MARCONI WIRELESS TELEGRAPHY.*

By Mr. G. MARCONI.

THE discoveries connected with the propagation of electric waves over long distances, and the practical applications of telegraphy through space, which have gained for me the supreme honour of sharing the Nobel prize for Physics, have been to a great extent the result of one another.

The application of electric waves to the purposes of wireless telegraphic communication between distant parts of the earth, and the experiments which I have been fortunate enough to be able to carry out on a larger scale than is attainable in ordinary laboratories, have made it possible to

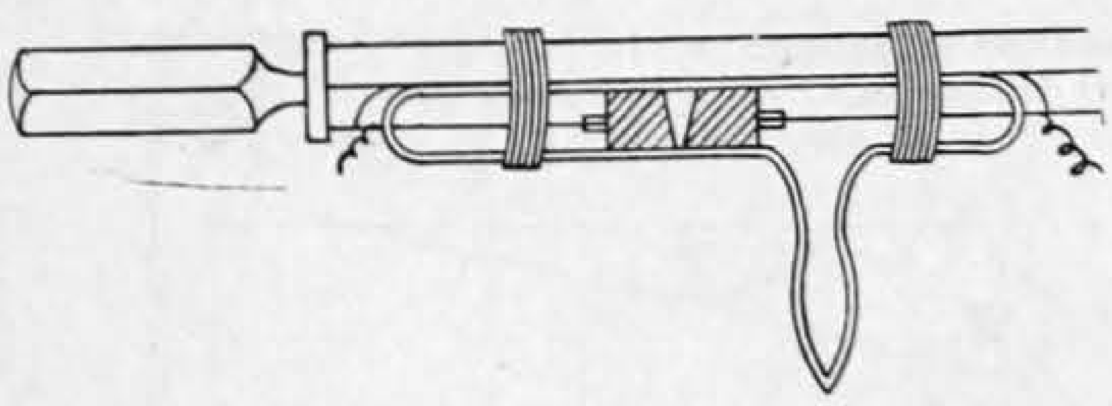

Fig. 1

investigate phenomena and note results often novel and unexpected. In my opinion many facts connected with the transmission of electric waves over great distances still await a satisfactory explanation, and I hope to be able in this lecture to refer to some observations which appear to require the attention of physicists.

In sketching the history of my association with radiotelegraphy, I might mention that I never studied physics or electrotechnics in the regular manner, although as a boy I was deeply interested in these subjects. I did, however, attend one course of lectures on Physics under the late Professor Rosa, at Livorno, and I was, I think I might say, fairly well acquainted with the publications of that time dealing with scientific subjects, including the works of Hertz, Branly and Righi. At my home near Bologna, in Italy, I commenced early in 1895 to carry out tests and experiments with the object of determining whether it would be possible by means of Hertzian waves to transmit to a distance telegraphic signs and symbols without the aid of connecting wires. After a few preliminary experiments with Hertzian waves I became very soon convinced that if these waves or similar waves could be reliably transmitted and received over considerable distances a new system of communication would ecobme available possessing enormous advantages over flashlights and optical methods, which are so much dependent for their success on the clearness of the atmosphere. My first tests were carried out with an ordinary Hertz oscillator and a Branly coherer as detector, but I soon found out that the Branly coherer was far too erratic and unreliable for practical work.

