside the region embraced by the magnet poles, the cross-section and mass of the armature can be considerably increased without giving rise to distortion.

Patent issued to C. Mahé de Chenal de la Bourdonnais (Prince de Mahé).

VALVE AMPLIFIERS.

Application date, 16th January, 1928. No. 309846.

For low-frequency amplification, the grid G is maintained at a high potential relative to the plate and filament. The input is applied across the plate and filament, whilst the output is taken from the grid. The arrangement is stated to be advan-



No. 309846.

tageous because the impedance across the short grid-filament space is comparatively low, and can therefore be more nearly equated to the impedance say of a gramophone pick-up. A separate filament rheostat R, R_1 is provided for each leg, the two being varied inversely so that the mean operating potential of the plate can be adjusted without changing the total resistance included in the filament circuit.

Patent issued to A. F. Pollock and D. A. Pollock.

COATED CATHODES.

Convention date (Austria), 30th April, 1927. No. 289763.

Relates to a process for the deposition of an alkali-earth metal, such as barium strontium, or calcium on to a filament wire of platinum-copper, nickel, or chrome nickel. Vapours of the alkali metal are liberated by a reduction process (initiated by heating) from a mixture of barium, strontium, or calcium oxides, together with calcium or magnesium as a reducing agent. The mixture is formed into a small rod which is attached to the inner side of the anode—*i.e.*, the side next to the cathode. The bulb is then exhausted and the electrodes heated by high-frequency currents in the known manner.

Patent issued to Vereingte Gluhlampen und Electricitats A.G.

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THERMIONIC RELAYS.

Convention date (France), 18th November, 1926. No. 280948.

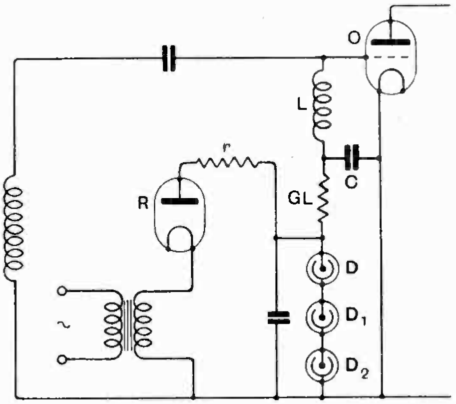
A thermionic relay suitable for use in distant-control systems, for radio communication, or for television, comprises a glass vessel containing neon or helium gas or mercury vapour under low pressure and arranged to have two discharge paths. The first or main discharge takes place between an anode located at one end of the tube and a transverse set of electrodes located at the other end of the tube. The second or auxiliary discharge takes place across a heated filament, a control grid, and a plate grouped together at one end of the tube, and forming the transverse set of electrodes above mentioned. The input is applied between the grid and filament of the transverse electrodes, and initiates a local or auxiliary discharge between the heated filament and plate. The consequent ionization breaks down the gap between the transverse set of electrodes and the distant anode, and allows a main discharge to set in along the length of the tube.

Patent issued to G. Valensi.

VALVE OSCILLATION-GENERATORS.

Application date, 19th March, 1928. No. 308085.

In order to maintain a safe negative bias on the grid of a power oscillator, even during non-oscillatory periods, the grid circuit is provided with one or more discharge tubes D, D_1, D_2, the "threshold" value of which is at least equal to the required grid bias. In parallel with the discharge tubes is a rectifier R and series resistance r capable of producing an electromotive force of the same threshold value. So long as the generator O is developing oscillations, the grid condenser C is charged up to the required biasing voltage, any excess leaking



No. 308085.

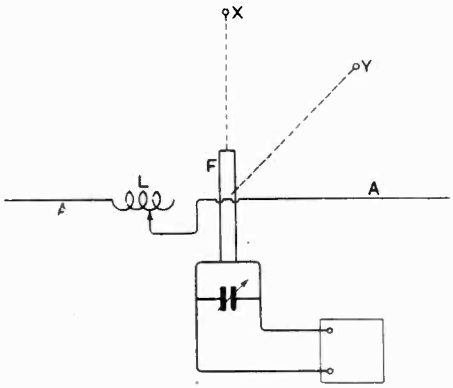
away through a choke L, high resistance GL, and the discharge tubes D—D_2. Should the oscillator cease to function, the negative charge on the grid is maintained at a safe value by the rectifier R, which may be replaced by a battery.

Patent issued to S. G. S. Dicker.

DIRECTIONAL WIRELESS.

Application date, 11th April, 1928. No. 307237.

In order to increase the directional effect of a frame aerial, particularly in a commercial installation of the kind in which two stations are kept permanently in tune and are normally intended only to communicate with each other, means are



No. 307237.

provided to mitigate the effect on the receiving frame of any signals coming from directions other than that to which the frame is orientated.

As shown in the Figure the frame F is set in line with its companion station at X. A long horizontal wire A, having a tuning coil L, is arranged at right angles to the frame. This has no effect upon signals from station X since it is symmetrically disposed to the latter. Its effect upon signals from an interfering station such as Y, is to distort or guide the incoming wave so that its front is shifted more into line with the wire A, where it has less effect on the frame aerial F than if it maintained its normal direction.

