A Directive System of Wireless Telegraphy

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There is an alternative mechanical way of describing the motion in the cycloidal case. It can be shown without difficulty that it is identical with the motion of a cycloidal pendulum, or of a particle sliding on a smooth cycloidal wire, the range of swing extending from cusp to cusp. Here the acceleration of gravity takes the place of the electric force, and the normal reaction of the wire or string that of the magnetic force. But this analogy cannot be extended to the trochoidal motion; the velocity of the moving corpuscle does not alter in the same way as that of a particle sliding under gravity on a smooth trochoid.

23rd May 1908.

XXI. *A Directive System of Wireless Telegraphy.* *By* E. Bellini *and* A. Tosi *.

Part I.—Bilateral Directive Wireless Telegraphy using Closed Oscillatory Circuits: (i.) for Transmission; (ii.) for Reception; (iii.) for both Transmission and Reception.

Part II.—New Unilateral Directive Method: Simultaneous Use of Closed Oscillatory Aerial Circuits and the Open Oscillator or Vertical Antenna.

The authors, having lately obtained some interesting and very remarkable results in the course of their work upon a further development of their directive system, propose to give an account of the arrangements employed and the results attained.

Since the complete understanding of these experiments depends upon the properties shown by the closed oscillatory circuits used by the authors, it is considered desirable, in the first part of the paper, to recapitulate, as briefly as possible, the main features of the original method, thus enabling a more comprehensive view to be taken of the later arrangements, as well as supplying the necessary information to those who are not familiar with the earlier work, which has been fully dealt with elsewhere †.

* Read June 12, 1908.

† Electrical Engineering, ii. pp. 771–775 (1907), and iii. pp. 348–351 (1908). The blocks referring to this part of the paper have been kindly lent by the Kilowatt Publishing Company.

Part I.

The aerial of the bilateral system is composed of vertical closed oscillatory circuits.

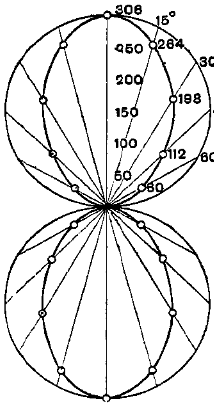
The closed oscillatory circuit is, as is known, an oscillatory circuit, the metallic portion of which forms a geometrically "nearly closed" figure, the electric field of which is concentrated in a very narrow region, and the conditions of vibration of which are independent of the position of the spark.

Although in such circuits the electric field is situate almost exclusively between the armatures of the condenser, none the less there always exists an electric field of dispersion the lines of force of which go from different points of the circuit to neighbouring conductors and to earth. Consequently, if one of these circuits be vertically placed in proximity to the ground, and with the condenser at the upper part, a number of lines of force will reach the earth, giving rise to an electromagnetic field which propagates itself in space. Since one of the armatures of the condenser has at the same instant an equal potential of opposite sign to that of the other, the electromagnetic field of one side will be opposed in phase relative to the field of the other side. As a result it is evident that in the direction perpendicular to the plane of the circuit there is no radiation whatever; that is to say, the said type of circuit radiates principally in its own plane.

An oscillatory circuit placed in an electromagnetic field will become the seat of an E.M.F. due to the variation of magnetic flux across the surface bounded by the circuit. This E.M.F. will vary with the cosine of the angle which the plane of the circuit makes with the direction of propagation of the field.

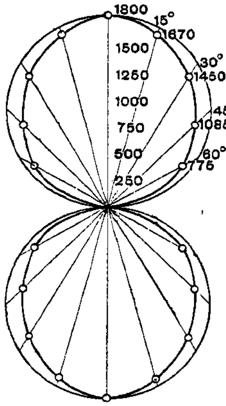
Using the Duddell thermogalvanometer, the authors have determined the diagrams of the energy emitted or received by such a circuit. The energy diagrams obtained were equal and composed of two equal tangent curves (fig. A) whose equation is $E = E_0 \cos^2 \alpha$, where α is the angle which the direction of propagation makes with the plane of the circuit. The diagram of the electromagnetic field is composed of two equal tangent circles (fig. B).

Fig. A.



Energy Transmission Diagram (Microwatts).

Fig. B.



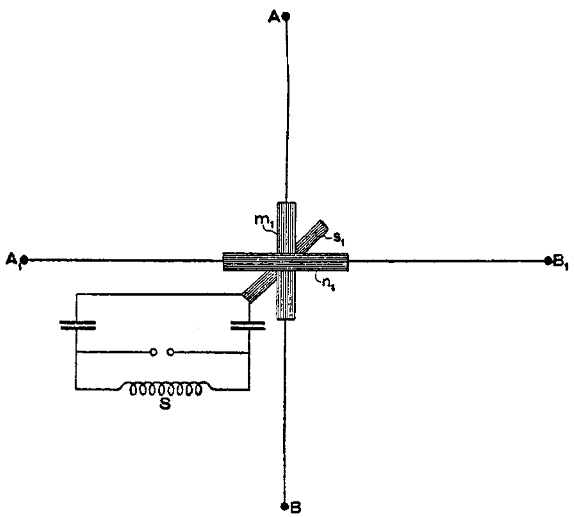
Transmission Diagram of Electromagnetic Field Intensity (Microamperes).

It is owing to these properties possessed by closed oscillatory circuits that such circuits were chosen by the authors for use as directive aerials; and the triangular form of circuit, open at the apex, was employed, owing to the fact that it could easily be sustained by a single mast. In order to be able to transmit and receive to or from any direction whatsoever, without having to turn the aerial, or having recourse to a large number of aerials in fixed positions, the aerials were built up of two equal closed oscillatory circuits, vertically placed and mutually perpendicular. This aerial system is connected up to special instruments for transmission and reception which the authors have called "Radiogoniometers."

