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FIELD STRENGTH MEASUREMENTS OF SHORT WAVE TRANSMISSIONS

The following analysis of the results of a series of systematic measurements of Short Wave signal intensities, made at the Research Laboratories of the Marconi Wireless Telegraph Company at Chelmsford, covers the period October, 1930—*January,* 1931.

THE measurements were made with the type 205 signal measuring apparatus described in THE MARCONI REVIEW (May, 1929).

Checks of the performance of the apparatus were also described in the same article, and it is hardly necessary to comment further on this, other than to state that a comparison was made with apparatus used by the Post Office (Designed by Friis of the American Telegraph and Telephone Company Limited), and agreement within about 10 per cent. (on the average) was obtained.

The stations chosen for observation were as far as possible those with well defined C.W. carriers, *i.e.*, telephone stations (working regularly) and multiplex beam stations.

With such stations it is easy to match the heterodyne note of the signal with that of the auxiliary oscillator in the signal apparatus. For completeness the Marconi beam stations, India and Australia, were included, although they have a modulated note and are consequently more difficult to measure. The following is a list of the stations systematically observed.

TABLE I.

STATION.	APPROXIMATE WAVELENGTH.	NATURE OF TRANSMISSION.
Java (Bandoeng)	14·5 metres	Telephone
Buenos Aires	15·2 ,,	,,
Java (Bandoeng)	16 ,,	,,
Cape Town	16·08 ,,	Multiplex Telegraph
Poona	16 ,,	Modulated C.W.
New York	16·4 / 20·7 ,,	Telephone
Melbourne	25·7 ,,	Modulated C.W.

Station.	Approximate Wavelength.	Nature of Transmission.
Rugby	27·8 ,,	Telephone
Sydney	28·6 ,,	,,
Montreal	32·1 ,,	Multiplex Telegraph
Bodmin GBK	32·3 ,,	,, ,,
New York	32·5 ,,	Telephone
Cape Town	33·7 ,,	Multiplex Telegraph
Bodmin GBJ	34 ,,	,, ,,
Grimsby	34·2 ,,	Modulated C.W.
Poona	34·5 ,,	,, ,,

In November the following were added—

New York	44·41 metres	Telephone
Rugby	43·45 ,,	,,

In February—

Cairo	21·7 metres	Modulated C.W.

In general during the winter months, two eight hour watches were kept from 0800 to 2400 G.M.T. for 3 weeks in the month and a night watch for the remaining week.

In taking an observation a record (on a recording millimeter) was usually run for a few minutes and was calibrated by means of the signal measuring apparatus. In giving a numerical value to the strength, the usually rather well determined peak values were used. Mean values could be obtained from the records, but the labour would be excessive and probably hardly justified.

Some of the observations for the months October, November, December, January, are plotted in the accompanying figures, 1—12 inclusive.

It will be observed that the scatter of the points is excessive on the results obtained from Montreal and New York where the routes pass close to the north magnetic pole and the results are subject to great variations on account of magnetic disturbances. It is no rare thing to find a variation of 100 to 1 in signal strength from day to day (at a given time) on these routes.

The scatter of the observations of the South African signals is very much less and may be associated with the fact that this service is relatively free from magnetic effects. (See curves A and B) (Fig. 16).

The excessive variability is confined to the stations New York 16·4 m., Montreal 16·5 m., New York 20·7 m., Montreal 32·1 m., in fact to the America route. For such observations it is very difficult to give any significance to the monthly averages which have been plotted in each case. But for the purpose of the analysis of the results some definitive figures must be given and the average, being the simplest representative figure, was taken.

In certain cases the diurnal intensity curve predicted from shadow charts* is included as a check on the accuracy of such predictions. For this purpose the predicted R strengths have been translated into microvolts per meter.

An approximate relation (over a limited range up to R9) between R strength and field strength has been obtained and this relation is exhibited in the curve (Fig. 13).

The charts and this relation have been used to compute the predicted curves. It will be found that there is a fair agreement, thus justifying the method, and by inference the theoretical considerations, on which the charts were based.

During the months considered, the month-to-month variation of the average signal strength was not great except for Montreal and New York. Thus the mean strength on Montreal increased nearly tenfold between October and November, and although the mean value for December was not quite up to the November level, a high level, compared with the October one, has been maintained ever since. The gain in the New York signals between October and November is not so marked, being 4 or 5 to 1, but is still very significant. This change might be a seasonal one, but in the opinion of the author, is probably due to magnetic disturbances. Nine days of magnetic storms were reported in October, one very considerable storm being recorded on October 17th, and only four in November.

The average signal intensity depends probably more on the frequency of minor disturbances than those great enough to be reported as magnetic storms and there is no doubt that October was a very disturbed month in this respect. The fact that only the American routes were largely affected seems to point to magnetic activity as the cause of the low level of such signals.

Variations with Magnetic Cycle.

In comparing the results obtained in these few Winter months in 1930-31, with those obtained qualitatively in the same months of 1927 (R strength observations), the most striking difference is in the behaviour of the 30 m. night transmissions over the transatlantic route.

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* A description of these charts and their use was given in a paper entitled "World Wide Communications with Short Wireless Waves," by T. L. Eckersley and K. W. Tremellen, read before the World Engineering Congress, held at Tokio in October, 1929, and in an abstract of this paper published in the MARCONI REVIEW for February 1930.

Whereas in 1927—1928, signals on this wavelength were generally maintained at a commercial level throughout the night, in 1930—1931 signals dropped to such low values after midnight that they became useless for traffic, and longer waves were found to be necessary. On the other hand there have been indications that the daylight attenuation on wavelengths of the order of 25 to 50 metres decreased on the North Atlantic routes.

It appears possible that gradual changes in short wave transmission have been occuring since 1928.

Perhaps these results may be taken as evidence of a cyclic change associated with the eleven year sunspot or magnetic cycle. The year 1928 was near a sunspot maximum. Although the evidence cannot be considered in the least conclusive, the changes are such as might reasonably be expected if this were the case.

Attenuation.

Although these results cover a very considerable ground, it will be found that if predictions are required for other services, there are always differences in geographical conditions, which make it difficult to apply any one of the results without some degree of interpolation. From a purely practical point of view, some sort of theory to connect up the isolated observations into a continuous body of doctrine is necessary in order to enable one to generalise with some degree of confidence from the limited amount of material available.

Assuming that long distance short wave transmission takes place in the region between the earth and the Heaviside layer, we have to enquire how such factors as the amount and distribution of electronic density in the Heaviside layer, the collision time, etc., affect the transmission characteristics. In a recent paper the writer has shown that whatever the type of layer, the received intensity, at distances large compared with the skip distance, consists of terms of the type

$$\frac{A}{\sqrt{\sin\theta}}\, e^{-\alpha_r d} \sin\left(\frac{2\pi l_r d}{\lambda} - 2\pi v t\right)$$

where α_r the attenuation constant, and l_r the direction cosine of the ray depend on the constants and distribution of electronic density in the upper layer.

d is the distance measured along the earth's circumference from transmitter to receiver and θ the angular separation of the two stations, so that $d = R\theta$, R being the earth's radius. v is the frequency.

The facsimile experiments described by the author in the Proceedings of the Institution of Radio Engineers (Vol. 18, No. 1, January, 1930), enable one to particularise this formula a little more closely, at least for the type of transmission disclosed by these experiments.

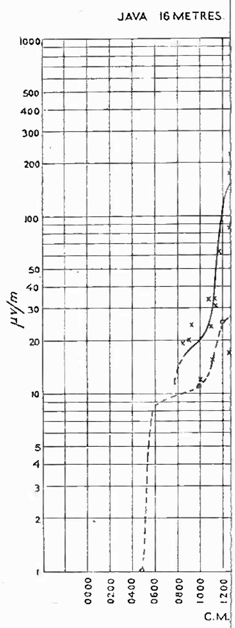

Fig.

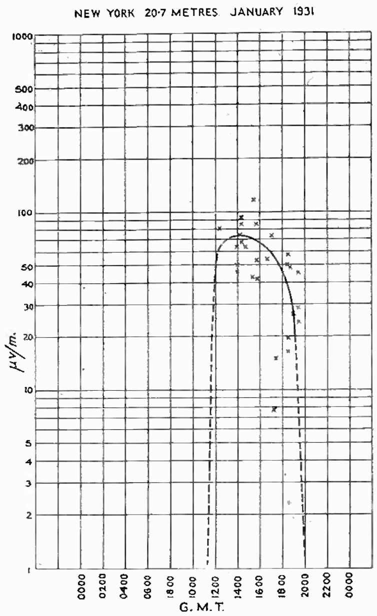

Fig. 6.

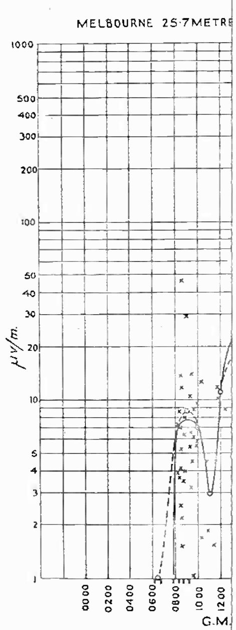

Fig.