Patent issued to L. Mellersh-Jackson.

ELECTRIC PICK-UPS.

Application date, 9th December, 1927. No. 307767.

The vibrating reed is pivoted substantially at a point which is an anti-node of the fundamental vibration, or is otherwise mounted so as to have a relatively free rocking motion about that point. The fundamental, and certain of the overtones, are thereby largely damped and a more even tone response is secured.

Patent issued to P. Wilson.

Application dates, 16th December, 1927, and 25th January, 1928. No. 307971.

The vibrating reed is so mounted between the opposite poles of the magnet that no flux normally passes through it, *i.e.*, it normally lies midway between and transversely of the poles. Under the impulse of the stylus needle it moves towards one pole and away from the other.

Patent issued to A. E. Barrett.

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MAINS-SUPPLY UNITS.

Application date 22nd December, 1927. No. 305771.

In practice it is often found that as soon as an earth-connection, even if made through a condenser, is introduced at the input end of a multi-valve receiver fed from a mains-supply unit, "noise" is apt to arise although the installation may work quietly so long as it is unearthed. According to the invention this defect is eliminated by inserting, between the mains and the standard filter circuit, a double choke consisting of a winding in series with the positive and a second winding in series with the negative main, the two windings being closely coiled around the same magnetic core in such sense that the supply and return currents flowing in the main leads neutralise each other and produce substantially no flux in the core.

Patent issued to R. E. H. Carpenter.

ELECTROLYTIC RECTIFIERS.

Application dates, 13th January and 12th November, 1928. No. 309622.

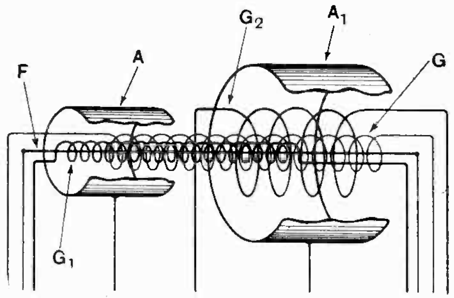
An electrolytic rectifier or "valve" comprises a cathode containing tungsten alloyed or combined with cobalt, iron, aluminium, or tantalum. The electrolyte consists of ammonium phosphate (30 per cent. solution); tartaric acid (20 per cent. solution) to which is added a small quantity of salicylic acid; and boric acid (3—6 per cent. solution); the whole being electrolised. The anode is of aluminium.

Patent issued to S. D. White and R. J. Jones.

A DUPLEX VALVE.

Convention date (France), 10th August, 1927. No. 295351.

A long single-wire filament F is surrounded by two spiral wires, G, G_1, forming a space-charge grid and a control grid respectively. Two separate cylindrical anodes, A, A_1 are spaced apart from each



No. 295351.

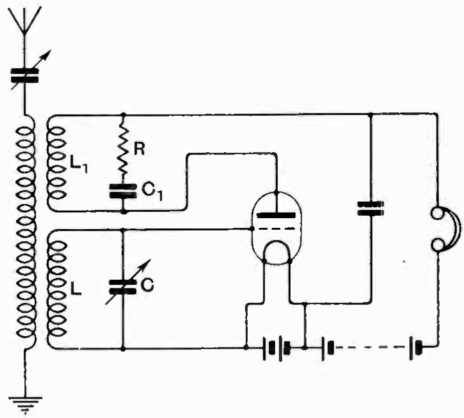
other along the length of the filament. One anode is of smaller dimensions than the other so that for the same value of H.T. applied to both anodes, the current taken from one is less than that from the other. The smaller anode can then, for instance, be used to provide the local oscillations in a superheterodyne receiver. A third grid G_2 may be interposed in the space between the control grid and the larger anode.

Patent issued to Soc. des Etablissements Industriels de E.C. et de Alexandre Grammont.

CONSTANT COUPLING RECEIVERS.

Convention date (U.S.A.), 3rd January, 1927. No. 283121.

In order to maintain the degree of back-coupling constant, irrespective of the particular signal-frequency being received, the plate coil L_1



No. 283121.

is shunted by a resistance R in series with a condenser C_1. As the input circuit L C is tuned to a higher frequency, thus tending to increase the coupling-factor, this tendency is automatically offset by the action of the shunt circuit R C_1 in diverting a larger proportion of the total plate current from the coupling-coil L_1. For lower frequencies the proportion of plate current by-passed through the shunt circuit decreases.

Patent issued to The British Thomson-Houston Co., Ltd.

MAGNETOSTRICTIVE OSCILLATORS.

Application date, 3rd January, 1928. No. 283116. (Original Convention date, 4th January, 1927.)

A system for generating oscillatory currents comprises a magnetostrictive vibrator, *i.e.*, a core of nickel, nickel-steel, or other metal or alloy, resting freely on or clamped to a support and surrounded at each end by exciting windings. The resulting mechanical vibrations set up in the core by magnetostrictive action may vary from hundreds to hundreds of thousands of cycles per second, according to its shape, mass, and elasticity. Resonance occurs at a fundamental and at harmonic frequencies. The movements of the vibrator may be used to modulate a local current, which may in turn be back-coupled with the exciting windings so as to produce sustained oscillations of a frequency determined by the natural magnetostrictive period of vibration.