The radiogoniometer for transmission comprises two fixed windings, m_1, n_1, mutually perpendicular, one of which is inserted in each of the two aerial circuits AB, A_1B_1, as shown diagrammatically in horizontal projection in fig. C. A third winding s, enclosed by the two first, is arranged so as to be movable on its vertical axis, which axis is that of the intersection of the planes of the two fixed windings. This winding *s* is included in the oscillatory exciting circuit, by means of contact brushes. S is the secondary of the spark coil or transformer.

It is evident that on placing the movable winding in different positions the magnetic flux which passes through the two fixed windings will vary, as also will the oscillatory currents in the aerials. The electromagnetic field in space will be produced by the superposition of the partial fields created by the two aerial circuits. Its intensity will be

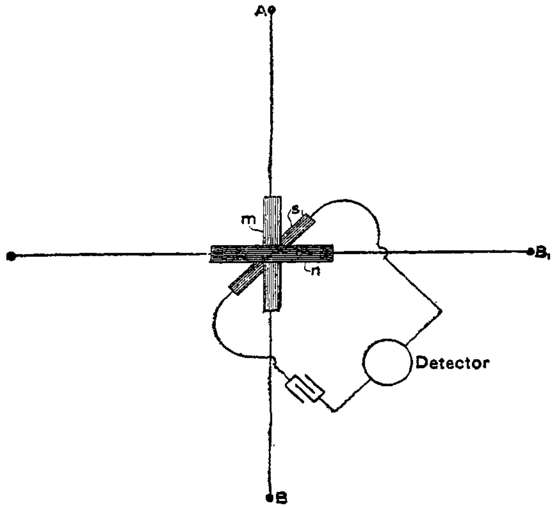
Fig. C.



independent of its direction, and this latter will coincide with the direction of the central plane of the movable winding. The law of angular variation of the energy and of the magnetic field is the same as for a single circuit.

The apparatus is provided with a fixed dial over which moves a pointer rigidly attached to the movable winding. On setting the pointer in the direction of the station to which the signals are to be sent, the emission will be a maximum in the vertical plane which contains the transmitting and receiving stations—that is to say, both towards the receiving station, and at 180° from this. The receiving radiogoniometer is similar in construction to that for the transmission. The fixed windings *m*, *n* (fig. D) are connected to their respective aerial circuits. The movable winding s_1 is suitably connected up to the detector, through two brushes.

Fig. D.



The oscillatory currents set up in the two aerials, when these latter are subjected to the influence of an electromagnetic field, create, in the interior of the fixed windings, a resultant magnetic field of an intensity which is independent of the direction of the transmitting station. When, therefore, the movable winding is perpendicular to this resultant field, that is, its central plane is oriented towards the transmitting station, the effect on the detector will be a maximum. In this position the reception is practically limited to the plane containing the transmitting station, and the pointer indicates on the dial the direction of this plane. One is, however, not able to determine *which* side of the receiving station the transmitting station is located.

The receiving radiogoniometer is provided with special contacts for tuning the fixed windings to the lengths of the waves to be received, which is effected by varying the number of active turns equally and simultaneously on the two windings.

The experiments with the system have been carried out at three stations on the French side of the English Channel, at Dieppe, Havre, and Barfleur respectively. The distance Dieppe-Barfleur is 107 miles, all over sea; that between Dieppe and Havre 54 miles, entirely over land; the angle made by the three stations Havre-Dieppe-Barfleur is 23°.

Employing this bilateral system it has been possible to transmit from Dieppe to either Havre or Barfleur without the emission which was directed towards the one post troubling the other one. The energy sufficing for this purpose was about 500 watts.

By the use of the receiving radiogoniometer at the Dieppe and Havre stations the authors have been able to determine the direction of stations both known and unknown. Further, by receiving the same transmission (signals) simultaneously at both Dieppe and Havre, and determining at each station the bearing of the unknown station, it has been possible to locate, by intersection, the actual position of the station which was transmitting. The accuracy obtainable by the use of the receiving radiogoniometer is about one degree of arc.

The triangular closed oscillatory circuits comprising the aerial system were 45 metres high, with a base of 55 metres.

Part II.

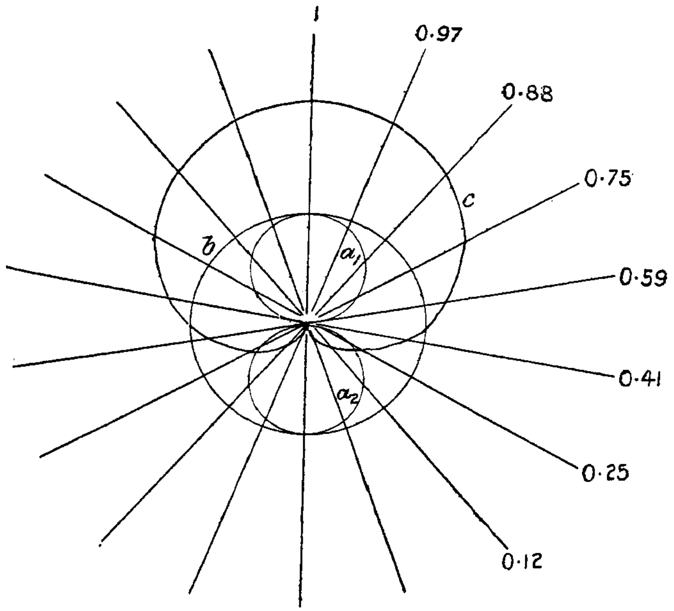
The system of wireless telegraphy reviewed in the first Part allows of transmission and reception in the plane in which the station with which one is communicating is situated. That is to say, in transmitting, one is sending the signals to the corresponding station and at the same time in the opposite direction also. As regards the reception, either of two diametrically opposite transmitting stations will affect the receiver in the same way, and it will not be possible to decide as to which side of the receiving station the transmitting station is actually located.

Since the sending of the waves in a single useful direction is often of great importance, and it is desirable to be able to decide not merely the direction but the azimuth, the authors have worked out a method of achieving this object, and have solved the problem in the following manner.

Transmission.—The diagram of the electromagnetic field of the bilateral directive system already described is composed of two equal tangent circles, and the one half-field, represented by one of the circles, is opposite in phase to the other half-field.