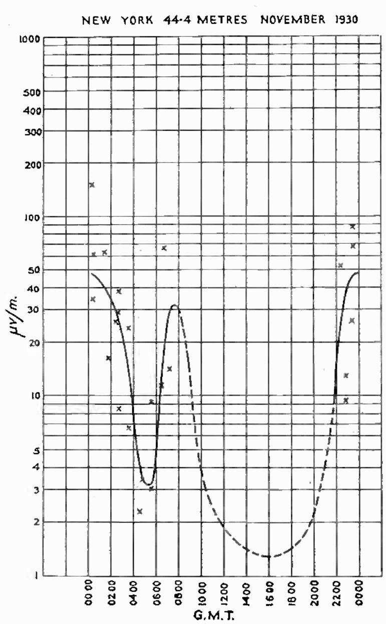

Fig. 12.

The experiments described indicate that on this wavelength and route, *i.e.*, 22 m. on the New York—Somerton route, the transmission is carried out by the rays usually 4 or 5 in number refracted (fairly sharply) at a height of about 340 km. in a region where the electronic density is about 9×10^5 (see Fig. 14). These rays pass, with very little bending through the lower layer at the height of 90 to 100 km. above the earth's surface (N about 10^5). In this region collisions between electrons and ions are so frequent that considerable attenuation ensues. From the experimental results it appears that the attenuation is much the same for all rays, a conclusion which follows theoretically if we integrate the attenuation along each path.

There is no definite phase relation for the phases of the EMF's of such rays, and we must, according to Rayleigh's law, add up the energies of each ray.

Now the energy of each ray is $\frac{(3\pi)^2 W}{(R \sin\theta)^2} e^{-2\alpha_r d}$

W = power radiated and the total received amplitude is

$$E = \left\{ \sum_{r=1}^{r=n} \frac{(3\pi)^2 W e^{-2\alpha_r d}}{(R \sin\theta)^2} \right\}^{\frac{1}{2}}$$

If α_r is the same for all the rays this is

$$E = \frac{3\pi\sqrt{Wn}}{R \sin\theta} e^{-\alpha_r d}$$

Now n can be expressed in terms of the skip distance. In the simple theory outlined above n is approximately the ratio of d the total distance, to d_0 the skip distance

i.e.,
$$E = \frac{\sqrt{R\theta}}{\sqrt{d_0}} \frac{3\pi\sqrt{W}}{R \sin\theta} e^{-\alpha d} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

In order to conform with the form (1) we write R sin θ for Rθ and obtain

$$E = \frac{3\pi\sqrt{W}}{\sqrt{d_0 R \sin\theta}} e^{-\alpha d} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

If a beam is employed of magnification M, E will be increased M fold and the final simplified formula is

$$E = \frac{3\pi\sqrt{W_1} M}{\sqrt{d_0 R \sin\theta}} e^{-\alpha d} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

For this type of layer, as explained in the facsimile paper, α should be proportional to λ^2.

The observations obtained are compared with the numerical values derived from this formula, in order to see how far actual conditions conform to the rather idealised conditions assumed (see Table II.).

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For this type of layer, as explained in the facsimile paper, α should be proportional to λ^2.

The observations obtained are compared with the numerical values derived from this formula, in order to see how far actual conditions conform to the rather idealised conditions assumed (see Table II.).

For this purpose we have to make an estimate of W the power radiated in each case, and M the magnification factor. In general for long distance transmission quite considerable changes in the assumed values of W and M will make but little difference to the final calculated value of α, so that an accurate estimate of them is not required.

The only unknown quantity in the formula is the equivalent attenuation coefficient α, and by comparison with experiment this value can be found.

This is shown in the final column and for convenience the value αd, for 10,000 km., which in round numbers is of the order of 5, is given.

Confining our attention to daylight attenuation in the A and B grades,* and excluding New York and Montreal in October as abnormal, we find that the value of αd does not vary over a large range. The following table shows this.

TABLE II.

STATION.	λ	MONTH.	αd	GRADE.
Buenos Aires	15·2	October	4·38	A – AB
		November	4·19	A – AB
Cape Town	16·08	October	5.45	all A except 1,000 km.
		December	5·07	A – AB
		October	<u>2·37</u>	B
		December	<u>3·30</u>	
New York Phone ..	16·45	November	4·03	B
		December	5·94	B
Poona	16	October,		
		November	5·26	A – AB
		December	5·66	AB – B
Montreal	16·5	November	5·01	B
		December	5·70	B
New York	20·7	November	4·47	B
		December	6·25	B
Montreal	32·1	January	<u>8·7</u>	B

It will be seen that the values only vary between 4·03 and 6·25 (except for Montreal on 32·1 m. and South Africa in the B Grade).

In attempting to find the attenuation law the difficulty lies in the insufficiency of the material. Thus not only is it difficult to find a long distance route (which is required for satisfactory determination of α) all in one grade, but it is next to impossible to find such a route on which there are observations on widely separated wavelengths.

The only cases are those of Montreal and New York on 16, 20·7 and 32·1 metres respectively.

* Grades of shadow density in charts referred to on page 3.

We can also compare South Africa in B grade (λ16 m.) with Montreal in the same grade on 32·1 (assuming that the B grade in the lower latitudes has the same characteristics as on the Montreal route).

The various values are plotted in Fig. (15) in which the ordinate is αd and the abscissæ the square of the wave length. The results are meagre. Most of them, being in the neighbourhood of λ 16 m., give no information of the wavelength variation of α.

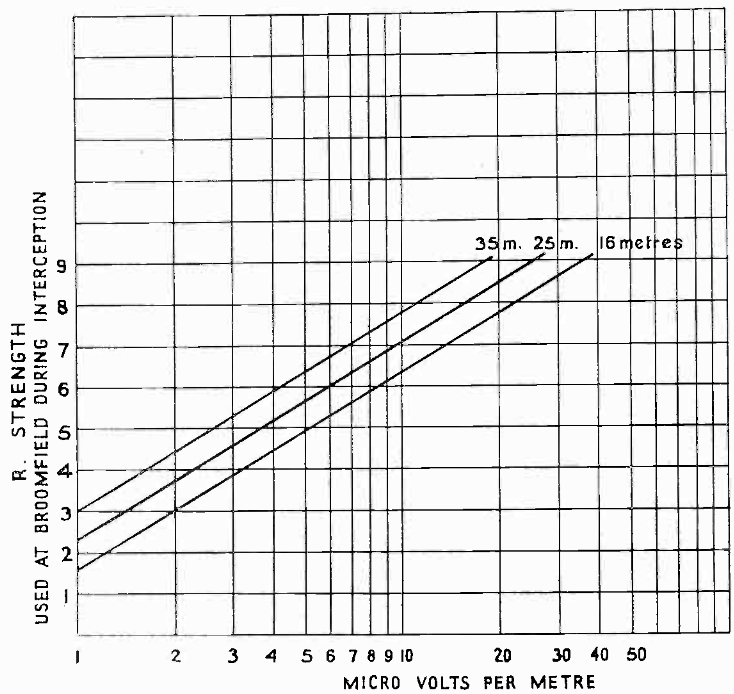


FIG. 13.

One fact is remarkable. The attenuation factor over the New York route of only 5,500 km. (on 16 m.) in B grade is as great as the attenuation factor for the A grade on South Africa, or more than twice the attenuation for the B grade from South Africa.

Fixing our attention on the transatlantic route and comparing the 16 m. and 32 m. stations we see at once that the attenuation coefficient does not vary with λ^2 as it should do. For waves $<$ 25 m. there is some unexplained attenuation over and above that determined by the λ^2 law. If, however, we compare South Africa on 16 m. on the B grade with Montreal on 32 m. on the same grade, we find that α is very nearly proportional to λ^2 in this case. It is probable that the abnormally high attenuation on the Transatlantic routes on the shorter waves, say below 25 m.

is caused by magnetic storm disturbances and is connected with the abnormal variability of signal intensities at such times.

According to the results on South Africa, the attenuation on the A grade is some 2 to 2·5 times greater than that on the B grade. This agrees with the qualitative difference found on analysis of the years' interception results at Chelmsford where the ratio of the attenuations for the A and B grades is 2 : 1.

Although the evidence cited here is entirely insufficient to establish the λ^2 law (in normal conditions) yet when taken in conjunction with the qualitative attenuation charts* where the analysis of a large amount of qualitative data shows attenuation coefficients for A and B grade as proportional to λ^2, this may be considered as a confirmation (except for the Transatlantic route).

The attenuation coefficient determined by the method described above is an overall figure and depends to a certain extent on the accuracy of the assumed first factor, *i.e.*,

$$\frac{3\pi\sqrt{W}\,M}{(d_0\ R \sin\theta)^{\frac{1}{2}}} \quad \ldots \quad (8)$$

A more definite figure for the attenuation would be obtained if it were possible to determine the field intensity at all distances.

The only observations of this nature are the field intensity measurements made on the voyages of the *Homeric* (6—12 June and 14—21 June, 1930).

These observations were made under rather disturbed magnetic conditions, and the evariation from day to day and insufficiency of the material make it rather a matter of guess-work to draw the smooth attenuation curve. These observations are discussed more in detail elsewhere. The attenuation constant was determined from the " distance—field intensity " curve in the following manner.

Assuming it to be of the type

$$\frac{A}{\sqrt{R \sin\theta}}\, e^{-\alpha d} \quad \ldots \quad (9)$$

then $$\log E = \log A - \tfrac{1}{2}\log R \sin\theta - \alpha d \quad \ldots \quad (10)$$

or $$\log E + \tfrac{1}{2}\log R \sin\theta = \log A - \alpha d \quad \ldots \quad (11)$$

We plot the quantity $\log E + \frac{1}{2}\log R \sin\theta$ against d. The slope of this curve, if E is of the form expressed in (10), should be a constant and equal to α.

Actually we find that the slope is not constant, being greater for small values of d than for great ones, suggesting that the intensity is the sum of a number of components, the more absorbable of which are rapidly attenuated in the initial stages, leaving the less rapidly absorbed components to traverse the greater distances.

