EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial.

The Allocation of Broadcast Frequencies.

BROADCASTING has brought the States of Europe face to face with a problem of a type entirely different from any which has arisen in the past, a problem daily becoming more acute and requiring to be faced and solved. It is true that broadcasting breaks down the barriers between countries and cultivates a feeling of brotherhood, and, as Mr. Baldwin recently pointed out in a speech at the Guildhall, any enmity that you may be nursing towards the inhabitants of some other State is likely to melt as you listen to them raising their voices in hymns and prayer ; but, on the other hand, the feeling of enmity is likely to be restored if he persists in jazzing in a very loud tone just when you yourself wish to indulge in hymns and prayer.

In no other branch of human activity are neighbouring states so interdependent as in broadcasting ; frontier guards and tariff walls are alike powerless to keep the electromagnetic waves either in or out. Whether the waves generated in one country cause interference or not with those generated in other countries depends principally upon their frequency, and it is therefore essential that in the allocation of frequencies the States of Europe should act in unison. This was early recognised and a central parliament was established at Geneva under the name of "L'Union Internationale de Radiophonie." This organisation devised a scheme which came into operation in November, 1926, and this has been the controlling factor in the subsequent organisation of European broadcasting. It was not to be expected, however, that the scheme would prove entirely satisfactory even at the date of its inception, still less that it would not require revision at an early date in view of the rapid growth of interest in broadcasting in countries which, for various reasons, were late in entering the field, and in view also of the great technical developments of transmitting and receiving. Another reason for revising the scheme is the effect of the decisions reached at the recent meetings of the International Radio Conference at Washington.

In July we published an article by M. Sifter Lemoine, the Chief Engineer of the Swedish Telegraph Administration and a member of the Geneva Technical Committee, in which he criticised the 1926 scheme and suggested modifications. We suspect that the subtle humour of his comment that "in spite of its defects, the scheme cannot be regarded as representing a final solution of the problem" was unintentional and due to linguistic difficulties.

We now publish an article by M. W. S.

Heller, the Technical Director of the Polish Broadcasting Company, criticising both the 1926 scheme and M. Lemoine's suggested modifications. The frequency bands allotted to broadcasting by the Washington Conference were hardly up to the expectations of those engaged in this branch of radio communication. Apart from short waves, the bands allotted are as follows: from 200 metres to 545 metres (1,500 to 550 kilocycles per second) except 220 metres (1,365 kc./sec.) which is reserved for shipping; from 1,340 metres to 1,550 metres (224 to 194 kc./sec.) to be used jointly with the air services, and from 1,550 metres to 1,875 metres (194 to 160 kc./sec.) reserved exclusively for broadcasting. The problem of fitting all the broadcast stations of Europe within the available bands without mutual interference is a formidable one. If signal strength always diminished with increasing distance as it does during the day and nobody showed any interest in transmissions from stations beyond a few hundred miles away the problem would be very much simpler. One of the greatest fascinations of wireless consists in receiving programmes from distant continental stations, but this should not be regarded as of the first importance in drawing up schemes of frequency allocation. Both M. Lemoine and M. Heller assume, as indeed they must, that the signal strength falls off with increasing distance according to certain curves, but as everyone knows, very distant stations can often be received at very great strength during the hours of darkness.

Any acceptable scheme must take into account a number of factors of which the principal are: area, population, geographical situation and geophysical character of the country, relative service values of different frequencies and different powers. A country such as Switzerland, in which different languages are spoken in different parts, presents problems which do not arise in a country like Germany, where the same language is spoken from Kiel to Gleiwitz. Such questions as this cannot be settled by any formula, but the weight to be given to area and population, and the relative values of different frequencies can probably be represented by approximate formulæ, and it is with suggestions for such formulæ that MM. Lemoine and Heller deal in their articles. If a is the area and p the population of a country, each expressed as a percentage of the area and population of the whole of Europe, then M. Lemoine suggests $a + 0.5p$ as a measure of the broadcast need of the country. M. Heller does not agree that greater weight should be given to area than to population and suggests $\sqrt{(ap)}$ as a fairer measure of the broadcast need of a country. In neither case is it suggested that the standard of cultural development of a country should be taken into account, nor any question of priority except in the retention of frequencies which have been long in use by stations. These two authorities also differ as to the relative value to be attached to different wavelengths. While both agree that a 500 metre wavelength is better than a 250 metre one and should be reckoned as of greater value in any allocation, M. Lemoine suggests the cube root of the wavelength as a measure of its value, whereas M. Heller maintains that within the range from 200 metres to 545 metres the service value is directly proportional to the wavelength, so that a country might be allocated either one station with a wavelength of 500 metres or two of 300 and 200 metres. Above 1,000 metres he gives them all an equal value.

Little reference is made by either writer to the power transmitted, but M. Heller bases his figures on 25 kilowatts in the aerial, and there is little doubt that the tendency in the future will be to replace a large number of low power stations by a smaller number of high power stations. G. W. O. H.

The Problem of International Distribution of Broadcast Wavelengths.

Proposals of the Polish Broadcasting Company.

I.

THE distribution of wavelengths in Europe, which was based on the Geneva agreement and accepted by the participating powers in November, 1926, had in mind the state of affairs which was in existence at the time that this Convention was signed and the interests of the founders of the Union Radiophonique. The countries which came in later have with difficulty found accommodation in the distribution, especially as no one amongst the privileged members was willing to deprive himself of any advantage for the benefit of the new-comers. This state of affairs, so unfavourable to the non-privileged countries, is a menace not only to the existence of the Union Radiophonique, but is liable to bring about a general disruption of broadcasting. The distribution of wavelengths should be on the principle of absolute equality. The idea of preference for the strongest should be entirely banished as both unjust and impossible to maintain in the ether, except at the cost of complete disruption of any kind of organisation. Any restriction of the right of each country to dispose freely of its title to the ether is impossible, except by mutual agreement between the interested countries.

The system of distribution of wavelengths should be based on the area of the country and the number of its inhabitants, without giving to either of these two factors a superior position, either in area (because radio is for

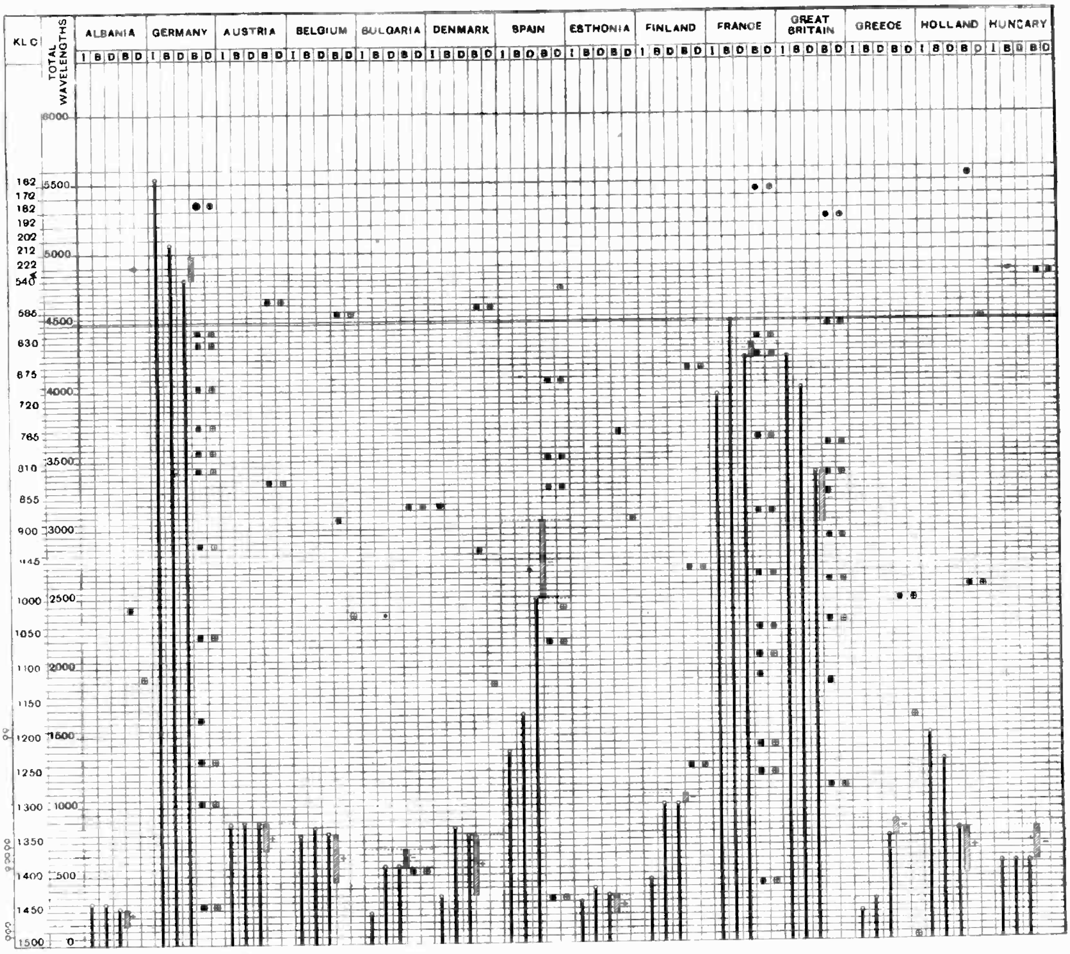
TABLE I.

1. Col.	2. Country.	3. Population in Millions.	4. Area 2 × 1,000 Km.	5. Cols. 3 × 4 in Millions.	6. 2/V of Col. 5.	7. Sum Total "T" of Theoretical Wave-lengths.	8. Per Cent.	9. Sum Total of Wave-lengths Plan "B."	10. Per Cent. Polish.	11. Sum Total of Wave-lengths Plan "D."	12. Per Cent.
1	Albania	0,830	27,500	23	4.7	135	0.37	294.1	0.80	267.8	0.72
2	Germany	63,180	472,037	29,800	172.6	4,977	13.52	5,062.1	13.89	4,807.9	13.05
3	Austria	6,535	83,833	548	23.4	675	1.83	879.2	2.41	879.2	2.38
4	Belgium	7,874	30,444	240	15.5	446	1.21	841.7	2.31	796.3	2.21
5	Bulgaria	5,483	103,146	566	23.7	684	1.85	557.9	1.54	557.9	1.51
6	Denmark	3,452	43.017	148	12.0	345	0.94	833.3	2.28	778.3	2.11
7	Spain	22.127	505,208	11,178	106	3,057	8.40	1,650.7	4.54	2,482.4	6.74
8	Esthonia	1,116	47.459	53	7.2	208	0.56	392.2	1.07	336,7	0.91
9	Finland	3,526	388,483	1,370	37	1,068	2.89	995.9	2.73	995.9	2.70
10	France	40,743	550,986	22,448	150	4,326	11.75	4,493.1	12.33	4,225.3	11.47
11	Gt. Britain	45,370	244,181	11,078	105	3,028	8.23	4,007.5	11.00	3,391.1	9.21
12	Greece	6,483	140,135	908	30	866	2.34	297.0	0.81	751.2	2.04
13	Holland	7,526	34,218	258	16	461	1.25	1,303.0	3.58	800.5	2.17
14	Hungary	8,368	92,928	777	27.8	802	2.17	555.6	1.53	555.6	1.50
15	Ireland	2,972	68,873	205	14.3	412	1.12	630.4	1.74	630.4	1.71
16	Italy	40,548	310,090	12,570	112	3,230	8.78	1,866.6	5.12	2,866.6	7.78
17	Latvia	1,867	65,791	123	11	317	0.86	529.1	1.45	320.5	0.87
18	Lithuania	2,229	55,658	124	11	317	0.86	314.5	0.86	314.5	0.85
19	Luxemburg	0,268	2,586	7	2.6	75	0.20	227.3	0.63	227.3	0.62
20	Norway	2,788	323,793	902	30	866	2.35	1,287.1	3.53	1,043.2	2.83
21	Poland	29,589	388.279	11,500	107.2	3,092	6.33	2,470.4	6.78	2,943.2	7.99
22	Portugal	6,080	91,944	559	23.5	679	1.83	300.0	0.82	300.0	0.81
23	Roumania	17,153	294,892	5,058	71	2,048	5.56	637.8	1.75	1,316.2	3.57
24	Sweden	6,074	448,460	2,724	52.1	1,503	4.08	2,735.5	7.51	1,677.6	4.55
25	Switzerland	3,059	41,295	126	11.2	323	0.87	909.0	2.50	681.8	1.85
26	Czecho-Slovakia	14,353	140,345	2,014	44.9	1,295	3.51	1,538.0	4.22	1,538.0	4.17
27	Yugo-Slavia	12,492	248,488	3,104	55.7	1,607	4.36	828.3	2.27	1,357.4	3.68
		362,085	5,244,069	118,411	12,777.4	36,842.8	100%	36,437.3	100%	36,842.8	100%
28	Not provided for in the Geneva plan							405.5			
								36,842.8			

the service of man), nor the number of inhabitants (because the density of population facilitates the task of distribution).

An analysis of the information contained in Table I indicates the impossibility of basing the distribution of wavelengths on the product of the area of a country and the number of its inhabitants. In such a case the lesser powers would be left with nothing, or almost nothing. This can be remedied on the basis of the argument we have already raised that equality should come before everything, working on the basis of a progressive system, that is to say, giving advantages to the weaker at the cost of the stronger, on the same lines as progressive taxation is arranged. Calculation shows that this can be arrived at by replacing the product of the number of inhabitants and the surface of the country by the square root of this product. This would work much better than a haphazard allocation of positions to the small Powers. The analysis of such a distribution shows in many cases agreement with the existing state of affairs. The differences which are noted are easily ex-

TABLE II.—CHART GIVING DATA



I TOTALS OF WAVELENGTHS ACCORDING TO THE GENEVA PLAN

B TOTALS OF WAVELENGTHS ACCORDING TO PLAN B OF THE UNION INTERNATIONALE DE RADIOPHONIE

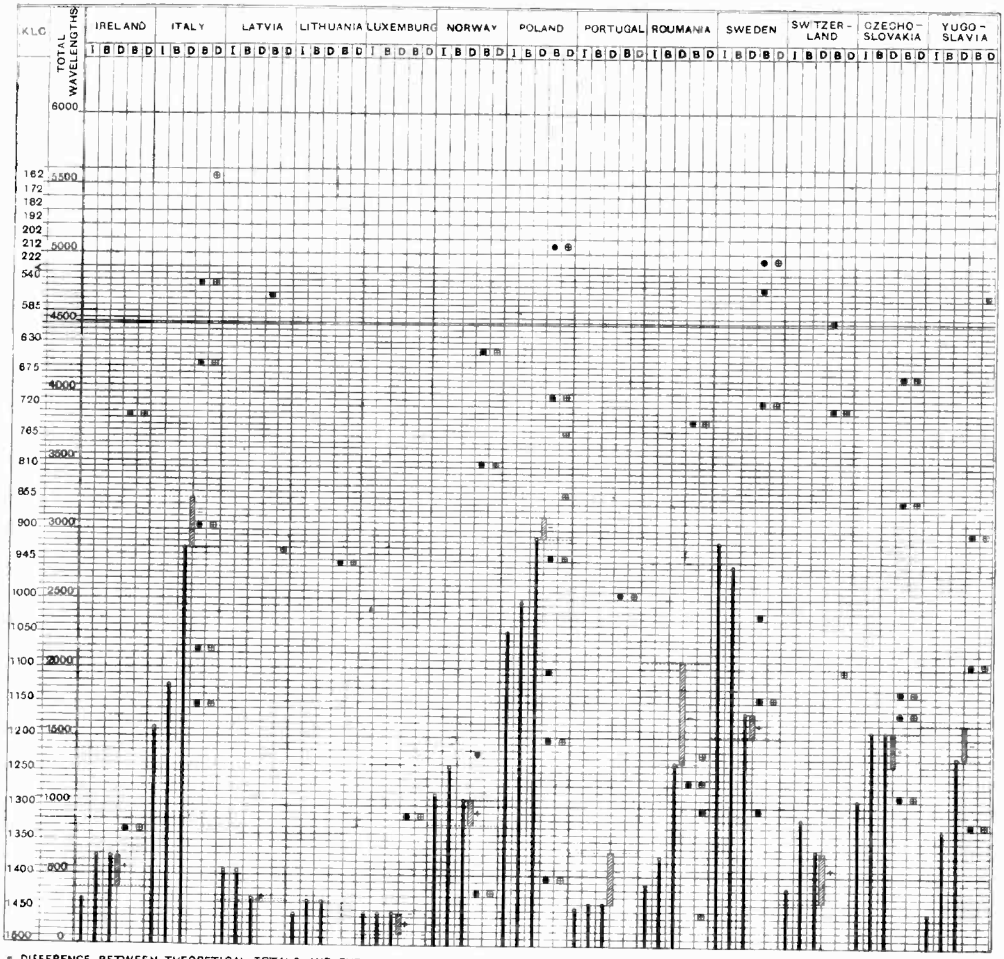
D TOTALS OF WAVELENGTHS PROPOSED BY POLAND

THEORETICAL TOTALS OF WAVELENGTHS

plained. They are precisely the advantages which have been obtained by a few favoured Powers. Leaving out of the question the possibilities of broadcasting progress and considering only the present state of affairs and the distribution of waves in proportion to their importance and usefulness, it is possible that this distribution will lose in value as time goes on, particularly if new methods of transmission are introduced or the strength of transmitting stations is greatly augmented, as may already be anticipated. The countries which are leading in the march of progress will soon regain considerable advantages and privileges by comparison with the countries where progress develops slowly. Such privileges are natural and even necessary and inevitable.

The countries animated by ambition and prepared to incur considerable outlay can maintain their present supremacy without occupying a privileged place in the ether, on the basis of technical progress and organisation. This is a further argument against giving privileges in the way of distribution of wavelengths to those who

RELATIVE TO BROADCAST DISTRIBUTION



DIFFERENCE BETWEEN THEORETICAL TOTALS AND THE TOTALS PROPOSED BY POLAND

DISTRIBUTION OF WAVELENGTHS ACCORDING TO PLAN B

DISTRIBUTION OF WAVELENGTHS PROPOSED BY POLAND

COMMON WAVELENGTHS

possess all the necessary means for the sure and rapid development of their broadcasting.

II.

Efficiency of Wavelengths.

The comments attached to the present memoir and based on the publications of P. P. Eckersley, of the Institution of Electrical Engineers, prove that within the limits of broadcasting wavelengths, that is to say, between 540 and 1500 metres, attenuation remains proportional to wavelength, provided that intensity does not vary and does not exceed 2.5 mV/m ; in other words, up to the limit of receptivity with a crystal detector. With a voltage below this value reception becomes insufficient from the point of view of service and measurement, too, becomes uncertain.

A comparison could also be made with the proposals of M. Lemoine published in *E. W. & W. E.* As a result of the relationship established between attenuation and wavelength, the efficiency of wavelengths from the point of view of utility may be expressed by the sum total in metres. This simplifies enormously the assessment of the value of wavelengths of each country and also easily establishes their mutual reciprocity.

To wavelengths above 1,000 metres, and particularly the seven wavelengths between 1351.3 and 1,852 metres, we need not trouble to apportion values, because the variation from this rule would be so slight. The coefficient which limits the usefulness of wavelengths from the point of view of the service of broadcasting is due to the growing difficulties of reception. The falling-off of long-wave reception results from the increased damping of the circuit of crystal receivers, the field strength remaining the same. This necessitates the use of external aerials, which appreciably hinders the popularity of broadcasting.

For this reason we regard wavelengths beyond 1,000 metres as equivalent and of the same order of efficiency as those of 1,000 metres ; although this coefficient is only chosen as a compromise it is adaptable to actual conditions, and a variation up to 50 per cent. will not require any appreciable modifications to the plan of distribution. Table I, column 7, shows us the sum total of wavelengths in metres, available for each country, the total being 36,842.8 metres, placed at the general disposal of broadcasting, and divided into 98 exclusive wavelengths. The six long wavelengths are counted as equivalent to a wavelength of 1,000 metres, the seventh long wavelength (the Russian wavelength) not having been taken into account.

Table II shows us the total of wavelengths of each country according to the Geneva plan, proposals of the Commission Technique de l'Union Internationale, and the effect which would result from the principles indicated in this Memoir. Certain countries are favoured at the expense of their neighbours, when it would have been easy to have avoided it, but the basis of this proposal is in agreement with the present state of affairs and would introduce only slight modifications, and in the case of some countries no changes at all. The result is arrived at by applying impartial methods of treatment to all members of the Union Radiophonique and eliminates all chance.

This memoir does not attempt to merely modify the present arrangement for the distribution of wavelengths by replacing it with the proposal "D," but endeavours to emphasise the necessity for accepting certain principles in the absence of which a fair and proper distribution must be impossible.

Comments on the Above Proposals.

By W. S. Heller.

(Technical Director of the Polish Broadcasting Company.)

THE question of the allocation of wavelengths for European broadcasting stations is at present especially important, having regard to the limitation of the wavelength band decided upon by the Washington Conference and also the increasing demands of new stations for broadcasting service. This question has been recently discussed by M. S. Lemoine in Volume V, No. 58, *E. W. & W. E.*

The principle of distribution suggested by M. S. Lemoine will find full approval as a first serious effort to find a practicable and just solution. The present system of allocation known as the Geneva Plan, now in use, is based on priority, and is the reason for various troubles. A new system of distribution must be undoubtedly introduced on a common basis resulting from the value of area and population. Consequently a multiplication coefficient should be used for the calculation of the numerical value, but it is not satisfactory to take the full area and only half of the population into account, as is done by M. Lemoine, because the population and not the area is the object of the service. A trial of such multiplication coefficients indicates, as would be expected, a great privilege for the larger in comparison with the smaller countries. To equalise this difference to the rightful level it is proposed to take the square root of the product of area and population. In this way a comparison can be found, which corresponds with the actual conditions and gives desirable proportions. Comparing the results of this theory with the percentage values estimated by M. Lemoine some great differences will be noticed, which are caused by the especially great areas taken in these cases (Finland, Norway and Sweden).

Service Value for Different Wavelengths.

Curves prepared by Captain P. P. Eckersley (*Journal of the Institution of Electrical Engineers*, Vol. 66, No. 377, published in February, 1928) give results as shown in the table above.

The reciprocal ratio of the frequencies 1,040/610, or the direct ratio of the wavelengths, is 1.71 and is equal to the ratio of the distances for equal field strength within 5 per cent. This principle can be approximately extended for broadcasting wavelength range from 200 m. to 550 m. and field strength values down to 2 mV./m. Smaller field strength values are not suitable for broadcasting service. The above figures are based on 25 kW. in the aerial, and it can be assumed that with the development of Broadcasting an increase of the power used for stations will take place.

Since direct proportion exists between service values and wavelengths, a comparison between the total sums of the wavelengths is also possible; in other words, since average service values depend upon wavelengths or sum of the wavelengths in a direct ratio, the total sum of the wavelengths corresponds with the service value of the wavelengths allocated to any given country. With regard to the longer waves, above 1,000 m. no experiments have been carried out to determine and to compare their service values. Probably the same direct proportion holds approximately, but it does not seem reasonable to bring it into consideration. The service value of longer wavelengths is limited by less favourable reception conditions. The crystal detector reception of longer wavelengths depènds, assuming the same values of field strength as for the shorter wavelengths, upon better constructed aerials and H.F. circuits in order to counteract the increased damping effect. Therefore the six possible longer wavelengths of the broadcasting band are estimated as having the same service values as the 1,000 m. wavelength. This consideration seems to be reasonable, until further experiments have been made to determine the actual service values.

There are fundamental differences between the above valuation system and that proposed by M. S. Lemoine. Taking the service value of a 200 m. wavelength as

FOR 5GB STATION AND 25 KW. AERIAL OUTPUT.

Field strength	30	25	20	15	10	8	6	4	mV./m.
Distance for 1,040 kcl. ..	11.5	12.5	14.5	18.0	22.5	26.0	30.0	36.0	miles.
,, ,, 610 kcl. ..	20.0	22.0	26.0	31.0	38.5	43.5	50.0	65.0	miles.
Proportional ratio	1.74	1.76	1.79	1.72	1.71	1.67	1.67	1.80	

unity, then a

300 m. wave, according to M. Lemoine is	..	1.15 ;	and accord. to this proposal ..	1.5
428.6 m. ,,	,,	1.30 ;	,, ,,	2.14
500 m. ,,	,,	1.37 ;	,, ,,	2.5
1,563 m. ,,	,,	2.00 ;	,, ,,	5.0

The results estimated by M. Lemoine are probably for much smaller field strengths and depend upon correspondingly smaller aerial outputs (Fig. 2 and 3, *E. W. & W. E.*, Vol. V, No. 58). It seems to be certain that the valuation system here explained corresponds much more closely than the system of M. Lemoine to the results being obtained at present in the erection and valuation of broadcasting stations. No special difficulties will be met in the realisation of this system of valuation, as can be seen from the tables (see pp. 3, 4, and 5).

It is possible that, in the future, progress in the research of radiation and in the erection of high-power stations will lead to a correction of the valuation plan outlined above. For all that, it is obviously desirable to find and to introduce a system of distribution and valuation of the waves which on the basis of present technical development can be accepted by every member of the Union.

Ferranti Multi-Range Test Set.

THE Ferranti multi-range test set illustrated comprises two 2½ in. 8-range moving-coil instruments with knife-edge pointers and mirror scales fitted in the same case of moulded insulating material and calibrated, respectively, to read volts and amperes independently, each instrument having a separate 10-way switch to select the required range. The self-contained ranges included are :—

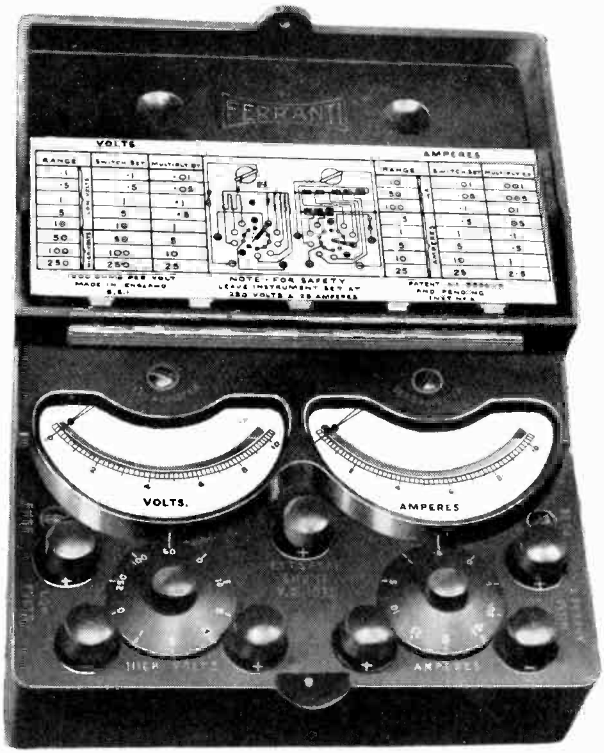
Volts.	Amperes.
0—0.1	0—0.01
0—0.5	0—0.05
0—1	0—0.1
0—5	0—0.5
0—10	0—1
0—50	0—5
0—100	0—10
0—250	0—25

As the resistance of the voltmeter is 1,000 ohms per volt, an additional self-contained range of 0–1 mA. can be obtained on the voltmeter using the low-range terminals with the switch set at 0.1 volt. Moreover, an additional terminal is provided to permit of the use of external shunts having the full load volt-drop of 75 mV., thus extending the range of the ammeter indefinitely.

The terminals can be connected so as to put the two instruments in series when, as the ammeter has a full scale consumption of 6 mA., one-third of the maximum reading (2 mA.) represents 500 volts, thus giving an additional voltage range. Although the voltmeter will be overloaded during such a test, its exceptionally robust construction prevents it from being damaged.

There is a replaceable fuse in circuit for each volt and milli-amp. reading, the ammeter is compensated for temperature, and all its shunts are solidly connected, thus obviating internal variable contact resistance errors.

For the testing of radio valves, two plugs can be supplied each with a set of leads permanently attached. One plug is used when it is desired to measure anode current and filament voltage ; the other plug being used for the measurement of grid bias voltage, and filament current and also to give an indication of continuity of the grid circuit.



Each valve plug is provided with an engraved plate showing the quantities which can be measured, and the free ends of the leads are marked to indicate to which terminal of the test set they are to be connected.

Some Remarks on Ultra Short Wave Broadcasting.*

By Balth. van der Pol, D.Sc.

(Radio Research Department, Philips Radio, Eindhoven, Holland.)

A. Emission.

When the range of wavelengths between 20,000 and 1,000 metres is denoted by "long" waves, the waves between 1,000 and 100 metres by "short" waves and the waves between 100 and 10 metres are called "ultra-short," it will be clear that the ratio between the commercial frequency of 50 cycles and the frequency of "long" waves is of the same order as the ratio between the frequency of "long" waves and the frequency of "ultra-short" waves.

Therefore, it is obvious that certain technical considerations have to be borne in mind in the construction of an ultra-short wave telephone transmitter which are not to be adhered to primarily in the working with much lower frequencies.

Outstanding amongst these considerations is the constancy of frequency (wavelength). Not only constancy of frequency in the course of, say, one hour, but especially during *modulation*. The normal ideal modulation consists of *pure amplitude modulation*. This ideal aim is most clearly expressed by a few mathematical symbols. When we confine ourselves to anode potential modulation and when the variable part of the air pressure in front of the microphone is given by

$$f(t) \quad \ldots \quad (1)$$

(which therefore is a low-frequency function) the ideal modulation consists of making the anode tension V_a (which, without modulation, would be a constant $V_a = V_{a0}$) apart from this constant value an exact image of the air pressure in front of the microphone, *i.e.*:

$$V_a = V_{a0} + a f(t) \quad \ldots \quad (2)$$

where a is some constant.

Again, let the antenna-current $i_{\text{ant.}}$ corresponding to the anode potential V_a be

$$i_{\text{ant.}} = \beta V_a \sin \omega t \quad \ldots \quad (3)$$

where again β is a constant and ω the angular frequency of the transmitter.

From (2) and (3) it follows that the antenna-current obtained with ideal amplitude modulation is given by

$$i_{\text{ant.}} = \beta\{V_{a0} + a f(t)\} \sin \omega t \quad \ldots \quad (4)$$

(4) expresses the fact that the variable part of the amplitude of the high frequency antenna-current is an exact image of the variable part of the air pressure in front of the microphone.

However, a serious difficulty arises which, especially with ultra short waves, is to be borne in mind. For it is a well-known fact, that the angular frequency ω of an ordinary oscillatory circuit is *not* given by

$$\omega^2 = \frac{1}{LC}$$

but by

$$\omega^2 = \frac{1}{LC} - \frac{r^2}{4L^2} = \omega_0^2\left(1 - \frac{r^2C}{4L}\right)$$

where

$$\omega_0^2 = \frac{1}{LC}$$

represents the ideal frequency without the correction due to the presence of the resistance r.