If one operates simultaneously, at the same station, both the directive system and an ordinary system giving a circular emission, whose vertical antenna is symmetrically placed with reference to the directive aerial, the resultant electromagnetic field of the simultaneous emissions of the two systems, can, in general, be obtained by vectorially adding the partial diagrams of the two systems.

Fig. 1.



As an example, let a_1 and a_2 (fig. 1) be the two tangent circles forming the diagram of the electromagnetic field of the directive system; the circumference b represents the diagram of the system with circular emission, of amplitude equal to the maximum amplitude of the directive system; let the phase-difference between b and a_1 be zero, and that between b and a_2 180°. The resultant diagram c is obtained in this case by adding algebraically the *radii vectores* of the curve a_1 to those of the diagram b and by subtracting the *radii vectores* of the curve b from those of curve a_2. The resultant diagram is represented by a "cardioid."

It is evident from the figure, that the resultant maximum electromagnetic field is directed to one side only; that it has a value double that of the component electromagnetic fields; and that the field on the other side is zero.

The intensity of the electromagnetic field set up by the directive system at a point whose direction makes an angle α with the maximum radiation, is expressed by $C \cos \alpha$. Let M be the intensity of the electromagnetic field produced by the circularly radiating system at the same point, and let ϕ be the phase-difference between the electromagnetic field of the circular system and that of one side of the directive system.

The intensity of the resultant electromagnetic field at the point considered will be

$$\begin{aligned} I &= \sqrt{(M + C \cos \alpha \cos \phi)^2 + C^2 \cos^2 \alpha \sin^2 \phi} \\ &= \sqrt{M^2 + C^2 \cos^2 \alpha + 2MC \cos \alpha \cos \phi}. \end{aligned}$$

The minimum of I with reference to α is obtained when

$$\cos \alpha = -\frac{M}{C} \cos \phi.$$

This value of $\cos \alpha$ is imaginary when $M \cos \phi > C$.

In the case when $M \cos \phi \leqq C$, one has $I_{min} = M \sin \phi$; when $M \cos \phi > C$ one has

$$I_{min} = \sqrt{M^2 + C^2 \cos^2 \alpha - 2MC \cos \alpha \cos \phi}.$$

In the special case when $\phi = 0$ the equation of the resultant electromagnetic field transforms itself into

$$I = M + C \cos \alpha,$$

which is the equation of a curve that can have three different forms according to the value of the ratio M/C. The curve represented by the condition M = C is the cardioid above mentioned.

But since in wireless telegraphy the action depends chiefly upon the energy, it will be useful to consider this in preference to the intensity of the electromagnetic field.

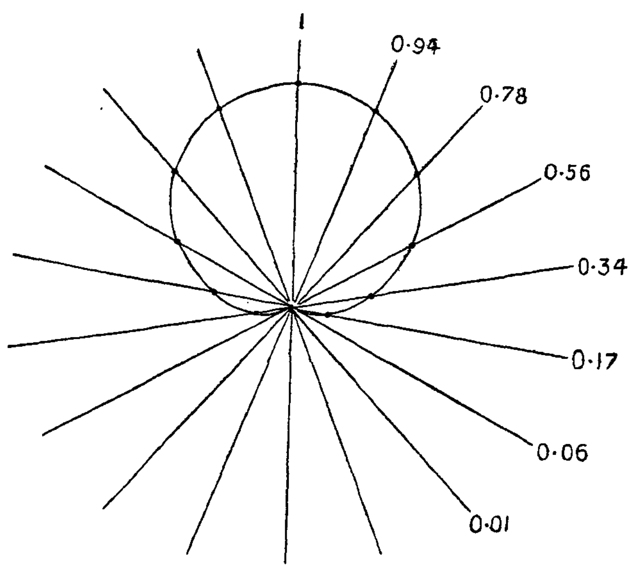
In the general case the energy radiated in the different directions is expressed by the equation—

$$W = M^2 + C^2 \cos^2 \alpha + 2MC \cos \alpha \cos \phi,$$

and in the case of the cardioid by the equation—

$$W = M^2(1 + \cos \alpha)^2,$$

Fig. 2.



The corresponding curve is given in fig. 2.

Fig. 3 represents the energy diagram in the case where $M/C = 0{\cdot}72$ and $\phi = 53°$.

Fig. 3.

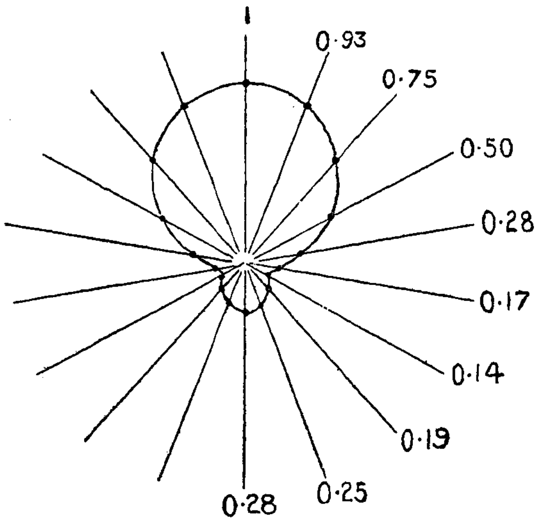


Fig. 4.

