"Note on a Magnetic Detector of Electric Waves, which can be employed as a Receiver for Space Telegraphy." By G. MARCONI, M.I.E.E. Communicated by Dr. J. A. FLEMING, F.R.S. Received June 10,—Read June 12, 1902.

The present note bears upon the special manner in which a core or rod of iron or steel placed in a varying magnetic field is affected by high-frequency oscillations transmitted from considerable distances.

The magnetisation and demagnetisation of steel needles by the effect of electrical oscillations has long been known, and has been noted especially by Professor J. Henry, Abria, Lord Rayleigh, and others. Mr. E. Rutherford also has described a magnetic detector of electric waves, based on the partial demagnetisation of a small core composed of fine steel needles, previously magnetised to saturation, and placed in a solenoid of fine copper wire connected to exposed plates. By means of a magnetometer Mr. Rutherford succeeded in tracing the effects of his electrical radiator up to a distance of ¾ mile across Cambridge.*

The detector which I am about to describe is, in my opinion, based upon the decrease of magnetic hysteresis which takes place in iron when, under certain conditions, it is exposed to the effect of high-frequency or Hertzian waves.

As employed by me up to the present, it has been constructed in the following manner:—On a core or rod consisting of thin iron wires are wound one or two layers of thin insulated copper wire. Over this winding, insulating material is placed, and over this again, another longer winding of thin copper wire contained in a narrow bobbin.

The ends of the winding nearest the iron core are connected to the plates or wires of the resonator, or as is the usual practice in long-distance space telegraphy, to earth and to an elevated conductor; or they may be connected to the secondary of a suitable receiving transformer or intensifying coil, such as are now employed for syntonic wireless telegraphy. The ends of the other winding are connected to the terminals of a telephone or other suitable receiving instrument. Near the ends of the core, or in close proximity to it, is placed a magnet, preferably a horse-shoe magnet, which, by a clockwork arrangement, is so moved or revolved as to cause a slow and constant change, or successive reversals, in the magnetisation of the iron core. I have noticed that if electrical oscillations of suitable period be sent from a transmitter according to the now well-known methods, rapid changes are effected in the magnetisation of the iron wires, and these

* See 'Phil. Trans.,' A, vol. 189 (1897), pp. 1—24.

changes necessarily cause induced currents in the windings, which induced currents in their turn reproduce on the telephone with great clearness and distinctness the telegraphic signals which may be sent from the transmitting station.

Should the magnet be taken away, or its movement stopped, the receiver ceases to be perceptibly affected by the electric waves, even when these are generated at very short distances from the radiator.

This detector has been successfully employed for some time in the reception of wireless telegraphic messages between St. Catherine's Point, Isle of Wight, and the North Haven, Poole, over a distance of 30 miles, and also between Poldhu, in Cornwall, and the North Haven, over a distance of 152 miles, of which 109 are over sea and 43 over high land. It has also been ascertained that signals can be obtained over these distances with the new detector when employing less power at the transmitting station than is necessary if a reliable coherer be substituted for the magnetic detector. I have had occasion to notice, however, that the signals audible in the telephone are weakest when the poles of the rotating magnet have just passed the core and are increasing their distance from it, whilst they are strongest when the magnet poles are approaching the core.

Very good results have also been obtained by keeping the magnet fixed, and using an endless iron rope or core of thin wires revolving on pulleys (worked by a clockwork arrangement), which cause it to travel through the copper wire windings, in proximity to a horse-shoe magnet, or, preferably, two horse-shoe magnets with their poles close to the windings, and with their poles of the same sign adjacent. In this case the copper wire windings are separated from the iron by means of a stiff, thin pipe of insulating material in order to prevent chafing of the wires. With this arrangement the signals appear to be quite uniform in strength.

There appears to be a certain magnetic force which gives best results, but different qualities of iron require different values. There would also appear to be a particular speed of revolution for the magnets employed which is more suitable than any other. I have obtained good results when causing the magnets to revolve at the rate of one revolution every 2 seconds, or, when using a moving core, by causing it to travel at a speed of about 30 cm. in 4 seconds.

Either iron or steel can be used for the cores or revolving rope, but I have observed that by far the best effects are obtained when using hard-drawn iron wires or iron wire that has been considerably stretched or twisted beyond its limits of elasticity prior to its employment.