As a triode characteristic is always curved (which curvature we make use of in detection and modulation) it is obvious that, when V_a is varied, every time a different differential resistance will be present in the system, resulting in a different frequency correction due to the resistance terms in the equations. Thus the momentary frequency ω will also depend on the momentary anode potential, *i.e.*:

$$\frac{\delta\omega}{\delta V_a} \neq 0$$

or

$$\omega = \omega_0\{1 + \phi(V_a)\}$$

* Report to the Technical Committee of the "Union Internationale de Radiophonie."

where $\phi(V_a)$ is a function of the anode potential having the character of a frequency correction which is intimately connected with the curvatures of the grid- and anode-characteristics.

Thus we obtain for the expression of the momentary antenna-current instead of (4) :

$$i_{\text{ant.}} = \beta\left\{V_{a0} + \alpha f(t)\right\} \sin\left\{\omega_0 \int (1 + \phi(V_a))\, dt\right\} \quad .. \quad (5)$$

This formula clearly shows that, during modulation, it is not only the amplitude of the antenna-current

$$\beta\{V_{a0} + \alpha f(t)\}$$

which is varied in audio rhythm, but that *also* the frequency

$$\omega_0(1 + \phi(V_a))$$

varies unintentionally. Therefore, unless special precautions are taken, the transmitter does not only produce the intended *amplitude modulation*, but also an unintended *frequency modulation*.

The pronounced hum often audible during the reception of badly designed amateur ultra short wave transmitters is no doubt due to this latter *frequency modulation*, even when the smoothing system of the transmitter is sufficient to cause a negligible *amplitude modulation*. Especially with faint signals the receiver, when used with nearly critical retroaction, has a very sharp resonance curve. The *frequency modulation* of the transmitter may be the cause that, even without appreciable *amplitude modulation*, the high frequency of the incoming signal varies periodically—with the frequency of the hum—to such an extent, that periodically the receiver is in tune and out of tune several times per second (with the frequency of the hum). This would cause a very pronounced hum in the telephones.

Therefore, the first requirement of an ultra short wave telephone transmitter is *constancy of frequency*, not only from day to day, but also during modulation, *i.e.*, the absence of *frequency modulation*.

As is well known, this constancy of frequency is obtainable through the use of

(*a*) piezo electric quartz oscillators (when necessary temperature controlled) ;

(*b*) the complete elimination of the reaction from the power stage on the "drive."

A short explanation of the reason why the frequency of quartz crystals is affected only to a very small extent by external means may be given here. The equivalent electrical circuit of a piezo electric quartz crystal is as given in Fig. 1.

It consists of a big inductance L of the order of 50 henrys in series with a very small capacity C_1 of the order of 0.05 $\mu\mu$F and a series resistance r of, say, 2,500 ohms.

When the crystal is connected to a triode the system is shunted by a capacity C_2 of the order of 5 or 10 $\mu\mu$F. The value of the

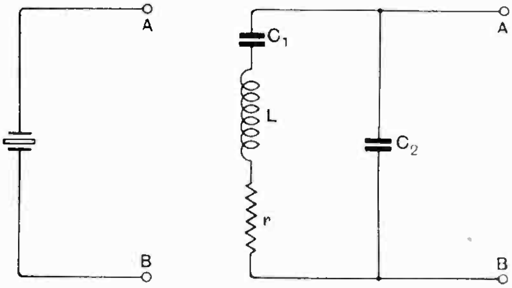


Fig. 1.

relatively large capacity C_2 (compared with C_1) has little influence on the frequency ω of the circuit rLC_1C_2, which is given by the formula

$$\omega^2 = \frac{1 + C_1/C_2}{LC_1(1 + r^2C_1/4L)}$$

but the fact that C_2, across which the external circuit is connected, is much greater than C_1, gives *a very loose capacity coupling to a very low damped oscillatory* circuit, the logarithmic decrement δ being about

$$\delta = 2\pi \cdot \frac{r}{2\omega L} \doteq 0.00025.$$

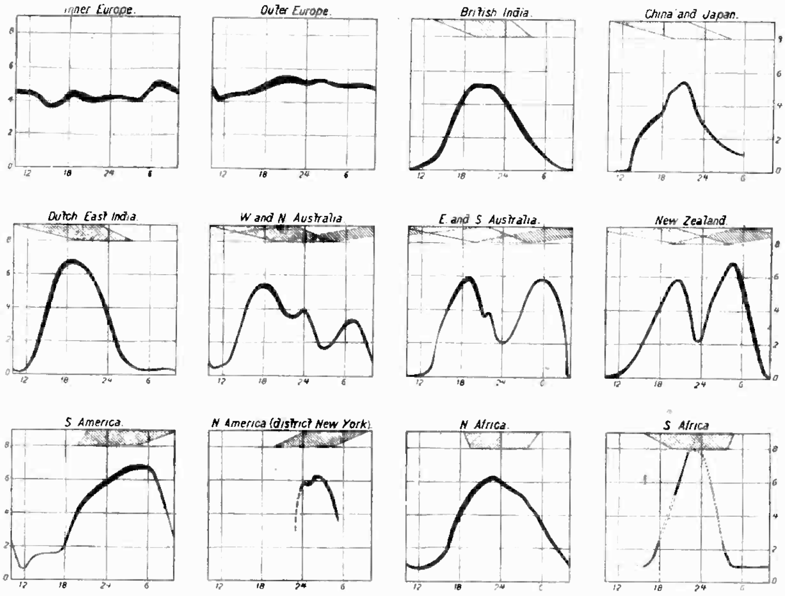
As the terminals A, B are the only ones accessible, one can use this equivalent electrical system with an extremely loose coupling only, and it is therefore impossible to influence the system by external means to any great extent.

B. Transmission.

The transmission phenomena of ultra short waves are extremely complex and partly still little understood. It is therefore out of the question to give any detailed or complete account of it here. However, some results of a continuous 24-hour emission (July 26th-27th, 1927) of the ultra short wave telephony station PCJJ of *Philips Radio Laboratory* (Eindhoven, Holland) will be of interest. The station worked with a wavelength of 30·2 metres, and the power supplied to the last stage was 20 to 25 kilowatts. The above-mentioned 24-hour transmission was announced beforehand, and the many correspondents from all over the world were asked to send detailed reports of received intensity as a function of the time.

Many hundreds of letters were received and each report was treated as follows. According to the data supplied by each correspondent each hour of the day was given a number representing the intensity of reception. These numbers ranged from 0 (nothing audible), 1 (carrier just audible), etc. . . . to 9 (extremely strong reception). Afterwards the world was divided in 12 parts as indicated in the accompanying graphs, and all the numbers obtained from the data supplied by correspondents living in the same " part " of the world were averaged. The accompanying graphs illustrate the results thus obtained. The abscissa represent the time (G.M.T.) and the ordinates the averaged signal strength.

Obviously this procedure is a very rough one and as the correspondents used quite different receiving sets no very accurate results can thus be expected. The results, however, are in the main quite consistent. " Inner Europe " is defined as England, Holland, Denmark, Belgium, France and Germany, the rest of Europe being taken as " Outer Europe." The shaded portions on the top of each diagram represent in the well-known manner the distribution of light and darkness between transmitter and receiver. The thickness of the curves is an indication of the number of reports received for every hour.



The following conclusions may be drawn from the graphs. It is seen that the average signal strength in " Outer Europe " is somewhat higher than in " Inner Europe " pointing towards a skipped distance. British India and China and Japan have their maximum of reception roughly at the period where the complete track of the waves is in darkness. W. and N. Australia and E. and S. Australia show *two* main maxima of reception, the second maximum being higher in E. and S. Australia than in W. and N. Australia. This second maximum is still more pronounced in the reception in New Zealand. No doubt this second maximum is due to the waves travelling in western direction round the globe. A small secondary maximum after the first main maximum is present in the whole of Australia. It occurs one hour after sunrise in Australia and seems to occur quite regularly. The transmission to S. and N. America seems also best when the whole track is in darkness and the same rule applies to N. and S. Africa.

As stated above, the figures given only apply to a wavelength of 30.2 metres and will be quite different for other frequencies.

C. Reception.

Both ordinary retroactive sets specially designed for ultra high frequencies, and superheterodyne sets can be used for reception. The width of the received band in a superheterodyne set is obviously determined mainly by the intermediate frequency amplifier, and therefore the same rules are valid for these sets whether used for the short wave or ultra short wave band. On the other hand, the selectivity of a simple one-stage retroactive receiving set, as used quite extensively by many listeners, depends very markedly on the amplitude of the incoming signal. Measurements in *Eindhoven* have shown that signals from stations like *Schenectady* and *Bandoeng* (Java) when received with a retroactive receiver adjusted for maximum intensity, have such an amplitude that another signal of the same intensity but at 10 to 15 kilocycles separation would be inaudible in the headphones. However, the theory as well as the experiment shows that, when the signals are stronger, the selectivity of such a simple receiving set is much reduced.

We feel quite sure that the constancy of frequency of the transmitter (the absence of *frequency modulation*) is a very important factor in determining the quality of reception, especially with ultra short waves. A relatively simple theoretical consideration, which will not be given here, clearly shows that, when the waves reach the receiver along more than one path, the frequency modulation may, even with a flatly tuned receiver, be a pronounced source of distortion.

As the effect of frequency modulation was early recognised, special care was taken in the design of the station PCJJ that this source of distortion would be absent as much as possible. From the many thousands of letters received from correspondents from all over the world during a period of about one year and a half, the general conclusion may be drawn—with the present state of the technique—that at the time of maximum reception the quality of reception generally improves with the distance (also the fading being less) and may be such—though not yet yielding a highly artistic satisfaction—that the greater part of the listeners receive the station with much enthusiasm. Especially many letters reached us from grateful listeners living in the Dutch East Indies relatively far away from the civilised towns. Though the number of these listeners may not be high, the great appreciation they show for enabling them to listen to their mother country (even though the quality of reception is not yet ideal) can hardly be overestimated.

As to the most advisable frequency difference between two wireless telephone transmitters for ultra short waves, relatively few data are so far at hand. In view of the resolutions adopted at Washington the wavelength of PCJJ was recently changed from 30.2 metres to 31.4 metres. It happens that this frequency is relatively near the one of Schenectady, the difference according to some preliminary measurements made at Eindhoven being 38.7 kilocycles. Though often both stations worked simultaneously, so far only ***one*** complaint has reached us about mutual interference.* In view of the difficulties encountered with regard to the constancy of frequency in the waveband 300–600 metres it would, according to the author, be strongly advisable that all ultra short wave broadcasting stations to be erected in the future should be obliged to use crystal control exclusively. At the same time, this would greatly reduce or eliminate altogether *frequency modulation*. Whenever possible the crystal should be mounted in a thermostat, so as to keep its temperature and frequency constant. Under these circumstances, a frequency separation of about 30 kilocycles would be sufficient.

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* Since writing this report, more complaints about mutual interference between Schenectady and Eindhoven have reached us. The matter is being investigated further.

P.S.—In writing this note free use was made of the following papers:

BALTH. VAN DER POL.—Free and forced triode oscillations. *Radio Review I*, 701, 1920.

J. R. CARSON.—Notes on the theory of modulation, *Proc. Inst. of Radio*, Eng. 10, 57, 1922.

R. BOWN, K. MARTIN, R. POTTER.—Some studies in Radio broadcast-transmission. *Proc. Inst. of Radio*, Eng. 14, 57, 1926.

BALTH. VAN DER POL.—Het gebruik van piëzo-electrische kwarts kristallen in de draadlooze Telegrafie en Telefonie. *Gedenkboek Ned. Ver. voor Radiotelegrafie*, 1926, 293.

BALTH. VAN DER POL.—Forced oscillations in a circuit with non-linear resistance (reception with reactive triode). *Phil. Mag.* 3, 65, 1927.

BALTH. VAN DER POL.—Enkele physische beschouwingen over ultra korte golven, mede in verband met de uitzendingen van het Philips' Radio Laboratorium. *Tijdschrift van het Ned. Radiogenootschap* III, 161, 1927.

The High-Frequency Resistance of Toroidal Coils.

By S. Butterworth, M.Sc.

1. THE characteristic property of a toroidal coil is its complete astaticism, that is to say, its magnetic field lies entirely within the coil and there is therefore no electromagnetic interference between the coil and neighbouring coils.

Although in certain cases toroidal coils are essential, the writer cannot recommend this type of coil in the construction of wireless receiving sets for the reason that, bulk for bulk, a well-designed toroidal coil has more than twice the high-frequency resistance of a well-designed solenoidal coil. This would not be a sufficient reason if with the latter type of coil it were impossible to avoid electromagnetic interference, but it is readily possible to arrange three solenoidal coils to have no mutual interference by putting their centres in line and their axes in mutually perpendicular directions. Toroidal coils should only be employed when one cannot afford the slightest trace of electromagnetic interference, for example, when it is desired to construct an oscillating set to inject a very

TABLE 1.

VALUES OF THE FUNCTIONS F AND G.

d = diameter of wire (cms.); ρ = resistivity (c.g.s. units); f = frequency (cycles per sec.); $z = \pi d\sqrt{2f/\rho}$. For copper of resistivity 1,700 c.g.s., $z = 0.1078\, d\sqrt{f}$.

z	$1+F$	G	z	$1+F$	G	z	$1+F$	G	z	$1+F$	G
0.0	1.000	—	2.5	1.175	0.2949	5.0	2.043	0.755	10.0	3.799	1.641
0.1	1.000	—	2.6	1.201	0.3184	5.2	2.114	0.790	11.0	4.151	1.818
0.2	1.000	$z^4/64$	2.7	1.228	0.3412	5.4	2.184	0.826	12.0	4.504	1.995
0.3	1.000	—	2.8	1.256	0.3632	5.6	2.254	0.861	13.0	4.856	2.171
0.4	1.000	—	2.9	1.286	0.3844	5.8	2.324	0.896	14.0	5.209	2.348
0.5	1.000	0.00097	3.0	1.318	0.4049	6.0	2.394	0.932	15.0	5.562	2.525
0.6	1.001	0.00202	3.1	1.351	0.4247	6.2	2.463	0.967	16.0	5.915	2.702
0.7	1.001	0.00373	3.2	1.385	0.4439	6.4	2.533	1.003	17.0	6.268	2.879
0.8	1.002	0.00632	3.3	1.420	0.4626	6.6	2.603	1.038	18.0	6.621	3.056
0.9	1.003	0.01006	3.4	1.456	0.4807	6.8	2.673	1.073	19.0	6.974	3.233
1.0	1.005	0.01519	3.5	1.492	0.4987	7.0	2.743	1.109	20.0	7.328	3.409
1.1	1.008	0.02196	3.6	1.529	0.5160	7.2	2.813	1.144	21.0	7.681	3.586
1.2	1.011	0.03059	3.7	1.566	0.5333	7.4	2.884	1.180	22.0	8.034	3.763
1.3	1.015	0.04127	3.8	1.603	0.5503	7.6	2.954	1.216	23.0	8.388	3.940
1.4	1.020	0.0541	3.9	1.640	0.5673	7.8	3.024	1.251	24.0	8.741	4.117
1.5	1.026	0.0691	4.0	1.678	0.5842	8.0	3.094	1.287	25.0	9.094	4.294
1.6	1.033	0.0863	4.1	1.715	0.601	8.2	3.165	1.322	30.0	10.86	5.177
1.7	1.042	0.1055	4.2	1.752	0.618	8.4	3.235	1.357	40.0	14.40	6.946
1.8	1.052	0.1265	4.3	1.789	0.635	8.6	3.306	1.393	50.0	17.93	8.713
1.9	1.064	0.1489	4.4	1.826	0.652	8.8	3.376	1.428	60.0	21.46	10.48
2.0	1.078	0.1724	4.5	1.863	0.669	9.0	3.446	1.464	70.0	25.00	12.25
2.1	1.094	0.1967	4.6	1.899	0.686	9.2	3.517	1.499	80.0	28.54	14.02
2.2	1.111	0.2214	4.7	1.935	0.703	9.4	3.587	1.534	90.0	32.07	15.78
2.3	1.131	0.2462	4.8	1.971	0.720	9.6	3.658	1.570	100.0	35.61	17.55
2.4	1.152	0.2708	4.9	2.007	0.738	9.8	3.728	1.605	Large	$(\sqrt{2z}+1)/4$	$(\sqrt{2z}-1)/8$
2.5	1.175	0.2949	5.0	2.043	0.755	10.0	3.799	1.641	—	—	—

small measurable electromotive force into another circuit. For this reason it is considered worth while to obtain formulæ for the high-frequency resistance of toroidal coils and thence deduce the conditions for minimum resistance.

2. The theory of the losses in inductance coils in general has been discussed by the present writer in a series of articles which appeared in *E. W. & W. E.* in April, May, July and August, 1926. The results of this theory so far as they affect toroidal coils are summarised below.

The general formula for the high-frequency resistance of a coil in which the turns are not too closely packed is

$$R_c = R\left\{1 + F + \left(\frac{KNd}{2D}\right)^2 G\right\} \quad \ldots \quad (1)$$

when the coil is wound with solid wire, and

$$R_c = R\{1 + F + (k/d_0^2 + \tfrac{1}{4}K^2N^2/D^2)\, n^2d^2G\} \quad \ldots \quad (2)$$

when the coil is wound with stranded wire.

In these formulæ the symbols have the following interpretation :—

R_c = H.F. resistance.
R = D.C. resistance.
N = Number of turns.
n = Number of strands.
d = Diameter of one strand.
d_0 = Overall diameter of stranded wire.
D = Overall diameter of coil.

The units of measurement of the resistances and the various diameters do not matter, as if R is in ohms, R_c is also in ohms, while since the diameters enter as ratios (d/d_0 and d/D) we can express the diameters as all in inches or all in millimetres indifferently.

The factors F and G depend upon the frequency, f, and the diameter, d, of a single strand. We first calculate a quantity z from the formula $z = d\sqrt{f}/92.8$, d in this formula being in mms. and the frequency in cycles per second, and then read off F and G from Table I.

The factor k entering only in the stranded wire formula depends on the number of strands and has the following values :—

n	1	3	9	27	large
k	0	1.55	1.84	1.92	2

The factor K depends upon the type of coil. Tables of K for solenoidal and disc coils have been given in the above-mentioned articles, but K has not hitherto been tabulated for toroidal coils.

The value of K is calculated by determining the mean square field acting on the wire of the coil when a current I is flowing. If, then, H_m be the root mean square field

$$K = H_m D/NI,$$

in which D is the overall diameter of the coil and N is the number of turns.

For a toroid the field at any point in the winding section is $2NI/r$, where r is the perpendicular distance of the point from

TABLE II.

Coil Factors for Single Layer Toroids (Circular Section).

D_s/D.	L_0.	K.	S.	Relative H.F. Resistances.	
				Toroid.	Solenoid.
0.05	0.00826	2.110	4.33	13.4	3.01
0.10	0.03502	2.243	2.23	7.0	2.05
0.15	0.08382	2.409	1.55	4.92	1.64
0.20	0.1596	2.602	1.21	3.86	1.43
0.25	0.2695	2.913	1.04	3.31	1.33
0.30	0.4244	3.327	0.95	2.98	1.24
0.35	0.6426	3.978	0.92	2.83	1.20
0.40	0.9599	5.180	1.00	2.90	1.16
0.45	1.468	8.341	1.28	3.54	1.14

D = Overall diameter of toroid.
D_s = Diameter of winding section.
L_0 = Inductance factor in formula (6).
K = Proximity factor in resistance formulæ (1) and (2).
S = Factor used in determining the optimum diameter of wire.

the axis of the toroid. Also, for a single layer toroid, we must take the field acting on the wire as half that just inside the winding section, so that to determine the mean square field we must integrate N^2I^2/r^2 round one turn and divide by the length of the turn. The integration is quite straightforward for toroids of circular or rectangular winding section, and we are led to the following formulæ for K.

For a single layer toroid of circular section

$$K = 2(1 - x)^{\frac{1}{2}}/(1 - 2x)^{\frac{3}{4}} \quad \ldots \quad (3)$$

in which x is the ratio of the diameter D_s of the winding section of the toroid to the overall diameter D.

For a single layer toroid of rectangular section of radial depth t, axial length b and of overall diameter D:

$$K = 2\{1 - 2x + 2x^2y/(x+y)\}^{\frac{1}{2}}/(1 - 2x) \quad .. \quad (4)$$

in which, now, $x = t/D$ and $y = b/D$.

The relative resistances refer to equally compact coils using the optimum diameter of wire for each shape. The corresponding values for solenoids refer to the solenoid in which the toroid will just fit, that is, the solenoid has diameter D and winding length D_s.

SINGLE LAYER TOROIDS OF RECTANGULAR WINDING SECTION.

TABLE III.

VALUES OF FACTOR L_0 IN FORMULA (6.)

b/D / t/D	0.125	0.250	0.375	0.500
0.1	0.0558	0.1116	0.1674	0.223
0.2	0.1278	0.256	0.383	0.511
0.3	0.229	0.458	0.687	0.916
0.4	0.402	0.805	1.208	1.660

TABLE IV.

VALUES OF FACTOR K IN FORMULÆ (1) AND (2).

b/D / t/D	0.125	0.250	0.375	0.500
0.1	2.25	2.25	2.26	2.26
0.2	2.65	2.67	2.69	2.70
0.3	3.37	3.47	3.54	3.58
0.4	5.25	5.68	5.96	6.14

The values given in column 3 of Table II are calculated from formula (3) and the values given in Table IV are found from formula (4).

If the toroid has m layers the tabulated values of K should be multiplied by

$$\{1 + \tfrac{1}{3}(1 - 1/m^2)\}^{\frac{1}{2}}.$$

3. The formula for the inductance of a toroid of circular winding section is

$$L = 2\pi N^2\{D_m - (D_m^2 - D_s^2)^{\frac{1}{2}}\}/1000 \quad (5)$$

in which L is the inductance in microhenrys and D_m is the mean diameter of the toroid. Writing $D_m = D - D_s$ we may put

$$L = L_0 N^2 D/1000 \quad .. \quad .. \quad (6)$$

in which

$$L_0 = 2\pi x^2/\{1 - x + (1 - 2x)^{\frac{1}{2}}\},\ (x = D_s/D) \quad .. \quad (7)$$

From (7) the values of L_0 given in column 2 of Table II have been calculated.

TABLE V.

VALUES OF FACTOR S FOR DETERMINATION OF OPTIMUM DIAMETER.

b/D / t/D	0.125	0.250	0.375	0.500
0.1	1.78	1.25	1.03	0.89
0.2	1.38	0.98	0.81	0.70
0.3	1.31	0.95	0.80	0.70
0.4	1.54	1.18	1.01	0.89

TABLE VI.

RELATIVE H.F. RESISTANCES OF EQUALLY COMPACT COILS.

b/D / t/D	0.125	0.250	0.375	0.500
0.1	6.5	5.5	5.4	5.5
0.2	4.8	3.7	3.4	3.4
0.3	4.5	3.2	2.9	3.0
0.4	4.8	3.6	3.2	3.5
Enveloping solenoid	1.81	1.32	1.18	1.13

For toroids of rectangular winding section

$$L = 2N^2b\{\log_e D - \log_e (D - 2t)\}/1000 \quad (8)$$

so that if we throw this into the form (6)

$$L_0 = -2y \log_e (1 - 2x),\ \begin{matrix} y = b/D \\ x = t/D \end{matrix} \quad .. \quad (9)$$

From (9) we get the values given in Table III. As regards the values of L_0, these hold equally for single layer and multi-layer coils.

4. Best Diameter of Wire.

A study of the resistance formula shows that the first part, $R(1 + F)$, diminishes as the diameter of the wire increases, while the second part, $R\left(\frac{KNd}{2D}\right)^2G$, increases with increase in the diameter of the wire. For a certain diameter of wire (depending upon the frequency) the resistance passes through a minimum value. It is important, therefore, to have a ready method for determining the diameter of the wire that will give this minimum resistance. The general method of determining the optimum wire diameter has been discussed in the writer's previous articles. The method is as follows.

Calculate the quantity P from the formula

$$P^2 = LS^2/D^3 \quad \ldots \quad \ldots (10)$$

in which L is the inductance of the coil in microhenrys, D is the overall diameter of the coil in centimetres and S is a shape factor, namely, $0.186K/L_0^{\frac{1}{2}}$. Then, if f is the frequency (in cycles per second) at which the coil is intended to be used, find the value of f/P^2. If this turns out to be less than 10^4, the optimum diameter d of the wire in millimetres is given by

$$d^3 = 7600/fP \quad \ldots \quad \ldots (11)$$

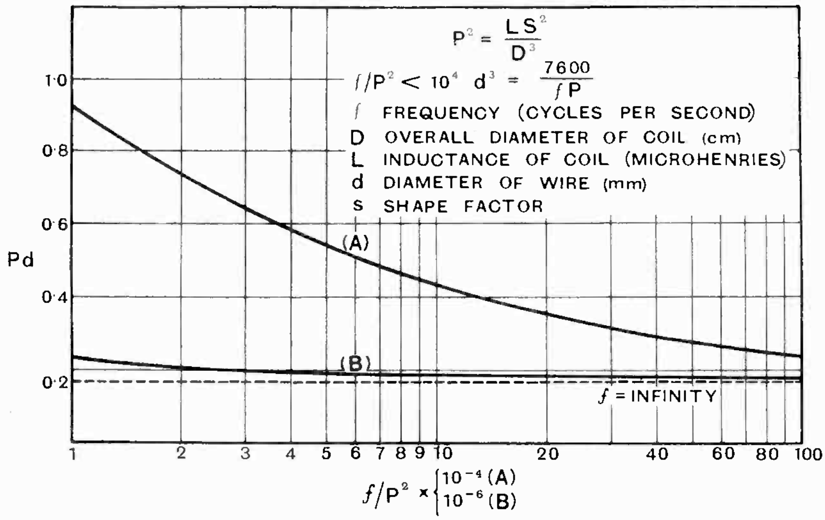
If f/P^2 is greater than 10^8,

$$d = 0.165/P \quad \ldots \quad \ldots (12)$$

while for intermediate values of f/P^2, Pd is read off from the accompanying chart.

Values of S for single layer toroids are given in Tables II and V. For multi-layer toroids these values should be multiplied by

$$\{1 + \tfrac{1}{3}(1 - 1/m^2)\}^{\frac{1}{2}}.$$



For values of S see Tables II and V.

As to whether to employ single or multi-layer coils depends upon the above calculation of optimum diameter. If it turns out that the single layer system can be wound with the requisite diameter, use the single layer system. It should also be used (but not with the optimum diameter) if the optimum diameter is not more than, say, 50 per cent. greater than the available diameter. There is some advantage in using a double layer winding provided that the turns of the second layer are wound in the opposite direction (but still inductively) round the toroid. This system is absolutely astatic, the stray field due to a single layer winding being equivalent to that due to a single loop. It should be noted, however, that such a double winding is liable to have a large self-capacity, so that the complete astaticism may be too dearly bought.

5. Best Shape of Toroid.

Following the method outlined for solenoids in the previous articles we can determine a best shape of the toroid under certain initial assumptions. Probably the most convenient is that the various shapes shall be equally compact. If we measure compactness by the smallness of the area of the bounding cylinder of the toroid we obtain (for high frequencies) the figures given in Tables II and VI for the relative resistances of various shapes when the various toroids are of equal inductance and are each wound with the optimum diameter of wire. The Tables correspond to that given as Table X(B) for solenoids in the writer's *E. W. & W. E.* article for July, 1926, and the figures are directly comparable. Since a single layer solenoid just big enough to envelop the toroid is equally compact, the values for such solenoids are also given in the Tables. It is seen that the single layer solenoid has a resistance which is very considerably less than that of the toroid, and we can summarise the result of the comparison by stating that the H.F. resistance of the best possible toroid is more than twice as great as that of an equally compact single layer solenoid of the same inductance. This, then, represents the price that has to be paid for the astatic property of the toroid.

The Transmission Unit and its Application to Radio Measurements.

By J. F. Herd, A.M.I.E.E.

THE increasing association of wire-cum-wireless to provide complete channels of communication—of which simultaneous and remote broadcasting and the Transatlantic telephony systems form ready examples—serves as a reminder that there is much in common in the technique of measurement in both links of the chain. In particular it may not be out of place to bring before British wireless readers a unit of measurement which is now regularly employed in telephony and which is also applicable to many radio measurements. This is the transmission unit of telephonic practice, which is now standardised in both Britain and America and in several other countries. The unit is no doubt familiar by name to readers of American and of some British wireless literature; the purpose of this article is briefly to explain the unit and describe some of its applications to radio measurements.

The Transmission Unit—Definition.

Fundamentally the transmission unit (usually abbreviated to T.U.) is the logarithmic ratio of two powers (*e.g.*, at two different points in a system, expressing the loss or gain existing between the points).

If we write

$$N_{\text{units}} = \log_{10} P_1/P_2 \quad \ldots \quad (1)$$

it is clear that this can also be written

$$N = \frac{\log P_1/P_2}{\log 10} \text{ or } P_1/P_2 = 10^N \quad \ldots \quad (2)$$

Log 10 then becomes the unit of the system, that is one unit will exist when $P_1/P_2 = 10$.

As this ratio was considered too large to form a single unit, the unit actually used was such as to make the ratio ($P_1/P_2 = 10$) to be 10 T.U. so that

$$N_{\text{T.U.}} = 10 \log_{10} P_1/P_2 \quad \ldots \quad (3)$$

Corresponding to (2)

$$N_{\text{T.U.}} = \frac{\log P_1/P_2}{\log 10^{0.1}} \text{ or } P_1/P_2 = 10^{N/10} \quad \ldots \quad (4)$$

Log $10^{0.1}$ thus becomes the transmission unit, and 1 T.U. will exist when $P_1/P_2 = \log 10^{0.1}$, *i.e.*, when $P_1/P_2 = 1.259$.

It has been suggested that out of compliment to the memory of Graham Bell, the greater unit described (*i.e.*, such that $N = \log_{10} P_1/P_2$) should be called the Bel, while its sub-multiple, the T.U. (such that $N = 10 \log_{10} P_1/P_2$), should be called the Decibel. These names are not yet, however, in general acceptance, and the so-called Decibel is still under the general name of T.U.

TABLE 1.