* See papers referred to in footnote of page 3.

The average attenuation slope (between 1,500 km. and 5,000 km.) estimated by two independent workers is $6 \cdot 3 \times 10^{-4}$ and $6 \cdot 0 \times 10^{-4}$ so that the attenuation over 10,000 km. distance is 6·3, or 6·0. These figures are of the same order as those determined for the New York Telephone on 21 m. for the B grade. The *Homeric* tests were taken in summer, when the Transatlantic route is in the A grade. The figures therefore refer to the A grade.

These attenuation constants are rather less than those attributed to the A grade (according to Fig. 15). This is no doubt partly due to the fact that the *Homeric* attenuation was measured as an average for distance 1,500 to 5,000 km., whereas the overall attenuation which includes the shorter distances, is greater as it includes the more absorbed rays weeded out earlier than 1,500 km. in the transmission range.

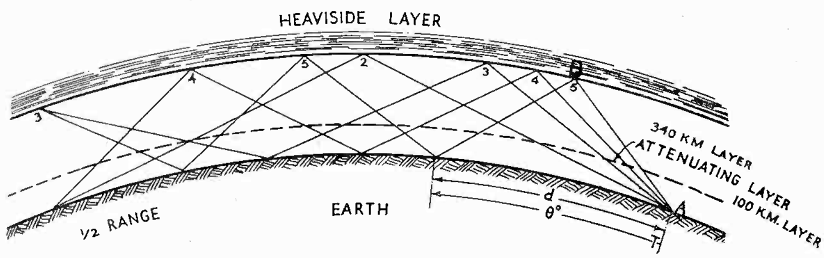


FIG. 14.

The measurements suggest that the overall attenuation measures are not greatly in error, and that consequently the first factor $\frac{3\pi\sqrt{W}}{\sqrt{d_o \, R \sin \theta}}$ is probably approximately correct. They do however, suggest that it is not entirely accurate to consider each ray as equally attenuated (as was assumed in the derivation of formula (6). In practice it would appear probable that the overall attenuation factor would tend to diminish with distance.

In accordance with the assumed mechanism of transmission used in deriving formula (6) it should be possible to calculate the attenuation for each ray, and hence the overall attenuation, if the distribution of ionic density and collision frequency in the lower 100 km. layer is known.

The knowledge of these factors is by no means complete, but there is sufficient data to justify an attempt at the theoretical prediction. This calculation was made for $\lambda = 22$ m., for which wavelength facsimile experiments have given the ray paths.*

We require to know the distribution of ionic density in the layer. This was determined from Appleton's results (published in Proc. Physical Society of London,

* See "Multiple Signals in Short Wave Transmission." Proceedings of the Institution of Radio Engineers. Vol. 18, Jan. 1930, p. 106.

Vol. 42, Part 4, p. 321), the values being taken during the period two hours after sunrise, which corresponds to a grade between A and B. The collision frequencies were those given by S. Chapman (Proceedings of the Royal Society, Vol. 122, p. 369) and are calculated from the Kinetic Theory for an atmosphere in which wind mixing occurs up to heights of 110 km. and in which the temperature at or in the neighbourhood of 100 km. is assumed to be 300°C.

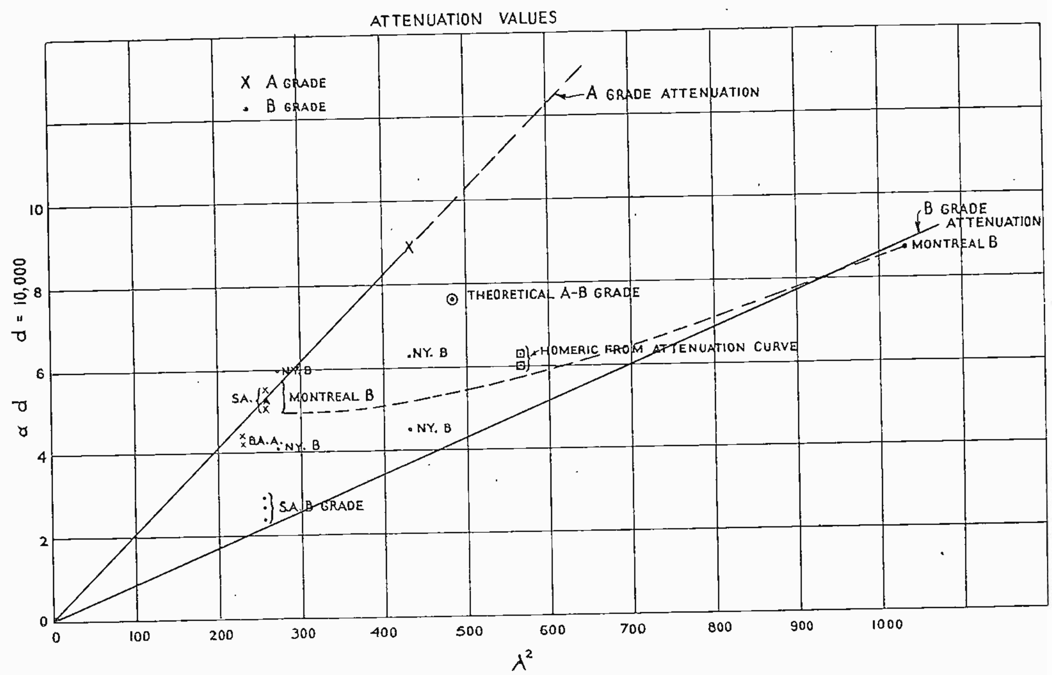


FIG. 15.

The attenuation per centimeter of path where the electron density is N and the collision frequency $\frac{1}{\tau}$ is approximately $\frac{Ne^2}{\pi m \gamma^2} \cdot \frac{1}{2 c \tau}$. N and $\frac{1}{\tau}$ being known at every point of the path, it is possible to integrate the total attenuation along any path joining receiver and transmitter.

The results obtained are :—

RAY.	θ	$\alpha d_{5,500}$	$\alpha d_{10,000}$
2	10°	3·86	
3	21°	3·86	
4	28°	3·80	
5	36°	5·20	
		Mean 4·18	7·6

This excludes a calculation for the first ray which cannot penetrate the lower layer. The calculation for this ray depends on a more accurate specification of the density distribution than is obtainable.

The value obtained, 7·6, is between the extremes observed for the 20 m. New York Telephone circuit. It is rather larger than the value, 6·3, obtained from the *Homeric* readings, but reasons for considering this a rather low value for the overall attenuation have already been given. On the whole, considering the nature of the data, the agreement is as near as could be expected.

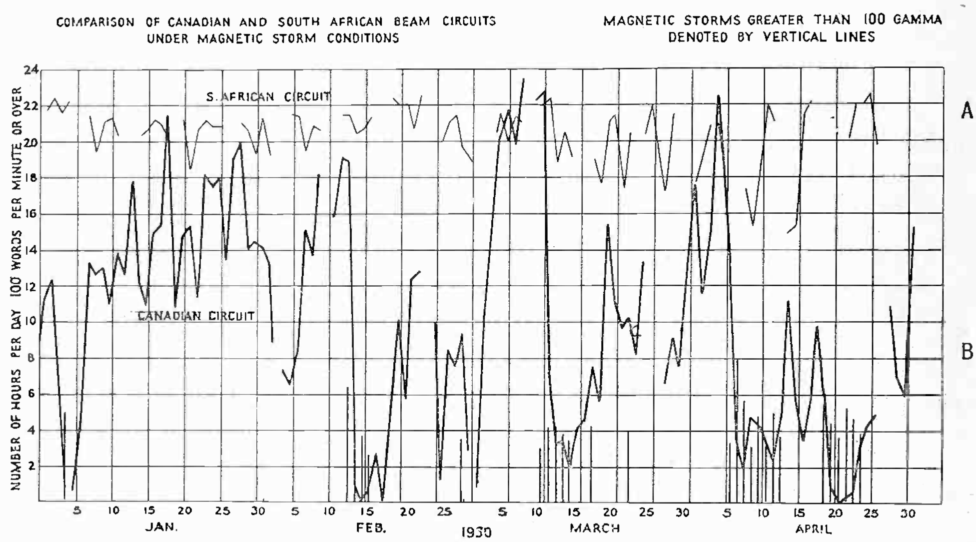


FIG. 16.

Night Transmission.

Whereas day transmission is largely controlled by attenuation, night transmission is chiefly controlled by electron limitation. This factor, which depends on the maximum ionic density in the highest layer, varies throughout the night on account of recombination. It also varies with latitude in such a manner that it is difficult to find long distance paths in which the conditions are uniform. This added difficulty, in the case of night transmission makes a serious complication.

In considering the ideal case of a uniform condition along a route in darkness, a formula of the same type as (1) may be used. The theoretical justification for this is obtained in the fact that the mechanism of transmission is just the same *i.e.*, ricochets between the earth and Heaviside layer, the differences consisting only in the change in density in the upper layer, and according to Appleton's measurements,—a reduction in density and rise in equivalent height in the lower layer. These both have the effect of reducing the attenuation of any ray passing through the lower layer. In applying a formula of this type to the more general case, a difficulty in estimating the effective skip distance occurs, for the skip distance appropriate to the layer conditions varies along the path. In such cases the skip distance at that end of the route at which it is greatest has been taken. The information gained in the years' interception at Chelmsford (1927—1928) indicates that this is the controlling factor in such a case. Where a region of low electronic density is halfway between a receiver and transmitter, it appears to have less effect than if this region were at either end, suggesting that if the lower angle rays can get a good start (or finish) they can jump a region of lower density as shown in the figure.

