"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. Elster and Geitel in Wiedemann's 'Annalen,' pp. 38—40, also p. 497; also remarks of Professor Righi in 'Comptes Rendus,' vol. 107 p. 559.

PROCEEDINGS

OF

THE ROYAL SOCIETY.

"Magnetic Observations in Egypt, 1893—1901." By Captain H. G. Lyons, R.E. Communicated by Professor Rücker, Sec. R.S. Received June 6,—Read June 20, 1901.

The following Magnetic Observations have been made at various times during the years 1893 to 1899, at first with a Declinatorium, made by Bamberg, of Berlin, the property of the Egyptian Government, and later with a Kew Magnetometer, No. 73, and Dover's Dip Circle, No. 99, both kindly lent by the Council of the Royal Society on the recommendation of Professor A. W. Rücker, F.R.S. These observations are most conveniently divided into five groups, each of which includes observations made during a single period and with a single instrument—

I. Observations made with a Declinatorium by Bamberg, of Berlin:

(*a.*) In the neighbourhood of Cairo, 1893—1894.

(*b.*) In the Lybian Desert, near the Kharga and Dakhla Oases, in December, 1893, and January, 1894.

(*c.*) In the Lybian Desert from the Wadi Natrun to the Baharia Oasis, April, 1894.

II. Observations taken with Kew Magnetometer, No. 73, and Dover's Dip Circle, No. 99, in the Nile Valley from Cairo to the 2nd Cataract, November, 1894, to June, 1896.

(*a.*) Declination. (*b.*) Dip and Horizontal Force.

III. Observations taken to determine the Diurnal Variation of the Declination.

IV. Observations taken at Helwan, near Cairo, in November and December, 1898.

V. Determination of the Annual Variation from the above observations and those of various observers in previous years.

"A Note on a Form of Magnetic Detector for Hertzian Waves, adapted for Quantitative Work." By Dr. J. A. FLEMING, F.R.S., Professor of Electrical Engineering in University College, London. Received February 11,—Read March 5, 1903.

The known power of electrical oscillations to demagnetise iron or steel was first applied in the construction of a detector of Hertzian waves, as far as the author is aware, by Mr. E. Rutherford.* The power possessed by electrical oscillations to annul the magnetic hysteresis of iron was discovered by Mr. G. Marconi and applied by him in the construction of his ingenious and extraordinarily sensitive Hertzian wave detector, for use in connection with wireless telegraphy.†

The following note describes a form of magnetic Hertzian wave detector, which has been constructed by the writer for the purpose of quantitative experiments in connection with Hertzian waves.

Every one who has experimented with a Hertzian oscillator, or electric wave radiator in any form, involving a spark gap, is well aware of the immense difference in the radiative power produced by slight alterations in the nature of the spark or the spark balls, and has felt the want of some instrument which shall indicate and measure exactly the intensity of the radiation. As a receiving instrument, the coherer or sensitive imperfect contact is of very little use quantitatively, because its indications are influenced by very slight accidental changes at the contact or contacts. Thus, the sensitiveness of the metallic filings coherer depends upon the manner in which it was left after its last use, and by the mode in which it is tapped or shaken, and the change in the conductivity which it experiences on the impact of an electric wave, is variable and uncertain. Hence, although sensitive as a mere wave detector, the coherer is of little or no use in quantitative work. On the other hand, the magnetic detector is not only superior to the coherer in sensitiveness when properly constructed, but is capable of being used as a measuring instrument. In the form in which it was constructed by Mr. Rutherford, an extremely fine bundle of iron or steel wires was magnetised by means of a magnet, or by being placed in the interior of a solenoid, and then demagnetised by an electrical oscillation passing through another coil

* See Mr. E. Rutherford, "On a Magnetic Detector of Electric Waves and some of its applications," 'Roy. Soc. Proc.,' 1896, vol. 60, p. 184; see also 'Phil. Trans.,' A, 1897, vol. 189, p. 1.

† Mr. G. Marconi, "Note on a Magnetic Detector for Electric Waves which can be employed as a Receiver for Space Telegraphy," 'Roy. Soc. Proc.,' 1902, vol. 70, p. 341.

surrounding it. The amount of demagnetisation was detected by means of a magnetometer. In this form, it has been much used in experimental work, but it was not a telegraphic receiver.*

In the sensitive telegraph receiver invented by Mr. Marconi the change in magnetisation of the iron, due to the temporary abolition of hysteresis, is detected by the production of a sound in a telephone connected to a secondary coil surrounding the iron.

After trying various forms, the writer has found that a convenient magnetic detector for Hertzian waves can be constructed in the following manner :—

On a pasteboard tube, about $\frac{3}{4}$ of an inch in diameter and 5 or 6 inches long, are placed six bobbins of hard fibre, each of which contains about 6000 turns of No. 40 silk covered copper wire. These bobbins are joined in series, and form a well-insulated secondary coil, having a resistance of about 6000 ohms. In the interior of this tube are placed seven or eight small bundles of iron wire, each about 6 inches in length, each bundle being composed of eight wires, No. 26 S.W.G. in size, previously well paraffined or painted with shellac varnish. Each little bundle of iron is wound over uniformly with a magnetising coil formed of No. 36 silk-covered copper wire in one layer, and over this, but separated from it by one or two layers of gutta-percha tissue, is wound a single layer of No. 26 wire, forming a demagnetising coil. This last coil is in turn covered over with one or two layers of gutta-percha tissue.