A.			B.		
T.U.	Power Ratio.	Current or Voltage Ratio.	Ratio, Power, Current or Voltage	T.U. for Power Ratio.	T.U. for Current or Voltage Ratio.
1	1.259	1.122	1	0	0
2	1.585	1.259	2	3.010	6.020
3	1.995	1.412	3	4.771	9.542
4	2.512	1.585	4	6.021	12.042
5	3.162	1.778	5	6.990	13.980
6	3.981	1.995	6	7.782	15.564
7	5.012	2.239	7	8.451	16.902
8	6.310	2.512	8	9.031	18.062
9	7.943	2.818	9	9.542	19.084
10	10.0	3.162	10	10.0	20.0
20	100	10.0	20	13.010	26.02
30	1,000	31.62	30	14.771	29.542
40	10,000	100	40	16.021	32.042
50	100,000	316.2	50	16.990	33.980
60	1,000,000	1,000	100	20.0	40.0
—	—	—	1,000	30.0	60.0

Use of Current or Voltage Ratios.

The use of a power ratio (instead of a current or voltage ratio) in defining the fundamental unit is justified especially in telephonic practice where the impedances may not be equal and where I or V ratios alone would be inadequate. In the case of the wire-cum-wireless chain, this would be especially so in comparing the wire and wireless levels, where comparison of, say, current levels might be meaningless.

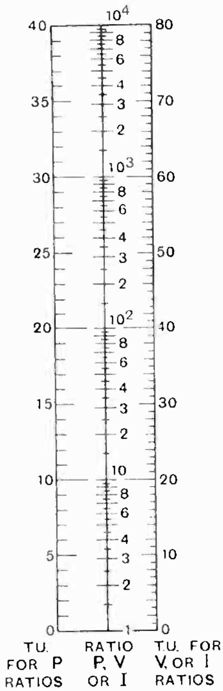


Fig. 1.—*T.U. Conversion Scales.*

At the same time, the definition in terms of power does not interfere with the use of current or voltage ratios, where these are associated with equal impedances. In this case, since the currents (or voltages) are proportional to the square roots of the powers, it is merely necessary to use twice as large a constant in computing the T.U. from the current or voltage ratio, *i.e.*,

$$N_{\text{T.U.}} = 20 \log_{10} \frac{I_1}{I_2}, \text{ or } \frac{I_1}{I_2} = 10^{N/20}$$

and $\qquad\qquad\qquad\qquad$ (5)

$$N_{\text{T.U.}} = 20 \log_{10} \frac{V_1}{V_2}, \text{ or } \frac{V_1}{V_2} = 10^{N/20}$$

The value of transmission units corresponding to known ratios of power, voltage or current is, of course, readily calculable from a table of common logarithms, or by slide rule. Table I may, however, help readily to visualise these values, while the scales of Fig. I give a convenient means of conversion to sufficient accuracy for most practical purposes.

Advantage of Logarithmic Ratio.

The advantage of a logarithmic ratio is obvious in that it permits addition and subtraction instead of multiplication and division. This is frequently of great convenience in considering a system made up of gains and losses, and in arriving at a comparison of the net result. Additionally in comparing values which are very different in magnitude, the logarithmic ratio gives a much more convenient figure to handle, *e.g.*, in expressing the increase due to a high-gain amplifier (which may easily run into tens of thousands), or in illustrating the cut-off effect of a filter. An example of the latter is given in Fig. 2, taken from Col. A. G. Lee's chairman's address to the Wireless Section I.E.E.*

Other Logarithmic Ratios in Use.

Even in those telephone administrations where the T.U. is not in use, another logarithmic ratio still prevails. This is called the Napier or Neper, and is expressed in terms of the natural or Naperian logarithm of current ratios, *i.e.*,

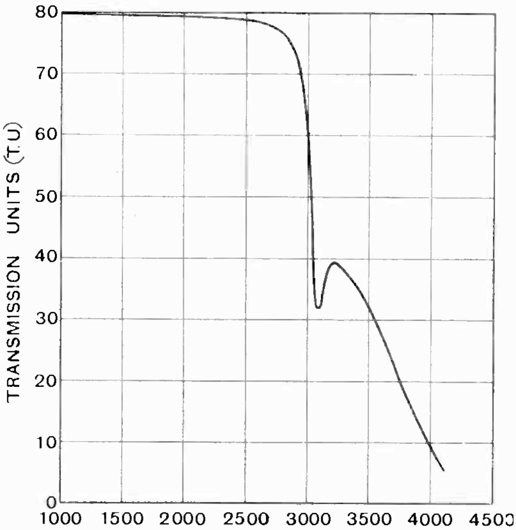


Fig. 2.—*Frequency characteristic of audio-frequency low-pass filter, Transatlantic telephony receiver.*

$$N_{\text{Napiers}} = \log_e I_1/I_2 \quad \ldots \quad \ldots \quad (6)$$

This unit is also used in wireless practice in those countries where it is in force.†

In this case, if power ratios be used,

* *J.I.E.E.*, Vol. 66, p. 12, 1928.

† *C.f.* "Les Filtres Electriques," P. David, Gauthier-Villars et Cie, Paris, 1926.

instead of current ratios,

$$N_{\text{Napiers}} = \tfrac{1}{2}\log_e P_1/P_2 \quad \ldots \quad (7)$$

Since $\log_{10} N = 2.3026 \log_e N$ it follows that 1 Bel = 1.15 Napiers, and that 1 T.U. = 0.115 Napier or 1.15 decinapiers, or that 1 Napier = 8.686 T.U.

The relative merits of the two systems was the subject of some controversy in *The Electrician* a few years ago when the T.U. was first proposed §, but since the English and American literature is more likely to contain references to the T.U., only this system need be further considered.

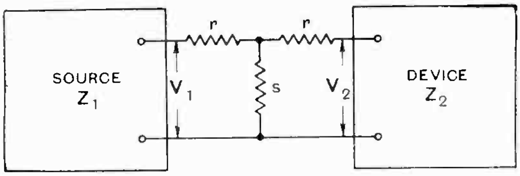


Fig. 3.

Prior to the introduction of the T.U. the unit of telephonic measurement was the "Standard Mile at 800 cycles." In the course of the development of telephone technique, this unit was effectively shorn of its physical significance and came to exist rather as a logarithmic ratio, in the same way as the T.U. and of very nearly the same value. Relative figures are, for the British Specification 1 T.U. = 1.088, 800-cycle miles, and for the American 1 T.U. = 1.056 miles. This calls for mention because non-reactive attenuation boxes are still to be found calibrated in miles.

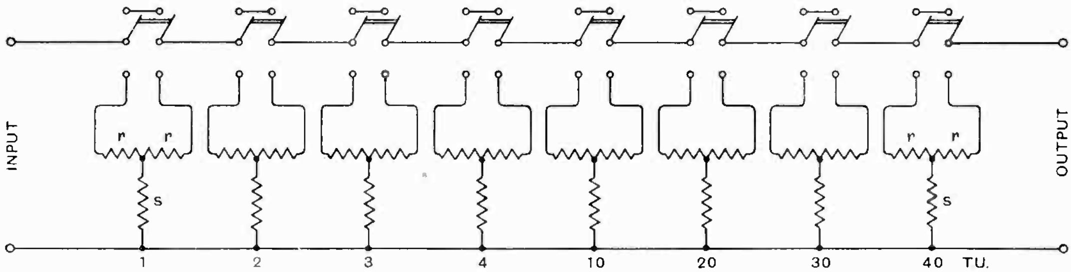


Fig. 4.—110 *T.U. Attenuation Box, T-Type.*

Reasons for Choice of T.U.

The reasons for using a power (rather than a current or voltage) ratio and for the size of the T.U. have been very fully dealt with by R. V. L. Hartley in "Electrical Communication,"‡ and need only be referred to very briefly.

The T.U., although a power ratio, is not necessarily the input/output power ratio ordinarily used to define the efficiency of a machine, but it may be the ratio of any two powers whatsoever, according to the circumstances. It may be the efficiency of an instrument or system compared to some fixed reference, the relative powers at two points in the system (as in the case of the powers in a transmitting and receiving aerial) or it may be power in the form of ether waves compared to power in the form of currents in a wire.

Power measurement is of first importance in engineering. Current ratios as a measure of transmission demand knowledge of the impedances involved, and, if this is known, no more measurements are required to give the necessary information about the powers than about the currents. If it is not known the same steps as are required in measuring power must be taken before a knowledge of current ratios has any significance.

The facility with which the T.U., defined on a power basis, can be used in the case of current (or voltage) ratios with equal impedances has already been pointed out.

As regards the size of the unit, from the point of view of a logarithmic base, 10 or ϵ is naturally suggested, or, if these be considered too large for the ratio to be encountered in practice, a suitable submultiple is obviously indicated. The T.U., as chosen, has the merit of representing about the least difference in loudness that can be detected by the ear without special training. This makes it of more convenient

§ *The Electrician*, Vol. 94, 1925.

‡ Vol. 3, No. 1, July 1924.

magnitude than either log 10 or log ϵ, while its closeness to the previous "800-cycle mile" involves little change in the case of administrations hitherto using that

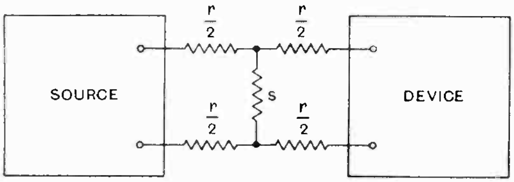


Fig. 5.

unit. At the same time it is, by definition, capable of wider application and can be used in many cases where a statement of miles would be meaningless and could only be employed to denote a ratio. This is particularly the case in the application of the unit to wireless measurements.

T.U. Attenuation Networks.

The practical use of the T.U. in actual measurement is greatly facilitated by a suitable type of calibrated attenuation box. Such networks, calibrated in "standard miles," are of some years standing in telephone practice, but now, calibrated in T.U., form a very useful accessory permitting the employment of the newer and more useful unit.

This type of box employs a non-reactive network of the general type shown in its simplest form in Fig. 3. This will readily be recognised as a frequent practical case, where the measured output from a source has to be reduced by some known amount before application to the device to be operated. (The Americans use the expressive term "sink" as a generic description of such a device.)

Working in terms of attenuation of the source voltage, V_1, the ratio V_1/V_2 can be written in the form

$$\frac{V_1}{V_2} = \frac{X(r + Z_2)}{aZ_2} \quad \ldots \quad \ldots \quad (8)$$

where X is the impedance of the network to which the output terminals of the source are connected, while a is the joint impedance of s, Z_2 and the right hand r.

Various values of r and s can be so chosen that the impedance X remains constant for all values of V_1/V_2, that is for all values of attenuation. It can further be arranged that $Z_2 = X$, that is, the impedance looked into from the source terminals remains constant and equal to the characteristic impedance of the device to be operated. (Generally speaking, also, there will be the tendency for the impedances Z_1 and Z_2 to be matched, this being especially so in telephone practice and in the technique of linking line and radio channels.)

When $X = Z_2$,

$$\frac{V_1}{V_2} = \frac{r + s + Z_2}{s} \quad \ldots \quad (9)$$

from which it follows that

$$r = Z_2\left(\frac{K - 1}{K + 1}\right) = Z_2\left(\frac{1 - R}{1 + R}\right) \quad \ldots \quad (10)$$

and $$s = 2Z_2\left(\frac{K}{K^2 - 1}\right) = 2Z_2\left(\frac{R}{1 - R^2}\right) \quad (11)$$

where

$$K = \frac{V_1}{V_2} \text{ and } R = \frac{1}{K} = \frac{V_2}{V_1}$$

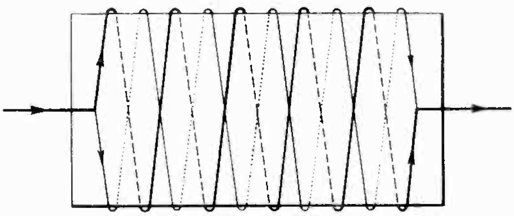


Fig. 6.—*Ayrton-Perry Non-reactive Winding.*

Since V_1 and V_2 are associated with equal impedances, viz., X and Z_2, the ratio V_1/V_2 can be expressed directly in T.U., in accordance with the relations of equation (5).

The resistances r, r, and s can obviously be made adjustable so as to give variable and controllable attenuation calibrated directly in T.U. Such boxes are of regular commercial make, and are a common adjunct of telephonic measurements, while their use at moderate radio frequencies has also been described. The resistance values may be controlled in decade steps, the three resistances being varied by one movement according to the attenuation desired.

A less expensive and more frequently encountered type of box is shown in Fig. 4. Each section of the network introduces a definite attenuation (in T.U.) and the introduction of the various sections is effected by means of two-way keys of familiar pattern. The calibration of such a box is, of course, only true when it is used in association with the characteristic impedance for which it is designed, and which

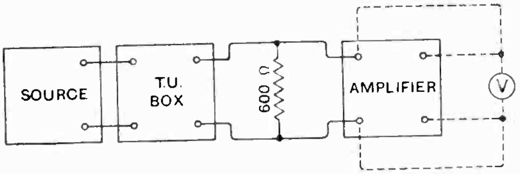


Fig. 7.

satisfies the conditions outlined above. Normally they are made for use with impedances of 600 ohms or of 6,000 ohms, the former being the more usual type. The resistance values (maker's figures) of a T-type network for use with a 600 ohms impedance are shown in Table 2. It will be

TABLE 2.

T.U.	*r* ohms.	*s* ohms.
1	34.5	5,201
2	68.8	2,583
3	102.6	1,703
4	135.8	1,258
10	311.6	421.6
20	490.9	121.2
30	563.2	37.99
40	588.1	12.00

Resistance values of T-type network for 600 ohms impedance.

seen that with the different sections proportioned in accordance with the above reasoning, the attenuation values afforded by each section are additive to give a total of 110 T.U. by steps of 1 T.U.

Boxes are also made to give H-type networks, of the form shown in Fig. 5, both by decade adjustment and by switch adjustment as mentioned for the T-type network.

The resistance units of these boxes are wound in the Ayrton-Perry non-reactive winding, shown schematically in Fig. 6, on flat cards of bakelite or like material. In addition to their obvious uses at telephonic frequencies, their employment at radio frequencies up to at least 50 or 60 k.c., has been described, both in connection with carrier-frequency systems,* and also in connection with field strength measurements on the Transatlantic telephone system.†

It should also be noted that a potentiometer can be divided off or calibrated in terms of transmission units, provided that the resistance of the output portion (and therefore of the whole potentiometer) is not altered by movement of its tapping point. This will be true if the device joined across the output portion takes no current, as, for example, when the potentiometer is used as the gain control feeding into a negative grid. In this case potentiometric adjustment of amplifier gain, calibrated directly in T.U., may be of great advantage.

Typical Uses of T.U. Boxes.

A suitable method of using the T.U. box for a typical and frequent measurement is given in Fig. 7, to measure the gain of the amplifier shown. If the amplifier is not

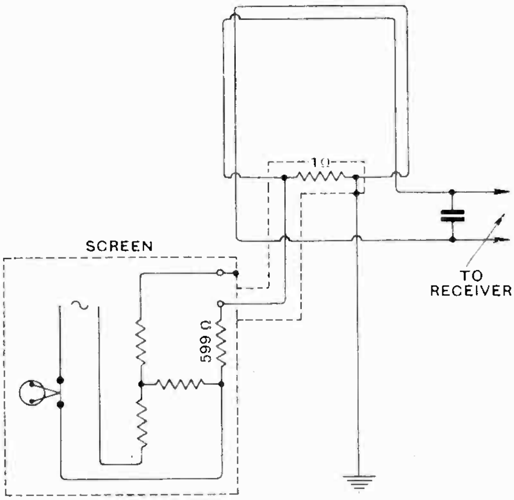


Fig. 8.

already of 600 ohms input impedance, it must be so terminated as shown in the figure. With no attenuation in the T.U. box a thermionic voltmeter, joined across

* Affel and O'Leary. *Trans. Amer. I.E.E.* XLVI, p. 504, 1927.

† England, *Proc. I.R.E.*, II, p. 26, 1923, also Bown, England and Friis, *Proc. I.R.E.*, II, p. 115, 1923.

the 600 ohms terminating resistance, can be used to measure the voltage applied to the input terminals of the amplifier. Attenuation can then be introduced, the voltmeter transferred to the output terminals and the attenuation adjusted, until the voltmeter reads the same as it did on the input terminals. Variations in detail of the method will no doubt occur to the user.

The general method of applying the T.U. box for adjustment of voltage injection in field strength measurements is illustrated in Fig. 8. This is typical of the methods used in the extended series of measurements which preceded the inauguration of the Transatlantic system. The measured output from the oscillator is fed through the T.U. box, terminated on $599 + 1$ ohms. The box is adjusted to the degree required for signal comparison, when the voltage across the 1 ohm in the middle of the frame aerial can be calculated.

Book Reviews.

HOCHFREQUENZ-MESSTECHNIK (High-frequency Measurements). By August Hund, pp. xix. + 526, with 287 Figs. J. Springer, Berlin. 39s.

This is the second edition of this book; the first appeared in 1922. Although the book is written in German, the author has resided for some years in the States and is thus familiar with American methods. It hardly need be said that the subject is dealt with very thoroughly. The theory and practice of all the various classes of high-frequency measurement are described and discussed in twenty-nine chapters, but the author goes so fully into the theory of the phenomena which are to be the object of the measurement that much of the book would better be described as a text-book of high-frequency currents. The formulæ which are to be actually employed in any measurement are printed in heavy type, and special care is taken to indicate the units in which each term is expressed. Short sections dealing with damped oscillators and with Poulsen arc generators are retained because these are still employed in special investigations although no longer a part of ordinary radio work. Modern methods of measuring the strength of the received electric and magnetic fields are described and discussed. Special attention has been given to the theory of long horizontal aerials of the Beverage type, to filter systems with numerical examples and to piezo-electric generators and resonators. The book can be unreservedly recommended to any serious worker in the subject of high-frequency currents who has the necessary knowledge of German.

MATHEMATICS FOR ENGINEERS—PART I. By W. N. Rose, pp. xiv. + 524, with 257 Figs. Chapman & Hall.

The fact that this is the seventh edition of a book first published in 1918 speaks for itself. It obviously meets a need and its appeal is easily understood, for it presupposes very little mathematical knowledge, explains every step very fully and gives a large number of worked numerical examples. Its twelve chapters are entitled: Aids to Calculation; Equations; Mensuration; Introduction to Graphs; Further Algebra; Plane Trigonometry; Areas of Irregular Curved Figures; Calculation of Earthwork Volumes; The Plotting of Difficult Curve Equations; The Determination of Laws; The Construction of Practical Charts; Various Algebraic Processes. The examples consist largely of the application of the mathematical formulæ to problems occurring in various branches of engineering. It is a book that we can recommend to anyone wishing to lay a thorough foundation of practical mathematics.

WIRELESS OBSERVATIONS DURING THE ECLIPSE OF THE SUN, 29TH JUNE, 1927 (being Radio Research Board Special Report). No. 7, pp.25. H.M. Stationery Office. 1s. 3d.

This is a collection of the results obtained in the tests carried out under the supervision of the Board, and also in some experiments made at Liverpool University under the direction of Prof. Marchant. Most of these results have already been published in some form or other, but it is very convenient to have them collected in this form. The long-wave section was prepared by Dr. Hollingworth, the medium-wave section by Prof. Appleton, and the section dealing with direction-finding by Dr. Smith-Rose. Signals from St. Assize ($\lambda = 14,350$ metres) measured at Slough, Aberdeen and Exeter all showed marked effects similar to the preliminary phenomena of a sunset. It is interesting to note that the path from St. Assize to Slough lay entirely outside the totality band and yet the effects were very marked. A large number of measurements were made at various points on the signals sent out from several B.B.C. stations (300 to 500 metres). They indicated a large increase in the downcoming ray, the reasons for which are discussed in the Report. The direction-finding tests indicated a temporary return to night conditions. At Liverpool the signal from Stavanger rose to nearly twice its normal night strength when totality was about midway between the stations. The large amount of interesting data in this Report shows that although the eclipse was generally regarded as a failure, it was certainly a success from a wireless point of view.

G.W.O.H.

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.

SUMMARY

THIS article is intended to augment the author's previous articles* in which a new precision variable condenser was described. In these articles the author discussed the increased permanence of calibration due to the fact that adjacent dielectric air gaps of this condenser are arranged to be electrically in series and complementary. The increased constancy was shown to be chiefly due to the negligible effect of post-calibration small relative axial displacements of the fixed and moving conductor systems—displacements (amounting to, say, 10 per cent. to 20 per cent. of the total dielectric gap) that would destroy completely the calibration of an ordinary parallel gap condenser.

In the first part of the present article is described a new type of moving plate in which a number of completely insulated sections are employed. By using a multi-sectioned plate of this type the full benefit is obtained from the complementary nature of the adjacent dielectric air gaps by ensuring more complete immunity from that component of calibration inconstancy which is due to small rotation irregularities and to slight post-calibration twisting or tilting of plates. The completeness of the elimination of these errors is discussed to some extent quantitatively.

In the second part final consideration is given to the possible overall accuracy anticipated in a sub-standard wavemeter employing the new variable condenser. In this section are also given various suggested methods of eliminating or reducing errors due to interpolation between calibrated scale points, and of linear interpolation approximations and corrections for use with them.

PART I.

It is not generally realised that the series gap variable air condenser is not entirely immune from capacity changes (for a given angular setting) due to twisting, tilting or uneven sagging of the moving plates subsequent to calibration.

Even assuming perfectly rigid and geometrically permanent fixed plate systems (*i.e.*, absolutely constant *total* dielectric gap distance) the value of a series gap condenser for a given angular setting will not *strictly* be permanent if the planes of the moving plate surfaces are not perfectly parallel to those of the fixed plates at the time of calibration, or do not remain so subsequently, unless a special design of moving plate is adopted.

Since there is a possibility of the dielectric air gaps d_1 and d_2 on either side of the moving plate MP_1 (Fig. 1) varying throughout the area of the latter, the total capacity between fixed and moving plates must be regarded as a number of small capacities in parallel, each of a different capacity as determined by the mean of the gap distances throughout its small area. In Fig. 1 two such parallel sections are shown and the total capacity of such an arrangement will be seen to be

$$C = \frac{(C_1 + C_3)(C_2 + C_4)}{C_1 + C_3 + C_2 + C_4}.$$

the value of which will not remain constant unless

$$C_1 = C_3$$

and

$$C_2 = C_4,$$

for all values of C_1 and C_2.

This condition is, of course, only obtained when the displacement of the moving plate

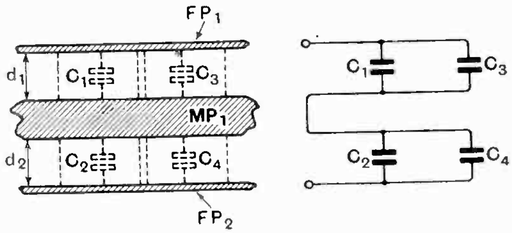


Fig. 1.

is in a direction normal to the planes of the fixed plate surfaces, *i.e.*, a purely axial displacement, such as that due to the wearing

* *E.W. & W.E.*, Jan., Feb. and May, 1928.

of a bearing of a vertical spindle or to "end play" of a horizontal spindle.

In an extreme case of a moving plate tilted so much that two of its edges nearly touch the upper and lower fixed plates as shown in Fig. 2 it is possible to experience a great increase of capacity which reaches infinity upon the two fixed plates being touched by the moving plate.

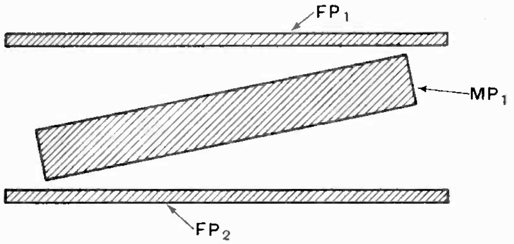


Fig. 2.

Moreover, if the fixed and moving plate systems are not initially in parallel planes, even purely axial relative displacement will not fulfil the above condition for constancy of calibration.

A Novel Design of Moving Plate.

Although the trouble of tilting or untrue rotation is not very difficult to overcome in variable condensers of precision and is, in any case, rendered less effective by the series gap arrangement, the author has devised a special moving plate which eliminates almost entirely this source of error.

This plate, which is shown in Fig. 3, takes the form of a thick semicircular plate *MP* of glass or other permanent insulating material the surfaces of which are silvered by a reliable process and then copper-plated. By removing fine strips J_1, J_2 of this deposit a number of insulated conducting areas H_1, H_2, H_3, H_4 (coincident on the upper and lower surfaces of the plate) are formed. All the coincident pairs of conducting areas such as H_1, H_3 and H_2, H_4, are joined electrically through the plate. This connection may be made by metal pins by which the plate is pierced before plating, the metal being, of course, deposited on to these pins during the plating process.

Another method of connecting electrically the coincident metallic "islands" is that shown in Fig. 3, the connections being effected by perfect continuity of metal deposit over the slightly rounded edges of the plate or through holes in the inner sections which can be afterwards filled in with metal if desired.

The insulating channels J_1, J_2 must be cut so as to have the least possible effect on the law connecting capacity with angular position of moving system. In the case of the semi-circular linear law plate shown in Fig. 3 it will be seen that the channel J_1, being circular and concentric with the axis of rotation of the plate, does not affect the

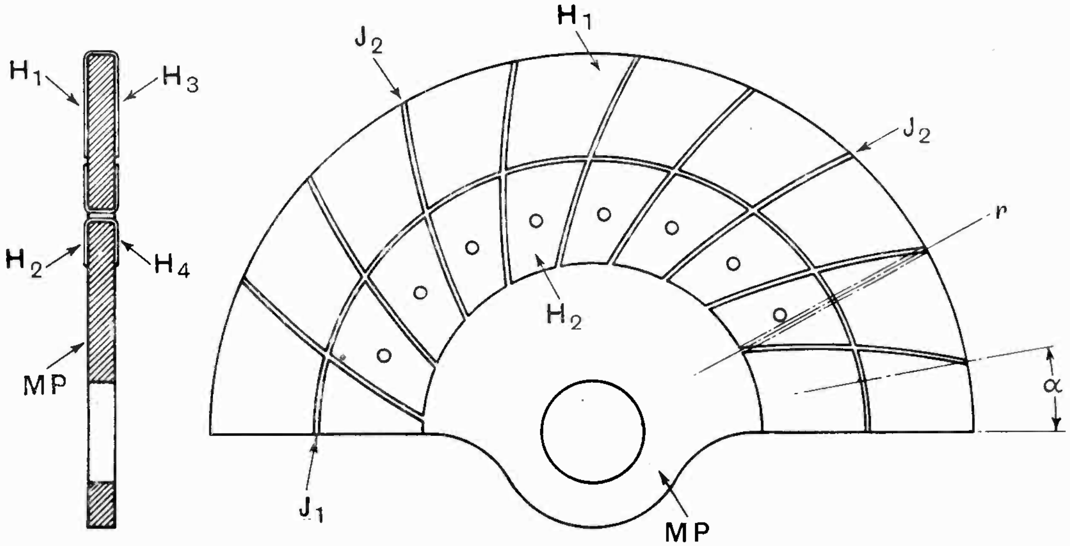


Fig. 3.

law. The channels J_2 are arranged so that the angle at which they intersect any radius is constant so as to have an effect on the law as nearly constant as possible. For this reason also, adjacent J_2 channels are arranged to commence and terminate on the same radius as indicated at r.

Moreover, in order to ensure very close uniformity of law, the J_2 channels are displaced relatively in all the plates of the condenser by varying the angle α by a constant amount in successive plates; the sum of all the displacements being equal to the angular dimension of one island. In other words, for successive plates the whole system of channels is uniformly swung round on the axis of the plate so that, throughout the completed condenser, no J_2 channels are exactly coincident and all are angularly equidistant. The number (and position) of channels which are entering or leaving the radial edges of the fixed plate system is therefore constant throughout the range of the condenser, the effect (on the law) of these channels being in consequence very small indeed.

In order to ensure perfect reliability, the plating thickness as well as the nature of the surface upon which it is to be deposited must be carefully considered. For permanence the plating must be very thin, but this is not an objection from a power factor point of view, for even a 0.0002in. deposit has a resistance not greater than 0.01 Ω per island, corresponding to a power factor (from this cause only) of the order 5×10^{-6} even at frequencies as high as 3×10^7 per second (10 metres).

It is interesting to note that the "skin-depth" for copper at this frequency is safely greater than half this thickness, and is not therefore a limiting factor.

In practice the plating thickness can conveniently be made greater than 0.0002in., and the continuity of deposit ascertained by a resistance measurement of each pair of islands as well as by a microscopic examination of all edges.

This design of plate, which may be used in the condenser as described in the author's previous articles, produces a changed electrical scheme since the moving plate now consists of a number of conductors sufficiently insulated from one another to permit their maintaining the slightly different potentials consequent upon their different positions in the field between the two fixed plates. Thus a number of independent series gap capacities are formed, the whole being joined in parallel by the continuity of the adjacent fixed plates. The four elementary capacities C_1, C_2, C_3 and C_4 of the simple two-area gap previously considered may now be represented as in Fig. 4.

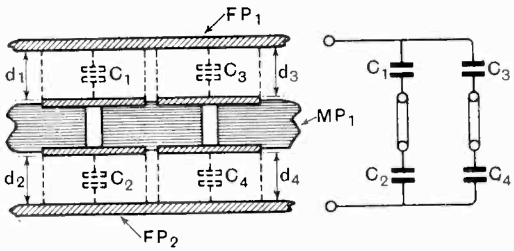


Fig. 4.

The capacity of C_1 and C_2 in series is constant irrespective of changes of position of the moving plate

$$\left(\text{since } C = \frac{C_1 C_2}{C_1 + C_2} \propto \frac{1}{d_1 + d_2}\right)$$

and, that of C_3 and C_4 in series being similarly constant, the sum of $\frac{C_1C_2}{C_1 + C_2}$ and $\frac{C_3C_4}{C_3 + C_4}$ must now be constant, irrespective of any relation between C_1 and C_3 or between C_2 and C_4, *i.e.*, irrespective of a twisting, tilting or uneven sagging of the moving plate (causing differences between d_1 and d_3), as well as of purely axial displacement or "end play."

For this latter statement to be perfectly true it would, of course, be necessary to assume an infinite number of conducting sections, but in practice the gap unevenness is so small that relatively few sections will suffice to bring about the desired permanency.

Another feature which will, from theoretical considerations, militate against absolute constancy is the existence of capacity between adjacent metallic sections of the moving plate. These capacities will, of course, bridge points which will not necessarily be at the same potential if gap irregularities are present, but again, in practice, this contribution to inconstancy is small even for comparatively few sections if these unwanted capacities are kept small, as the potential differences between those sections which are immediately adjacent will in any case be small.

It will therefore be obvious that in order to obtain the best condition for constancy the capacity between adjacent sections of the moving plate must bear some relation to that between those sections and the fixed plates. The former should, of course, be made smaller than the latter but not at the expense of the linearity of the capacity law by making the insulating channel wide. If 1in. square be taken as the practicable order for the section areas of the moving plate, the most suitable channel width may be selected from the curve (Fig. 5) plotted between intersection capacity and width of channel. This curve is plotted from measurements made when the dielectric gap distances d_1, d_2 between adjacent moving and fixed plate surfaces was 0.045in., the moving plate to fixed plate capacity per section corresponding with this gap dimension being 5μμF approximately.