With this proviso it is possible to make a comparison between the observed results and those calculated from the formula, assuming there is still residual attenuation. The results obtained are almost wholly for the longer wave stations $\lambda > 25$ m. since, especially in winter time, the short wave stations cannot work through the hours of darkness.

It appears that even at night-time we must assume that there is some residual attenuation. Part of this may be due to an under-estimate of the skip distance, values of which were obtained from experience during the last few years of sunspot maximum. There is evidence, as already cited of a gradual increase of skip distance as sunspot minimum is approached.

The effect of scattering in the late hours of darkness introduces further complications in the analysis of night transmission.

Such scattering signals will not behave in the same way as the main signals, and it is doubtful if we are in a position to make any theoretical estimate of their behaviour.

It will be better to leave this analysis to a later occasion when more material has accumulated.

T. L. ECKERSLEY.

MARCONI PORTABLE PICTURE APPARATUS

The Marconi Portable Picture Transmitting and Receiving Apparatus has been designed to provide means of a semi-portable nature, to enable rough sketches, maps, weather charts and the like to be transmitted by wireless from the air to ground or between two ground stations.

THE following description of the Picture Transmitting Apparatus deals only with that part of the complete installation which serves to control the modulation of the aircraft or ground wireless transmitter. The details of the design of its output circuits are bound up to a large extent with the methods employed in the wireless transmitter itself for normal operation when transmitting continuous wave telegraphy or telephony, and are omitted.

Each of these normal types of transmission is provided for by readily interchangeable output circuit units in the Picture apparatus which are referred to respectively as the "C.W. Keying Unit" and the "Tone Amplifier Unit." It is the design of these output units which is affected by that of the wireless transmitter which is to be employed.

The standard output units are designed primarily to operate in conjunction with the Marconi Aircraft Transmitters Types AD.18a or AD.19. The standard C.W. keying unit would successfully control a C.W. transmitter which complies with the following :—

1. It should be capable of being keyed at very high speeds.
2. It should be "driven" by a separate master oscillator.
3. It should be capable of keying by the application of a negative bias of from 60 to 90 volts to the grids of the master oscillator and the magnifier valves.

Condition No. 1 above is an essential one for any transmitter with which it is required to utilise the Picture Apparatus. On the other hand deviation from No. 2 and No. 3 may probably be accommodated by suitably adapting the design of the C.W. keying unit or the addition of an intermediate linking unit between the two instruments.

When the telephony range of the transmitter is sufficient for the service required the method of transmitting the pictures by modulation of the carrier wave may be employed by means of utilising the Tone Amplifier Unit in lieu of the C.W. keying unit.

With this type of transmission the technical requirements in the output circuit are less exacting and the standard output unit will be found suitable to operate with most telephone transmitters of moderate power with, in some cases, the addition of an output transformer between the Picture Apparatus and the modulation circuits of the transmitter, or an additional stage of L.F. magnification.

Conversely, the function of the Picture Receiving Apparatus is essentially to utilise the output from a wireless receiver which is tuned for the reception of signals

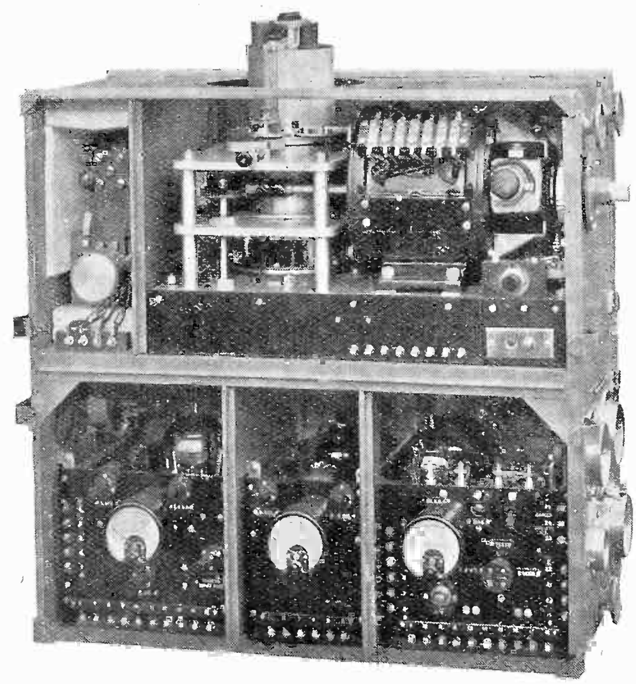


FIG. 1.

from the transmitter discussed above, in order to record the signals in visible form in such a manner as to reproduce the sketch which is being transmitted.

It may be successfully operated by any good class, selective receiver which is capable of giving 8 to 10 milli-watts of undistorted power at the output terminals.

The performance of the Picture Receiving Apparatus is naturally dependent upon that of the wireless receiver with which it is operated.

Transmission.

The sketch or plan to be transmitted is made upon a specially prepared form consisting of very thin metallic foil mounted upon a stout paper backing. The surface of the foil is covered with a non-conductive fine tissue, the three layers of the form being made perfectly homogenous. A fountain pen containing a special solution of graphite is used for sketching which impregnates the tissue and renders it electrically conductive where marked by the pen. An alternative type of form the surface of which is capable of being rendered conductive by marking with an

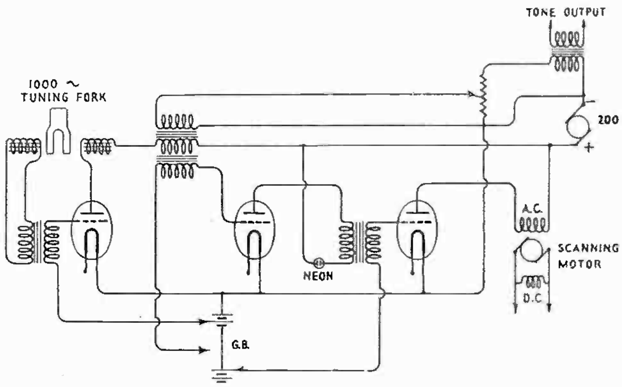


FIG. 2.

ordinary lead pencil may also be supplied. The sketch is placed around a cylindrical drum, tissue outwards. Along one edge the foil is left exposed and is thereby connected in the electrical circuits of the apparatus.

The whole surface of the form is now explored by a metal stylus point which revolves continuously around the cylinder, while the latter maintains a steady end-wise movement of 1/80th part of an inch per revolution of the stylus.

The parts of the tissue which have been impregnated with graphite permit of the passage of current between the stylus and the foil as the former passes over them. The blank portions of the tissue are however entirely non-conductive and the circuit is opened when the stylus rests on these portions.

This successive closing and opening of the circuit is utilised through suitable stages of amplification to control the output of the picture transmitter, which (in the case of the standard C.W. keying unit) consists of a difference in potential of 80 volts produced across a resistance when the stylus is on " mark," this negative potential being applied to the transmitter valve grids for keying.

For telephony modulation of a transmitter using the standard tone amplifier unit, the output consists of a 1,000 cycle note when the stylus is on " mark," which is applied to the modulating circuits of the wireless transmitter.

Constancy of speed of the motor driving the scanning mechanism is maintained by tuning fork control, by a method to be described later.

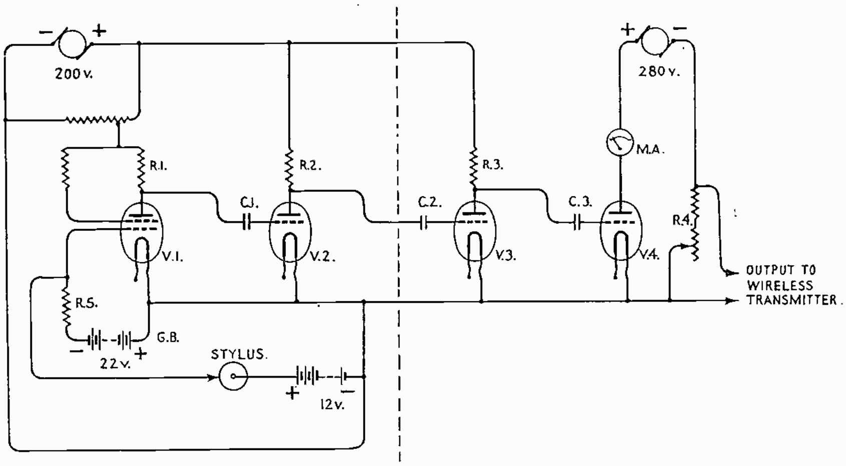


FIG. 3.

Reception.

The mechanical features of the scanning mechanism and drum in the Picture Receiving Apparatus are duplicates of those in the transmitter. Speed control in this case, however, is obtained by utilising the output from a 1,000 cycle inductance-capacity circuit in lieu of the tuning fork control. The tuning of this circuit is variable, by means of an adjustable condenser, over a small range which enables the frequency of the transmitter fork to be precisely duplicated, and perfect synchronism between the transmitter and receiver drums to be maintained.

The medium employed for recording the received signals consists of an absorbent paper form moistened with a solution of potassium ferri-cyanide and common salt.

This form is scanned by the iron stylus of the receiver in synchronism with the movement of the transmitter stylus over the surface of the message.

The output from the wireless receiver is taken through a transformer to the grid of a valve which is backed off to the rectifying point, in the anode of which are connected the stylus and drum. The train of signals is thereby recorded upon the message form by the local coloration of the solution, produced by the passage of current through the paper during "marking" periods.

