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Editorial.

Transmitting Aerials.

IN no branch of radio-telegraphy or telephony is there greater uncertainty, greater diversity of views or greater possibilities of development along new lines than in the design of transmitting aerials to meet the many new requirements which are arising in various branches of the subject. Since the advent of short-wave telegraphy various methods have been devised for concentrating the radiated energy predominantly into one direction. These methods were at first concerned primarily with the distribution of energy in the horizontal plane, and its concentration towards one point of the compass by means of parabolic reflectors or arrays of vertical aerials, but the further question of the concentration of the beam along a path at a given inclination to the horizontal quickly forced itself upon the attention of those interested in long-distance transmission. If the energy arriving at a distant receiving station is a part of that which was radiated from the transmitting aerial in a certain upward direction, it is obviously desirable to concentrate as much of the radiation as possible in that direction.

A great amount of experimental work on this subject has been carried out in Germany by Dr. Meissner, of the Telefunken Company, using a horizontal Hertzian antenna with a parabolic reflector which could be rocked about a horizontal axis. This reflector consisted of a wooden framework carrying 9 horizontal wires 31 feet long; such an arrangement was found to act as efficiently as a copper sheet reflector. The aperture of the reflector was about 60 feet; standing in the field, the structure looked very much like the skeleton of a grandstand and considerable ingenuity was required to rock it about a horizontal axis through an angle of almost 60 degrees. The receiving station was situated at Buenos Aires.

Experimental Observations.

At first sight one might think it strange that a horizontal aerial was chosen for these large-scale experiments, since the plane of polarisation of the waves is at right angles to that of the waves radiated from a vertical aerial. Seeing, however, that with a vertical transmitting aerial the wave after refraction in the upper atmosphere may arrive at the receiver with its plane of polarisation rotated through a large angle, it is probable that the initial polarisation is of little consequence Such waves with the electric field horizontal cannot travel over the earth's surface in the same way as those with the electric field vertical and they are probably rapidly attenuated in the neighbourhood of the transmitter, but the tests showed excellent reception in South America. In the early experiments the wavelength was 11 metres and the reflector could be made to direct the beam upwards at any angle between 35 and 90 degrees from the horizontal. The results were erratic; on some days the received signals were much stronger than those from a vertical aerial of ten times the power, whereas on some days they were inaudible. Generally speaking, however, the signals were strong when the transmitted ray had an inclination of 35 to 40 degrees, which was as near the horizontal as was possible with the reflector then in use; as the angle was increased to 60 degrees the signals became much weaker, but on further increasing the angle they became stronger, and for inclinations between 80 and 90 degrees were of about the same strength as for 35 degrees. That strong signals should be received in Buenos Aires when the transmitted ray at Nauen was directed vertically upwards is certainly very surprising. Subsequent arrangements to enable the ray to be directed at smaller inclinations than 35 degrees showed no definite variation in the signal strength from that observed at 35 degrees. The reflector was then enlarged so that the tests could be repeated at the commercial wavelengths of 15 to 20 metres. The results of these tests have recently been published and they show a surprisingly large increase in signal strength as the inclination is reduced from 40 to 0 degrees, the received signals being 5 times as strong when the beam is directed horizontally along the ground as for an angle of 40 degrees and twice as strong as for an angle of 10 degrees. This agrees with the practice of the Marconi Company in making each vertical member of the beam aerial several half wavelengths long, the separate half wavelengths being connected by non-radiating half-wave phasing coils, so that the current in the whole vertical member is simultaneously in the same direction. In a horizontal direction, the effects of all the elements of wire are additive, whereas in other directions they arrive out of phase and tend to cancel out. Hence, for short-wave work there appears to be general agreement that to get the best long-distance transmission the ray should be concentrated in a horizontal direction so that it starts off tangentially from the earth.

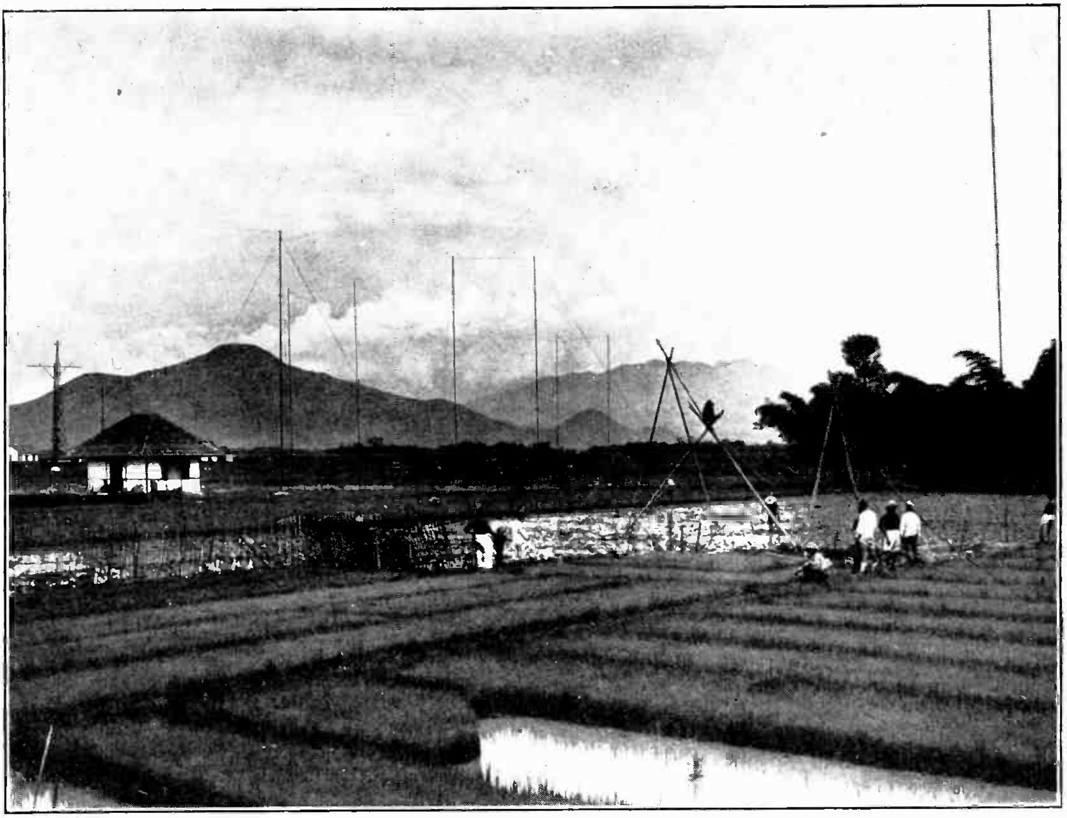
At the last meeting of the Wireless Section of the Institution of Electrical Engineers, a paper was read by Messrs. P. P. and T. L. Eckersley and H. L. Kirke on the "Design of Transmitting Aerials for Broadcasting Stations." They favour exactly the same procedure, their conclusions being, "(1) The design of aerials for broadcasting should aim at using the energy to produce the strongest possible horizontal radiation while diminishing upward radiation. (2) To produce this desirable end, high aerials are a *sine qua non*." It is very interesting to note, however, that their reason for advocating this policy is that they maintain that such a radiation will not be transmitted to a great distance, but will be confined to a limited area around the transmitter, and consequently will not cause interference with distant transmitters. In contemplating this apparent paradox it must be remembered that the wavelength in the first case is about 20 metres, and in the second from 200 to 600 metres, and that although they are both electromagnetic waves, they behave very differently.

Congestion of Wavelengths.

The idea on which this new suggestion is based is that the difficulties in finding accommodation for all the broadcasting stations in the wavebands available are largely caused by interference from very distant stations, due to the energy radiated above the horizontal, which after refraction in the upper atmosphere produces strong signals at distances far beyond what could possibly be regarded as the service area of the station in question. Undoubtedly the problem which we discussed in our January number would be greatly simplified if the radiation from every station could be attenuated to a negligible amount at a certain radius so that it could be guaranteed to cause no interference beyond that radius. At present this is far from being the case, and therein lies what to many people is the chief attraction of broadcasting, for there is no doubt that to many listeners the reception of distant stations, even at some sacrifice of quality, is more attractive than the perfect reception of stations nearer home. We do not think that such people need feel very scared at the proposals put forward in the paper, since the elimination of the upward radiation depends on the height of the aerial with reference to the wavelength. With a wavelength of 20 metres it is an easy matter to make the height equal to several half wavelengths, but when the wavelength is increased even to 200 metres it is a very different matter, and the high cost of very high masts will set a limit. The authors of the paper are fully alive to this and discuss it. They advocate that the finances of every broadcasting organisation should be stretched to the utmost in order to erect very high masts so that the aerial height can be made as large as possible. The statement that "the importance of obtaining a maximum ground ray and a minimum indirect ray would seem to override all questions of economics, and only the mechanical limits of mast height should set a barrier between the ideal and the actual," shows the importance which the authors attach to this matter. Coming from such a quarter it serves to emphasise the troubles which are brewing in the broadcasting world.

G. W. O. H.

BANDOENG RECEIVING STATION.



One of the short-wave telephony receiving sub-stations at Bandoeng, Java, in course of erection. Three separate receiving stations are employed, the signals so received being combined at one amplifier as a means of reducing fading.

An Apparatus for the Projection of Frequency-Output Characteristics.

By C. G. Garton and G. S. Lucas.

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IN the course of any serious work on the design either of amplifiers, intervalve transformers, or loud speakers, it becomes necessary to obtain curves connecting the frequency of the input power and the amplitude of the resultant output, more briefly called the "frequency-output" characteristic. These curves have for some years been familiar to those interested in the subject in the case of intervalve transformers, but it is only comparatively recently that careful investigation has been made into the frequency characteristics of complete amplifiers and loud speakers.

Although the importance of an accurate knowledge of the frequency characteristic has for some time been realised, the methods available for obtaining such curves have been extremely tedious, and have prevented the development which the importance of the subject deserves.

The obvious method of obtaining the required information is to provide a source of power of adjustable frequency, and to take a series of simultaneous readings on input and output meters. Anyone familiar with work of this type will realise the time required and the difficulties involved in repeating results owing to gradual changes in the apparatus with time. In the case of loud-speaker characteristics, also, the curve is of such an irregular nature that a very great number of readings is necessary before an accurate result can be obtained.

Efforts have been made by various experimenters* to evolve bridge methods of measurement, in which the ratio of input to output is determined by obtaining zero deflection or zero sound on a galvo. or telephone respectively. While these methods eliminate the tediousness of taking numerous meter readings, the time required is still inconveniently long, and considerable care is necessary in order to obtain satisfactory results. Moreover, bridge circuits take account of phase relationship between input and output, which renders the method inapplicable to loud-speaker problems, since the phase of the emitted sound arriving at the measuring microphone varies with the relation between the wavelength and the distance separating the loud speaker and microphone. The complication introduced by this more than counterbalances any advantages of the method.

The authors, being continually concerned with the characteristics of audio-frequency apparatus, were led to devise an equipment which should quickly and automatically trace the frequency characteristic of any piece of apparatus appropriately connected with it, the labour involved being thus reduced to the mere operation of control knobs, and the time to a negligible amount.

With such a device it is feasible to take a large number of curves in quick succession, without undue labour or fatigue, making it possible for the experimenter quickly to see the results of any changes made in the apparatus under investigation. Moreover, the experimenter is left free to concentrate on the work in hand, without being distracted by the routine task of taking numerous readings.

It should be acknowledged at this point that the basic idea of such a method is not novel, a somewhat similar scheme having been described by B. S. Cohen and colleagues†, but their apparatus, as published,

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* "The Performance of L.F. Transformers," D. W. Dye, B.Sc., *E.W. & W.E.*, September, 1924, Vol. I, p. 691. "The Performance of Amplifiers," H. A. Thomas, M.Sc., *J.I.E.E.*, February, 1926, Vol. 64, p. 253. Discussion, *ibid.*, p. 274. "L.F. Intervalve Transformers," P. W. Willans, M.A., *J.I.E.E.*, October, 1926, Vol. 64, p. 1065.

† "Frequency Characteristics of Telephone Systems and Audio-frequency Apparatus," B. S. Cohen, A. J. Aldridge and W. West, *J.I.E.E.*, October, 1926, Vol. 64, p. 1023.

is applicable only to the taking of photographic records, whereas the authors, by incorporating a second deflecting mirror, are able to obtain characteristics projected upon a stationary screen, a form more suited to laboratory work where rapid and non-permanent indications are desired. Moreover, Cohen's method involved the rectification of the output from the apparatus under test, in order to secure the operation of a moving coil galvanometer, while the authors, by developing a novel and very sensitive form of hot wire galvanometer, are able to dispense with rectification and its attendant difficulties.

The object of this paper is to give a description of the construction, operation and scope of the projecting apparatus. The detailed construction of each component will be dealt with at a later stage, but the following paragraphs will give a general outline of the principles involved and the necessary apparatus.

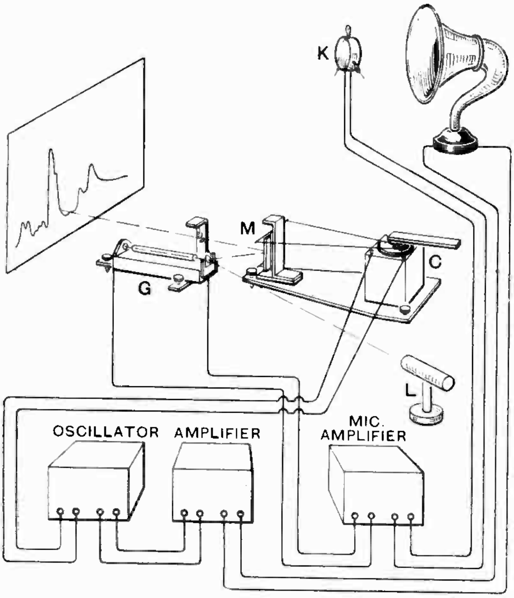

Fig. 1.—*Arrangement of Apparatus.*

The first essential in any method of tracing frequency characteristics is a source of power of which the frequency can be continuously varied over the entire audio range, without variation of the voltage or current supplied. Such a device is termed a "constant voltage generator." Secondly, in order to project a curve in rectangular co-ordinates, two deflections at right angles are required; one providing a horizontal scale of frequency; the second, in a vertical direction, representing output. The second deflection is readily obtained by the motion of a galvanometer mirror actuated by the output of the apparatus under test. The frequency deflection may be obtained by turning the galvanometer bodily about an axis normal to the axis of deflection of its mirror, in synchronism with the frequency control of the generator; or more conveniently by a mirror mechanically coupled to the frequency control, on which the beam of light falls in its passage from the galvo. mirror to the screen. The latter alternative has been chosen by the authors as simplifying the design of the galvo.

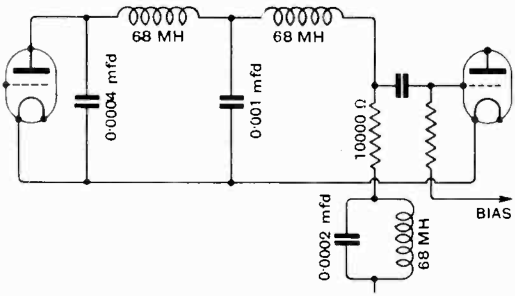

Fig. 2.—*Filter Circuit.*

Fig. 1 gives a schematic view of the apparatus as arranged for obtaining the characteristic of a loud speaker. Power from the constant voltage generator is supplied to the loud speaker, the sound energy emitted being picked up by a microphone K and passed on to an amplifier. The amplified energy, proportional to the output of the loud speaker, operates the galvo. G (shown in detail in Fig. 4), thus deflecting the beam of light along a vertical axis. A condenser C, forming the frequency control of the generator, is coupled to the second mirror M, as shown more completely in Fig. 3. Variation of the frequency, by rotation of C, thus causes a corresponding deflection of the light beam along the horizontal frequency axis. The simultaneous combination of the two deflections obviously traces the "frequency-output" characteristic of the loud speaker. Particulars of the circuit modifications necessary for obtaining curves on transformers and amplifiers will be given after the detailed description of the apparatus.

The constant voltage generator used is substantially that described by H. L. Kirke* in *E.W. & W.E.*, but with certain small modifications found necessary in the course of experiment. For the benefit of those not having access to Kirke's paper, it may be briefly explained that the generator consists of two radio-frequency oscillator circuits, tuned to about 10^5 cycles, of which one is variable over the range $.9 \times 10^5$ to 1.0×10^5 cycles. The difference frequency, variable from 0 to 10^4 cycles, is picked up in a "mixing" circuit, detected, and amplified. A variable condenser in the tuned circuit of one oscillator forms a convenient means of varying the output frequency.

The main modification which the authors found necessary was in the method of filtering out unwanted radio-frequency components from the audio-frequency output. With the published arrangement of filter circuits it was found impossible, in the authors' generator, simultaneously to obtain a uniform "frequency-output" characteristic and an adequate freedom from radio-frequency interference. The cause could not be discovered, but the difficulty was solved by the use of a different filter circuit, shown in Fig. 2, interposed between the detector valve and the first amplifier. The other filters were discarded. Other modifications were the provision of two large-power valves in the final stage, giving an output of 2.5 watts, and the substitution of a potentiometer resistance in the output circuit in place of an output transformer. The characteristics of the latter device are likely to vary with the type of load which is being supplied; a resistance is more stable in this respect. The final stage is "choke-capacity" coupled to the output circuit, and a useful addition, when working on loud-speaker characteristics, is a variable high resistance across this capacity; so that a D.C. component may be superposed on the alternating output of the generator. The variation in output is within ± 2 per cent. between 100 and 10,000 cycles, and within 5 per cent. at 50 cycles.

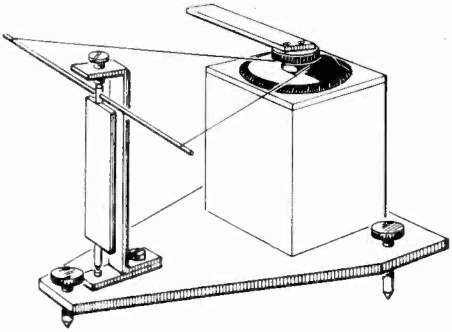

Fig. 3.—*Rotating Mirror.*

As previously explained, frequency control is obtained by a condenser in the tuned circuit of one oscillator, and use is made of the rotation of this condenser to operate the deflecting mirror which provides the frequency axis. As shown in Fig. 3, the mechanical coupling between mirror and condenser is of the simplest possible form. A thread passing round the spindle of the condenser is secured at both ends to opposite arms of a bar passing through the mirror spindle. The thread may be tightened by winding the surplus upon the bar, while different "gear ratios" are obtained by spreading the ends nearer or farther apart along its length. The calibration of the frequency scale will not in general be uniform, but will depend upon the shape of the condenser plates and upon the mechanical characteristics of the coupling. The authors have found convenient a scale which is "spread out" at the lower end up to about 1,000 cycles, and is thereafter approximately linear.

The flexible lead from the oscillator circuit to the condenser and the condenser itself should preferably be shielded to avoid erratic changes of frequency due to movements of the operator.

The next essential component to be described is the galvanometer, which records the output of the apparatus under test. The requirements are:—

(1) That it should be sensitive, so as to demand as little power as possible from its associated amplifier.

(2) Its indications should be independent of phase and frequency.

(3) It should be capable of being arranged to deflect about a horizontal axis, so that the "output" scale is projected vertically.

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* "The Design of a Heterodyne Type Low Frequency Oscillator," H. L. Kirke, *E.W. & W.E.*, February, 1927, Vol. 4, p. 67.

Requirement (1) rules out the use of soft iron instruments; dynamometer types do not comply with (1) if both windings be supplied from the same source, nor with (2) if the field be separately excited, while requirement (3) prevents the use of any type involving the usual galvanometer suspension.

We are left with three possibilities; rectification of the output, and the use of a pivoted moving coil milliammeter; a vacuo-thermo-junction and a pivoted microammeter; or some form of hot wire instrument. The first expedient, as noted above, has been successfully used by B. S. Cohen, operating a suspended type of galvanometer, but the problem of obtaining distortionless rectification of sufficient power to operate a moderately robust pivoted instrument is one to be avoided if other methods are available. The second suggestion, which obtains rectification by a thermo-junction, would probably be quite successful, but the microammeter required would be a somewhat delicate and costly instrument.

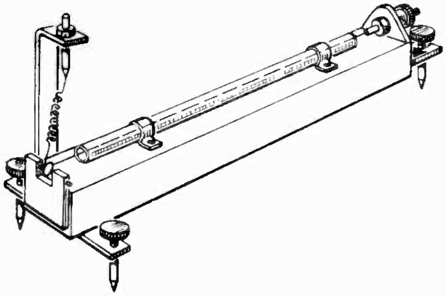

Fig. 4.—*Galvanometer.*

The authors finally decided to eliminate rectification altogether, and to concentrate upon the design of a suitable hot wire instrument, and an unexpectedly simple construction proved to have all the required characteristics. The essential features of the design are shown in Fig. 4. A fine filament of tungsten, forming the hot wire, is secured at one end to the wooden base by a tensioning screw, and at the other end passes through 90 deg. around a small steel spindle free to rotate in jewelled pivots. The free end of the wire is then secured to a helical spring, which holds it in tension. It will be realised that any expansion of the wire, due to current passed through it, will result in a corresponding rotation of the small spindle, provided that slip does not occur between it and the wire. A galvanometer mirror, secured to the spindle with shellac, serves to record the amount of rotation upon the screen. Since the angular motion obtained, for a given expansion of the wire, is inversely proportional to the diameter of the spindle, the sensitivity may be increased indefinitely by decreasing the diameter, subject to mechanical limitations.

Some dimensions and practical details of the authors' instrument will be useful to anyone contemplating the construction of a similar device. The wire used is of tungsten 16in. long and 0.0006in. (six ten-thousandths) in diameter. The spindle is of hardened steel, ground to pivot points at the ends, $\frac{5}{8}$in. in length, and 0.025in. in diameter The mirror attached to it is the usual galvanometer type, of $\frac{3}{8}$in. diameter and 2 metres focal length. The tension upon the wire does not appear to be important, so long as it is sufficient to keep the wire straight, and tightly stretched around the spindle. The base, which carries the fixed supports, is of wood and is provided with three levelling screws. It is essential that the wire be protected from draughts, and it is therefore surrounded by a metal tube, $\frac{1}{2}$in. diameter and 15in. long, slotted longitudinally so that it may be placed in position over the wire, and secured to the base.

The technique of handling tungsten wire of such small diameter is somewhat difficult, but is soon acquired. Work should be carried on in a strong light over white paper, using instrument tweezers for manipulation. The ends of the wire are best secured by the use of a short length of soft nickel or copper wire about .04in. in diameter. One end of this is hammered flat and bent over upon itself through 180 deg., so forming a flat hook. The end of the tungsten wire is drawn into this, and the hook strongly compressed upon it with pliers. A few trials will show the degree of compression needed to grip the tungsten firmly without breaking it. When equipped with these ends the wire may be secured in any desired manner to the tensioning screw and spring. After a little experience a new wire can be mounted in less than half an hour. When the wire is in position and under tension it is desirable to pass through it momentarily a current as great as can be used without destructive effect (about 100 milliamps in the case of .0006in. tungsten). This has the double effect of annealing any kinks in the wire, and of removing traces of grease, etc., which cause the wire to cling to the spindle instead of rolling freely. To prevent slipping between wire and spindle a minute spot of shellac should be applied after the wire is in position. The spot must be so small that it does not reach the points where the wire is to roll on and off the spindle, and it is best applied with a penknife blade, covered with a film of nearly dry shellac varnish, and held at 45 deg. to the direction of the wire.

The calibration obtained is given in Fig. 5.

In the authors' instrument no attempt has been made to provide compensation for changes in ambient temperature, and the zero is consequently somewhat unstable, but it is a simple matter to re-level the instrument before taking a curve. Also, no attempt has been made to obtain maximum sensitivity, nor are the dimensions quoted above in any way critical, the instrument being the first model constructed from spare material readily available in the laboratory.

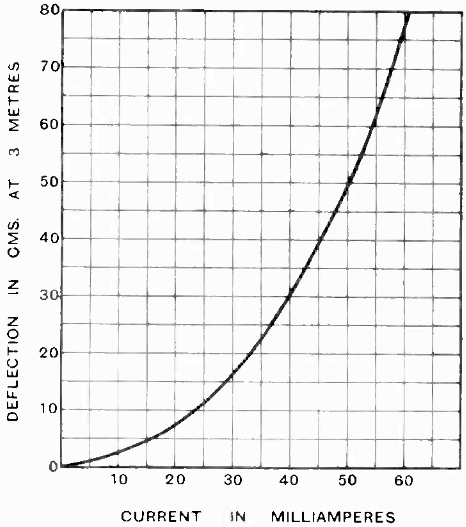

Fig. 5.—*Calibration Curve of Galvanometer.*

There is no doubt that by using finer wire and a smaller spindle, or by employing one of the mechanical multiplying devices common on hot wire instruments, the sensitivity could be increased, but the authors have preferred to retain the simplicity and robustness of the first model, since ample power was available to operate it.

The optical system finally adopted for projecting the spot of light is extremely simple. A small (10 amp.) carbon arc lamp is provided with an opaque diaphragm pierced with a circular hole $\frac{1}{4}$in. in diameter. The divergent cone of light emerging falls on the galvanometer mirror, and is reflected thence to the larger mirror of the frequency control device, from which it is reflected to the screen. The galvanometer mirror having a focal length of 2 metres, if the arc be placed at about that distance from the mirror an approximately parallel beam will be reflected therefrom. Although this does not form a true optical image upon the screen the spot obtained is sufficiently definite, and the method has the advantage of requiring no lenses and no accurate focussing. A suitable arrangement of the various components is shown in Fig. 1.

If a more intense spot of light is required, a convex lens, about 0.25 metres focal length, may be placed directly in front of the arc lamp diaphragm, which has the effect of directing more light upon the mirror. The spot is made somewhat larger, but much brighter.

In obtaining loud-speaker characteristics a microphone and amplifier are needed to operate the galvanometer. These will now be described. The choice of microphone is practically limited to three types: a good type of carbon instrument, such as the Reisz pattern; the magnetophone, which depends on the motion of a coil in an annular magnetic field; and the electrostatic type in which the motion of a stretched membrane is used to give capacity variations corresponding to the sound pressure.

From considerations of sensitivity the carbon microphone is much to be preferred, being between 10^2 and 10^3 times more sensitive than the other types; but it is inherently unstable in its characteristic, depending as it does on the chance variations of contact between carbon granules. With a well-designed instrument, quite good results are obtainable, but the authors feel that it is advisable for regular work in the laboratory to adopt a more stable type. For lecture and demonstration purposes, where the great insensitivity of other types would demand inconvenient values of amplification, the carbon pattern is undoubtedly preferable. As between the magnetophone and the condenser microphone, the latter has the advantage of small bulk, and does not require an auxiliary magnetic field ; the authors have therefore adopted the latter instrument. With any microphone it is, of course, essential to have a calibration of the instrument (generated volts against frequency) obtained by some absolute method such as the Rayleigh disc.*

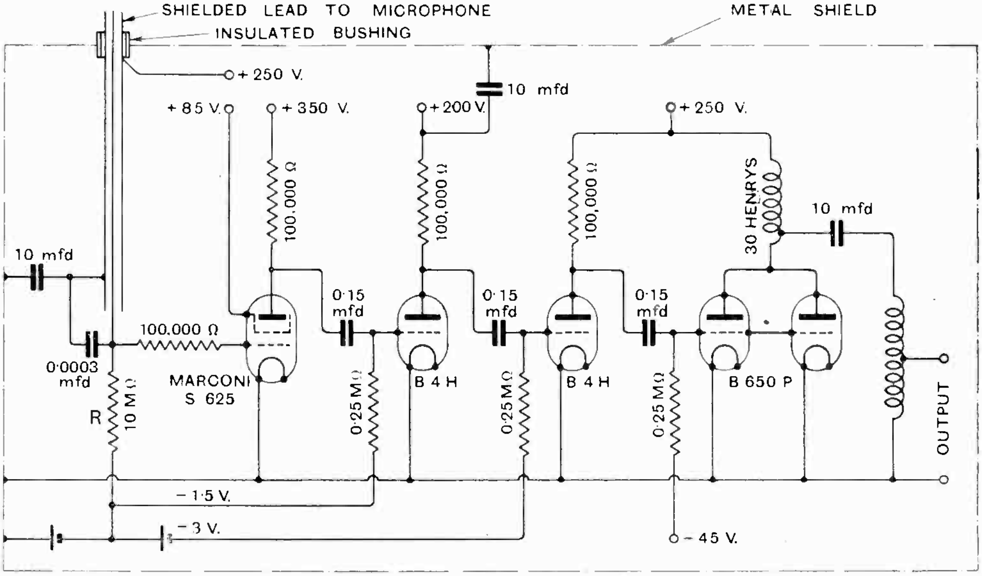

Fig. 6.—*Microphone Amplifier.*

Although it is not at present possible to design a microphone having a linear characteristic over the entire frequency range, such a characteristic can be achieved for the amplifier, and is highly desirable in order to minimise the necessity for correcting the curves obtained. Consequently, a fairly comprehensive description will be given of this part of the apparatus. The connection diagram, with appropriate values, is shown in Fig. 6, but there are a number of points in the design which require explanation.

The coupling of the microphone to the first grid is obtained through the resistance " R," and in order to obtain a satisfactory amplification of the lower frequencies it is necessary that the impedance of the microphone shall be small compared with the value of *R*. The capacity of the microphone used by the authors is only 200 cms., corresponding to an impedance of 14.3 megohms at 50 cycles, and it will be obvious that a value for " R " large compared with 14 megohms is not practicable. Accordingly, a fixed condenser is used in parallel with the microphone, bringing the total capacity to 500 cms., which when used with a 10 megohm value for " R " gives 87 per cent amplification at 50 cycles. It is important that the insulation resistance of the microphone and the parallel condenser should have the highest possible value, since any leakage which occurs will flow through the the resistance " R " and affect the grid bias voltage. Since 200 volts are used on the microphone, a leakage resistance of 1,500 megohms will result in +1.5 volts being applied to the grid circuit, and lower values will give positive grid bias, causing loss of amplification, more particularly at low frequencies, where the microphone impedance is large.

The amplifier is a standard resistance capacity coupled type, with the exception of the first stage, where a screen grid tetrode valve is employed. Although the use of this

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* " The Technique of Testing Microphones and Receivers," B. S. Cohen, M.I.E.E., *J.I.E.E.*, February, 1928, Vol 66, p. 185.

type of valve for audio-frequency amplification is not yet common, very satisfactory results are obtainable where a high voltage amplification is desired, and when adequate plate voltage is available. With the values given in Fig. 6, a "step-up" of about 50 to 1 on the first stage is obtained.

The design of the final stage is a matter of considerable importance, since a large amount of power (2.5 watts) is to be handled, with uniform amplification from 50 to 10^4 cycles. "Choke-capacity-transformer" coupling has been adopted, a transformer being necessary owing to the low resistance of the galvanometer, and the capacity coupling serving to keep the superposed D.C. from magnetising the transformer core, thus considerably facilitating the design of the latter. It is difficult, and probably impossible, to design an output transformer to carry a large superposed D.C. current and yet have a good characteristic at both ends of the frequency scale. The transformer used consists of a ring core 2in. in depth, and with stampings $4\frac{5}{8}$in. and $2\frac{1}{4}$in. in external and internal diameters respectively. This is wound with 2,500 turns of .0148in. silk-covered wire, of which 700 turns are tapped off at one end to form the secondary. The secondary section is interleaved between two primary sections, to reduce the leakage reactance.

In general, the characteristic of the amplifier will not, without some adjustment, prove to be level. A tendency to rise at the higher frequencies may be overcome by a small condenser (about 1 to 10 cms.), between the plate and grid of either the second or third valves. An opposite tendency may be neutralised by a similar value of capacity between the plate of the third valve and the grid of the second. These expedients operate by introducing negative and positive reactions respectively, which increase with the frequency. The second method must not be carried to excess, or the amplifier will oscillate.

