Wireless Telegraphic Communication

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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 high honour of sharing the Nobel Prize for Physics, have been to a great extent the results 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 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 those 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 become available possessing enormous advantages over flash-lights 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. After some experiments I found that a coherer constructed as shown in *Figure* 1, and consisting of nickel and silver filings placed in a small gap between two silver plugs in a tube, was

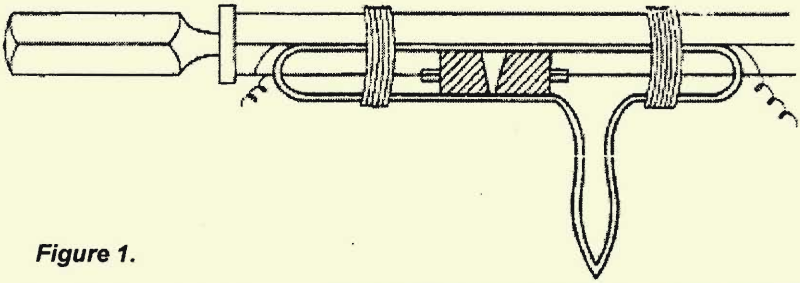


Figure 1.

remarkably sensitive and reliable. This improvement together with the inclusion of the coherer in a circuit tuned to the wavelength of the transmitted radiation, allowed me to gradually 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 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 communicate, but also seemed to make the transmission independent from the effects of intervening obstacles. This arrangement (*Figures* 2 and 3) 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.

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

Figure 2.

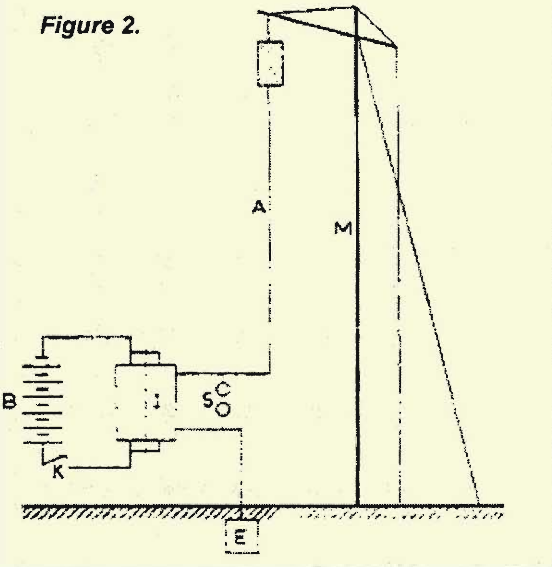
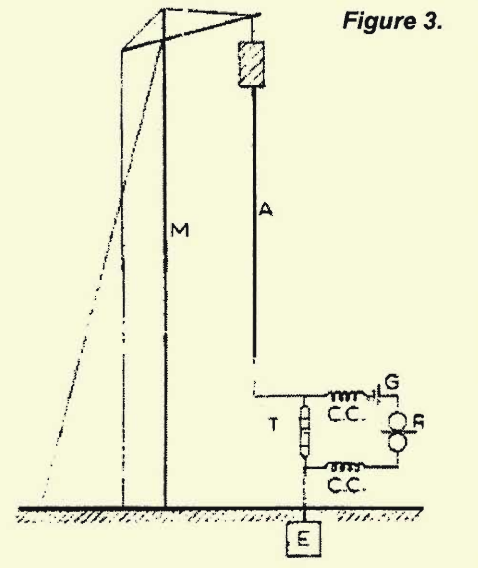


Figure 3.

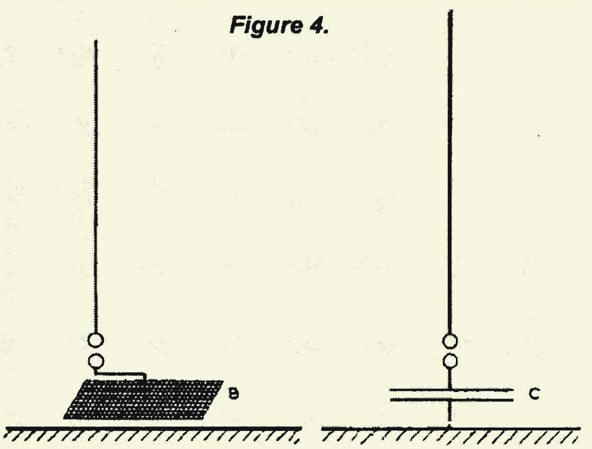


the distance over which it was possible to telegraph. Thus I found that when using cubes of tin of about 30 cm side as elevated conductors or capacities, placed at the top of poles 2 meters high, I could receive signals at 30 meters distance, and when placed on poles 4 meters high, at 100 meters, and at 8 meters high at 400 meters. With larger cubes 100 cm side, fixed at a height of 8 meters, signals could be transmitted 2,400 meters all round.