Owing to the synchronism existing between the movements of the transmitter and receiver scanning mechanisms the resultant record is a reproduction of the sketch or message transmitted, having a scanning mesh of 80 lines to the inch.

An example of a message transmitted from air to ground over 80 miles is shown in Fig. 6.

Design.

The main requirements for the service in view which have formed the basis

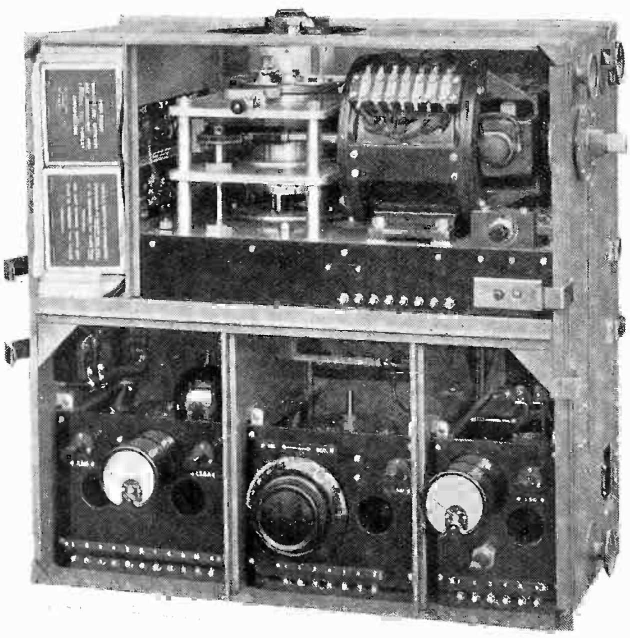


FIG. 4.

of the design of the apparatus may be summarised as follows:

The transmitting apparatus must be compact and as light as possible, suitably encased for housing in aircraft when required.

The operator should be able to make a rough sketch or write a message and transmit it straight away without delay or preparation.

The useful area of the message form should be at least $8\frac{1}{2}$ inches by $4\frac{1}{2}$ inches.

The time taken to scan this area completely should not be greater than 5 minutes.

At the receiving end it should be possible to observe the picture continuously as it is being received therefore the cylinder on which it is recorded must not revolve and the record should be immediately visible without further processes to be carried out.

Synchronism between transmitter and receiver must be maintained by means which are independent of any transmitted signal, since if this is not so, any jamming by interfering signals would cause not only the loss of a portion of the picture but also of synchronism. To avoid this would require a very high signal interference ratio and consequently a very limited range would be possible.

As many parts of the transmitting and receiving apparatus as possible, such as recording drums, scanning mechanism, motors, etc., should be interchangeable.

Provision should be made to enable the receiving stylus to be correctly phased with that of the transmitter in relation to the edges of the message forms, in addition to maintenance of their synchronised speeds.

It should be possible to remove and replace the cylinders without stopping the scanning mechanism with consequent loss of phasing and synchronism.

The above conditions have all been met in the design of the apparatus under consideration.

Details of Transmitter.

The Picture Transmitter Type P.T.1a is illustrated in Fig. 1.

The Scanning Stylus Mechanism will be seen in the top compartment, on the left of which is the tuning fork control.

The scanning mechanism consists of a stylus mounted on an annular ring revolving in a horizontal plane about the central cylinder round which the picture is clipped. The cylinder, which is 3 inches in diameter, does not revolve but is supported by three guide rods and has a steady vertical movement of 1/80th part of an inch per revolution of the stylus, which is imparted by means of a lead screw driven through a worm reduction gearing.

The stylus makes 90 revolutions per minute, the scanning speed being fourteen inches per second. The time of transmission is therefore $4\frac{1}{2}$ minutes for the maximum area of 9·4 inches by 5 inches. In practice a small percentage of this area at the margin is lost in operating.

The motive power is supplied by a small machine of the motor alternator type running at 1,666 r.p.m. which drives the stylus and lead screw through reduction gearing.

The D.C. side of this machine is supplied from a 12 volt accumulator or other source of power and takes approximately 36 watts. The A.C. side is in the anode circuit of the last valve of an amplifier, the input to which is controlled by the 1,000 cycle tuning fork. The constant frequency output of this valve is thus applied to the A.C. windings of the motor serve to keep its speed perfectly uniform.

A stroboscopic wheel on the shaft of the motor is illuminated by a Neon lamp which is connected in the anode circuit of the first valve of the fork amplifier and provides a positive indication that the motor speed is under the control of the fork impulses.

A small cam mechanism is mounted on the stylus ring and is operated by push rod from the front of the apparatus. This cam is used to raise the stylus off the cylinder at the end of a message, and allows the cylinder to be removed, and a duplicate cylinder ready charged with the next message to be inserted without loss of time, while the stylus ring is still revolving.

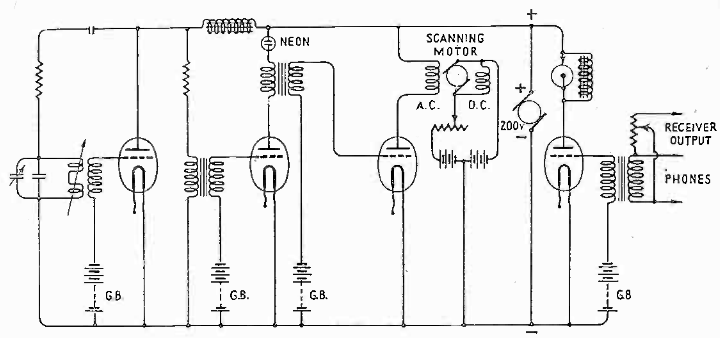


FIG. 5.

The stylus itself is supplied in the form of a ribbon whose width is equal to the mesh of the picture. This ribbon is fed out of its housing as required thereby compensating for the wear which takes place more especially at the receiver, due to the electro chemical action.

The cylinder engages with the lead screw by means of a half nut which is raised or lowered into mesh with the screw-threads by means of a knob operated from the top of the cylinder. The latter can be rotated by hand in order to obtain the correct phase relationships between the transmitter and receiver.

The Tuning Fork Amplifier is contained in the left hand bottom unit shown in Fig. 1. It comprises three valves, the first of which maintains the fork in vibration in the usual manner. The consequent 1,000 cycle oscillations are then amplified by the succeeding valves, which are transformer coupled ; this frequency is then passed via the anode of the last valve through the A.C. windings of the scanning motor to control its speed. For telephony working this tone is also applied by means of a transformer to the tone amplifier unit.

Fig. 2 shows the theoretical diagram of this unit and the scanning motor.

The centre section of the bottom half of the case is occupied by the intermediate amplifier unit, comprising a screened grid valve which is capacity coupled to a second amplifying stage. The control grid of the first valve is maintained at a negative potential when the stylus is on white by a grid bias battery through a high resistance R_5 (Fig. 3). This grid is also connected to the positive side of the common 12 volt battery through the drum and stylus, which when on white holds off this positive potential. There is therefore no voltage drop across R_1 when the stylus is on white and the grid of the limiter valve V_2 becomes less negative thus allowing current to pass in this valve with a consequent drop across R_2.

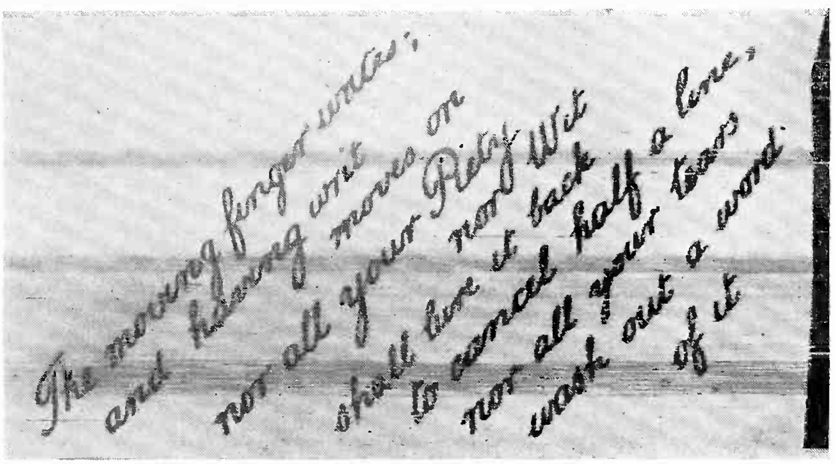


Fig. 6.

The voltage applied to C_2 is then of such a value as will allow the accumulated negative charge on the grid of V_3 to back this valve off. C_3 receives a positive charge and V_4 is conductive. The drop across R_4 is thus available for application to the transmitter grids for keying.

When the stylus is on mark a small current flows through R_5 and the grid of V_1 becomes positive. Hence the drop in R_1 causes V_2 to be backed off. This renders V_3 conductive and V_4 is backed off. No drop then occurs across R_4 and the transmitter grids are relieved of the negative potential, allowing the transmitter to oscillate.

Output Unit.

This is housed in the right hand bottom compartment and may be either the C.W. keying unit, the operation of which is described above, or the tone amplifier unit if telephony modulation of the transmitter is employed.

A three way switch is incorporated in the C.W. keying unit which enables the wireless transmitter to be used either independently of, or in conjunction with, the picture transmitter. The third position of the switch enables the picture transmitter to be tested out when the wireless transmitter is shut down.

Receiver Type P.R.1a.

The general construction of the receiving apparatus is similar to that of the transmitter. It is illustrated in Fig. 4. The top half is occupied by the scanning mechanism with a grid bias battery compartment on the left.