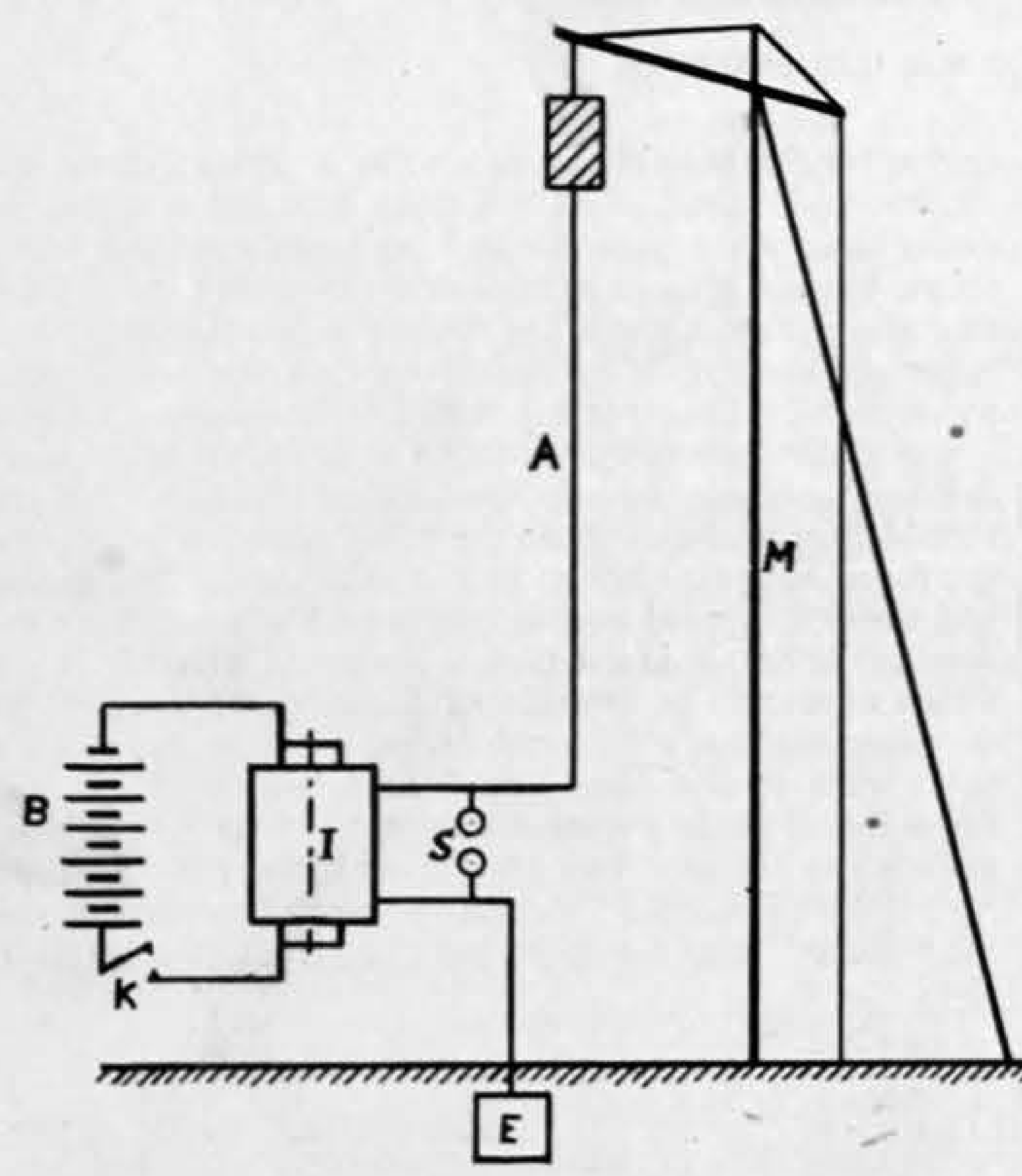

Fig. 2

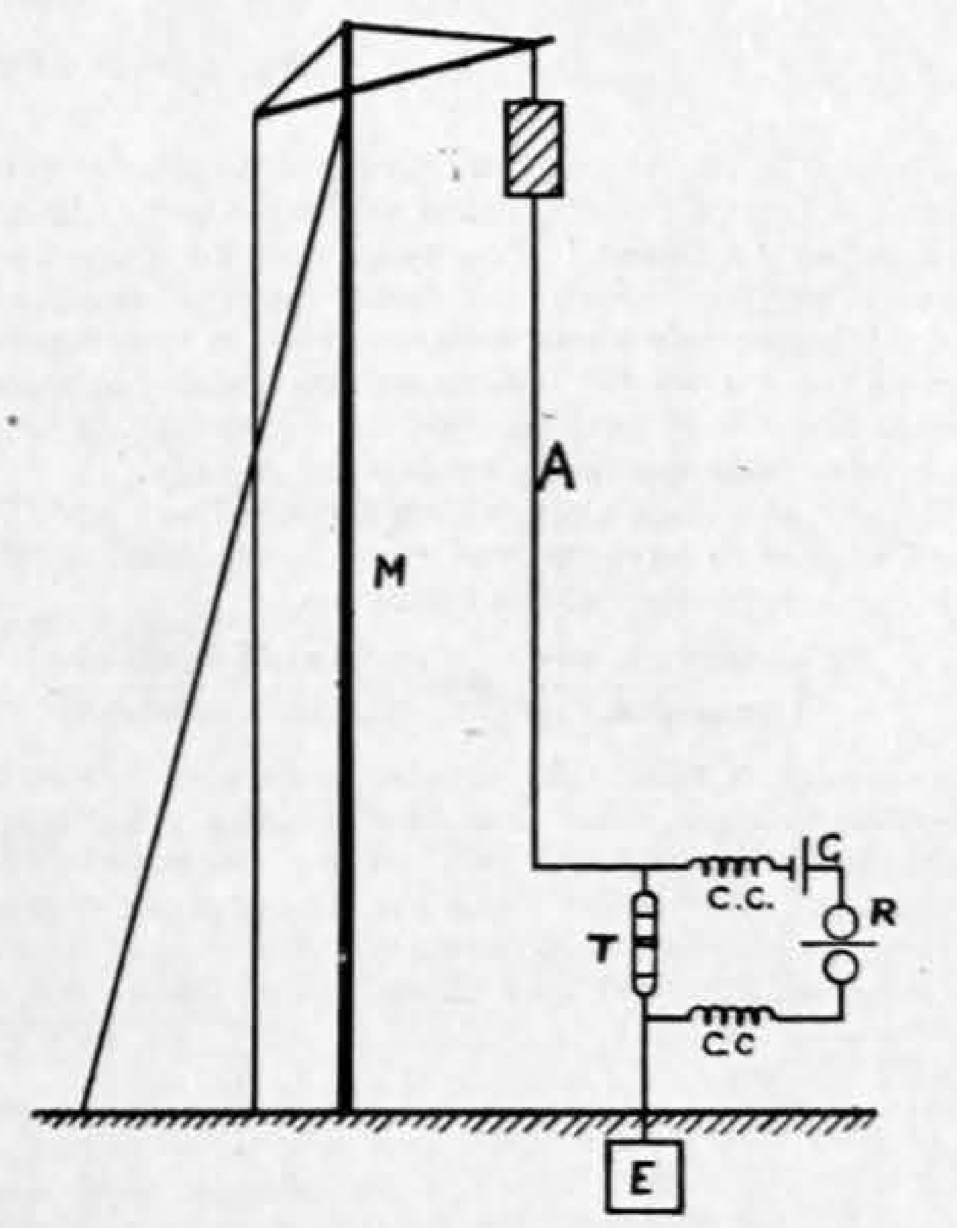

Fig. 3

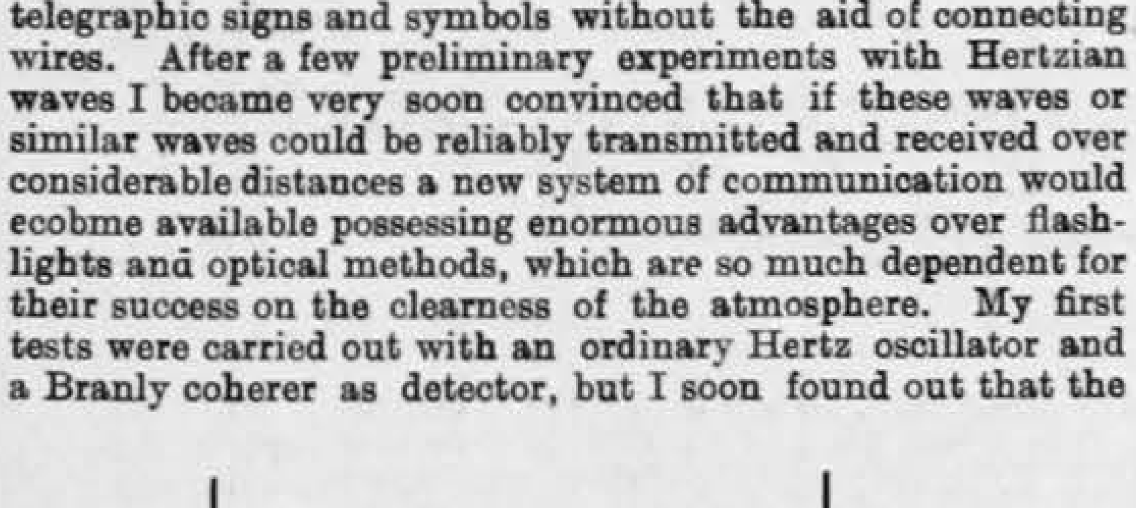

Fig. 4

After some experiments I found that a coherer, constructed as shown in Fig. 1, and consisting of nickel and silver filings placed in a small gap between two silver plugs in a tube, was remarkably sensitive and reliable. This improvement, together with the inclusion of the coherer in a circuit tuned to the wave-length of the transmitted radiation, allowed me gradually to extend up to about a mile the distance at which I could affect the receiver.

Another, now well-known, arrangement which I adopted was to place the coherer in a circuit containing a voltaic cell and a sensitive telegraph relay actuating another circuit, which worked a tapper or trembler and a recording instrument. By means of a Morse telegraphic key placed in one of the circuits of the oscillator or transmitter, it was possible

Fig. 5

to emit long or short successions of electric waves, which would affect the receiver at a distance and accurately reproduce the telegraphic signs transmitted through space by the oscillator. With such apparatus I was able to telegraph up to a distance of about half a mile. Some further improvements were obtained by using reflectors with both the transmitters and receivers, the transmitter being in this case a Righi oscillator. This arrangement made it possible to send signals in one definite direction, but was inoperative if hills or any large obstacle happened to intervene between the transmitter and receiver.

In August, 1895, I discovered a new arrangement which not only greatly increased the distance over which I could

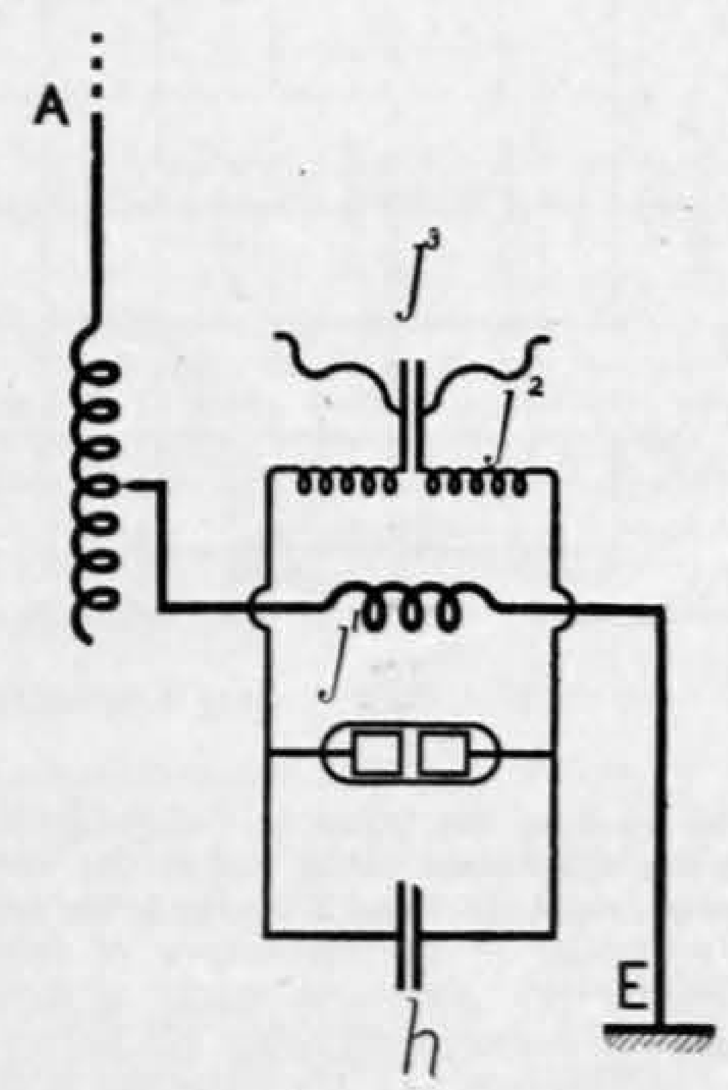

Fig. 6

communicate, but also seemed to make the transmission independent from the effects of intervening obstacles. This arrangement consisted in connecting one terminal of the Hertzian oscillator, or spark producer, to earth, and the other terminal to a wire or capacity area placed at a height above the ground, and in also connecting at the receiving end one terminal of the coherer to earth and the other to an elevated conductor.—Figs. 2 and 3. I then began to examine the relation between the distance at which the transmitter could affect the receiver, and the elevation of the capacity areas above the earth, and I very soon definitely ascertained that the higher the wires or capacity areas the greater the distance over which it was possible to telegraph.