These experiments were continued in England, where in September 1896 a distance of 1 3/4miles was obtained in tests carried out for the British Government at Salisbury. The distance of communication was extended to 4 miles in March 1897, and in May of the same year to 9 miles.

In all these experiments a very small amount of electrical power was used, the high tension current being produced by an ordinary Rhumkorff coil. The results obtained attracted a good deal of public attention at the time, such distances of communication being considered remarkable. I have explained, the main feature in my system consisted in the use of elevated capacity areas or antennae 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. Prof. Ascoli of Rome gave a very interesting theory of the mode of operation of my transmitters and receivers in the *Elettricista* (Rome) issue of August 1897, in which he correctly attributed the results obtained to the use of elevated wires or antennae. Prof. A. Slaby of Charlottenburg, after witnessing my tests in England in 1897, came to somewhat similar conclusions. 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.

Figure 4.



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 'connected 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 (*Figure* 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 antennae.

After numerous tests and demonstrations in Italy and 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 (*Figure* 5).

At the time (twelve years ago) when communication was first established by means of radiotelegraphy between England and France, much discussion and speculation took

Figure 5.

place as to whether or not wireless telegraphy would be practicable for much longer distances than those then covered, and a some-what 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 radio telegraphy, 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 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 over-looked. 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 perturberant Earth than had been expected, and it imparts a great interest to the theoretical problem”.

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 4,000 kilometers, 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.

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 Prof. 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 utilization of large amounts of energy.

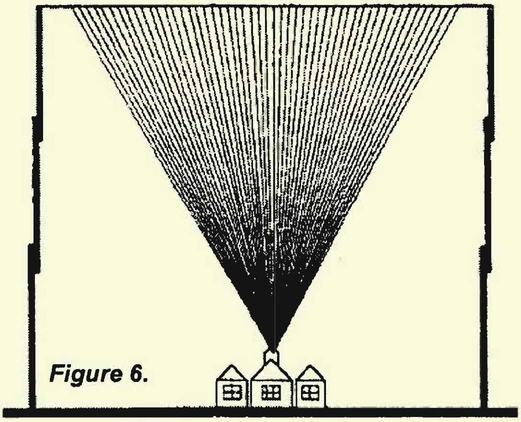


Figure 6.

The arrangement of transmitting antennae which was used at Poldhu is shown in *Figure* 6, and consisted of a fan-like arrangement of wires supported by an insulated stay between masts only 48 meters high and 60 meters 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 antennae. 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.

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.

With regard to the utility of wireless telegraphy there is no doubt that its use has become a necessity for the safety of shipping, all the principal liners and warships being already equipped, its extension to less important ships being only a matter of time, in view of the assistance it has provided in cases of danger. Its application is also increasing as a means of communicating between outlying islands, and also for the ordinary purposes of telegraphic communication between villages and towns, especially in the colonies and in newly developed countries. However great may be the importance of wireless telegraphy to ships and shipping, I believe it is destined to an equal position of importance in furnishing efficient and economical communication between distant parts of the world and in connecting European countries with their colonies and with America. As a matter of fact, I am at the present time erecting a very large power station for the Italian Government at Coltano, for the purpose of communicating with the Italian colonies in East Africa, and with South America. Whatever may be its present shortcomings and defects, there can be no doubt that wireless telegraphy – even over great distances – has come to stay, and will not only stay, but continue to advance. If it should become possible to transmit waves right round the world, it may be found that the electrical energy travelling round all parts of the globe may be made to concentrate at the antipodes of the sending station. In this way it may some day be possible for messages to be sent to such distant lands by means of a very small amount of electrical energy, and therefore at a correspondingly small expense. But I am leaving the regions of fact, and entering the regions of speculation, which, however, with the knowledge we have gradually gained on the subject, promise results both useful and instructive.