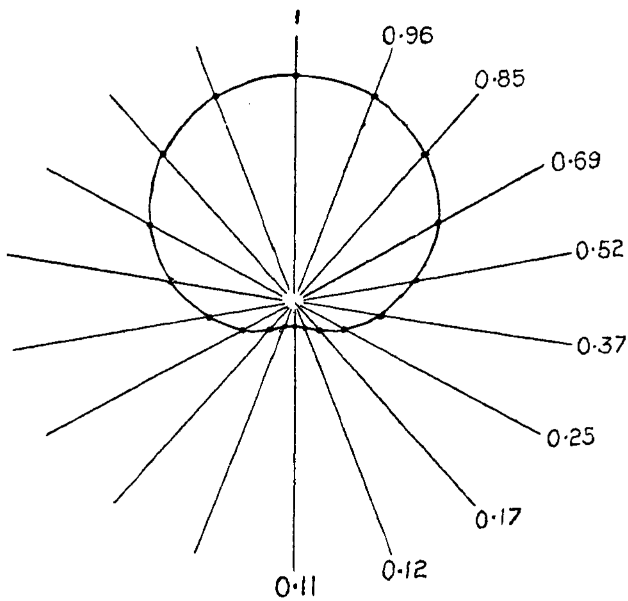
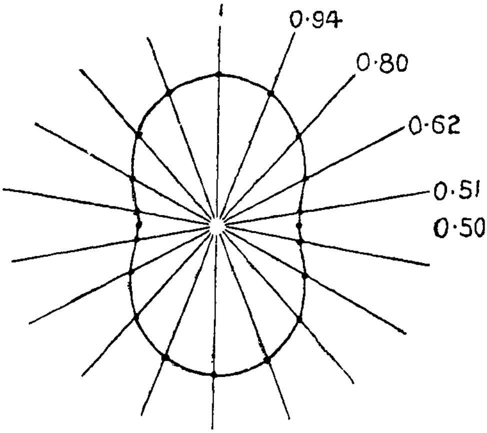


Fig. 4 shows the same diagram for the case where $M = 2C$

and $\phi=0$, and finally fig. 5 the same diagram for $M=C$ and $\phi=90^{\circ}$.

Fig. 5.



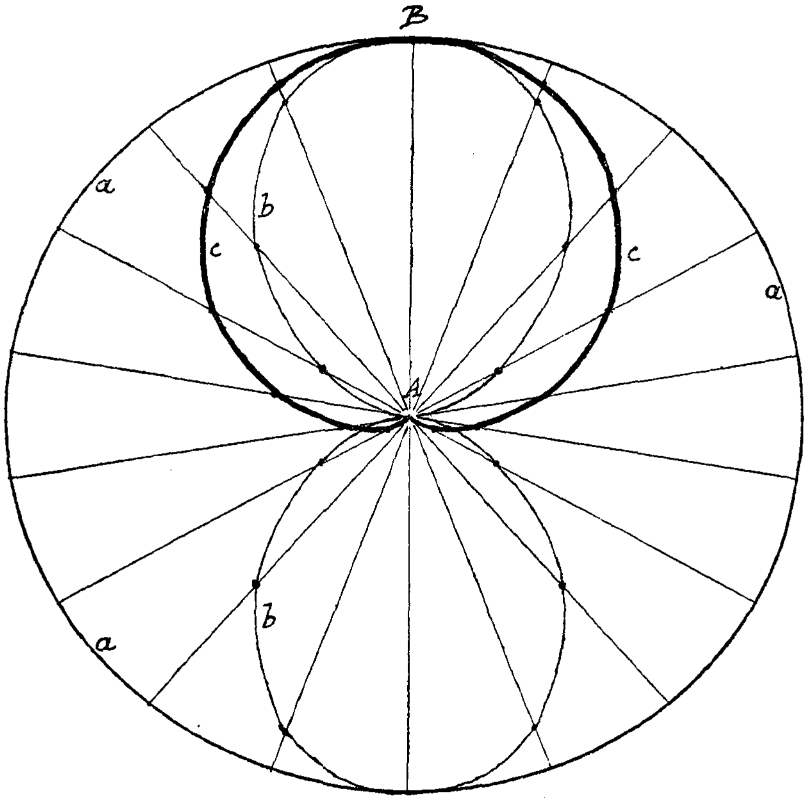
In consequence, one can conclude that the shape of the diagram of the energy radiated in the different directions depends upon the value of the phase-difference of the component electromagnetic fields, and that the superposition of a circular system on a directive system allows of the concentration of the emitted energy in the desired direction and in the useful sense only.

Fig. 6 (p. 316) shows diagrammatically the advantages which the employment of the mixed unilateral system has over the ordinary circular, or the simple bilateral directive method.

Let it be supposed that a station A ought to transmit to a station B. If the station A uses a circular system the energy is radiated all over the circular region *a*, affecting all the stations comprised within this region. If A uses the bilateral directive system the active area is the region bounded by the two tangent curves *b*, *b*. If the station uses the mixed unilateral system adjusted for $M=C$ and $\phi=0$, the active area is considerably smaller than that with the other methods.

The practical realization of the superposition of the two systems has been effected by employing as the directive system the bilateral system already dealt with in Part I. It was evident *a priori* that, owing to the different conditions under which the radiation from the directive circuit takes place with reference to the radiation from the vertical antenna, a phase-difference between the emissions of the two systems should exist, for equality of phase in the excitations.

Fig. 6.



As will be seen further on, the experiments have shown that this phase-difference is 90° or near to that value. The aerial of the unilateral system is formed by the aerial of the directive circuit to which has been added a vertical antenna in a position symmetrical with reference to the first. To secure the simultaneous excitation of the closed oscillatory circuits and of the vertical antenna, various arrangements have been employed which are diagrammatically depicted in figs. 7, 8, 9, 10.

Fig. 7.

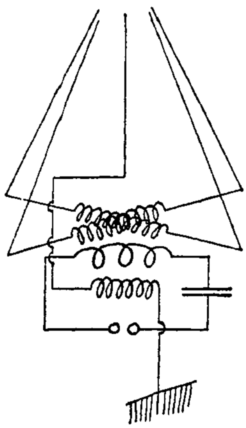


Fig. 8.

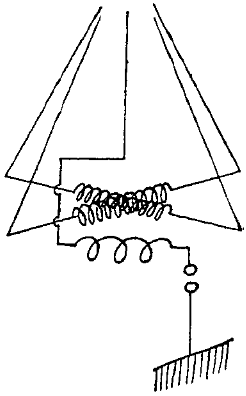


Fig. 9.