Thus I found that when using cubes of tin about 30 cms. side as elevated conductors or capacities, placed at the top of poles 2 m. high, I could receive signals at 30 m. distance, and when placed on poles 4 m. high at 100 m., and at 8 m. high at 400 m. With larger cubes 100 cms. side, fixed at a height of 8 m., signals could be transmitted 2400 m. all round.[1] These experiments were continued in England, where, in September, 1896, a distance of 1¾ miles was obtained in tests carried out for the British Government at Salisbury. The distance of communication was extended to four miles in March, 1897, and in May of the same year to nine miles. Tape messages obtained during these tests, signed by the British Government officers who were present, are exhibited. In all these experiments a very small amount of electrical power was used, the high-tension current being produced by an ordinary Rhumkoff coil. The results obtained attracted a good deal of public attention at the time, such distances of communication being considered remarkable.

As I have explained, the main feature in my system consisted in the use of eleva ed capacity areas, or vertical wires, attached to one pole of the high-frequency oscillators and receivers, the other pole of which was earthed. The practical value of this innovation was not understood by many physicists for quite a considerable period, and the results which I obtained were by many erroneously considered simply due to efficiency in details of construction of the receiver, and to the employment of a large amount of energy. Others did not overlook the fact that a radical change had been introduced by making these elevated capacities and the earth form part of the high-frequency oscillators and receivers. Professor Ascoli, of Rome, gave a very interesting theory of the mode of operation of my transmitters and receivers in

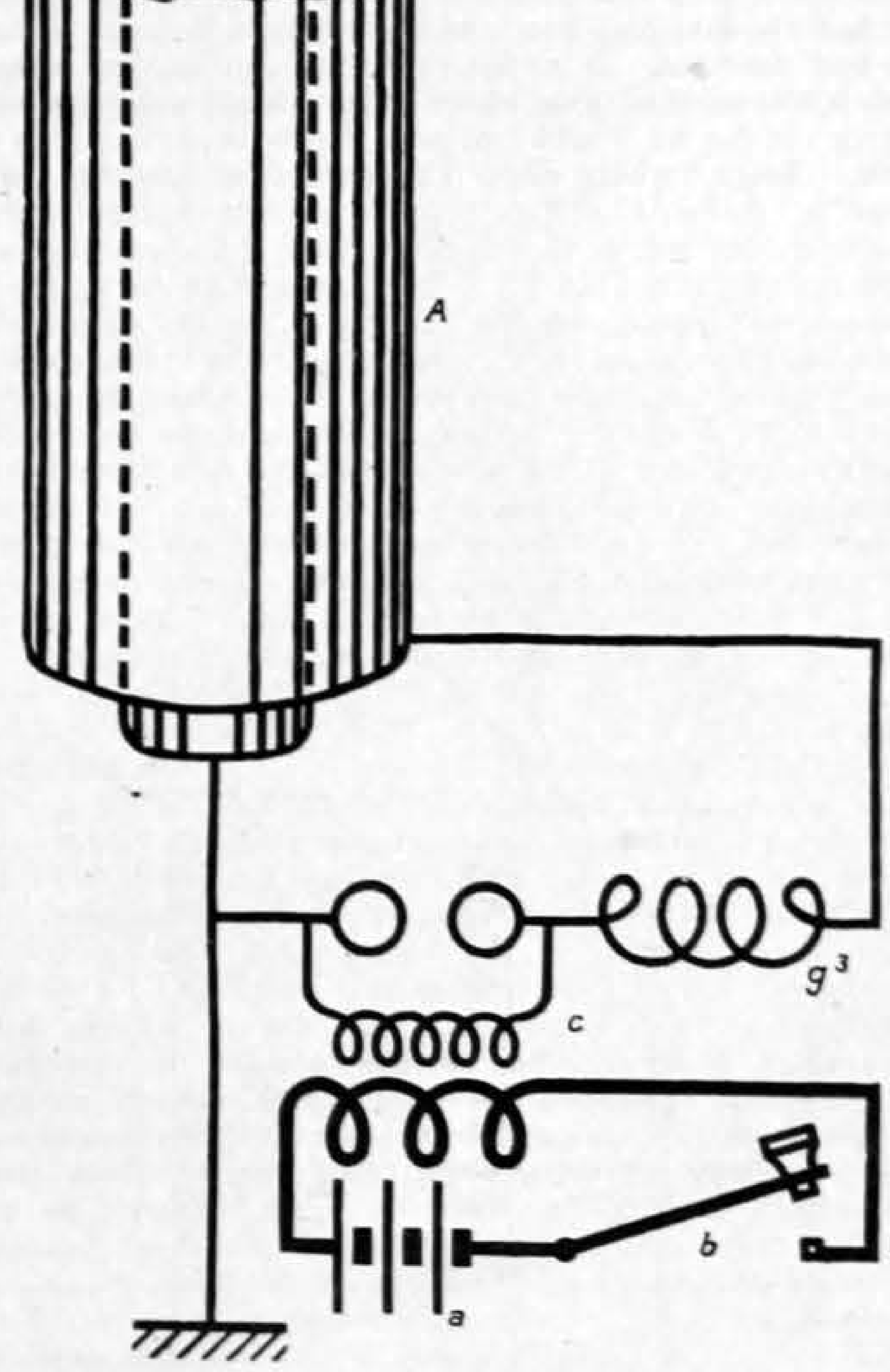

Fig. 7

the *Elettricista* (Rome) issue of August, 1897, in which he correctly attributed the results obtained to the use of elevated wires or antennas. Professor A. Slaby, of Charlottenburg, after witnessing my tests in England in 1897, came to somewhat similar conclusions.[2]

Many technical writers have stated that an elevated capacity at the top of the vertical wire is unnecessary. This is true if the length or height of the wire is made sufficiently great, but as this height may be much smaller for a given distance if a capacity area is used, it is more economical to use such capacities, which now usually consist of a number of wires spreading out from the top of the vertical conductor.

The necessity or utility of the earth connection has been sometimes questioned, but in my opinion no practical system of wireless telegraphy exists where the instruments are not connected to earth. By "connecting to earth" I do not necessarily mean an ordinary metallic connection as used for ordinary wire telegraphs. The earth wire may have a condenser in series with it, or it may be connected to what is really equivalent, a capacity area placed close to the surface of the ground—Fig. 4. It is now perfectly well known that a condenser, if large enough, does not prevent the passage of high-frequency oscillations, and therefore in these cases the earth is for all practical purposes connected to the antennæ. After numerous tests and demonstrations in Italy and in England over distances varying up to 40 miles, communication was established for the first time across the English Channel between England and France in March, 1899.[3] (Fig. 5.)

From the beginning of 1898 I had practically abandoned the system of connection shown in Fig. 2, and instead of joining the coherer or detector directly to the aerial and earth, I connected it between the ends of the secondary of a suitable oscillation transformer containing a condenser and tuned to the period of the electrical waves received. The primary

* Address delivered in Stockholm on 11th December by Mr. Marconi on the occasion of the awarding of his share of the Nobel prize.

[1] See "Journal" of the Institution of Electrical Engineers, London, 1899. Vol. XXVIII., page 278.

[2] See A. Slaby, "Die Funkentelegraphie," Berlin, 1897, Verlag von Bronhard Simion; also A. Slaby, "The New Telegraphy," the *Century Magazine*, April, 1898, Vol. LV., page 867.

[3] See *Journal* of the Institution of Electrical Engineers, 1899, London, Vol. XXVIII., p. 291.

of this oscillation transformer was connected to the elevated wire and to earth—Fig. 6. This arrangement allowed of a certain degree of syntony, as by varying the period of oscillation of the transmitting antennæ it was possible to send messages to a tuned receiver without interfering with others differently syntonised.[4]

As it is now well known, a transmitter consisting of a vertical wire discharging through a spark gap is not a persistent