In the bottom centre is the 1,000 cycle oscillation generator unit, with its amplifier on the left. The amplified oscillations are employed to control the speed of the scanning motor in the same manner as the tuning fork output in the transmitter unit described above. On the bottom right hand is the signal amplifier which amplifies the output from the wireless receiver.

The anode of this amplifier valve is supplied with H.T. current at 200 volts through the stylus and receiving drum. The passage of feed current to this valve through the receiving form when the valve is rendered conductive by the swing of grid voltage caused by the incoming signal, is recorded by the production of the familiar Prussian Blue colour on the form.

The theoretical diagram of connections of the receiving apparatus is shown in Fig. 5.

Synchronism

It has already been stated that synchronism is accomplished by means of a tuning fork at the transmitter and a 1,000 cycles oscillator at the receiver. In order to check the synchronism it is only necessary to observe the message drawn at the receiver during the reception of a picture, and watch the formation of the reproduction of the bar which clips the message on to the cylinder at the transmitter. If the received bar deviates slightly in either direction from the vertical it indicates that the receiver stylus is running either too fast or too slow as the case may be. By slightly adjusting the frequency of the 1,000 cycles oscillator this can be corrected at once, in practice very little attention to synchronism being necessary.

Power Supplies.

When used in aircraft the Picture Transmitter receives its high tension power supply from a wind driven generator fitted with a constant speed windmill. The generator is of the double output type and provides current at 280 volts to the anode of the last valve of the C.W. keying unit when this is employed, and at 200 volts to the anodes of the remaining valves. This generator is independent of that which supplies the wireless transmitter.

The valve filaments are heated from one half of the 12 volt accumulator which drives the scanning motor, and changeover switching is provided whereby either half of the accumulator may be employed at will for the filaments to maintain an even discharge of the cells.

When used on the ground the double output generator may be driven by a motor or the H.T. current may be supplied from suitable batteries or other local source.

When telephony modulation is employed the 200 volt supply is alone required.

The receiving apparatus requires a H.T. supply of 200 volts and this may be derived from the rotary transformer provided which is driven from the 12 volt accumulator used for the scanning motor and filaments, or may be obtained from a H.T. accumulator or other suitable local source.

TELEPHONE TRANSMITTING EQUIPMENT ON BOARD THE "HOMERIC"

The following description applies to that type of short wave telephone transmitter which was originally designed for use on Marchese Marconi's yacht, the " Elettra," *operating on one spot wavelength of* 26 *m. A number of important demonstrations which were given with this set, were described in* THE MARCONI REVIEW *for April, May and August,* 1930.

Transmitters of similar design, but modified to make them suitable for the short waves of 9.87 *m. and* 9.77 *m. respectively, are now being employed on the Rome-Sardinia commercial duplex telephone service.*

The White Star Liner " Homeric " *has a transmitter of the* " Elettra " *type, but in this case an additional panel is employed to provide alternative wavelengths of* 24 *m. and* 70 *m.*

Another of these transmitters has been erected recently on the " Empress of Britain," *and it is hoped to describe the installation on this ship in the next issue of* THE MARCONI REVIEW.

THE Radio Telephone installation on board the " Homeric " has been designed to enable a regular telephone service to be established from that ship to Great Britain and the United States of America, which has since been extended to include several other countries.

At the shore end in Great Britain, transmission takes place from the Post Office Rugby Station, while the Post Office Baldock Station is employed for reception from the ship. These stations are connected to the London Trunk Exchange, thus enabling a normal telephone service to the ship to be provided from anywhere in Great Britain.

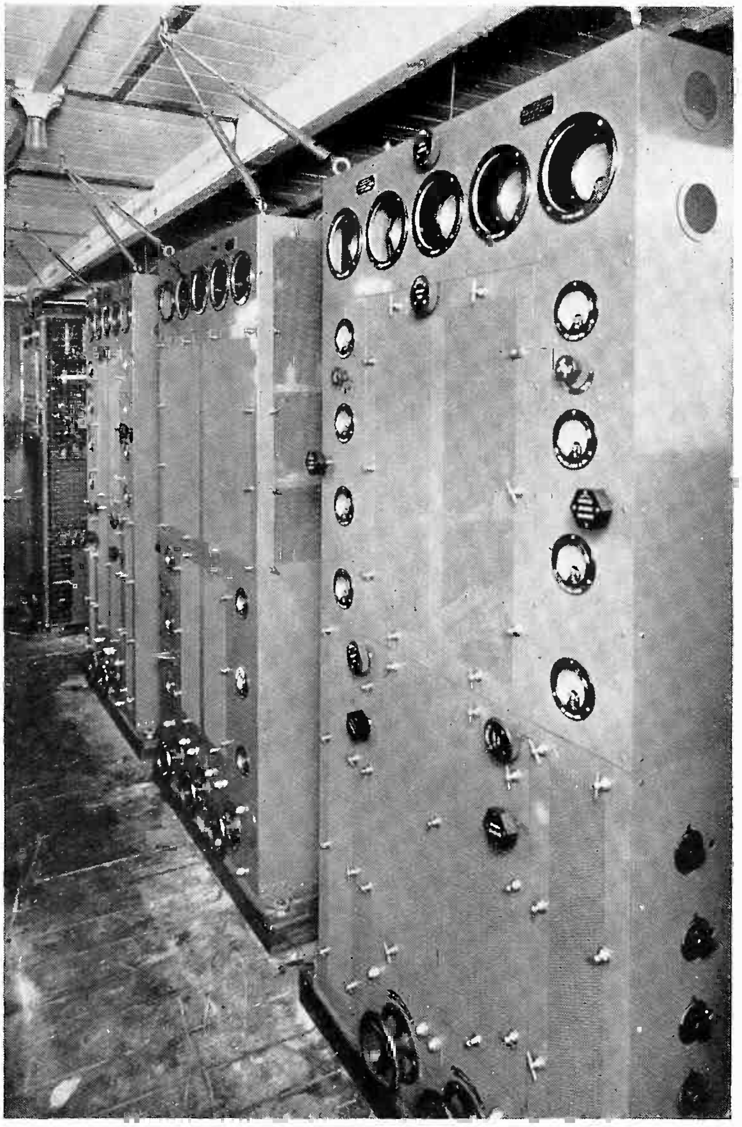
On board the " Homeric " a special extension of the Marconi wireless cabin has been built to house the transmitter and receiver, and a telephone room has been erected nearby from which passengers can make their calls.

The complete installation includes the transmitter, receiver and terminal equipment.

The Transmitter.

The transmitter consists of four separate units :—

(1) The rectifier unit.
(2) The modulator unit.
(3) The short wave oscillator unit.
(4) The long wave oscillator unit.



Transmitter Panels on board the "Homeric."

Power Supply.

The rectifier unit for power supply to the valves consists of suitable valve rectifiers and their associated circuits, for converting the high tension alternating current into direct current.

Single phase alternating current from the generator is transformed to the required voltage in the main power transformer and is thence rectified by two M.R.9 valves. The smoothing system has been carefully designed to obtain a very steady rectified current to ensure high quality speech transmission.

The main filament supply to the valves is from a direct current generator. The master oscillator filament supply is from a battery, and grid bias and master oscillator anode supplies are from small rectifier units.

The main power transformer is mounted as a separate component.

Modulator Unit.

This unit consists essentially of one sub-sub-modulator valve, type M.T.4b, the grid circuit of which is modulated via a transformer by the speech currents. The sub-sub-modulator is resistance capacity coupled to a sub-modulator valve type M.T.6b, and this is resistance capacity coupled to four main modulating valves type M.T.9L.

The anodes of the main modulators are connected to the high tension supply through a speech choke, which varies the high tension supply to the anode of the third power amplifier in accordance with the magnified speech variations.

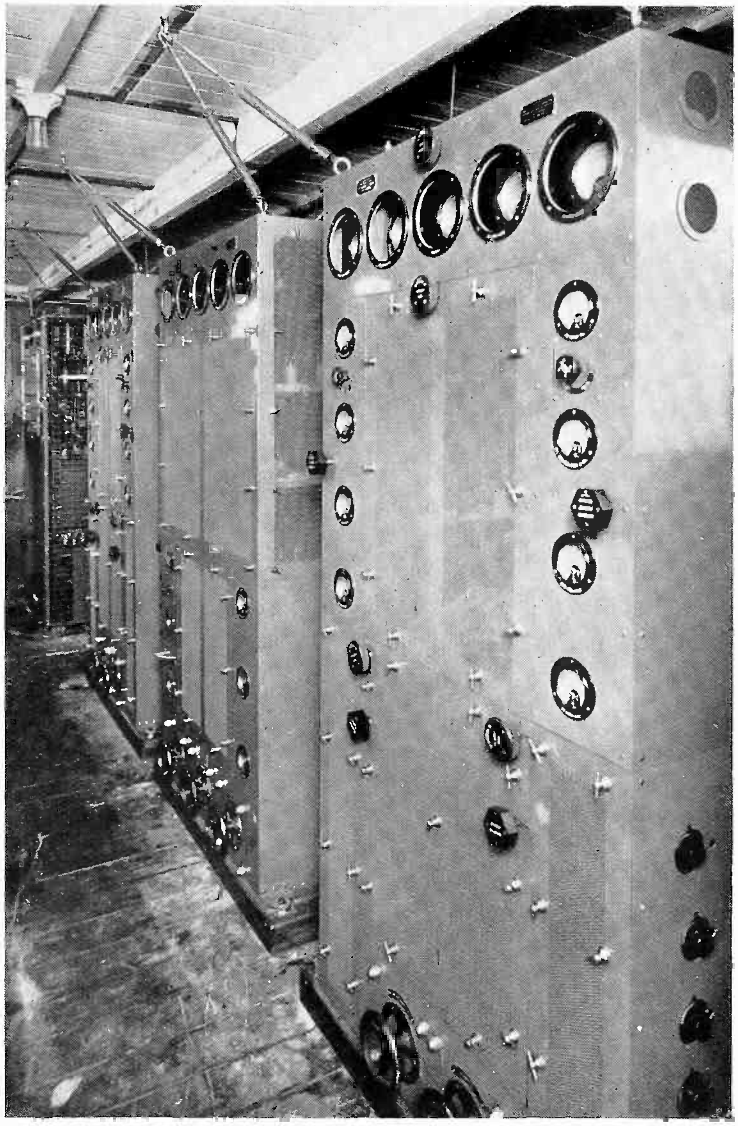
Oscillator Units.