The method adopted to check the characteristic of this amplifier is shown diagrammatically in Fig. 7. A small voltage is tapped off from the output potentiometer of the constant voltage oscillator, and is injected into the microphone circuit. The condenser "*C*" in Fig. 6 is replaced by one of .0003 mfd., as the 10 μF normally used would short-circuit the injected voltage, also a resistance of 10,000 ohms is inserted in the battery lead for the same reason. By rotating the frequency control the characteristic of the amplifier corresponding to constant voltage from the microphone will be obtained. The total drop at 50 cycles, including the generator drop, is about 20 per cent., and at 100 cycles 5 per cent., the remainder of the curve is flat within ± 2 per cent.

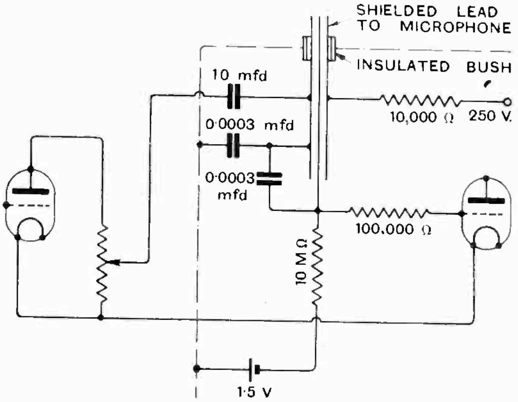

Fig. 7.—*Microphone Calibration Circuit.*

A few precautions are necessary in the design of so sensitive an amplifier to prevent radio-frequency transients from being amplified, otherwise any slight disturbance of the circuit, due to switching for instance, results in sudden and destructive deflections of the galvanometer. The resistance of 0.1 megohm in series with the first grid is one such precaution, also the 10 μF condenser directly connected to the shielding of the condenser cable, and the multiple earthing of the filament circuits by the shortest possible paths as shown. Of course, the whole must be enclosed in a metal box, and this is preferably enclosed again in a heavily felt-lined box to avoid noise from the loud speaker under test reaching the valves and giving spurious microphonic amplification.

In obtaining the characteristics of loud speakers it is essential to specify the type of enclosure in which the loud speaker and microphone are placed, since the sound arriving at the latter is not only that proceeding directly from the former, but is the sum of all the echoes returning from adjacent walls and objects. The ideal would be a room so heavily draped with sound absorbent materials that no echoes could occur, but this cannot be realised in practice, as all available substances reflect more or less of the sound incident upon them. The echoes in any ordinary room are of sufficient magnitude to mask the true nature of any characteristic obtained in it, and it is therefore essential that such tests be carried out in a special room rendered as nearly echoless as possible. That used by the authors is built of wood, 12 ft. by 9 ft. in plan and 9 ft. high. The walls, ceiling and floor are loosely draped with two layers of soft felt, each ½ in. in thickness, and one layer of cotton wool. Although standing waves are not entirely eliminated, they are sufficiently reduced that the general shape of the curves obtained is correct, as determined by numerous check tests taken under various conditions, though significance cannot be attached to every peak and valley. Many workers in acoustics advocate swinging the microphone through an arc while taking readings, in order to average out the effect of standing waves. This method cannot readily be applied to the authors' apparatus, as the light damping of the galvanometer enables it to follow the variations in intensity as the microphone swings, giving a band instead of a line curve. However, by heavily damping the galvanometer with an oil-immersed vane, this can be prevented, and work along these lines is proceeding.

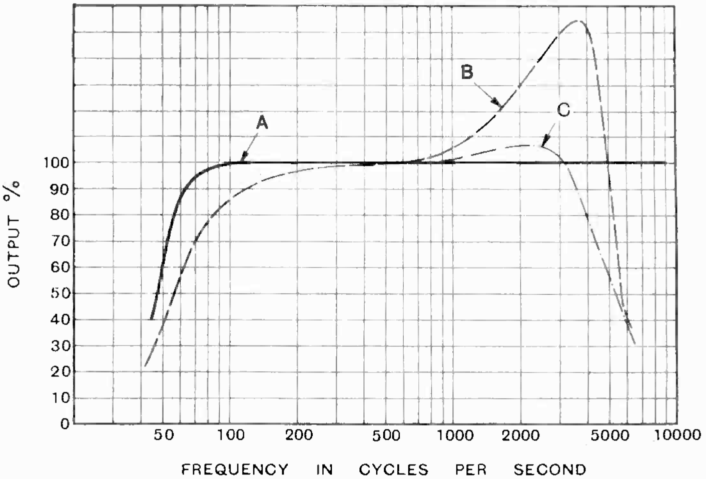

Fig. 8.—*Amplifier Characteristic Curves :*
A—Resistance-capacity-coupled.
B—Transformer-coupled.
C—As " B " Transformer Connections reversed.

We have dealt, so far, mainly with the circuits necessary for the testing of loud speakers, but the apparatus is equally applicable to the obtaining of characteristics of amplifiers and transformers.

In the case of an amplifier, the input circuit is supplied from the constant output oscillator with a constant value either of current or voltage, according to the circumstances under which the amplifier will normally be used. If the final stage of the amplifier is sufficiently large to operate the hot wire galvanometer, it may be coupled to that instrument through a suitable transformer ; otherwise, it is loaded on an appropriate resistance, the voltage across which is used to operate the final stage of the microphone amplifier described above, to which the galvanometer is connected.

In the case of an intervalve transformer a two-stage amplifier should be set up, using the transformer in question for coupling purposes. The first valve must, of course, be the type with which it is intended normally to operate the transformer, and its grid is supplied as in the previous arrangement, with constant voltage from the generator. The second valve has also an influence on the results at high frequencies, due to its reaction upon the transformer secondary ; therefore it should if possible also be similar to that with which the valve will normally work.

It is important, in all these tests, to keep a direct earth connection through all the various amplifier circuits, or unexpected reactions may occur. It is a good practice to earth every negative filament connection. When working in a laboratory subject to radio-frequency disturbance it is essential to use shielded cable when making connections from the generator to the grid circuits of amplifiers.

In Figs. 8 and 9 are given some typical curves obtained by the use of the apparatus. In Fig. 8 are shown characteristic curves for resistance-coupled and transformer-coupled two-stage amplifiers. Curves "*B*" and "*C*" illustrate well the effect of inter-electrode capacity reaction in producing peaks at the higher frequencies, and how this can vary with the direction of the transformer winding. Fig. 9 is typical of results obtained upon loud speakers. Curve "*A*" is obtained from a well-known make of horn type instrument, curve "*B*" from the best available moving coil type, and "*C*" from an instrument similar to "*B*" but with a diaphragm of unsuitable material.

While the greatest field of use for this apparatus lies probably in facilitating quick observation of the effect of changes made during the course of experimental work, it is also well adapted for lecture purposes, since the curves are obtained in large size on a screen, readily visible to an audience. A desirable addition, for laboratory work, would be a camera attachment to the galvanometer, so that permanent records could be obtained if desired, but no work has yet been done in this direction.

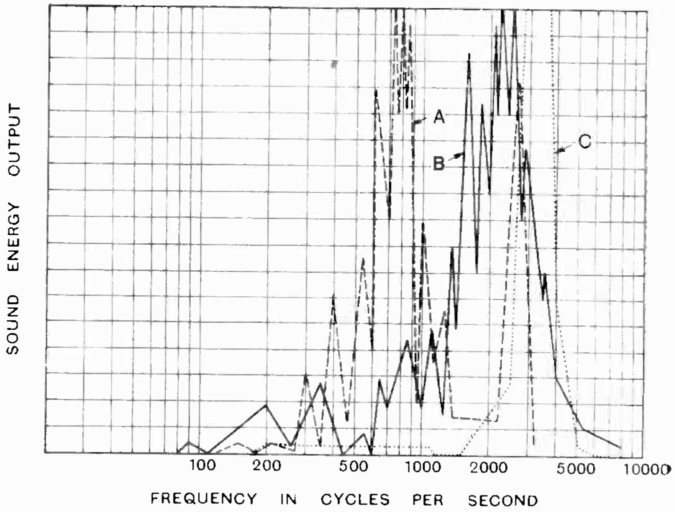

Fig. 9.—*Loud Speaker Curves :*
A—Horn Type Loud Speaker.
B—Good Moving Coil Loud Speaker.
C—Bad Moving Coil Loud Speaker.

In conclusion, the authors wish to express their thanks to the B.T.H. Co., Ltd., for ths use of the resources of their Engineering Laboratory, without which the experimental work of this paper could not have been accomplished.

Effect of Anode-Grid Capacity in Anode-Bend Rectifiers.

By *E. A. Biedermann, B.Sc., A.M.I.E.E.*

Introduction.

THIS subject has been discussed by Mr. W. B. Medlam* in a recent issue of *E.W. & W.E.*, and the conclusion reached that the feed-back due to the anode-grid capacity of the valve leads to considerable distortion. In the writer's opinion, Mr. Medlam's analysis is open to considerable criticism for reasons which are given in the correspondence columns of this issue.

The object of this article is to outline what the writer believes to be the correct theory of the subject, which it will be found leads to results quite opposite to those arrived at by Mr. Medlam.

The case considered by Mr. Medlam is that of an anode-bend detector valve with an input circuit consisting of an inductance L, of resistance r, in parallel with a tuning capacity C, which may be considered to include the grid-filament capacity of the valve.

The anode circuit radio-frequency load is treated in the paper referred to as purely capacitative on the grounds that the impedance, at radio-frequency, of the capacity in the anode circuit is always much less than that of the resistance, or inductance. While this is, no doubt, mostly the case, it may not be so invariably—for example, with RC coupling using a comparatively low value of anode resistance—and as it is not obvious what the effect of the resistance may be, the more general case will be considered of an anode circuit consisting of a resistance R_a in parallel with a capacity C_a. In the case of transformer coupling it will certainly be legitimate to regard the anode circuit as being for all practical purposes purely capacitative so far as the radio-frequency is concerned. This case is therefore obtained by making R_a infinite.

For convenience of comparison the same symbols will for the most part be employed as in the article referred to, but $E \sin \omega t$ will in the present article be taken to denote, not the grid-filament potential difference, but the effective E.M.F. acting in the input circuit.

The method of impedance operators will be used instead of the differential equations employed by Mr. Medlam, the former method facilitating the mathematical work.

Input Circuit Relations.

The equivalent circuit of the valve with its associated input and output circuits, as described above, is shown in Fig. 1, where the arrows denote the directions in which the various currents and voltages are regarded as positive for the purpose of forming the circuit equations.

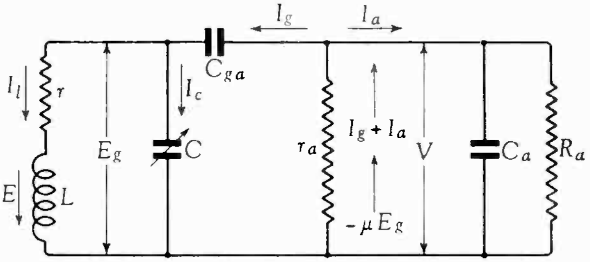

Fig. 1.

The same symbols will be used for the vectors representing the various quantities as for the maximum values of those quantities, since it is easy to distinguish where the vector quantities are referred to and where the scalar magnitudes.

Referring to the figure, we have the following relations for the input circuit, where E denotes the effective E.M.F. acting in the inductance of the input circuit:

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* Effect of Anode-Grid Capacity in Detectors and L.F. Amplifiers, by W. B. Medlam, B.Sc., A.M.I.E.E. (*E.W. & W.E.*, Oct., 1928).

$$E + E_g = (r + j\omega L)I_l \quad .. \quad .. \quad (1)$$

$$I_c = j\omega C E_g \quad .. \quad .. \quad .. \quad (2)$$

$$I_g = I_l + I = j\omega C_{ga}(V - E_g) \quad .. \quad (3)$$

from which

$$I_l = I_g - I_c = j\omega C_{ga}V - j\omega(C + C_{ga})E_g$$

and hence, by (1)

$$E + E_g = (r + j\omega L)\{j\omega C_{ga}V - j\omega(C + C_{ga})E_g\} \quad .. \quad (4)$$

We shall now introduce the, at present, undetermined relation

$$V = -(\mu_1 + j\mu_2)E_g \quad .. \quad .. \quad (5)$$

On substituting this in (4), we obtain

$$E + E_g = (r + j\omega L)\{(\mu_2 - j\mu_1)\omega C_{ga} - j\omega(C + C_{ga})\}E_g$$

so that

$$E_g = \frac{E}{\{(\omega^2 LC_0 - 1 + \mu_2 r\omega C_{ga}) - j(r\omega C_0 - \mu_2\omega^2 LC_{ga})\}} \quad .. \quad .. \quad (6)$$

where

$$C_0 = \{C + (\mu_1 + 1)C_{ga}\} \quad .. \quad .. \quad (7)$$

Hence the instantaneous value of E_g is given by

$$e_g = E_g \sin(\omega t + \theta) \quad .. \quad .. \quad (8)$$

where

$$E_g = \frac{E}{\sqrt{(\omega^2 LC_0 - 1 + \mu_2 r\omega C_{ga})^2 + (r\omega C_0 - \mu_2\omega^2 LC_{ga})^2}} \quad .. \quad .. \quad (9)$$

and

$$\tan\theta = \frac{(r\omega C_0 - \mu_2\omega^2 LC_{ga})}{(\omega^2 LC_0 - 1 + \mu_2 r\omega C_{ga})} \quad .. \quad (10)$$

Output Circuit Relations.

Referring again to Fig. 1, the anode circuit relations are

$$V = -\mu E_g - r_a(I_g + I_a) \quad .. \quad (11)$$

$$I_g = j\omega C_{ga}(V - E_g) \quad .. \quad .. \quad (12)$$

$$I_a = \left(\frac{1}{R_a} + j\omega C_a\right)V \quad .. \quad .. \quad (13)$$

from which

$$V = -\mu E_g - r_a\left\{j\omega C_{ga}(V - E_g) + \left(\frac{1}{R_a} + j\omega C_a\right)V\right\}$$

so that

$$V = \frac{-(\mu - jr_a\omega C_{ga})E_g}{\left\{\left(1 + \frac{r_a}{R_a}\right) + jr_a\omega(C_a + C_{ga})\right\}}$$

$$= -\frac{\left[\left\{\mu\left(1 + \frac{r_a}{R_a}\right) - r_a^2\omega^2(C_a + C_{ga})C_{ga}\right\} - jr_a\omega\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}\right]E_g}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega^2(C_a + C_{ga})^2\right\}}$$

Comparing this with (5), we obtain

$$\mu_1 = \frac{\left\{\mu\left(1 + \frac{r_a}{R_a}\right) - r_a^2\omega^2(C_a + C_{ga})C_{ga}\right\}}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega^2(C_a + C_{ga})^2\right\}} \quad (14)$$

$$\mu_2 = \frac{-r_a\omega\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega^2(C_a + C_{ga})^2\right\}} \quad (15)$$

Tuning Condition and Corresponding Value of E_g.

It will be seen that both μ_1 and μ_2 are independent of C, so that $\frac{dC_0}{dC} = 1$, by (7), and the condition for E_g to be a maximum for the carrier wave frequency, for which we may put $\omega = \omega_c$, is, from (9), found to be

$$C_0 = \frac{L}{(r^2 + \omega_c^2 L^2)} \quad .. \quad (16)$$

Substituting this value of C_0 in (9), we find

$$E_g = \frac{E}{\sqrt{\left\{\frac{\omega^2 L^2}{(r^2 + \omega_c^2 L^2)} - 1 + \mu_2 r\omega C_{ga}\right\}^2 + \left\{\frac{r\omega L}{(r^2 + \omega_c^2 L^2)} - \mu_2\omega^2 LC_{ga}\right\}^2}},$$

which reduces to

$$E_g = \frac{\sqrt{r^2 + \omega^2 L^2}\,E}{\sqrt{\{r - \mu_2(r^2 + \omega^2 L^2)\omega C_{ga}\}^2 + \frac{\omega^2(\omega^2 - \omega_c^2)^2 L^6}{(r^2 + \omega_c^2 L^2)^2}}},$$

and for the corresponding value of tan θ we find from (10)

$$\tan\theta = \frac{\{r - \mu_2(r^2 + \omega_c^2L^2)\omega C_{ga}\}\omega L}{-\left\{(r - \mu_2(r^2 + \omega_c^2L^2)\omega C_{ga}) - \frac{(\omega^2 - \omega_c^2)L^2}{r}\right\}r}.$$

Since $\frac{r^2}{\omega^2L^2}$ is always very small compared with unity, we can neglect r^2 compared with ω^2L^2 and $\omega_c^2L^2$, so that the above expressions reduce to

$$E_g = \frac{\omega LE}{r\sqrt{\left(1 - \frac{\mu_2\omega^3L^2C_{ga}}{r}\right)^2 + \frac{\omega^2(\omega^2 - \omega_c^2)^2L^2}{\omega_c^4r^2}}} \quad .. \quad (17)$$

and $\tan\theta =$

$$\frac{(r - \mu_2\omega\omega_c^2L^2C_{ga})\omega L}{-\left\{(r - \mu_2\omega\omega_c^2L^2C_{ga}) - \frac{(\omega^2 - \omega_c^2)L^2}{r}\right\}r} \quad (18)$$

Evaluation of E_g in Terms of $\frac{m}{\omega_c}$.

Putting $\mu_2 = -\,\omega\phi(\omega)$ .. .. (19)

where, from (15),

$$\phi(\omega) = \frac{r_a\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega^2(C_a + C_{ga})^2\right\}} \quad (20)$$

we have for any side band frequency $\omega = (\omega_c + m)$ (where m may have both positive and negative values)

$$\begin{aligned}\phi(\omega) &= \phi(\omega_c + m) = \phi(\omega_c) + m\phi'(\omega_c) + \tfrac{1}{2}m^2\phi''(\omega_c) + \text{etc.}\\ &= \phi(\omega_c)\left\{1 + \frac{\omega_c\phi'(\omega_c)}{\phi(\omega_c)}\frac{m}{\omega_c} + \frac{\omega_c^2\phi''(\omega_c)}{2\phi(\omega_c)}\frac{m^2}{\omega_c^2} + \text{etc.}\right\}\\ &= \phi(\omega_c)\left\{1 - 2a\frac{m}{\omega_c} - a(1-4a)\frac{m^2}{\omega_c^2}\right\} \quad (21)\end{aligned}$$

on neglecting higher powers of $\frac{m}{\omega_c}$ than squares, where

$$\phi(\omega_c) = \frac{r_a\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a\omega_c^2(C_a + C_{ga})^2\right\}} \quad (22)$$

and
$$a = \frac{r_a^2\omega_c^2(C_a + C_{ga})^2}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega_c^2(C_a + C_{ga})^2\right\}} \quad (23)$$

Writing (17)

$$E_g = \frac{\omega L}{r}\frac{E}{A} \quad .. \quad .. \quad (24)$$

we have

$$\begin{aligned}A^2 &= \left(1 - \frac{\mu_2\omega^3L^2C_{ga}}{r}\right)^2 + \frac{\omega^2(\omega^2 - \omega_c^2)^2L^2}{\omega_c^4r^2}\\ &= \left(1 + \frac{\phi(\omega)\omega^4L^2C_{ga}}{r}\right)^2 + \frac{\omega^2(\omega^2 - \omega_c^2)^2L^2}{\omega_c^4r^2}\\ &= \left[1 + \frac{\phi(\omega_c)\omega_c^4L^2C_{ga}}{r}\left(1 + \frac{m}{\omega_c}\right)^4\left\{1 - 2a\frac{m}{\omega_c} - a(1 - 4a)\frac{m^2}{\omega_c^2}\right\}\right]^2\\ &\quad + \frac{\omega_c^2L^2}{r^2}\left(1 + \frac{m}{\omega_c}\right)^2\left(2\frac{m}{\omega_c} + \frac{m^2}{\omega_c^2}\right)^2\end{aligned}$$

Putting

$$(r + \phi(\omega_c)\omega_c^4L^2C_{ga}) = r_0 \quad .. \quad .. \quad (25)$$

and neglecting higher powers of $\frac{m}{\omega_c}$ than squares, we obtain

$$\begin{aligned}A^2 &= \left[\frac{r_0}{r} + \left(\frac{r_0}{r} - 1\right)\left\{2(2 - a)\frac{m}{\omega_c} + (6 - 9a + 4a^2)\frac{m^2}{\omega_c^2}\right\}\right]^2 + \frac{4\omega_c^2L^2}{r^2}\frac{m^2}{\omega_c^2}\\ &= \frac{r_0^2}{r^2}\left[1 + 4(2 - a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}\right.\\ &\quad + \left\{2(6 - 9a + 4a^2)\left(1 - \frac{r}{r_0}\right)\right.\\ &\quad \left.\left. + 4(2 - a)^2\left(1 - \frac{r}{r_0}\right)^2 + 4\frac{\omega_c^2L^2}{r_0^2}\right\}\frac{m^2}{\omega_c^2}\right]\end{aligned}$$

Now a is essentially less than unity, so that

$$\left\{2(6-9a+4a^2)\left(1-\frac{r}{r_0}\right)+4(2-a)^2\left(1-\frac{r}{r_0}\right)^2\right\}$$

is in any case less than 28. In general, too, a will be only slightly less than unity, which would make the value of the above expression less than 6, and usually considerably less, since $\left(1 - \frac{r}{r_0}\right)$ is essentially less than unity.

On the other hand, $\frac{4\omega_cL^2}{r_0^2}$ is, in general, very large, of the order 1000 at the very least, so that only a very small error can be introduced by neglecting the above terms in the coefficient of $\frac{m^2}{\omega_c^2}$, an error, in fact at the most only of the order $\frac{r_0^2}{\omega_c^2 L^2}$ compared with unity.

We can therefore put

$$A^2 = \frac{r_0^2}{r^2}\left\{1 + 4(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega} + 4\frac{\omega_c^2 L^2}{r_0^2}\frac{m^2}{\omega_c^2}\right\}$$

so that

$$\frac{1}{A} = \frac{r}{r_0}\left\{\left(1 + 4\frac{m^2L^2}{r_0^2}\right) + 4(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}\right\}^{-\frac{1}{2}}$$

$$= \frac{r}{r_0}\left(1 + 4\frac{m^2L^2}{r_0^2}\right)^{-\frac{1}{2}} \left\{1 + \frac{4(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}}{\left(1 + 4\frac{m^2L^2}{r_0^2}\right)}\right\}^{-\frac{1}{2}}$$

Now

$$\frac{m}{\omega_c}\Big/\left(1 + 4\frac{m^2L^2}{r_0^2}\right) = \frac{m}{\omega_c}\Big/\left(1 + 4\frac{\omega_c^2 L^2}{r_0^2}\frac{m^2}{\omega_c^2}\right),$$

which cannot be greater than $\frac{r_0}{4\omega_c L}$. Since $4(2-a)\left(1 - \frac{r}{r_0}\right)$ is essentially less than 8, and usually less than 4, owing to a being, in general, only slightly less than unity, the term involving $\frac{m}{\omega_c}$ in the expression for $\frac{1}{A}$ is less than $\frac{2r_0}{\omega_c L}$, usually less than $\frac{r_0}{\omega_c L}$. We have already neglected terms of the order $\frac{r^2}{\omega_c^2 L^2}$ compared with unity, and $\frac{r_0^2}{\omega_c^2 L^2}$ will not be of a higher order of magnitude than $\frac{r^2}{\omega_c^2 L^2}$. We can, therefore, safely neglect terms of the order $\frac{r_0^2}{\omega_c^2 L^2}$ compared with unity, and therefore obtain finally

$$\frac{1}{A} = \frac{r}{r_0}\left(1 + 4\frac{m^2L^2}{r_0^2}\right)^{-\frac{1}{2}} \left\{1 - \frac{2(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}}{\left(1 + 4\frac{m^2L^2}{r_0^2}\right)}\right\}$$

Hence, from (24),

$$E_g = \frac{\omega_c L}{r_o}\left(1 + 4\frac{m^2L^2}{r_0^2}\right)^{-\frac{1}{2}}\left(1 + \frac{m}{\omega_c}\right) \left\{1 - \frac{2(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}}{\left(1 + 4\frac{m^2L^2}{r_0^2}\right)}\right\}E$$

Since we have seen that the expression involving $\frac{m}{\omega_c}$ in the last factor is always less than $\frac{r_0}{\omega_c L}$, we can clearly neglect the term involving $\frac{m^2}{\omega_c^2}$, and so obtain finally

$$\left.\begin{aligned} E_g &= \frac{\left(1 + B\frac{m}{\omega_c}\right)}{\sqrt{1 + 4\frac{m^2L^2}{r_0^2}}}\frac{\omega_c L}{r_0}E \\ \text{where}\quad B &= \left\{1 - \frac{2(2-a)\left(1 - \frac{r}{r_0}\right)}{\left(1 + 4\frac{m^2L^2}{r_0^2}\right)}\right\} \end{aligned}\right\} \quad \ldots \quad (26)$$

$B\frac{m}{\omega_c}$ will always differ from $\frac{m}{\omega_c}$ only by a quantity less than $\frac{r_0}{\omega_c L}$.

We can now compare the case of an actual detector valve with that of a hypothetical valve having no appreciable anode-grid capacity. In the latter case, by (25), $r_0 = r$, so that $B = 1$.

Hence in this case

$$E_g = \frac{\left(1 + \frac{m}{\omega_c}\right)}{\sqrt{1 + 4\frac{m^2L^2}{r^2}}}\frac{\omega_c L}{r}E$$

Except, therefore, for the small difference due to the fact that in the case of an actual valve $B\frac{m}{\omega_c}$ is equal to $\frac{m}{\omega_c}$ plus a quantity less than $\frac{r_0}{\omega_c L}$, the effect of the anode-grid capacity is only to increase the resistance of the input circuit from r to r_0. This reduces distortion by reducing the extent to which the side bands are cut off.

So far, therefore, as the effect of the feedback on the *amplitude* of the side bands is concerned, it is clear that no distortion of any significant amount is produced, but that, on the contrary, quality tends to be improved by the flattening of the resonance curve due to an increase in the effective resistance of the input circuit.

We must next determine the effect on the phase shift of the side-bands.

Evaluation of Phase Shift in Terms of $\frac{m}{\omega_c}$.

The angle θ represents the phase difference between the grid-filament potential difference and the E.M.F. acting in the input circuit. What we have to find, however, is the phase shift between the side-bands and the carrier wave component of the potential difference. Denoting this phase shift by ϕ, we have $\phi = (\theta - \theta_c)$, where θ_c denotes the value of θ for the carrier-wave frequency.

From (18) we have

$$\tan\theta_c = \frac{\omega_c L}{-r}.$$

Thus the feed-back produces no phase shift of the carrier-wave at all.

Putting $(r - \mu_2\omega\omega_c^2L^2C_{ga}) = R$, we find from (18)

$$\tan\phi = \tan(\theta - \theta_c)$$

$$= \frac{\left[\dfrac{\omega LR}{-r\left\{R - \dfrac{(\omega^2-\omega_c^2)L^2}{r}\right\}} - \dfrac{\omega_c L}{-r}\right]}{\left[1 + \dfrac{\omega\omega_c L^2R}{r^2\left\{R - \dfrac{(\omega^2-\omega_c^2)L^2}{r}\right\}}\right]}$$

$$= \frac{-\left\{(\omega-\omega_c)\dfrac{LR}{r} + \dfrac{\omega_c(\omega^2-\omega_c^2)L^3}{r^2}\right\}r}{\left\{\dfrac{R}{r}(r^2+\omega\omega_cL^2) - (\omega^2-\omega_c^2)L^2\right\}}$$

which, on neglecting r^2 compared with $\omega\omega_cL^2$, reduces to

$$\tan\phi = \frac{-\left\{\dfrac{R}{r} + \dfrac{\omega_c(\omega+\omega_c)L^2}{r^2}\right\}\left(\dfrac{r}{\omega_cL}\right)\dfrac{m}{\omega_c}}{\left\{\dfrac{R}{r}\dfrac{\omega}{\omega_c} - \left(\dfrac{\omega^2}{\omega_c^2} - 1\right)\right\}}.$$

Substituting for $\phi(\omega)$ from (21), and neglecting higher powers of $\frac{m}{\omega_c}$ than squares, we have

$$R = (r - \mu_2\omega\omega_c^2L^2C_{ga})$$
$$= (r + \phi(\omega)\omega^2\omega_c^2L^2C_{ga})$$
$$= \left\{r + \phi(\omega_c)\omega_c^4L^2C_{ga}\left(1+\frac{m}{\omega_c}\right)^2\left(1 - 2a\frac{m}{\omega_c} - a(1-4a)\frac{m^2}{\omega_c^2}\right)\right\}$$
$$= \left\{r + \phi(\omega_c)\omega_c^4L^2C_{ga}\left(1 + 2(1-a)\frac{m}{\omega_c} + (1-a)(1-4a)\frac{m^2}{\omega_c^2}\right)\right\}$$
$$= r_0\left\{1 + \left(1-\frac{r}{r_0}\right)(1-a)\left(2\frac{m}{\omega_c} + (1-4a)\frac{m^2}{\omega_c^2}\right)\right\}$$

Substituting for R in the expression for $\tan\phi$, we obtain

$$\tan\phi = \frac{-\left\{1+\left(1-\dfrac{r}{r_0}\right)(1-a)\left(2\dfrac{m}{\omega_c}+(1-4a)\dfrac{m^2}{\omega_c^2}\right)+\left(2+\dfrac{m}{\omega_c}\right)\dfrac{\omega_c^2L^2}{rr_0}\right\}\left(\dfrac{r_0}{\omega_cL}\right)\dfrac{m}{\omega_c}}{\left[\dfrac{r_0}{r}\left(1+\dfrac{m}{\omega_c}\right)\left\{1+\left(1-\dfrac{r}{r_0}\right)(1-a)\left(2\dfrac{m}{\omega_c}+(1-4a)\dfrac{m^2}{\omega_c^2}\right)\right\}-\left(2\dfrac{m}{\omega_c}+\dfrac{m^2}{\omega_c^2}\right)\right]}$$

$$= \frac{-\left[\left(2+\dfrac{m}{\omega_c}\right)+\left\{1+\left(1-\dfrac{r}{r_0}\right)(1-a)\left(2\dfrac{m}{\omega_c}+(1-4a)\dfrac{m^2}{\omega_c^2}\right)\right\}\dfrac{rr_0}{\omega_c^2L^2}\right]\dfrac{mL}{r_0}}{\left[1+\left\{\left(1-2\dfrac{r}{r_0}\right)+2(1-a)\left(1-\dfrac{r}{r_0}\right)\right\}\dfrac{m}{\omega_c}+\left\{(4-7a+4a^2)\left(1-\dfrac{r}{r_0}\right)-\dfrac{r}{r_0}\right\}\dfrac{m^2}{\omega_c^2}\right]}.$$

We can neglect, compared with the terms $\left(2+\frac{m}{\omega_c}\right)$, the terms in the numerator which are multiplied by the very small quantity

$\frac{rr_0}{\omega_c^2L^2}$, while the denominator may be written $\left(1 + b_1\frac{m}{\omega_c} + b_2\frac{m^2}{\omega_c^2}\right)$, where b_1, b_2 are clearly comparable with unity, so that

$$\tan\phi = -\left(2+\frac{m}{\omega_c}\right)\left(1+b_1\frac{m}{\omega_c}+b_2\frac{m^2}{\omega_c^2}\right)^{-1}\frac{mL}{r_0}$$

$$= -\left(2+\frac{m}{\omega_c}\right)\left\{1-b_1\frac{m}{\omega_c}+(b_1^2-b_2)\frac{m^2}{\omega_c^2}\right\}\frac{mL}{r_0}$$

neglecting higher powers of $\frac{m}{\omega_c}$.