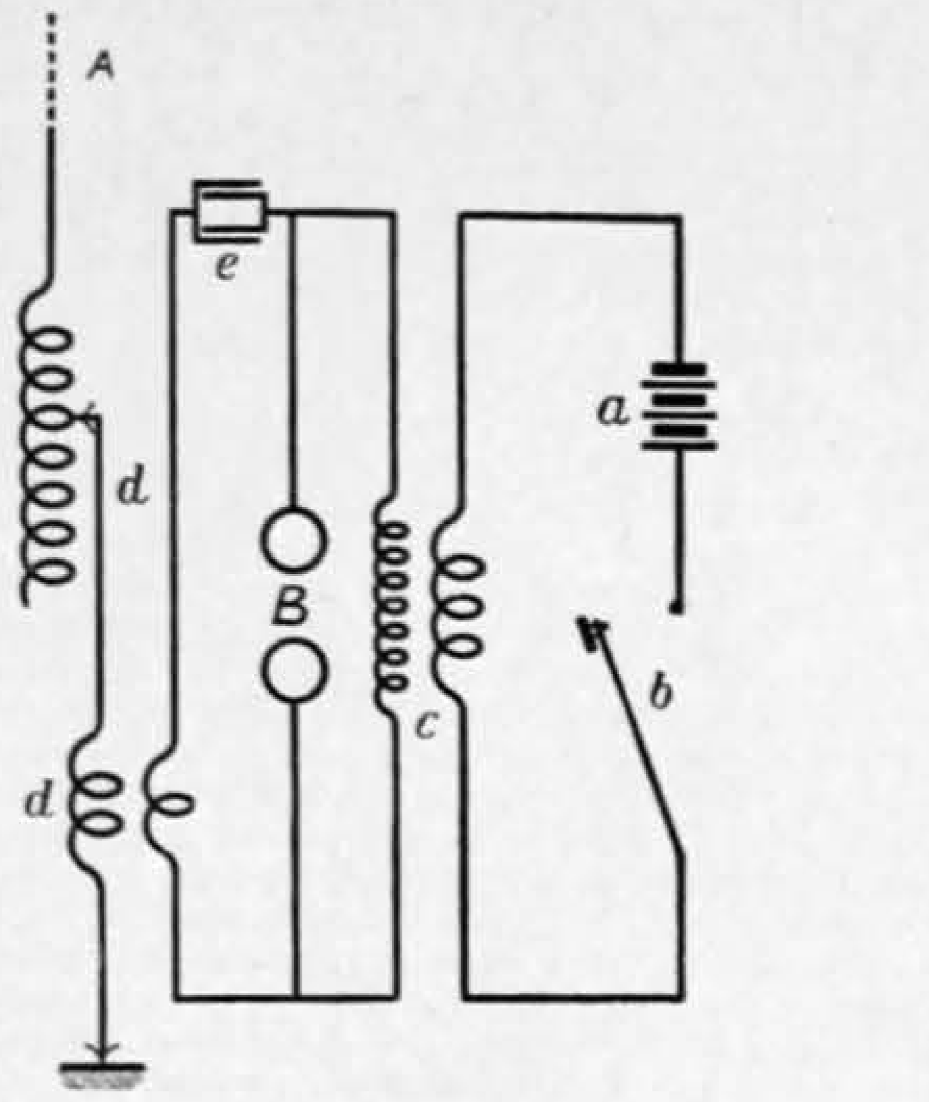

Fig. 8

oscillato the radiation it produces is strongly damped. Its electrical capacity is comparatively so small and its capability of radiating energy so large that its oscillations decrease or die off with great rapidity. In this case receivers or resonators of a considerably different period or pitch are likely effected by it. Early in 1899 I was able to improve the the oscillating circuit and radiating circuit, were more or less closely "coupled" by varying the distance between them. By the adjustment of the inductance inserted in the elevated conductor and by the variation of the capacity of the condenser circuit the two circuits were brought into resonance, a condition which, as I have said, I found essential in order to obtain efficient radiation.

Part of my work regarding the utilisation of condenser circuits in association with the radiating antennæ was carried out simultaneously to that of Professor Braun, without, however, either of us knowing at the time anything of the contemporary work of the other.

A syntonic receiver has already been shown in Fig. 6, and consists also of a vertical conductor or aerial, connected to earth through the primary of an oscillation transformer, the secondary circuit of which included a condenser and a detector, it being necessary that the circuit containing the aerial and the circuit containing the detector should be in electrical resonance with each other, and also in tune with the periodicity of the electric waves transmitted from the sending station. It is also possible to couple to one sending conductor several differently tuned transmitters, and to a receiving wire a number of corresponding receivers, as is shown in Figs. 9 and 10, each individual receiver responding only to the radiations of the transmitter with which it is in resonance.

At the time (twelve years ago) when communication was first established by means of radiotelegraphy between England and France, much discussion and speculation took place as to whether or not wireless telegraphy would be practicable for much longer distances than those then covered, and a somewhat general opinion prevailed that the curvature of the earth would be an insurmountable obstacle to long-distance transmission, in the same way as it was, and is, an obstacle to signalling over considerable distances by means of light flashes. Difficulties were also anticipated as to the possibility of being able to control the large amount of energy which it appeared would be necessary to cover long distances. What often happens in pioneer work repeated itself in the case of radiotelegraphy—the anticipated obstacles or difficulties were either purely imaginary or else easily surmountable, but in their place unexpected barriers manifested themselves, and recent work has been mainly directed to the city, every line of electric force in the ether must be either a closed line or its ends must terminate on electrons of opposite sign. If the end of a line of strain abuts on the earth and move, there must be atom-to-atom exchange of electrons, or movements of electrons in it. We have many reasons for concluding that the substances we call conductors are those in which free movements of electrons can take place. Hence the movements of the semi-loops of electric force outwards from an earthed oscillator or Marconi Aërial is hindered by bad conductivity on the surface of the earth and facilitated over the surface of a fairly good electrolyte, such as sea water."

Professor[9] Zenneck has carefully examined the effect of

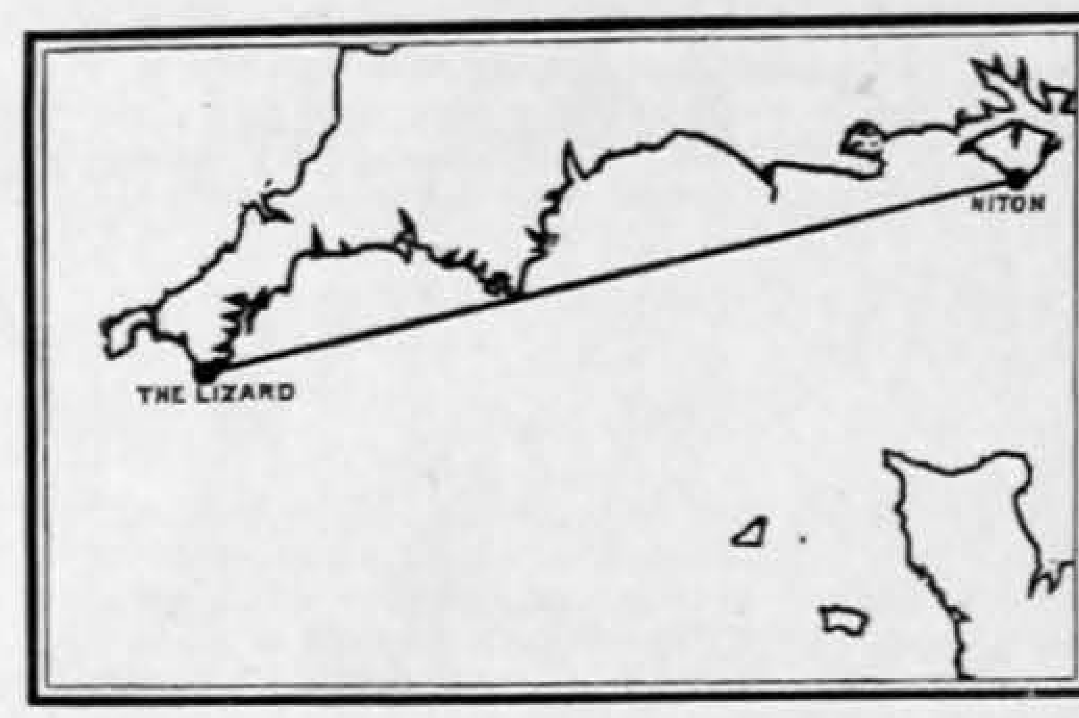

Fig. 12

earthed transmitting and receiving aërials, and has endeavoured to show mathematically that when the lines of electrical force, constituting a wave front, pass along a surface of low specific inductive capacity, such as the earth, they become inclined forward, their lower ends being retarded by the resistance of the conductor to which they are attached. It therefore seems well established that wireless telegraphy, as practised at the present day, is dependent for its conductivity of the earth, and that the difference in