Two separate oscillator units are provided, one for the short wave of approximately 23 metres, and one for the long wave of approximately 70 metres.

The power stages of these oscillators are controlled by their respective master oscillator. These master oscillators consist of specially designed valve circuits, comprising a valve oscillator and frequency doubling stages. The valve oscillator is so designed that, once set to any frequency, any change of filament voltage, anode supply voltage, or temperature that is likely to occur in practice up to 1 per cent. will not affect the frequency to more than one part in 25,000.

The frequency of the master oscillator can be adjusted to within about 4 per cent. either side of the medium wave, which in the case of the short wave oscillator is approximately 2,136 k.c. (141 m.). This fundamental frequency is doubled at the first screened grid valve stage of the amplifying section of the master oscillator unit. The output is then amplified before the frequency is tripled in the third stage. The frequency output of 12,820 k.c. (23·4 m.) is then passed through two more stages of amplification before being input to the power stages. In the long wave master oscillator the initial frequency of 2,150 k.c. (139·5 m.) is amplified in two stages and is doubled at the third stage. The output is then further amplified in the fourth and fifth stages.

Constant frequency of the oscillator with change of temperature is obtained by means of an inductance and condenser assembly which when once adjusted



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Constant frequency of the oscillator with change of temperature is obtained by means of an inductance and condenser assembly which when once adjusted automatically compensates for any expansions or contractions due to varying temperature.

The master oscillator units are shown in the bottom right-hand compartment of the second and fourth panels from the left in the photograph.

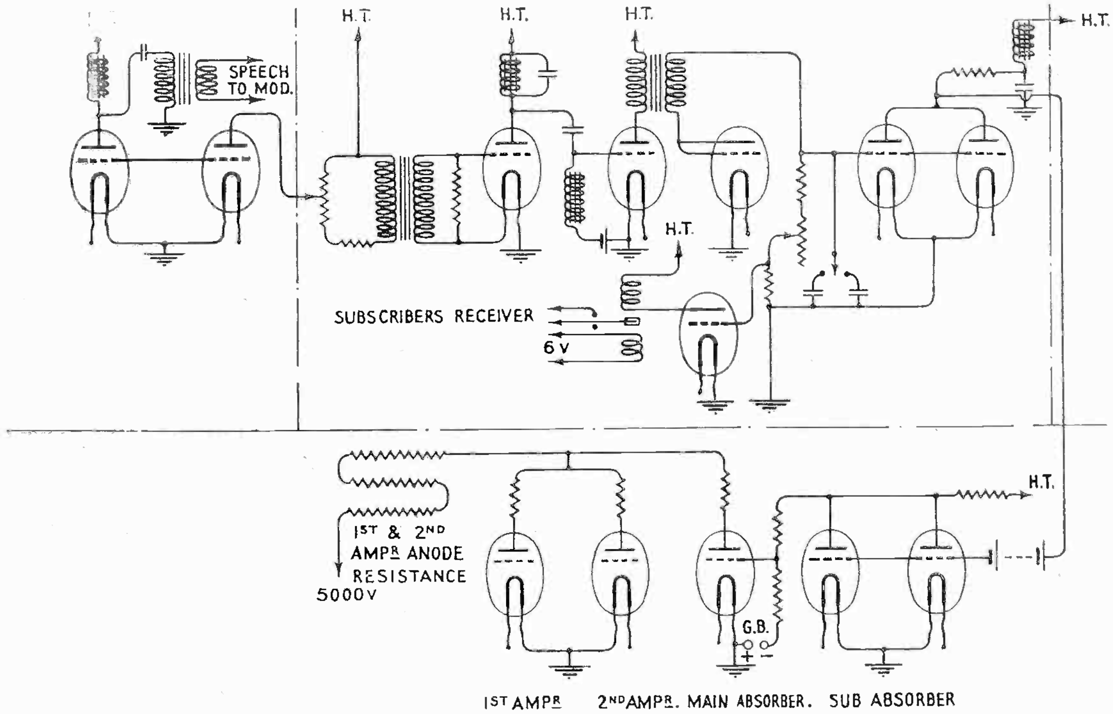


Fig. 1.

Power Stages.

The output from the final stage of the master oscillator unit is capacity coupled to an auto transformer for feeding the grid circuit of the first amplifier.

The power amplifier consists of three stages of amplification. The first and second amplifiers are single valve stages and are neutralised by connection in the form of a bridge, the capacities of the valves being balanced by means of small variable condensers in the opposite arms of the bridges.

Semi-fixed coupling is used between all the power stages in the following manner. A comparatively high inductance is connected across the output circuit of the preceding stage, and the grid circuit of the next stage which is part of the bridge network is connected through fixed condensers across a suitable amount of this inductance.

The grid circuit is roughly tuned by a second inductance.

The third stage of amplification consists of two valves in opposite arms of a bridge network but is otherwise similar to the preceding stages.

The output circuit consists of a coupling coil and series condenser, with a series coil which is connected either in place of or in series with the tuning condenser as required by the aerial conditions. The output circuit on this ship is connected to the aerial direct.

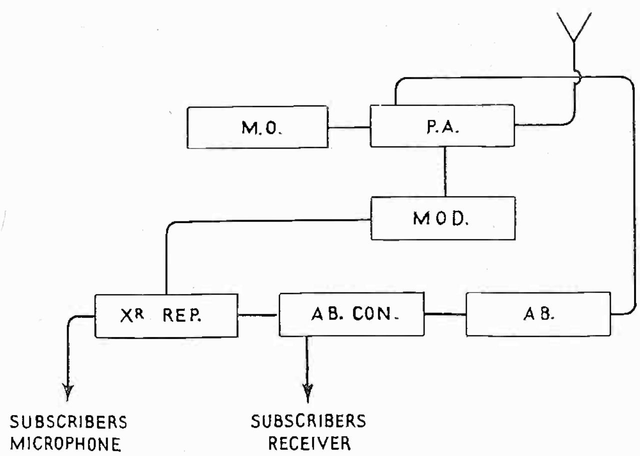


FIG. 2.

The Absorber System.

The absorber circuits are provided in order to cut off the carrier during the periods when no modulation is applied to the transmitter, and thus assist in obtaining quiet reception.

From the diagram of connections shown in Fig. 1, it will be seen that the speech currents from the microphone act on the grid circuits of two valves in the transmitter repeater, one of these valves serves to transfer the speech variations to the modulator system of the transmitter, the other operates the absorber control unit which in turn actuates the absorber system.

The absorber control unit consists of two stages of audio frequency amplification, a diode rectifier, two valves in parallel (the sub-sub-absorber valves) operating as a further amplifier stage, and an additional valve which serves, by relay action, to open the subscriber's receiver circuit when the transmitter is being modulated by him.

The action of the absorber control unit is as follows. Audio frequency applied to the input of the unit produces a unidirectional current in the anode circuit of the diode rectifier and alters the potential of the grid circuit of the sub-sub-absorber valves which are connected to earth through a resistance capacity network having a definite time constant. This time constant is so adjusted that once the carrier has been started by the absorber system acting on the anode voltage supply of the power amplifier, it can be retained for the required fraction of time after the modulation has ceased.

The relay valve which disconnects the subscriber's receiver circuit, is operated off a part of the potential applied to the sub-sub-absorber valve grids. Due to the presence of this relay the cutting off of the carrier must not lag too long behind the cessation of modulation, as otherwise the reception of speech may be "clipped" and interjections, etc., lost.

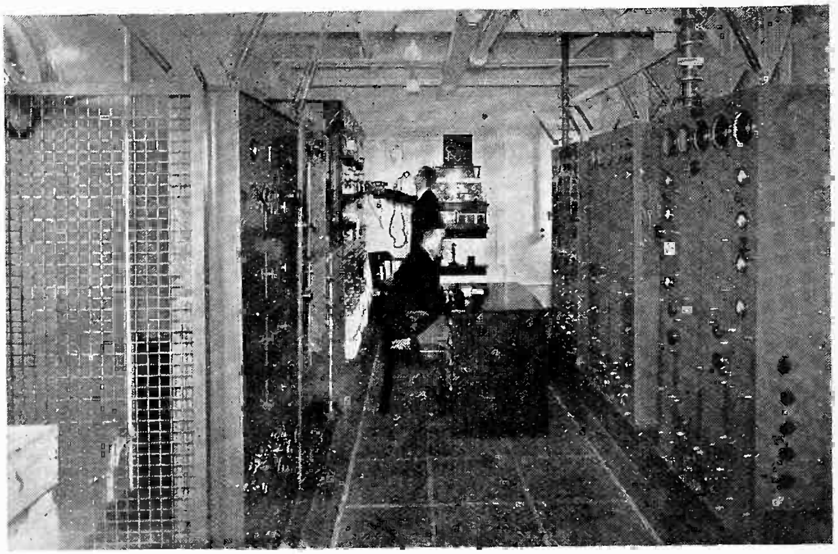
The absorber system itself comprises two stages, a sub-absorber, and a main absorber, arranged as a D.C. amplifier. The main absorber draws its anode current through the common anode resistance of the first and second power amplifiers. Thus when the main absorber valve is taking its correct anode current, the voltage supplied to the first and second power amplifiers is reduced to such a low figure that the third amplifier delivers no power to the aerial.