I have used cores generally consisting of about thirty hard-drawn iron wires of approximately 0·5 mm. in diameter, with a winding on them made up of a single layer of silk-covered copper wire 0·019 cm. in diameter and of a total length of 2·4 metres. The other winding, connected to the telephone, has consisted of similar wire, and I have been in the habit of employing a sufficient number of turns of it to give a resistance about equal to that of the telephone used.

It would, no doubt, be possible to obtain the signals by causing the iron core to act directly on a telephone diaphragm, and in this case the secondary winding on the core could be omitted. The length of the electric waves used in the experiments between St. Catherine's Point and North Haven was about 200 metres. If longer waves are employed, it is desirable that the length of the winding nearest the iron should be increased.

This detector, as I have already stated, appears to be more sensitive and reliable than a coherer, nor does it require any of the adjustments or precautions which are necessary for the good working of the latter.

Further advantages in its use become apparent when it is employed in connection with my syntonic system of space telegraphy. According to this system, electrical syntony between the transmitter and receiver is dependent on the proper electrical resonance of the various circuits of transformers used in the receivers. With certain coherers one difficulty has been that it was not always possible to restore them by mechanical tapping to the same electrical resistance which they possessed before being affected by the transmitted electric waves, the result being that the secondaries of the receiving transformers were at certain times open and at other times closed by a variable resistance, thus causing an appreciable variation in their natural period of electrical oscillation.

The magnetic detector which I have described possesses, on the other hand, a practically uniform and constant resistance much lower than that of a coherer in its sensitive condition, and, as it will work with a much lower E.M.F., the secondaries of the tuning transformers can be made to possess much less inductance, their period of oscillation being regulated by a condenser in circuit with them, which condenser may be much larger (in consequence of the smaller inductance of the circuit) than those used for the same period of oscillation in a coherer circuit, with the result that the receiving circuits can be tuned much more accurately to a particular radiator of fairly persistent electric waves.

The considerations which led me to the construction of the above-described detector are the following:—It is a well-known fact that after any change has taken place in the magnetic force acting on a piece of iron, some time elapses before the corresponding change in the magnetic state of the iron is complete. If the applied magnetic force be either subjected to a gradual increase followed by an equally gradual diminution, or caused to effect a cyclic variation, the corresponding induced magnetic variation in the iron will lag behind the changes in the applied force. To this tendency to lag behind, Professor Ewing has given the name of Magnetic Hysteresis.

It has been shown also by Gerosa, Finzi, and others that the effect of alternating currents or high-frequency electrical oscillations acting upon iron is to reduce considerably the effects of magnetic hysteresis, causing the metal to respond much more readily to any influence which tends to alter its magnetic condition. The effect of electrical oscillations probably is to bring about a momentary release of the molecules of iron from the constraint (or viscosity) in which they are ordinarily held, diminishing their retentiveness, and consequently decreasing the lag in the magnetic variation taking place in the iron.

I therefore anticipated that the group of electrical waves emitted by each spark of a Hertzian radiator would, if caused to act upon a piece of iron which is being subjected at the same time to a slowly varying magnetic force, produce sudden variations in its magnetic hysteresis, which variations would produce others of a sudden or jerky nature in its magnetic condition. In other words, the magnetisation of the iron, instead of slowly following the variations of the magnetic force applied, would at each spark of the transmitter suddenly diminish its magnetic lag caused by hysteresis.

These jerks in the magnetic condition of the iron would, I thought, cause induced currents in a coil of wire of strength sufficient to allow the signals transmitted to be detected intelligibly on a telephone, or perhaps even read on a galvanometer.

The tests to which I have referred above confirm my belief that the magnetic detector can be substituted for the coherer for the purposes of long-distance space telegraphy.

"A Note on the Effect of Daylight upon the Propagation of Electromagnetic Impulses over Long Distances." By G. MARCONI, M.I.E.E. Communicated by Dr. J. A. FLEMING, F.R.S. Received June 10,—Read June 12, 1902.