Therefore, finally,

$$\left.\begin{aligned} &\tan\phi = -\left(1+\beta\frac{m}{\omega_c}+\gamma\frac{m^2}{\omega_c^2}\right)\frac{2mL}{r_0} \\ &\text{where} \\ &\beta=\left(\frac{1}{2}-b_1\right)=\left\{\frac{3}{2}-2(2-a)\left(1-\frac{r}{r_0}\right)\right\} \\ &\text{and} \\ &\gamma=\left(b_1^2-\frac{1}{2}b_1-b_2\right)=\left\{\frac{5}{2}-(15-12a\right. \\ &\qquad\left.+4a^2)\left(1-\frac{r}{r_0}\right)+4(2-a)^2\left(1-\frac{r}{r_0}\right)^2\right\} \end{aligned}\right\} \quad (27)$$

Since usually a will only be slightly less than unity, β will not differ much from

$$\left\{\frac{3}{2}-2\left(1-\frac{r}{r_0}\right)\right\},$$

nor γ from

$$\left\{\frac{5}{2}-7\left(1-\frac{r}{r_0}\right)+4\left(1-\frac{r}{r_0}\right)^2\right\},$$

so that β and γ will not differ by more than about 2 and 3 from the values, $\frac{3}{2}$ and $\frac{5}{2}$, which they have in the case of a valve with negligible anode-grid capacity. Consequently, so far as is indicated by the factor

$$\left(1+\beta\frac{m}{\omega_c}+\gamma\frac{m^2}{\omega_c^2}\right),$$

the feed-back does not produce any large percentage change in the phase shift of the side-bands. A greater possible change of phase shift is indicated by the factor $\frac{2mL}{r_0}$, but as r_0 is essentially greater than r, this change is always in the direction of decreasing the amount of the phase shift, and this to an equal extent for both positive and negative corresponding side-bands.

Thus, in so far as the feed-back causes an increase of the effective resistance of the input circuit, it decreases any distortion which may arise from phase shift of the side-bands, of which phase shift there is always a certain amount present.

(To be concluded.)

Professor Heinrich Barkhausen, photographed on the occasion of a visit to the laboratory of Baron Manfred von Ardenne in Berlin.

Further Notes on the Calibration Permanence and Overall Accuracy of the Series-gap Precision Variable Air Condenser.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

(Concluded from page 30 of January issue.)

Part II.

A Final Consideration of Overall Constancy.

In Fig. 12 the curve of capacity change due to plate tilting calculated for a moving plate having an intersection capacity of $2.5\mu\mu$F. will be found to be about half that obtained experimentally for a purely axial displacement. A curve giving the error due to this latter defect was given in a previous article* and is reproduced here for the purpose of comparison (Fig. 17, curve SG_2).

Allowing therefore for the possibility of a post-calibration displacement of the whole moving system relative to the fixed system amounting to 5 per cent. purely axial displacement *plus* 5 per cent. tilting or " incline displacement " the resultant consequent change of capacity, it would seem, would certainly be less than 1 part in 5,000 (1 part in 10,000 in frequency).

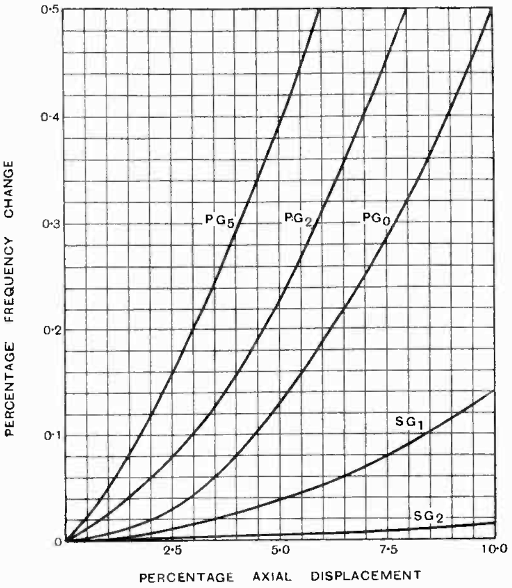

Fig. 17.

The temperature coefficient of capacity of this condenser is always less than that of a precision fixed value air condenser—very appreciably less for the higher scale readings. The temperature coefficient of a *good quality* fixed air condenser (assuming that the contribution to this factor by the insulating mounting is sensibly zero) is positive by the amount of the coefficient of *surface* expansion of the metal from which the conductor plates are constructed and negative by the amount of the coefficient of *linear* expansion of the material of the spacing washers.

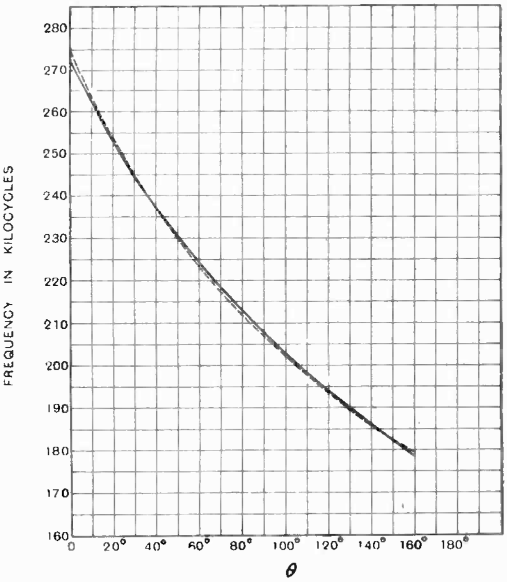

Fig. 18.

The resultant temperature coefficient of capacity is therefore of the order + 0.00001 per degree Fahrenheit (the temperature coefficient of linear expansion of ordinary metals).

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* " The Demonstration of a New Precision Wavemeter Condenser," *E.W. & W.E.*, May, 1928.

In the series-gap variable condenser, since glass or similar material is employed for the moving plate, the negative component of temperature coefficient may be made to compensate for the positive component. In order to make sure that the temperature coefficient has the lowest possible value throughout the range of the condenser its value at the maximum capacity setting should be made sensibly zero by a slight adjustment of the ratio of the moving plate thickness to the dimension of the dielectric air gap.

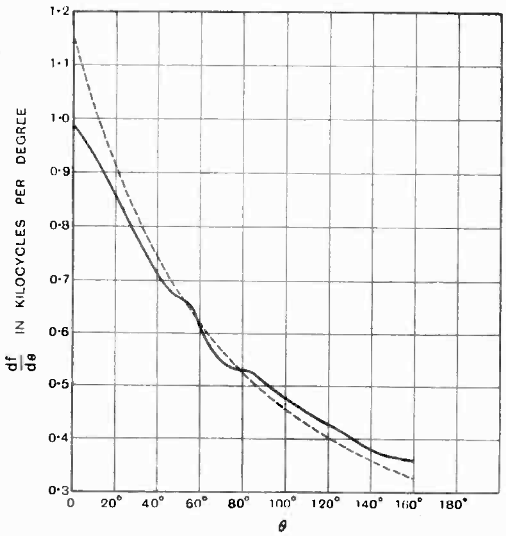


Fig. 19.

Let R be this ratio and x, y and z be the temperature coefficients of linear expansion of fixed plates, spacers and moving plates respectively, then equating positive and negative coefficients

$$2x = y + 0.5R(y - z).$$

from which

$$R = \frac{2(2x - y)}{y - z}$$

approximately for zero temperature coefficient of capacity at its maximum setting.

This assumes that the conducting area of the moving plate extends *very* slightly beyond the boundaries of the fixed plates, a condition which is also advantageous in reducing the field through the insulating material of the moving plate and in increasing the ratio of maximum to minimum capacity if the fixed plate supports are kept well away from the outer edge of the moving plate.

Fortunately, in practice, the gap and plate dimensions are such that this temperature coefficient condition is approximately satisfied. The temperature coefficient at lower capacity settings will, of course, be greater, but even at minimum capacity it will be slightly less than that of a good quality fixed air condenser.

It is seen, therefore, that with a temperature coefficient less than 1 part in 10^5 a temperature variation of 20 deg. F. will not necessitate a calibration correction even for the most accurate sub-standard work.

Methods of Interpolation.

That the reading or setting of the scale will not limit the accuracy of the condenser has already been shown in the previous articles, but mention should, it is thought, be made here of the possible methods of interpolation which can be employed between the points for which a calibration exists.

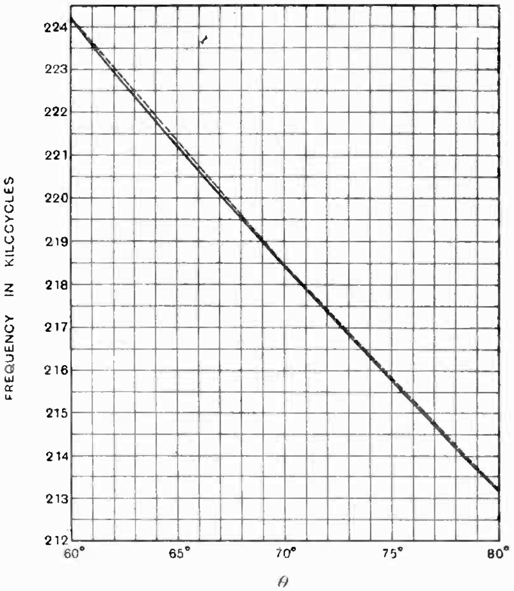


Fig. 20.

Although not impossible it would obviously be costly to construct a series-gap variable condenser so perfectly that its degree of conformity to a linear law of capacity change was of a sufficiently high order to permit linear capacity interpolation between adjacent calibrated points without impairing the high degree of overall accuracy (constancy) obtainable with such a condenser.

If departures from a linear law are present the condenser must be calibrated in terms of frequency at a fairly large number of points (say at about every 10 deg. of its scale of 180 deg., although preferably at exact kilocycle multiples) and a curve of $df/d\theta$ plotted against degree scale reading θ in order to ascertain the variations of law.

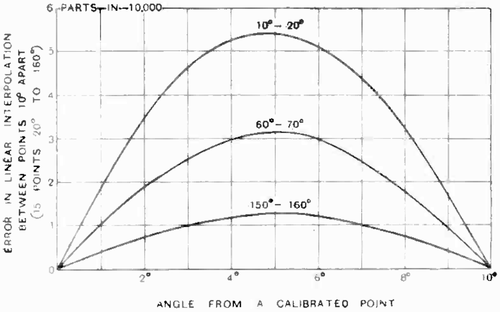


Fig. 21.

Fig. 18 gives a frequency calibration curve for a single range of a wavemeter whose variable condenser has a slope variation of about 15 per cent. throughout its range, the dotted curve of the same figure is the corresponding curve for a truly linear variable condenser.

In Fig. 19 are plotted curves of $df/d\theta$ for these actual and ideal condensers.

The values of $df/d\theta$ are, of course, obtained from the differences between successive calibrated points and are plotted at scale readings midway between such points.

In a wavemeter of many ranges one range could, with little extra cost, be calibrated at a larger number of points than the remainder in order to determine with accuracy the $df/d\theta$ curve which will then have the same characteristics for all ranges.

The exact frequency at any setting of the condenser can now be determined by finding from such a curve the value of $df/d\theta$ corresponding with a point on the degree scale midway between that setting and the nearest calibrated point (f_1) lower on the degree scale and simply computing the required frequency from :

$$f_x = f_1 - \beta \frac{df}{d\theta}$$

where β is the angular difference between the two settings f_x and f_1.

In order to obtain accurate interpolation without computation the frequencies obtained in this manner can, of course, be plotted on large scale curves, such as that of Fig. 20, a curve embracing three calibrated points and extending therefore over 20 deg. of the condenser scale only. The full line curve shows an interpolation curve plotted from the full line $df/d\theta$ curve of Fig. 19. The dotted curve of the same figure shows how closely approximate a linear interpolation may be if the adjacent calibrated points are sufficiently close (10 deg. in the present example).

For linear interpolation, of course, $df/d\theta$ is assumed to be constant between calibrated points and to have the value :—

$$k = \frac{f_1 - f_2}{a}$$

where f_1 and f_2 are the frequencies of the adjacent calibrated points and α the angle between their degree scale settings. The frequency of the required setting is then

$$f_x = f_1 - k\beta \text{ approximately.}$$

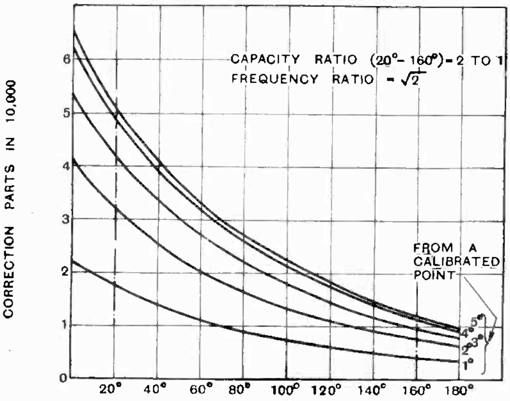


Fig. 22.—*If linear interpolation between adjacent calibration points 10° apart is employed the correction given must be subtracted from the frequency reading.*

The maximum errors introduced by this linear method of approximate interpolation in the present example are about 4 parts in 10,000 between 60 deg. and 70 deg. and about 1 part in 10,000 between 70 deg. and 80 deg., the two maximum errors being greatly different owing to the considerable irregularity of the $df/d\theta$ curve at this part of the scale.

Linear Interpolation. Approximations—and Corrections.

If a good quality variable condenser is employed in a wavemeter the errors introduced by linear interpolation are always of this order if the total frequency change per range is not too great and if the calibration points are not too infrequent. This fact may be made to save much labour in the plotting of large scale interpolation curves of frequency such as that of Fig. 20, by merely drawing straight lines between successive calibration points instead of obtaining many interpolated points for the correct curve from a curve of $df/d\theta$. The frequency read from such a linear interpolated curve will, of course, need correction for work of the greatest accuracy. The correction required will vary with the distance from the point being read to the nearest point for which a calibration exists, as is shown well by the curves of Fig. 21. These curves give the necessary correction for various portions of the scale of a wavemeter whose ratio of maximum to minimum capacity per range (at 20 deg. and 160 deg.) is 2 to 1 and whose calibration has been effected at intervals of 10 deg. The same corrections are shown in a more complete manner in Fig. 22.

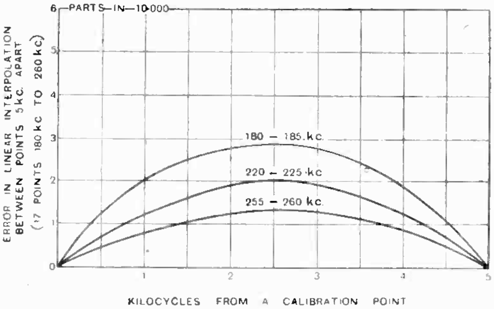


Fig. 23.

These curves are, of course, characteristic of the variable condensers of the wavemeter and will vary in shape with variations in its law. Those given in Figs. 21 and 22 are for a perfectly linear relationship between *capacity* and degree scale reading. If the condenser law is imperfect these curves will themselves be irregular in shape, but the important point to note is that they will be constant in shape for all ranges of the wavemeter in which the particular condenser is used and only one set of correction curves need therefore be plotted. Moreover, no great accuracy is needed in plotting correction curves.

For S.L.C. condensers, if the wavemeter is calibrated at equal frequency intervals instead of at equal angular intervals, the variation in the correction necessary at different parts of the scale is much reduced, even though the total number of calibrated points per range is approximately the same in each case. This is shown by the curves of Figs. 23 and 24 for the same case as that of Figs. 21 and 22 and plotted to the same scale of correction for comparison with them, the only difference being that 17 calibration points of equal frequency intervals were employed instead of 15 of equal angular intervals.

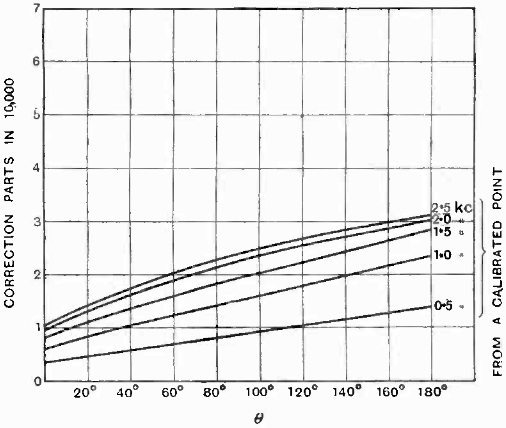


Fig. 24.

The difficulty with correction for a uniform frequency interval calibration is that of making one set of correction curves serve for all ranges of the wavemeter. This can be overcome to a great extent if approximately the same number of calibration points are obtained on each range, in which case the set of curves as those of Fig. 24 will be approximately true for distances from calibration points proportionally similar on all ranges.

The Physical Society's Exhibition.

Matters of Wireless and Laboratory Interest.

THE Nineteenth Annual Exhibition of the Physical Society and the Optical Society was held this year at the Imperial College of Science and Technology on 8th, 9th and 10th January. The Exhibition again lived up to the reputation which it has acquired in recent years of being perhaps the most important display of the year from the point of view of laboratory and measurement interests, both wireless and general.

ELECTRICAL MEASURING INSTRUMENTS.

Electrical measuring instruments, *e.g.*, Ammeters, Voltmeters, Milliammeters, etc., were, as usual, in considerable number, and while there was little of very striking novelty, the instruments on view were typical of the modifications and refinements effected in design and manufacture since the last Exhibition.

Rectifier instruments in which an ordinary moving coil D.C. instrument is used in conjunction with a copper oxide rectifier for A.C. measurements at commercial frequencies, were on display by Everett Edgcumbe & Co., Ltd., and by Ferranti, Ltd. The notable feature of these instruments is, of course, their uniformity of scale as compared with the usual types of A.C. instrument. Everett Edgcumbe had these available down to 1 mA for full scale, and Ferranti, Ltd. down to 1.5 mA and one volt, in their small pattern, and up to 500 volts in a larger size.

Another new feature of the former firm was a Synchronous Time Interval Meter, for measurement of short time intervals ranging from 1/20th second upwards.

In addition to the rectifier instruments, Ferranti, Ltd., had on view a large range of instruments of wireless and general interest. Their now well-known 2½-inch instrument was shown in various forms for D.C., while they had also on view instruments of thermal pattern employing a non-contact thermo-couple in conjunction with this movement for A.C. of all frequencies. The thermo-junction pattern was also available in a 4-inch dial instrument. Various switchboard instruments were also on view, while another exhibit was the valve tester which was shown at the last Radio Exhibition at Olympia. A very interesting instrument was a multirange D.C. test set, which provides very complete D.C. measuring facilities on small compass. Without extra apparatus the lower current range is down to 1 mA., and the highest voltage range up to 500 V., while leads and accessories are available for use of this as a valve tester.

At the stand of Crompton Parkinson, Ltd., an A.C. Test Portable Multirange Ammeter and Multirange Voltmeter, shown for the first time last year, was again on view with various new attachments, increasing its utility and scope.

Elliott Bros. showed precision instruments of various patterns, moving iron and dynamometer, and a range of miniature instruments suitable for many wireless purposes. Another feature of wireless interest was vacuum junctions of various ranges with the heater insulated from the couple.

Evershed & Vignoles, Ltd., showed various forms of their well-known resistance testing apparatus and a number of recording instruments both of portable and switchboard pattern.

Nalder Bros & Thompson, Ltd., had on view a large range of first-grade induction instruments, notable for a very large (nearly circular) scale, while a laboratory standard pattern instrument was shown in dynamometer type for A.C. and D.C. and in permanent-magnet moving-coil type for D.C. only, the accuracy being 0.1 per cent.

Cambridge unipivot thermionic voltmeter.

Circular scale D.C. instruments of the "Cirscale" pattern were on view at the stand of the Record Electrical Co., Ltd., who also showed a "change coil" ammeter covering 0–600 amps. in six consecutive steps and giving accurate readings on D.C. and A.C. at commercial frequencies.

The Weston Electrical Inst. Co., Ltd., showed the usual wide range of instruments to be expected from this firm. Their laboratory standard instrument, moving coil for D.C. and dynamometer for D.C. or A.C., is a well-known feature, while standard portable testing instruments were shown in wide variety. Portable testing instruments for radio service were well represented, both in A.C. and D.C. patterns, while this company's Direct Reading Valve Tester (shown last year) was also again on view.

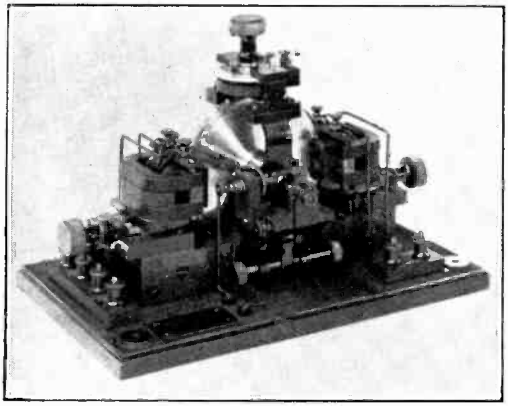
LABORATORY EQUIPMENT.

The customary excellent display of laboratory apparatus was again a marked feature, and several new and interesting instruments were on view.

The Cambridge Instrument Co., Ltd., had on view a recording potentiometer, capable of application to many purposes of low-power recording. The instrument was actually shown in the form of a Recording Gas Calorimeter, and also of a Frequency Recorder over the range 46–54 cycles. Another new instrument of this firm was the Campbell A.C. potentiometer—a development of the Larsen type of potentiometer—permitting the measurement of unknown A.C. voltage in terms of its inphase and quadrature components with reference to a fixed standard. Other attractive exhibits were thermionic (Moullin) voltmeters in various ranges, an improved Paschen galvanometer, a self-contained Wheatstone bridge in three or four decades, and a new decade resistance box using a new system of winding for the minimising of residual inductance. Various other instruments of industrial application were also on view incorporating modifications and improvements effected during the past year.

In addition to the instruments already noted, **Crompton Parkinson, Ltd.**, had on view their well-known Standard Potentiometer Equipment, also a potentiometer of sub-standard grade, and many other articles—bridges, galvanometers, etc.—of laboratory use.

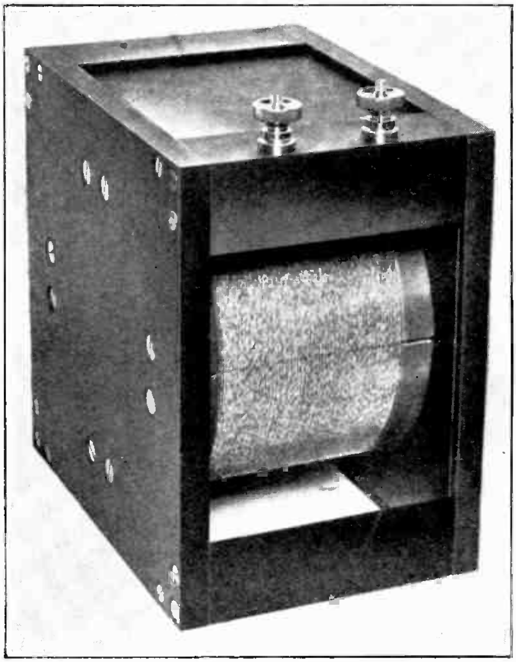
G. Cussons, Ltd. (Manchester) showed a Fractional Chronograph, demonstrated in operation. While usually supplied to mark 1/50th second, a 3-speed gear enables two other definite time values to be obtained, while it is stated that the instrument can be supplied, if required, to record intervals of 1/1000th second.



Sullivan valve-driven phonic wheel for determining the frequency of a standard fork.

W. Edwards & Co., showed vacuum pumps of various pattern, gauges and other vacuum-working accessories, and a complete range of modern types of photo-electric cell.

Gambrell Bros., Ltd., devoted part of their display to high tension bridges and accessories for work of this type. Other instruments exhibited were a Kelvin Bridge and a Laboratory Variable Condenser.



Special type inductance for standard wavemeters, shown by H.W. Sullivan.

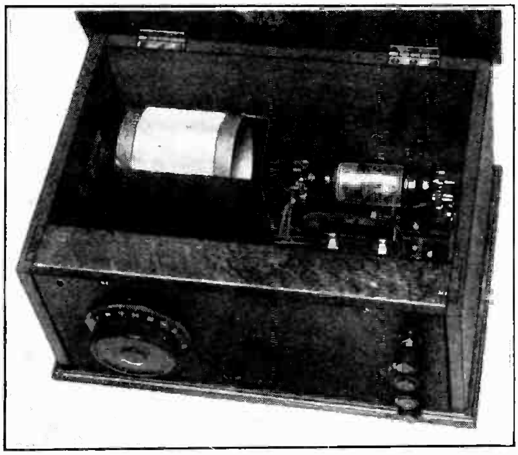
J. J. Griffin & Baird & Tatlock, Ltd., showed the "Microid" Adaptable Galvanometer in a universal model and in a sensitive model. The former may be used vertically or horizontally. Other forms of laboratory galvanometer—Ayrton Mather and d'Arsonval—were also on view.

Adam Hilger were showing the Holweck High-Vacuum Pump, which has been used in conjunction with the Holweck demountable valve and also with the Holweck demountable cathode-ray oscillograph.

W. G. Pye & Co., of Cambridge, had a considerable display of useful laboratory apparatus, including such articles as electrically maintained forks, phonic-wheel motors, potentiometers, bridges, etc.

H. W. Sullivan, Ltd., made a very extensive exhibit of apparatus for both radio and audio frequency work. Among the radio frequency was the Standard Multivibrator Wavemeter and a highly accurate 1,000-cycle fork for use with it. A phonic wheel and amplifier for standardisation check of the fork was also on view, the total exhibit being a prominent display of high frequency standard technique. The latest form of Sullivan-

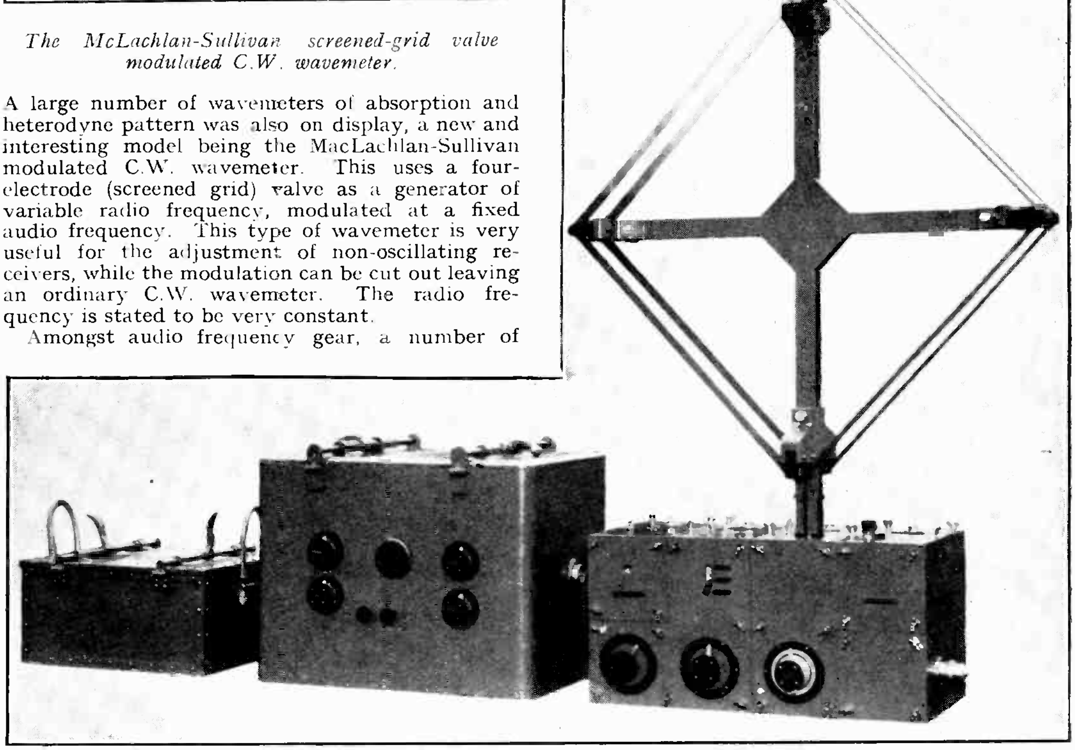
Griffith's precision condenser (described in the January issue) was also on demonstration, along with a group of fixed-value inductance standards, suitable for use with the condenser for a precision sub-standard wavemeter of the absorption pattern.



The McLachlan-Sullivan screened-grid valve modulated C.W. wavemeter.

A large number of wavemeters of absorption and heterodyne pattern was also on display, a new and interesting model being the MacLachlan-Sullivan modulated C.W. wavemeter. This uses a four-electrode (screened grid) valve as a generator of variable radio frequency, modulated at a fixed audio frequency. This type of wavemeter is very useful for the adjustment of non-oscillating receivers, while the modulation can be cut out leaving an ordinary C.W. wavemeter. The radio frequency is stated to be very constant.

Amongst audio frequency gear, a number of valve generators was also on view, along with A.C. bridges, fixed mica condensers, etc.



Marconi equipment for measurement of signal strength.

H. Tinsley & Co. had a very useful display of laboratory apparatus—potentiometers of various form, including several A.C. patterns, an extensive display of galvanometers and Wheatstone bridges, Dr. A. B. Wood's Cathode Ray Oscillograph, Prof. Miles Walker's Harmonic Analyser, etc. Forks and phonic motors were also on display, while more purely radio apparatus included a standard (N.P.L.) condenser and absorption wavemeter.

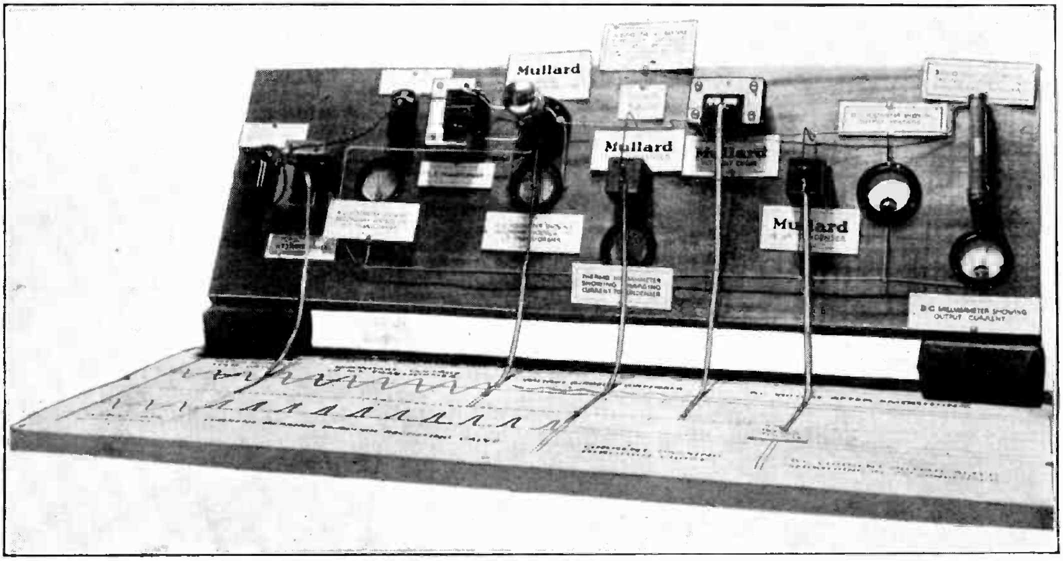
Precision variable, fixed and adjustable standard condensers for laboratory use were on view at the stand of the Dubilier Condenser Co., Ltd.

WIRELESS APPARATUS, ACCESSORIES, Etc.

As in recent years, several of the stands were devoted entirely to articles of purely radio interest.

The M. O. Valve Co., Ltd., in addition to a large range of valves, demonstrated processes of construction, including an automatic process involved in filament making, and an eddy current heating process. The valves on show included cooled-anode valves for rectification, long wave transmission and beam transmission, and glass transmitting and rectifying valves of both dull emitter and bright emitter pattern. Amongst receiving valves were shown screened-grid types for 2 or 6 v. filaments, pentodes, and a range of A.C. valves for direct and for indirect cathode heating.