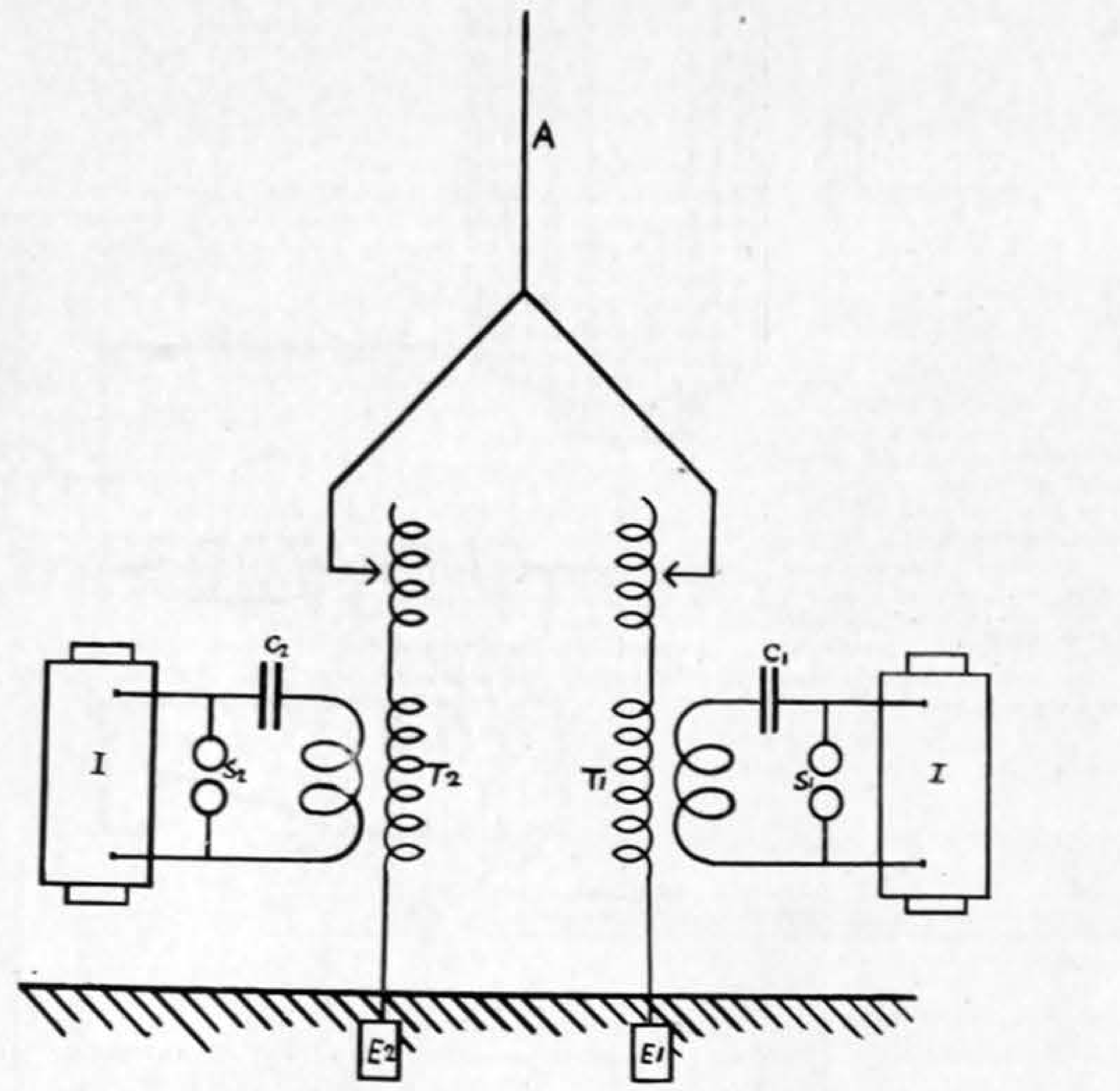

Fig. 9

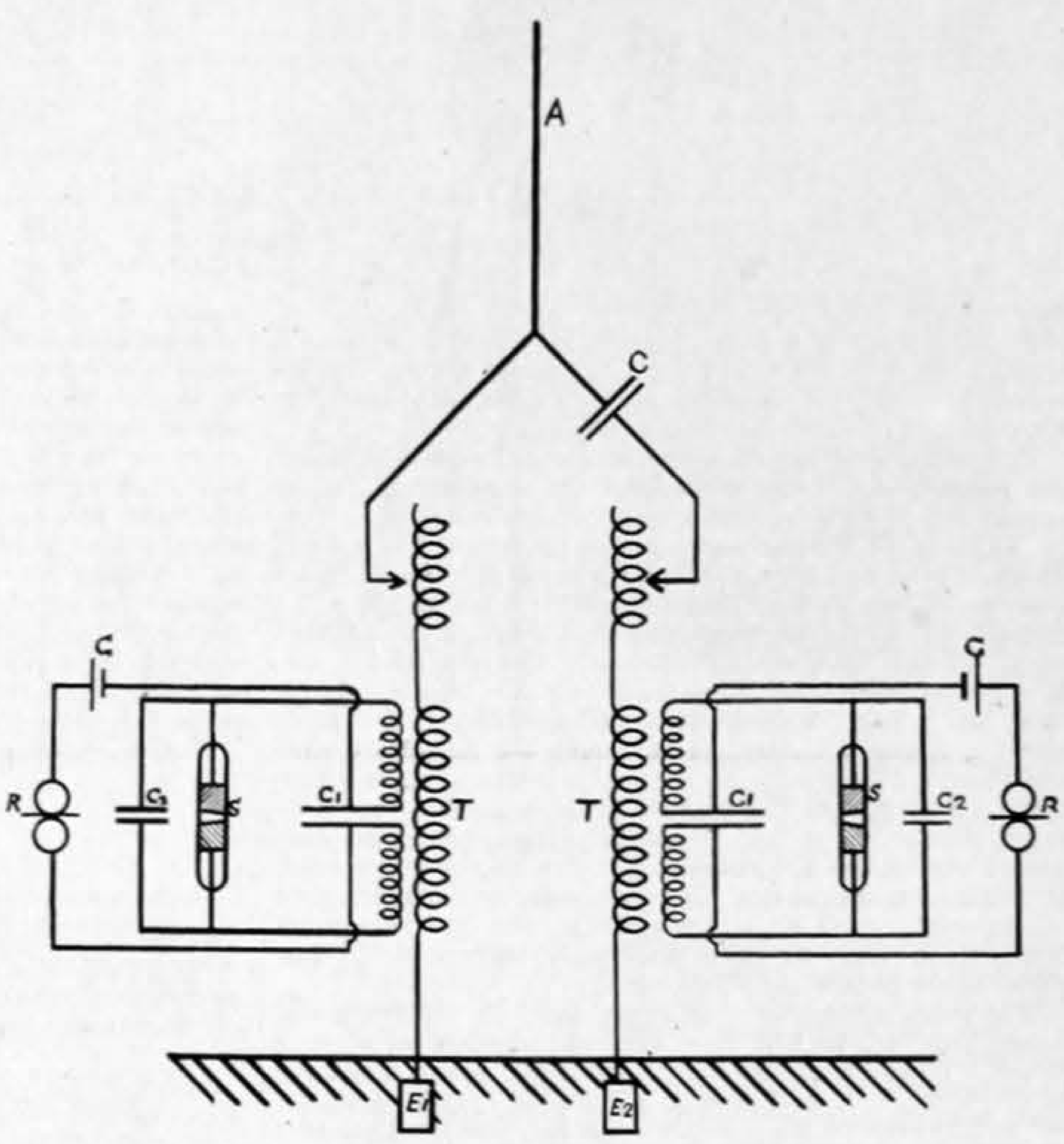

Fig. 10

resonance effects obtainable by increasing the capacity of the elevated wires by placing adjacently to them earthed conductors, and inserting in series with the aerials suitable inductance coils[5]. By these means the energy storing capacity of the aerial was increased, whilst its capability to radiate was decreased, with the result that the energy set in motion by the discharge formed a train or succession of feebly damped oscillations. A modification of this arrangement, by which excellent results were obtained, is shown in Fig. 7.

In 1900 I constructed and patented transmitters which consisted of the usual kind of elevated capacity area and earth connection, but these were inductively coupled to an oscilla-

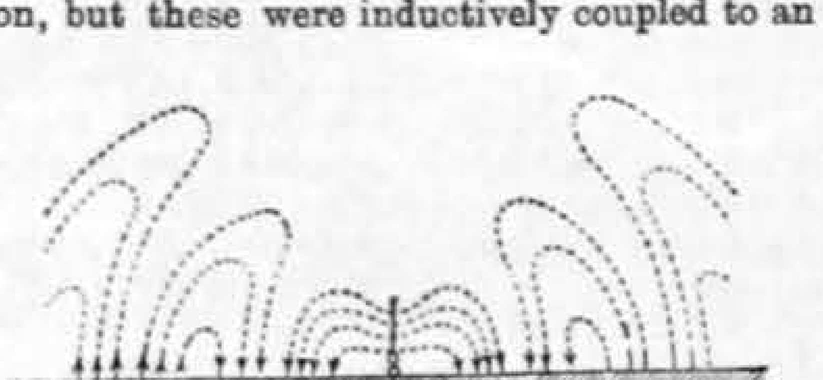

Fig.

tion circuit containing a condenser, an inductance and a spark gap, the conditions which I found essential for efficiency being that the periods of electrical oscillation of the elevated wire or conductor should be in time or resonance with that of the condenser circuit—Fig. 8[6]. The circuits, consisting of

[4] British Patent No. 12326 of June 1st, 1898; also No. 6982 of April 1st, 1899.