Patent issued to G. W. Pierce.

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MULTI-STAGE VALVES.

Convention date (Germany), 18th December, 1926. No. 291735.

In a multi-stage valve arranged for heterodyne reception, a piezo-electric crystal is mounted within the same evacuated bulb, between the plate circuit of the first detector stage and the grid of the first intermediate amplifier. This allows sharp tuning in a system which is normally resistance-coupled, and ensures a corresponding gain in selectivity.

Patent issued to W. Kunze and Radiofrequenz G.m.b.H.

SOUND DIAPHRAGMS.

Application date, 2nd December, 1927. No. 307106.

The vibrating diaphragm of a loud speaker or telephone earpiece is provided with one or more short-circuited conductors, inserted in holes specially bored in the diaphragm. Or the armature may be cut out into the form of a reed or a star, and short-circuited copper bands wound around one or more of the limbs. These damping elements tend to stabilise the magnetic flux and increase sensitivity.

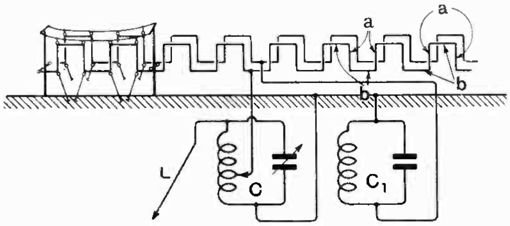
Patent issued to British Thomson-Houston Co., Ltd., and A. P. Young.

AERIAL SYSTEMS.

Application date, 7th December, 1927. No. 307446.

A directional broadside aerial is built up of interconnected active and non-active elements, forming a zig-zag grid. For unidirectional working the aerial is backed by a second similar structure acting as a reflector. The active elements *a* are vertical, whilst the inactive elements *b* are horizontal and serve merely to complete a transmission line for the feed currents, which are supplied by a one-wire power cable *L*. The speed at which the supply currents are distributed over the whole aerial system is apparently infinite, so that the currents in all the vertical or active elements are in phase, and the radiation is in the form of a current sheet.

In order to secure this result the vertical and horizontal elements must be of the same order of magnitude, whilst the sum of the length of a vertical and horizontal element is an odd multiple



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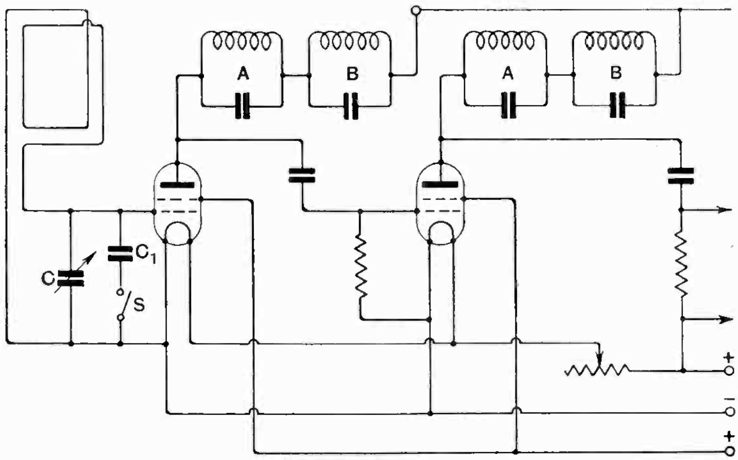
of half the working wavelength. Finally the length of each horizontal is chosen so that the induced currents in each of the verticals are in phase. The centre of the aerial system as a whole is earthed through a tuned loop circuit *C*, the reflector system being similarly grounded through a tuned circuit C_1.

Patent issued to Standard Telephones and Cables, Ltd.

SWITCH-TUNED RECEIVERS.

Application date, 10th October, 1927. No. 307519.

The circuits are arranged so that reception from a given short-wave station can be changed to a long-wave programme by the mere operation of a switch, without further tuning adjustment. The invention is illustrated as applied to two stages of screened-grid amplification to be followed by the usual detector and L.F. stages. The plate circuit of each valve comprises two circuits *A*, *B* tuned respectively to the selected short and long wave stations it is desired to receive. Owing to the difference in wavelength, the circuit *B* offers very little impedance to currents to which the circuit *A* is resonant, and *vice versa*.



No. 307519.

The actual selection between one programme and the alternative is determined by the switch *S*. In its open position as shown, the condenser *C* automatically tunes the frame aerial to the short-wave station, to which the plate circuits *A* are also permanently tuned. In this case the circuits *B* are ineffective. When the switch *S* is closed, to bring a parallel condenser C_1 into circuit, the receiving frame is automatically tuned to the long-wave station, and co-operates with the circuits *B*, the circuits *A* having practically no effect on the strength of the received signals.

Patent issued to British Thomson-Houston Co., Ltd. and T. H. Kinman.

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