Many of these receiving valves were also on exhibition at the stand of the associated **Marconiphone Co., Ltd.**, where were also a large range of new receivers, such as Model 23A, a self-contained 2-valve set with cone loud speaker; Model 35, a 3-valve set (one screened) with pentode output, and Model 44, a 4-valve set using two screened-grid stages. Power units for A.C. and D.C. mains were also available in many types, including models applicable to any 2- or 3-valve sets for complete elimination of batteries. Moving-coil and cone loud speakers were also shown, as well as a large range of components, including transformer variable condensers, short wave coils, etc.



A demonstration H.T. eliminator for A.C. mains shown by Mullards. Meters in the various circuits indicate amplitude of A.C. and D.C. components.

Marconi's Wireless Telegraph Co., Ltd., had a large display of gear for both maritime and aircraft purposes. Amongst the former were two D.F. sets one (D.F.M. 4) primarily for naval purposes, arranged for bridge operation or for handling by unskilled wireless personnel, and the other (Type 11G.) for mercantile marine use, capable of working up to 250 miles from a 1½ kW. coast station. The Marconi Type Rg. 18 Receiver is also primarily for naval purposes, while another marine exhibit was this Company's Automatic Alarm Device. Aircraft Type A.D.18 set provides telegraph or telephone send/receive facilities for 2-seater or larger aircraft. A signal strength measuring set was also on view for 14–5,000 m.

The **Radio Communication Co., Ltd.**, displayed their new design of marine D.F. set. The frame aerial is enclosed in a chromium-plated copper tube and mounted on a deck pedestal. A supersonic receiver of five valves has very simple controls, the whole being arranged for the minimum of technical skill in operation.

The joint display of the **Mullard Radio Valve, Co., Ltd.**, and of the **Mullard Wireless Service Co., Ltd.**, was naturally chiefly connected with valves. A very complete display of transmitting, modulating and rectifying valves in glass and silica were on view with a high power metal-glass valve of input up to 30 kW. An equally representative collection of P.M. receiving valves included screened-grid valves, "Pentones" and a number of low impedance rectifiers for eliminator use. The Holweck pump was also on display at this stand. A demonstration of a short-wave generator at a frequency of abcut 100 megacycles was on view working to a Lecher wire system and showing nodes and antinodes along the wires, while another interesting demonstration was that of a wireless amplifier dissected and showing the functions of each part of the system, measuring instruments indicating the various voltages present.

Shimwell, Alexander & Co., displayed the Codd cell which was exhibited last year in the Research Section. This cell is of the single fluid type, with zinc-carbon electrodes and ferric chloride depolariser. Cells of this pattern were shown in sizes of 36–144 ampere hour capacity, for L.T. and like purposes, and in a 6 a.h. size for H.T. supply.

In addition to the laboratory apparatus already mentioned **Gambrell Bros., Ltd.**, showed new models of their mains receivers (D.C. and A.C.), some incorporating screened valves.

The Dubilier Condenser Co., Ltd., showed a very large range of condensers for all wireless purposes, including smoothing condensers and condensers for various transmitter purposes. H.F. Chokes, Toroidal Coils, H.T. supply units and smoothers were also on display.

The exhibits of the **Igranic Electric Co., Ltd.**, were almost entirely wireless. Various receivers and receiver outfits were on view, these including a screened-grid short-wave receiver, using

H.F. amplification down to 10 m.; the Neutro-Regenerative Short Wave Receiver covering 15 to 20,000 m., the Igranic Universal Portable Receiver and the Igranikit Outfit for home construction, the latter being available in both A.C. and battery models. A considerable section was devoted to gramophone pick-ups and associated devices, while an interesting range of transformers of various kinds included the "Pentoformer," designed for best volume and quality in the last stage using a pentode valve. Wire-wound variable resistances of 50,000 and of 250,000 ohms were also attractive features.

The MacLachlan-Sullivan Wavemeter, already described under H. W. SULLIVAN'S display, should also be mentioned among wireless items.

BAKELITE, LTD., had an extensive display of mouldings, sheets, etc., of insulating material, including a new preparation "Flaked Fabric Moulding Material" which is particularly resistive to shock.

An exhibit of particular interest was that of the BRITISH METALLISING CO., LTD., showing a process of producing a metal film or coating firmly adherent to a non-metallic base, on which coating, in turn, a large range of non-ferrous metals may subsequently be plated to any desired thickness. Panels were exhibited showing four stages in the metallising and plating process, while specimen panels were on view showing the finished process with light deposits of (*a*) silver on vulcanite and (*b*) copper on vulcanite. Such panels should prove of use for many wireless and electrical purposes.

RESEARCH AND EXPERIMENTAL SECTION.

The Research and Experimental Section, inaugurated two years ago, was again a feature of the Exhibition and contained various items of wireless and allied interest.

The BRITISH THOMSON HOUSTON CO. (ENGINEERING LABORATORY) demonstrated an apparatus for tracing visual characteristics of loud speakers and amplifiers, using a calibrated condenser microphone and a beat oscillator up to 10 kc.

THE CAMBRIDGE INSTRUMENT CO. (RESEARCH DEPARTMENT) had on view a patented valve method of controlling H.T. supply and a microscopic display of welded joints for use in vacuo thermo junctions.

THE G.E.C. RESEARCH LABORATORIES showed a heterodyne low-frequency oscillator of 50 to 6,000 cycles, a sensitive electroscope and a precision variable condenser, previously exhibited in an unfinished state.

THE GRAMOPHONE CO. (RESEARCH LABORATORIES) had demonstrations of (*a*) the measurement of mechanical impedance, (*b*) a logarithmic recording galvanometer (shown plotting the electrical response characteristic of a pick-up device), (*c*) vibrations of a stretched membrane loud speaker.

THE NATIONAL PHYSICAL LABORATORY had several exhibits of wireless interest. These included :—

(a) *Dr. D. W. Dye*—a heterodyne low-frequency oscillator 10 to 10,000 cycles.

(b) *Wireless Division*—Apparatus for the recording of wireless time signals on wavelengths from 1,000 to 20,000 metres.

(c) *Wireless Division*—A portable direction finder for 50 to 2,000 metres.

(d) *Wireless Division*—Simple apparatus for rapid measurements of the capacity and power factor of variable condensers.

(e) *Wireless Division*—Mercury-in-glass coil used for investigations of high frequency resistance.

(f) *Mr. G. P. Barnard*—A demonstration of some simple practical applications of the properties of the selenium cell.

MR. E. B. MOULLIN demonstrated his new ammeter for currents of extremely high frequency, which can be calibrated by a steady current. The action of this instrument depends on measuring the force between two cylinders carrying oppositely directed currents, and a correction factor for any frequency can be determined.

DR. J. H. VINCENT showed some experiments in magneto-strictive oscillators at audio and radio frequencies. These were well demonstrated as frequency stabilising devices, a very minute high frequency rod, working at 843 kc., being a particularly interesting illustration of the use of magneto-striction.

Book Review.

DIE AUSBREITUNG DER ELEKTROMAGNETISCHEN WELLEN (The Propagation of Electromagnetic Waves). By Dr. A. Sacklowski, pp. xii. + 129, with 46 Figs. Published by Weidmannsche Buchhandlung, Berlin.

This is a review of all the work which has been published on the subject prepared by the author, who was in the Government Telegraph Department. Dr. K. W. Wagner who asked the author to undertake this compilation has contributed an introduction. The first ninety-three pages are devoted to a necessarily brief but well-arranged description of the theoretical and practical research which has been carried out on the propagation of radio waves. The last thirty-six pages contain a most useful bibliography, giving 474 references to original publications on the subject arranged alphabetically according to authors' names.

It is a most useful book of reference.

G. W. O. H.

The Design of Transmitting Aerials for Broadcasting Stations.

(Paper by Messrs. P. P. Eckersley, M.I.E.E., T. L. Eckersley, B.A., B.Sc., and H. L. Kirke, read before the Wireless Section, Institution of Electrical Engineers, on 2nd January, 1929.)

ABSTRACT.

The paper deals with the important technical aspect of the design of the transmitter aerial, and it is suggested that attention to this subject might help to improve conditions in Europe generally. Difficulties of mutual interference between stations and of the limited service area of stations indicate the need for an aerial which produces only a direct or ground ray. The indirect ray interferes with other distant stations, produces fading and bad quality in the local service area, while all energy radiated upwards is wasted, from a broadcasting point of view. The more the aerial can be made to radiate only in a direction tangential to the earth's curvature at the base of the aerial, the more will the ideal conditions be approached.

It is further important to know the rapidity at which these rays will be attenuated, and the second section of the paper deals with this subject, giving a complete set of attenuation curves for various broadcasting wavelengths.

SECTION I.

THEORETICAL CONSIDERATIONS OF THE AERIAL AS A RADIATOR.

S. Ballantine has shown* that radiation from an aerial can be resolved into radiation due to the aerial itself and radiation from an image of the aerial in the earth.

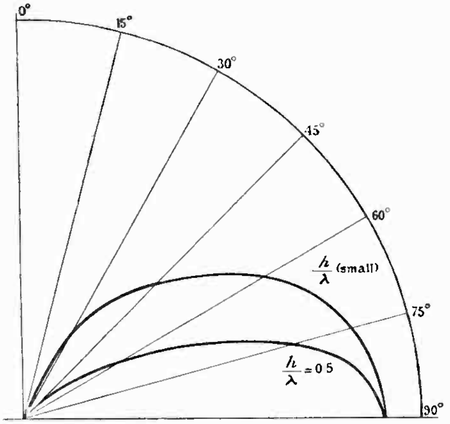


Fig. 1.—*Vertical polar diagram of radiation for ½λ and ¼λ (or less) aerials. Drawn for the same maximum radiation intensity in the horizontal plane.*

For aerials of vertical height h less than ¼λ the space phase of the element currents in the real aerial and its image will not be sufficiently different to cause cancellation of radiation in non-horizontal directions. As h is increased to ½λ, however, the maximum current I in the aerial is at a distance ½λ (180 deg.) from the maximum image current. There will be, in this case, considerable cancellation of radiations at high angles. As h is still further increased, then, provided the currents are in phase all along the aerial, the cancellation will be greater still in all directions other than the horizontal.

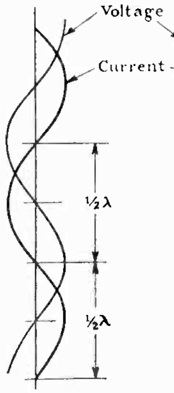


Fig. 3.—*Current and voltage in a long uniform aerial.*

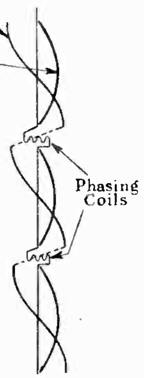


Fig. 4.—*Current and voltage in a Franklin aerial.*

Fig. 1† gives vertical polar diagrams, due to Ballantine, for ¼λ and ½λ aerials for the same field strength on the ground, and assuming the earth a perfect conductor. This shows that a given field strength can be obtained by the use of a high aerial with small current or a small aerial with large current.

The field strength on the ground for a given wavelength is proportional to metre-amperes (h,I), so that for a given power we must produce a maximum value of $h,I/\lambda$. Increasing the aerial height cancels angular radiation while the ground vector remains the same, so that less total power is radiated with the high aerial for the same effect on the ground.

It is shown that the advantage of the tall aerial decreases beyond ½λ, due to the fact, illustrated in Fig. 3, that the phase reverses in the upper part of a long homogeneous aerial. The obvious correction is to add ½λ aerials one above the other, as in Fig. 4,

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* *Proc. I.R.E.*, 1924, Vol. 12, p. 836.

† The author's original figure numbers are adhered to throughout this abstract.

and to introduce a "phasing-coil" to reverse the phase at each join. This device has been adopted by Franklin in his beam system for short waves.

Fig. 5 shows the relative power required to produce a given field strength for different values of $4h/\lambda$, up to 2, the curves being shown for different values of dead-loss resistance. Fig. 6 shows the increase of field strength, using different heights of aerial with the same aerial power.

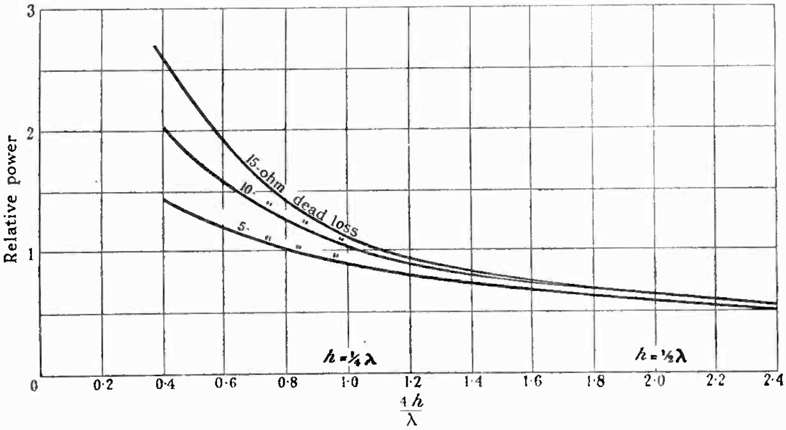

Fig. 5.—*Relative power required to produce a given value of metre-amperes.*

Fading.—The flattening-out of the vertical polar diagram reduces the indirect ray and so should reduce fading. It is shown that the ratio of indirect ray to direct ray with a $\frac{1}{2}\lambda$ aerial is reduced, at 100 miles, to 0.05 of the ratio when using a $\frac{1}{4}\lambda$ aerial—assuming 100 km. as the height of the Heaviside layer.

Effective height.—It is known that the theoretical effective height h_1 for a $\frac{1}{4}\lambda$ aerial is $2/\pi \times$ actual height h. But it is important not to use this value for h_1 if an aerial less than $\frac{1}{4}\lambda$ in height has to be loaded by added inductance to give it the same natural wavelength as if it were a vertical wire of length $\frac{1}{4}\lambda$. Effective height is a misleading term for loaded aerials—effective current is more definite. This would mean the average value of the current in the vertical part of the aerial, and metre-amperes would be found by multiplying the actual height of the vertical part by the average current in that part. The authors feel that effective height is best expressed therefore as $h_1 = E\lambda d/(377I)$ (I being the maximum current in the aerial, d the distance at which the field strength is measured, and λ the wavelength), whatever the form of aerial. Effective height taken in this way depends upon the distance d. This distance must be chosen so that the field strength at that distance does not suffer attenuation. In practice this distance is safely taken as 5 wavelengths.

Experimental Tests.—The theoretical analysis was tested by full-scale experiments with a kite balloon supporting various lengths of aerial. The experiments were conducted near Amesbury on Salisbury Plain.

The first experiment was to determine whether, for the production of a given field strength, the necessary power in the aerial was decreased, as theory indicated, by changing from a $\frac{1}{4}\lambda$ to a $\frac{1}{2}\lambda$ vertical aerial. The power in the aerial was measured, and the received field strength was taken as the average of 6 measurements at different points on a circle around the aerial, each reading being taken at 2 km. from the transmitter. Results are shown in table below.

Type of Aerial, h/λ.	Power in Aerial.	Field strength, E, at 2 km.	Effective height (practical), $h_1 = \frac{E\lambda d}{377I}$	Effective height (theoretical), $h_1 = \frac{2}{\pi}h$	Metre-ampere efficiency, $\frac{h_1^2}{\lambda^2}R_T$, where $h_1 = \frac{E\lambda d}{377I}$	Relative watts in aerial to produce given field strength.		Relative field strength at same distance with equal power.	
						Practical.	Theoretical.	Practical.	Theoretical.
	watts	mV/metre	metres	metres		watts	watts	mV/metre	mV/metre
$\frac{1}{4}$	281	64	38	43.5	4.17×10^{-4}	1,000	1,000	1	1
$\frac{1}{2}$	506	109	79.5	87.0	6.66×10^{-4}	625	610	1.26	1.28

The results as regards effective height are presumably due to earth resistivity, and show that effective height should always be measured rather than assumed. In fact, the choice of a site for a transmitter might well be determined, *inter alia*, by the measure of the effective height of aerials upon it. (The effective height of an aerial at Brookmans Park, near London, used for the attenuation experiments, was the same both by measurement and theory.)

It is to be noted that the measured effective height of the $\frac{1}{2}\lambda$ aerial is practically twice that of the $\frac{1}{4}\lambda$ aerial, while measurements have been checked in all ways and there is no doubt as to their accuracy. The results show a substantial gain by the use of the $\frac{1}{2}\lambda$ aerial.

Tests with Franklin Aerials.—Franklin has used, on short waves, as many as three $\frac{1}{2}\lambda$ aerials, one above the other, with a "phrasing-coil" as already shown in Fig. 4. In effect he "wraps up" a $\frac{1}{2}\lambda$ aerial in such a way that it will have the "surge impedance" of a wire $\frac{1}{2}\lambda$ in length but will not produce radiation. The authors tried to produce this effect at frequencies of the order of 1/10th of those used in the beam system, but their efforts were unsuccessful. Fig. 10 shows methods tried or proposed. System (*a*) had been used on 20,000 kc. with complete success, the bifilar phasing device being pulled out at right angles to the aerial. This was impossible, however, on the dimensions necessary for a 300 m. wave-length and with a kite balloon support. The methods are to be tried again on some future occasion, probably using masts for aerial support.

Experimental Fading Tests.—On account of bad weather there was only one fading test. This was to compare fading from a vertical $\frac{1}{2}\lambda$ aerial with that from a T aerial supported by 70ft. masts. The T aerial had a natural wavelength of 288.5 m. (the wave-length used) and was loaded with inductance. The power in the two aerials was not measured. The metre-amperes were, however, measured and the ratio was approximately 2 : 1 in favour of the $\frac{1}{2}\lambda$ aerial, for the same total power input to the transmitter.

There was no fading at 50 miles. At 65 miles the $\frac{1}{2}\lambda$ aerial gave from 20 to 25 per cent. fading, while the 70ft. aerial gave a 30 to 40 per cent. fading variation. At 75–80 miles the fading was more pronounced with the low aerial but at 100 miles there was little difference in signal strength on the two aerials, and the fading was less (but not pronouncedly so) with the $\frac{1}{2}\lambda$ aerial.

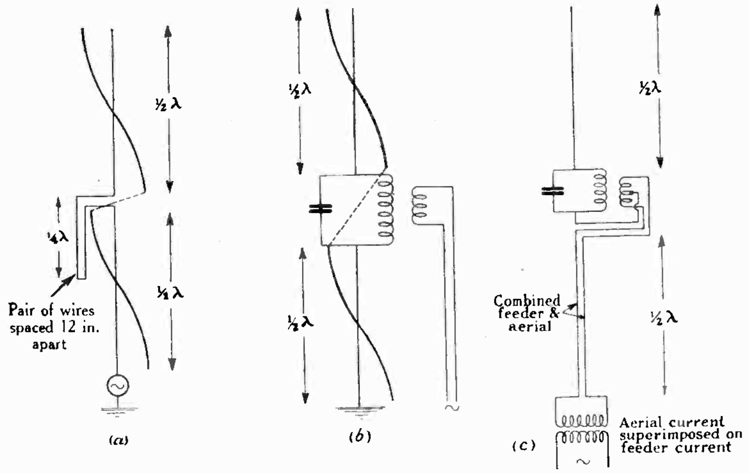

Fig. 10.—*Types of circuit. Circuit* (*b*) *is the most promising.*

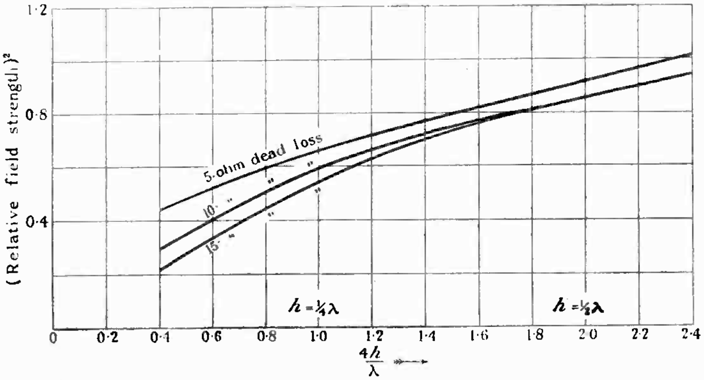

Fig. 6.—*Relative field strength for a given power for various values of* h/λ.

It appears that at close ranges the ratio of down-coming direct ray was twice as great with the 70ft. aerial as with the $\frac{1}{2}\lambda$ aerial.

There is very little evidence to go upon, but one might generalise by saying that it appears as though the upward radiation was for a given power appreciably the same for both aerials, but, as has been proved by other experiments, the stronger direct ray (for a given power) made a less apparent fading. It would be wrong to place too much reliance upon the results of one experiment undertaken in somewhat trying conditions, but further experiments will be undertaken in the future using high masts. This will allow a more leisurely investigation of the whole problems of fading influenced by the aerial design.

Practical points arising from the results.—The outstanding fact is that high aerials appear necessary, involving high masts and high costs. For the broadcast band of 550 to 200 m. (1,800 to 650ft.) masts for $\frac{1}{2}\lambda$ aerials would have to be of about 1,000 to 400 ft. For two $\frac{1}{2}\lambda$ aerials masts of 2,000 to 750ft. would be required. Mechanical and economic conditions impose a limit of about 800ft., so that Franklin aerials cannot be used for more than 213m., but $\frac{1}{2}\lambda$ aerials can be used on most wavelengths.

A compromise may be looked for in the T aerial, and it would appear best to arrange a T aerial so that the current in the vertical part is a maximum at the greatest possible height from the earth.

It is insisted by the authors that the higher the masts, the greater is the metre-ampere efficiency.

The possibility of using the masts themselves as aerials is discussed, but the authors conclude that the method is not to be recommended, chiefly on account of the lack of flexibility.

If dual masts carrying the conventional type of aerial are to be used, it is particularly important to guarantee that they will not cast shadows of a serious nature. This trouble has been acute at the Daventry broadcasting station and a repetition of the difficulties would be foolish. It is therefore imperative to insulate the mast. It is suggested that the masts could be tuned to have a natural wavelength, when unearthed, equal to the wavelength used, so that no current would flow in the mast when earthed.

SECTION 2.—ATTENUATION OF WAVES.

Sommerfeld's formula for attenuation shows that for a given value of metre-amperes, the field strength is a function of distance x, wavelength λ, the earth's conductivity σ, and its inductivity ϵ, the latter being unimportant except on the very short waves of 10 to 20m. Sommerfeld shows that the signal intensity is only a function of the quantity d_n, which he calls the "numerical distance" and which involves the above quantities in the following way :—

$$d_n = \frac{\pi x}{\lambda} \cdot \frac{1}{2\sigma\lambda c} \text{ very nearly,}$$

i.e., within about $\frac{1}{2}$ per cent. on the broadcast band of wavelengths [for σ of the order $\frac{1}{3} \times 10^{-12}$ (electro-magnetic units)]. c is the velocity of light.

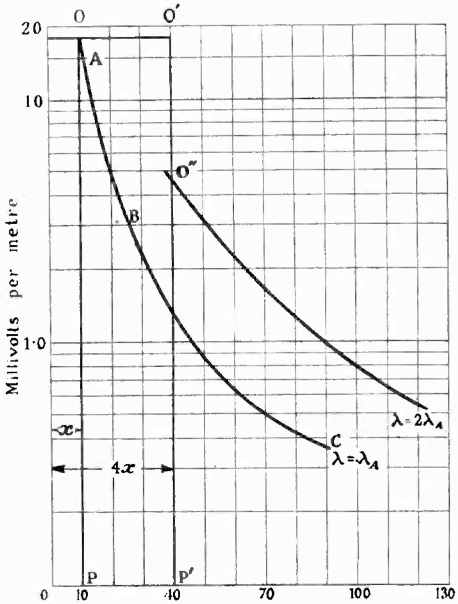

Fig. 11.

The authors then proceed to derive an expression for field strength from the above, reaching the value

$$E = A_1 \left(\frac{h_1 I}{\lambda}\right) \frac{1}{\lambda^2} F_1 \left(\frac{x}{\lambda^2}\right) \quad .. \quad (1)$$

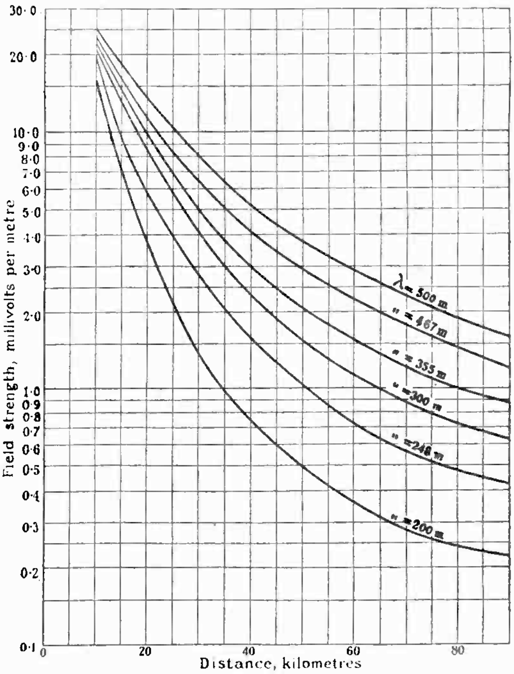

Fig. 12.—*Mean attenuation curves of the northerly and westerly directions.*

The quantity $h_1 I/\lambda$, mentioned previously in the paper, is the similarity factor for all aerials, and expresses the metre-amperes. It gives the initial power radiated and is the multiplier for all attenuation formulæ.

From this it is possible to derive the attenuation curve for any wavelength if that for one wavelength is known. It is only necessary to determine an irreproachable curve for one wavelength or to test the uniformity of the district on two fairly widely separated wavelengths. If such a curve for one wavelength λ_A is plotted others can be derived as follows :—

Let ABC (Fig. 11) be a curve for $\lambda = \lambda_A$, then the curve for $\lambda = 2\lambda_A$, for example, can be constructed as follows :—Let O be a point on the curve ABC for a distance x ; then transfer O to O' at a distance $(4x)$ and reduce O' to O'', where $P'O'' = \frac{1}{4} P'O'$, then O'' will be a point on the curve for $\lambda = 2\lambda_A$. In this way, by choosing a series of points O on the original curve ABC we get a series of points O'' on the curve for $\lambda = 2\lambda_A$. These two curves will give the field strengths for two "similar" stations of λ_A and $2\lambda_A$ respectively.

Barfield has argued* that there may be an extra

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* *J.I.E.E.*, 1928, Vol. 66, p. 204, also *E.W. & W.E.*, January 1928.

loss due to trees and vegetation. The authors consider that the only quantity that matters is effective earth resistivity which includes vegetation loss. To take account of changes in the earth's conductivity, E can be written in the form

$$E = \frac{A_2}{x} \mathrm{F}_2(d_n) \doteq \frac{A_2}{x} F_2\left(\frac{x}{\sigma\lambda^2 c}\right)$$

where $A \propto h_1 I/\lambda$.

If the conductivity be increased n^2-fold and the wavelength reduced $1/n$-fold, keeping A_1 and x constant, the field strength remains unaltered.

In practice it would be usual to make a measurement of the signal strength in a proposed district, from a transmitter of a known value of metre-amperes on a given wave-length.

If the conductivity in this district is different from the normal it will not lie on the normal curve for λ_1; but will lie, say, on a different curve for, say, λ_2. Then if all the wavelengths on the normal set of curves are altered in the ratio λ_2/λ_1 this new set of curves will represent the complete data for the district.

Experimental Tests.—The B.B.C. made experiments to attempt to get attenuation curves in a given region for all frequencies between 500 and 1,500 kc. The site was near Potters Bar, the aerial consisting of 95ft. of vertical wire, on masts 110ft. high and 300ft. apart, with their bases and stays insulated from earth. Tests showed that the radiation was equal in all directions. The current in the aerial was adjusted so that the field strength at the same point close to the aerial was the same for all the frequencies employed. This meant that $h_1 I/\lambda$ was the same for every wavelength, so that the curves were for the same radiated power on all waves. Curves are given in Fig. 12.

An example is also given of the applications of the method, already outlined, for transferring the curves from one wavelength to another.

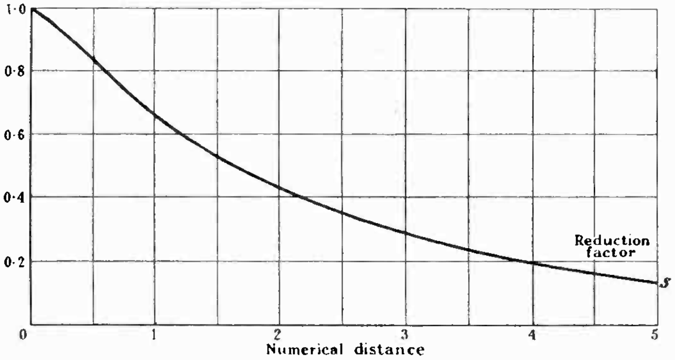

Fig. 14.—*Sommerfeld's theory.*

The authors then discuss the transference of curves for different values of σ. Two transmitters having the same value of $h_1 I/\lambda$ can be said to be similar, whence

$$\frac{377\, h_1 I}{\lambda} = B \text{ (a constant)} \quad \ldots \quad \ldots \quad (2)$$

Therefore $E = (B/x)S$, where x is distance. If there were no losses due to the earth and houses, trees, etc., on its surface, the field strength would be $E_0 = B/x$, so that S can be called the reduction factor, and is a function of Sommerfeld's numerical distance, its value being shown in Fig. 14.

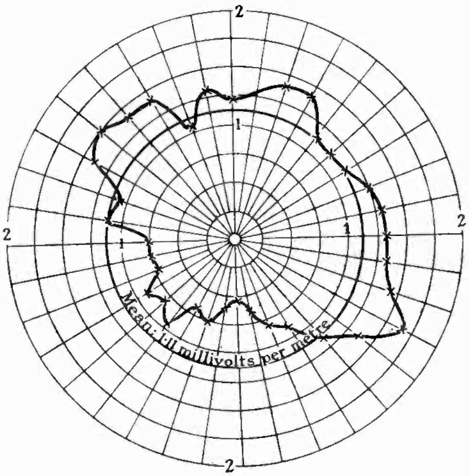

Fig. 15.—*Brookman's Park site. Field-strength map at 40 miles with* 10 *amperes in the aerial,* 388 *metres,* 780 *kilocycles per sec., and* 60-*ft. masts.*

From Fig. 12 with $x = 60$ km., $\lambda = 248$ m., $E = 0.63$ mV/m. Since these curves are for a radiated power of 1 kW., E_0, the field strength apart from attenuation, will be given as

$$E_0 = \frac{377 \sqrt{\left(\frac{1000}{1580}\right)}}{x} = 5 \text{ mV/metre}$$

therefore $S = E/E_0 = 0.126$.

From Fig. 14, $d_n \doteq 5.2 = \frac{\pi x}{2\pi^2 \sigma c}$

therefore $\sigma = 10^{-13}$

with $x = 60$ km. and $\lambda = 503$ m.,

$E = 3$ mV/metre and $S = 0.6$.

From Fig. 14, $d_n = 1.22$, and $\sigma = 10^{-13}$.

The value of σ is thus 10^{-13}, and lies between the wide limits of 0.66 to 5×10^{-13} as given by other observers and found by different methods. It is suggested that it is premature to assume that the total value of σ can be sub-divided into earth loss and vegetation loss. Generally it seems unnecessary to assume that there is any loss over and above the earth loss, except where the waves traverse large cities or heavily wooded country. More "irreproachable" curves must be taken before this can be accurately determined.

Fig. 15 gives a polar diagram for an aerial, the initial radiation from which was strictly symmetrical in all directions. Middlesex lay on the south side, which explains the large degree of concavity of the base of the Figure.

Conclusion.

The facts which emerge from the paper are

(1) Aerials for broadcasting should produce the strongest possible horizontal radiation, while diminishing upward radiation.

(2) To do so, high aerials are essential.

(3) Special aerial design will not prevent a serious limitation of service area with short waves, relative to that obtained with longer waves.