[5] See "Etat Actuel et Progres de la Telegraphie sans Fil" by A. Blondel and G. Ferrie, read at the Congres International d'Electricite, Paris, 1900; also "Journal" of the Society of Arts, 1901, Vol. XLIX, page 5.9.

[6] See British Patent No. 7777 of 26th of April, 1900; also "Journal" of the Society of Arts, Vol. XLIX., May 17th, 1901, page 510-511.

solution of problems presented by difficulties which were certainly neither expected nor anticipated when long distances were first attempted.

With regard to the presumed obstacle of the curvature of the earth, I am of opinion that those who anticipated difficulties in consequence of the shape of our planet had not taken sufficient account of the particular effect of the earth connection to both transmitter and receiver, which earth connection introduced effects of conduction which were generally at that time overlooked. Physicists seemed to consider for a long time that wireless telegraphy was solely dependent on the effects of free Hertzian radiation through space, and it was years before the probable effect of the conductivity of the earth between the stations was satisfactorily considered or discussed.

Lord Rayleigh, in referring to Transatlantic telegraphy, stated, in May, 1903: "The remarkable success of Marconi in signalling across the Atlantic suggests a more decided bending or diffraction of the waves round the protuberant earth than had been expected, and it imparts a great interest to the theoretical problem."[7]

Professor J. A. Fleming, in his book on "The Principles of Electric Wave Telegraphy,"[8] gives diagrams showing what is now believed to be the diagrammatic representation of the detachment of semi-loops of electric strain from a simple vertical wire—Fig. 11. As will be seen, these waves do not propagate in the same manner as free radiation from a classical Hertzian oscillator, but glide along the surface of the earth. Professor Fleming further states in the above-quoted work:—"The view we here take is that the ends of the semi-loops of electric force, which terminate perpendicularly on the earth, cannot move along unless there are movements of electrons in the earth corresponding to the wave-motions above it. From the point of view of the electronic theory of electri-

[7] See "Proceedings" of the Royal Society, Vol. 72, May 28th, 1903

[8] See page 348 (published by Longmans, Green and Co., London. 1906.)

operation over long distances on the conductivity between the surface of the sea and land is sufficient to explain the increased distance obtainable with the same amount of energy in communicating over sea as compared to over land.

I carried out some tests between a shore station and a ship at Poole, in England, in 1902, for the purpose of obtaining some data on this point, and I noticed that at equal

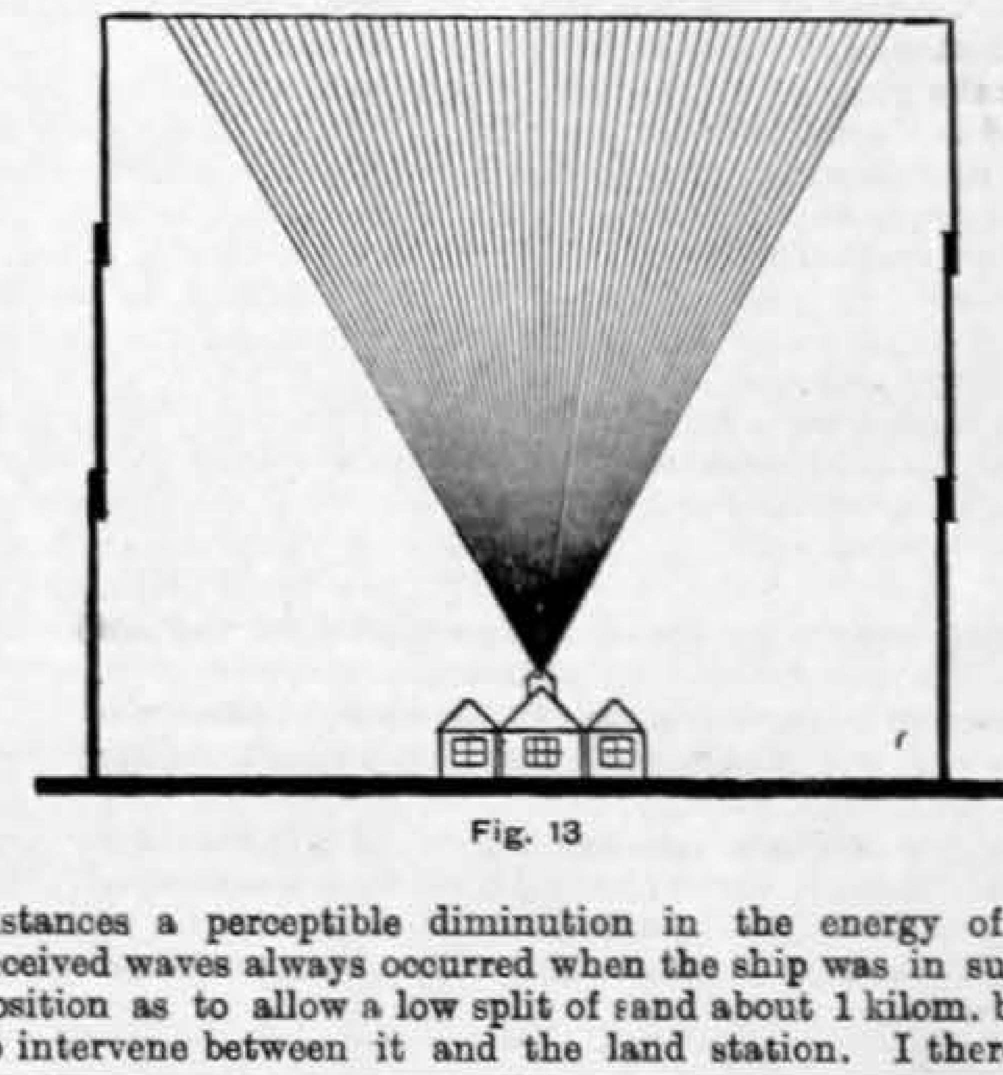

Fig. 13

distances a perceptible diminution in the energy of the received waves always occurred when the ship was in such a position as to allow a low split of sand about 1 kilom. broad to intervene between it and the land station. I therefore

[9] See J. Zenneck. "Annalen der Physik," 23, 5, p. 846, September 1908. "Physikal Zeitschrift," No. 2, p. 50; No. 17, p. 553.

believe that there was some foundation for the statement so often criticised which I made in my first English patent of June 2nd, 1896, to the effect that when transmitting through the earth or water I connected one end of the transmitter and one end of the receiver to earth.

In January, 1901, some successful experiments were carried out between two points on the South Coast of England 186 miles apart, *i.e.*, St. Catherine's Point, Isle of Wight, and the Lizard, in Cornwall.[10]—Fig. 12. The total height of these stations above sea level did not exceed 100 m., whereas to clear the curvature of earth a height of more than 1600 m. at each end would have been necessary. The results obtained from these tests, which at the time constituted a record distance, seemed to indicate that electric waves produced in the manner I had adopted would most probably be able to make their way round the curvature of the earth, and that therefore even at greater distances, such as those dividing America from Europe, the factor of the earth's curvature would not constitute an insurmountable barrier to the extension of telegraphy through space.