During some long-distance space telegraphy tests carried out towards the end of February last between a transmitting station situated at Poldhu, on the coast of Cornwall, and a receiving station on board the U.S. s.s. "Philadelphia" travelling from Southampton to New York, I had the opportunity of noticing for the first time in my experience, considerable differences in the distances at which it was possible to detect the received oscillations during daylight, as compared with the distances at which the effects could be obtained at night.

Before describing the results obtained, it may be useful if I give a brief description of the nature of the apparatus used at the transmitting and receiving stations.

The transmitter at Poldhu was similar in principle to that used by me in previous work,* but the elevated conductor at the transmitting station was much larger, and the potential to which it was charged at the peak of each electrical oscillation very much in excess of any that had been previously employed. The transmitting elevated conductor consisted of fifty almost vertical naked copper wires, suspended at the top by a horizontal wire stretched between two poles each 48 metres high and placed 60 metres apart.

These wires were separated from each other by a space of about 1 metre at the top, and, after converging together, were all connected to the transmitting instruments at the bottom. The potential to which these conductors were charged during transmission was sufficient to cause sparking between the top of the said wires and an earthed conductor across a space of 30 cm.†

The general engineering arrangements of the electric-power station erected at Poldhu for creating the electric waves of the frequency which I desired to use, were made by Dr. J. A. Fleming, F.R.S., who also devised many of the details of the appliances for producing and controlling the electric oscillations. These, together with devices introduced by me and my special system of syntonisation of inductive circuits, have provided an electric-wave generating plant more powerful than any hitherto constructed.

At the receiving station on the ship, one of my receivers, as described in the Society of Arts paper above referred to, was employed, and the signals were recorded on the tape of a Morse recording instrument.

A receiving transformer accurately tuned to the period of the electrical oscillations radiated from the transmitting station at Poldhu was connected to the coherer in the usual manner.

The receiving elevated conductor was constituted of four almost vertical wires sustained in position by the ship's mast, the summit of which wires was about 60 metres above the sea-level. At their lower end they were all connected to the receiving instrument.

My assistants at Poldhu had received instructions to send a succession of Ss and a short message at a certain pre-arranged speed, every ten minutes, alternating with five minutes of rest, during the following hours:—From 12 to 1 A.M., from 6 to 7 A.M., from 12 to 1 P.M., and from 6 to 7 P.M., Greenwich mean time, every day from the 23rd

* See 'Journal of the Society of Arts,' vol. 29, pp. 506—517.

† *Note, added* July 5, 1902. The spark-length here stated to be 30 cm. was, by a misunderstanding on the part of the communicator of the paper, altered to 50 mm., which appeared on the first proof. It was correctly stated as 30 cm. in the original MS.

February to 1st March inclusive. On board the "Philadelphia," I did not notice any apparent difference between the signals received in the day and those received at night-time, until after the vessel had reached a distance of 500 statute miles from Poldhu. At distances of over 700 miles, however, the signals transmitted during the day failed entirely, while those sent at night remained quite strong up to 1551 miles, and were even clearly decipherable up to a distance of 2099 miles from Poldhu.

It is interesting to note that at the time of the year at which these experiments took place, daylight at Poldhu was rapidly increasing between the hours of 6 and 7 A.M., and on the "Philadelphia," I noticed that at distances of over 700 miles from the sending station, the signals at 6 A.M. were quite clear and distinct, whereas by 7 A.M. they had grown weak almost to total disappearance, their strength thus apparently diminishing in proportion as daylight increased at Poldhu. No such weakening of the signals was noticeable between the hours of 12 midnight and 1 A.M.

With a view to further tests in this same connection, I carried out other experiments between the station at Poldhu and a receiving station (in all respects similar to the one on the "Philadelphia") situated at the North Haven, Poole, Dorset. The distance between the North Haven and Poldhu is about 152 statute miles, of which 109 are over sea and 43 over high land. It was found that the signals from Poldhu could be perfectly well received at the North Haven during the night when four vertical wires 12·1 metres high were used in connection with the receiving instruments, whilst, all other conditions being the same, during the day the height of the wires required to be 18·5 metres in order to receive the same signals with equal clearness.

The cause of these observed differences in the effects obtained by night as compared with those noticed by day may be due to the dis-electrification of the transmitting elevated conductor, operated by the influence of daylight. The electrical oscillations in the transmitting elevated conductor may thus be prevented by the discharging influence of light from acquiring so great an amplitude as they attain during darkness.