(4) That organisations must nevertheless employ such waves, which are more efficiently used with high aerials.

The curves of Fig. 17 show theoretical field strength for a vertical aerial 400ft. high, while Fig. 18 shows the improvement of increasing the aerial to 700 ft.

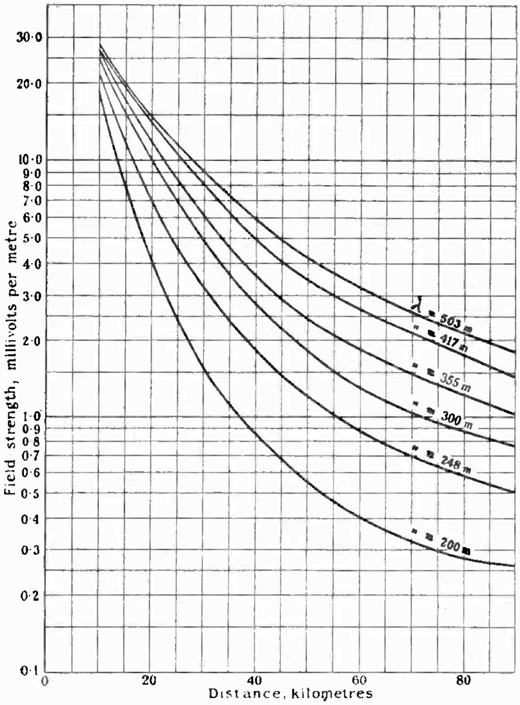

Fig. 17.—*Theoretical field-strength curves for various wavelengths using a vertical aerial 400 ft. high (500 ft. masts) having a constant dead loss of 10 ohms. All curves for 1 kW. input to aerial.*

It is also shown that interference—natural and artificial—diminishes with wavelength, and the authors take this factor of diminution as being proportional to the square of the frequency. This still further improves the curves of Fig. 18, so that if, with $\frac{1}{4}\lambda$ aerials, say 25 kW. are required for a given service, with 700ft. aerials this can be done with 10 kW.

It is thus suggested that the broadcast engineer need not so greatly fear to use waves below 300 m., the use of which must come, while it is hoped that the paper may be of help to those who will one day have to use them.

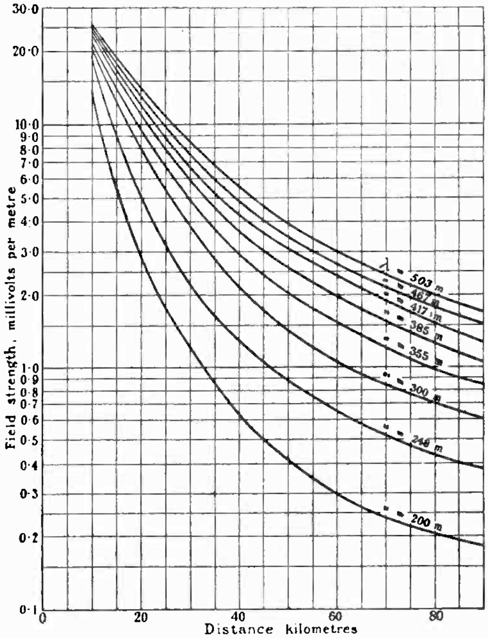

Fig. 18.—*Theoretical field-strength curves for various wavelengths using a vertical aerial 700 ft. high (800 ft. masts) having a constant dead loss of 10 ohms. All curves for 1 kW. input to aerial.*

Discussion.

The discussion which followed the reading of the paper was opened by *Dr. R. L. Smith Rose*, who expressed his appreciation of the paper and of its presentation. The authors followed the perceptible trend to use the direct wave. The resistance of the ground as a factor of attenuation had been neglected for 20 years and it was not until broadcasting that attention had been paid to ground attenuation.

In connection with the upward radiation, he quoted the case of an aerial at Teddington, practically entirely vertical, from which little radiation upwards would be expected. Nevertheless at such short distance as King's College waves had been detected which had been up to two layers and were arriving at 1 deg. to 4 deg. from vertical and of strength comparable to the direct ray.

The author's method of deriving a family of attenuation was interesting, but there was difficulty in getting an "irreproachable" attenuation curve as suggested. The country was nowhere uniformly flat. He did not see that any new knowledge had been brought out. Mr. Barfield had already dealt with attenuation in great detail and he thought that this work might have been used by the B.B.C.

The curves given were not superior to those already in existence.

Mr. R. M. Wilmotte discussed the subject of effective height and referred to the difficulties of measuring this even at 5 wavelengths distance. Ratcliffe and Barnett had found an increase at short distances, and it was necessary to find reasons for such effects. The author's suggestion of the use of " effective current " did not meet the case as this was not a property of the aerial, but of other factors. Such a value as " radiation factor " might be more useful. In his own work on aerials he had used a " directive efficiency " which was the ratio of radiation in space to that in a given direction. He had recently calculated the effect of an increase in the top of a T aerial and results obtained by Messrs. Barfield and Munro had shown very good agreement with the increase calculated from theory. He suggested that more information on the methods of measurement used in the experimental work described would be desirable.

Mr. R. H. Barfield said that his chief interest in the paper was in the section on attenuation. His own work gave results in different directions on one wave; the present paper gave results on different waves. Where they overlapped they agreed. He quoted from an earlier paper* of his own on the subject of earth conductivity and the effect of trees. The actual conductivity over regions does not vary within wide limits. He had recently made experiments on the seasonal change of absorption due to trees and had found as much as 30 per cent. as between winter and summer. Observations on Bournemouth over all the year also showed a seasonal effect. The value of the curves given by the authors was limited without a knowledge of the conductivity of the earth involved.

Mr. E. H. Shaughnessy spoke briefly of the author's work and of the importance of aerial design as a factor of economy.

Mr. F. H. Amis thought that foreign broadcasting authorities realised the need for good service. Much of the interference experienced was accidental and could possibly be improved by representation to the authority concerned. A great need was for several stations to work on one wavelength without interference. As regards the lessening of fading from higher aerials, he quoted the considerable fading noticed from Germany—the home of the high aerial. In experiments in Sweden on 260 m. a half wavelength T aerial had shown 25 per cent. improvement over a quarter wavelength vertical, while a half wavelength vertical had shown 80 per cent. improvement. Other comparisons of improvements effected in some European stations were also quoted. It was necessary to keep the maximum current away from absorbing masses. This meant that the point of maximum current must be raised farther up the aerial.

Lt.-Col. A. G. Lee did not think that the authors had found a cure for fading. He did not consider the improvements shown by the authors were worth the cost. While they had made a case for higher aerials, they had not worked out the relative costs. Why not use more power in a quarter wavelength aerial? He also asked had the authors considered the use of horizontally polarised waves? This should be possible without any cost of masts.

Capt. P. P. Eckersley briefly replied to the discussion. He said they had not reached the stage of irreproachable curves, but that every care was taken in the measurements. For effective height six points were taken. In the matter of the effect of trees, they were not in conflict with Mr. Barfield, but he thought it was difficult to apply this effect in practice. High aerials did not show as much amelioration of fading as was expected, but might lead to the use of less power. Consideration of cost still showed in favour of higher masts and less power.

On the motion of the Chairman (Commander J. A. Slee, C.B.E.), the authors were cordially thanked for their paper.

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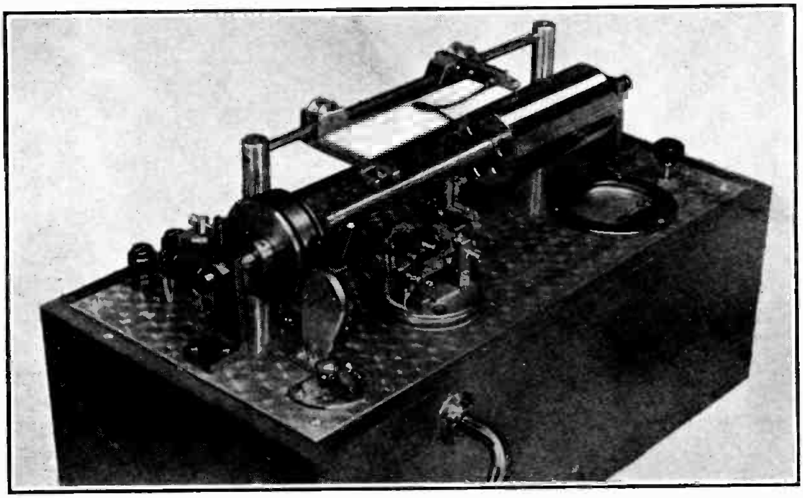
* *Loc. cit.*



Facsimile Picture Reception.

A rapidly growing interest in broadcast picture reception is giving rise to the development of designs for apparatus suitable for amateur and home use. This machine, for home assembly, which conforms to the conditions of the 5XX picture broadcasts, as well as those from German and Austrian stations, has been the subject of recent articles in *The Wireless World*. Synchronisation is effected by the transmission of a brief signal once each revolution, for which purpose a relay, magnetic clutch and catch and switching cams are provided, the necessary valve rectifier being on the underside of the panel.

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.

Effect of Anode-grid Capacity in Detectors and L.F. Amplifiers.

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

SIR,—In his article on the above subject Mr. Medlam claims to show that the feed-back due to the anode-grid capacity of a valve operating as an anode-band detector produces quite a considerable amount of distortion—in fact, such an extraordinarily large amount as to call for a very careful examination of the analysis by which Mr. Medlam is led to this conclusion. Such examination, I think, reveals that some of the mathematical work is open to very considerable criticism. The two points in the purely mathematical development to which I would draw attention are the equations

$$\frac{dv}{dt} = \frac{i_g}{C_{ga}} + L_e \frac{d^2 i_g}{dt^2} \quad \ldots \quad \ldots \quad (12)$$

and

$$e_r = \omega L_e i_g \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

L_e denotes what Mr. Medlam terms the "equivalent inductance" of the input circuit and the above equation (12) is clearly derived on the basis that the voltage drop across this equivalent inductance, due to the current i_g fed back through the anode-grid capacity, is equal to $L_e \frac{di_g}{dt}$. Although it is only intended to use the steady state solution of the differential equation subsequently derived, the above equation can only legitimately be used if the resistance of the input circuit can be neglected. This limitation is not mentioned at this stage of the work, though it is subsequently shown that under the particular conditions of tuning assumed by Mr. Medlam the resistance terms in the expression derived for this equivalent inductance are relatively negligible (*see* (24)).

But how, then, can we reconcile equation (14)? e_r denotes the feed-back voltage, and this is precisely the potential drop across the equivalent inductance which has been taken in equation (12) as equal to $L_e \frac{di_g}{dt}$. But equation (14) states that this potential drop is equal to $\omega L_e i_g$. Since we are dealing with the instantaneous values of e_r and i_g, $\omega L_e i_g$ is not at all the same thing as $L_e \frac{di_g}{dt}$. As a relation between *instantaneous* values the equation $e_r = \omega L_e i_g$ can only mean that e_r is in phase with i_g, whereas $L_e \frac{di_g}{dt}$ represents a voltage 90 deg. out of phase with i_g. While, therefore, the use of the expression $L_e \frac{di_g}{dt}$ to represent the voltage drop across the equivalent inductance is open to criticism, the statement $e_r = \omega L_e i_g$ appears to me to be quite indefensible, and any conclusions derived from an analysis making use of this relation cannot be expected to be valid.

Quite apart, however, from the soundness, or otherwise, of the mathematical work, there is another point to which, I think, exception must be taken. If I understand rightly, Mr. Medlam assumes the input circuit to be so tuned as to apply a maximum potential difference between grid and filament when the latter is disconnected from its supply, and the circuit is not supposed to be re-tuned to allow for the de-tuning effect of the feed-back when the valve is working. If this is so, it would not be at all surprising if a correct analysis were to show that distortion does occur in such circumstances. Surely it is well known that a slightly de-tuned circuit does cause a certain amount of distortion! Again, it appears to me that to obtain a true estimate of the amount of distortion produced, it is not sufficient to consider merely the distortion which may be produced in the grid-filament potential difference, but it is necessary to examine what is the amount of consequent distortion of the wave-form of the rectified current in the anode circuit. This would appear to be the only true criterion of the distortion produced. While it is quite certain that distortion of the potential difference to the extent indicated by the curves in Figs. 7 and 9 would result in considerable distortion of the current wave-form, it is by no means certain that it would be comparable with that present in the potential difference, and it is quite possible for a certain relatively small amount of distortion of the potential difference to occur without its being reproduced in the current waveform to any appreciable extent at all.

A further point which strikes one in Mr. Medlam's results is the enormous reduction in the carrier-wave component of the grid-filament potential difference which is indicated by Fig. 4, particularly in view of the small values of amplification factor to which the curve applies. Since, by (37), the ratio $\frac{cE_g}{E}$ varies nearly inversely as μ, consider what an enormous reduction of potential difference is indicated in the case of a valve working as a grid-leak detector with a value of μ of anything from 10 to 20! This result in itself appears to me to be sufficient to throw considerable doubt on the validity of Mr. Medlam's conclusions.

Since reading his article I have examined the question somewhat carefully, taking account even of terms of the order $\frac{m^2}{\omega_c^2}$ compared with unity, and the conclusions I have reached are the exact opposite of those derived by Mr. Medlam.

According to my analysis, *provided the input circuit is properly re-tuned to allow for the de-tuning effect of the feed-back*, the distortion produced in the grid-filament potential difference by the feed-back—both as regards magnitude and phase—is only of the order $\frac{m}{\omega_c}$ compared with unity, and the resulting distortion of the rectified current of modulation frequency is only of the order $\frac{m^2}{\omega_c^2}$ compared with unity.

The sole appreciable effect of the feed-back is to increase the effective resistance of the input circuit, and this it does only to a far less extent than indicated by Mr. Medlam. In fact, for the example given by him, I find an increase of only 3 per cent. for a value of $\mu = 0.15$, whereas he finds an increase of 100 per cent.!

While I do not expect these conclusions to be taken on trust, I think it must be admitted that there are adequate grounds for not accepting Mr. Medlam's results without further examination.

E. A. BIEDERMANN.

Brighton.
25th October, 1928.

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

SIR,—Mr. Biedermann's letter contains a whole series of unfortunate assumptions. The first of these occurs in the latter part of his opening sentence. Mr. Biedermann assumes that I was led to the conclusion stated as the result of a mathematical analysis. As a matter of fact I first became aware of the distortion experimentally some twelve months ago. In a certain test a surprising amount of distortion occurred. Its origin was investigated and traced experimentally to feed-back. Some time afterwards it occurred to me to attempt a mathematical analysis to see if the observed effects could be accounted for on theoretical grounds. The resulting analysis gave such a reasonably close quantitative agreement with the experimental observations, on the carrier and outer side-bands, that I had no hesitation in assuming the substantial accuracy of the results of the analysis.

The first point of Mr. Biedermann's criticism is on the omission of resistance terms from the equations. This omission was deliberate, and was made with full knowledge of its implications. A complete and exact solution of the problem, applicable to all cases, is so complex as to be of no practical value. Thus one is forced to narrow the scope of the solution, by assuming this and that, until a manageable result emerges. In the present case, even if the resistance terms had been of considerably more importance than they really are, I should probably have restricted the scope of the solution still further rather than include them; provided, of course, that the order of the results still agreed with experimental observations.

I agree with Mr. Biedermann's comment on equation (14). There is an obvious slip here. This equation, for the case considered, should read $e_r = L_e \frac{di_g}{dt}$. This change slightly alters the form of the solution, but has little effect on the numerical values of e_g on the carrier and outer side-bands. The phase shifts of the side-bands, however, are modified considerably, particularly as there is a misprint in the original equation! The corrected solution (equation 18) should read

$$e_g = E\sqrt{\frac{k_1^2 + k_2^2}{(k_1 - \mu)^2 + k_2^2}} \sin\left[\omega t + \tan^{-1}\frac{k_2}{k_1} - \tan^{-1}\frac{k_2}{k_1 - \mu}\right],$$

in which k_1 has its original value, and k_2 (equation 20) has a + instead of a − sign between the terms in the brackets. Equations (26) and (27) may be taken to be unaltered. The denominators in (34), (35) and (36) should be corrected to the form $(k_1 - \mu)^2 + k_2^2$, and (37) should read

$$cE_g = .091E/(.091 + \mu).$$

The only other change is in (38), in the numerator of which μ should replace μ^2, while the denominator should read $(k_1 - \mu)^2 + k_2^2$.

The tuning condition given in my article was assumed only after due consideration. The exact condition could be obtained only by differentiating for a maximum value of e_g a complete solution for the untuned case. This solution, including resistance terms, involves a differential equation of the fifth order, the coefficients of which involve, literally, thousands of terms. For example, the coefficient of $\frac{d^4 e_g}{dt^4}$ has 2416 terms! In view of the complex nature of the exact solution I did not present this in the article, but finally adopted the much simpler tuning condition given. The difference between the two conditions is minute; and besides, it was known from experimental results, obtained under average conditions, that re-tuning to allow for feed-back has no appreciable effect.

The question of distortion of the L.F. current wave form in the anode circuit is outside bounds. I am not sure that I agree with the last part of the paragraph in Mr. Biedermann's letter dealing with this point—but it would take too long to explain.

Regarding the enormous reduction in the carrier wave component when μ has its normal value, this effect has been experimentally verified for a valve adjusted for amplifying conditions. Although I did not personally carry out the experiments on this point, I have seen results showing the input voltage reduced by feed-back to some 5 or 10 per cent. of its original value. That my theoretical results show a large reduction does not at all "throw considerable doubt on the validity" of my conclusions: *it proves them.*

In view of the above it is unnecessary for me to comment on the theoretical results Mr. Biedermann claims to have obtained. On this matter I will take up only the statement to the effect that the rectified current of modulation frequency is proportional to the square of the input modulation voltage. This is not at all the case if an anode bend detector is used under proper operating conditions. It has been shown theoretically by Colebrook, and experimentally in the paper referred to in my article that the relation between the anode current of modulation frequency and the input voltage modulation depth is practically linear if the mean carrier input is of the order of 1 volt. The square law does not operate until the mean input drops to about 0.25 volt—and this type of detector would not be used, normally, on such small inputs for other reasons.

Regarding the last sentence in Mr. Biedermann's letter, I hope that, after reading my reply, he will come to the conclusion that my results are better grounded than he imagined.

In conclusion, I may add that since reading Mr. Biedermann's letter I have made some measurements on modern types of valves. A PM4DX valve with a capacity of 50 $\mu\mu$F. across the external anode resistance showed a drop in input voltage due to anode-grid capacity somewhat exceeding 50 per cent. on the carrier frequency (10^6 cycles), with little disturbance of the original input on the side-bands corresponding to the higher audio frequencies. Also, a Pentode tested under the same conditions failed to show this effect—the change in input voltage due to anode-grid capacity was in this case very slight, both on the carrier and all side-band frequencies.

WM. B. MEDLAM.

The Problem of International Distribution of Broadcast Wavelengths.

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

SIR,—I beg to advise you that a mistake has occurred in Table I, where in 21/Poland, column 8, the figure 8,33 should appear in place of 6,33. The total will, however, remain unchanged.

W. S. HELLER.

The Transmitting Station actually sends out Waves of One Definite Frequency, but of Varying Amplitude.

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

SIR,—The recent correspondence on the above subject has presented several features of considerable interest. The question raised by your correspondent, Mr. Frank Aughtie, whose letter was published in your December issue, falls into this category.

It must be admitted that it is at first sight difficult to form a clear mental picture, from the purely physical standpoint, of the reason why, if we listen to the second harmonic of a modulated radio-frequency wave, we do not observe all the tones of the modulation to have been raised in pitch by one octave. A simple mathematical analysis, however, renders the matter perfectly clear.

Let us assume that we have a carrier whose instantaneous value, unmodulated, may be represented by $i = i . \sin \omega t$. Then, if we assume this to be modulated by a sine wave of frequency $\phi/2\pi$, to a degree α, the complete expression for its instantaneous value is known to be

$$\begin{aligned}\bar{i} &= i . \sin \omega t(1 + a \cos \phi t) \quad \dots \quad \dots \quad \dots \quad (1)\\ &= i . \sin \omega t + ai . \sin \omega t . \cos \phi t.\\ &= i . \sin \omega t + \tfrac{1}{2}ai\,[\sin (\omega + \phi)t + \sin (\omega - \phi)t]\\ &= i\,[\sin \omega t + \frac{a}{2} \sin (\omega + \phi)t + \frac{a}{2} \sin (\omega - \phi)t] \quad (2)\end{aligned}$$

The above is, of course, perfectly well known, and shows why it is necessary to regard a carrier modulated with a sine wave as being identical in all respects as the same carrier plus two side bands, all of constant amplitude. It is to be noted that the two expressions, (1) and (2), are mathematical identities, no mysterious processes, valve rectification, etc., are involved in the production of one from the other.

If now we take such a modulated wave, and apply it to the grid of, say, an amplifying valve, which is not working in a linear manner, harmonics will be present in the radio-frequency output of the device. Now a dynamic valve characteristic is very nearly parabolic in form, and may therefore be represented mathematically in the form

$$Y = AX^2 + BX + C \quad \dots \quad \dots \quad (3)$$

where A, B and C are suitably chosen constants, and where X, which may be any function we please, represents the input to the valve, Y representing the corresponding output.

In order to see what will be the terms present in the output of the amplifier which we have imagined, we have plainly to substitute for X in equation (3), X being of the form of either (1) or (2).

Now the term in (3), which is instrumental in producing harmonics, is that involving X^2; in other words, all we have to do in order to find the relation between the various harmonics produced by such a valve is to square either (1) or (2), and examine the terms contained in the result. Plainly it will not matter which form of the function we employ.

From (1):

$$\begin{aligned}\bar{i}^2 &= i^2 \sin^2 \omega t(1 + a \cos \phi t)^2.\\ &= i^2\,[\sin^2 \omega t + 2a \sin^2 \omega t . \cos \phi t\\ &\qquad + a^2 \sin^2 \omega t . \cos^2 \phi t].\\ &= i^2[(1 - \cos 2\omega t)/2 + a(1 - \cos 2\omega t) \cos \phi t\\ &\qquad + a^2(1 - \cos 2\omega t)(1 + \cos 2\phi t)/4].\\ &= i^2[\tfrac{1}{2} - (\cos 2\omega t)/2 + a \cos \phi t - a \cos 2\omega t . \cos \phi t\\ &\qquad + a^2(1 - \cos 2\omega t + \cos 2\phi t\\ &\qquad - \cos 2\omega t . \cos 2\phi t)/4].\\ &= i^2[\tfrac{1}{2} - (\cos 2\omega t)/2 + a \cos \phi t\\ &\qquad - \tfrac{1}{2}a \cos (2\omega - \phi)t - \tfrac{1}{2}a \cos (2\omega + \phi)t\\ &\qquad + a^2/4 - (a^2 \cos 2\omega t)/4 + (a^2 \cos 2\phi t)/4\\ &\qquad - a^2/4 . \tfrac{1}{2} \cos (2\omega - 2\phi)t\\ &\qquad - a^2/4 . \tfrac{1}{2} \cos (2\omega + 2\phi)t].\\ &= i^2[\tfrac{1}{2} + a^2/4 + a \cos \phi t + \frac{a^2}{4} \cos 2\phi t\\ &\qquad - \tfrac{1}{2}\,(\cos 2\omega t + a \cos \overline{2\omega - \phi} . t + a \cos \overline{2\omega + \phi} . t)\\ &\qquad - (a^2/4)\,(\cos 2\omega t + \tfrac{1}{2} \cos \overline{2\omega - 2\phi} . t\\ &\qquad + \tfrac{1}{2} \cos \overline{2\omega + 2\phi} . t)] \quad \dots \quad \dots \quad (4)\end{aligned}$$

By inspection of expression (4) we see that the radio-frequency harmonics present in the output of the valve consist of (a), a carrier of twice the original carrier frequency, together with side-bands corresponding to modulation of the original frequency, and (b), a carrier of twice the original frequency, together with side-bands corresponding to twice the original modulation frequency.

It is to be noted further that in the case of (a), the percentage modulation is double that of the original modulated carrier, and therefore if the latter was more than 50 per cent. the harmonic will be overmodulated and therefore its envelope will not be sinusoidal.

In the case of (b), the magnitude of the whole group of terms is small compared with (a) on account of the factor $\alpha^2/4$, α being never greater than unity.

Thus, in practical terms, if we listen to the second harmonic of any modulated carrier we shall hear the original modulation and not the octave, but a certain amount of harmonics of the original modulation frequencies will always be present, introducing more or less distortion. This, of course, is strictly in accordance with practical experience.

As already stated, it is plainly immaterial whether we start with expression (1) or (2), since these are identities. Had we started with expression (2) we should have had to square a function of the form $A + B + C$. The result would have been of the form

$$A^2 + B^2 + C^2 + 2AB + 2BC + 2CD.$$

This would have reduced to expression (4) above. The fallacy in Mr. Aughtie's argument arises from the omission, in effect, of the last three terms, $2AB + 2BC + 2CD$.

The whole matter only confirms that from every point of view all observed facts can be explained by either the side-band or the varying amplitude theory of a modulated carrier.

In this connection it is interesting to consider the effect of a fairly lightly damped tuned circuit, such as an aerial may be, on a modulated carrier. Some of your correspondents seem to have difficulty in visualising the cutting off of the higher modulation frequencies by such a circuit on the basis of the constant frequency—changing amplitude conception, though they readily appreciate the effect of a sharp resonance curve as regards response to side-bands. Surely the explanation is that if a tuned circuit has a sharp resonance curve its decrement is low, and hence it is difficult for any oscillation at the resonant frequency of the circuit to build up and decrease in amplitude sufficiently rapidly to reproduce the higher modulation frequencies.

A. B. Howe, M.Sc.

The British Broadcasting Corpn.,
Clapham Park, S.W.4.

Effect of Frequency on the Value of Resistances.

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

Sir,—In reply to Mr. Coursey's correspondence on my tests on grid leak resistances, I regret that my description of the Dubilier leaks tested has led to a misunderstanding.

The type of Dubilier leak tested and described as consisting of a strip surrounded by a glass enclosure was one of the earliest of the Dumetohm pattern marketed by the Dubilier company. The misleading description of this leak is the result of an incomplete examination of the metallised filament, which I am now pleased to correct.

The leak described as the "usual type of Dubilier leak" and consisting of a strip of compressed material surrounded by a layer of wax and enclosed in a cylindrical casing of compressed paper, conforms to the old pattern mentioned by Mr. Coursey, a pattern which I was unaware is now obsolete.

I trust that this may remove any possible misunderstanding which my statements have incurred.

W. Jackson.

Burnley.

Alignment Valve Characteristics.

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

Sir,—In a recent article your contributor, Mr. Reed, described an alignment chart for the purpose of deriving valve characteristics, and claimed that by means of it any one of the three usual forms of graphical characteristic could be rapidly reproduced. This, of course, is quite correct. May I, however, be allowed to express the opinion that in thus limiting the functions of the alignment chart Mr. Reed is, perhaps unconsciously, passing over the chief merits of a method which deserves to be more widely known.

I would suggest that, in cases where alignment representation is possible (as in this instance by virtue of an assumed formula) it would be better to connect the related variables directly by alignment in a manner analogous to that described in an article which I contributed to your pages in May, 1927. To describe the method would occupy too much space for a letter, but it may be said here that such an empirical chart will be much easier to construct than Mr. Reed's example. But the chief merit of such an inverse chart is that by means of it we can go behind and dispense with the formula, which is, after all, only an approximation. If desired, too, such a chart can be used as a basis from which the constants of the formula themselves may be derived. This is an important feature of the method, and is worth special emphasis.

Mr. Reed says nothing as to the process by which the constants of the Van de Bijl formula were derived. It is only after they are determined that he calls the alignment process into play. Since the whole application of these methods to valve characteristics is admittedly approximate, it seems in every way more desirable that the nature and amount of the approximation should throughout be determined by alignment methods. In other words, an alignment chart constructed directly from the observed data is likely to be more satisfactory than one which is derived at second hand, as it were, through the medium of a particular numerical formula. The extreme flexibility of the alignment process when thus used inversely (*e.g.*, simplicity of arrangement and graduation of scales) has already been mentioned in these pages (*loc. cit.*). On the whole it seems a pity that when dealing with so essentially an experimental subject as valve characteristics, Mr. Reed confined himself solely to the computational uses of alignment, and omitted all reference to its value in the correlation of experimental data.

As an enthusiastic advocate of alignment methods, and a firm believer in their utility in wireless engineering, I do not feel such criticism to be a particularly gracious task. But it is, I hope, constructive, and in the interests of the science Mr. Reed will, I am sure, pardon my impression that it was necessary.

W. A. Barclay.

Arcadia, Bieldside, N.B.

Abstracts and References.

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PROPAGATION OF WAVES.

Feldstärkemessungen auf grosse Entfernungen im Rundfunkwellenbereich (Field Strength Measurements at great distances for Broadcast Wavelengths).—M. Bäumler. (*E.N.T.*, November, 1928, V.5, pp. 473–477.)

Preliminary results of a quantitative investigation into the propagation of test waves of 190, 405 and 585 m., transmitted in long dashes from Döberitz and measured at five collaborating institutions at distances ranging from 90–545 km. all using the Anders method. Tables and charts are given. The Hertzian values (calculated for propagation in free space) are nearly reached—once, apparently, actually reached—by occasional night peak-values. This was also found by the writer, in 1924, to occur on Rocky Point and Marion wavelengths (16,400 and 11,600 m.). It is supposed that intermediate wavelengths behave similarly. Fading observations are discussed. Some of these, recorded by a semi-automatic procedure, were on 190 m. and showed slow fading periods of 1½ minutes. Possibly these could be attributed to the transmitter. Apart, however, from this particular group, the writer states that the observed strong fadings at night, if caused at all by interference between two waves, could only be caused by interference between two waves of practically equal strength: the surface wave would not be strong enough: two waves by similar but differing paths must be concerned, or else some meteorological cause. The paper deals next with attenuation, giving a table of values for alpha (in the expression $\epsilon^{-\alpha d}$) for the several wavelengths and over the several distances. A comparison with Austin's "over-sea" formula gives an average value for α over land about 10 times as great as over sea—"a relation confirmed by other measurements in the broadcast zone." The paper ends with some atmospheric measurements, chiefly of "grinders" which varied from 1.5 to 6, with an occasional rise to 10 microvolts per metre. On 190 m. wavelength somewhat smaller values were obtained. Occasional strong "clicks" reached 26 $\mu V/m$.

Das Verhalten kurzer Wellen in unmittelbarer Nähe des Senders (The Behaviour of Short Waves in the Immediate Neighbourhood of the Transmitter).—J. Fuchs. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, pp. 170–171.)

The difference in short wave radio reception by day and night is supposed to be due to the variation in ion concentration in the upper atmosphere. The smallest height for the conducting layer is estimated by Pedersen at 70 km. The writer, since 1926, has observed field strength decreases at night (as great as from $40\mu V/m$ to $3\mu V/m$) on 43 and 30 m. waves at a distance of a mere 10 km., and smaller decreases at distances down to 4 km., on a 20 m. wave. Attempts to reconcile these results with the theory would involve assuming either that the lowest surface of the Heaviside layer was only about 3.5 km. from earth, or that the night ionisation was far greater than it is thought to be—a supposition involving great difficulties in the matter of long distance reception of other short waves. A third explanation—that the ray is inclined at about 88 deg. and at night penetrates the layer and does not return to earth—is untenable because in actual fact the signals at night were excellent behind the skip zone.

Short Wave Echoes and the Aurora Borealis.—B. van der Pol. (*Nature*, 8th December, 1928, V. 122, pp. 878–879.)

Facts here mentioned prove the authentic character of the Stôrmer-Hals echoes dealt with in last month's Abstracts. They are difficult to observe, but they have been heard by several observers at different places and sometimes simultaneously. Though their oscillation frequency could easily be identified as the same as that of the original signal, the three dots of the latter could not be recognised in the echo, which was of a blurred nature; except in one case where the echo was 3 seconds after the signal and the three dots were plainly audible.