It is necessary to make such measurements

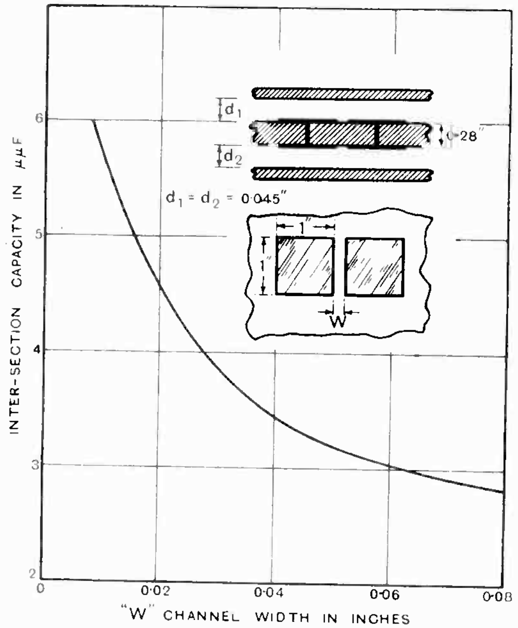


Fig. 5.

with the gap dimension adjusted correctly because this has a bearing upon the capacity between adjacent moving plate sections, owing to the fact that the neighbouring fixed plates intercept a portion of the field between these sections to an extent which naturally increases as the gap diminishes as is shown by the curve of Fig. 6. The capacity measurements of Figs. 5 and 6 were therefore made while the two 1in. square sections were enclosed by a screening plate on either side, which plates, when connected together, formed the third or screen terminal of a three-terminal condenser.

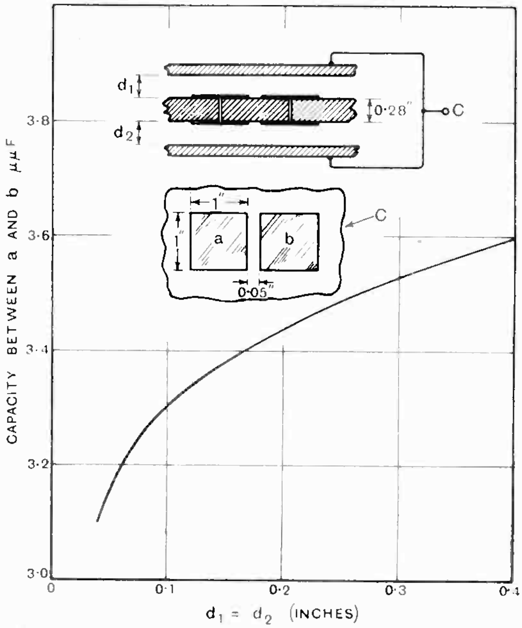


Fig. 6.—*Capacity between a and b with screen plates removed completely* 3.9*F*.

With this screening system earthed the pure intersection capacity between *a* and *b* was then determined independently of that between *a* and *c* and between *b* and *c* by a double capacity bridge method in which earth capacities do not contribute to the capacity being measured.

It will be seen from Fig. 5 that an insulating channel width of about 0.05in. besides being convenient and practicable also gives an intersection capacity appreciably less than 5μμF, thus justifying the adoption of section areas of the order originally decided upon.

In order to ascertain to what extent this subdivision of moving plate is effective in reducing the change of capacity with an "incline displacement" of the fixed and moving systems, a number of cases have been calculated for strips of moving plate having varying numbers of these unit section areas of 1in. square, all of which have a main fixed to moving plate capacity of $5\mu\mu$F when the moving plate is adjusted to its normal mid-gap position.

These calculations are made from capacity networks, examples of which are given in Figs. 7a and 7b, for moving plate strips of two and three sections respectively.

In these networks C^i, C^{ii}, C^{iv} C^v, C^{vii} C^{viii}, vary from their normal value of $5\mu\mu$F. according to the post-calibration "incline displacement" of the moving plate—each pair in a complementary manner—if the incline be considered as negligible throughout the length of each section.

The first of these sets of calculations was made for an incline displacement per section of 10 per cent. of the total dielectric air gap from the normal mid position, and as an approximation for the purposes of calculation the incline throughout the length of each section was ignored. Thus of the gap

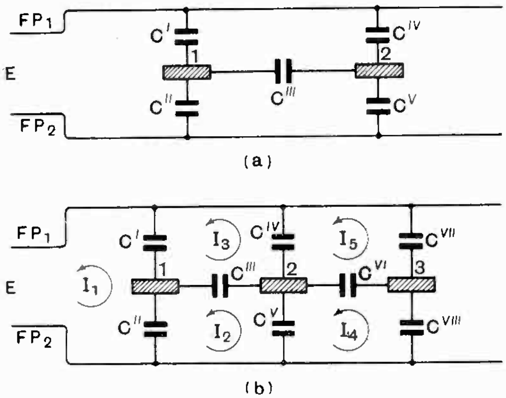


Fig. 7.

capacities for a 10 per cent. incline displacement per section in the case of Fig. 7b, C^{iv} and C^v *remain constant*, C^{ii} and C^{vii} *increase* corresponding to a 10 per cent. reduction of normal gap distance and C^i and C^{viii} *decrease* corresponding to a 10 per cent. increase of gap distance.

The resultant capacity C_R after this change has taken place is best determined by adopting Maxwell's theory of networks in which I_1, I_2, I_3, I_4 and I_5 of Fig. 7b are hypothetical cyclic currents. Thus in the case being given as an example five equations can be formed :—

$$\frac{1}{\omega}\left(\frac{1}{C^i}+\frac{1}{C^{ii}}\right)I_1-\frac{1}{\omega}\left(\frac{1}{C^{ii}}\right)I_2-\frac{1}{\omega}\left(\frac{1}{C^i}\right)I_3=E \quad .. \quad (1)$$

$$-\frac{1}{\omega}\left(\frac{1}{C^{ii}}\right)I_1+\frac{1}{\omega}\left(\frac{1}{C^{ii}}+\frac{1}{C^{iii}}+\frac{1}{C^v}\right)I_2-\frac{1}{\omega}\left(\frac{1}{C^{iii}}\right)I_3-\frac{1}{\omega}\left(\frac{1}{C^v}\right)I_4=0 \quad .. \quad (2)$$

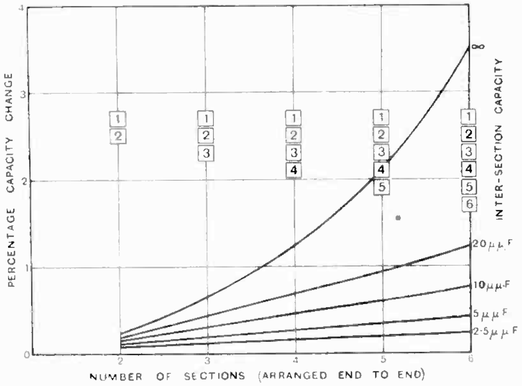


Fig. 8.—1 *inch square sections* (5*F*.) 10 *per cent. displacement per section.*

$$-\frac{1}{\omega}\left(\frac{1}{C^i}\right)I_1-\frac{1}{\omega}\left(\frac{1}{C^{iii}}\right)I_2+\frac{1}{\omega}\left(\frac{1}{C^i}+\frac{1}{C^{iii}}+\frac{1}{C^{iv}}\right)I_3-\frac{1}{\omega}\left(\frac{1}{C^{iv}}\right)I_5=0 \quad (3)$$

$$-\frac{1}{\omega}\left(\frac{1}{C^v}\right)I_2+\frac{1}{\omega}\left(\frac{1}{C^v}+\frac{1}{C^{vi}}+\frac{1}{C^{viii}}\right)I_4-\frac{1}{\omega}\left(\frac{1}{C^{vi}}\right)I_5=0 \quad .. \quad (4)$$

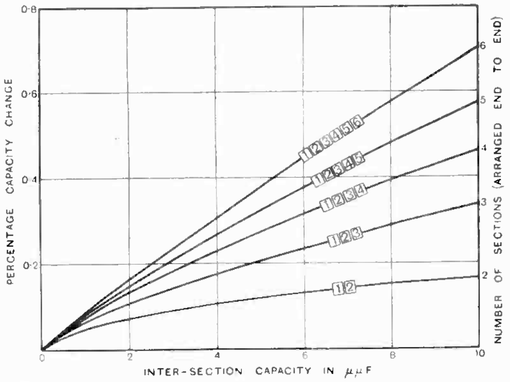


Fig. 9.—1 *inch square sections* (5*F*.) 10 *per cent. displacement per section.*

$$-\frac{1}{\omega}\left(\frac{1}{C^{iv}}\right)I_3-\frac{1}{\omega}\left(\frac{1}{C^{vi}}\right)I_4+\frac{1}{\omega}\left(\frac{1}{C^{iv}}+\frac{1}{C^{vi}}+\frac{1}{C^{vii}}\right)I_5=0 \quad .. \quad (5)$$

These equations can be simplified by making ωE equal to unity in (1) and by eliminating $\frac{1}{\omega}$ in the remainder, then,

$$C_R = \frac{I_1}{\omega E} = I_1$$

and the equations are therefore solved by the method of determinants for I_1 only.

In the curves of Fig. 8 are given the post-calibration changes in capacity for strips of various numbers of moving plate sections, each of 1in. square area, and arranged end to end as depicted, due to an incline displacement of 10 per cent. per section. Curves for several possible values of inter-

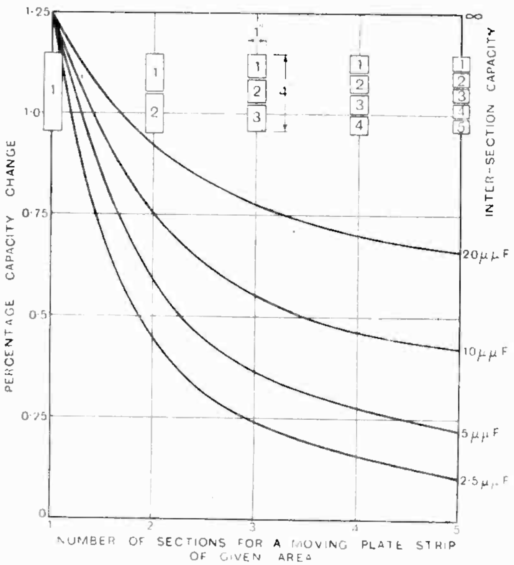


Fig. 10.—30 *per cent plate tilt over* 4 *inches.*

section capacity are given as well as one for infinity intersection capacity which gives, for comparison with the others, the capacity change which would be experienced with a solid moving plate under similar circumstances.

It may at first be thought from the simple consideration of a two-element system that no *great* benefit can be derived from the sub-division of the moving plate—the error in this case with an intersection capacity as low as 2.5μμF being only reduced to one-third. The curves of Fig. 8, however, at once show the marked benefit to be derived

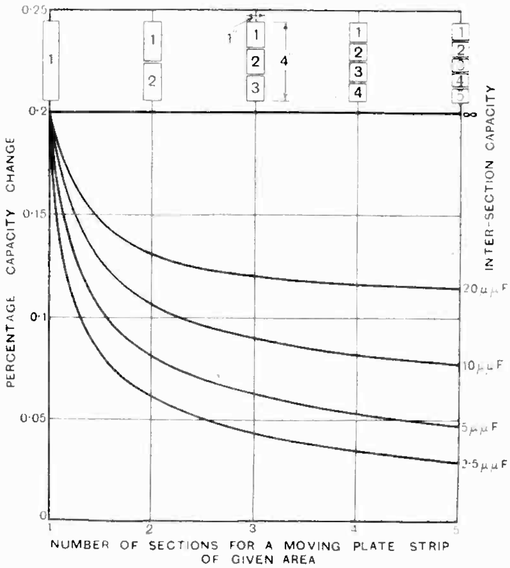


Fig. 11.—15 *per cent. plate tilt over* 4 *inches.*

from the use of a multi-sectioned moving plate when the inter-section capacity is kept low and a large number of sections are considered; the error when six sections are considered being reduced to about 0.06 of that for a solid plate.

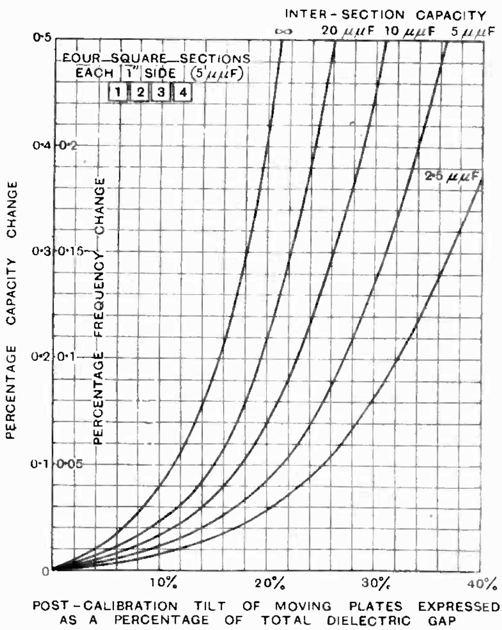


Fig. 12.

Fig. 9 shows these results plotted in a different manner to show the greater benefit derived from keeping the intersection capacity low when many sections are considered.

The curves of Fig. 10 show the reduction of error due to a given post-calibration moving plate tilting in *a given plate area* for various numbers of sub-divisions as depicted on the curve, and for intersection capacities of various values. These curves are for a plate area strip of 4in. by 1in. throughout the length of which an incline of 30 per cent. of the normal gap occurs, the normal moving plate to fixed plate capacity being 5$\mu\mu$F per sq. in. as in all previous curves. The purpose of this family of curves is to show that there is a limiting number of sub-divisions *for a given plate area* beyond which no extra benefit is derived, largely owing to the fact that the fixed to moving plate capacity becomes smaller as the number of sub-divisions is increased, thus making a given intersection capacity too high for the extra sub-division to be effective.

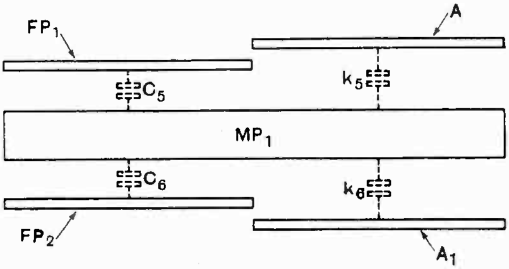


Fig. 13.

In Fig. 11 is given a similar family of curves for a total post-calibration incline of plate of only 15 per cent. (half that of Fig. 10) the errors it will be observed are of a much lower order.

The most useful set of curves is, perhaps, that of Fig. 12 for a 4×1in. strip of moving plate subdivided into four sections, each having a normal capacity to fixed plate of 5$\mu\mu$F. The capacity error is given for various degrees of post-calibration moving plate tilting—the total tilt being expressed as a percentage of the normal dielectric air gap. Curves are given for various values of intersection capacity—that for infinity capacity being included to show the error that would occur with a solid (unsubdivided) moving plate under similar conditions.

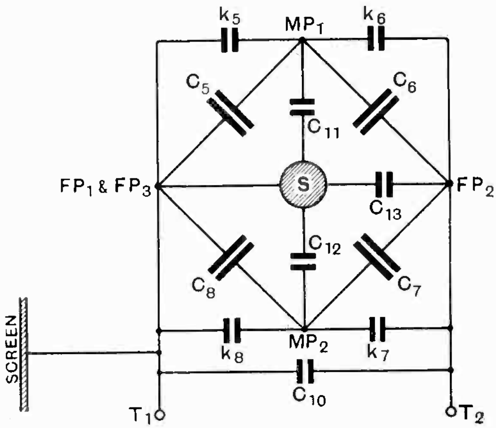


Fig. 14.

A Further Advantage of Using a Multi-sectioned Moving Plate.

The adoption of this multi-sectioned moving plate also removes another minor imperfection, which contributes to the inconstancy of a series gap condenser due to the capacities from MP_1 to the screening plates A and A_1 (Fig. 13) not varying in the same ratio as those from the same plate to the actual fixed plates FP_1 and FP_2 when an axial relative displacement of fixed and moving plates occurs. The five plates concerned are shown in elevation in Fig. 13, which indicates the moving plate

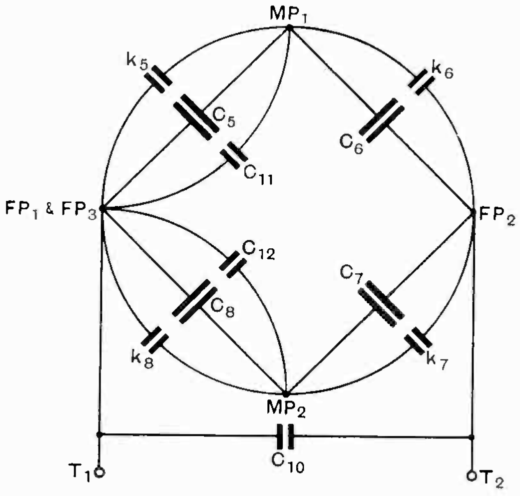


Fig. 15.

only half entered between the fixed plates FP_1 and FP_2 corresponding to the 90 deg. scale position.

Fig. 14 shows the complete electrical diagram of one section (three fixed plates and two intermediate conductors or moving

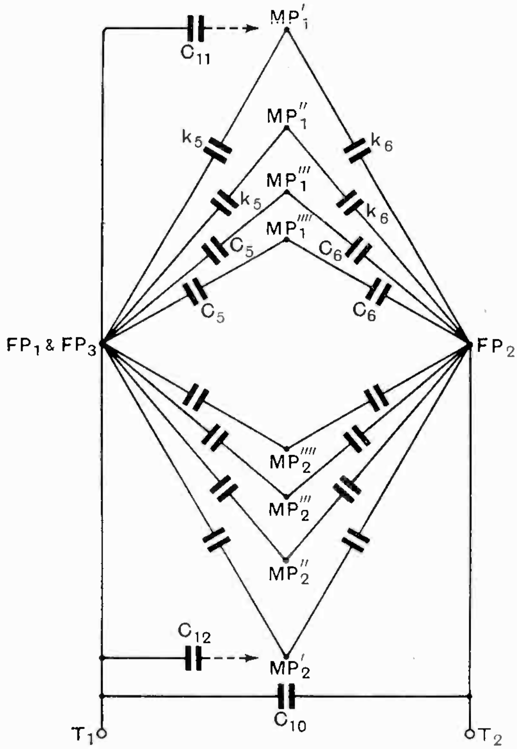


Fig. 16.

plates) of the series gap condenser, showing the gap capacities C_5 and C_6 on either side of the moving plate MP_1 augmented by those, k_5 and k_6, from the same plate to the screening plates which are connected to the appropriate fixed plate systems.

Unfortunately k_5 and k_6 cannot, if the moving plate be solid, be treated separately as a series gap capacity.

$$\frac{k_5k_6}{k_5+k_6} \text{ in parallel with } \frac{C_5C_6}{C_5+C_6}$$

because MP_1 is a potential fixing point common to both circuits. With a given axial displacement, therefore, even though it be in a direction purely normal to the planes of the plate surfaces, the gap capacities k_5 and k_6 are more nearly constant than the larger capacities C_5 and C_6 and therefore assist the spindle capacities C_{11} and C_{12} in tending to oppose the complementary changes in the capacities of the arms of the Wheatstone bridge upon which the whole principle depends. The diagram of Fig. 14 is redrawn in Fig. 15 for simplicity.

With the multi-sectioned moving plate, however, the capacities C_5 and C_6, k_5 and k_6, etc., consist of many insulated pairs of series capacities as shown in Fig. 16, the intermediate conductors MP_1^{i}, MP_1^{ii}, MP_1^{iii} and MP_1^{iiii} of which are not necessarily at the same potential. The resultant capacity of each series pair of capacities will, of course, remain constant and the sum of all the pairs will therefore also be constant for all axial positions of the moving plate, irrespective of the difference of total dielectric gap distance between adjacent fixed plates at various portions of the moving plate surface

$$\left(\textit{e.g.}, \text{ irrespective of the difference between the values of } \frac{C_5C_6}{C_5+C_6} \text{ and } \frac{k_5k_6}{k_5+k_6}\right)$$

The limiting factor of intersection capacity of course applies here as in the case of plate tilting, but it will be found that the limitation is not serious if these parasitic capacities are kept down to the order already given.

(To be Concluded.)

The Attenuation of Wireless Waves Over Towns.

Paper by Messrs. R. H. Barfield, M.Sc., A.M.I.E.E., and G. H. Munro, M.Sc., read before the Wireless Section Institution of Electrical Engineers on 5th December, 1928.

Abstract.

THE present paper is supplementary to a paper on "The Attenuation of Wireless Waves Over Land,"* read before the Wireless Section last year by one of the authors. The previous paper dealt with the effect produced by the open country, while the present paper discusses the attenuation over towns, including the effect of buildings and tuned aerials and other structures.

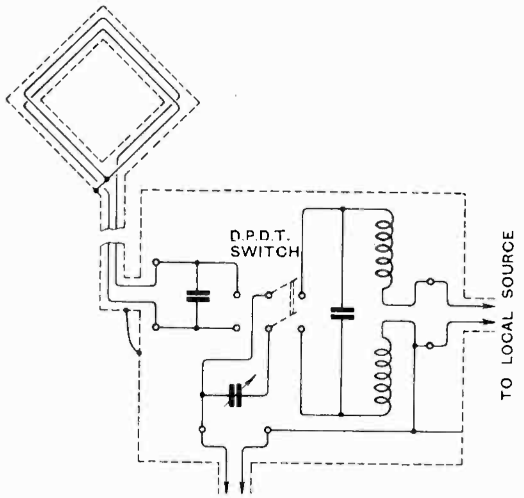


Fig. 1.—*Portable intensity measuring apparatus (dotted lines indicate screening).*

DESCRIPTION OF EXPERIMENTAL WORK.

(1) MEASUREMENT OF THE POLAR CURVE OF 2LO AND CONSTRUCTION OF A REVISED CONTOUR MAP.

For measurement of a polar curve at comparatively short distances from the transmitter it was necessary that the apparatus should be convenient for use in crowded town districts and capable of allowing a large number of observations to be made in a day's run. It was therefore designed for use in a motor van with a frame aerial coil on the top, so that the apparatus could remain set up and be brought quickly into use when the van was stopped at a suitable site.

The arrangement of the circuits is shown in Fig. 1.† The frame aerial is of "pancake" type with a screen of aluminium, to serve as a weather protection, as well as to reduce "antenna effect." The centre of the coil is earthed to the screen and to a brass tube passing into the inside of the van, and containing leads to the tuning panel. A standard 7-valve amplifier is used in a screened case, with batteries in another screened box, while a third box contains the detector H.T. battery, series micro-ammeter and shunts. A screened oscillator of measured output supplies a local signal to the dummy circuit having the same constants as the frame aerial.

The method consists in comparing the received signal in the frame aerial with the local signal in the dummy circuit. The strength of the signals is indicated by the deflection of a micro-ammeter in the detector anode circuit. The coil is turned until the deflection due to the received signal produces the same deflection as does the signal from the local source. The strength of the received signal is then $1/\sin\theta$ times that of the local signal, provided that the frame reception follows a cosine law.

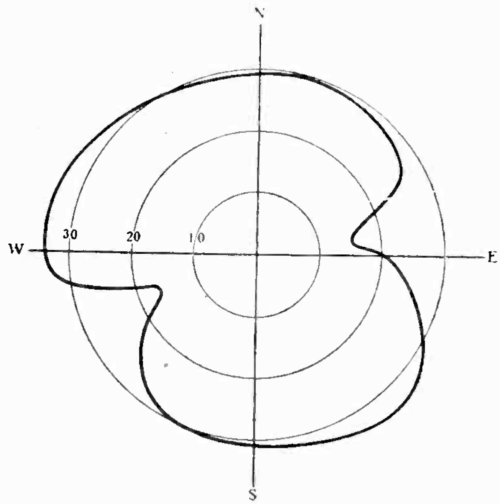


Fig. 2.—*Polar curve of signal strength of 2LO at 10 km. from transmitter (March, 1927); intensities in millivolts per metre.*

Observations were made on sites which were reasonably level and as free as possible from likely sources of error, such as telegraph wires and trees. A final observation was taken on returning to the Research Station after each run and the day's

* *J.I.E.E.*, 1928, Vol. 66, p. 204; Abstract in *E.W. & W.E.*, January, 1928.

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

results calculated relative to it. The apparatus was calibrated against a local transmitter.

Polar Curve of 2LO.—Observations were taken on suitable sites approximately on a radius of 10 km. from the transmitter, or, where suitable sites were not available at this distance, on a radius of 15 km. Readings were taken at intervals of not greater than 10 deg.

The resultant polar curve is shown in Fig. 2, due to surface. This may be further evidence of the "negative" surface attenuation effect found by Ratcliff and Barnett in the neighbourhood of the long-wave Daventry station.* On the other hand it may be that the effective height of the aerial is greater than that assumed.

The two mimina in the polar curve are clearly due to the directional characteristics of the aerial, and are no doubt owing to currents induced in the

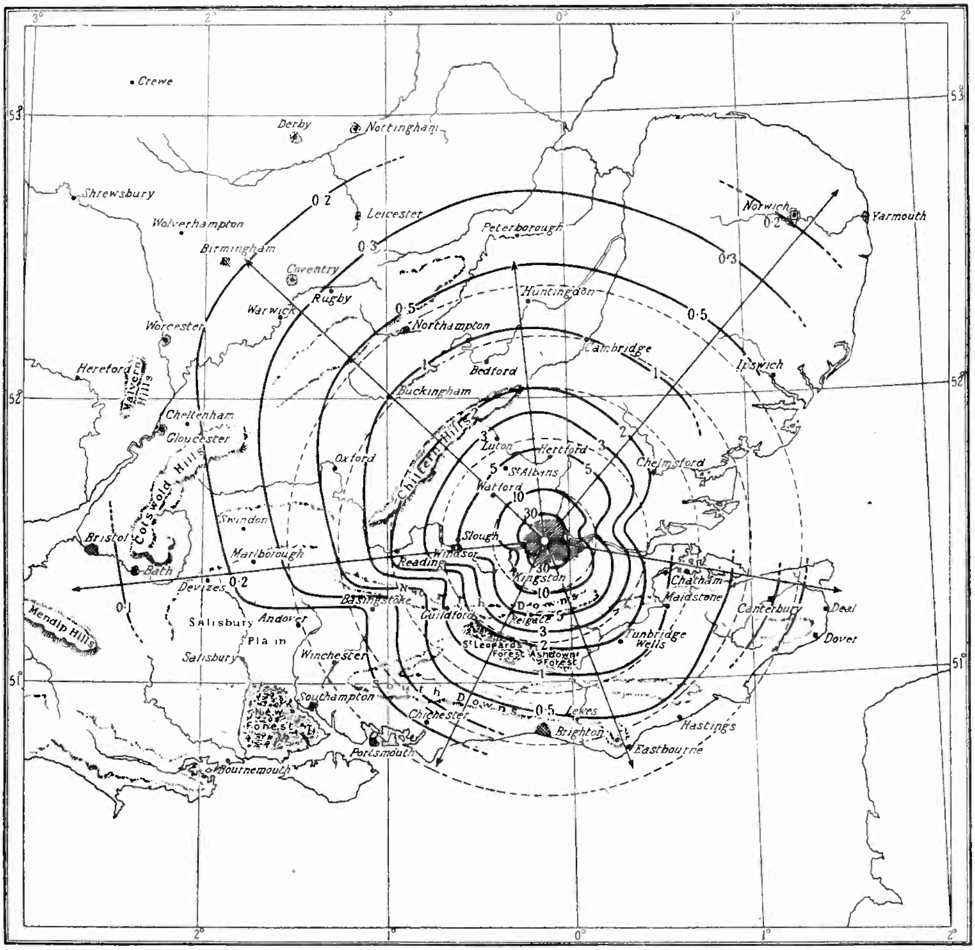


Fig. 3.—*Radio contour map of 2LO; revised survey made March, 1927 (distances from 2LO shown by dotted circles at intervals of 20km.); intensities in millivolts per metre.*

the values being corrected to 10 km. As a check of the sudden dip to the West a series was taken on a radius of 40 km., showing that the change was of the same order at that distance.

The calculated theoretical intensity of 2LO at 10 km.—neglecting surface attenuation—is shown to be 28 mV./m., though a certain amount of doubt arises as to the effective height of the transmitting aerial which is on the top of a large building and is taken as 30 m. The average value in Fig. 2 is 30 mV./m., suggesting no attenuation two masts. To produce the effect shown in the curve the currents induced in the mast must be of the same order as that in the aerial. This is surprising as the mast height (40 m.) is well below $\frac{1}{4}\lambda$ and therefore well out of resonance.

Revised Survey of 2LO.—This polar curve and the attenuation curves of the previous paper have been used to draw Fig. 3, a contour map of the signal strength of 2LO, which is a revision of that

* *Proc. Camb. Phil. Socy.*, 1926, Vol. 23, p. 288.

previously given. This revision became necessary because the first contour was constructed from observations at intervals of about 50 deg., while there have also been changes to the transmitting aerial which have altered its directional characteristics. The chief difference is the appearance of the crevasses W. S. W. and E. N. E., due almost certainly to the directional properties of the aerial, and corresponding to the minima in the polar curve. These may have existed at the time of the earlier survey remaining undiscovered because these directions were not selected for a tour. Their appearance now does not affect the previous conclusions with regard to the attenuation of waves (due to trees).

(2) Experiments to Determine Change of Attenuation with Wavelength.

The first experiments of this nature were in November, 1926, when measurements of the B.B.C. Strand transmitter were made at Slough and at the N.P.L. on a number of wavelengths in the region of 360 m. The results are in Fig. 4, both showing a rapid fall-off of intensity with decrease of wavelength.

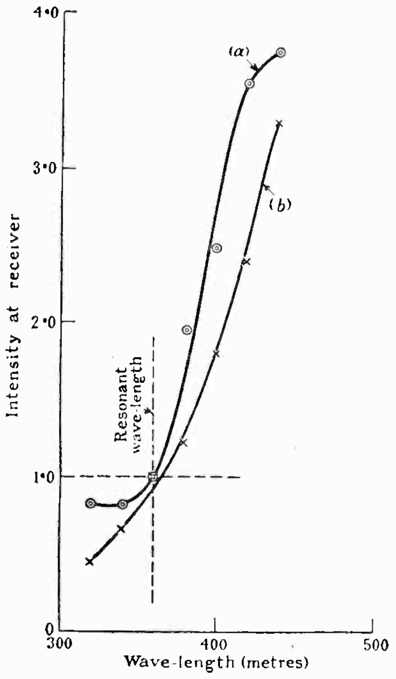


Fig. 4.—*Effect of wavelength change on received intensity. Transmitter: 2LO. Receivers: (a) Slough. (b) Teddington.*

To determine whether this was due to characteristics of the transmitter or to those of the intervening space, experiments were carried out using the N.P.L. transmitter (5HW) which could work over a greater wavelength range.