The diselectrification of negatively charged metallic bodies by light has been noticed by many observers,* and as each alternate half-oscillation in the transmitting elevated conductor must necessarily charge it negatively, the dissipating effect of light on each alternate oscillation of the electrical wave in the transmitting wire may be sufficient to cause a material decrease in the amplitude of the oscillations.

* See papers by Messrs. Elstor and Geitel in Wiedemann's 'Annalen,' pp. 38—40, also p. 497; also remarks of Professor Righi in 'Comptes Rendus,' vol. 107 p. 559.

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The composition of the "heavy hydrocarbons" is somewhat uncertain. One hundred volumes of gas require 576 volumes of air for complete combustion. One hundred volumes of gas burnt in 900 of air give about 133 volumes of steam, 57·of CO_2, and 780 of inert gases; assuming that there is no dissociation.

On Methods whereby the Radiation of Electric Waves may be mainly confined to Certain Directions, and whereby the Receptivity of a Receiver may be Restricted to Electric Waves Emanating from Certain Directions.

By G. Marconi, LL.D., D.Sc.

(Communicated by Dr. J. A. Fleming, F.R.S. Received March 15,—Read March 22, 1906.)

This Note relates to results observed when for the usual vertical antenna employed as radiator or absorber in wireless telegraph stations there is substituted a straight horizontal conductor placed at a comparatively small distance above the surface of the ground or water.

When an insulated horizontal wire, AB, such as is shown in sketch 1, is connected at one end to a sphere of a spark gap, the other sphere of which

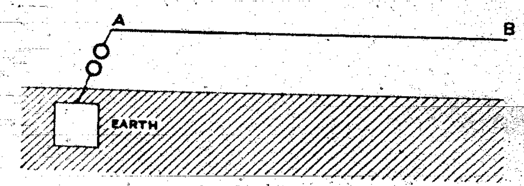

FIG. 1.

is earthed, and sparks are caused to pass between the spheres, it will be noticed on investigating the space around such an oscillator that the radiations emitted reach a maximum in the vertical plane of the horizontal wire, AB, and proceed principally from the end, A, which is connected to the spark-gap, whilst the radiation is *nil*, or reaches a minimum, in directions which are approximately 100° from the direction in which the maximum effect occurs.

I have also noticed that any horizontal conductor of sufficient length placed upon or at a short distance above the surface of the ground, and connected at one end through a suitable detector to earth, will receive with maximum efficiency only when the transmitter is situated in the vertical plane of the said horizontal receiving conductor, and in such a direction that the end connected to the detector and to the ground is pointing towards the transmitting station.

If, therefore, such a horizontal conductor be swivelled about its earthed end in a horizontal plane, the bearing or direction of any transmitting station within range of the receiver can be ascertained.

I have carried out a number of tests with transmitters and receivers having radiating or receiving antennæ or conductors arranged as follows:—

(1) Transmitting conductors consisting of horizontal wires, the radiations being received at a distance by means of the usual vertical wires suitably attuned.

(2) Both transmitting and receiving conductors consisting of horizontal wires.

(3) Transmitting conductors consisting of one or more vertical wires with or without capacity areas at top, such as have been generally employed in wireless telegraphy, the radiations being received by means of horizontal conductors.

At long distances I almost invariably used as a detector my magnetic receiver.* At shorter distances I utilised a Duddell thermogalvanometer,† by means of which it was possible to measure the root-mean-square values of the currents induced by the oscillations in receiving wires disposed in various positions relative to the transmitting conductors.

With arrangements such as are referred to in (1), the following tests have been carried out:—

1. *Transmitter.*—Horizontal wire 100 metres in length, direct excitation, spark-length 2 cm., wave-length approximately 500 metres.

Receiver.—A vertical wire 8 metres in length, tuned to the period of the transmitter by means of a syntonising coil, and connected to a magnetic detector and to earth in the usual manner.

Results.—Signals quite distinct at 16 kiloms. in the vertical plane of the horizontal transmitting wire and in the direction of its earthed end; weak at 10 kiloms. in the same vertical plane, but in the reverse direction; inaudible at 6 kiloms. at right angles to the directions above mentioned.