The magnetising or inner coils are connected in series with one another, so that when a current passes through the whole of them, it magnetises the whole of the wires in such a manner that contiguous ends have the same polarity. The outer or demagnetising coils are joined in parallel. Associated with this induction coil is a rotating commutator, consisting of a number of hard fibre discs secured on a steel shaft, which is rotated by an electric motor about 500 times a minute. There are four of these fibre discs, and each disc has let in its periphery a strip of brass, occupying a certain angle of the circumference. These wheels may be distinguished as Nos. 1, 2, 3, and 4. The brass sector of No. 1 occupies 95° of its circumference; the brass sectors of Nos. 2 and 3 occupy 135° of their circumference; and that of No. 4 disc 140° of its circumference. Four little springy brass brushes make contact with the circumference of these wheels, and therefore serve to interrupt or make electric circuits as the disc revolves. The function of the disc No. 1 is to make and break the

* Note added March 7th. A general term seems to be required to include all forms of wave-detecting devices. The author suggests the word *kumascope* (from κῦμα, a wave) for this purpose. Uncouth phrases, such as *anticoherer* or *self-decohering-coherer*, which have crept into use in connection with Hertzian wave telegraphy, would be rendered unnecessary.

circuit of the magnetising coils placed round the iron bundles, and thus by applying a magnetising current to magnetise them during a portion of one period of rotation of the disc, and leave them magnetised in virtue of magnetic retentivity during the remaining portion. The function of discs 2 and 3 is to short-circuit the terminals of the secondary coil of the bobbin during the time that the magnetising current is being applied by disc No. 1. A sensitive movable coil galvanometer is employed in connection with the secondary coil, one terminal of the galvanometer being permanently connected to one terminal of the secondary coil, and the other terminal connected through the intermittent contact made by the disc No. 4. This disc No. 4 is so set that during the time that the secondary coil is short-circuited, and whilst the battery current is being applied to magnetise the iron wire bundles, the galvanometer circuit is interrupted by the contact on disc No. 4.

The operations which go on during one complete revolution of the discs are as follows:—First the magnetising current of a battery of secondary cells is applied to magnetise the iron bundles, and during the time this magnetising current is being applied, the terminals of the fine wire secondary coil are short-circuited and the galvanometer is disconnected. Shortly after the magnetising current is interrupted the secondary bobbin is unshort-circuited, and an instant afterwards the galvanometer circuit is completed and remains completed during the remainder of one revolution. Hence, during a large part of one revolution, the iron wire bundles are left magnetised, but the magnetising current is stopped and the galvanometer is connected to the secondary coil. If during this period an electrical oscillation is passed through the demagnetising coils, an electromotive force is induced in the secondary bobbin by the demagnetisation of the iron and causes a deflection of the galvanometer coil. Since the interruptor discs are rotating very rapidly, if the electrical oscillation continues, these intermittent electromotive impulses produce the effect of a continuous current in the galvanometer circuit, resulting in a steady deflection, which is proportional to the demagnetising force being applied to the iron, other things remaining equal. If the oscillation lasts only a very short time, the galvanometer will make a small deflection; but if the oscillation lasts for a longer time, then the galvanometer deflection is larger, and tends to become steady.

By means of such an arrangement it is possible to verify the law according to which variation falls off with distance. The instrument can be employed also as a telegraphic receiving instrument, but its chief use will be for comparing together the wave-making power of different radiators. For this purpose the oscillation coils must be connected to two long connecting wires, or one end may be connected to the earth and the other to a vertical aerial. This detector serves, for instance, to show in a very marked manner the great effect of slight differences in the surface of the spark balls. If a steady series of sparks from an induction coil is passed between the spark balls of a Hertz linear radiator, it will produce a steady deflection on a galvanometer connected with the above-described receiver placed at a distance. If the balls are then polished, the galvanometer deflection immediately increases considerably. If, on the other hand, the balls are slightly smeared with oil, the galvanometer deflection decreases. If the radiator is approached to the receiver, or withdrawn from it, corresponding variations in the galvanometer deflection take place.

Such an instrument will probably be found of great use in connection with the design of radiators and transmitters for Hertzian wave wireless telegraphy. Up to the present it has been generally difficult to ascertain whether an improvement in the signalling is due to an accidental increase in sensitiveness in the coherer, or to any alteration or change made in the transmitter.

Similarly, the instrument promises to be of considerable use in the investigation of the transparency or opacity of various substances to Hertzian waves, not merely qualitatively, but in the determination of a coefficient of absorption. Preliminary experiments of this description made with the above-described instrument seem to promise for it a field of practical utility, both in the laboratory and in connection with Hertzian wave telegraphy.

In the numerous experiments which finally resulted in the construction of the above-described form of wave detector, it was found to be essential to have the iron core in the form of a number of small bundles of iron wire, each wound over with its own magnetising and demagnetising coil. No good results could be obtained when the iron core was in the form of a large bundle, say half an inch in diameter, and enveloped by a single magnetising and demagnetising coil.

Another condition of success is the short-circuiting of the fine wire secondary coil during the time of magnetisation of the core. The core can be indefinitely increased in size, provided the augmentation of mass is obtained by multiplying small individual cores, each consisting of not more than eight or ten fine iron wires, and each wound over with a separate magnetising and demagnetising coil. The electromotive force in the secondary coil can in this manner be increased as much as is desired, and a very sensitive wave detector produced. The commutator can be driven either by an electric motor or by any other source of power.

In conclusion, I have pleasure in mentioning the intelligent assistance rendered to me by Mr. A. Blok in the experiments conducted in connection with this appliance.