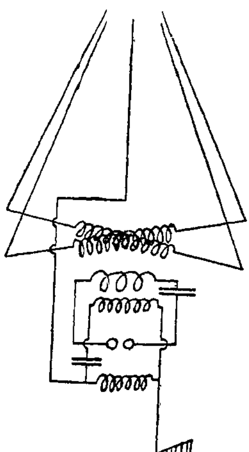
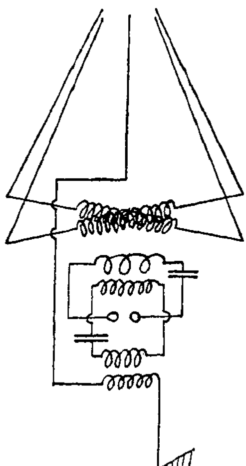
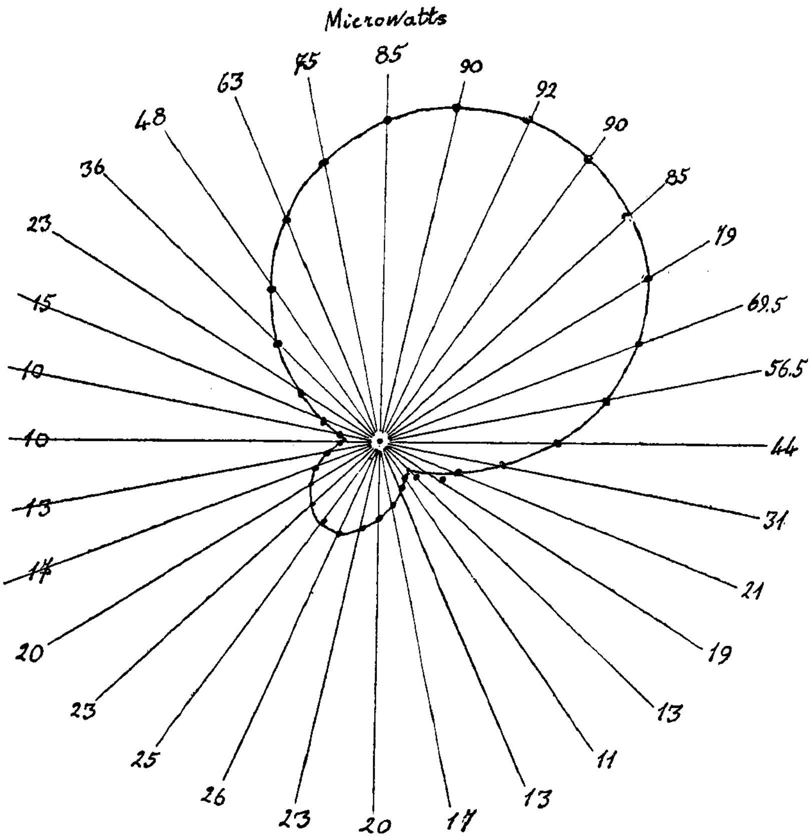


Fig. 10.



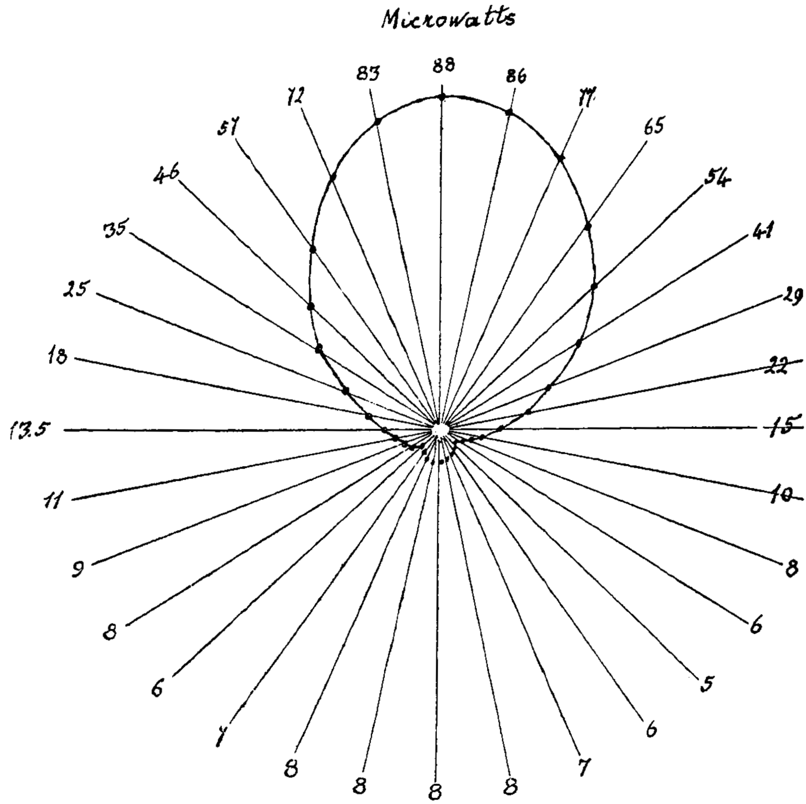
In the first of these arrangements (fig. 7) the excitations of the two systems are in phase; in the other three cases they are in quadrature. The diagrams of the energy radiated in the different directions (figs. 11 and 12) are selected from among the large number which have been determined. They were obtained with the thermo-galvanometer in a similar manner to that employed in the case of the bilateral directive system. In particular the diagram of fig. 11 was obtained

Fig. 11.



when using the arrangement shown in fig. 7; and that of fig. 12 with the arrangement of fig. 10. In the last diagram (fig. 12) the phase-difference between the radiation from the two component systems turns out to be much smaller than in the preceding diagram, and only by means of this last arrangement (fig. 10) have the very small values of the backwardly radiated energy been obtained. This proves the existence of a phase-difference of 90°, or thereabouts, between the emissions from the two systems. The diagram of fig. 12 shows besides, that the problem of the emission of the energy exclusively on the useful side can be considered as having been practically solved.

Fig. 12.