2. *Transmitter.*—(At Mullion, Cornwall), consisting of horizontal conductor 150 metres in length, composed of four parallel wires about 3 mm. an

* See 'Roy. Soc. Proc.,' London, 1902, vol. 70, p. 341.

† 'Phil. Mag.,' 1904, vol. 8, p. 91.

diameter, placed 1·50 metres apart, supported at a height of 20 metres, and all connected to earth through the spark gap of an induction coil placed in a building on the ground; spark length about 2 cm.

Receiver.—At the Haven, Poole (distance, 240 kiloms.), consisting of vertical wire 50 metres long, connected through a syntonising coil to a magnetic detector and to earth.

Results.—A movement of 15° of the plane of the transmitting conductor out of the right direction was sufficient to cause signals to become indetectible at Poole.

Polar diagram D (fig. 2) gives the values of the received current in micro-ampères, with conditions as marked under the diagram. The values of current in micro-ampères shown in each diagram are the mean of a considerable number of readings, the transmitted energy being kept as nearly as possible constant by means of a suitable interrupter applied to the sending induction coil.

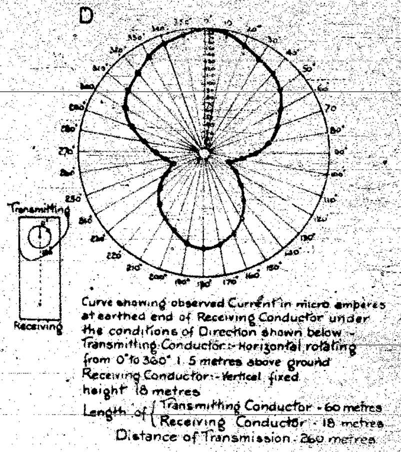

FIG. 2.

With the arrangement mentioned at (2) *i.e.*, both transmitting and receiving conductors horizontal, the following results, among others, were obtained:—

1. *Transmitter.*—Conductor 200 metres in length, supported at a height of 15 metres above ground; spark length about 2 cm.

Receiver.—Similar conductor supported 1 metre above ground, connected at one end to a detector and to earth as usual.

Results.—In the direction for maximum effect (as already explained) readable signals at 25 kiloms. At about 90° from said direction at 12 kiloms., nothing; in the same direction at 5 kiloms., weak signals.

2. *Transmitter.*—Consisting of four wires each 330 metres in length, separated from one another by a distance of 1·4 metres, supported at a height of 20 metres above ground and connected by means of a nearly vertical conductor to a spark producer; spark length, 3 cm.

Receiver.—Consisting of one wire 220 metres in length, covered with insulating material, placed on the ground and connected to the end nearest the sending station through a syntonising coil to a magnetic receiver and to earth.

Results.—When in the vertical plane of the transmitting antennæ, and in the best direction, weak but distinct signals were received at a distance of 160 kiloms.; at 45° from said direction and at 150 kiloms. distance nothing was received; at 25° from the best direction, and at 160 kiloms. distance, very weak signals were received.

The results over shorter distances are given by the readings obtained on the thermogalvanometer, and are shown in the polar diagrams E and B.

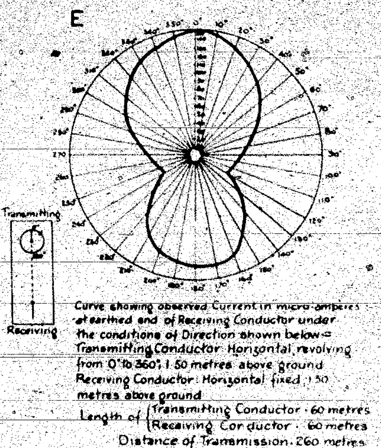

Fig. 3.

With arrangements such as are mentioned at (3), *i.e.*, the transmitting conductor consisting of the usual vertical type and the receiving conductor horizontal, the following results among others merit attention:—

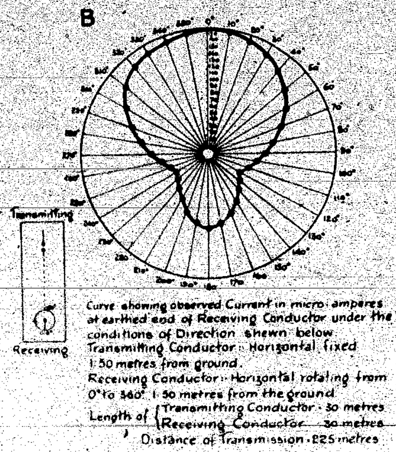

FIG. 4.