The writer suggests, as an alternative to Stôrmer's hypothesis that the waves actually penetrate the layer, that the waves may penetrate well into but not through the layer. As Appleton has shown, the layer usually has a relatively well marked lower boundary against which waves travelling nearly vertically are sharply reflected. The apparent dielectric constant diminishes with [an increase of] the density of electrons, and even becomes zero for waves of 31.4 m. length when the density is about 10^6 electrons per c.c. Moreover, since $v_p \times v_g = c^2$, at the places where the electron density is near the critical one the phase velocity becomes infinite—but at the same time the group velocity approaches zero. When it happens that the relative variation of density with height (over a distance of a wavelength) is small, the waves may penetrate and soak well into the layer and travel in regions where v_g is small; they will then be reflected at the region where the apparent dielectric constant approaches zero. Thus any time-interval between signal and echo can be expected to occur, the phenomenon being wholly governed by the gradient of electron density; this fits in with the other echoes found by Taylor and Young, and with the general fact that the time-interval is extremely variable.

Short Wave Echoes and the Aurora Borealis.—E. V. Appleton. (*Nature*, 8th December, 1928, V. 122, p. 879.)

In connection with the Stôrmer-Hals echoes, the writer suggests that such long temporal retardations of short wave signals may be explained by purely terrestrial agencies. At the U.R.S.I. meeting last September, in discussing the first announcement of similar (shorter) retardations (Taylor and Young, Abstracts, 1928, V. 5, p. 460) he pointed out that waves meeting the ionised layer at vertical incidence would travel upwards until they were "reflected" at a point where the group velocity was reduced to zero; and that if the ionisation gradient in this region was not large, the waves might be appreciably retarded before and after reaching the critical value of ionisation. The retardation of any signal sent up from the ground and received there again is $\frac{1}{c}\int\frac{ds}{\mu}$ (where c is velocity of radiation *in vacuo*, ds an element of path, and μ the refractive index), and this quantity may greatly exceed $\frac{1}{c}\int ds$ if μ is very small for an appreciable part of the path. He mentions here that Borrow, in London, has obtained photographic registration of echoes from Eindhoven corresponding to retardations of 1 second—intermediate between the Taylor-Young and Stôrmer-Hals retardations. As possible paths in which the waves could remain travelling with a low group velocity in the ionised layer for so long as 10 seconds and yet reach the ground again with appreciable intensity, he suggests voyages round the earth or horizontal journeys into the sunset (or sunrise) discontinuity in the layer, with reflection there (*cf.*, Hoag and Andrew, January Abstracts). If the group velocity is small the signal intensity is reduced to $\epsilon^{-ft/2}$ of its initial value, f being the frequency of electron collisions with air molecules and t the time of retardation in the layer. If the commonly accepted values for f are correct, the attenuation of signals retarded by travelling at heights up to 400 km. would be very great. But if there were sufficient ionisation at heights of 600 km. or more, retardation without much absorption could take place. The writer suggests another possibility—that if the ionised layer is regarded as a reflecting shell, there will be convergence of transmitted waves to some point near the Antipodes which—in turn—may be regarded as a source whence another set of waves emerges. Conditions in the layer alter very rapidly, so that the points to which the waves converge every 1/7 sec. (the time of a circumferential journey) will vary rapidly. It thus may be some seconds before a particularly loud repetition reaches a particular region of the earth. He concludes by foreshadowing some tests on 30 m. waves to determine whether they do or do not penetrate the layer when they meet it at approximately vertical incidence.

The Attenuation of Wireless Waves over Towns.—R. H. Barfield and G. H. Munro. (*E.W. & W.E.*, January, 1928, V. 6, pp. 31–37.)

Full abstract of the paper read before the Wireless Section of the I.E.E. on 5th December, 1928, and of the subsequent discussion. It is divided into three parts: Description of Experimental Work (measurement of the polar curve of 2LO and construction of a revised contour map; experiments to determine change of attenuation with wavelength); Theoretical Discussion of Results; and Conclusion. There is an Appendix, Experimental Confirmation on Short Wavelengths.

Radio Transmission and the Upper Atmosphere.—G.W.O.H. (*E.W. & W.E.*, December, 1928, V. 5, pp. 657–659.)

An editorial on the results of Appleton's investigation as to the concordance which might be expected between the three main methods of determining the effective height of the Heaviside layer: namely, the wavelength change, angle of incidence, and group-retardation methods. If the atmospheric ray travelled with a constant velocity until it met the lower surface of an ionised layer and were there reflected in the ordinary way, all three methods would necessarily give the same result for the height of that lower surface, unless the reflection introduced a change of phase which varied with the wavelength. If, however, the ray enters the ionised layer and, owing to the increasing ionisation and consequent increasing velocity with increased height, is refracted along a curved path back to the surface, through it, and down to earth, it is by no means evident that the three methods should give the same result; in fact, at first sight, it looks rather improbable. But the complete theoretical investigation shows that even here the three methods should lead to the same value for the equivalent height: which is a greater height than the refracted ray ever reaches. Appleton's paper was communicated to the U.R.S.I. in September, 1928, and later to the Physical Society.

Note on the Determination of the Ionisation in the Upper Atmosphere.—J. C. Schelling. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1471–1476.)

The pulse-time, earth-angle, and shift of interference fringe methods for measuring the effective layer height lead substantially to the same result for short waves. Pedersen states that the last method gives apex-height values which are too small. This would be the case if the measurement gave the total number of wavelengths in the path. The writer, however, maintains that none of the three methods does give this total, and that all three give heights which are too great. He then describes a difficult but direct method for obtaining the total: starting at a very low frequency, and gradually working upwards, the fringes at a receiver one or two hundred kilometres away would be counted. Each fringe would represent the gain of one wave in the overhead path as compared with the number—also increasing—in the direct path. This number, integrated from zero frequency to the frequency in question, would give the difference in wave numbers for the two paths. Hollingworth has obtained fringes at 20 kc., and even if the tests started no lower than there, the error due to having to take estimates for the still lower frequencies would be very small. Having obtained the wave number, the height of the apex of the path could be determined by Pedersen's construction (wave number in true path to apex = straight line distance to apex divided by wavelength in vacuo) where the error is small if the initial earth angle is less than 60 deg. The above "prohibitive and unnecessary" experimental procedure can be cut out, however, by the use of an equation connecting the *group* times with the quantities actually measured by the ordinary methods—namely, $T_{g2} - T_{g1} = \frac{d\,(N_2 - N_1)}{df}$, the right-hand expression (where N_2 and N_1 are the total number of wavelengths in the two paths) being the quantity actually measured. The writer, in the absence of really sufficient data, illustrates his method by applying it to averaged data for four different frequency zones, representing the adapted results of Hollingworth (20 kc.), Bown, Martin and Potter (610 kc.), Appleton and Barnet (750 kc.), and Heising (5,000 kc.). Plotted on a frequency scale, the four equivalent heights fall on a straight line, the equation of which is $H = 80 + 0.0440\ f$. The straight line representing the values calculated by the present method, while coinciding with this line at the lowest frequency, slopes up much less quickly, so that—for example—at 5,000 kc. it reaches rather above 192 km. instead of 300 km. The writer also calculates the ionisation on the basis of the earth angles calculated from the original data, showing the results on a height ionisation curve. They assume that collisions and the earth's magnetic field do not greatly affect them; it is suggested that these assumptions are satisfactory at frequencies higher than 2 or 3 megacycles. The curve (for night time) indicates an approximate increase in proportion to the square of the height above 80 km.; reaching a value of 3×10^5 at about 200 km. The writer emphasises that all these calculations are given on meagre data as examples of his method, but suggests that the results "look plausible and are probably more accurate than the original data." He foreshadows a series of echo or fringe experiments at several frequencies from 1,000 to 10,000 kc., the base line being made sufficiently long to avoid initial ray angles greater than 60 deg. from the horizontal.

RÔLE POSSIBLE DE LA DIFFUSION PAR LES ÉLECTRONS DANS LA PROPAGATION DES ONDES COURTES (Possible Rôle of the Diffusion by Electrons in the Propagation of Short Waves).—Ponte and Y. Rocard. (*Comptes Rendus*, 10th November, 1928, V. 187, pp. 942–943.)

To explain his experimental results, T. L. Eckersley imagines a diffusion of short waves by the free electrons of the Heaviside layer: Jouaust and Fabry have also directed attention to such a diffusion (*cf.* Abstracts, 1928, pp. 221 and 578; 1929, p. 39). The writers consider waves of "some dozens of metres" length: their diffusion by the layer, "which has at least some twenty kilometres thickness" would seem to be analogous to that of light by a perfect gas. But to produce the received signals, effects thus calculated would have to be multiplied by 10^5: or—as this may be interpreted—the free electrons must vibrate in groups of 10^5, in phase agreement. The writers thus picture that for some unknown reason the layer is not like a gas of electrons but has a true structure, being made up of "molecules" (each a little cloud of electrons comparatively dense—*cf.* Eckersley's "clouds small in dimensions compared with the wavelength"—*Abstr.*), which repel each other and take up more or less definite mean distances: a structure analogous to that of a liquid. If d (the mean distance between the two "molecules") is of the order of λ, the diffusion may be compared to that of an X-ray by a liquid or a crystalline powder. In the case of the X-ray, there is a very pronounced maximum of diffusion on the generating lines of a cone of revolution having as axis the direction of incidence and as half-angle of apex the angle θ given by Bragg's law $\lambda = 2\,d \sin\frac{\theta}{2}$. Assuming this to hold for the Heaviside layer diffusion, each little element of the layer will be hit by a direct ray and will diffuse chiefly at an angle θ to the ray. Considering the combined effects of all the little elements, it will be seen that the diffused rays thus produced have an envelope which will ordinarily cut the earth, *at a point which will actually be the limit of the silence zone*—"for there is no diffused radiation inside the envelope": (but *cf.* final paragraph). The writers treat the Hulburt-Taylor results thus: Above $\lambda = 45$ m. (about) there was no silence zone: this leads to taking $d = 22$ m. They then try out their calculations for various assumed effective heights of the layer, and with one particular assumed height they obtain the following skip distances for the wavelengths used by Hulburt and Taylor (16, 21, 32 and 41 metres):—2,400 km. (2,410), 1,500 km. (1,300), 740 km. (710), and 324 km. (325). The brackets give the values actually observed. The effective height which has to be assumed in order to get such an agreement is 360 km. Simple trigonometry gives, as the shortest wave which can pass (*i.e.*, that for which the envelope touches the earth instead of cutting it) the wave of 14 m. The large observed variations in skip distance are explained either by fairly large variations of effective height or by relatively much smaller variations of d. The energy of the diffused rays is accumulated along the envelope, rather as in a caustic curve: the edge of the silence zone should therefore be a region of strong reception, and the slightest variations of height or of d should create correspondingly strong fading. Finally, the energy diffused by an element is not confined to the direction θ: in other directions there is a feeble diffusion which would account for the weak reception found by Eckersley in the silence zone.

RADIO COMMUNICATION AND MAGNETIC DISTURBANCES.—C. S. Wright. (*Nature*, 22nd December, 1928, V. 122, p. 961.)

Henderson's data on the working of the Macquarie Island station during 1914 and 1915 give the days on which the receipt of wireless signals was difficult or impossible—apparently excluding the days when atmospherics were serious enough to cause the trouble. The writer has tabulated the international magnetic character numbers for each of these "bad" days · the mean number is 1.1 for 1914 and 1.0 for 1915, compared with 0.55 for 1914 and 0.64 for 1915 *for all the days of the months in question*. "This close relation between bad wireless communication and magnetic disturbance is the more surprising because the international character numbers are awarded mainly on the results from the more numerous magnetic observatories of the northern hemisphere. It would be interesting to compare these results with the magnetograms from the Christchurch Magnetic Observatory. . . . These polar regions contain the auroral belts which are highly disturbed magnetically, and world-wide communication along great circle paths will often cross these belts. . . . It may be that close study will enable rules to be laid down as to the best means of round-about communication by relay stations on bad days, analogous to the mariner's rule for avoiding the centre of a hurricane. It may be mentioned that the apparent relation between bad wireless communication from New Zealand and neighbouring parts to Macquarie Island, and magnetic disturbance defined by the international character number, is closer than the relation between this character number and exceptional aurora observed at Macquarie Island."

FADING CURVES ALONG A MERIDIAN.—R. C. Colwell. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1570–1573.)

The fluctuations in signal strength of KDKA, Pittsburgh, Pa., were observed through the sunset period of Morgantown, W. Va., which is nearly on the same meridian; any variation at sunset should therefore be due to changes in the Heaviside layer and not to refraction through the earth's shadow. The typical curve for a clear day is rather disturbed during the daylight hours, and after sunset increases and shows considerable fading; that for a cloudy day is uniform during the daylight hours, and the increase after sunset is fairly steady. "These observations indicate a new relation between signal intensity and the state of the atmosphere. Other relations have been noted by Austin (Abstracts, 1927, V. 4, p. 177; also *Proc. Inst. Rad. Eng.*, December, 1924) and Pickard" (Abstracts, 1928, V. 5, p. 519). The new relation can be explained if the layer is assumed to be partially operative even during the daylight hours. On fine days there is a reflected ("sky") wave which interferes with the ground wave, causing a slight fluctuation during the afternoon. After sunset the reflected wave increases in intensity and fading becomes more pronounced. On cloudy days the atmospheric conditions prevent the sky wave from reaching the reflecting layer, and only the steady ground wave is received. "It should be understood, however, that the typical cloudy weather curve can only be obtained in the middle of a cloudy period, and similarly for the fine weather curve. When the weather is changing from cloudy to clear and vice versa, the curves are very irregular and depart from the typical forms."

THE PROPAGATION OF AIR WAVES AND THE UPPER ATMOSPHERE.—F. J. W. Whipple. (*Engineering*, 2nd November, 1928, V. 126, p. 562.)

Summary of the paper read before the British Association. The sound of a great explosion can generally be heard at distances exceeding 200 km.; but there is, beyond the inner zone of audibility, a zone of silence and, further, a usually incomplete and irregular outer zone of audibility. The waves appear to travel by curved paths through the layers of the atmosphere, rising to heights of 40 and 50 km., at which the velocity seems to be greater than near the ground (agreeing with the Lindemann-Dobson theory). Recent research is described: wind effects interfere with the interpretation of results, but neglecting these, the uniform temperature of the stratosphere seemed, on a particular day, to extend up to 30 km. above the ground.

THE STRATOSPHERE OVER NORTH INDIA.—K. R. Ramanathan. (*Nature*, 15th December, 1928, V. 122, p. 923.)

Sounding-balloon results regarding the height and temperature of the base of the stratosphere, and their remarkable seasonal variations.

LONG WAVE RADIO RECEPTION AND ATMOSPHERIC OZONE.—K. Sreenivasan. (*Nature*, 8th December, 1928, V. 122, p. 881.)

A reply to Dobson's comments on the writer's suggestion of correlation between reception at Bangalore and European ozone-values (Abstracts, December, 1928, and January, 1929.)

PHOTOCHEMICAL OZONISATION.—O. R. Wulf. (*Nature*, 24th November, 1928, V. 122, p. 825.)

Summary of a paper in the *Journ. Am. Chem. Soc.* for October. A consideration of electronic levels indicates that radiation of wavelengths 2,070 and 2,530 A.U. is probably incapable of effecting the dissociation of the O_2 molecule, although Warburg (studying the formation of ozone from oxygen under pressure) obtained ozone by such radiation and concluded that the primary photochemical process was the dissociation of the O_2 molecule. On various grounds the writer suggests that the absorbing molecule is O_4, which dissociates into O_3 and O.

DIE FORTPFLANZUNG ELEKTRISCHER WELLEN IN KABELN MIT ZWEI ISOLATIONSSCHICHTEN (The Propagation of Electric Waves in Cables with two Insulating Layers).—N. H. Frank. (*Ann. d. Physik*, No. 11, 1928, V. 86, pp. 422–434.)

By Sommerfeld's method, the solution of Maxwell's equation is obtained for the case of a wire surrounded (first) by two co-axial insulating layers of different dielectric constants; and (secondly) by a conducting sheath. Among other assumptions the wavelength is taken to be long compared with the thickness of the cable. The formula is confirmed experimentally by the use of Pedersen's method for measuring short times by Lichtenberg figures, which shows itself applicable also to the measurement of dielectric constants. A surge is distributed between two electrodes on a photographic plate: from the position of the line of separation of the two electrical figures on the plate, small differences in travel along the two paths are measured.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

THE ULTRA-VIOLET LIGHT OF THE SUN AS THE ORIGIN OF AURORÆ AND MAGNETIC STORMS.—H. B. Maris and E. O. Hulburt. (*Nature*, 24th November, 1928, V. 122, pp. 807–808.)

Preliminary conclusions from a theoretical investigation of the outlying regions of the earth's atmosphere and of the effects of sunlight on those regions. The calculations confirm the idea that above 100 km. the daytime temperatures increase with height, till at 300 or 400 km. temperatures of 1,000 deg. K. seem reasonable. Above 400 km. the atmosphere becomes very rare, and the free paths of the particles would be practically infinite but for the restraining effects of gravity and of sunlight. Some of the particles (atoms or molecules), under the influence of upward thrusts from thermal impacts below, may reach heights of 10,000 km. Some atoms, by "collision of the second kind" with outlying atoms excited by short-wave ultra-violet light, may receive a velocity high enough to send them beyond the normal gravitation of the earth: so may other atoms which absorb the energy of recombination of a positive ion and an electron. Such high-flying atoms may hasten out towards interplanetary space, but soon become ionised by the ultra-violet radiation and are caught by the earth's magnetic field; as ion pairs they are constrained to spiral around the line of magnetic force, eventually being brought back to earth. If the magnetic line ends in night latitudes (as in polar regions after sunset), the ion pairs, plunging to the lower levels, hand over their energy of recombination to the atmosphere of those regions; this energy going into heat or, if the conditions are suitable, reappearing as light such as the auroral display. Quantitative estimates based on reasonable assumed values indicate that enough of the solar ultra-violet energy is carried to a zone 20 deg.–30 deg. from the magnetic poles by high-flying ion pairs, ejected to heights of 20,000–40,000 km., to supply (from a quiet sun) a mild auroral display; this is in keeping with the fact that the aurora occurs on a rough average two or three times a week throughout the year. Other auroral characteristics fit in with the theory. When the sun becomes active, the magnetic effects of the high-flying ions become pronounced and result in magnetic storms. If 1/10,000 part of the solar surface (normally at 6,000 deg.) is removed and the black body radiations from regions at 30,000 deg. exposed, the total ultra-violet energy in the wavelengths 500–1,000 A.U. is increased by 10^5, with a corresponding increase of high-flying ions; whereas the solar constant increases only 1 per cent. (Actually, in times of solar activity, this variation is found to be 3 per cent. or more, and temperatures above 30,000 deg. are indicated.) Calculations show that the blast of solar ultra-violet light pictured above produces enough high-flying ions to give (by their flow under the combined action of gravity and the earth's field) a current of 10^6 A. for an hour or so, causing a magnetic field of the order of 10^{-3} gauss simultaneously over the whole earth —of the right order of magnitude for the first phase of a world-wide magnetic storm. The high-flying ions descend to form diamagnetic concentrations in the zones about 25 deg. from the magnetic poles. If the blast of ultra-violet light continues with lessening intensity for a day or two, these concentrations would wax and wane by day and night, causing changes which agree "in practically every detail" with the observed complicated diurnal storm variations.

THE ULTRA-VIOLET LIGHT OF THE SUN AS THE ORIGIN OF AURORA AND MAGNETIC STORMS.—S. Chapman. (*Nature*, 15th December, 1928, V. 122, p. 921.)

A criticism of the letter abstracted above. The terrestrial effects of the occasional sudden blasts of ultra-violet light would be felt almost immediately; and would depend relatively little upon the position of the emitting area on the sun's disc. The latter consequence appears incompatible with the marked tendency for abnormal terrestrial magnetic conditions to recur after about 27 days—the rotation period of the sunspot zone relative to the earth: indicating that the cause must be something which travels outwards from particular disturbed areas in laterally limited beams—almost certainly corpuscular. Accumulating evidence indicates that the material of the stream occupies a time of the order of a day in passing from the sun to the earth. This appears incompatible with the former consequence. Apart from these fundamental objections, the writer criticises the proposed explanations of the two phases of a magnetic storm. He refers to Gunn's recent diamagnetic theory of the solar diurnal magnetic variation (Abstracts, 1928, V. 5, p. 578) with which also he finds himself in disagreement, and ends by promising to publish shortly a new discussion of the theory of magnetic disturbances, assuming the cause to be a neutral ionised stream (as suggested by Lindemann).

ÜBER ELEKTROMAGNETISCHE STÖRUNGEN (On Atmospherics).—F. Schindelhauer. (*E.N.T.*, November, 1928, V. 5, pp. 442–449.)

The writer (of the Meteorological Magnetic Observatory, Potsdam) gives a number of curves representing his Potsdam results on atmospherics; then, combining these with data put at his disposal by Watson Watt, representing similar observations at Ditton Park, Lerwick and Aboukir, draws his own conclusions, which he summarises somewhat as follows: Since the directions of maximum electromagnetic disturbance lie either in the direction of the earth's magnetic lines of force or at right angles thereto, the view is taken that the majority of atmospherics originate, at great heights in the upper atmosphere, in field changes caused (1) by those electrons arriving from the sun which are constrained by the earth's field to form an equatorial ring-stream, and (2) by what he calls the "horizontal current-eddies" in the heights of the Heaviside layer, maintained only on the day light half of the earth by ultra-violet radiation, and therefore moving over the earth from E. to W., attaining their greatest magnitude in summer. They are due to the conducting layer suffering, from time to time, displacement in the magnetic field, owing to movements of the atmosphere. Atmospherics caused by (1) are "clicks": they come at night, from the direction at right angles to the magnetic lines of force; at daybreak the horizontal eddy in the Heaviside layer begins to screen the earth from the effects of these higher impulses, the "clicks" begin to decrease, while simultaneously the "grinders" due to cause (2) begin to come in from the N.-S. direction. This theory fits in well with the daily and yearly variations in direction and frequency of atmospherics.

Atmospheric Oscillations shown by the Microbarograph.—N. K. Johnson. (*Nature*, 8th December, 1928, V. 122, p. 908.)

Summary of paper read before the Roy. Met. Soc. Regular wave-like records are obtained representing oscillations of atmospheric pressure ranging from about 6 minutes to an hour, with a marked maximum for a period of about 10 minutes.

On the Association of the Diurnal Variation of Electric Potential Gradient in Fine Weather and the Distribution of Thunderstorms over the Globe.—F. J. W. Whipple. (*Nature*, 8th December, 1928, V. 122, p. 908.)

Summary of a paper read before the Roy. Met. Soc. Observations of the gradient in polar regions and at sea give results consistent with C. T. R. Wilson's suggestion that the connection between the upward currents produced by thunderstorms and the downward currents elsewhere is *via* the Heaviside layer.

Molecular Hydrogen in Sunspots.—G. Piccardi. (*Nature*, 8th December, 1928, V. 122, p. 880.)

From spectroscopic photographs the writer deduces the presence of molecular hydrogen in sunspots.

Character Figures of Solar Phenomena.—(*Nature*, 22nd December, 1928, V. 122, p. 974.)

A paragraph announcing the first number of a Bulletin issued from Zurich under the auspices of the International Astronomical Union.

TRANSMISSION.

Secrecy System for Signalling.—(*N. Zealand Patent* 61093, *Standard Telephones and Cables, Australasia*, pub. 16th August, 1928.)

A speech wave separately modulates two carrier waves of such frequencies that the resulting upper side bands, for example, are contiguous, and when selected and added form a band of frequencies double the width of the speech-band, the carrier waves being suppressed in the modulators. This band, of double speech-band width, modulates a *variable-frequency* carrier wave, which is suppressed in the modulator. The resulting upper side-band, for example, is a "wobbling" band, its width in the frequency scale being twice the width of the speech frequency-band at each instant, and its position in the frequency scale varying in synchronism with the frequency-variation of the carrier wave. This "wobbling" band is filtered through a band-pass filter which passes only the speech-band width with its centre (*e.g.*) midway between the frequency limits of the wobbling band. The band thus passed is radiated, and contains components representing all the components of the original speech wave but permuted in a cyclic order. At the proper receiving station, where all the various factors are known, this band is demodulated separately by two waves of variable frequency, the one having a frequency equal to the algebraic sum of the variable carrier frequency and the lower of the two fixed carrier frequencies, the other the algebraic sum of the variable carrier frequency and the higher of those two fixed carrier frequencies. These two demodulations, when combined, yield the whole of the speech-wave components plus distortion components, some of which are filtered out, the remainder not rendering the received speech unintelligible. *Cf.* January Abstracts, under "Miscellaneous."

Über die neuere Entwicklung des Maschinensenders für kleine Wellenlängen (New Developments in H.F. Generators for Short Wavelengths).—W. Hahnemann. (*E.N.T.*, November, 1928, V. 5, pp. 431–437.)

These improvements in the Lorenz-Schmidt system were called for by the needs of Broadcasting (*i.e.*, transmission on wavelengths under 1,000 m.). (1) Suppression of harmonics and partial frequencies close to the transmitting frequency. The greater the frequency multiplication the nearer do these come to the main frequency. For the wavelengths in question, requiring a multiplication of 100, the process must be done in two stages, and the filtering and rejecting must be applied in each stage. To reduce the interfering waves to the required amplitude (1/1,000 or less of their original value) only the use of the most advanced methods of damping-reduction can suffice. The apparatus and methods successfully employed are illustrated. (2) Improving the life of the frequency-transformer. With the previous design, this life was short owing to carbonisation of the very thin iron lamellæ even with apparently adequate oil-cooling. This trouble has been completely overcome by a new design in which the thin sheets are made into "spiral discs" abreast of one another with spacing between. The path from the inside of the sheet to the outside (oil-cooled) is only 1 mm. (3) Improvement in speed-regulation. This was attained by adding refinements to the Lorenz-Schmidt governor (see these Abstracts, and also January) which cut out all sparking at the spring contacts. The arrangement shown here includes a control relay and an auxiliary dynamo as a "relay-machine," for fine regulation, and another relay and a regulating motor (working a field resistance in the main motor circuit) for coarse regulation. (4) Cutting out the "trill" effect. This effect is found chiefly in heterodyne reception, and is not obvious in telephony reception. But certain distortion observed in Broadcast reception was traced down to this "trill" effect. Oscillographic investigation showed that the trill was due to very small (one in 6,000) periodic variations of transmitter-frequency, and after many false starts the cause was proved to be vibrations of the H.F. dynamo stator—of an amplitude amounting to about 1/40 mm. A new, more solid design, combined with a very careful balancing of the rotor, completely cured the trouble. The combined results of these researches have, it is claimed, made the system equal to the very latest valve-transmitters in the Broadcasting region of wavelengths.

Über eine Methode zur Erzeugung von sehr kurzen elektromagnetischen Wellen (A Method for the Production of Very Short e.m. Waves).—A. Záček. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, p. 172.)

Referring to Yagi's (and Okabe's) "Magnetron" method (Abstracts, 1928, V. 5, pp. 519 and 399, and 1929, p. 42) the writer mentions that he obtained the same results with an identical method four years ago. He quotes his own words in the Czech "Zeitsch. f. Math. u. Phys." of 1924; extracts from which are: A straight filament cathode and concentric cylindrical anode—no grid. . . . A magnet coil whose axis is the filament. . . . A gradually increasing current is passed through the coil, and the (hitherto) radial electron paths are bent so that the electrons impinge on the anode no longer normally but at an acute angle, acuter as the magnetic field increases. . . . At a critical value of field they no longer reach the anode but curve back to the cathode, as can be seen by a milliammeter in the anode circuit. . . . If an oscillatory circuit is connected between anode and cathode, and the magnetic field kept constant just past the critical value, oscillations are produced in the circuit. . . . The wavelength is independent of the oscillatory circuit (actually a pair of parallel straight wires—"antennæ"—one connected to the cathode and one to the anode): only the intensity of the oscillations depends on the lengths of the "antennæ." The wavelength depends on diameter of anode, anode voltage and the intensity of the magnetic field. The intensity of the oscillations reaches its maximum at a certain field intensity H_m dependent on the anode voltage E_a;

then, approximately, $\lambda = \frac{a}{H_m}$ and $\lambda = \frac{A}{\sqrt{E_a} - B}$,

where a, A and B are constants. The shortest wave obtained at the time was about 29 cm. (E_a = 300 v.).

RECEPTION.

Empfangstörungen durch ein Heizkissen (Interference due to an electrically heated cushion).—(*E.T.Z.*, 29th November, 1928, p. 1756).

The automatic cut-out of such a cushion or pillow causes, by its sparking, serious intermittent disturbances at intervals of 15 seconds or so. A mica condenser of 10,000 to 20,000 cm. capacity cures the trouble, but it must be connected straight on to the regulator inside the cushion.

A Note on Some Interfering Oscillations Experienced in a Supersonic-Heterodyne Receiver.—R. L. Smith-Rose. (*E.W. & W.E.*, December, 1928, V. 5, pp. 673–676.)

These interferences were encountered in the development of a highly sensitive receiver for the reception of C.W. Signals: their origin and the methods of eliminating them are described. Intermittent action of a valve oscillator due to "squegging" causes one kind, particularly liable to be found—it seems—if one valve is made to serve the dual purpose of first oscillator and first detector: a bad practice adopted by some manufacturers. A second kind is produced by the self-oscillation of the intermediate frequency amplifier. A third, more subtle kind, can only be distinguished from an incoming signal by lack of direction: it is due to the second local oscillator giving an impure oscillation, so that under certain conditions a harmonic from here gets into the primary or secondary receiving circuits.

A Double Super-heterodyne: A Description of a Receiver built by the Author.—J. F. Ramsay. (*E.W. & W.E.*, December, 1928, V. 5, pp. 669–672.)

The article begins by discussing why the super-heterodyne receiver is not more popular in England: a bad reputation regarding quality may be one cause—this is the fault of manufacturers who strain to get a maximum gain per stage: another cause is that we obey admonitions to "cultivate the local station." The double super-heterodyne described and illustrated, when receiving short waves say of 45 m., transforms to 500 m. and amplifies, then transforms again to 2,000 m. and amplifies again; when thus used it employs 10 valves and two oscillators: broadcast from Schenectady can be made to overload the loud speaker—it has been received without an aerial but was barely intelligible. No screening has been found necessary.

The Distortionless Diode: Practical Applications of the Two-electrode Rectifier.—H. F. Smith. (*Wireless World*, 12th December, 1928, V. 23, pp. 783–786.)

A 3-electrode valve used as a diode rectifier, the grid being merely employed to neutralise the space charge (by a grid voltage of some 9 or 10 V), has the advantages of giving a rectifier output strictly proportional to the input voltage over a wide range, and of requiring no high tension, so that it is completely isolated from the anode circuits of the L.F. valves: the possibility of low-frequency reaction is thus very considerably reduced. This is of special importance in cases where the anode voltage is derived from an eliminator. Its disadvantages are that it does nothing towards magnifying the applied signal voltages, and that reaction from the detector anode circuit is no longer obtainable. Thus for long distance reception an extra H.F. stage is almost essential. But for good reproduction from the local station the diode, combined with a two-stage L.F. amplifier, is excellent. Its action is improved by a slight positive bias on the anode, derived from a potentiometer across the filament battery. Like a galena crystal, the diode puts a heavy load on the tuned circuit preceding it, and the anode connection should be made to an anode-tap forming (as a general rule) only about one-third of the tuning coil. Various circuits are given showing the use of the diode under the best conditions for long distance work.

The Effect of Frequency on the Value of High Resistances of the Grid Leak Type.—W. Jackson. (*E.W. & W.E.*, December, 1928, V. 5, pp. 677–679.)