It is interesting to note that, even if the phase-difference between the radiation from the two systems is as much as a certain number of degrees, and the ratio of the partial fields is slightly different from unity, the backward radiation is always practically zero. The phase-difference has to be over 45° for the backward radiation to become noticeable. In order to see if the energy emitted by each component of the system and by the resultant system satisfied the theoretical predictions, these have been measured in several cases with the thermo-galvanometer. The results were always in practical agreement with the theory.

The simultaneous excitation of the two systems was effected by adding, internal to the primary of the transmitting radiogoniometer, a winding, fixed in position relatively to the primary and inductively excited by it. To this winding is connected the vertical antenna. On turning the movable winding of the apparatus the excitation of the vertical antenna remains constant whilst the excitations of the closed circuits forming the aerial of the bilateral system, vary. Consequently, to transmit by the unilateral system in a given direction, one has merely to turn the movable pointer until it points in this direction.

The tests of the unilateral system at long distance were made between the stations of Dieppe and Havre, and have confirmed the results obtained at short range—that is to say, on placing the pointer of the transmitting radiogoniometer in the direction of Havre, reception was effected ; on turning the pointer to 180° from this the reception ceased entirely.

Reception.—The same principle of the superposition of the two systems has been applied to the case of the reception. Considering the case of a receiving station provided with an aerial composed of a single closed oscillatory circuit, fixed in position, and of a vertical antenna symmetrically placed with respect to the closed oscillatory circuit, let it be supposed that any transmitting station is moving along a circumference of which the receiving station is the centre ; it is evident that the intensity and phase of the oscillatory current in the vertical antenna of the receiving station will remain constant, whilst in the closed oscillatory circuit they will vary with the position of the transmitting station. The intensity passes through two maxima and two minima, and its phase varies by 180° when the transmitting station passes from one side to the other of the plane perpendicular to the closed oscillatory circuit. Further, although a closed oscillatory circuit utilises the variation of magnetic flux across the surface bounded by such circuit, the E.M.F. generated in it will be in quadrature with the E.M.F. generated in the vertical antenna, and the same phase-displacement will exist between the currents in the two types of aerials if these latter are both tuned to the length of the waves received.

Let it be supposed, for instance, that the closed oscillatory circuit is oriented in a certain meridian and that the transmitting station in moving about arrives in the plane of the closed oscillatory circuit, on the north side. In such a position, by bringing the actions of the two systems on the detector into phase by any means, the effects of the two will be added. When the transmitting station finds itself, similarly, in the plane of the closed circuit but on the south side, the effects of the two systems counteract one another. If the directive aerial of the receiving station is composed of two closed oscillatory circuits connected to the receiving radiogoniometer, the phase of the E.M.F. induced in the movable winding of the apparatus will vary by 180° when the coil is turned through 180°. So that the action of the directive aerial in one case will add itself to that of the vertical antenna, and in the other case will subtract itself therefrom. It follows that, to the position of maximum reception of the movable coil, there corresponds a position of zero or minimum reception when the coil is turned through 180°, which thus permits of the determination not merely of the direction of the transmitting station, but also of the side which it is on.

The action of the detector depends, as in the case of the transmission, upon the values of the phase-difference between the actions of the two systems and on the ratio M/C. The law of variation of this action is the same as that of the variation of the resultant electromagnetic field at the transmitter and the diagrams are the same.

To obtain quadrature between the actions of the vertical antenna system and that of the directive bilateral system several arrangements have been tried which are shown in figs. 13, 14, 15.

In the case of fig. 13 the phase displacement was obtained by inserting an excess of self-inductance in one or other of the aerial circuits ; in the arrangements of figs. 14 and 15 the shift of phase was produced automatically when the circuits were all carefully tuned, but the arrangement of fig. 14

Fig. 13.

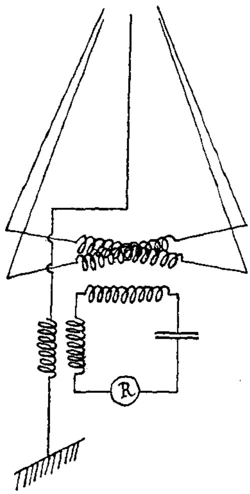


Fig. 14.

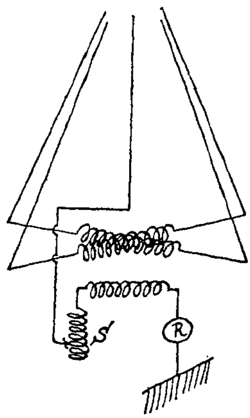
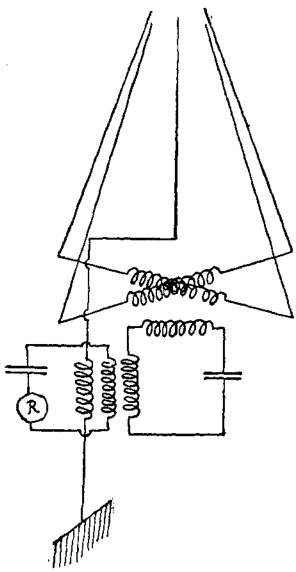
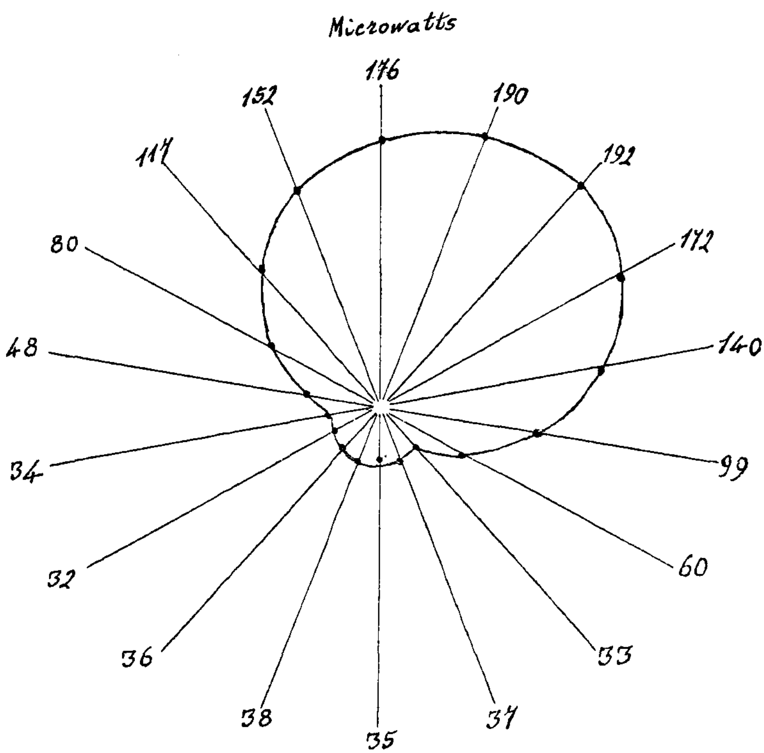