At Clifden, Connemara, Ireland, by means of a horizontal conductor 230 metres in length, laid on the ground and connected at one end to a magnetic receiver and to earth, it is possible to receive with clearness and distinctness all the signals transmitted from the Poldhu station (situated 500 kiloms. distant) provided that the free end of the said conductor points directly away from the direction of Poldhu. No signals can be received if the horizontal wire at Clifden makes an angle of more than 35° with the line of direction of Poldhu.

The signals from the Admiralty station at Scilly can be received at Mullion, Cornwall (distance about 85 kiloms.) by means of a horizontal wire 50 metres in length, 2 metres above ground, provided said wire is placed in a radial position with respect to the sending station and with its free end pointing away from it. But it is unreceptive if placed so as to make an angle of more than 20° with the line of direction of the station at Scilly.

Some tests have also been carried out for the Admiralty in the vicinity of Poldhu in conjunction with H.M.S. "Furious." For this purpose eight horizontal wires 60 metres in length, supported at a height of about 2 metres, were arranged radially and made to converge in a small building situated in a field near Poldhu. These radial wires were so arranged as to divide the circle into eight equal sectors. By means of a suitable switch any one of the ends of these wires at the position where they converged together could be connected to earth through a magnetic receiver.

The wireless telegraph station on H.M.S. "Furious" consisted of an ordinary vertical wire aerial about 50 metres in length, connected to a suitable spark gap. The station on the ship transmitted at intervals, and the ship followed a course describing an arc of about 180° round Poldhu, keeping at distances varying up to 16 miles. By means of the horizontal wire arrangement, the bearing of the ship from Poldhu could be determined at any time by noting on which particular wire or wires the reception of signals was strongest, and also by observing which wires were non-receptive.

It was also found possible to receive simultaneously and without mutual interference different signals sent by means of oscillations of the same wave-length coming from the ship and from the Lizard wireless station (10 kiloms. away) whenever the ship was in such a position that its bearing from Poldhu made an angle of at least 50° with the bearing of the Lizard station.

For further values and curves of received current in receivers, I refer to Diagrams A, A', C, C'.

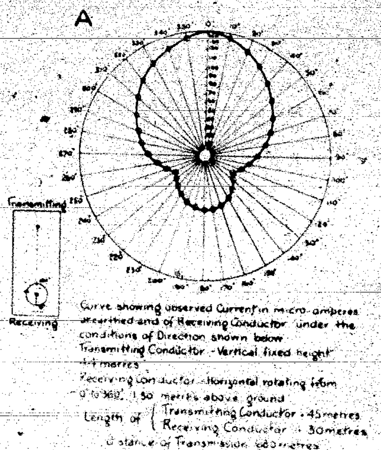

FIG. 5.

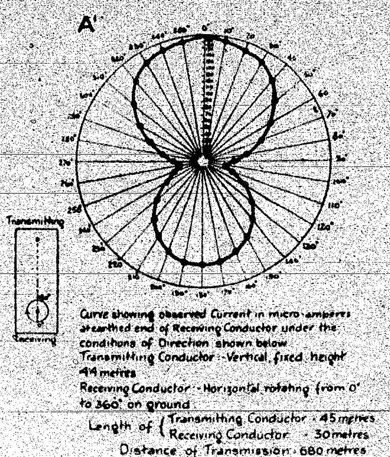
A'
Transmitting
Receiving
Curve showing observed Current in micro-amperes at earthed end of Receiving Conductor under the conditions of Direction shown below
Transmitting Conductor :- Vertical, fixed height 44 metres
Receiving Conductor :- Horizontal rotating from 0° to 360° on ground
Length of { Transmitting Conductor - 45 metres
Receiving Conductor - 30 metres
Distance of Transmission - 680 metres

FIG. 6.