CERTIFIED TRACK CHART OF S.S. PHILADELPHIA. AMERICAN LINE.
SHEWING POINTS WHERE MR G. MARCONI RECEIVED MESSAGES FROM CORNWALL, ENGLAND

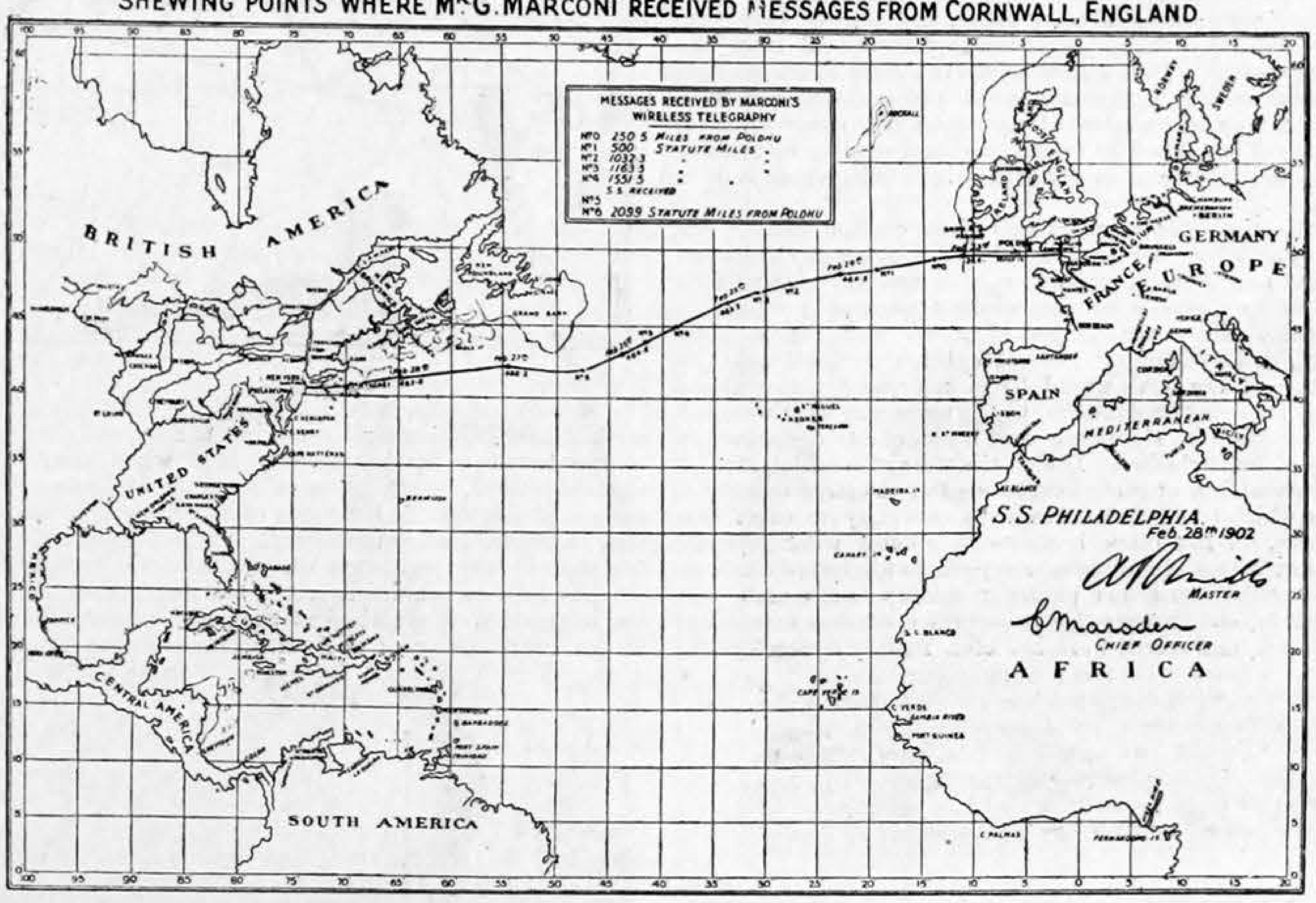

Fig. 14

The belief that the curvature of the earth would not stop the propagation of the waves, and the success obtained by syntonic methods in preventing mutual interference, led me in 1900 to decide to attempt the experiment of testing whether or not it would be possible to detect electric waves over a distance of 4000 kiloms., which, if successful, would immediately prove the possibility of telegraphing without wires between Europe and America. The experiment was, in my opinion, of great importance from a scientific point of view, and I was convinced that the discovery of the possibility to transmit electric waves across the Atlantic Ocean, and the exact knowledge of the real conditions under which telegraphy over such distances could be carried out, would do much to improve our understanding of the phenomena connected with wireless transmission. The transmitter erected at Poldhu, on the coast of Cornwall, was similar in principle to the one I have already referred to, but on a very much larger scale than anything previously attempted.[11] The power of the generating plant was about 25 kilowatts.

Numerous difficulties were encountered in producing and controlling for the first time electrical oscillations of such power. In much of the work I obtained valuable assistance from Professor J. A. Fleming, Mr. R. N. Vyvyan, and Mr. W. S. Entwistle. My previous tests had convinced me that when endeavouring to extend the distance of communication, it was not merely sufficient to augment the power of the electrical energy of the sender, but that it was also necessary to increase the area or height of the transmitting and receiving elevated conductors. As it would have been too expensive to employ vertical wires of great height, I decided to increase their number and capacity, which seemed likely to make possible the efficient utilisation of large amounts of energy. The arrangement of transmitting antennæ which was used at Poldhu is shown in Fig. 13, and consisted of a fan-like arrangement of wires supported by an insulated stay between masts only 48 m. high and 60 m. apart. These wires converged together at the lower end, and were connected to the transmitting apparatus contained in a building.

For the purpose of the test, a powerful station had been erected at Cape Cod, near New York, but the completion of the arrangements at that station were delayed in consequence of a storm, which destroyed the masts and antennæs. I therefore decided to try the experiments by means of a temporary receiving station erected in Newfoundland, to which country I proceeded with two assistants about the end of November, 1901.

The tests were commenced early in December, 1901, and on the 12th of that month the signals transmitted from England were clearly and distinctly received at the temporary station at St. John's, in Newfoundland. Confirmatory tests were carried out in February, 1902, between Poldhu and a receiving station on the s.s. Philadelphia, of the American Line. On board this ship readable messages were received by means of a recording instrument up to a distance of 1551 miles, and test letters as far as 2099 miles from Poldhu—Fig. 14.

The tape records obtained on the Philadelphia at the various distances were exceedingly clear and distinct, as can be seen by the specimens exhibited.

These results, although achieved with imperfect apparatus, were sufficient to convince me and my co-workers that by means of permanent stations and the employment of sufficient power it would be possible to transmit messages across the Atlantic Ocean in the same way as they were sent over much shorter distances. The tests could not be continued in Newfoundland owing to the hostility of a cable company, which claimed all rights for telegraphy, whether wireless or otherwise, in that Colony.

(*To be continued.*)

[10] See "Journal" of the Society of Arts, London, Vol. XLIX., page 512, 1901.

[11] Royal Institution of Great Britain, Lecture by G. Marconi, June 13th, 1902.

THE LUBRICATION OF CHECK-RAILS.

SINCE the introduction of electrical traction on railways the wear of check-rails has been a matter of considerable concern to those responsible for the permanent way. It will be generally known that a check rail is an additional rail provided inside the inner rail on a curve, as in Fig. 2. This will be seen in elevation in the middle illustration, from which it will be appreciated that the check-rail assists in keeping the wheel on the outer side of the curve from mounting the rail and becoming derailed. It may be remarked that the Board of Trade requirements specify that all curves, where the radius is ten chains or less, are to be provided with a check-rail. Naturally, therefore, there must be considerable friction between the wheels and check-rails, and this is greater on an electrically operated than on a steam-worked road, because with the latter the locomotive is the only propelling force, and as it draws the train past the check-rail the wheels of the train are disposed to "give." But with an electric train, on the multiple-unit system, each motor grinds its way through, which leads to considerable wear of both check-rail and wheel.