The experiments were carried out at a number of different sites in different directions from the transmitter. At each site the transmitter wavelength was changed in steps of 20 m. from 440 m. to 260 m. The transmitter was found to have a very marked frequency characteristic of its own. To eliminate this from the results, the measurements have all been expressed in terms of their value in a direction free from houses (viz., the route from N.P.L. to Wimbledon).

Intensity/wavelength curves are given in Fig. 6. In Curve 1 (N.P.L. to Regent's Park) transmission is over five or six miles of open country, then over five or six miles of densely populated town area (Hammersmith, Earl's Court, Paddington). A very rapid decrease of intensity with decrease of wavelength is seen.

For Curve 2 (Kew) the path is over three miles of closely built suburban area, then over the river and about half a mile of open grass. This is also the route for Curve 3 (Willesden), then over seven miles of sparsely populated districts (Gunnersbury, Park Royal, Wembley) with the crowded suburbs of Ealing and Acton on its flanks. Both curves show a marked minimum at between 320 and 340 m. with a marked difference of attenuation on the extreme wavelengths, *i.e.*, about 2 to 1.

Curve 4 (Richmond Park) shows a less marked minimum, with intensity ratios of 1.2 to 1, while in Curve 5 (Ham Common) the dip is again present, but still less marked, while the overall change in attenuation is small and reversed.

In the case of Curve 6 (Streatham Common) the transmission passes over the outskirts of Kingston, open country South of Wimbledon Common, and over the crowded districts of Merton, South Wimbledon and Tooting. The curve is irregular, without a dip but with a sudden drop of intensity at 300 m. The ratio on the extreme wavelengths is again about 2 to 1.

Curves 8, 9 and 10 are for Hampton Barracks, Hampton and Ditton Park respectively. These transmissions do not pass over any area of buildings and show no sign of dip and no great change in attenuation.

From these it is concluded that when transmission is wholly over a dense town area there is a very marked increase of attenuation with frequency. In the case of the Regent's Park site the change in intensity over ten miles, of which only four are in town area, is approximately 9 to 1, corresponding to a variation proportional to fourth or fifth power. Over a similar distance to Ditton Park there is a change of 2 to 1, corresponding to a law embodying a power between the first and second, which is in accordance with Sommerfeld's theory.

Another effect is that over well-populated suburban areas there is selective absorption between 320 and 350 m. It seems that this can only be caused by the number of receiving aerials all tuned to the 360 m. of 2LO. This selective absorption is a maximum when the area traversed contains the maximum number of houses, in the cases of Kew and Willesden and decreases in importance in other curves. The result for Streatham is unexpected, for, although the last part of the route is over dense residential districts, no selective absorption is recorded.

It is concluded that when transmission is confined to " town " areas only, consisting of offices, large buildings and residential districts without gardens, there is an increase of attenuation with frequency following approximately a fifth power law. Over suburban areas there is marked selective absorption which is a maximum on a wavelength just below the tuned wavelength. In the case of 2LO to Slough (Fig. 4) there are indications that the steep attenuation curve is combined with the curve of selective absorption.

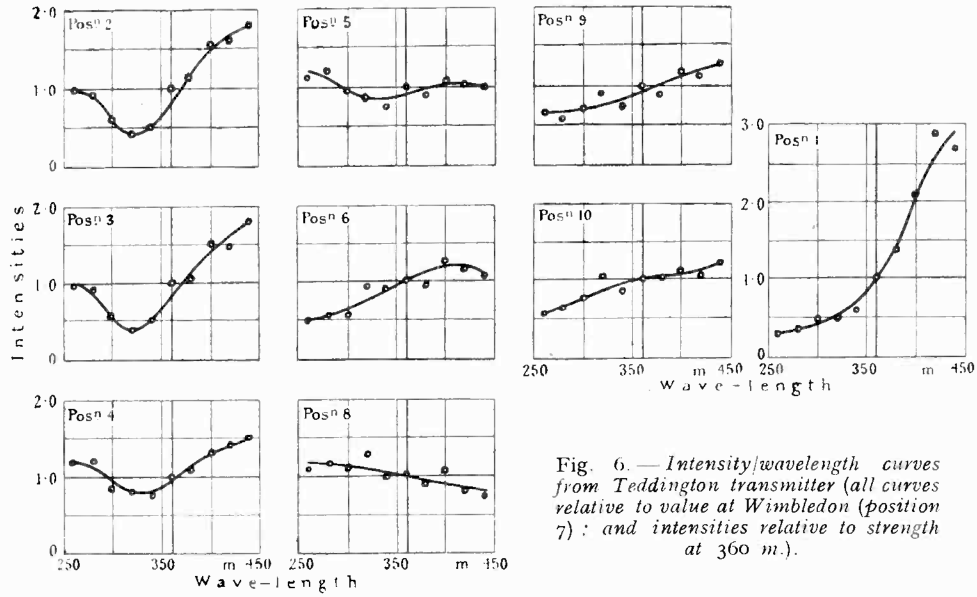


Fig. 6.—*Intensity/wavelength curves from Teddington transmitter (all curves relative to value at Wimbledon (position 7): and intensities relative to strength at* 360 *m.*).

THEORETICAL DISCUSSION OF RESULTS.

Considering the rate of change of attenuation with wavelength over town areas, the surface may be considered as being made up of :—

(1) Vertical conductors, earthed and unearthed.

(2) Horizontal conductors.

(3) Vertical and horizontal closed metallic loops.

(4) Dielectrics.

Sommerfeld's expression for surface attenuation is then considered and converted to a form which makes it applicable to any kind of surface.

Vertical Conductors.—A further expression is then derived for the energy absorbed by a distribution of N vertical earthed conductors per unit area, and it is shown that the intensity would vary as the fifth power of the wavelength which is in accordance with the experiments. A value for N is also traced, suggesting that it would have to be of the order of 100,000 per km.^{2}, corresponding to a mass of conductors spaced about 10ft. apart. This is undoubtedly too close for the average state of affairs, but the calculation is based on very rough estimates. It seems probable that absorption by short vertical conductors would account for an appreciable portion of the absorption.

Horizontal Conductors.—It is impossible to estimate the various constants, but it is probable that long lengths of such conductor would rather assist propagation.

Vertical Loops.—The effect will be chiefly in the vertical sides of the loops, as for vertical conductors.

Horizontal Loops.—Absorption effect theoretically zero.

Dielectric Losses.—The energy absorbed by dielectric losses in stones, plaster, etc., is very difficult to estimate. An approximate calculation is given, however, showing that the attenuation will vary inversely as λ^5.

It is thus concluded that vertical conductors, such as pipes, steel frames of buildings, lamp-posts, electric wiring, etc., give losses following a frequency law of the correct nature, while dielectric losses might also account for it if of a certain nature and sufficiently intense. No account has here been taken of receiving aerials which would be small and inefficient in such localities.

Selective Absorption.—There are two ways in which a mass of tuned receiving aerials might influence the field strength at a point remote from them: (1) by absorbing energy from the waves as they pass over, and (2) by re-radiating waves which interfere with the main waves at the point under consideration.

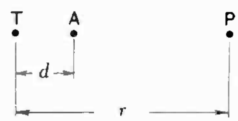


Fig. 7.—*Diagram to illustrate theory of aerial shadow effect.*

(1) *Energy absorbed by Mass of Tuned Aerials.*—It is shown that with 100 aerials per km.^{2} corresponding to 1 every 100 m. in parallel streets of houses 100 m. apart, the attenuation would be about 0.75. That is, at 10 km. away from the transmitter the field-strength would be 0.75 of its

normal value so long as the receiving aerials were tuned to the transmitter. For wavelengths above and below this value the signal strength would be greater approaching the normal value. Hence this type of absorption will give a minimum signal strength at the resonant wavelength, while the density of aerials which actually occurs in suburbs would produce an appreciable effect.

(2) *Shadow Effect of Mass of Receiving Aerials.*—Assume a collection of N receiving aerials of broadcasting type all tuned to the same frequency λ_0 with average height h and resistance R. Considering first the effect of a single aerial situated at a distance d from the transmitter (Fig. 7), the resultant intensity E of the electric field at P is derived as

$$E = K\sqrt{\left[1 - \frac{2A}{\lambda Z_A}\sin\phi + \left(\frac{A}{\lambda Z_A}\right)^2\right]}$$

where $A = \dfrac{4\pi x h^2{}_A}{cd(x-d)}$; $\phi = \text{arc tan}\,\dfrac{\omega L - 1/(\omega c)}{R}$

and $$K = \frac{4\pi I_T h_T}{c\lambda},$$

while c is velocity, and I_T and h_T refer to the transmitting aerial.

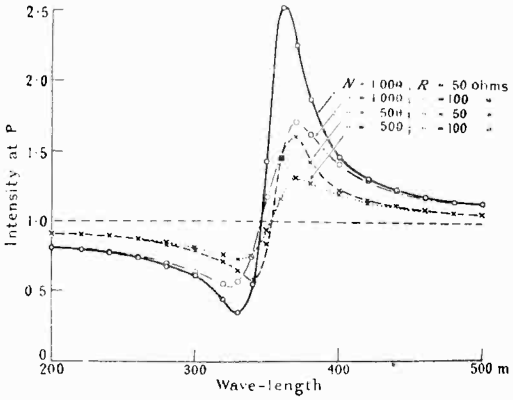


Fig. 8.—*Aerial shadow curves.*

The calculation of the effect of a number of aerials is complicated due to their mutual effect on each other. Assuming N aerials in a given area at A and that they produce at P an effect N times that of the single aerial, the expression becomes

$$E = K\sqrt{\left[1 - \frac{2AN}{\lambda Z_A}\sin\phi + \left(\frac{AN}{\lambda Z_A}\right)^2\right]}$$

It is now possible to work out a practical case of the variation of E with λ round about the resonant wavelength. The case taken will resemble as closely as possible the condition holding in the transmission from Teddington to Kew.

From an inspection made of the intervening district, and by studying a large-scale map, a rough estimate can be made, taking

$N = 500$; $h_A = 10$ m.;
$d = 2$ km.; $R = 50$ ohms;
$x = 5$ km.; $C = 200\ \mu\mu$F.

Assume that the aerials are tuned to 2LO ($\lambda = 360$ m.). The resultant curve of E with respect to λ is shown in Fig. 8, where the minimum value of the resultant field occurs at about 335 m.

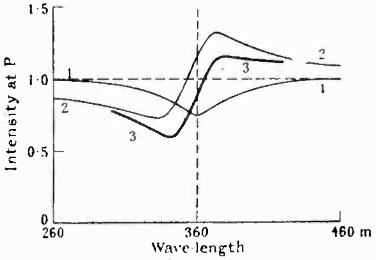


Fig. 9.—*Curve* 1 : *Energy absorption curve.*
Curve 2 : *Aerial shadow curve.*
Curve 3 : *Sum of curves* 1 *and* 2.

Combination of Absorption and Shadow Effect.—In practice these two effects will be combined, so that addition of a typical curve of each case should get somewhere near to the resultant effect. This superimposition is shown in Fig. 9, where the curve is clearly of the same nature as the experimental curve. In particular it has its minimum just below the resonant wavelength.

Conclusion.

The experimental results show that the attenuation over large towns is different from that over country. Over the town itself the attenuation is determined by the absorption of energy in the vertical metal conductors, pipes, steel frame works, etc., and possibly by dielectric losses in brickwork, etc. This attenuation increases rapidly with frequency. From theoretical reasoning, based on Sommerfeld's investigation, this appears to be consistent with the assumption that the losses occur in the vertical conductors. Tuned aerials in the dense part of the towns absorb little energy compared with that absorbed by other conductors, as such aerials are usually inefficient and heavily screened.

Over the suburbs this rapid attenuation disappears but tuned aerials play an important part. The experiments show that a comparatively small area of about 5 km.^{2} may produce a selective decrease of signal strength to half normal value,

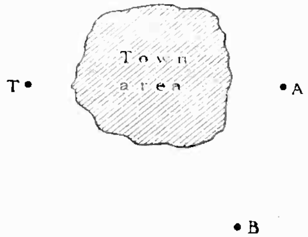


Fig. 10.

while the wavelength for lowest signal strength is slightly below that to which the aerials are tuned. The actual position of the minimum appears to vary with the number of aerials traversed

The results can be used to some extent to discuss the effect of towns in connection with proposed broadcasting schemes. If transmitter T (Fig. 10) works on 440 m. and 260 m., at receiver B the intensity on 440 m. is 6 mV./m. and on 260 m. (for the same power radiated) it will be about 2 mV./m. At A the experiments show that the strength on 440 m. will be about the same as at B, whereas on 260 m. it will drop to about 0.4 mV./m. In other words, it appears that at the upper limit of the broadcasting range towns have little effect, whereas on the lower range they cast a decided shadow.

APPENDIX.

Experimental Confirmation on Short Wavelengths.

The appendix describes check measurements carried out on an experimental scale to imitate the conditions. The wavelengths were less than 1/10th of those formerly employed as it was possible to produce the same shadow effect with a much smaller number of aerials. This is due to the fact that on short waves the radiation resistance of the aerial tends to predominate over the ohmic resistance. With the absorbing aerials under control the effects can be obtained by tuning these aerials, so that frequency characteristics of the transmitter and receiver are eliminated.

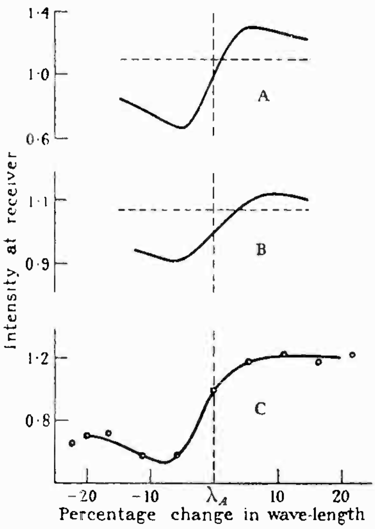


Fig. 15.—*Comparison of theoretical and experimental curves. Horizontal dotted lines show intensity, in the absence of the disturbing aerials.*

A low-power transmitter first sent on 24 m. to a single absorbing aerial 200 yards away while measurements were made at a receiver half-a-wavelength beyond it. The absorbing aerial was tuned down to 21 m. and up to 28 m.

Five aerials were then formed into the corners and centre of a square and the measuring apparatus moved to one wavelength from its centre. Transmissions on 20 m. and on 28 m. were also made.

The similarity between the results obtained with the experimental model and those for transmission over the suburbs of London is very striking. The comparison is given in Fig. 15, where B is for the experimental group, while A is the calculated and C the measured curve for London suburbs, redrawn from Fig. 9.

The work described in the paper is part of the programme of the Radio Research Board and is published by permission of the Department of Scientific and Industrial Research.

Discussion

The discussion which followed the reading of the paper was opened by Capt. R. P. Eckersley, who said that the paper was of particular interest to the B.C.C., and had an important influence on the general question of siting stations. Should the station be inside the town and work out, or outside the town and work in ? The paper was of help in considering this problem. Undoubtedly the effects described did exist. In surveying for the London Regional Station, they had made many measurements and found that the field-strength on the other side of London was about 0.6 of what it should have been. He would ask the authors, if the radiation did not obey Sommerfeld's law, could not another value of conductivity be given for various types of ground ? As regards the action of aerials, he had himself tried to calculate the effect in terms of the energy absorbed in each aerial, and had concluded that there were not enough aerials. He agreed that the effective height of 30 metres for the 2LO aerial might be subject to variation, and added that while the current in the aerial was about 9 amperes, that in the masts was considered to be more of the order of 2 amperes.

Mr. R. A. Wilmotte referred to the large quantity of original matter contained in the paper. With reference to the subject of dielectric losses, he had measured the dielectric losses in a powdered brick (results of which were exhibited in a slide). It was normally considered that dielectric loss varied but little with frequency. One possible source of error in measurement was the frequency characteristic of the transmitting antenna. The polar diagram might also have a frequency characteristic, *e.g.*, reducing the frequency might vary the polar curve. This would affect the values of Fig. 6. He also discussed the distortion of the field due to one aerial (as in the experimental model) and the effect of the masts in giving the polar diagram of 2LO, building up from consideration of the phase of the field due to the aerials and that due to the masts.

Mr. J. McPetrie also referred to the model experiment (of the Appendix) and to the distance at which the measurements had been made. At the distance quoted, the field was not completely a radiation field, and the necessary corrections, which he showed in a slide, moved the theoretical curve in the direction of closer agreement with the experimental.

Mr. E. B. Moullin thought that the effect of the building on which the transmitter stood could be estimated to get an idea of the effective height. Altering the earth-lead might have an effect on the polar diagram. As regards the authors' estimate of the effect of N aerials, he suggested that the effect was comparable to theories of light due to Rayleigh, from which $\sqrt{N}$ might be a more likely value. This would alter Fig. 8 considerably.

MR. R. A. WATSON WATT suggested carrying out the investigation of the disturbing effect of receiving aerials over much greater distances, while MR. BAINBRIDGE-BELL asked if it would be possible to have all the aerials in a neighbourhood switched off simultaneously—say, by advice of the transmitting station—while a measurement was being made.

DR. R. L. SMITH ROSE amplified Mr. McPetrie's remarks on the calculation in the case of the model experiments. He offered the criticism that the work was all done outside ordinary broadcasting hours.

MAJOR BINYON also referred to this point, and asked if any observations had been made from say 3 p.m. to 9 p.m. continuously, and whether there was any trace of a maximum effect with aerials being brought into circuit.

MR. H. L. KIRKE said that in doing polar curves about London, they had found differences according to the amount of London embraced. It would be interesting to have, if possible, a value for effective conductivity for normal towns. The B.C.C. were doing work on the attenuation due to towns, and also on the effect of masts.

MR. R. H. BARFIELD briefly replied to several of the points raised. In reply to Capt. Eckersley, he said that the particular value of effective conductivity to fit Sommerfeld's theory would be different for each district of towns and for different wavelengths. In reply to Mr. Wilmotte he said that allowance had been made in the curves for the directional effect of the aerial. In reply to Major Binyon, he doubted whether it was a prevailing practice for listeners to earth aerials when not in use.

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

The Chairman also announced that, at the next meeting, on January 2nd, a paper on "The Design of Aerials for Broadcast Transmitters" would be read by Capt. Eckersley, Mr. T. L. Eckersley, and Mr. Kirke.

Correspondence.

The Transmitting Station actually sends out Waves of one Definite Frequency, but of varying Amplitude.

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

SIR,—From Professor Howe's reply in your November issue, it is evident I did not make my point at all clearly in my letter. The real tilt was at the inconsistency of the treatment. Presumably the current in the receiving circuit can still be called a wave of one definite frequency varying in amplitude (provided the receiver is broad tuned enough), but it is found more convenient to treat the wave here as a spectrum of frequencies, so why not consider the current at the transmitter in the same light and get away from the single frequency idea ; surely it is more heplful and just as accurate. For instance, will Professor Howe tell us how he can treat from the single frequency basis, "suppressed carrier" or "single side band working," *i.e.*, a modulated wave from which the carrier wave (or carrier and one side band) has been suppressed. Presumably since one has only one wave to deal with, we must suppress that portion of it which we consider as of constant amplitude and radiate that portion we consider as varying. Such a picture is reminiscent of the smile on the face of the Cheshire cat, where if it is remembered, the face disappears leaving the smile (I apologise for such a simile in a serious technical journal) ; but no doubt Professor Howe can give us something better and I should be very indebted to him if he can give an illuminating treatment of the suppressed carrier case from the single wave basis.

A minor tilt was whether it is not misleading to call any wave or group of waves which can be analysed into component harmonic waves, as consisting of one definite frequency. Should we not reserve such a term solely for a periodic sine wave ? The qualification that there is an amplitude variation in a group does not clear matters, as it is insufficiently realised that an amplitude variation alters the whole complexion of things. This, of course, is really quibbling, but I suggest that it is our lack of concise terminology that is responsible for many of us having hazy ideas on wave formation.

I apologise for misquoting Professor Howe even though the portion misquoted is not in question.

A. W. LADNER.

Effect of Frequency on the Value of Resistances.

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

SIR,—In the current issue of *E.W. & W.E.* I notice an article describing some tests carried out on grid leak resistances. As that article contains a somewhat misleading statement I will be obliged if you will permit the necessary correction to be published.

The author describes a grid leak resistance of the varnish impregnated strip type as "the usual type of Dubilier leak." Grid leaks of this type have been obsolete for some years and have not been manufactured or marketed by the Dubilier Condenser Company since 1925. It is also implied that another type of Dubilier grid leak consists of "the strip surrounded by a glass enclosure." I would like to point out that no resistances constructed in such a manner have been manufactured by the Dubilier Company. As the only type of grid leak resistance now manufactured by that Company and known as a "Dumetohm" resistance consists of a glass filament with a metallised coating which is sealed inside a glass tube, it would be interesting to know whether or not the resistance tested by Mr. Jackson was of this pattern in order that any possible misunderstanding may be removed.

PHILIP R. COURSEY, Chief Engineer,
Dubilier Condenser Co. (1925) Ltd.

Abstracts and References.

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PROPAGATION OF WAVES.

SHORT WAVE ECHOES AND THE AURORA BOREALIS. C. Störmer. (*Nature*, 3rd November, 1928, V. 122, p. 681.)

J. Hals of Oslo reported echo-signals from Eindhoven, arriving three seconds after the true signal. Störmer connects these with his theory (1904) on the Aurora Borealis, one feature of which was the idea that streams of electrons coming towards the earth are deviated by the earth's magnetic field in such a way that an immense space is formed free from electric particles, and having the shape of a torus described by the revolution of an oval tangent to the magnetic axis of the earth at the centre. Birkeland's results with cathode rays directed towards a magnetic sphere fit in with this theory. Now if wireless signals could penetrate the Heaviside layer they would pass into this empty space, and might be reflected by the walls of electrons forming its outer boundary. The long time interval between the signal and the echo agrees well with the immense dimensions of these toroidal spaces. Störmer and Hals have now confirmed these long-time echoes, obtaining during last October echoes from Eindhoven with intervals varying from three to fifteen seconds: sometimes two echoes were heard with an interval of about four seconds. Similar results (three—fifteen seconds) were noted by van der Pol at Eindhoven the next night: 50 per cent of the echoes were heard after eight seconds. The writer points out that the study of this new phenomenon may throw much light on the electric currents in space outside the earth and on their connection with the Aurora Borealis and magnetic storms.

In a similar paper to the French Academy (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 811–812) the writer suggests that the rays entering the space are reflected by currents or surfaces of corpuscles moving outside the space. The minimum distance from earth to the point of reflection, according to his theory, would be equal to $(\sqrt{2}-1)\sqrt{\frac{M}{H\rho}}$ cm., where M is the magnetic moment of the earth ($=8.4 \times 10^{25}$) and $H\rho$ a product characteristic of the corpuscles, equal to $\frac{m}{e}.v$, where m is the mass, v the velocity, and e the charge in c.g.s. electromagnetic units. From this formula, the echo-interval comes out at 15 secs. if the reflection is from currents of cathode rays corresponding to $H\rho = 300$, and at 4 secs. if the currents are formed of radium β rays corresponding to $H\rho = 4{,}000$. These calculated values agree well with the observed times. The paper is followed by remarks by H. Deslandres, who quotes particulars of the sun's condition at the dates in question, which show that on the 11th October, when the first results (February) were confirmed, the condition was favourable to the strong emission of particles—and particles, moreover, from different points of the sun and possessing different velocities: which would explain the remarkable fact that successive echo-times were so different within the space of half an hour.

RADIO ECHOES AND MAGNETIC STORMS.—S. Chapman. (*Nature*, 17th November, 1928, V. 122, p. 768.)

Referring to Störmer's letter (see above) the writer remarks that the reflection of 31.4 m. waves back to earth from a great distance involves an electron density of the order of 10^5 to 10^6 per c.c.; that these electrons (at that distance from the earth) must be accompanied by an approximately equal number of positive ions; and that the density of the stream may thus be considered as similar to that of the solar chromosphere, or greater than this at emission. Also, that the presence of the positive ions will render the electron motions in the earth's field very different from those deduced by Störmer in his Aurora calculations.

RADIO ECHOES AND MAGNETIC STORMS: ATMOSPHERIC "WHISTLERS."—T. L. Eckersley. (*Nature*, 17th November, 1928, V. 122, p. 768.)

The writer considers that the phenomena of "whistlers" (a class of atmospheric heard in telephones connected in series with a large aerial) fit in well with Störmer's explanation of the long-time echoes. Whistlers are definitely associated with magnetic storms, and on many occasions they occur in groups of echoes preceded by a violent click, the interval between the click and the first echo being approximately 3 secs., and between successive echoes about 3.8 secs. As many as 7 echoes have been heard: each successive echo is spread over a longer period than the last. The suggestion is that the original pulse spreads into the toroidal ring and circulates round it five or six times before its extinction.

A STUDY OF SHORT-TIME MULTIPLE SIGNALS.—J. B. Hoag and V. J. Andrew. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1368–1374.)

This paper deals with the intermediate type of multiple signals (arriving from 0.01 to 0.04 sec. after the direct signal, and therefore between the latter and the first "round-the-world" signal) discussed by Taylor and Young (these Abstracts, pp. 460–461, 1928). These particular signals were observed at Chicago, on 23–30 m. waves, whereas Taylor and Young were working with 15–21 m. Photographic (oscillograph) records are shown and from these the short-time echoes are divided into two classes: the "normal," in which the echo signals are of the same form as the direct-signal, though of smaller amplitude—in the fraction of a second between the dots a considerable variation both in time and intensity occurs, indicating great instability in the paths followed : and the "wedge-shaped," in which either the signal dwindles down at the end or is extended by a dwindling "hang-over"—the evidence does not decide between these alternatives. The dwindling is not a case of rapid fading, since it has repeatedly appeared at times when fading was slight. If the wedge-end is not part of the signal but an extension, it may be due to a large number of multiple paths (corresponding to the case mentioned by Heising—*ibid*, January, 1928—of transmission of a short jab and reception of a longer diffuse signal). The writers suggest that certain of the short-time echoes fit in well with Taylor and Young's idea of reflection from regions of high electron concentration near the magnetic pole, and point out that other time intervals would conform with the picture of reflection by the Aurora Borealis (known to be most prominent above N. America in latitude 60°N. and in the N. Atlantic). They are particularly disposed to attribute the "wedge-type" signals to the Aurora. For the longest time-interval signals they suggest an inverted bowl-like "lifting" of the Heaviside layer above the geographic north polar regions due to their comparative darkness for many months of the year : the rays being reflected around the inner surface of the "bowl." They also mention the vertical component of the layer along the twilight zone, which would serve as a source of horizontal reflection or refraction for rays travelling at a certain elevation and impinging at a certain angle. The writers express the hope that additional information may be obtained, especially from stations farther North, and including directional and polarisation data.

Über die Wellenausbreitung in einem dispergierenden Medium (Wave propagation in a dispersive Medium).—K. Sreenivasan. (*Zeitschr. f. Hochf. Tech.*, October, 1928, V. 32, pp. 121–124.)

Neglecting the effect of the earth's magnetic field and of the movement of the medium, the paper investigates mathematically the motion of an electron under the influence of an electromagnetic radiation field, in an atmosphere of free electrons whose energy loss by collision is negligible. The velocity of propagation suffers dispersion ; the group-frequency being smaller, the higher the frequency of the wave. At a certain critical frequency, depending on the electron-density, the group velocity becomes zero : the medium becomes opaque to the corresponding wave. The dispersion has the result, on the transmission of wireless signals, that the partial frequencies of a modulated wave arrive at different times, so that distortion of the modulation is caused. This effect decreases when shorter wavelengths are employed. The writer suggests that a test of great interest would be to transmit signals with a large number of harmonics (*e.g.*, squarely modulated waves) and to record the resultant signals by a Braun tube or similar device on a rapidly moving film : taking care that the amplifier used was distortionless.

Long Wave Radio Reception and Atmospheric Ozone.—G. M. B. Dobson. (*Nature*, 10th November, 1928, V. 122, pp. 725–726.)

The writer adds a note of warning to Sreenivasan's letter under the above title (Abstracts, December, 1928). He points out that the steady decrease in the ozone values during the period in question is due to the regular annual variation of ozone found in regions outside the tropics : and the danger of assuming a direct connection between two quantities where the variations of at least one of them are chiefly due to an annual periodicity, and particularly where the two values show only a steady increase or decrease during the period under review. There is no evidence of any world-wide variations of the amount of ozone : results at low latitudes (not India) indicate that the annual variation of ozone in these latitudes is very small.

Remarques sur la Diffusion de la Lumière et des Ondes Hertziennes par les Électrons Libres (Remarks on the Diffusion of Light and Hertzian Waves by Free Electrons.)—Ch. Fabry. (*Comptes Rendus*, 3rd November, 1928, V. 187, pp. 777–781.)

An electron in the path of a ray of electromagnetic radiation takes on a vibratory movement under the influence of the electric field, and radiates in its turn in all directions. Unlike molecular diffusion, this electronic diffusion is independent of the wavelength ; for example, one of the relations here obtained is that the free electron diffuses six times the energy which it intercepts, and this holds good whether the waves are light waves or those used in wireless. But in reality the waves encounter not one free electron but a great number, and as a result the independence of wavelength vanishes. For the short waves of light, there is no phase relation between the separate waves sent out by the electrons even in quite a small area ; it is only the intensities which add together. Thus with the degree of ionisation occurring in nature, diffusion of light rays by electrons is always very slight, and plays no appreciable part in the production of the light of the sky ; though it may—as Dufay suggests—in certain astrophysical phenomena. But with the waves used in wireless, the case is very different ; all the electrons contained in a large volume take up corresponding movements and send out into space waves whose amplitudes add together, giving an intensity enormously greater than the sum of the intensities which would be produced by the individual charges. Thus an intense wave can be produced by a relatively small number of electrons, and one can have—according to the shape and size of the areas holding the electrons—either a regular true reflection or a complete diffusion in all directions. Between these two extremes, many intermediate results are possible ; for example, a layer of little thickness and of horizontal dimensions which are not very large compared with the wavelength would give a mixture of reflection and diffusion. Finally, if the layer is thick in comparison with the wavelength, the optical "thin film" effect may be realised, and if the ray is not strictly "monochromatic" there may result unequal reflection of the various frequencies and an apparent change of wavelength on reflection. This paper is the result of thinking over Jouaust's article (Abstracts, 1928, p. 578).