The effective resistance of the usual type of grid or anode resistance decreases, as the frequency increases, by reason of its self capacity: this reduction becomes pronounced at frequencies approaching 10^6 p.p.s. and explains the unsatisfactory voltage amplification of resistance-capacity-coupled amplifiers at high frequencies. The present paper investigates whether the actual ohmic resistance varies to any marked extent with the frequency, quite apart from any variation of effective resistance due to the self-capacity. A series of measurements on several commercial types shows that such a variation does occur, " in some cases to a greater extent than would have been expected ": in some types the resistance increases, in others it decreases, with increase of frequency. The magnitude of the variation may be indicated by two examples: for a change of wavelength from 7,000 to 300 m. (approx.), one type increased from 0.239 meghom to 0.263, while another decreased from 0.368 megohm to 0.208.

Über die Dynamik der Selbsttätigen Verstärkungsregler (The Dynamics of the Automatic Amplification-Regulator).—K. Küpfmüller. (*E.N.T.*, November, 1928, V. 5, pp. 459–467.)

From the Siemens & Halske laboratories. All " indirect " types of regulating (see H. F. Mayer, below) are liable to oscillation: a state of stable balance can only exist under certain conditions. These conditions are here investigated mathematically and various conclusions arrived at: the stability of a system is greater in proportion to the slowness of its regulating-action: the use of long series of filter chains in such a system leads to liability to oscillation.

Über automatische Amplitudenbegrenzer (Automatic Amplitude Limiters).—H.F. Mayer. (*E.N.T.*, November, 1928, V. 5, pp. 468–472.)

This paper (from the Siemens-Halske laboratories) begins with a short historical survey in which a number of British and American patents are cited (1914-1925). It then defines two classes of regulator—the direct and indirect: in the former, the unregulated control frequency is employed for regulation, the receiver being thus controlled from the input end: while in the latter the control is from the output end, the control frequency being itself regulated at the same time. A third class, the true " amplitude-limiter," is independent of any control frequency, being used in circuits where the amplification has to be controlled directly by the amplitudes of the signal currents—*e.g.*, Broadcast transmitters, microphone-loud speaker installations, or recording apparatus for picture telegraphy, talking films or gramophone recording. More recent patents are here cited and the Siemens-Halske arrangement is described, of the indirect type. The indirect type has the advantage that the control can never cut out the main amplifier entirely, since it is itself controlled; whereas this can easily happen with direct control, unless special precautions are taken against such a result. On the other hand, the direct method has the advantage of providing no back-coupling, which (in the indirect type) is a source of oscillation. The influence of operating time on satisfactory performance is discussed, and the factors governing it; also the question of duration of the " after effect " (depending chiefly on the size and perfection of insulation of the control condenser; also on the insulation of the grid-leak condenser of the controlled stage), and its results and uses.

AERIALS AND AERIAL SYSTEMS.

Die Bündelung der Energie kurzer Wellen (Beam-Concentration of the Energy of Short Waves).—O. Böhm. (*E.N.T.*, November, 1928, V. 5, pp. 413–421.)

A communication from the Telefunken laboratories. After dealing first with the simple di-pole aerial and its directivity, it treats the simple systems derived from this—the straight line type throwing the beam fore and aft, and the plane type projecting at right angles (in both cases it is stated that it is not yet certain whether the earth functions as a dielectric or as a metallic surface; with the frequencies in question—3 to 20 megahertz—the capacitive resistance of the earth is probably of the order of an ohmic resistance). Both types give equal concentration, the increase of signal strength at the receiver being in both cases proportional to the total number of elements. The cutting out of the backward radiation is then dealt with; the received energy is still proportional to the number of elements in the aerial system plus screen. Various special polar curves can be produced at will by suitable adjustment of spacing, phasing, and current-distribution: a particular one is illustrated having two very concentrated main beams separated only by a very small angle. This form, produced by so feeding a plane system that one half oscillates oppositely to the other, is about to be used at Nauen for simultaneous communication with Buenos Ayres and Rio de Janeiro. The reciprocal action of a beam-receiving aerial is then discussed: theoretically, the best use of a given number of di-poles is to employ them half at the sending and half at the receiving end. But since in the latter position they do not increase the ratio signal/interference unless the chief sources of interference fit in with their polar diagrams, the question is not so simple. Additional importance, however, attaches to the extended beam-receiving aerial by reason of its effect in minimising fading. The receiving reflector, also, is of the greatest importance for cutting out the backwards-round-the-earth signals. A striking record strip is shown of Morse Signals from Buenos Ayres at Geltow, received on a simple di-pole and on an eight-wire reflector-beam system respectively: interference, echoes and fading are clearly evident on the former and practically invisible on the latter. With a 12-wire antenna and a 12-wire reflector, the strength of signal was trebled and the speed of communication multiplied by six. Oscillograms (using no reflector) are also given showing the interference by these echoes: some of these are stronger than the direct signal; another oscillogram shows the presence of the Doppler effect due to the lengths of the paths varying during the transit. The paper is based on work undertaken by the Telefunken Company, to see how far actual results agreed with theory and to decide whether horizontally or vertically polarised beams were the most effective. W. Moser has published his account from the transmitting point of view (see below). It was found that the horizontally polarised were the most useful, giving signals twice as loud as the vertically polarised. Several horizontal di-poles one above the other improved matters still more. All this agrees with the theory worked out by Lassen and the results of Meissner and Rothe with a rotatable parabolic mirror (Abstracts, 1928, V. 5, p. 637). The exhaustive tests led to the design of transmitting and receiving aerials on a plan which is described and schematically pictured.

DIE ÜBERTRAGUNG DER ENERGIE VOM SENDER ZUR ANTENNE BEI KURZEN WELLEN (The Feeding of Energy from Transmitter to Aerials, for Short Waves).—W. Moser. (*E.N.T.*, November, 1928, V. 5, pp. 422–426.)

Deals in detail with the method of feeding the power to the aerial systems described in Böhm's article (see above). Parallel wires in a common metal sheath and strip conductors were tried, but the paper confines itself to concentric tubes and unsheathed parallel wires. The two most important points are loss through radiation (which may, moreover, cause field-distortion) and through heating. The former is absent in the case of the concentric tube feeders, and even with parallel wires can be made negligible. The latter (heating of feeder, joints, dielectric losses in insulators and earth-losses) must be reckoned with, and limit the distance of aerial from transmitter and the dimensions of the aerial system itself. Measurements of these losses, for parallel wire feeders, present difficulties at the frequencies in question (wave-lengths 10–30 m.). The methods of Arkadiew and Kartschagin and of Roessler are referred to, but the method used and described (for both types of feeder) is a new one due to Roosenstein. It depends on the measurement and plotting of the voltage distribution at the potential node near the beginning of the feeders, when standing waves are excited in these; the damping being calculated from the shape of the curve. With concentric tube feeders, there must be holes at suitable intervals along the earthed outer tube to enable these measurements to be taken. Tables of results are given showing that the measured losses are always (sometimes much) greater than the calculated losses, since these do not allow for the effects of earth, coating of oxide, and insulators; nor for the resistance of the joints (in tube feeders especially). Nevertheless tube feeders of 100 m. length can have an efficiency of 97 per cent. and those of 1 km. length one of 77 per cent. Losses in feeders depend on the proportioning of the total effective impedance. If this is correct, only travelling waves exist in the feeders; otherwise standing waves, with increased losses, are superimposed. The use of transformers is of service here: various arrangements of these are shown: the simpler—auto-transformer—being really less serviceable than the more complex. But a special connection is shown which partly or wholly dispenses with transformers, the impedance of the feeders being so adjusted that the impedance of the branches is equal to that of the main feeder. The impedances can be altered considerably by changes in spacing and diameters of the conductors, as is shown by the curves.

ÜBER DRAHTREFLEKTOREN (Wire Reflectors).—A. Gothe. (*E.N.T.*, November, 1928, V. 5, pp. 427–430.)

A paper based on the Telefunken tests (see above two abstracts). It deals first with a simple single wire reflector ($\lambda/4$ behind a single aerial) excited only by radiation from that aerial. A reduction of the backward radiation could only be obtained when the natural wavelength of the reflector wire was greater than the transmitting wave: otherwise the backward radiation was increased (*cf.* Yagi's "directors." Abstracts, 1928, V. 5, p. 519). With the optimum reflector length the backward beam could be cut down to one-third. Two reflector wires, $\lambda/4$ away from each other and from the aerial, cut it down to one-sixth. More than two gave no better effect. Preliminary results of Sommer's theoretical investigation of the radiation-coupled reflector are given, based on the Hertz field-equations applied to a half-wave dipole. Between $\lambda/8$ and $\lambda/2$ from the aerial, the reflector is in a zone where the three fields (near-field, transition and distant fields) are of the same order of magnitude. A curve is given, showing the calculated falling off of the current induced in the reflector with increase of distance from $\lambda/16$ to $2\lambda/3$: and the change of phase difference, in the case where reflector and aerial are tuned together. Even at $\lambda/8$ the induced current is markedly smaller than the aerial current: yet the necessary phase-difference of 270 deg. can only be obtained at about $5\lambda/12$: or by detuning—which reduces the reflector current still more. For a single aerial, curves show that the best compromise is a distance of $\lambda/8$; but with a multiple system the mutual reactions make $\lambda/4$ the optimum distance. If the object of the reflector were merely to increase radiation in the right direction, a 90 per cent. reflector effect would be quite enough: this can be attained with the radiation-coupled method. But the main object is the cutting out of echo signals: in view of the effects of fading, the mean ratio of indirect to direct signals should—for perfect communication—be not more than 1 to 50. In times of strong echoes, this involves a reflector effect of at least 100 to 1: this is beyond the scope of radiation-coupled reflectors. But it can be reached and surpassed by the use of auxiliary coupling in the form of a double transformer. With this arrangement the tuning and phase-regulation no longer involves altering the length of the reflector wires, since each secondary has a condenser in series and a variable coupling to the primary. It is thus possible to interchange the functions of aerial and reflector, and in this way to reverse the direction. The method of auxiliary coupling is equally effective with receiving and transmitting systems.

DIE WIRKUNGSWEISE VON REFLEKTOREN BEI KURZEN ELEKTRISCHEN WELLEN (The Action of Reflectors on Short Electric Waves).—G. Gresky. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, pp. 149–162.)

An investigation, carried out under the auspices of A. Esau, on the behaviour of cylindrical-parabolic and plane reflectors, for wavelengths of 260–437 cm., in relation to their various dimensions. The transmitter used as its circuit condenser a glass plate copper-coated; plates with coatings stuck on were found to be useless for prolonged service. The valve was a Telefunken RS.19, socketed and provided with thick leads. Anode supply was 500 frequency A.C. at 2,000 V. The aerial was a straight vertical wire with a hot wire ammeter at its mid-point: it was inductively coupled to the transmitting circuit and tuned to oscillate to the half wave. The reflectors were composed of wires of length l stretched vertically on a rotatable frame and spaced by a gap d. The receiver (at a distance of about 170 metres) consisted of a similar di-pole aerial with detector (Seibt) and galvanometer (a Zeiss Loop galvanometer which was found very suitable on account of its great damping) shunted by a variable resistance. The detector was calibrated by a hot-wire air thermometer (Scheibe). After each measurement the constancy of the detector was checked by turning the reflector back to the "zero" position. The detector was found to remain constant for days at a time, giving the same reading for the same reflector position. For the parabolic reflector, the optimum ratio focal length/wavelength was found to be 0.27; for the plane reflector the optimum ratio distance between aerial and screen/wavelength was 0.20. The parabolic is much superior to the plane in directivity and "magnification" (ratio max. energy of transmitter plus reflector to max. energy of transmitter alone). Of parabolic reflectors two kinds are possible: if l is made long (about as long as λ) and d is made small ($\lambda/30$), the nearest approach to a metal surface is obtained. This is the "untuned" reflector. If $l < \lambda/_2$, and d is made about $\lambda/8$, the "tuned" reflector is obtained. (If $d = 20$ cm., the two types merge). The untuned gives results better by a small percentage than the tuned, in directivity, magnification and absence of backward radiation; but the tuned is preferable in practice because of its smaller height. In either type the opening should not exceed 1.5λ. All this is based on a wave of 298 cm. which was used as the working wave. Results were confirmed by qualitative observations at distances of 4 and 18 km.

VALVES AND THERMIONICS.

DIE FELDKRÄFTE AUF DIE GLÜHDRÄHTE VON ELEKTRONENRÖHREN (The Field Forces on the Filaments of Thermionic Valves).—K. Pohlhausen. (*Wiss. Veroff. a.d. Siemens Konz.*, No. 1, 1928, V. 7, pp. 109–119.)

Formulæ are derived for the calculation of the electrostatic forces on the filaments. It is concluded that as a general rule the introduction of a central support is without value. In a H.T. rectifying valve with ten filaments, a voltage of 100 kV. produced a force of 2.12 g. per cm. length of one filament. A central support raises the force by 7 per cent.

VACUUM-TUBE PRODUCTION TESTS.—A. F. Van Dyck and F. H. Engel. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1532–1552.)

A description of the methods and apparatus employed by the authors (of the Technical and Test Department, Radio Corporation of America) in the testing of valves in large quantities.

THREE-ELECTRODE VALVES WITH FILAMENTS FOR A.C. HEATING. (*French Patent* 640,184, *E. C. and A. Grammont*, pub. 7th July, 1928.)

Two parallel filaments are used cross-connected so that they are fed in opposite directions. They can, if desired, be used in conjunction with the usual "centre point tapping" (of transformer secondary or special resistance) to the grid.

PHYSIK DER GLÜHELEKTRODEN (The Physics of Hot Electrodes).—W. Schottky and H. Rothe. (*Handbuch d. Experimentalphysik*, Part 2, V. 13, 1928, pp. 1–281.)

HERSTELLUNG DER GLÜHELEKTRODEN (Construction of Hot Electrodes).—H. Simon. (*Handb. d. Exp.-physik*, Part 2, V. 13, 1928, pp. 283–340.)

TECHNISCHE ELEKTRONENRÖHREN UND IHRE VERWENDUNG (Commercial Electronic Valves and their Application).—H. Rothe. (*Handb. d. Exp.-physik*, Part 2, V. 13, 1928, pp. 341–482.)

DIRECTIONAL WIRELESS.

WIRELESS BEACON AT START POINT. (*Nature*, 8th December, 1928, V. 122, p. 898.)

A paragraph on the seventh beacon of its kind just completed by the Marconi Co. for Trinity House. Main details are mentioned.

ÜBER FEHLWEISUNGEN DER FUNKPEILUNG IN ABHÄNGIGKEIT VON DER WETTERLAGE (Direction-finding Errors and their Dependence on Weather Conditions).—P. Duckert. (*E.N.T.*, November, 1928, V. 5, pp. 438–441.)

After referring to seven previous papers in which (since 1925) he has published the results of his investigations into the influence of atmospheric conditions on the direction and strength of wireless signals, the writer describes how nearly he has been able—in the observations on which the present paper is based—to obtain the ideal conditions which render those observations perfectly reliable. They lead to the conclusion that, so far as daytime errors and rapid direction-variations are concerned, they occur always and only (with very few exceptions) when the meteorological and aerological conditions have produced—between transmitter and receiver—an unstable surface of discontinuity, so that a temperature inversion is present together with a specific humidity increasing (or at any rate not decreasing) upwards in the bottom 200 metres. The surfaces which affect the loudness of signals (usually particularly stable formations) have almost no appreciable effect on direction. The unstable ones, on the other hand, have the invariable result that if at one station the direction found for the second station makes too great an angle with N (compared with the great circle), at the second station the direction of the first will make an angle with N too small by practically exactly the same amount: so that the "bearing beam" (to coin a name) appears to follow a symmetrically curved path between the two stations. The symmetry at the two ends is only upset by some local source of error—a local re-radiated field, for example.

Referring to twilight and night signals, the writer mentions Falckenberg's recent pronouncement that the greatest bearing-variations appear one to two hours after sunset. He then announces the preliminary results of his own observations at these times, namely, that whereas in daytime no variations of signal strength accompanied the bearing-variations, in twilight and at night the latter were always attended by simultaneous fading. It thus seems that the interference effect between ground and space waves (which cause both fading and twilight bearing-deviations) have nothing to do with the daytime deviations, which are wholly governed by the meteorological influences described. It may be of interest to remember that it is just this type of surface of discontinuity which provides a great proportion of atmospherics—as can be seen from automatic direction-finder records of atmospherics.

ACOUSTICS AND AUDIO-FREQUENCIES.

High-Quality Reproduction of Music.—H. Backhaus. (*Siemens Zeitschr.*, May, 1928, V. 8, pp. 298–304.)

An article based on the use of the Siemens "Public Address" system at the International Music Convention at Geneva in 1927.

Improvements in Telephone Receivers.—R. G. E. Bury. (*French Patent No.* 641,201, pub. 30th July, 1928.)

A simplification of the magnet system which claims to be cheaper and no less effective. The received currents flow through a single cylindrical bobbin whose iron core shunts the magnetic circuit between the open ends of a fixed U-shaped magnet.

Über neuere akustische ... (Latest Work on Acoustics, and in particular Electro-acoustics).—F. Trendelenburg. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, pp. 173–179.)

Penultimate instalment of this long paper. Electrical recording of gramophone records is dealt with, particularly the work of Maxfield and Harrison, whose treatment (as well as Kellog's) of electrical reproduction is also referred to. A table of equivalent mechanical and electrical quantities is given. Engl and Rankine's work on Talking Films is briefly mentioned, and the "ultra-phone principle" of gramophone-reproduction is outlined in which two sound-boxes are used with a time-difference of about 1/10 sec. for the two needles, producing a subjective increase in loudness. The production of supersonic waves is next treated briefly (Langevin, Pierce, Wood and Loomis) and the rest of the article deals with the acoustics of musical instruments: particularly the work of Raman on the theory of stringed instruments, and the results in sound-analysis of Stumpf and Backhaus. The latter devotes himself to the violin, and various curves are reproduced showing the characteristics of violins by famous makers. His results contradict the previous views of Hewlett (based on Rayleigh disc tests) that a violin is better the greater the energy concentrated in the fundamental as compared with that in the overtones.

The Transmission of Sound through Sea Water.—J. H. Service. (*Journ. Franklin Inst.*, December, 1928, V. 206, pp. 779–807.)

Introduction: Work of Heck and Service on Speed of Sound in Sea Water. British Admiralty Tables: Comparison with the Tables of Heck and Service. Measurements by the German Survey and Research Ship "Meteor." Tests of H. and S. Tables by U.S. Coast and Geodetic Survey (Piano Wire and Echo Soundings). Determination of Sound Speeds for Echo Soundings in U.S. Coast and Geodetic Survey. Ditto, for Radio-acoustic Position Finding. Experience with Radio-acoustic Position Finding in Various Regions. Discussion: Why is the transmission of sound in radio-acoustic work good to excellent off the coasts of Washington and Oregon, and poor to fair off the coasts of N. Carolina and Florida? Phenomena observed in connection with radio-acoustic position finding and echo sounding; parasite noises; the work of Brillié; shielding the hydrophone; wall thicknesses nearly an exact multitude of wavelength. Relative Attenuation with distance of Sounds of great and of small Amplitudes. Variation of Speed with Intensity. Appendix: Methods in use in the U.S. Coast and Geodetic Survey for Measurement of Depth of Water. Bibliography.

Electrostatic Microphone-Telephone.—L. Lévy. (*French Patent No.* 640,870, pub. 24th July, 1928.)

The attraction of the membrane by the electrode is balanced by the attraction of a second electrode on its other face; this arrangement allows the membrane to be very light, with very little inertia and very slight rigidity; resonances due to the natural period of the membrane are thus avoided. The thin films of air between membrane and electrodes produce a damping which is easily adjustable by the size of the holes connecting interior with exterior.

Les Instruments de Musique à Oscillations Électriques: Le Clavier à Lampes (Electrically oscillating musical instruments: the valve keyboard).—A. Givelet. (*Génie Civil*, 22nd September, 1928, V. 93, pp. 272–276.)

An article which takes very seriously the future possibilities of such instruments, and reviews the progress already made. The diagram is given of a single keyboard controlling simultaneously hautbois, saxophone, flute and trumpet effects, by the use of a loud speaker and suitable filter for each timbre. Percussion instruments such as the piano can also be represented by a suitable circuit. The cathode ray oscillograph is of great use in the research.

PHOTOTELEGRAPHY AND TELEVISION.

ZUR FRAGE DES BILDRUNDFUNKS (The Question of Picture Broadcasting).—A. Korn. (*E.T.Z.*, 29th November, 1928, pp. 1747–1748.)

The question, much discussed in the Press, whether the time is ripe for picture broadcasting is here treated. The writer considers that satisfactory television will not be attained (except in the laboratory) until a new advance in technique is made which will give, with simple apparatus, several hundred thousand signals per second. Till then, the best that can be done is to divide the image up into 2 or 3 thousand elements at most. Such television (of which he has not a high opinion) can be broadcast; he rather fears that the public will be disappointed. But he admits that even such poor television has two advantages over still picture-broadcasting—the interest is much greater, and the eye supplies, subjectively, the lacking details far more than it does in still pictures.

BEGINN DER VERSUCHSWEISEN BILDRUNDFUNKVERSUCHE IN DEUTSCHLAND (Preliminary Trials of Picture Broadcasting begin in Germany).—(*E.N.T.*, November, 1928, V. 5, p. 437.)

Since 20th November, 1928, Königswusterhausen has sent out Fultograph picture broadcasting every day at fixed times (10.45 p.m. on Tuesdays and Fridays, other days at 1.45 p.m.). France will this winter begin broadcasting from Toulouse (on the Bélin system), during the intervals of an opera, the pictures of the various performers.

FORTSCHRITTE IN DER BILDTELEGRAPHIE (Advances in Picture Telegraphy).—F. Schröter. (*E.N.T.*, November, 1928, V. 5, pp. 449–458.)

From the Telefunken laboratories. Schriever's ring-shaped photoelectric cell is described. The cone-shaped ray, concentrating on a point of the picture, passes through the central space, so that the cell can be quite close to the picture and receives a large fraction of the diffused reflection. It has only two objections: loss of light by reflection, at the glass surface, of the obliquely-incident rays, and the difficulty and dearness in manufacture of the ring shape. The writer has invented a plan avoiding these difficulties, using a right-angled prism to direct the ray on to the picture and a paraboloid reflector to collect the diffused light on to the ordinary type of cell; the rays thus collected cut through the glass wall of the cell at very favourable angles. The point next dealt with is the difficulty of perfect half-tone working, one requirement for which is a straight line characteristic for the receiving circuits. A special design of point-glow lamp is described and illustrated, which in the anode circuit of an amplifying valve gives a practically straight line characteristic; it also possesses many other desirable properties. Excellent examples of its work are shown. The rest of the paper is devoted to short wave facsimile telegraphy. Fruitless attempts to annul atmospheric disturbances by "compensation" circuits have now been replaced by the new principle of replacing a single signal impulse by an "impulse-statistic"; the method of spaced-repetition, invented by Verdan and applied (for ordinary telegraphy) in the Baudot-Verdan system (Abstracts, 1928, V. 5, p. 406) has been adapted by the writer to the subject in question. Fading is a serious trouble in short wave facsimile telegraphy, and although useful reduction of its effects has been attained by combined aerials, limitation of signals, and wave-changes ("wobbles"), much remains to be done against both fading and atmospherics. According to the writer's invention, the record (transmitting or receiving) is in the form of a narrow tape the moving path of which is so looped that at every sweep of the scanning point the latter passes across two or three widths of the tape side by side yet separated from each other, along the tape, by any desired distance. Thus the Verdan effect is produced; but for speeds of 500 wds./per min., involving a scanning-point velocity of 3.8 metres per sec., a further refinement has been introduced; the scanning point crosses the tape not at right angles to its length but at an angle of 5 deg. to 10 deg., so that any disturbance occurring during one sweep of the point is split up among several neighbouring letters. The combined process thus obtained is called the "slanting line-jump scanning."

THE SELENIUM CELL: ITS PROPERTIES AND APPLICATIONS.—G. P. Barnard. (*Journ. I.E.E.*, December, 1928, V. 67, pp. 97–120.)

Early history; the Construction of Selenium Cells (of various types); their Properties; Theories of the Action; Practical Applications (Photometry and Relay Problems; the Optophone—by which the blind can read ordinary print; the Photophone; Talking films; Television); and a bibliography mounting into hundreds.

CONTROLLING THE TELEVISION SCANNING DISK. (*Scientific American*, November, 1928, p. 458.)

Manual control of the motor by means of a continuously adjustable rheostat is here recommended, aided by an accelerator push-button to increase the speed momentarily when bringing the disc into synchronism. Alexanderson is quoted as saying, "with a little practice and co-ordination between the eye and the hand, it is possible to hold the picture in the field of vision as easily as one steers one's car down the middle of the road."

TELEVISION.—A. Dinsdale. (Review in *Electrician*, 21st December, 1928, V. 101, p. 705.)

From this review, it appears that the Baird system is chiefly dealt with, being described in probably greater detail than ever before; but information is also given of the methods of the Bell Laboratories, Jenkins, Alexanderson, Belin, Holweck, Mihaly, and Szczepanik. Dr. Fleming's "foreword" is here summarised, and various criticisms are made of omissions in the book. It is compared with Dauvillier's account (Abstracts, 1928, V. 5, p. 291).

STANDARDISATION OF TELEVISION APPARATUS. (*Nature*, 1st December, 1928, V. 122, p. 853.)

In the U.S.A. it is officially recommended that forty-eight lines with fifteen separate pictures (frames) per second shall be standardised. *Nature* remarks that the pictures will not show much detail, being decidedly inferior in this respect to those of Baird.

RADIOVISION. (*Nature*, 24th November, 1928, V. 122, pp. 809–810.)

Correspondence on the use of the terms "radiovision" and "television."

THE DISTRIBUTION IN DIRECTION OF PHOTO-ELECTRONS FROM ALKALI METAL SURFACES: THE VOLTAGE-CURRENT RELATION IN CENTRAL CATHODE PHOTO-ELECTRIC CELLS.—H. E. Ives, A. R. Oplin and A. L. Johnsrud; T. C. Fry. (*Phys. Review*, June, 1928, V. 31, p. 1127.)

STUDIES IN FLUORESCENCE AND PHOTOSENSITISATION IN AQUEOUS SOLUTIONS.—W. West, R. H. Müller and E. Jette. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121A, pp. 294–317.)

MEASUREMENTS AND STANDARDS.

THE DEPENDENCE OF THE FREQUENCY OF QUARTZ PIEZO-ELECTRIC OSCILLATORS UPON CIRCUIT CONSTANTS.—E. M. Terry. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1486–1506.)

Author's summary and conclusions are as follows:—

The mathematical theory for the quartz piezo-electric stabilised, vacuum-tube-driven oscillator is given for the following cases: tuned plate circuit, inductance-loaded and resistance-loaded triode with the crystal between grid and plate, and also between grid and filament for each case. The condition for oscillations and the exact expression for the frequencies, damping factors, coupling coefficient, tube constants, etc., is given. In the analysis of the oscillator the equivalent network for the crystal given by Van Dyke has been used. The theory has been checked by measuring the variation in frequency of a quartz-stabilised oscillator for variations in impedance of the plate circuit, for the tuned circuit and resistance-loaded tube respectively. To satisfy the condition for oscillation it is necessary to use values for the equivalent resistance of the crystal somewhat smaller than those given by Van Dyke's formula. A discussion of the general method by which conditions for oscillation and expressions for the driven frequency of an oscillator may be obtained from the coefficients of differential equations up to the fourth order is included.

A quartz crystal oscillator, when used to stabilise a vacuum-tube-driven circuit, does not oscillate at a frequency determined by its elastic and piezo-electric properties alone, but becomes part of a coupled system, and the actual resultant frequency is influenced by the degree of coupling of the two systems and the values of the constants of the entire circuit, including those of the driving device in the case of continuous oscillations. In doubly periodic vacuum-tube-driven circuits, one of the normal modes of oscillations is excited when the crystal is connected between grid and plate, and the other when connected between grid and filament. Although the oscillations are more powerful when the frequency of the plate circuit is close to that of the crystal, the departures of the resultant frequency from the natural frequency of the crystal are greater. For purposes of accurate frequency standard maintenance, the resistance-loaded circuit is much to be preferred, and when a crystal has been standardised it must always be used in exactly the same circuit and under exactly the same conditions as when the standardisation was made. It is desirable from this standpoint to preserve not merely the crystal, but the entire circuit permanently assembled.

DEVELOPMENT OF FORMULÆ FOR THE CONSTANTS OF THE EQUIVALENT ELECTRICAL CIRCUIT OF A QUARTZ RESONATOR IN TERMS OF THE ELASTIC AND PIEZO-ELECTRIC CONSTANTS.—P. Vigoureux. (*Phil. Mag.*, December, 1928, V. 6, pp. 1140–1153.)

PIEZO-ELECTRIC OSCILLATOR CIRCUITS WITH FOUR-ELECTRODE TUBES.—J. R. Harrison. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1455–1470.)

The original Cady circuit has been superseded by the Pierce circuit because it cannot be used for crystal oscillations at the high-frequency modes, *i.e.*, the vibrations at the frequency determined by the thickness of the plate. The writer, however, finds that the Cady type of circuit can be directly applied to the screen-grid valve, and when thus applied can be used to advantage at the high-frequency modes of the crystal. Such a circuit, he says, has advantages over the Pierce type in more constant frequency and greater stability*; and (at the lower radio frequencies) greater power output; particularly at those lower frequencies for which flexural vibrations are employed; at 6,000 m., such a circuit gave an output more than twice that of a corresponding Pierce circuit. When thus oscillating the crystal shows a tendency to creep lengthways until a position is reached which gives maximum power output; if displaced from this position it will return to it again; this is not due either to air blasts or to a dielectric phenomenon, but to the vibration of the crystal against its support. Two of these circuits are described, and compared with Hull's recent four-electrode circuit. The occurrence of twin oscillation frequencies is discussed, and the difficulties in obtaining flexural vibrations with a three-electrode valve. In the subsequent discussion, there is an argument between the writer and A. Hund.

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* *i.e.*, the power of starting oscillating without retuning.

SUR UN PENDULE TRÈS PEU AMORTI (A Very Lightly Damped Pendulum).—R. Planiol. (*Comptes Rendus*, 19th November, 1928, V. 187, pp. 933–935.)

A torsion pendulum, consisting of a brass cylinder 7 cm. in diameter and 8 cm. long suspended by a quartz fibre 25/100 mm. in diameter and 4.5 cm. long, was set twisting in a container exhausted by a Holweck molecular pump. The period of a complete oscillation was 10.942 sec. In 16 days the amplitude of the swing had decreased from a value 12.67 to 2.17. The damping due to the medium would appear to have been abolished, the only damping being due to the elastic hysteresis of the quartz and to the support. The energy lost during the period was 2×10^{-4} erg for the larger amplitudes and 10^{-5} erg for the smaller. The small damping suggests that the pendulum could be kept going by pressure of radiation; it would carry a mirror on to which a light ray, controlled by a photoelectric cell, would be directed. The comparison of a torsion pendulum of this type with a swinging pendulum similarly mounted would perhaps be useful in the study of the variations of gravity.

THE MAINTENANCE OF MECHANICAL OSCILLATIONS BY MAGNETOSTRICTION.—J. H. Vincent. (*Electrician*, 28th December, 1928, V. 101, pp. 729–731.)

After a historical summary, the writer describes experiments on the longitudinal vibration of ferromagnetic bars under forces mainly due to magnetostriction; mild and cast steel bars could be maintained in resonant vibration with great ease; with nickel the effects were even more striking. With cast steel, frequencies up to 5,200 p.p.s. were obtained; with nickel, 19,900 has been reached and the experiments are being continued towards still higher frequencies. The paper is to be concluded in a later issue. (*Cf.* Pierce, Abstracts, 1928, V. 5, p. 643.)

A SYSTEM FOR FREQUENCY MEASUREMENT BASED ON A SINGLE FREQUENCY.—Bureau of Standards Note. (*Journ. Franklin Inst.*, December, 1928, V. 206, p. 844.)