Fig. 15.



is preferable owing to its simplicity, rapidity, and certainty of operation. In this case, as can be seen from the figure, the vertical antenna is joined to one end of the secondary circuit of the receiving radiogoniometer, through a self-inductance S ; the other end of the secondary is earthed through the detector R. The working of the arrangement is very simple, since it only requires the tuning of the two circuits as in ordinary cases of circular reception. The diagrams of the reception were obtained in the same way as

Fig. 16.



those of the transmission, by means of the thermo-galvanometer in place of the detector, and by turning the movable secondary of the receiving radiogoniometer, the transmitting station being fixed. The curve of fig. 16 in particular was obtained by means of the arrangement shown in fig. 13 ; the curve of fig. 17 (p. 324) by that of fig. 15 ; and the curve of fig. 18 (p. 324) by the arrangement of fig. 14.

Fig. 17.

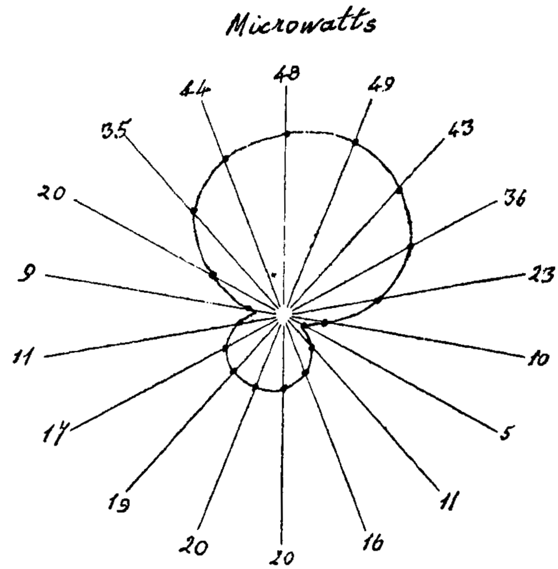

Microwatts
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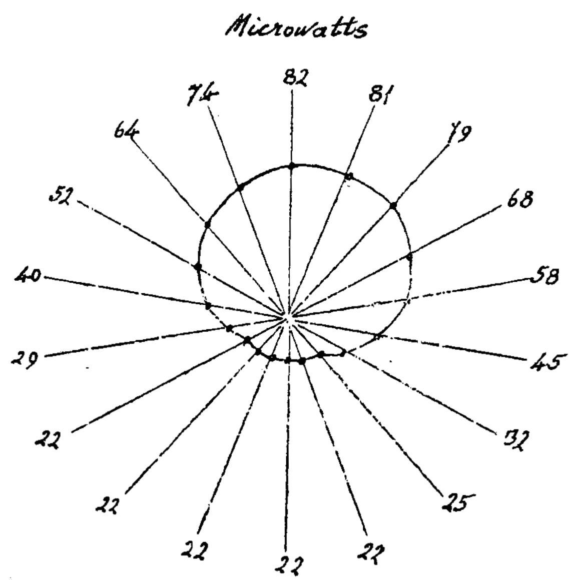
Fig. 18.


Microwatts
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68
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74

The arrangements have always enabled the sense of the received transmissions to be determined, and in many cases to get no reception when the pointer of the movable coil of the receiving radiogoniometer was turned in the opposite direction, which was precisely the object to be achieved.

The directive system of wireless telegraphy described can be employed in many ways, according to the requirements, owing to the facility with which one can pass from one system to the other. For example, when the operator expects a message from a station whose position is unknown, he could employ the single vertical antenna system; a soon as reception is effected he can, by using either the bilateral or unilateral system, determine the direction and upon which side the transmitting station lies, and make himself independent of other transmissions.

For the transmission the operator could, similarly, employ the system with circular radiation when he does not know the position of the receiving station or when he wishes to send the same message to several stations. He could in other cases use the unilateral or bilateral system according to the position of the stations which should not receive the messages.

The directive system described presents some advantages over other systems, which are very important either from the commercial or the strategic point of view.

So far as the commercial services are concerned, the possibility of transmitting messages to one station without affecting the others, results in the stations having an increased working capacity and consequently in an enhancement of their commercial value. The ability to receive from one determined direction renders the receiving station independent of extraneous transmissions, and even owing to this circumstance alone the working capacity of the stations is raised. Further, the ability to determine the origin of a transmission, apart from its obvious advantages, presents the advantage of enabling the route to be followed by a ship proceeding to the assistance of another in danger, to be indicated.

From the strategic point of view the directive reception enables one to learn of the presence of the enemy in a certain direction and to follow him in his movements. The directive transmission will allow, when suitably employed, of transmitting to one's friends without the enemy being able to receive the waves—for the simple reason that there are no waves there to be detected in the undesired region.

In conclusion, the following is given as one practical example of the main strategical advantage of the directive system. Supposing it were necessary to send radiotelegraphic messages to the cruiser squadrons on the north east, north, north-west, and west coasts of the United Kingdom; if the messages were sent by an ordinary vertical antenna system they would be perceived in Denmark, in Germany, in Belgium, Holland, and France. Employing, on the other hand, the unilateral system, the messages sent from London to the Fleet would not be received outside the United Kingdom.