THE INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON ELECTRIC TRANSMISSION IN THE UPPER ATMOSPHERE.—S. Goldstein. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121, A., pp. 260–285.)

The writer develops a formula for the general problem (when the magnetic field is oblique to the direction of propagation) which appears to correspond with that given by Appleton to the U.R.S.I. in 1927 (Abstracts, December, 1928). After applying the formula to the special cases (field perpendicular to or along the direction) and deducing the resulting states of polarisation, the writer considers the "forbidden" wavelengths for various values of N (effective ions per unit volume), and the variation of the refractive index with N for a given wavelength.

In the light of his deductions he then considers the polarisation measurements of Appleton and Ratcliffe (Abstracts, p. 221, 1928) on approximately 400 m., where those workers ascribe the observed absence of the right-handed polarised wave to increased dissipation of energy by collisional friction. This explanation he finds at first unsatisfactory, asking for too much damping in such a short path; but after considering alternatives he agrees that the fact must be that the bottom of the ionised layer is much lower than 100 km., and that the density of ions up to about 100 km. is sufficient to cause considerable damping, though not considerable bending, in a 400 m. wave. A further deduction is that the right-handed component should be in greater strength in the middle of a winter night than just after sunset or before sunrise; also, that multiply reflected rays should be more in evidence in the middle of the night than at other times. With regard to the energy in the downcoming wave, he works out the ratio downcoming wave/incident wave as approximately 0.29 for W to E transmission and 0.47 for S to N; these values being upper limits and on the large side. (*Cf.* the old tradition among Wireless engineers that E and W communication was always more difficult than N and S: this was provisionally attributed to sunlight effects.—*Abstr.*). Summarising the results of the various workers, he agrees with Appleton (*Nature*, 1927, V. 100, p. 330) in picturing a three-fold layer: 40–70 km. effective height for long waves; 90–110 for waves in the Broadcasting band; and 200–250 for short waves. He considers the distribution of ionisation: the bottom layer is connected with the ozone layer and is also, roughly, that in which occurs the Lindemann-Dobson temperature inversion: the height of the middle layer coincides roughly with the auroral height; the upper layer must (if Chapman and Milne are right) be predominantly helium, but there is some difficulty in accounting for the large ionisation required in the short distance transmission of short waves. The paper concludes by considering the polarisation of very short and very long waves.

DER EINFLUSS DER ERDATMOSPHÄRE AUF DIE AUSBREITUNG KURZER WELLEN (The Influence of the Earth's Atmosphere on the Propagation of Short Waves).—J. Fuchs. (*Zeitschr. f. Hochf. Tech.*, October, 1928, V. 32, pp. 125–129.)

An investigation with the object of establishing a definite relation between meteorological changes and the propagation of wireless waves. For this purpose the writer considers short waves (under 100 m.) to be more useful than long waves, as they avoid more than the latter the local and inconsistent variations of the troposphere and of earth conductivity, and are chiefly affected by the more consistent changes in the stratosphere. He uses, therefore, the Time-signals from Washington on approx. 75 m. and 37.4 m. received in Vienna: over about 2,000 km. of land, 3,000 km. of sea, and another 2,000 km. of land; the period being 29th December, 1927, to 29th February, 1928, when the sun was still well below the horizon at Vienna at the time of the programmes. The first figure shows the curves of audibility of the two sets of signals, compared with curves showing the temperatures at Washington, Belle Isle, Ireland and Vienna, and the atmospheric pressures over America and Europe. In spite of a certain apparent agreement between signal audibility and the Washington temperature curve, the writer concludes that there is no definite relation between the signal strength and the American or European temperature curves. Nor can any satisfactory correlation be noticed between signals and the individual atmospheric pressure records on the diagram. At this point, however, the writer introduces records, from the German Marine Observatories, of the atmospheric conditions over the whole 7,000 km. By classifying this material into "high, medium or low" pressures over "America, the Atlantic and Europe," he obtains a table from which he deduces the following conclusions:—(1) 75 m. wave. Fall of pressure results in increase of signals. (2) 37.4 m. wave. A rising gradient from Washington to Vienna gives strongest signals: a falling gradient gives weaker signals. Some readers would perhaps interpret the table rather differently, particularly as the weakest signal strength corresponds with conditions "low, low, low" over the whole distance; and at least one of the strongest signals corresponds with "high" over America, "low" over the Atlantic and "high" over Europe, so that the important gradient would here seem to be Atlantic-Vienna rather than Washington-Vienna. (3) The 75 m. wave is as strong as or stronger than the 37.4 m. wave, when a depression is over the Atlantic and either a depression or a medium pressure is over Europe; but in the latter case the writer postulates the absence of high pressure over America.

On these and other data the writer explains the relative behaviours of the two waves as a result of alteration of skip-distance due to a dispersion (resembling a diffuse reflection) whose magnitude depends either directly or indirectly on pressure changes. It is right to mention that aural methods were only used after they had been proved so reliable that there was no need to take field-strength measurements.

ELIMINATION OF FADING.—(U.S.A. Patents Nos. 1,669,218 and 9, Taylor, 8th May, 1928.)

In the second patent, two separate aerials each have a separate receiver with its own local oscillator; the outputs of the two receivers are combined in a common telephone. The two local oscillators generate heterodyning waves of different frequencies, so that the heterodyne notes themselves are of different pitch and cannot interfere with each other when combined in the telephones, as they would do if their pitches were equal. In the first patent, the arrangement differs in that the two receivers are provided with reaction so as to dispense with local oscillators; the autodyne notes are arranged so as to be different, and each is received in one ear-piece of a binaural telephone headgear. *Cf.* Abstracts, 1928, p. 684.

THE VARIATION OF DIELECTRIC CONSTANTS OF AIR AND CARBON DIOXIDE WITH WAVE-LENGTH (600–60 m.).—M. Forró. (*Zeitschr. f. Phys.*, 18th October, 1928, V. 51, pp. 374–377.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

L'ÉTÉ 1928 ET LES VARIATIONS SOLAIRES (The Summer of 1928 and Solar Variations).—H. Mémery. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 831–833.)

The writer considers that with very few exceptions, the cause of all abnormal variations in temperature in our regions can be found in the variations of sun-spot phenomena. He quotes the very different sun-spot records of the summers of 1927 and 1928 as an example of bad and good summers, and mentions a number of other summers since 1827 which show a similar correlation.

SUN-SPOTS IN WEATHER PREDICTION.—H. N. Russell. (*Scient. American*, June, 1928, pp. 512–513.)

"It is now impossible to predict the weather from sun-spots, and such predictions need not be taken seriously."

ACTIVITÉ SOLAIRE ET MAGNÉTISME TERRESTRE (Solar Activity and Terrestrial Magnetism).—Ch. Maurain. (*L'Onde Élec.*, October, 1928, pp. 413–427.)

The writer mentions that it happens fairly often that no spot is visible on the sun during a day of magnetic disturbance: further, that no spot may appear several days before or after. But results averaged over 40 years show that there is a very definite correlation between magnetic disturbance and solar activity, the former coming on an average 2½ days after the latter. He points out that the spots themselves are merely a particular symptom of abnormal solar activity, which need not always be accompanied by them; also, that there is good reason to believe that certain magnetic disturbances have their origin in the earth's atmosphere and are independent of solar activity. The paper concludes with a consideration of the periodic variation, yearly and daily, of magnetic agitation; the former is apparently indirectly influenced by solar activity, the latter is apparently quite independent of it.

SUR UN ORAGE OBSERVÉ AU PIC DU MIDI, ET SUR LA FORMATION DE LA GRÊLE (A Storm on the Pic du Midi, and the Formation of Hail).—C. Dauzère. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 835–837.)

From his observations the writer concludes that atmospheric electricity plays an important part in the formation of hail. The droplets in the cumulo-nimbus, for the most part negatively charged, are attracted by the little crystals of ice in the cirrus into which the cumulo-nimbus rises; these crystals having attained a positive charge by ultra-violet light. The droplets congeal round each crystal, and form a hail-stone out of each. The hail-storm ceases when the supply of crystals is exhausted; the hail-stones must be either positive or neutral, which is confirmed by the observations of MacClelland and Nolan.

PROPERTIES OF CIRCUITS.

SOME PRINCIPLES OF GRID-LEAK GRID-CONDENSER DETECTION.—F. E. Terman. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1384–1397.)

Author's summary: The action taking place in this method of detection is reduced to an equivalent circuit consisting of the grid-leak condenser impedance in series with the dynamic grid resistance. The effect of applying a signal voltage to the detector, as far as the rectified grid current is concerned, can be represented by the introduction, in the equivalent circuit, of a fictitious voltage that is determined by the signal, and by a single valve constant called the "voltage constant" $\left(2R_g\Big/\frac{dR_g}{dE_g}\right)$ as used by Carson (*ibid.*, June, 1921). The voltage drop produced by this fictitious voltage across the grid-leak condenser impedance is the change of grid potential resulting from the detector action. A bridge method of measuring all detector constants is described. The effects of grid leak and condenser sizes are discussed, and the factors involved in the selection of conditions for best detection with telephone and telegraph signals are considered.

LES TRANSFORMATEURS INTERMÉDIAIRES EN BASSE FRÉQUENCE (Inter-valve L.F. Transformers). R. Jouaust. (*L'Onde Élec.*, October, 1928, pp. 437–445.)

Miller has shown that owing to the internal capacities of the valve there is always, in the grid-filament circuit, a degradation of energy corresponding to a fictitious resistance depending on the anode charging circuit; being different according as this circuit possesses resistance only or resistance plus inductance or capacity. One important consequence is that an inter-valve transformer can only be studied properly under conditions corresponding as nearly as possible with working conditions. The writer begins with a mathematical treatment of L.F. transformers, describes a bridge scheme for quantitative investigation, and finishes by considering the effects of leakage and the virtual grid filament resistance discussed by Miller.

RADIO VALVE ANODE CAPACITIVE RESISTANCE. (*Elec. Review*, 10th August, 1928, and following numbers.)

An argument by various writers, started by an article by E. W. Braendle.

COMPENSATION FOR INNER VALVE CAPACITIES. (German Patent 464,096, Koomans, published 10th August, 1928.)

With multi-grid valves the undesired internal capacities can be compensated for by the natural capacities between the grids. Two simple circuits are illustrated in which this effect is produced by suitable adjustment of a tapping along a coil in the circuit inside-grid-anode. If the capacity between control-grid and anode equals that between the two grids, the tapping-point is at the mid-point of the coil.

THE HEARTBEAT CONSIDERED AS A RELAXATION OSCILLATION, AND AN ELECTRICAL MODEL OF THE HEART.—B. van der Pol and J. van der Mark. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 763–775.)

An English version of the paper referred to in Abstracts for December, 1928. A remarkable list of phenomena forming instances of these oscillations is given, including an æolian harp, the scratching noise of a knife on a plate, the humming noise sometimes made by a water-tap, the Abraham-Bloch multivibrator, the Wehnelt break, the periodic sparks from a Wimshurst machine, the sleeping of flowers, and the periodic density of an even number of species of animal living together, and one species serving as food for the other.

AMPLIFICATION OF LONG WAVES. (German Patent 464,227, Lorenz, published 14th August, 1928.)

This patent was applied for on 4th February, 1921. It deals with the heterodyning, in one or more steps, of long waves to produce a suitable frequency increase.

TRANSMISSION.

HIGH FREQUENCY A.C. GENERATION.—E. D. McArthur. (*Elec. Review*, 24th August, 1928, V. 103, pp. 303–306.)

Description of an American transmitting valve (G.E.C.) with a water-cooled anode whose diameter is about three times that which is usual. Not only does this enable 20 kW. to be dissipated by a flow of water of 3 gallons per minute, but the decreased inter-electrode capacity allows very short waves to be produced. Experiments are described with 5.6 m. waves, dramatic effects such as the cooking of food by a neighbouring receiving aerial being quoted. Physiological effects (headache, etc.) are mentioned. (A. M. Codd, however—*ibid.*, 7th September—explains these as the normal results of excessive diathermy, which can be produced by quite small apparatus.) The grid and filament are of conventional design and size, but the anode is 9in. long and 3⅛in. in diameter. Details of workings are as follows :

Plate Voltage.	Plate Current.	Power Output.	Megacycles Frequency.
12,000 V.	1.9 A.	15.0 kW.	49.2
10,000	1.4	5.0	60
8,000	0.7	0.8	69.8

ZUR FRAGE DER ERZEUGUNG KURZER ELEKTROMAGNETISCHEN WELLEN (The Production of Short E.M. Waves).—M. Grechowa. (*Physik. Zeitschr.*, 15th October, 1928, pp. 726–729.)

An investigation of the Barkhausen oscillations by the use of specially designed valves in which the various constants can be readily calculated. The conclusion is that every valve possesses a series of internal oscillating circuits, each of which can be excited by a suitable adjustment of working conditions. The observed oscillations agree very well with the values thus calculated, though not all the calculated overtones could be detected in practice.

IMPROVEMENTS IN VALVE OSCILLATOR CIRCUITS. (German Patent 462,980, Trautwein, published 21st July, 1928.)

A " linking resistance " is connected in the part of the circuit common to anode and grid—*i.e.*, close to the filament connection—and is so proportioned that at the setting-in of oscillation the anode current is cut down to exactly, or nearly, the same value as it had before. If a condenser is connected in parallel with this resistance, under suitable conditions a self-modulation is set up. If the oscillator is tuned to the frequency of incoming waves, these can be made evident by the alteration of the modulating frequency.

DER WEHNELT-UNTERBRECHER ALS GENERATOR ELEKTROMAGNETISCHER SCHWINGUNGEN (The Wehnelt Break as an Oscillation Generator).—W. M. Schulgin. (*Physik. Zeitschr.*, 15th October, 1928, pp. 724–726.)

By connecting in the manner opposite to the usual, so that the platinum electrode goes to the negative pole, the writer uses the Wehnelt break as the " simplest and cheapest oscillation generator."

ON THE PRODUCTION OF INTENSE UNDAMPED ELECTRIC WAVES OF EXTRA SHORT WAVE-LENGTHS.—K. Okabe. (*Tech. Rep. Tôhuku Imp. Univ.*, No. 4, 1928, V. 7, pp. 1–28 and 2 plates.)

A paper by the same author on his split-anode magnetron work was briefly abstracted on p. 399, 1928. The present report is in English, and is on the same lines. The split-anode design allows the use of a resonant circuit, which does not give good results with the ordinary anode. The shortest fundamental wave now reached is 12cm., the shortest harmonic, 8cm. The most intense oscillation obtained was at 42cm. Various methods for the projection and reception of the waves are described and illustrated by photographs of the valves, reflectors, etc. The "wave directors" of Yagi and Uda were employed for reception (Abstracts, p. 519, 1928), while a lattice-type aerial was used for transmitting. Numerous curves, tables, etc., showing laboratory results and the result of field tests are given.

ÜBER EINEN RÖHRENSENDER FÜR KURZE UNGEDÄMPFTE WELLEN (A Valve Transmitter for Short Undamped Waves).—L. Bergmann. (*Ann. d. Physik*, 2nd May, 1928, V. 85, No. 7, pp. 961–966.)

A circuit is described, using an ordinary commercial type of valve, which by suitable adjustment gives (with regularity) wavelengths from a few metres to about 82cm. Anode voltage 600, average anode current 40 milliamperes.

INCREASING THE EFFICIENCY OF A SHORT-WAVE TRANSMITTER. (German Patent 461,526, Telefunken, published 23rd June, 1928.)

Short-wave transmitters are often separately controlled by a crystal-driven circuit stepping up by a series of valve circuits, the last of which is coupled to the aerial circuit. According to the invention, a self-excited transmitter circuit is also coupled to the aerial circuit and has its grid circuit coupled sufficiently closely to the crystal-controlled circuits for it to be drawn into synchronism.

RECEPTION.

ON THE DISTORTIONLESS RECEPTION OF A MODULATED WAVE AND ITS RELATION TO SELECTIVITY. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, p. 1422.)

Further discussion of Vreeland's paper (these Abstracts, 1928, V. 5, p. 286). Raven-Hart points out that Vreeland does not appear to have taken into consideration the "demodulating" effect of a stronger on a weaker signal (Beatty, *E.W. & W.E.*, June, 1928, V. 5), which should increase the effect of selectivity.

RADIO RECEIVER VOLUME CONTROL.—N. W. McLachlan. (*Elec. Review*, 9th November, 1928, V. 103, pp. 825–826.)

Referring to Whittaker's article (see Abstracts, December, 1928), the writer mentions that the control should precede the detector, and describes the method he himself uses in the "Megavox" receiver.

PERMISSIBLE GRID SWING WITH A PENTODE: HOW THE VALVE AND THE LOUD SPEAKER MAY CAUSE RECTIFICATION.—N. W. McLachlan. (*Wireless World*, 31st October, 1928, V. 23, pp. 584–586.)

THE EUROPA III: A POST-EXHIBITION RECEIVER.—F. H. Haynes. (*Wireless World*, 21st November, 1928, V. 23, pp. 694–697.)

First part of a paper giving constructional details of a new receiver based on the experience of the recent exhibitions.

MARCONIPHONE SHORT-WAVE SET: A SENSITIVE SHORT-WAVE RECEIVER ADAPTABLE FOR LONG WAVES. (*Wireless World*, 31st October, 1928, V. 23, pp. 593–595.)

SALON DE T.S.F.: THE RADIO SITUATION IN FRANCE TO-DAY. (*Wireless World*, 7th November, 1928, V. 23, pp. 643–647.)

A review of the recent Paris Show, larger than the Olympia Radio Exhibition.

WAVEBAND SWITCHING—FROM SHORT TO LONG WAVES WITHOUT CHANGING COILS.—H. F. Smith. (*Wireless World*, 7th November, V. 23, pp. 625–629.)

SETS OF THE SEASON: A COMPARATIVE ANALYSIS OF THIS YEAR'S DESIGNS. (*Wireless World*, 14th November, 1928, V. 23, pp. 654–658.)

BUYERS' GUIDE, 1928–29.—The *Wireless World* Reference List of Receiving Sets. (*Wireless World*, 14th November, 1928, V. 23, pp. 663–672.)

AERIALS AND AERIAL SYSTEMS.

MULTIPLE ANTENNA SYSTEMS. (Austrian Patent 109,586, Surjaninoff, published 10th May, 1928.)

In the usual systems, in which separate aerials are fed by currents of adjusted phase differences, the aerials are so widely spaced that there is no magnetic field containing them all. According to the invention, more aerials are used, arranged as near together as the voltage allows. The phase differences between the individual feeding currents are so arranged that the total does not exceed 180 deg.: thus a magnetic field is produced containing all the aerials.

DIRECTIONAL PROPERTIES OF WIRELESS RECEIVING AERIALS.—D. Burnett. (*Proc. Camb. Phil. Soc.*, October, 1928, V. 24, pp. 521–530.)

Colebrooke's extension of Moullin's equations has shown that the intensity of the received signal is independent of the orientation of the receiver (antenna partly vertical and partly horizontal) if the wave is plane polarised with its electric vector vertical. The present paper investigates the effect of orientation of such a bent antenna, and also of the Beverage Aerial, in the reception of a wave such as is received in practice—namely with an incident wave front *not* vertical but tilted by an amount depending on the wavelength and the resistance of the earth.

VALVES AND THERMIONICS.

GAS-FILLED THERMIONIC TUBES.—A. W. Hull. (*Journ. Am.I.E.E.*, November, 1928, V. 47, pp. 798–803.)

In gas-filled tubes the electrons freely emerge from cavities $\frac{1}{8}$ to $\frac{1}{4}$ inch wide and 4 inches deep. This makes it possible to use internally coated cathodes (heated indirectly), which are heat-insulated on the outside, so that the only appreciable loss of heat is that from the open end through which the electrons emerge. Radial vanes, coated on both sides, increase the electron-emitting area many times. The combined result is that the tube can be operated at 1,000 deg. K., which would give only 24 mA. per heating watt for a filament, but 600 mA. per watt for the "shielded cathode." Since ions produce no disintegration when their kinetic energy is less than a critical value, the life of such a cathode should be more than seven years. The paper describes forms of Thyratron based on the use of such cathodes: the grids are large, and emit no electrons: they shield the whole cathode from the anode.

Note on the Effect of Temperature on the Auto-electronic Discharge.—N. A. de Bruyne. (*Proc. Camb. Phil. Soc.*, October 1928, V. 24, pp. 518–520.)

Leading from the work of the author and Pforte (Abstracts, 1928, pp. 582 and 642) and of Schottky, the author has separated the auto-emission from the thermionic and finds that the auto-emission is independent of the temperature up to 1,944 deg., the highest temperature investigated. He deduces that the statement of Millikan, Eyring, and Lauritsen (that above 1,000 deg. it is affected by temperature) is a wrong conclusion from results due to the beginning of thermionic emission above that point. He gives the equations for the total current, agreeing with the picture of the auto-electric discharge put forward by Fowler and Nordheim (Abstracts, 1928, p. 400). The auto-electrons come from the lower energy levels and are practically unaffected by the temperature of the cathode or the height of the potential-jump at the metal surface. The thermions come from high energy levels and are controlled almost entirely by these two factors.

Einfluss positiver Ionen auf die Elektronen-Raumladung innerhalb eines Zwei-platten Systems (Influence of Positive Ions on the Electron Space-Charge in a Two-plate System).—H. Cohn. (*Ann. d. Physik*, 12th October, 1928, V. 87, No. 4, pp. 543–569.)

The type of valve dealt with was first used by de Forest and further applied by Wien: it has two equal parallel plates symmetrically on either side of the cathode.

Zur Theorie der Raumladegitterröhren (The Theory of the Space-Charge-Grid Valve).—F. Below. (*Zeitschr. f. Fernmeldtech.*, 29th August and 29th September, 1928, pp. 113–118 and 136–143.)

The space-charge-grid does not give the ideal rectangular characteristic hoped for by Langmuir and Schottky. The present paper investigates the reasons for its imperfect action, with a view to improving the design of the valve. The thorough theoretical and experimental work leads to the following practical conclusions: The space-charge-grid should be as fine-meshed as possible, to make the angle of deflection low; its radius as small as possible, so that the space-charge voltage may be kept small: the distance of the control-grid from the space-charge-grid should not be greater than 1.6 times the space-charge-grid radius, so that the secondary space-charge may be harmless: in-directly-heated equipotential cathodes must be used; the directions of the openings of the two grids should cross at right angles, the space-charge-grid being advantageously a spiral, the control grid a straight rod one. The space-charge voltage should be so high that when control voltage is zero, the saturation current flows to the space-charge-grid. Increase of voltage decreases the steepness. The steepness increases in proportion with the saturation current. At low temperatures the lower bend is very sharp.

Systematic Variations of the Constant A in Thermionic Emission.—L. A. Du Bridge. (*Proc. Nat. Acad. Sci.*, October, 1928, V. 14. pp. 788–793.)

Richardson in 1915 discovered an empirical relation (for tungsten and platinum) which may be stated as follows: In the Richardson-Dushman equation $I = AT^2e^{-b/T}$ whenever the work function, b, of a given surface is changed by any method (heating, outgassing, coating, etc.) the constant A also changes in such a way that log A is a linear function of b. This relation seems to have been completely neglected by subsequent workers, who have regarded any found variations of A as due to surface contamination. The present writer's results with thoroughly cleaned platinum have shown that A may have values 200 times or more greater than Dushman's value of 60; Goertz has obtained similar results with nickel. The present paper collates the various published results and deduces, in agreement with Bridgman, an expression for A which is A_0e^{α}, alpha being interpreted as the negative temperature derivative of the (photo-electric) work function: it can be obtained from measurements on the shift of the photoelectric threshold with temperature. For tungsten it is zero, so that $A = A_0$; whereas for platinum a shift occurs which may give 4.5 for alpha—of the right sign and order of magnitude to fit in with the writer's results on platinum.

The Increase of Thermionic Currents from Tungsten in Strong Electric Fields.—R. S. Bartlett. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121, A., pp. 456–464.)

Author's summary: Experimental results for the increase of thermionic currents with applied electric field at constant temperature show general agreement with theory, but the departures from a predicted straight line are greater than can be accounted for by experimental deficiencies. In the dependence of this rate of increase upon temperature, the failure of experiment to agree with the theory is still more marked, even after due allowance is made for certain experimental difficulties. It is suggested that Schottky's equation should be modified to take account of the influence of neighbouring electrons close to the surface—electrons that emerge from the surface, but do not completely escape. Attention is drawn to the marked effect of surface impurities in the cathode upon the experimental results.

FIELD CURRENTS FROM POINTS.—C. F. Eyring, S. S. Mackeown, and R. A. Millikan. (*Phys. Review*, May, 1928, V. 31, pp. 900–909.)

The laws previously obtained by experiments with crossed wires, then with fine wire cathodes discharging to cylindrical planes, have now been found to hold for field currents between points and planes. The smallest current found possible to measure accurately required a field of 2,000 kV/cm for a platinum, and less than half that value for a tungsten point: the metal in each case forming the cathode. When the metal was the anode, 100,000 V (corresponding to 35,000 kV/cm) produced no detectable current.

THE EFFECT OF ELECTRIC FIELDS ON THE EMISSION OF ELECTRONS FROM CONDUCTORS.—A. T. Waterman. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121 A., pp. 28–40.)

The writer points out that Houston's recent explanation is a treatment of the Schottky effect, for very intense fields: that if the Sommerfeld electron theory is accepted, the expression for the Schottky effect should be modified, and that this modification becomes significant at high fields. The object of the present paper is to derive an expression, on the Sommerfeld theory, for the thermionic current in the presence of an electric field, and to point out the difficulties in the way of accepting the Schottky effect as the correct explanation of the "field currents." The writer concludes that the process involves some factor not yet considered, and that possibly it is only to be explained in some entirely different manner, such as the treatment recently presented by O. W. Richardson.

MESSUNG DER WÄRMEENTWICKLUNG BEI DER KONDENSATION VON ELEKTRONEN IN METALLEN (Measurement of the Heat developed by the Condensation of Electrons in Metals).—R. Viohl. (*Ann. d. Physik*, 5th October, 1928, V. 87, No. 2, pp. 176–196.)

Allowing for the effect of contact potential (which has vitiated the results of other experimenters) the value for nickel comes out at (97,800 ±9,800) cal. per Mol.

ÜBER DIE AUSLÖSUNG VON SEKUNDÄRELEKTRONEN DURCH ELEKTRONEN VON 1–30 KILOVOLT.—E. Buchmann. (*Ann. d. Physik*, 12th October, 1928, V. 87, No. 4, pp. 509–535.)

DIRECTIONAL WIRELESS.

WIRELESS AS AN AID TO NAVIGATION.—Chetwode Crawley. (*Discovery*, November, 1928, V. 9, pp. 351–354.)

The short wave (about 6 m.) rotating beacons in the Firth of Forth and S. Foreland: the Orfordness rotating loop beacon: the fixed double loop, rotating double and single loops for ship-board: and the all-round beacons now being erected at various points on the coast, are briefly outlined.

ERROR-CORRECTION IN DIRECTION FINDERS.—(French Patent 635,849, S.F.R., published 26th March, 1928.)

To correct for errors due to masses of metal, steel masts, etc., the receiving loops are encircled by a guard loop provided with adjustable resistance and inductance.

ACOUSTICS AND AUDIO-FREQUENCIES.

ÜBER NEUERE AKUSTISCHE . . . (New Work on Acoustics and in particular Electro-acoustics).—F. Trendelenburg. (*Zeitschr. f. Hochf. Tech.*, October, 1928. V. 32, pp. 131–135.)

Third part of the long survey dealt with in October and December Abstracts, 1928. The present instalment deals with sound-transmitters which have to reproduce as uniformly as possible a wide range of frequencies—*i.e.*, loud speakers and telephones for Broadcast reception. The principles and frequency-range curves of various types of loud speaker are given: including Riegger's copper band and multi-field design, the Rice-Kellogg, and Gerlach's "folded" design (including the four-leafed clover "Protos" type). Grützmacher and Meyer's curves for head-telephones, both electromagnetic and static, are given, the great superiority of the latter type being very evident. The instalment deals finally with the question of non-linearity of reproduction and its resultant introduction of partial frequencies which should not be present at all. Here the electrodynamic system comes to the fore, especially when great volume is required: the copper-band membrane, for example, can oscillate with a very large amplitude without the conductor leaving the field. Tables showing the non-linear distortion (measured by the ratio of the effective pressure-amplitude of overtones to that of the fundamental) for various types of loud speaker are given.

NUMERICAL VALUES CONCERNED IN TELEPHONY.—T. J. Monaghan. (*Electrician*, 16th November, 1928, V. 101, p. 550.)

Part of an address on "Communication Efficiency." The frequencies used in speech are about 80–5,000 p.s., and the average energy of an ordinary speaking voice is of the order of 10μW, the power peaks in the vowel sounds rising to about 200 μW. Although the low frequencies are the ones of high energy content (more than 80 per cent. of the whole energy of speech being contained in the frequencies up to 1,000), yet these low frequencies can be cut off to quite a large extent before the speech begins to lose its intelligibility. The voice frequency A.C. input at the sending end of a telephone circuit is about a microwatt or two at half a volt. It is estimated that the minimum current to energise a good telephone receiver so as to give a signal audible to an attentive ear is of the order of 10^{-9}A, the amplitude of the diaphragm movement then being of the order of 10^{-9} cm.—less than the mean molecular diameter of the diaphragm material. In an ordinary telephone receiver one microwatt* gives a very loud signal, 0.25 a loud sound, and

* In a similar article in the *Electrical Review*, the writer gives these three values as milliwatts.

say 0.02 a good audible signal. At resonance of the diaphragm, the efficiency of a receiver is of the order of 1 per cent., and off resonance it falls very much below this. This indicates how sensitive the ear itself is: pressure variations of the order of a thousandth of a dyne will produce an audible signal (*i.e.*, 2×10^{-10} μW).

ENERGIES IN BROADCASTING.—(*E.T.Z.*, 25th October, 1928, p. 1580.)

In an article describing an Austrian Technical Exhibition, some interesting energy measurements are given: a normal speaking person delivers one-millionth of a watt: a microphone delivers about one-hundredth of this to the input amplifier. The whole amplifier gives, to a 15 kW. transmitter, about 10 W.: the transmitter (at rest) radiates 15 kW., a receiver takes up at most one 15-millionth part of this and delivers back one-millionth of a watt from the head-telephones.

A TESTING METHOD FOR MICROPHONES.—K. Kobayashi. (*Journ. Jap. I.E.E.*, September, 1928, pp. 960–974.)

A direct and absolute method of measuring the electro-acoustic pressure ratio. The sound-pressure is measured by a vibrometer provided with a special diaphragm, the E.M.F. produced is measured by a thermionic voltmeter.

EIN NEUER EINROHR-ZWISCHENVERSTÄRKER (A New One-valve Intermediate Repeater).—L. Müller. (*E.N.T.*, October, 1928, V. 5, pp. 403–411.)