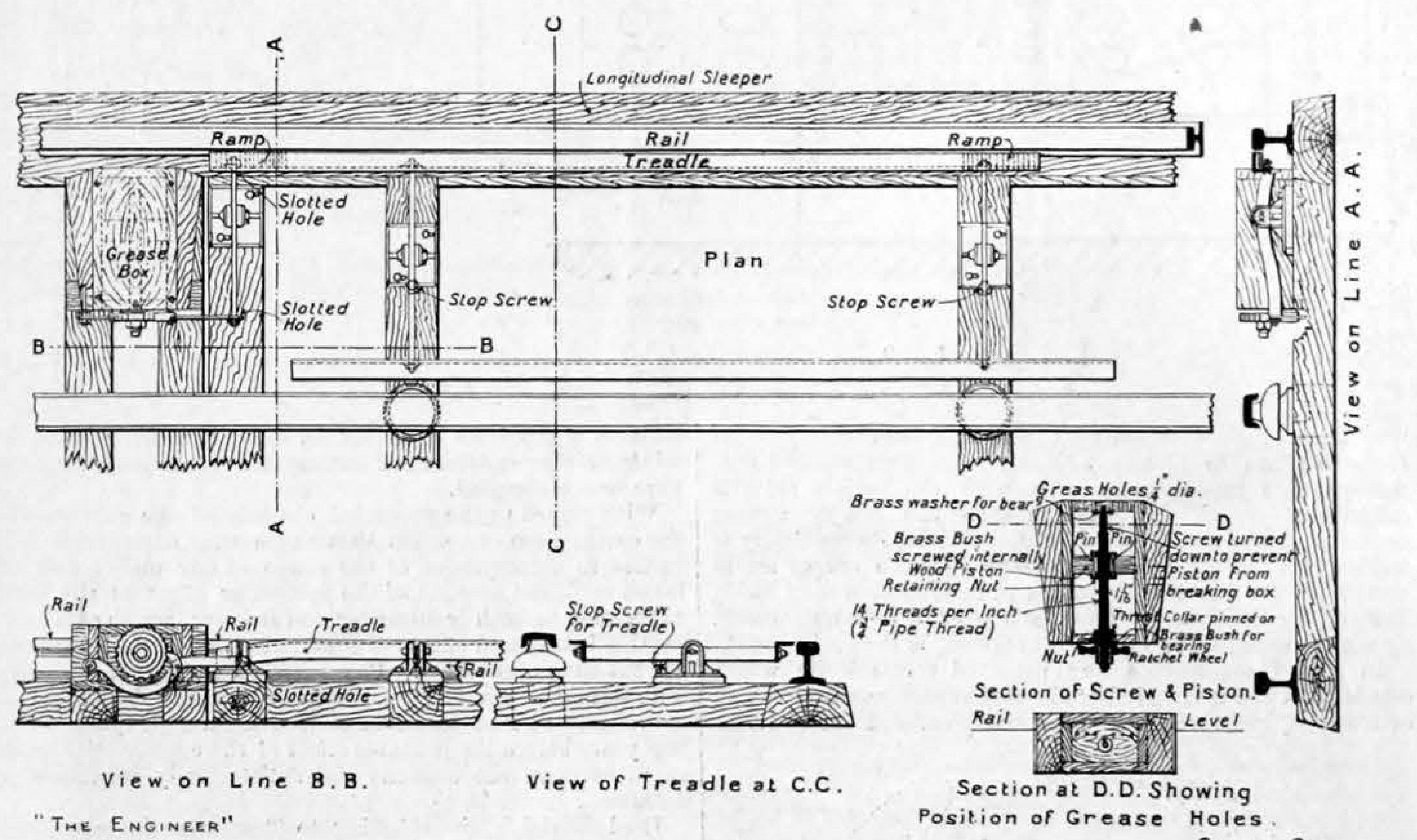

Fig. 1—NEACHELL'S APPARATUS FOR LUBRICATING CHECK RAILS

A remedy for this has, however, been found, and it is one that is equally applicable to steam and electric roads. It has been designed by Mr. E. J. Neachell, the general manager and engineer of the Liverpool Overhead Railway, on which line we recently inspected the apparatus. This line has always been electrically operated, and the troubles arising from check-rails have been particularly manifest there, as the railway has fourteen miles of track, of which one-sixth is on curves, and there is a five minutes' service on each road.

The apparatus will be understood on reference to Fig. 1. Fixed in the "four-foot," near the commencement of a curve, is a grease-box containing graphite or some other lubricant. In this box is a piston, driven forward by a screw actuated by a ratchet wheel. The ratchet wheel is turned by means of a pawl raised, through a series of levers, on the depression of a treadle by the side of the line. The treadle is carried by two or more levers fixed to the sleepers in the "four-foot," and is balanced by another treadle connected to the levers on the opposite end. The levers, not being centrally pivoted, cause the treadle nearer the rail to be normally raised and, being fixed close to the rail, it is depressed by the flange of the wheel of passing vehicles. The treadle may be balanced in other ways, but in the manner illustrated the distribution of weight and of stress is better equalised. As, then, the bar is depressed, the connecting levers and pawl are moved and a turn given to the ratchet wheel, and so the piston is driven forward. At the other end of the grease-box are holes through which the lubricant is forced out on to the inner vertical face of the flange of the wheel. The wheels are thus lubricated, also the check-rails as the wheels pass by them. In the centre of the four-foot is the third rail conveying the electrical power. This is, of course, no part of the apparatus, and each is independent of the other. By arranging the length of the treadle it is possible to actuate

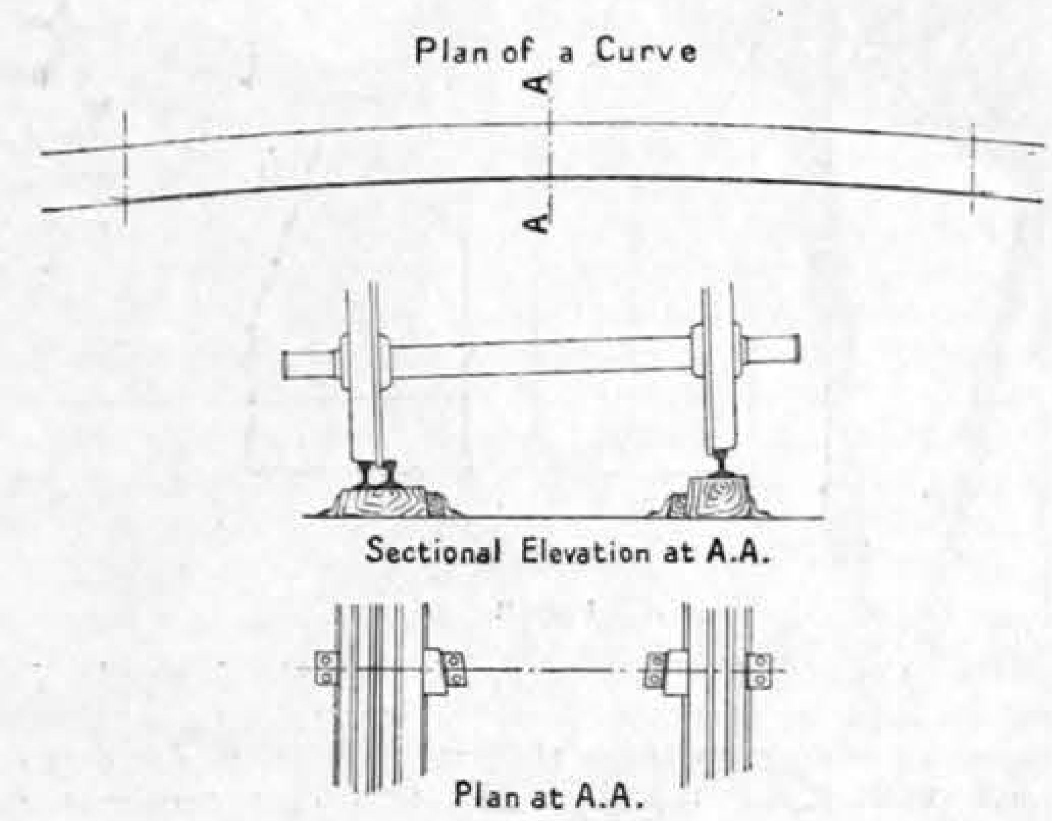

Fig. 2—ARRANGEMENT OF CHECK RAIL

the piston for every wheel or every bogie, or only once for each train.

On the overhead railway there is a grease box at the north end of the line and another at James-street Station. The latter is on the up-line, and we noticed grease on the opposite down-line, which showed that it had been carried to the south end of the line and back again—a distance of six miles—lubricating all the check-rails in the distance. Since the adoption of this apparatus it is estimated that there has been a saving of 50 per cent. in the wear of check-rails, and it is no longer necessary for men to go over the line every night to apply grease by hand. There is also a longer life in the tires, and, necessarily, some reduction in operating power.

The apparatus is, as we have said, equally applicable to steam-worked railways, although the need there is not so great for the reasons given above. The patent rights have been acquired by Graphite Products, Limited, 218-220, Queen's-road, Battersea, London, S.W., which company also manufactures the apparatus.

STERN FRAMES AND BRACKETS OF THE NEW WHITE STAR LINERS.

IN previous issues of THE ENGINEER, and notably those of 27th August and 3rd December of this year, the progress made by Harland and Wolff, Limited, of Belfast, in the construction of the two new mammoth steamships, Olympic and Titanic which they have on order for the New York services of the White Star Line, has been described and illustrated. As is now well known, these vessels will eclipse the new Cunarders in point of size, but their speed will not be so great. For both these new additions to the fleet of the White Star Line, the Darlington Forge Company was entrusted with the manufacture of the cast steel stern frames, brackets, and rudders, and these various pieces are far and away the largest and heaviest marine castings ever produced. The stern frame, rudder, and brackets of the Lusitania and of the Mauretania—which were also supplied by the Darlington Forge Company, and were described and illustrated in THE ENGINEER of September 29th, 1905—had a weight of about 220 tons. The total weight of the stern frame, rudder,