An accurate and rapid method of checking the frequencies of one piezo oscillator after another; the heterodyne note, produced by the oscillator under test and one set by the standard, is "matched" with a similar note from a calibrated audio-frequency generator.

A TUNING-FORK CONTROLLED AUDIO-OSCILLATOR.—C. L. Lyons. (*Journ. Sci. Inst.*, November, 1928, V. 5, pp. 361–363.)

Description of an American hummer which the writer has found more satisfactory and reliable than any other kind he has tried. Its output is about 60 milliwatts at 1,000 p.p.s. By use of a tapped secondary output transformer, three different voltages may be obtained (0.5 to 5.0 V), but by making use of resonance voltages of 50 or 100 may be obtained if required. The input voltage is 4–8 V.

THE GRAPHICAL ESTIMATION OF LOW-FREQUENCY CHOKE AMPLIFIER PERFORMANCE.—W. A. Barclay. (*E.W. & W.E.*, December, 1928, V. 5, pp. 660–666.)

Sowerby (*ibid.*, April 1928) has utilised the plate voltage/plate current graph to derive the best values of resistance, etc., for given conditions of amplification by resistance amplifiers. A similar treatment of choke-coupled L.F. amplifiers is impossible owing to the increased number of variables, 3 instead of 1. Indirect methods are therefore necessary, and the present paper describes a simple graphical construction devised by the writer to avoid the prohibitive labour of arithmetical work involved in the usual methods. The construction results in the finding of the centre and dimensions of the ellipse for greatest signal strength which will represent without distortion at a given frequency the working locus of a given choke, using a given H.T. voltage. The centre when found indicates the necessary grid bias to apply for the distortionless amplification of signals of the given strength and frequency. The paper includes a statement of the problem, a mathematical analysis and a proof of the construction.

QUANTITATIVE METHODS USED IN TESTS OF BROADCAST RECEIVING SETS.—A. F. Van Dyck and E. T. Dickey. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1507–1531.)

Phrases, such as "one hundred times audibility," a "half-stage audio better" (than the standard set), "audible two rooms away," selectivity "sharp as a knife," or even "razor-edge," are quoted as representing the average receiving set test methods during the "first twenty-five years or so" of wireless. In 1922 the authors (aided later by W. Van B. Roberts) began to develop methods and equipment for quantitative measurement of receiving set performance. It was soon found that measurements of individual parts gave no true measurement of the whole, so that except for special purposes (*e.g.*, in locating the cause of inferior performance, or in developing a new set) the tests evolved and here described are for the overall performance of a complete set; they are so arranged that the test results can be used to predict how the set will perform under any specified service conditions. They can be divided into two classes: "special engineering" and "production" tests; the apparatus and methods for both are described. A new form of radio-frequency oscillator, designed for this work, is described; also shielded test booths for the work. The methods include the measurement of sensitivity, selectivity and "fidelity."

THE CONSTANT IMPEDANCE METHOD FOR MEASURING INDUCTANCE OF CHOKE COILS.—H. M. Turner. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1559–1569.)

The method described has been used to measure, at power frequencies, the inductance of iron-cored choke coils (of the type commonly used in wireless as filters) of values from one to more than 2,000 henrys. The writer says that he discovered in 1918 the unique property of parallel circuits on which the method is based, namely, that when an alternating E.M.F. is impressed on a parallel circuit, a "critical condition" can be obtained (by a suitable choice of frequency, inductance and capacity) at which the supply current is absolutely independent of the resistance of the inductive branch, being equal to the current through the capacity branch. Under these conditions, a switch in the inductive branch can be opened and closed without altering (except momentarily) the reading of an ammeter in the supply circuit. The "critical frequency" is 0.707 times the resonant frequency for L and C in series; and when the standard variable condenser is adjusted so as to give this relation, L is calculated from $L = \frac{1}{2}\omega^2 C$. Two circuit arrangements are illustrated, each having its own advantages for certain cases. Several families of curves are given showing how the inductance depends on the magnitude of the superposed alternating and D.C. magnetomotive forces. The method can also be used at higher frequencies.

THE HIGH-FREQUENCY RESISTANCE OF TOROIDAL COILS.—S. Butterworth. (*E.W. & W.E.*, January, 1929, V. 6, pp. 13–16.)

It is pointed out that since a well-designed toroidal coil has more than twice the high-frequency resistance of a well-designed solenoidal coil of equal inductance, and since mutual interference can usually be avoided with the latter coils by suitable arrangement, toroidal coils should only be used when one cannot afford the slightest trace of electromagnetic interference. Formulæ and tables of constants are given for the resistance and inductance of these coils: methods of deriving the best diameter of wire and the best shape of toroid are shown.

SUPPLEMENTARY NOTE TO "ABBREVIATED METHOD FOR CALCULATING THE INDUCTANCE OF IRREGULAR PLANE POLYGONS OF ROUND WIRE."—V. I. Bashenoff. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1553–1558.)

Extension of a paper in the same journal, December, 1927, p. 1013.

SPULENBERECHNUNG (Coil Calculation).—O. Droysen. (*Zeitschr. f. Fernmeldetech.*, No. 6, 1928, V. 9, pp. 81–85.)

Coils for relays, telephones, etc., are usually reckoned from empirical curves and tables. Here the calculation is prosecuted purely by formulæ, with the advantage that the best winding for the apparatus in question can be obtained directly for various conditions of use.

THE VARIATION OF EFFECTIVE CAPACITY OF AN AIR CONDENSER DUE TO HUMIDITY AND PRESSURE CHANGES.—G. D. Rock. (*Phys. Review*, June, 1928, V. 31, p. 1129.)

A heterodyne method was used. No numerical results are given.

FURTHER NOTES ON THE CALIBRATION PERMANENCE AND OVERALL ACCURACY OF THE SERIES-GAP PRECISION VARIABLE AIR CONDENSER.—W. H. F. Griffiths. (*E.W. & W.E.*, January, 1929, V. 6, pp. 23–30.)

The first part of an article supplementing previous articles (*ibid.*, January, February and May, 1928). A new type of moving plate is described in which a number of completely insulated sections are employed. The completeness of the elimination of calibration inconstancy due to small rotation irregularities and to slight post-calibration twisting or tilting of plates, by the use of such multi-sectioned plates, is discussed.

THE TRANSMISSION UNIT AND ITS APPLICATION TO RADIO MEASUREMENTS.—J. F. Herd. (*E.W. & W.E.*, January, 1929, V. 6, pp. 17–22.)

The T.U. (transmission unit) is now standardised in Britain, America and elsewhere and is in regular use in telephonic practice. The writer shows how it would find useful application in wireless measurements: how, for example, T.U. boxes (attenuation boxes calibrated in T.U.) can be used to measure the gain of an amplifier: or to adjust the voltage injection in making field strength measurements.

THE APPLICATION OF VACUUM TUBES IN MEASURING SMALL ALTERNATING CURRENTS OF ANY FREQUENCY.—R. E. Martin. (*Phys. Review*, June, 1928, V. 31, pp. 1128–1129.)

Currents down to the limit of sensitivity of the moving coil galvanometer can be measured, irrespective of frequency, by a four-valve arrangement which delivers the current, rectified, to the galvanometer. The latter is calibrated by D.C.

THE ERRORS ASSOCIATED WITH HIGH RESISTANCES IN A.C. MEASUREMENTS.—R. Davis. (*Journ. Sci. Inst.*, November, 1928, V. 5, pp. 354–361.)

This final part of the paper mentioned in January Abstracts has two sections: the Determination of the Characteristics of a Unit, and Practical Considerations in the Designing of a Resistor for High Voltages, having a small Phase Angle at the low and high voltage ends.

SUBSIDIARY APPARATUS AND MATERIALS.

DREHZAHLREGELUNG VON GLEICHSTROMMOTOREN MIT ELEKTRONENRÖHREN (Speed Control of D.C. Motors by Valves).—E. Reimann. (Summary in *E.T.Z.*, 22nd November, 1928, p. 1719.)

Motors up to 100 kW. are governed by 2 or 3 amplifier valves combined with one or more power valves. A small D.C. generator is coupled to the motor and any variations in its voltage due to change of speed are impressed on the grid of the first valve: the voltage corresponding to the standard speed being counteracted by a fixed battery voltage. The field strength of the motor is varied by the output plate current. For motors of 100 kW. the regulating lag is from 0.5 to 1.5 sec., while the final variation in speed and the maximum relative phase-displacement are of the order of a few thousandths. The peak variations of speed may be 5 times the final.

KONSTANTHALTUNG DER DREHZAHL VON MASCHINEN FÜR SIGNALZWECKE (Constant Maintenance of the Speed of Machines for Signalling Purposes).—W. Dornig. (*E.T.Z.*, 22nd November, 1928, Vol. 47, pp. 1713–1715.)

A full description of a centrifugal governor apparently corresponding with the patent dealt with in Abstracts, January, 1929. Three of the contact-springs there described are used, equally spaced round the rim of the disc: the contact-adjustments being slightly different for each. The contacts are connected to short circuit a field resistance, and thus control the mean value of the field current. A commutator-device on the disc axle rhythmically short-circuits the resistance hundreds of times per second, thus preventing any serious sparking at the governor-contacts (which remain clean after months of use). Constancy of speed within 0.1 per cent. can easily be obtained for voltage fluctuations from 170 to 250 V. for full load and no load. The gravity action on the spring is an important factor in the success of the device, as it ensures only one contact per revolution for each spring.

METALLISIERUNG VON PAPIER (The Coating of Paper with Metal).—M. U. Schoop. (*E.T.Z.*, 13th December, 1928, p. 1826.)

In Schoop's laboratory in Zurich successful results have been obtained in coating paper of any kind with thin, uniform and strongly attached coats of various metals, which in spite of their thinness (0.01—0.015 mm.) show metallic continuity. The process involves the projection of extraordinarily fine sputtering from the liquefied metal.

TRANSPARENT STEEL (*Scientific American*, November, 1928. p. 463.)

By Muller's process, steel can be made in sheets of a few millionths' of a millimetre thickness, and as transparent as glass. The sheets are produced mathematically exact and uniform as to thickness without tears or flaws; the steel retains its structure unchanged. A sheet transmits light, cathode, Roentgen and radioactive rays; it can be magnetised. Applications to telephones, microphones, loud speakers, etc., and in the laboratory, are suggested.

MAGNETIC PERMEABILITY OF IRON AND MAGNETITE IN HIGH FREQUENCY ALTERNATING FIELDS. —G. R. Wait. (*Phys. Review*, April, 1927, V. 29, pp. 566–578.)

The relative values of the permeability of cast-iron filings, iron wires, and iron powder, in H.F. (50–1,700 m. wavelength) magnetic fields were investigated. Results disagree with those of previous workers who found anomalous changes at certain frequencies; these are suggested to be due to errors whose nature is specified.

DIE KATHODENSTRAHL-OSZILLOGRAPHENRÖHRE DER WESTERN ELECTRIC (The Western Electric Company's Cathode Ray Oscillograph Tube). —(*E.T.Z.*, 29th November, 1928, p. 1752.)

A description, with general arrangement diagram, of the Type 224 tube; with oxide-coated hot cathode needing only 300 V high tension and therefore workable off a dry battery giving 1 milliampere. A life of 100 working hours is mentioned; the sensitivity is about 1 mm./volt. Type 224A has a filament taking up to 1.7A (at 6 V) but an improved Type 224B has just been produced which needs only 0.85 to 1.15A at the beginning of its life, later on requiring gradually increasing current. The smaller initial current leads to a longer life.

FORTSCHRITTE IM BAU VON MITTEL- UND HOCHFREQUENZMASCHINEN (Progress in the Construction of Medium and High Frequency Machines).—K. Schmidt. (*E.T.Z.*, 25th October, 1928, pp. 1565–1569.)

Present applications (valve transmitters, induction furnaces, etc.) are first described. The rest of the paper deals with the " S " type generating plants designed by the writer: 100 kW., 500 cycles, with the high overall efficiency of 84 per cent.; 2 kW., 8,000 cycles, overall efficiency 52 per cent. (generator alone 74 per cent.); 300 W., 6,000 cycles, overall efficiency about 45 per cent.; and an aircraft propeller-dynamo, weighing 9 kg., output 1 kW. (" of the size of a 500 W. D.C.generator."). Curves are given.

STATIONS, DESIGN AND OPERATION.

RADIO STATIONS OF THE WORLD ON FREQUENCIES ABOVE 1,500 KILOCYCLES.—(*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1575–1604.)

A list drawn up by the Federal Radio Commission, giving in most cases the call letters, location, frequency, " frequency channel " and name of owner of the various stations: amateurs, being licensed for bands of frequencies rather than specific channels, are not included.

ANALYSIS OF BROADCASTING STATION ALLOCATION. —J. H. Dellinger. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1477–1485.)

An exposition of the new allocation announced by the Federal Radio Commission on 11th September, 1928. It was drawn up in compliance with the requirements (of the 1928 Amendment to the Radio Act) as to the equalisation of broadcasting facilities between the zones and states, and with the decision that no existing station should be abolished at the time of its inception. It is believed to provide the greatest aggregate of radio service possible under these two conditions. It provides a " definite, invariant basis " of station assignment for each zone and locality: it can be improved, wherever interference is found to exist in actual operation, by the reduction of power or the elimination of particular stations, without disturbing the allocation as a whole: it eliminates heterodyne interference on 80 per cent. of the listener's dial: it recognises the essentially different requirements of local, regional and distant service.

THE PROBLEM OF INTERNATIONAL DISTRIBUTION OF BROADCAST WAVELENGTHS: PROPOSALS OF THE POLISH BROADCASTING COMPANY.—W. S. Heller. (*E.W. & W.E.*, January, 1929, V. 6, pp. 3–8.)

The 1926 Geneva scheme was criticised by Lemoine (*ibid.*, July, 1928) who suggested modifications. The present paper (by the Technical Director of the Polish Company) criticises both the scheme and Lemoine's proposed modifications, and makes other proposals. There is an Editorial on the subject on pp. 1 and 2.

A BEAM WIRELESS DEVELOPMENT. (*Engineer*, 28th December, 1928, V. 146, p. 703.)

A paragraph on the latest developments in the Marconi-Mathieu Multiplex System tests between Bridgwater and Montreal (Abstracts, 1928, V. 5, p. 525). The working of the system in both directions simultaneously has now been accomplished.

NEW BROADCASTING TRANSMITTER FOR SERVICE IN CZECHO-SLOVAKIA. (*Electrician*, 28th December, 1928, V. 101, p. 752.)

A paragraph on the largest of the chain of five stations now being built. This station, shortly to be erected at Bratislava by the Marconi Company, will deliver 12 kW. to the aerial. Wavelength band is 200–545 m.

SOME REMARKS ON ULTRA SHORT WAVE BROADCASTING.—B. van der Pol. (*E.W. & W.E.*, January, 1929, V. 6, pp. 9–12.)

Report to the Technical Committee of the U. Internat. de Radiophonie. Deals first with Emission: the first requirement is constancy of frequency, not only from day to day, but also during modulation, *i.e.*, the absence of frequency-modulation: to be obtained by (*a*) piezo-electric quartz oscillators, if necessary temperature-controlled, and (*b*) complete elimination of reaction from the power stage on the "drive." Propagation is then dealt with: results of a continuous 24-hour emission from PCJJ (30.2 m.), based on hundreds of letters from all parts of the world, are plotted in separate graphs for Inner Europe, Outer Europe, India, S. Africa, etc., etc. The question of distortion is briefly treated, and tentative suggestions as to the advisable frequency gaps for such stations are made.

ÄNDERUNG DER RUSSISCHEN RUNDFUNKORGANISATION (Change in Broadcasting Organisation in Russia). (*E.N.T.*, November, 1928, V. 5, p. 426.)

It is announced that the Broadcasting Company "Radio Peredatscha" is being dissolved and the whole of Russian broadcasting taken over by the People's Commissariat for Posts and Telegraphs.

"WORLD-BROADCASTING" FOR GERMANY. (*E.T.Z.*, 25th October, 1928, p. 1584.)

A paragraph concerning the opening, in February, 1929, of a German short-wave high-power broadcasting station. Another short-wave broadcasting station is mentioned, in San Lazara, Mexico, working on 44 m. and audible in Europe.

GENERAL PHYSICAL ARTICLES.

ELECTRONIC WAVES AND THE ELECTRON.—J. J. Thomson. (*Phil. Mag.*, December, 1928, V. 6, No. 40, pp. 1254–1281.)

The discovery by G. P. Thomson and by Davisson and Germer of electronic waves (Abstracts, 1928, pp. 526 and 230) implies that the electron must be something much more complex than the point charge of negative electricity which had previously been regarded as its adequate representation. In "Beyond the Electron" and in a paper (*Phil. Mag.*, No. 33, p. 191), the writer has suggested a constitution for the electron which would cause a moving electron to be accompanied by a train of waves. In the present paper he develops the consequences of this hypothesis and describes some experiments which he has made in connection with it. The electron is pictured as built up of a nucleus (which—like the old conception of the electron—is a charge of negative electricity concentrated in a small sphere) surrounded by a structure of much larger dimensions referred to as the "sphere" of the electron, made up of parts which under electric forces of very high frequencies are set in motion and produce effects of the same type as are produced by convective currents of electricity. These parts are taken as being represented by an equal number of positive and negative particles of different masses but with equal and opposite electric charges. After considering such an electron in the stationary condition, and comparing its vibrations with the vibrations of an ionized gas (where the convection currents balance the displacement ones so that there is no effective current, no magnetic force, no transference of energy and therefore no radiation), the writer deals with the electron in motion parallel to the axis of x with the uniform velocity u. He shows that its frequency when in motion is greater than when stationary $\left(p = p_0 k\right.$, where p_0 and p are the natural frequencies of the "sphere" when stationary and in motion respectively, and $\left. k = \frac{1}{\sqrt{1 - \frac{u^2}{c^2}}}\right)$, and that the expressions for the electric and magnetic force round it contain the factor $\cos p\left(t - \frac{ux}{c^2}\right)$: *which represents plane waves travelling in the direction of motion of the electron.* The phase velocity is c^2/u and thus depends only on the velocity of the electron, and not upon the density of the electric charges in its sphere. The wavelength λ of the waves is given by

$$\lambda = \frac{2\pi c^2}{pu}, \text{ or } \lambda u = \frac{2\pi c^2}{p_0}\sqrt{1 - \frac{u^2}{c^2}}$$

$\left[\text{not } \sqrt{1 - \frac{u^2}{c^2}} \text{ as printed on p. 1267}\right]$. This is precisely the relation found by G. P. Thomson in his experiments on the diffraction of electrons. The relation between group velocity U and phase velocity V is $U = \frac{c^2}{V}$: in the case under consideration, $V = \frac{c^2}{u}$, so that $U = u$, and the energy travels along with the electron. Thus the electronic waves according to this view are waves of electric and magnetic forces of diminishing amplitude, differing from electric waves through the normal ether not only in phase velocity but also in having the magnetic force smaller relatively to the electric. If the direction of the electronic waves is deflected, as in the diffraction experiments, the path of the electron will be bent; conversely, if the path of the nucleus is changed by the action of applied forces on its charge, the path of the waves will be changed also. The electronic waves must be in a super-dispersive medium—*i.e.*, in the " sphere," so that the length of the train of these waves will be a guide to the diameter of the sphere. G. P. Thomson estimated the length of the train in his experiments as at least 5×10^{-8} cm., which at first sight indicates that the size of the sphere is large compared with an atom ; and while further consideration allows it to be less than this, the writer thinks (from the result of experiments) that it must be at least comparable with atomic dimensions. As regards the dimensions of the nucleus, the old calculations are entirely changed : the two parts of the electron, the nucleus and the sphere, are each capable of vibration, and when the electron is in a steady state the vibrations of the two parts will be in resonance : the electron has thus, in addition to the steady electric field due to the negative charge on the nucleus, an oscillating field (due to the sphere) in which the energy remains constant since there is no radiation. Thus the total energy of the electron is the sum of the energies of these two fields. The usual estimate for the radius a is deduced on the assumption that the energy due to the charge on the nucleus, $e^2/2a$, accounts for the whole electron energy : if $e^2/2a$ represents but a part—possibly a small part—of the total energy, the corresponding value of a would be much larger. Moreover, from G. P. Thomson's measurements of the wavelengths of waves associated with electrons moving with known speed, it can be deduced that p_0 is about 1.1×10^{20}, and from this it is found that a must be of the order of 5×10^{-11} cm., instead of 1.4×10^{-13} cm. The paper concludes by describing experiments which were to decide whether the deflection of an electron by an electric force is due primarily to the deflection of the electronic waves or (as on the usual theory) to the action on the negative charge on the nucleus. If the former is the case, the harder gamma rays from radium *C* (some of which must have frequencies about 1.1×10^{20}) should also be deflected by an electric force. So far the experiments are inconclusive.

Eine Bemerkung zur Arbeit von E. Rupp (A Comment on the Work of E. Rupp).—S. J. Wawilow. (*Zeitschr. f. Phys.*, 19th April, 1928, V. 48, pp. 1–10.)

Referring to Rupp's displacement of the wavelength of light by passage through a Kerr cell (Abstracts, 1928, p. 587) which was interpreted as a modification of the light frequency of the impressed voltage, the writer points out that the shift of wavelength can be regarded as an experimental verification of the Doppler-Michelson principle.

Modulation of Light Waves by High Frequency Oscillations. — A. Bramley. (*Nature*, 1st December, 1928, V. 122, pp. 844–845.)

Rupp's results (Abstracts, 1928, p. 587) seemed to agree well with the supposition that the wave form of frequency ν could be represented by an infinite wave train which would be split up into three wave trains of frequency $\nu + T$, ν, and $\nu - T$, where T is the frequency of the H.F. oscillations. The writer's results on light from an iron arc, however, indicate that the modulations may depend on the form of the light impulse ; two of the lines being shifted while the remaining eight remained unchanged. He suggests that the damping coefficients of the pulses corresponding to the shifted lines were related in a simple manner to the frequency of the oscillations present in the Kerr cell, and that for this reason the frequencies of these particular pulses were changed.

L'Effet Raman dans la Domaine des Rayons X. (The Raman effect in the region of X-rays).—M. Ponte and Y. Rocard. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 828–829.)

The writers point out that the phenomenon found by Davis and Mitchell—that the structure of an X-ray after diffusion by a body is more complex than the incident ray—is nothing more or less than the Raman effect applied to X-rays. Quantitatively, the results show that the Raman effect deserts more and more, as the frequency mounts, the classical theory, so that while in the low frequencies of wireless it conforms rigorously with the undulatory theory, in light it begins to demand quanta, and in X-rays it depends entirely on the quantum mechanics.

Sur les Moments Atomiques (Atomic Moments).—P. Weiss and G. Foëx. (*Comptes Rendus*, 29th October, 1928, V. 187, pp. 744–746.)

The writers give a table of the atomic moments (measured in magnetons) of a number of substances, with the names of the workers who measured them. Results whose accuracy is considered doubtful are excluded.

Evidence . . . as to the Ultimate Nature of Magnetism.—T. D. Yensen. (*Phys. Review*, July, 1928, V. 32, pp. 114–122.)

X-ray analysis of films of electrolytic iron in strong magnetic fields showed that even the most minute crystal aggregates were not oriented ; thus lending support to the conclusion that the magneton is an atomic property.

Über Wiedervereinigung positiver Ionen mit freien Elektronen (Recombination of Positive Ions with free Electrons).—R. d'E. Atkinson. (*Zeitschr. f. Phys.*, 12th October, 1928, V. 51, pp. 188–203.)

The question is studied experimentally whether, at the passage of a beam of positive ions through an electron cloud, signs of recombination are produced in the form of loss of ions. The negative result establishes an upper limit for the probability of recombination.

Schwingende Kontinua mit willkürlich verteilter, kleiner Dämpfung (Oscillating Continua with arbitrarily distributed small Damping).—M. J. O. Strutt. (*Ann. d. Physik.*, 5th October, 1928, V. 87, No. 2, pp. 145–152.)

The mathematical treatment is finally applied to two examples—the case of an open aerial and the case of the acoustics of a room.

MISCELLANEOUS.

Die Fernlenkversuche der Reichsmarine in den Jahren 1916-1918 (Distant Control Experiments in the German Navy, 1916-1918).—H. W. Birnbaum. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, pp. 162–170.)

Completed in 1919, this paper could not be published till now. It is divided into two parts: the Work of the Test Commission (Communications) and the Tests of the Department for Torpedo Inspection (Kiel). The former deals with the work of Max Wien, Droysen and the writer on the ideas of Wirth, Röver-Mauracher and Siemens and Halske: the question of relays: jamming: tests at Hausneindorf (Autumn, 1914); tests on distant control of motor boats from a land station (Müggelsee, Winter, 1914-1915); from aeroplanes (Travemünde, Spring 1915). The latter part deals with the practical applications, in the war, of the above work in the hands of the writer, Pungs and Pirani; the Siemens system of indirect control by cable; direct wireless control without cable; note-tuned circuits; the aircraft transmitter; the directional effect (unwanted) of the aircraft transmitting aerial; range, and freedom from interference, of distant-controlled motorboats. The recently paragraphed tests on the wireless-controlled battleship "Zähringen" were based on the above work.

Die Physikertagung im Rahmen der Versammlung Deutscher Naturforscher und Ärzte in Hamburg 1928 (Conference of Physicists at the German Association for Science and Medicine, Hamburg, 1928).—(*E.T.Z.*, 13th December, 1928, pp. 1814–1817.)

Short abstracts, by E. Lübcke, of 35 papers on electrical subjects.

Wie Hoch muss eine Spannung sein, um dem Menschen Gefährlich zu Werden? (How High must a Voltage be to be Dangerous to Life?)—H. F. Weber. (*Bull. d. l'Assoc. Suisse d. Élec.*, 5th November, 1928, pp. 703–706.)

A very full report, regarding A.C. only, made in 1897 to Brown Boveri & Cie, and now revived in view of the interest taken in the subject by the International Union of Producers and Distributors of Electrical Energy. One general conclusion can be mentioned—that any A.C. voltage over 100 v. is dangerous to life if there is any possibility of contact with both poles.

"The Transmitting Station actually sends out Waves of one Definite Frequency, but of Varying Amplitude."—A. W. Ladner. (*E.W. & W.E.*, January, 1929, V. 6, p. 37.)

In this further contribution to the argument (started by an Editorial in *E.W. & W.E.* for August, 1928, under the above title) the writer begs the Technical Editor to give an illuminating treatment of "Suppressed carrier" working, on the single wave basis. His own version of such a treatment brings in as analogy the celebrated smile on the face of the Cheshire cat.

The Washington International Radiotelegraphic Conference of 1927.—J. A. Slee. (*E.W. & W.E.*, Dec., 1928, pp. 666–668.)

The Chairman's Inaugural Address to the Wireless Section of the Institute of Electrical Engineers.

A Decimal Classification of Radio Subjects: An Extension of the Dewey System.—(*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1423–1428.)

Circular 138, of the same title, was published by the Bureau of Standards, Washington, in 1923. The present article describes a proposed revision of this Circular.

Things We Don't Think Of.—H. M. Hobart. (*G. E. Review*, October, 1928, V. 31, pp. 519–525.)

An unusual little address based on various actual occurrences where "things went wrong" owing to causes which should have been foretold by theory or by the proper correlation of already known facts.

Contractions for Titles of Periodicals.—R. L. Sheppard. (*Nature*, 3rd November, 1928, V. 122, p. 685.)

A continuation of the argument referred to in Abstracts for October and December, 1928. The writer concludes by urging the soundness of the rule that abbreviated titles must be intelligible without a key.

Sur les Spectres d'Étincelle du Sélénium et du Tellure (Spark Spectra of Selenium and Tellurium).—L. and E. Bloch. (*Comptes Rendus*, 1st October, 1928, V. 187, pp. 562–564.)

The use of the "electrodeless discharge" has enabled the writers to separate out, in the spectrum of Tellurium, at least three successive degrees of excitation, probably corresponding to atoms singly, doubly, and trebly ionised. Sulphur showed only the two degrees of excitation already found by the writers *without* the use of the electrodeless discharge; but Selenium (which hitherto had given two degrees only) now showed a distinct third degree.

Nouveau Système de Téléphonie Optique par la Lumière Visible ou Ultraviolette (New System of Optical Telephony by Visible or Ultraviolet Light).—Q. Majorana. (*Atti. Congr. Intern. d. Fis. Como.*, 1927, V. 1, 1928, pp. 287–289.)

Eine Optisch-elektrische Zugbeeinflussung (An Optical-electrical System of Train Control).—Baeseler. (*E.T.Z.*, 6th December, 1928, pp. 1790–1792.)

The locomotive carries the light transmitter, giving pulses of light which pass vertically through about 3 metres of air and then (at appropriate points on the track) encounter a track mirror and are reflected back to the locomotive on to a selenium cell with attached amplifier, etc. A special tachometer arrangement can be added which pulls up the train if the speed at a certain point is excessive. The apparatus works by day or night. It is being tested on a section of railway in Bavaria.

Sur la Résolution Complète du Problème de la Carte dans l'Espace (The Complete Solution of the Problem of Space Mapping).—H. Roussilhe. (*Comptes Rendus*, 26th November, 1928, V. 187, pp. 970–972.)

A method of obtaining the position of a point in space from which an aerial photograph is taken. The paper should be read in conjunction with others by the same writer (*ibid*, 1922 and 1928). When rapid orthochromatic plates can be obtained with grain 1/100 mm. instead of the present 1/20 mm., even greater accuracy will be possible.

Talking Films. No. 1.—The British Phototone System.—(*Wireless World*, 12th December, 1928, V. 23, pp. 793–794.)

Piezo-electric Generation of Mechanical Oscillations.—(*German Patent* 4,611,147, *Telefunken*, published 14th June, 1928.)

A piezo-crystal is so constructed or oriented, in an A.C. field, that an asymmetry is present: with the result that a torque is produced which can be used to drive a small motor or to release or re-set a relay.

Broadcasting Over the Supply Mains—Development in the U.S.A.—(*Electrician*, 7th December, 1928, V. 101, p. 665.)

A paragraph on a recent big business transaction "foreshadowing the lines on which broadcasting in the United States is expected to develop." The largest supplier of electric light and power in the U.S.A. (the North American Company) has granted the Kolster Radio Corporation title to 600 of its patents in return for exclusive licences in the field of wired radio to one of its subsidiaries, Wired Radio, Inc. A further clause deals with the manufacture of goods to an enormous estimated yearly value, for the latter company. The patents include the "fundamental patent" for chain broadcasting, as well as patents for television and talking motion pictures. It is predicted that within the coming decade or two "most of the broadcasting in the United States will be carried on over household electric light and power wires, the air being left clear for commercial and safety communications. In this way, according to wireless experts, the worst of the broadcasting difficulties with respect to interference will be overcome." *Cf.* O.F.B., January Abstracts.

Untersuchungen über die Elektrizitäts leitung durch sehr dünne Schichten fester Dielektrika (Investigation of the Conduction of Electricity through very thin Layers of Solid Dielectrics).—E. Espermüller. (*Arch. f. Elektrot.*, 1st November, 1928, V. 21, pp. 148–169.)

Co-existence of Power Lines and Communication Lines.—L. Selmo, E. Brylinski. (*Rev. Gen. d. l'Élec.*, 1st September, 1928, V. 24, pp. 303–306.)

On the General Characteristics of Induction. K. Kanaya. (*Researches of Electrot. Lab.*, Tokio, No. 231, June, 1928, 90 pp.)

A New Ultra-violet Lamp. (*Electrician*, 9th November, 1928, V. 101, p. 526.)

A paragraph on a new type of metallic vapour arc lamp in which the effect of these vapours is supplemented and modified by the presence of a mixture of permanent gases "having certain electrical and optical characteristics," and also by the presence of an incandescent solid body. The lamp requires no more manipulation during starting or running than an ordinary incandescent lamp.

Some Technical Uses of Ultra-violet Radiation.—L. V. Dodds. (*Elec. Review*, 2nd November, 1928, V. 103, pp 746.–747.)