Advantages are: cheapness compared with the usual two-valve repeaters, and insensitiveness to lack of symmetry in the associated lines.

UTILISATION DES LAMPES DE T.S.F. POUR LA PRODUCTION DE MUSIQUE ÉLECTRIQUE (The Use of Valves for the Production of Electrical Music).—E. Aisberg. (*L'Onde Élec.*, October, 1928, pp. 455–458.)

The "Dynaphone" of Bertrand, the instruments of Théremin and of Martenot are briefly dealt with.

ÜBER EINE EINFACHE METHODE DER AUTOMATISCHEN KLANGANALYSE UND DER MESSUNG DER NICHTLINEARITÄT VON KOHLEMIKROPHONEN (A Simple Method of Automatic Sound Analysis, and the Measurement of the Non-linearity of Carbon Microphones).—E. Meyer. (*E.N.T.*, October, 1928, V. 5, pp. 398–403.)

A method is described, accurate enough for most purposes, and dispensing with complicated amplifiers, resonance circuits, filter chains, etc.

It consists in the use of a circuit resembling a bridge circuit, supplied from a hummer with an A.C. of variable (pure) note frequency. In the diagonal of the bridge is an instrument which registers the magnitude of the difference-tone formed from the hummer frequency and that produced by the effect on the microphone of the partial tone in the sound under analysis. The measuring instrument is of too long a period to respond to the summation tone, and interference by the hummer frequency is obviated by the bridge circuit. The deflection is recorded photographically; the registering drum is mechanically linked to the rotating condenser of the hummer, so that the process goes on automatically.

PHOTOTELEGRAPHY AND TELEVISION.

DER BILDFUNK NACH DEM SYSTEM LORENZ-KORN (The L-K Picture Telegraph System).—W. Scheppmann and A. Eulenhöfer. (*E.N.T.*, October, 1928, V. 5, pp. 373–381.)

Description, illustrated by diagrams, photographs of apparatus, and specimen results, of the methods and apparatus used in the May, 1928, Berlin-Breslau trials (300 km., 600 W., 1,050 m.). Black-and-white and also half-tone pictures were used. Further developments, including a new synchronising method, are dealt with.

DERNIERS PROGRÈS DE LA TRANSMISSION BELINOGRAPHIQUE EN FRANCE (Latest Progress in Belinograph Transmission in France).—G. Ogloblinski. (*L'Onde Élec.*, October, 1928, pp. 446–455.)

The present Belin System transmits by the use of a photo-electric cell, controlling the amplitude of a current of musical note frequency; it receives by a photographic method, using a Blondel oscillograph: the recently resuscitated electro-chemical or purely mechanical methods being dismissed as "impracticable for commercial traffic." The article includes details of the apparatus and discusses synchronisation, amplifiers, bands of frequency and possible speeds under various conditions.

TELEVISION: PAST AND FUTURE.—A. A. Campbell Swinton. (*Discovery*, November, 1928, V, 9, pp. 337–339.)

Beginning with a brief historical outline, the writer points out that the "modern" revolving disc with staggered apertures was patented by Nipkow in 1884: mirrors on a rotating wheel were proposed in 1889, and rapidly vibrating mirrors were patented in 1897. Even the "scanning" of the object by a moving ray was patented by Ekstrom in 1910. He goes on to criticise severely the present achievements in the U.S. and England, and reverts to his advocacy of cathode ray methods proposed by himself twenty years ago.

TELEVISION APPARATUS.—G. Cristesco. (Roumanian Patent, published March, 1928.)

An outline of the multiple mirror arrangements mentioned in this patent is given in the *Rev. Gén. d. l'Élec.*, 10th November, 1928, p. 167D.

IMPROVEMENTS IN KERR CELLS.—(German Patent, 462,579, Karolus, published 14th July, 1928.)

The cell is placed not in a parallel ray but at the point of intersection of a convergent beam. Thus the condenser plates of the cell can be close together.

for increased sensitivity. To add to the effectiveness, the plates of the condenser are not flat but so shaped as to fit in with the convergent beam.

The Photoelectric Long Wave Limit of Potassium Vapor: The Emergent Energy of Photoelectrons in Potassium Vapor.—R. C. Williamson. (*Proc. Nat. Acad. Sci.*, October, 1928, V. 14, pp. 798–801.)

The Photoelectric Effect in Glow-Discharge Tubes.—H. J. Reich. (*Journ. Opt. Soc. Am.*, October, 1928, Part 1, V. 17, pp. 271–288.)

Gas-filled glow-discharge tubes are coming into prominence in connection with rectification, voltage-regulation, television and other purposes. The present paper investigates a number of points, regarding the photoelectric effect, not satisfactorily dealt with before. The writer summarises his experimental results and conclusions thus: (1) The light effect is a true photoelectric effect produced by the presence of small amounts of alkali metals on the electrodes and walls. These experiments do not necessarily prove that the light effects observed by Oschwald and Tarrant and by Ryde were due to the same cause, but the probability is that the latter were similar to those here described. This question can be fully answered only after a thorough study of tubes made specially for the purpose (Ryde, in criticising the O. and T. conclusions, attributed the effect either to the presence of hydrogen or to a film on the surface of the electrodes). (2) When the tubes are used in an oscillating circuit, the reduction of sparking potential with illumination is not proportional to light intensity, the reduction per unit of intensity being less for high than for low intensities. (3) There is no definite relation between the portion of the tube illuminated and the magnitude of the effect. (4) In addition to the polarising action studied by Taylor, which tends to raise the sparking potential in successive discharges, there seems to be in this type of tube another action producing the opposite effect. (The type in question is filled with neon or helium at 1–5 mm. pressure with aluminium electrodes about 2 cm. apart.) (5) In tubes which have been used for quite a few hours, when the tube is oscillating at frequencies below about 45 cycles, an increase of intensity will—at certain intensities—produce an abrupt increase of sparking potential rather than the normal decrease. (6) The voltage-time wave form is not that which would be expected from theory. The terminal voltage does not fall according to an exponential function of the time during discharge, the rate of discharge suddenly dropping to a much lower value shortly before the extinction potential is reached. The time of discharge takes up more than half the complete cycle, instead of about 1 per cent. or less, as theoretically predicted and as observed in other types of tube. This points out the necessity of studying the wave form of any glow-discharge tube before applying theoretical equations to it, or before using it in obtaining a linear time axis in oscillograph work. (7) Discharge can be controlled by means of an external shield or grid connected to various parts of the circuit, either directly or through a high resistance. For a complete list of references covering the theory of the tube and its application in oscillograph work, the writer refers to the paper by Bedell and Reich, *Journ. Am. I.E.E.*, June, 1927.

Further Consideration of the Photo-electric Phenomenon of the Audion.—Q. Majorana. (*Nature*, 10th November, 1928, V. 122, p. 754, *résumé* from *Roy. Nat. Acad. Lincei*, 1st June.)

The effect considered is produced when an intermittent strong beam of light falls on an audion in which the wire leading to the grid is covered with a substance semi-conductive (cuprite, molybdenite, etc.), or electrolytically conductive (artificially prepared silver sulphide). It appears to be a perturbation, electrical in character, caused by the arrival of the light, but not corresponding with external liberation of electrons.

MEASUREMENTS AND STANDARDS.

Eine vereinfachte Schaltung für die Aufnahme von Röhrenkennlinien (A Simplified Arrangement for Plotting Valve Characteristics).—L. Bergmann. (*Zeitschr. f. Hochf. Tech.*, October, 1928, V. 32, pp. 129–131.)

A sliding resistance is described with two independent and separately-insulated sliders, which when connected as a potentiometer gives—with one battery only—two variable P.D.s. Its use for plotting valve characteristics greatly simplifies the usual process.

Anordnung und Geräte zur Untersuchung von Hochfrequenzverstärkern (Arrangements and Apparatus for the Investigation of H.F. Amplifiers).—M. v. Ardenne. (*E.T.Z.* 15th November, 1928, pp. 1675–1678.)

The apparatus is distinguished by its comparatively easy construction and for the short time required for the measurements. The layout comprises the oscillator (mains-fed) fully screened; the wavemeter, a "dosing apparatus" by which the magnitude of the voltage handed on to the amplifier under tests is regulated; the amplifier itself; and the valve-voltmeter. Precautions as to screening, etc., are discussed. Diagrams of connections and photographs of the apparatus are given, and some specimen amplification curves.

Standard Frequency Transmissions by the Bureau of Standards. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1300–1301.)

A new schedule of monthly transmissions of signals of standard frequencies, ranging from about 2,400 m. to 50 m. wavelength.

The Vibrations of Tuning-Forks.—E. A. Harrington. (*Journ. Opt. Soc. Am.*, September, 1928, V. 17, pp. 224–239.)

Author's abstract: The energy dissipated by frictional forces in a tuning-fork was studied by means of two electrically driven forks: (1) an ordinary fork, (2) a fork made by clamping two steel bars with a rectangular block between them, in a vice so that very little energy was expended in moving the stand upon which the fork was mounted. The following properties were investigated: (1) the equivalent length of a rigid straight bar turning through the same angle as the tangent at the end of the prongs; (2) the relation between the current driving a fork and the deflections of the prongs produced, both for steady and resonant deflections; (3) the logarithmic decrement, and the effect on the logarithmic decrement of damping due to vanes at the end of the prongs; (4) the energy due to emission of sound. It was found that: (1) a straight bar about 73 per cent. of the whole length of the prong was approximately equal to the equivalent length; (2) the deflections of the prongs were proportional to the square of the current; (3) the change in the logarithmic decrement was roughly proportional to the area of the vanes; (4) about 3.5 per cent. of the total energy was converted into sound.

Über die vermittels einer Stimmgabel erregten Röhrenoszillatoren (Valve Oscillators driven by Tuning-fork).—Y. Watanabe. (*Zeitschr. f. Hochf. Tech.*, October, 1928, V. 32, pp. 116–121.)

Six types of valve circuit in which the reaction-coupling is provided by the vibrations of a tuning-fork are dealt with, in each case an equivalent purely electrical circuit being worked out by means of the (mutual and self) motional-impedance of the fork. The constants of the latter are determined by direct measurement of the induced E.M.F. by an A.C. potentiometer, and by an application of Rayleigh's theory. The properties of the various types of circuit are investigated, particularly their deviations from the natural frequencies of the forks, and the conditions for the production of oscillations. The types of circuit are: the simple circuit (Eccles, 1919); circuit with tuned grid; circuit with tuned grid and tuned anode; with grid transformer; with anode and grid transformers; circuit with combined electrical and mechanical reaction.

Determination of the Axes of Piezo Crystals.—(German Patent 461,497, Giebe and Scheibe, published 26th June, 1928.)

The optical axis is easily found and a plate is cut from the crystal perpendicular to this axis. A ring is cut from the plate, a mark being made before cutting to indicate the natural position of ring in plate. The ring is excited by a uniformly radial A.C. field from suitably shaped electrodes, so that three complete wavelengths are distributed along the circumference. Observed in a low-pressure atmosphere, luminous effects show the positions of the three electrical axes, and by the relative positions of these and of the indicator mark, the axes of the crystal itself are found.

Dynamic Study of Magnetostriction.—K. C. Black. (*Proc. Am. Academy*, April, 1928, V. 63.2, pp. 49–66.)

Work done after Pierce's application of the phenomenon to oscillators (November, 1928, Abstracts). With maximum resonance the amplitude of vibration may be 200 times as great as the length change in a steady field. (*Cf.* van Dyke, these Abstracts, 1928, p. 526: resonance in piezo-electric circuits magnified the effect "several thousandfold.")

A Visual Method for Studying Modes of Vibration of Quartz Plates.—A. M. Skellett. (*Journ. Opt. Soc. Am.*, October, 1928, Part I, V. 17, pp. 308–317.)

Photographs are shown of a number of patterns on the surface of a quartz plate formed by the glow discharge at low pressures of gas (Argon at about 5 mm.), at various radio frequencies of the exciting oscillator. Evidence is presented in support of the theory that the bright spots occur at the antinodes of standing waves; from which it appears that the value of Young's Modulus is the same for directions at angles from 0 to 78 deg. from the optic axis. Measurements of the distances between antinodal rows give wavelengths which agree, within less than 1 per cent., with wavemetre values of the oscillator; except in rare cases where the disagreement is 20 or 30 per cent., and it is supposed that the pattern is a part only of some larger pattern.

Sections in any direction in the crystals may have longitudinal standing waves set up in them, the lengths being such that there is either a node or an antinode at each end. Water vapour is found to condense on the crystal in the configuration of the pattern last formed. When the voltage was cut down to the threshold value for ionising the gas by crystal vibration, a thin momentary spark would sometimes jump between the electrodes close to the surface of the crystal, taking not the shortest route (10 mm.) but one varying in length up to 13 mm., and only occurring when the plate was oscillating so as to produce a pattern.

A New Method for Determining the Efficiency of Vacuum-tube Circuits.—A. Crossley and R. M. Page. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1375–1383.)

The writers point out the deficiencies of the two usual methods, the circuit resistance variation method and the optical pyrometer method gauging the temperature of the plate by its colour, more especially for measurements in the high-frequency band. They go on to describe a quick method reliable for any frequency-range, depending on the use of a Cambridge surface pyrometer (designed primarily to measure the temperature of rolls, etc., in the manufacture of paper, textile materials, etc., and comprising a flat strip thermocouple specially mounted, and a millivoltmeter). Readings are taken of the temperature of the valve-walls when the circuit is oscillating. The oscillation is then stopped and the plate input watts altered until the identical pyrometer reading is obtained. The difference in watts represents the radio-frequency output power. Examples are given of tests on crystal-controlled oscillators (where it was shown definitely that the output obtained with a push-pull circuit was double that of a single valve circuit): 250 W. shield-grid amplifier valves (the 3-electrode valve is a more efficient amplifier—on about 70 metres—than the shield-grid valve; greater efficiency is obtainable with greater excitation voltage to the grid), and on aerial resistance. Examples on this last measurement show fairly consistent results, seven tests spread over ten days and with varying outputs giving an average of 51.3 ohms with extreme values of 45.5 and 56.1.

A GENERAL THEOREM ON SCREENED IMPEDANCE.—R. M. Wilmotte. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 788–795.)

The theorem leads to the fact that the impedance of any piece of screened apparatus can be given without stating which terminal should be kept at the potential of the screen, provided that one of the two terminals is so kept at the potential of the screen, but without connection to it. Certain limitations are discussed.

THE ERRORS ASSOCIATED WITH HIGH RESISTANCES IN ALTERNATING CURRENT MEASUREMENTS.—R. Davis. (*Journ. Sci. Inst.*, October, 1928, V. 5, pp. 305–312.)

First part of a paper dealing with the properties of high resistances for use in electrical measurements at high voltages. In the case of a resistor having a resistance of 600,000 ohms, used for voltage transformer measurements, the capacity to earth of the windings was estimated to be of the order of 300$\mu\mu$F., large enough to cause a serious error, if not corrected for, in the determination of phase angle, etc. The paper considers one section of a resistor together with its shield. The effect of the screen potential on the phase angle at a point in the section is determined: the effect of adding units in series is considered and expressions are derived for the phase angle at the low and high voltage ends of the resistor. A method for determining the characteristics of a unit is described. Some of the practical limitations which may manifest themselves in the designing of a shielded resistor are discussed.

A GANG CAPACITOR TESTING DEVICE.—V. M. Graham. (*Proc. Inst. Rad. Eng.*, October 1928, V. 16, pp. 1401–1403.)

Testing equipment for a gang condenser system must be simple, accurate and reliable. The test described uses two oscillating circuits and the zero beat method of measurement. The complete procedure is described.

USEFUL DATA CHARTS (No. 15). EFFICIENCY OF COUPLING BY GRID LEAK AND CONDENSER.—R. T. Beatty. (*Wireless World*, 7th November, 1928, V. 23, pp. 648–649.)

One of a series of articles and Abacs for solving practical problems, the first of which appeared in the issue for 11th July, 1928.

SIMPLE INDUCTANCE FORMULAS FOR RADIO COILS.—H. A. Wheeler. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1398–1400.)

On the same pattern as the Hazeltine formula for the inductance of a multi-layer coil ($L = 0.8\, a^2n^2/(6a + 9b + 10c)$ microhenrys, where a = radius to mid-point, b = axial thickness, c = radial thickness, all in inches) the writer gives two easily remembered and accurate formulæ for single layer coils: $L = a^2n^2/(9a + 10b)$ and $L = a^2n^2/(8a + 11b)$, the former to be used when $b>a$, the latter when $a>b$. When the coil is a single layer spiral, the second formula is applicable in the form $L = a^2n^2/(8a + 11c)$.

DIE MESSUNGEN DES WIDERSTANDES VON ANTENNENSEILEN BEI HOHEN FREQUENZEN (The Measurement of the Resistance of Stranded Aerial Wire at High Frequencies).—W. P. Jakowleff. (*Zeitschr. f. Fernmeldetech.*, 31st May, 1928, pp. 76–77.)

An experimental comparison between metre lengths of stranded wire and solid conductors of the same cross-section, to determine the effect of the contact resistance opposing the passage of current from one strand to another. The writer concludes that while at low frequencies the stranded wire has less resistance than the solid, for thick wires the two values become equal at $\lambda = 4{,}000$ m., for thin wires at $\lambda = 110$ m. Above those frequencies the solid wire has the smaller resistance. A composite wire of parallel strands is also compared.

MESSUNG VON ANTENNENWIDERSTÄNDEN (Measurement of Aerial Resistance).—W. P. Jakowleff. (*Zeitschr. f. Fernmeldetech.*, 31st May, 1928, pp. 78–79.)

Description of a simple "Antenna-ohmmeter" for quick and accurate measurements, based on Pauli's method.

AN AMPERE METER FOR MEASURING ALTERNATING CURRENTS OF VERY HIGH FREQUENCY.—E. B. Moullin. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121 A., pp. 41–71.)

A long paper on the author's new type of ammeter to carry, unshunted, currents up to several hundred amperes at frequencies up to 30 megacycles, and with a frequency-correction which can be calculated (*cf.* Abstracts, 1928, p. 467). He describes very fully the conception, analysis and constructional development of the instrument, and outlines a modified form for large currents which would result in reducing the inductance. In the example taken of this modified form the power absorbed by 100A at 2.5 megacycles would be of the order of half a watt.

THE VIBRATION GALVANOMETER OBSERVED STROBOSCOPICALLY.—J. B. Saunders. (*Journ. Opt. Soc. Am.*, October, 1928, Part I, V. 17, pp. 326–327.)

When such a galvanometer is being used in the null method, its indications of unbalance do not tell whether the settings are too high or too low, both cases giving a hazy broadened image. Stroboscopic methods, either with sector disc or neon lamp, clear up this ambiguity.

LONG PERIOD MOVING COIL GALVANOMETERS.—C. V. Drysdale. (*Journ. Sci. Inst.*, October, 1928, V. 5, p. 330.)

A letter referring to D. C. Gall's article (see Abstracts, 1928, p. 644) and pointing out the possible great use of the principle for the measurement of very low P.D.s where the resistance of the galvanometer should be very low; which is impossible in the ordinary sensitive moving-coil galvanometer as the fine suspensions alone may have a resistance of some ohms. But if a thick suspension could be used and the major portion of the control counteracted by counter-magnetism, the low-resistance moving-coil galvanometer would become a possibility.

LOUD SPEAKERS: RECENT WORK ON. (See Trendelenburg's article under "Acoustics and Audio Frequencies.")

SUBSIDIARY APPARATUS.

DER KATHODENSTRAHL-OSCILLOGRAPH ALS REGISTRIERINSTRUMENT, SPEZIEL FÜR RASCHVERLAUFENDE VORGÄNGE (The Cathode-ray Oscillograph as a Registering Instrument, especially for rapidly occurring Processes). —K. Berger. (*Bull. d. l'Assoc. Suisse d. Élec.*, 5th November, 1928, pp. 688–694.)

A supplement to the former paper (Abstracts, 1928, p. 525); the special discharge tube and roll film attachment here described, combined with the method of ray deviation discussed in the former paper, complete an apparatus which is suitable for recording atmospheric disturbances or the phenomena of super-tensions in electrical installations. The roll-film gives 300 oscillograms for one vacuum. Specimen records are shown.

OSRAM-HOCHSPANNUNGS-GLIMMLAMPE (Osram High Voltage Glow Lamp).—(*E.T.Z.*, 1st November, 1928, p. 1616.)

This lamp works on voltages up to 1,500 V. It shows a weak light even down to 200 V., and can thus be used as a voltage indicator or measurer, the brightness of the light indicating the voltage.

DIE DEUTSCHE RAYTHEON-RÖHRE (The German Raytheon Valve).—H. Simon and M. Bareiss. (*E.T.Z.*, 1st November, 1928, pp. 1604–1606.)

The two-phase blue-glow rectifier valve developed by the Osram Company is described and illustrated, the return current curves for new and long-used valves are given, together with curves showing the variation of D.C. output voltage with applied A.C. voltage, for 20 and 100 mA. outputs: current-voltage curves; and wave-form curves. Advantages of this form of rectifier over other valve rectifiers (high vacuum: gas-filled hot cathode types) are mentioned, in regard to the absence of a heating winding for the transformer, and to the possibilities of mass production of uniform and long-lived valves.

A GOVERNOR FOR H.F. MACHINES.—(German Patent 461,905, Lorenz, published 2nd July, 1928.)

A disc rotating in a vertical plane carries near its edge the fixed end of a strip-spring lying along an arc, and weighted at a spot near the radius normal to the spring. When this weight moves towards the edge, a contact is closed. When the disc is in such a position that the weight is at the bottom, centrifugal force and gravity are working together to close the contact: when the weight is at the top, gravity opposes the centrifugal force and tends to open the contact. Thus the duration of contact—and therefore the value of the regulating current—is dependent on the number of revolutions per second.

MAINS TRANSFORMER DESIGN: A NEW METHOD OF DESIGN BASED ON ASSUMED DIMENSIONS OF THE IRON CORE: PROCEDURE FOR DETERMINING THE ACTUAL LOSSES IN TRANSFORMERS.—H. B. Dent. (*Wireless World*, 24th October and 7th November, 1928, V. 23, pp. 569–572 and 630–632.)

ÜBER DEN ZUSAMMENHANG ZWISCHEN KORNGRÖSSE UND MAGNETISCHEN EIGENSCHAFTEN BEI REINEM EISEN (The Relation between Grain Size and Magnetic Properties of Pure Iron).—G. T. Sizoo. (*Zeitschr. f. Phys.*, 27th October, 1928, V. 51, pp. 557–564.)

Coercive force and hysteresis work decrease, maximal permeability increases, as crystal-size increases. Remanence, electrical resistance and temperature coefficient are all independent of the size.

MAGNETISCHE HYSTERESIS BEI HOHER FREQUENZ (Magnetic Hysteresis at High Frequencies). —W. Neumann. (*Zeitschr. f. Phys.*, 18th October, 1928, V. 51, pp. 355–373.)

Swedish ribbon-steel and 50 per cent. Fe-Ni alloy are investigated at frequencies up to 2,550 p.p.s.

STATIONS, DESIGN AND OPERATION.

SINGLE WAVELENGTH WORKING: PREVENTION OF INTERFERENCE. (German Patent 462,905, Lorenz, published 21st July, 1928.)

When several transmitters on the same wavelength are controlled by one central station, certain localities suffer from bad reception owing to interference between the various incoming waves. According to the invention, this is remedied by imposing on one or more of the transmitters periodic variations of frequency, phase or amplitude, which follow on one another so rapidly that they do not spoil reception.

RADIOTELEGRAPHIC CENTRE AT ROME (SAN PAOLO). G. Pession and G. Montefinale. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1404–1421.)

The old 250 kW. Poulsen arc (10,750 m.) had a maximum range of 4,500 km. The station now has a 15 kW. valve transmitter using 34 m., a 6 kW. set using various waves, 32–106 m., and a 15 kW. medium wave set (2,250–4,800 m.) for communication with the Mediterranean Sea Stations. The 34 m. wave set gives a 12 hr. continuous winter service with the Far East, an 18 hr. service with Somaliland and practically continuous service with the Dodecanese and the N. African Colonies. It has not been found possible to eliminate the silent zone on the 34 m. wave at short distances from the station. A Beverage aerial is used for reception.

It is stated that after testing various types of receiving sets it was found that the superheterodyne circuit was the best. "For practical purposes, however, a simplified receiver with a regenerative valve in series with an audio-frequency stage through an audio-frequency filter and two stages of amplification was preferred." This set utilised a Wheatstone recorder. In the transmitter, rather serious variations of frequency were found to be greatly dependent on variations of filament voltage. A separate voltage regulator was therefore used for each set. Various forms of transmitting aerial were tried for the short waves, including the old 0.011 mfd. fan-form aerial with a natural wavelength of 3,500 m., and a horizontal aerial 5 m. above the ground. Results were indefinite, one aerial appearing about as good as another.

Die Europäischen Rundfunksender (European Broadcasting Stations). (*E.T.Z.*, 11th October, 1928, p. 1513.)

A list with names, sometimes call-letters, frequencies, wavelengths and powers; and a second list showing the total number of (licensed ?) listeners-in in each country and also the proportion per 1,000 of population, for 1927 and 1928. Denmark and Great Britain head this list with 57 per 1,000, Sweden coming near with 54.7; Germany has only 32.5. France is not given, though France and Sweden possess most stations in proportion to their size and population.

Some Studies of Radio Broadcast Coverage in the Middle West.—C. M. Jansky, Jr. (*Proc. Inst. Rad. Eng.*, October, 1928, V.16, pp. 1356–1367.)

Studies of the field intensities produced by broadcasting stations throughout the States of N. and S. Dakota and Minnesota. The determination of the service area of a broadcasting station on the basis of the field intensities produced throughout the territory involves, among other things, the establishment of a ratio of field intensity to static and interfering intensities which may be considered as determining the border line between satisfactory and unsatisfactory reception. It is also necessary to establish a standard of reliability which can be considered satisfactory. The paper is too short to deal with these points systematically, and is best abstracted by giving some of the most pertinent conclusions. With daylight field intensities of 100 microvolts per metre, the rural or small town listeners feel they are receiving *good* broadcast service; with 50 μV/m, *fair* service; though these values are far lower than would be satisfactory for thickly populated districts where interference from non-radio devices and other sources are more serious. In the region under consideration, not more than 40 per cent. of the sets come within the "good" range of any station. Daylight distribution and signal intensity charts for a few stations are here given, and a map of the distribution of receiving sets showing numbers of rural and urban listeners. A similar map gives the "saturation factor" (ratio of number of sets to number of families, expressed as a percentage), which shows that there is no apparent relationship between such factors and the daylight intensities. The conclusion is that the factor depends rather on the *need* for broadcast service, and that night-time reception is all that the majority of listeners can depend upon. Night-time reception and fading are touched on, and charts for fading on 300–400 m. waves are given. When the more serious limitations imposed by heterodyne interference and lack of power have been removed, fading will probably be the most serious trouble for night service. Failing the ideal plan of utilising a given channel by operating a sufficiently large number of synchronised stations scattered throughout the entire nation, all carrying the same programme, the author advocates the same idea on a localised scale.

GENERAL PHYSICAL ARTICLES.

The Physics of the Universe.—J. Jeans. (*Nature*, 3rd November, 1928, V. 122, pp. 689–700.)

The first Wills Memorial Lecture of the University of Bristol. The review of recent additions to our knowledge leads up to an exposition of the lecturer's belief as to the ultimate fate of the universe. "There can be no creation of matter out of radiation, and no reconstruction of radioactive atoms which have once broken up. The fabric of the universe weathers, crumbles, and dissolves with age, and no restoration or reconstruction is possible. The second law of thermodynamics compels the material universe to move ever in the same direction along the same road, a road which ends only in death and annihilation." (*Cf.* Millikan and Cameron, Abstracts, 1928, p. 691; whose contrary theories are referred to and rejected in the present lecture.)

The Cosmic Rays. (*Nature*, 10th November, 1928, V. 122, p. 746.)

Deals with Millikan and Cameron's paper in the October, 1928, *Physical Review* (Abstracts, 1928, p. 691). The writer concludes "It is noticeable that Professor Millikan and Dr. Cameron do not consider here why the most favoured condensations of protons and electrons should be those which go to build up the few nuclei which are actually found to constitute the greater part of ponderable matter."

Experiments on Supraconductors.—W. J. de Haas. (*Elec. Review*, 21st September, 1928, V. 103, p. 497.)

Abstract of paper read at the last British Association Meeting.

Evidence of the Presence of Protons in Metals.—A. Coehn. (*Journ. Franklin Inst.*, November, 1928, V. 206, p. 674.)

Summarised description of an experiment in which hydrogen, diffused in a palladium wire, is shown to yield protons which can be driven backwards and forwards along the wire by an electric current.

Electric Conductivity and Optical Absorption of Metals.—E. H. Hall. (*Proc. Nat. Acad. Sci.*, October, 1928, V. 14, pp. 802–811.)

The known facts of the optical behaviour of metals are used to condemn both the Lorentz and the Sommerfeld Theories of Conduction; whereas they fit in with the writer's "dual" theory—that the current is maintained in part by free electrons sharing the energy of heat agitation, but mainly by an interchange of electrons in encounters between atoms and positive ions.

La Cristallisation des Substances Mésomorphes dans le Champ Magnétique. Obtention d'un Solide à Molécules Orientées (Crystallisation of mesomorphic Substances in a Magnetic Field; the obtaining of a Solid with oriented Molecules).—G. Foëx. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 822–823.)

A special process is described which prevents the orientation being lost as the substance crystallises out. *Cf.* Cabannes, Abstracts, 1928, p. 691.

On the Penetration of an Electric Field through Wire-gauze.—W. B. Morton. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 795–801.)

Results of various workers in investigating mobilities of gaseous ions have differed rather widely, and one suggested cause of error is that the steady electric field used for pushing the ions through the partition of wire gauze, and the alternating field on the other side of the gauze, interpenetrate each other through the meshes. The present note examines such inter-penetration as a mathematical problem, to find an upper limit to this source of error. The conclusion is that the effect only changes the travel of the ion by an amount comparable with the spacing of the gauze; so that inter-penetration of the fields seems to be an unimportant cause of error.

Some Remarks concerning the Production and Absorption of Soft X-Rays and Secondary Electrons.—E. Rudberg. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121, A., pp. 421–432.)

The writer estimates the efficiency of the production of photoelectrons from metals by soft X-rays. No suggestion is made as to the nature of the process by which part of the energy of the primary electron would be transferred to a free electron of the conductor, but the writer refers to a paper by O. W. Richardson (Abstracts, 1928, p. 525), according to which this transfer involves the interaction of radiation. It seems that the adoption of this view will remove the most obstinate difficulties of the auto-photoelectric theory of thermionic emission and chemical reactions in general.