The authors desire to thank Mr. L. H. Walter, M.A., for translating this paper from the original.

Discussion.

Dr Fleming said that he had long been acquainted with the interesting experiments of the Authors of this paper, and desired to express his congratulations on the skill and inventiveness with which these investigations had been prosecuted. He was glad to see that the experiments of the Authors confirmed in many ways the theory which he (Dr Fleming) had given of the operation of a bent antenna as employed by Mr Marconi.

When Mr Marconi read his paper at the Royal Society in March 1906 describing his experiments on directive telegraphy, he gave no theory in the matter, but Dr Larmor pointed out in the discussion that an antenna partly vertical and partly horizontal was equivalent to the sum of a magnetic oscillator and an electric oscillator, and shortly afterwards he (Dr Fleming) had gone more carefully into the matter mathematically and showed that the observed effects could be accounted for on this theory.

Both Mr Marconi and he himself had obtained by the same methods as those employed by Messrs. Bellini and Tosi the same type of pear-shaped radiation curves obtained by the Authors of the paper by combining together the effect of closed and open oscillators. Although this theory had been criticised by Dr Mandelstam lately, yet nevertheless there did not seem sufficient grounds for objecting to it. Mr Marconi had, as everyone knew, employed directive antennæ for a long time past in his Power Stations at Poldhu and Clifden, and had also given demonstrations showing that the position of ships out of sight could be located by means of such receiving directive antennæ. Nevertheless, Messrs. Bellini and Tosi had worked out extremely ingenious arrangements for determining the direction of the radiant point without moving the antennæ themselves. He (Dr Fleming) had also shown that, having the power to locate the radiant point, two stations equipped with such antennæ at a known distance apart could by simultaneous observations determine also the distance of the radiant point, and this might become important in connection with marine work.

It ought also to be noticed that Dr F. Braun, of Strasburg, had by the employment of three open antennæ having oscillations in them of definite phase difference, been able to obtain radiation curves having the form of a cardioid similar to some of those given by the Authors of the paper.

Dr W. H. Eccles warmly congratulated the Authors upon their beautiful and original method. On this method, by merely rotating a small coil of wire on the table, a fixed aerial directive system of any size was made to do what could otherwise only be done by turning the whole system of aerial wires in azimuth. The essence of the system was the piece of apparatus styled the radiogoniometer, which, by causing appropriate component radiation from two fixed wire triangles set at right angles, brought about a resultant radiation in any direction desired—just as if a virtual aerial of the full size of the fixed aerials were being rotated in the air. Someone had compared the result so achieved with that obtained by Marconi's well-known arrangement of a number of fixed bent antennæ with their horizontal portions directed from a centre to various points of the compass. Apart from the fact that it is rarely feasible to fix up a large number of antennæ, the radiogoniometer method has the advantage that the direction of transmission or reception can be altered perfectly smoothly; so that if it can be used, as stated by the Authors, accurately to about one degree of arc, the radiogoniometer is the practical equivalent of 360 bent antennæ.

The looped aerials used by the Authors did not seem to the speaker to be the best kind of radiator for utilising the principle they had developed. The radiogoniometer would prove to be capable of giving excellent results with two fixed antennæ of the bent type set at right angles, one, for example, in the meridian plane and the other in the east-west plane. The two looped aerials of the Authors may each of them be assimilated to a pair of vertical antennæ emitting waves of 180° phase difference, and with the assumption that for a single vertical aerial the inverse square law holds for the propagation of electrical effects from a single aerial, the speaker showed by aid of the ordinary equation of wave-motion that a looped antenna obeying the condition stated emitted two waves of equal period, of phases differing 90° and 180° respectively from the phase of the radiation from either side of the loop, and of amplitudes having a ratio proportional to λ/x. This means that one portion of the resultant radiation obeys an inverse square law and the other portion an inverse cube law; the latter portion is the more important of the two when the distance x is small, the former is the more important when the distance x

is much greater than the wave-length λ. This explains why Dr Fleming's measurements of the radiation from closed oscillators, which were carried out at short distances, gave small promise of powerful propagation to a distance, and why Messrs Bellini and Tosi had found as a fact that good propagation occurred to great distances.

As regards the phases of the two portions of the radiation, the important portion for wireless telegraphy, namely that obeying the inverse square law, was 90° out of phase with the near side of the loop; and thus it is clear that the vertical aerial the Authors had used to cancel the radiation to one side of the sending station, must for that purpose emit radiation 90° out of phase with the near side of the loop. Messrs. Bellini and Tosi had reached this conclusion in the course of their experiments.

After eliciting that the power-supply to the primary of the induction-coil for the Dieppe-Havre experiments was 500 watts, Dr Eccles concluded by remarking that the Authors were worthy of special congratulation because in their method of unilateral transmission by phase and intensity adjustment of several radiators they had eluded the difficulties of managing the phases that had apparently baffled F. Braun when he was using the same principle.

Mr W. Duddell complimented the Authors upon their paper and asked for the wave-length of the waves given out by the transmitter. He also asked what would be the effect of opening the closed antennæ at the top.

Mr Tosi, in reply to Dr Fleming, stated that Braun's cardioid diagram was a theoretical diagram only; the method had not succeeded and no actual diagram obtained experimentally had ever been shown.

Referring to the similarity which Dr Fleming said the pear-shaped diagram of Marconi bore to the Authors' diagrams, Mr Tosi could only say that they had purposely shown some bad diagrams as well as some good ones. The good diagram of Marconi's corresponded to the Authors' bad diagram. With the Marconi horizontal aerial it would, moreover, be necessary, as Dr Eccles had pointed out, to employ 360 such wires to obtain an accuracy in locating the bearing of the radiant point equal to that secured with the system now described. Further, if the emitted energy is actually represented for longer distances by Marconi's pear-shaped diagram, it is difficult to understand why the transatlantic messages from Clifden to Glace Bay are readily picked up off the Algerian coast, at right angles to the line of transmission.

In reply to Mr Duddell he said that the wave-length of the waves employed was from 350 to 400 metres.