A switch is provided on the control circuit to put the absorber entirely out of action, and provision is made to read the anode current of all valves and the grid current of the sub-absorber in the receiving room. The absorber can also be controlled by means of a switch in the transmitter room.

A schematic diagram of the components of the transmitter is given in Fig. 2.

MARCONI NEWS AND NOTES

"EMPRESS OF BRITAIN": MARCONI WIRELESS TELEPHONE



Marconi telephone transmitter room on board the "Empress of Britain."

WHEREVER the luxurious new Canadian Pacific liner, the "Empress of Britain" may be in the Atlantic during one of her summer runs between Southampton and Quebec or in the Pacific Ocean or in the China Sea on one of her winter round-the-world cruises, her passengers will be in telephonic communication with the world's land telephone network, for she carries the largest and most powerful Marconi wireless telephone equipment of any ship afloat. It is also the first wireless telephone installation to be planned before the ship was built thus giving the wireless and telephone engineers an opportunity of planning and building it in the most efficient manner.

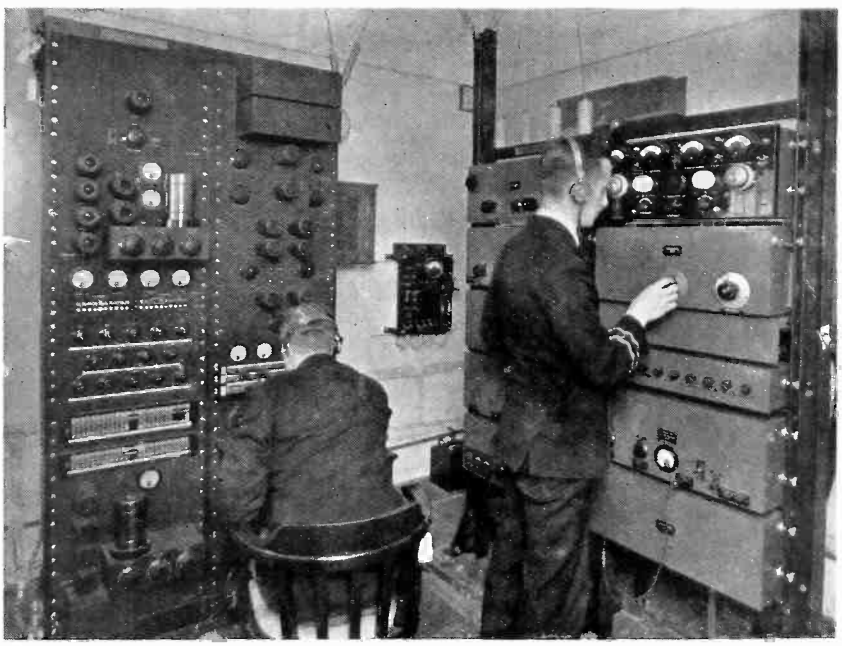
Its possibilities were demonstrated to the public on both sides of the Atlantic during the maiden voyage by broadcasts arranged from the ship. When about 500 miles out from Southampton a conversation between Captain Latta, her Commander, and Commander King-Hall at the British Broadcasting Corporation's Headquarters in London was broadcast and heard with the greatest clearness throughout Great Britain. On approaching Canada a similar broadcast was arranged for the benefit of listeners in Canada and the United States. This included a speech from the ship by Mr. E. W. Beatty, President of the Canadian Pacific Railway, and an orchestral concert.

Three large rooms are devoted entirely to the wireless equipment which, in addition to the wireless telephone, includes long and short wave telegraph transmitters and receivers, a Marconi Wireless Direction Finder, and emergency and lifeboat equipment.

The short-wave telephone equipment is similar to that used by Marchese Marconi in his series of experiments in world-wide telephony from his yacht "Elettra" in the Mediterranean early last year, but incorporating many new features which have been developed since that time.

A special feature of the "Empress of Britain's" equipment is the ability to speak from any of the ship's telephones, which are connected to the wireless apparatus through the ship's manual switchboard, so that the telephone service on the ship is as convenient as that on shore.

The enterprise of the Canadian Pacific Company in providing long-distance telephony as part of the normal wireless service of the "Empress of Britain" is an indication that, as the telephone has become an integral part of modern life for business, social and domestic affairs on shore, its extension by wireless to shipping will eventually become as general as the linking of countries and continents.



Marconi telephone receiver room on board the "Empress of Britain." *On the left is the monitoring equipment and switchboard, and on the right the receiving apparatus.*

Prince of Wales's Flight.

THE reliance placed upon wireless in air travel was indicated by the journey made by the Prince of Wales from Bordeaux to London in bad weather on April 27th and 29th. At the request of Imperial Airways Limited, Mr. T. A. Vallette, the Marconi wireless operator and engineer who accompanied the late Lieut.-Commander Glen Kidston on the first stages of his record trip to South Africa, was placed in charge of the Marconi wireless installation on the "City of Glasgow," in which the Prince of Wales flew from Bordeaux to London. The installation was of the world-famous Marconi A.D.6 type, arranged for operation either by the pilot in the cockpit or by the operator, the latter being enabled to employ either telephony or telegraphy as required. As is well known, the Marconi A.D.6 "All-purpose" aircraft equipment comprises a highly efficient transmitter of 150 watts power and a special receiver of extreme selectivity and stability.

For the guidance of shipping: a Marconi Automatic Wireless Beacon station in course of erection at Mizzen Head, Ireland.

The first stage of the journey with the Prince of Wales and Prince George and their party was from Bordeaux to Le Bourget, Paris, on April 27th. Communication with the ground was easily maintained throughout the flight in spite of bad weather, the Prince of Wales and members of his party utilising the wireless for private messages, in addition to the normal exchange of weather and position messages and information regarding the organisation of the flight.

Bad weather conditions again prevailed on the flight from Le Bourget to Windsor Great Park on April 29th, but the "City of Glasgow" was in touch by wireless with Croydon ten minutes after leaving Le Bourget, with excellent two-way communication. Over the French coast fog was encountered and Croydon was asked for and gave several direction finder bearings, the pilot, Captain G. P. Olley, making use of the wireless telephone for this purpose. The Prince of Wales, who spent most of the time during the flight in the cockpit, was particularly interested in this demonstration of the utility of wireless and in the ability of the pilot to communicate with the ground throughout the flight.

On landing in Windsor Park, Captain Olley demonstrated to the Princes that even when the aircraft was on the ground he could communicate with Croydon to report their safe landing. This was done by using the fixed aerial and running the front engine to provide sufficient slip-stream to revolve the generator windmill.

With the Princes in South America.

Marconi aircraft apparatus also rendered very useful service during the visit of the Prince of Wales and Prince George to Chili, both the areoplane and seaplane used for transporting the Prince of Wales during his flights in that country being fitted with Marconi A.D.6 installations. During the flight of the Princes from Antofagasta the machine was in constant touch with the chain of Chilian aerodrome ground stations, and for the whole of the flight from Ovalle to Santiago, a distance of 220 miles, positions were taken every five minutes by the two wireless direction finding stations at Quintero and Santiago, the progress of the machine and aircraft thus being followed and broadcast to an immense crowd awaiting their arrival at El Bosque aerodrome.

The First Marconi Stations in Canada.

THE reference in our last issue to the first Marconi stations to be opened for traffic in the United States has brought forth the following interesting comments from Commander C. P. Edwards, Director of Radio, Department of Marine, Canada.

"I was interested in the historical data given in your recent number of THE MARCONI REVIEW with regard to the first Marconi stations in the United States, and I find on looking up the dates, that Canada was not very far behind, the Marconi stations at Chateau Bay and Belle Isle on the Canadian Labrador, having been established on the 28th September, 1901.

"I have forgotten who was in charge of the work, but I am sure you will be interested to read the following extract from the report of the late D. H. Keeley, Superintendent of Telegraphs, of the Department of Public Works, in regard to this communication :—

"'The spot selected at Chateau Bay is a quarter mile from the village ; and a special hut for the winter accommodation of the apparatus as at Belle Isle had to be erected.

"'This Chateau Bay installation was in readiness on Sunday the 20th October, when signals from Chateau Bay were received at Belle Isle ; but none were receivable at Chateau Bay. The trouble on investigation was attributed to defective coherers, and the Company's agents proposed abandoning the plant till next year in the absence of a fresh supply.

"'On the 22nd, however, I personally succeeded in establishing communication and was thereby enabled to avert the threatened postponement of operations ; and on the 25th, after considerable practice and careful directions, for all that the working of the system as it stands is erratic, I felt confident in leaving our operators in charge, with the explicit intruction as to future action conveyed in the copy attached hereto.'

"These stations have long passed into oblivion. The Belle Isle station was replaced in 1905 by a standard coast station, and that, in turn, was replaced two or three years ago by a modern station equipped with C.W. transmitter, direction finding apparatus, etc.

"The Chateau Bay station was closed down and the service taken over by a new station at Point Amour about 1904, and that station, in turn, is now about to be replaced by a modern plant."