Theorie der Beugung von Electronen an Kristallen (Theory of the Diffraction of Electrons at Crystal Surfaces).—H. Bethe. (*Ann. d. Physik*, 5th October, 1928, No. 1, V. 87, pp. 55–129.)

Über die senkrechte Ablenkung langsamer Elektronen an Gasmolekülen (The Deflection at Right Angles of Slow Electrons by Gas Molecules).—R. Kollath. (*Ann. d. Physik*, 5th October, 1928, V. 87, No. 2, pp. 259–284.)

MISCELLANEOUS.

Method for Discovering Leaks in Glass Vacuum Apparatus.—P. Selényi. (*Zeitschr. f. Phys.*, No. 9/10, 1928, pp. 733–734.)

A method depending on the different coloured glows produced by Tesla currents in CO_2 and air. Thus if the vacuum apparatus contains air at low pressure and a current of CO_2 is passed over the suspected portions of the exterior, the glow produced by Tesla currents changes at the leaks from the red glow of the air to the bluish-white glow of the CO_2.

Conference of Australian Physicists at Canberra. (*Nature*, 10th November, 1928, V. 122, p. 747.)

Among other speakers, Professors Madsen and Laby contributed to a discussion on radio research in Australia; emphasis was laid on the need for pure research, and the suggestion was made that some fraction of the broadcasting revenue of a quarter of a million sterling should be set aside for this purpose. Dr. Beiler described the methods of prospecting now being tested in the field in Australia. Major Booth discussed the seismic method and described experiments on earth waves detected with a modification of the Tucker microphone.

Heating, Volatilisation and Atomisation by Heavy Electric Currents. (*Engineering*, 26th October, 1928, V. 126, p. 542.)

Summary of a Tokio paper entitled "Electric Explosions." The discharge from a condenser charged to 40 kV. was passed through wires of various materials and threads of mercury. Currents of 10^6 amperes per sq. cm. were used in some cases where the wires were kept under oil. In these latter experiments the transmutation of the metal was looked for but without success.

Secrecy in Radio Telephony. (*Scient. American*, June, 1928, p. 545.)

Photograph of part of a device which converts the speech at the transmitter into gibberish which is translated at the receiver. Demonstrated before the Engineers' Society.

Electrical Prospecting.—J. J. Jakosky. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1305–1355.)

Of the various types of electrical methods, some of which utilise natural earth currents, others direct or A.C. applied earth currents, and still others electromagnetic induction, the last has at present the widest application and is the one dealt with in this paper. The scope of the paper is indicated by some of the sub-headings: the Occurrence of Ores; Field of Application for the Electrical Methods (generally speaking, the difference in conductivity between the mineralised area and the surrounding envelope should be at least 100 to 1: it is often as much as 1,000 or even 10,000 to 1); Magnitude of Induced Voltage; Factors Affecting Current Flow; Impedance of Disseminated Ores; Impedance of Faulted Zones; Detection of Current Flow in a Conductor (direction-finding coil is best); "Sharpness" of Maxima and Minima; Operating Conditions; Effects of Phase Shift between Primary and Secondary Fields; Relationships between Depth and Length of Ore-body; Length of Ore-body (the change in energising frequency from low—1,000—to high—50,000 cycles or more—furnishes considerable information as to the structure of the body); Determining Depth of Conductor by Curve; Field Procedure during Detailed Survey;

Distortion of Primary and Secondary Fields; Phantom Dips; Effects of Frequency; Description of Energising Apparatus; Direction-finding Apparatus; Field Operating Conditions; Personnel of Crews; Interpretation of Field Data; Corrections for Topography and Dipping Conductor.

GEOPHYSICAL PROSPECTING.—A. S. Eve and D. A. Keys. (*Scient. American*, June, 1928, pp. 508–511 and 561.)

Reprinted from the Bureau of Mines paper referred to in Abstracts, 1928, p. 528.

GEOPHYSICAL EXPLORATION. (*Engineer*, 2nd November, 1928, V. 146, p. 487.)

A paragraph on the reported application by the American petroleum industry for licences for a number of short-wave transmitters. The method used for locating oilfields is to measure the lag between sound transmission and wireless: the velocity of the sound waves being affected by the presence or absence of salt formations which generally accompany oil deposits.

ELECTRIC ORE AND OIL DIVINING. (*Electrician*, 9th November, 1928, V. 101, p. 515.)

A paragraph dealing with the work now being done by about forty Swedish engineers, geologists, and their working crews, in different parts of the world, in locating "magnetic (*sic*) ore and oil deposits by means of a Swedish invention, the electrical prospector"; invented by Landberg and Sundberg, who were awarded the gold medal of the Royal Swedish Academy of Engineering Science. The method appears to be a resistance method, and it has successfully worked on copper and on oil deposits. No details are here given.

CONTINENTAL DRIFT.—A. Holmes. (*Nature*, 22nd September, 1928, V. 122, pp. 431–433.)

A review of a "symposium on the origin and movement of land masses, both inter-continental and intra-continental, as proposed by Alfred Wegener." (*See also* J. Vivié, Abstracts, 1928, p. 590.)

A SUGGESTED EXPLANATION OF THE CRYSTAL DETECTOR: RECTIFICATION PHENOMENA MAY BE TRACED TO PIEZO-ELECTRIC ACTION.—F. Regler. (*Wireless World*, 7th November, 1928, V. 23, p. 629.)

Summary of Regler's theory of the contact detector, from the *Physikalische Zeitschrift*.

LUMINOUS CARBORUNDUM DETECTOR AND DETECTION EFFECT AND OSCILLATIONS WITH CRYSTALS.—O. V. Lossev. (*Phil. Mag.*, November, 1928, V. 6, No. 39, pp. 1024–1044.)

Two types of luminescence, I and II, occur at a carborundum-steel-wire contact on the passing of suitable currents. Type I has a greenish-blue colour which is constant. Type II changes from orange to violet with change of P.D. from 6 to 28 V. (taking one crystal as an example—other crystals, or even other points on the same crystal, show corresponding but different changes). Rectification takes place in the same direction as that which increases Type I, but in the opposite to that which increases Type II. It is concluded that the unilateral conductivity of the carborundum contact is closely connected with its luminescence, and that the latter is a consequence of a process very similar to the cold electronic discharge. The carborundum substance does not produce thermoluminescence, hence the cause of the luminescence is *not* a Joule effect at the contact: only the colour change of Type II is due to the Joule effect on the fluorescence produced by the luminescence. The inertia both of beginning and cessation of luminescence is very small, hence the phenomenon can be used as a Light relay. Frequencies up to 78,500 p.p.s. do not blur the flashes. The brightness can be made enough to record perfectly an A.C. of about 500 p.p.s. on a moving photographic plate. The R.M.S. value of the current here used was 0.24 A. The paper deals also with the use of oscillating crystals, particularly zincite, for reception of short waves down to 24.3 m.

BROADCASTING BY WIRED WIRELESS: THE UNDERLYING PRINCIPLES OF THE SYSTEM FULLY EXPLAINED: METHODS OF DISTRIBUTING SIGNALS TO SUBSCRIBERS' LINES.—O. F. B. (*Wireless World*, 14th and 21st November, 1928, V. 23, pp. 677–679 and 698–700.)

Although "carrier" systems for extending the use of existing telephone circuits, and also for communication and control along high voltage power lines, are being used a good deal in America and Central Europe, their use for broadcasting has been limited to a few isolated experiments. But the Western Electric Co., of America, have worked out in detail, and patented, a complete system for the purpose. In view of the increasingly overcrowded state of the ether, the writer suggests that wired-wireless may later become a useful adjunct to ordinary broadcasting. After a general consideration of the problem, the paper discusses the patented system named above.

EIN NEUES SYSTEM FÜR WECHSELSTROMMEHRFACHTELEGRAPHIE (A new System for Multiplex A.C. Telegraphy).—M. Wald. (*E.N.T.*, October, 1928, V. 5, pp. 391–398.)

The system has been tested in Austria and is being adopted by the Administration of Telegraphs. For ordinary speeds (Hughes' apparatus) a difference of 50–60 cycles between two adjacent carrier-frequencies is enough, so that in the band of about 1,900 cycles available in Pupinised cables, about thirty separate frequencies can be utilised. For higher speeds the gap need only be increased to an unimportant extent.

DIE KETTENLEITER IN DER UNTERLAGERUNGSTELEGRAPHIE (Filter Chains in Telegraphy imposed on Telephone Lines).—Ch. Wisspeintner. (*E.N.T.*, October, 1928, V. 5, pp. 382–390.)

Multiplex A.C. telegraphy uses the frequency-zone employed in speech. For imposing telegraphic communication on telephone lines, on the other hand, frequencies from 0 to 50 cycles per sec. are used, in the so-called "under-imposing" (unterlagerungs) telegraphy. The paper deals with such a system in general, and in particular with the requirements and values of the necessary filters.

Some Recent Patents.

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

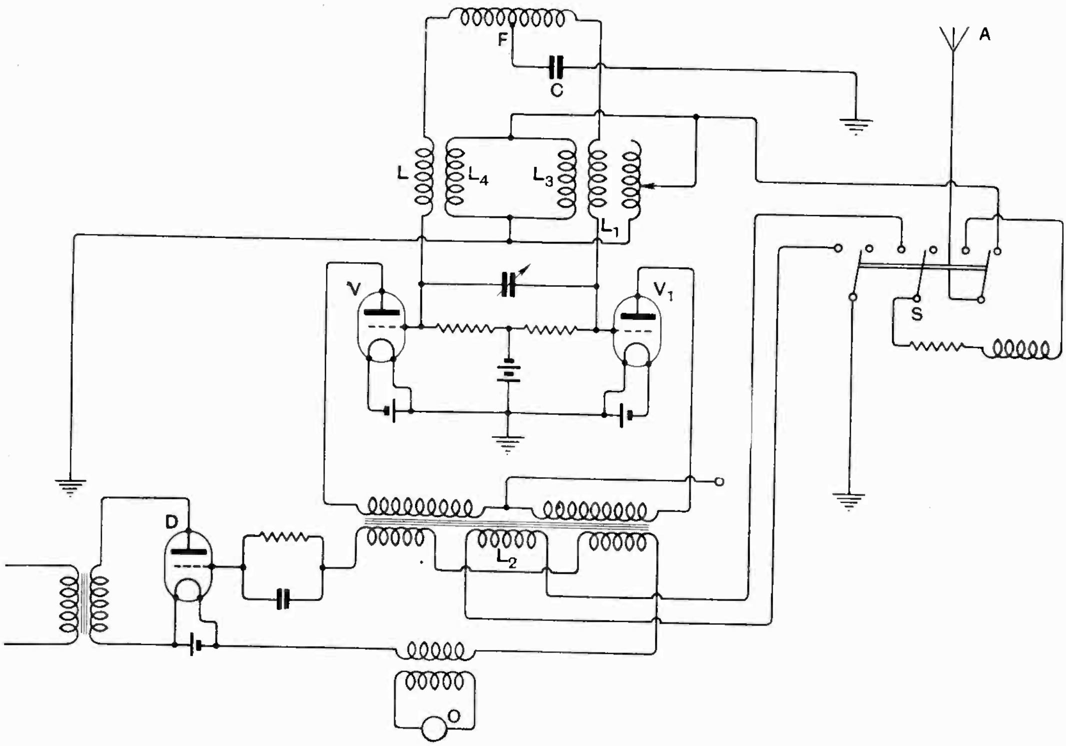
DIRECTION-FINDING.

(*Convention date* (*U.S.A.*), 29*th April*, 1927. *No.* 289490.)

When a rotating-loop D.F. installation is used aboard a ship, the presence of metallic structures such as iron masts, funnels, stays, etc. induces out-of-phase voltages in the receiving-aerial which tend to blur the sharpness of definition of the critical maximum and minimum points. This effect is to be distinguished from the so-called quadrantal error, which is due to in-phase induction, and causes a distortion of the incoming wave-front.

received on the aerial A is fed to a coil L_2 couple to the output from the valves V, V_1, which feed the detector D of a superheterodyne receiver supplied with local oscillations from a source O. This serves to remove the "sense of direction" ambiguity. In the right-hand position of the switch S, the pick-up from the aerial A is fed to coils L_3, L_4, the coupling of which with the input coils L, L_1 is then so adjusted as to compensate for any lack of definition in the "bearing" readings due to mast effect.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.



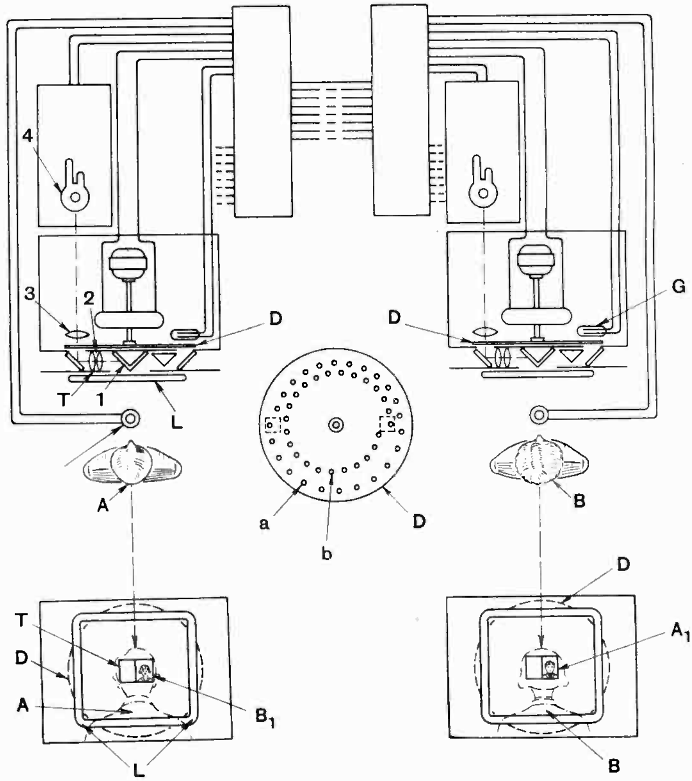
The Figure shows an installation in which provision is made to correct for the above-mentioned "mast effect," and also to remove the well-known 180° "sense" ambiguity. The directional frame-aerial F is earthed at its mid-point through a condenser C, and is connected through coils L, L_1 to two push-pull valves V, V_1. A non-directional aerial A is also connected through a switch S to the valve circuits.

In the left-hand position of the switch S, energy

TELEVISION APPARATUS.

(*Application date*, 17*th June*, 1927. *No.* 297152.)

A combined telephony and television system is so arranged that a person A at one end of the line is not only able to see the distant person B to whom he is speaking, but is himself "scanned" by local apparatus so that his image is transmitted to the distant end of the line. As the subscriber A speaks into his microphone, his features are framed and illuminated by a mercury-vapour lamp *L*. The reflected rays are projected through an aperture *T* on to a mirror 1 and are then focussed by lenses 2 and 3 on to a light-sensitive cell 4, by which



corresponding current-variations are sent to line. These are subsequently reassembled to control the luminosity of a lamp *G* at the distant station and so form an image A_1.

A scanning disc *D* is interposed between the illuminating lamp *L* and the photo-electric cell 4. The disc *D* has two separate series of spirals *a*, *b*, as shown in the detached Figure. One spiral serves for analysing the outgoing image through the transmitting orifice *T*, whilst the other synthesizes the incoming picture-signals and projects the received image B_1 on the local viewing-screen. The two stations are connected by four wire channels, one channel serving for two-way speech, a second for outgoing picture signals, a third for incoming picture signals, whilst the fourth carries the necessary synchronising currents.

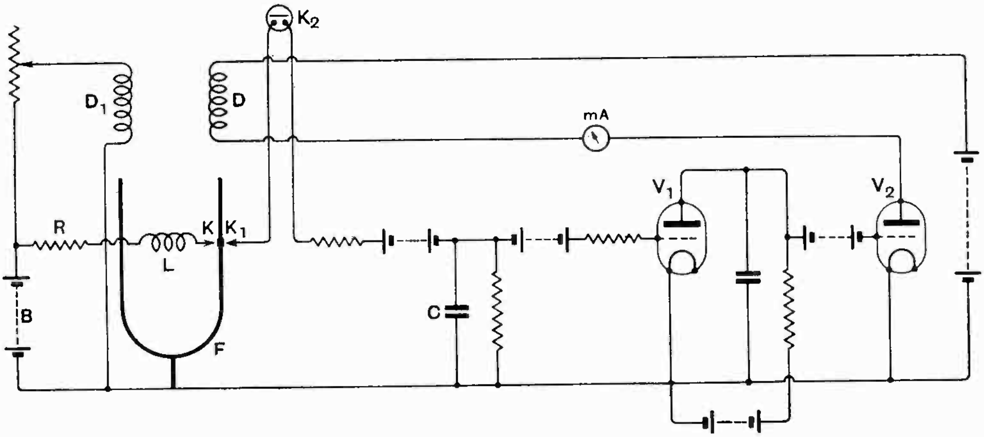
Patent issued to W. E. Beatty (Bell Telephone Laboratories, Inc.)

FREQUENCY STABILISERS.

(*Application date, 27th June, 1927. No. 297762.*)

When a master-control such as a tuning-fork is used to stabilise a valve generator, there is a tendency for a slow periodic " drift " to occur which is particularly difficult to remedy. In order to correct this tendency the frequency of the fork is arranged to be supervised by a chronometer and periodically corrected when necessary.

The fork *F* is maintained in oscillation in known manner by means of an energising coil *L* fed from a local battery *B* through a resistance *R* and an intermittent contact *K*. A second contact K_1 on the vibrating fork-leg controls a circuit containing another pair of contacts K_2, which are closed at regular intervals by a chronometer or other guaranteed time device. So long as the period of the tuning-fork remains absolutely constant, the time interval during which both contacts K_1 and K_2 are simultaneously closed will be a certain definite fraction of a second, and will occur say every 30th



vibration. During this time the grid bias applied to the valves V_1, V_2 will be such as to cause a definite value of current to flow through a damping coil D. Should any frequency "drift" occur in the fork, the "coincidence" interval of the contacts K_1, K_2 will vary. The discharging action of the condenser C then modifies the average grid-bias applied to the valve V_1, and the current in the damping or control coil D is corrected accordingly. A second damping coil D_1 may be provided as shown.

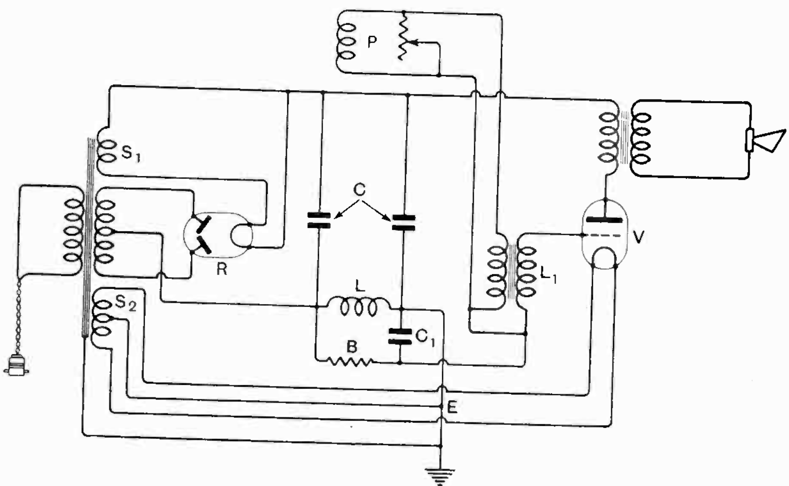
Patent issued to J. A. Smale.

BIASING POWER-AMPLIFIERS.

(*Convention date* (*U.S.A.*), *22nd July*, 1927. *No.* 294250.)

In order to economise power and save voltage-drop, grid bias is derived from one of the impedances in the smoothing-circuit of the eliminator unit, instead of being tapped off from a resistance shunted directly across the plate and filament of the valve as usual. The figure shows an amplifier valve V feeding a loud speaker from an electric pick-up P.

The plate supply is taken from a full-wave rectifier, whilst the filaments of both amplifier V and rectifier R are heated by AC current from the secondaries S_1, S_2. The usual smoothing-circuit is shown at L, C. It will be seen that the secondary S_2 is earthed, as is also one end of the filter inductance L, the latter being shunted by a resistance B and a condenser C_1. The grid-filament circuit therefore comprises the input coil L_1, resistance B, and inductance L to earth. The normal current



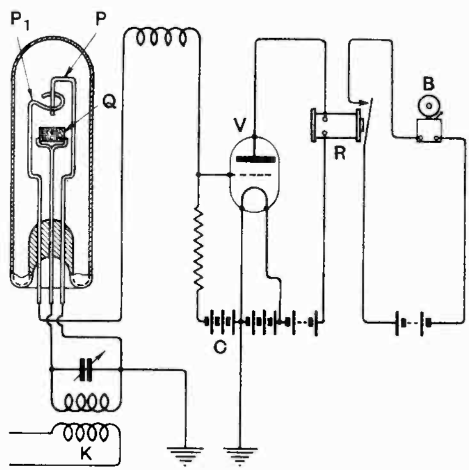
flowing through the coil L accordingly produces a voltage drop across its ends which serves to bias the grid.

Patent issued to The British Thomson Houston Co., Ltd.

SELECTIVE PIEZO-ELECTRIC DEVICES.

(*Convention date* (*U.S.A.*), *3rd January*, 1927. *No.* 283113.)

It is known that if a piezo-electric crystal is immersed in an atmosphere of neon, argon, or other readily-ionised gas at low pressure, a glow occurs when oscillations of fundamental frequency are applied across the crystal. Simultaneously owing



to ionisation the surrounding gas becomes conducting. This effect is utilised to secure a highly-sensitive indication of an applied frequency change.

A crystal of quartz Q is mounted in a glass bulb in close proximity to an electrode P. A second electrode P_1 is coiled closely around the first but without actually touching it. A connection is taken from the electrode P_1 to the grid of an amplifier, in the output current of which is a relay R operating an alarm bell B or other signal. Normally a paralysing bias is applied to the grid of the amplifier from a battery C.

When the frequency in the circuit K reaches a certain critical value, the piezo crystal Q glows, and the air inside the bulb is rendered conductive. This in effect connects the electrode P_1 to the electrode P, and so opens a relief path to ground for the negative charge on the grid of the amplifier V. The relay R thereupon sounds the alarm B.

Patent issued to the Metropolitan Vickers Electrical Co., Ltd.

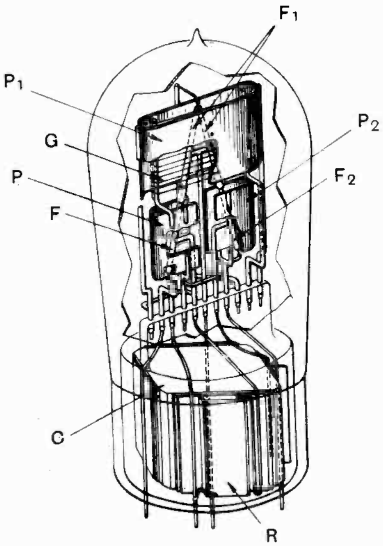
A MAINS-FED VALVE.

(*Application date*, *21st July*, 1927. *No.* 298296.)

Relates to a self-contained valve which is intended to be supplied directly from alternating-current mains. It comprises a rectifier-unit, and a current-limiting or smoothing device for supplying rectified current to the plate, together with a special smoothing-condenser and voltage-reducing resistance, all housed inside the same glass bulb.

The V-shaped cathode is divided into three parts F, F_1, F_2, of which the upper part F_1 co-operates with a grid G and plate P_1 to form an amplifying unit, whilst the two lower portions F and F_2 co-operate with plates P and P_2, which serve as current-limiting and rectifying devices respectively.

The filament consists of a spiral wire of suitable resistance to take the full mains-voltage. The wire is surrounded first by a quartz tube and then by a tube of nickel or tungsten coated with electron-emitting oxides of barium, thorium, etc. A smoothing-condenser C is housed inside the turned-up lower flange of the glass tube. The raw AC supply current is first rectified across the filament section F_2 and plate P_2 and then passes to the unit, F, P,



the saturation effect of which acts as a limiter or smoother. The output from the latter is fed to a resistance R from which the rectified voltage to the amplifier plate P_1 is tapped off.

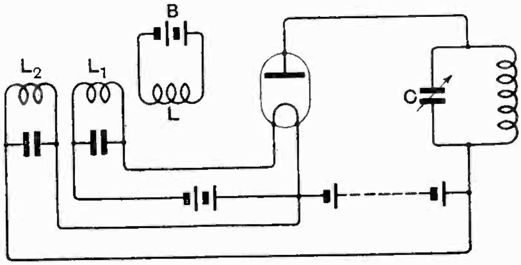
Patent issued to A. Mavrogenis.

CONSTANT-FREQUENCY OSCILLATORS.

(*Convention date (Germany), 24th June,* 1927. *No.* 292584.)

In the Habann type of valve generator, a negative-resistance effect is produced by the action of an electromagnetic and electrostatic field applied mutually at right-angles across the path of the electron stream inside the tube. The resultant frequency of the generated oscillations tend to vary with fluctuations in the filament and plate voltages, or with the source of supply of the auxiliary magnetic field.

The invention consists in balancing-out any such fortuitous fluctuations and so maintaining an output of unvarying frequency. As shown in the Figure, the auxiliary magnetic field is provided



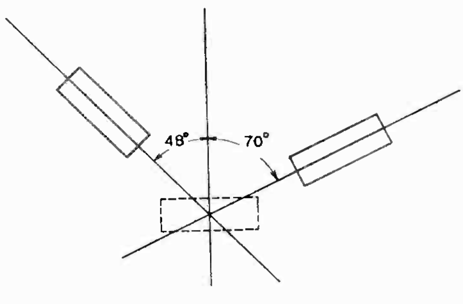
by a battery B and coil L. Associated with the latter are a coil L_1 through which the filament current flows, and a coil L_2 supplied from the high-tension battery. The number of turns and the direction of winding of the coils L, L_1, L_2 are so selected that variations in negative resistance due to any fluctuation in voltage of the several supply batteries mutually cancel one another in their effect upon the electron stream. The generated output is thus determined solely by the tuning of the circuit C.

Patent issued to the C. Lorenz Co., Ltd.

QUARTZ OSCILLATORS.

(*Convention date (Germany), 19th July,* 1927. *No.* 294174.)

As a result of exhaustive research the inventors have ascertained that specially favourable effects can be secured from a crystal cut so that the direction of mechanical oscillation is at an angle either of 70 deg. or 48 deg. to the optical axis. Both these planes have other unique characteristics. For instance the velocity of propagation of sound in the 70 deg. plane is 5,400 metres, whilst in the 48 deg. plane it is 7,700 metres per second. Again in both cases the crystal structure is particularly



regular. Piezo crystals so cut show optimum oscillation properties, and are very sensitive to excitation at their natural frequencies.

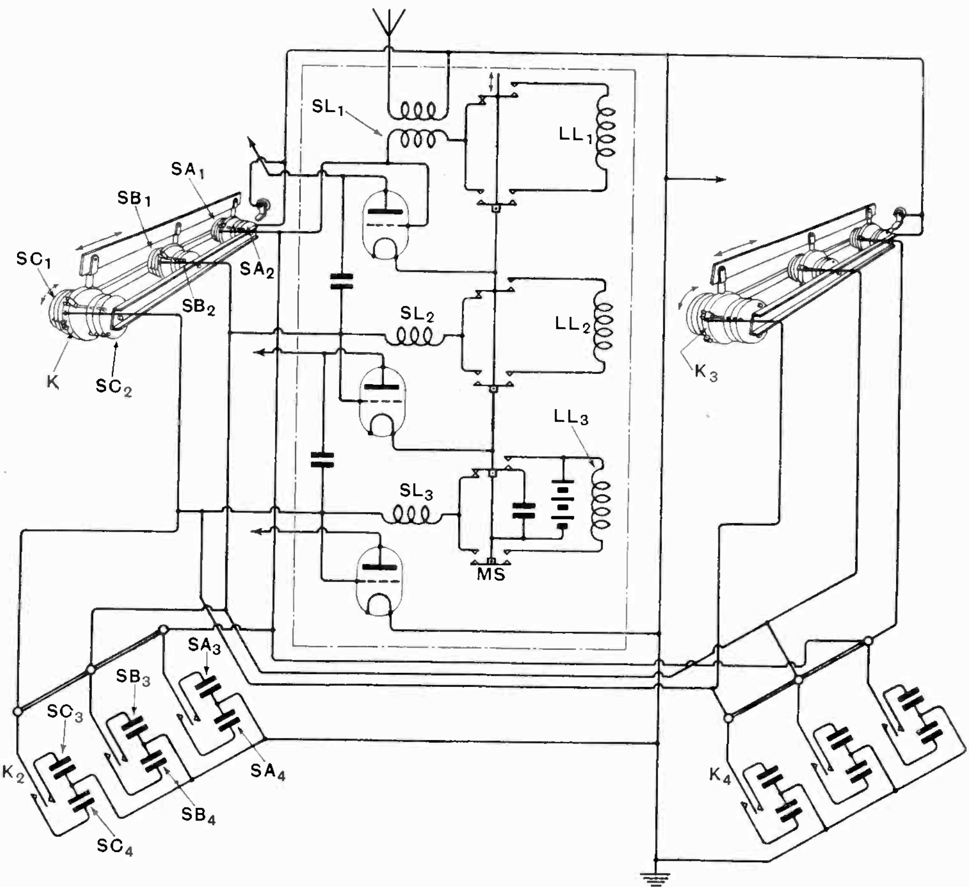
Patent issued to the Telefunken Co., Ltd.

SWITCH-CONTROLLED RECEIVERS.

(*Application date, 23rd September, 1927. No. 295849.*)

The input and tuned intervalve-circuits of a multi-stage high-frequency broadcast receiver are so arranged that selective reception from any one of at least eight different programmes can be secured by the simple operation of tumbler switches. The available stations are so distributed that four are brought in on the short-wave position of a main change-over switch *MS*, and the other four on the long-wave position. In the latter position the loading coils LL_1, LL_2, etc., are inserted in series with the short-wave inductances SL_1, SL_2, etc.

Banks of semi-fixed condensers SA_1, SA_2 . . . SC_4 are so introduced in conjunction with the inductances SL_1, SL_2, SL_3 that, according to the setting of the three-position tumbler switches *K*, K_1, the whole of the inter-valve circuits are simultaneously set to receive one or other of four different short-wave broadcasting stations. The suffixes *A*, *B*, *C* correspond to the different valve stages and the suffixes 1, 2, 3, 4 to different wavelength transmissions, whilst *S*, *L* represent the short and long wave components respectively. A similar arrangement of condensers and switches K_3, K_4 on the right-hand side of the figure enables any one of four different long-wave programmes to be selected.



Patent issued to the British Radio Corporation.