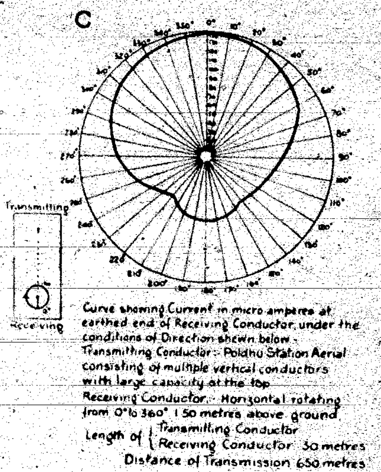
C
Transmitting
Receiving
Curve showing Current in micro amperes at earthed end of Receiving Conductor, under the conditions of Direction shewn below -
Transmitting Conductor :- Poldhu Station Aerial consisting of multiple vertical conductors with large capacity at the top
Receiving Conductor :- Horizontal rotating from 0° to 360° 1·50 metres above ground
Length of { Transmitting Conductor
Receiving Conductor 30 metres
Distance of Transmission 650 metres

FIG. 7

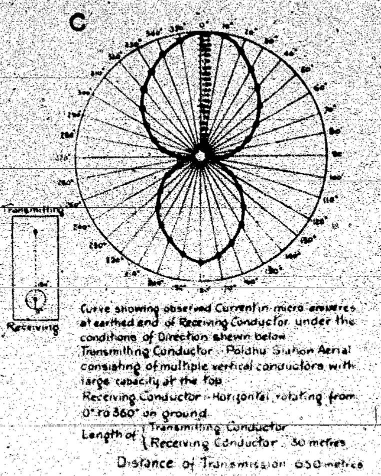

FIG. 8.

Referring generally to the results mentioned in this Note, I have observed that, in order that the effects should be well marked, it is necessary that the length of the horizontal conductors should be great in proportion to their height above the ground, and that the wave-lengths employed should be considerable—a condition which renders it difficult to carry out such experiments within the walls of a laboratory.

I have found the results to be well marked for wave-lengths of 150 metres and over, but have not been able to obtain as well-defined results when employing much shorter waves—the effects following some law which I have not yet had time to investigate. There also appears to be a decided advantage in so far as effects at long distances are concerned in utilising a directly excited radiating conductor—that is, an insulated conductor in which the high frequency oscillations are started by means of a suitable spark discharging it to earth or to another body, as was usual in my early forms of Hertzian-wave wireless telegraph transmitters.

If inductive excitation is employed, that is, if the oscillations are induced in the radiating conductor from another oscillating circuit, the comparative results in various directions appear to be in the same proportions as those noticed when using the method of simple excitation, but the distances over which the effects can be detected are much smaller at parity of the power employed at the transmitter.

I have noticed that the most advantageous length of the receiving horizontal wires, in order to obtain results at maximum distances, is about one-fifth of the length of the transmitted wave, if said wires are placed at a distance above the ground; but the receiving wires should be shorter if placed on the ground. It would be instructive to investigate more thoroughly the difference of the results and curves obtained by means of horizontal wires placed at different heights above ground, and also the effect of varying the length of said wires.

When using horizontal receiving wires arranged as described in this Note, I have often noticed that the natural electrical perturbations of the atmosphere or stray electric waves, which are generally prevalent during the summer, appear to proceed from certain definite directions which vary from time to time. Thus, on certain days, the receiving instruments when connected to wires which are oriented in such a way as to possess a maximum receptivity for electric waves coming from the south, will give strong indications of the presence of these natural electric waves, whilst on differently oriented wires the effects are at the same time weaker or imperceptible. On other days these natural electric waves may apparently come from other directions.

It would be exceedingly interesting to investigate whether there exists any relation between the direction of origin of these waves and the known bearing or direction of distant terrestrial or celestial storms from whence these stray electric waves most probably originate. A considerable number of observations would be necessary to determine whether there exists any relation between the bearing of storm centres and the direction of origin of these natural electric waves. I propose to carry out some further investigations on the subject.

I ought to explain that the experiments described in this Note were carried out during a period of many months, and that as other results achieved over greater distances coincide generally with those here described, I have not thought it necessary to make special reference to them.

I should also mention that the tests over short distances were carried out over practically flat country, whilst those over considerable distances took place over hilly country, such as the West of England, and in some cases partly across sea and partly across land.
