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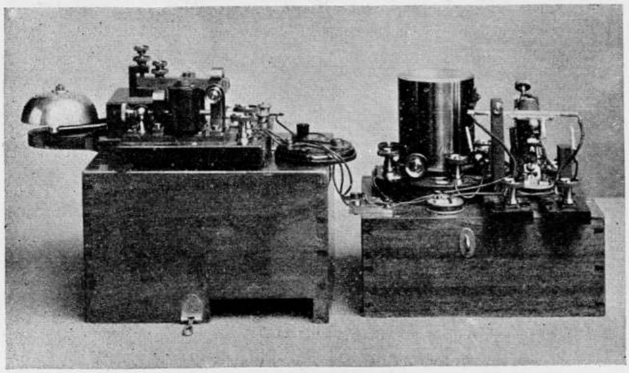
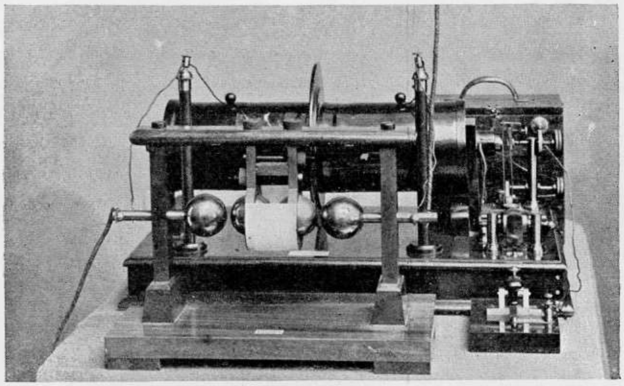


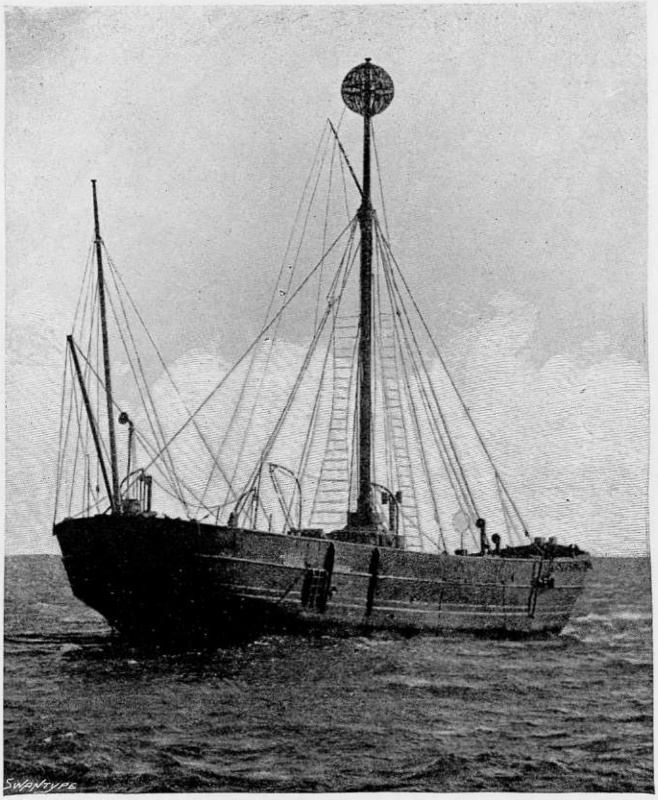
Marconi Lecture Type : Receiving apparatus.

receiving apparatus so that (like the Delaney instruments) each pair responds to one frequency of vibration only. Mr. Marconi has succeeded in applying a reflector in the way suggested, but only by a great sacrifice of the distance traversed ; he is now supposed to be working out the other solution with some success, and from his station at the South Foreland can telegraph at will to the Goodwin lightship or to Boulogne, without the other station receiving his message. Dr. Oliver Lodge has also exhibited, at the Royal Society, an ingenious system of tuning or "syntonising" the transmitting and receiving instruments. The next objection is that at present signalling without connecting wires is slow, the limit of manual dexterity being from fifteen to twenty words a minute. On the Atlantic cables a far higher rate of speed is maintained, and on land cables, as we have seen, the rate is enormously greater. Next, we do not know yet what effect the curvature of the earth will have in preventing signals over very great distances, although minor obstructions seem to be unimportant. This has yet to be tested. For signalling between forts in time of war, however ; between lightships and the shore, and in all places where cables are subject to much wear ; and possibly between ships at sea and permanent stations on land, a great field of usefulness appears to be open. Numbers of scientific men are at work on the problem ; some, like Dr. Lodge and Mr. Tesla (who first suggested in 1893 the use of the high vertical wire), for many years past ; others, like Dr. Slaby in Germany and M. Ducretet in France, with more activity since its success was demonstrated by Mr. Marconi. Governments, telegraphists, war-departments and admiralties are all keenly watching the outcome of these experiments, and inaugurating tests on their own account ; and before ten years are out, we ought either to see "wireless telegraphy" installed amongst the everyday facts of life, or relegated to that great lumber-room of forgotten inventions where so many sensational and brilliant discoveries lie *perdu* for all time.



Marconi transmitter : Lecture type.

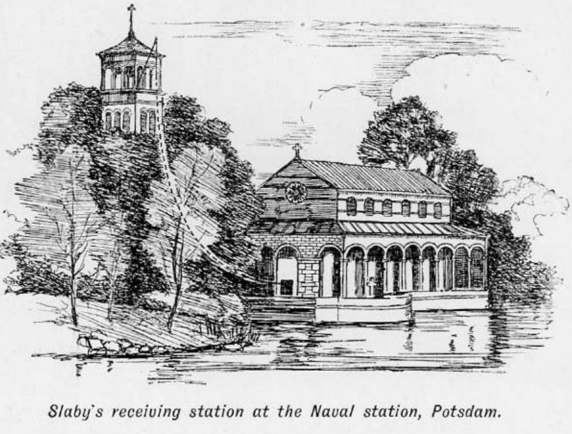
H. C. MARILLIER.


Lightship on the Goodwins, from which wireless communications are received.

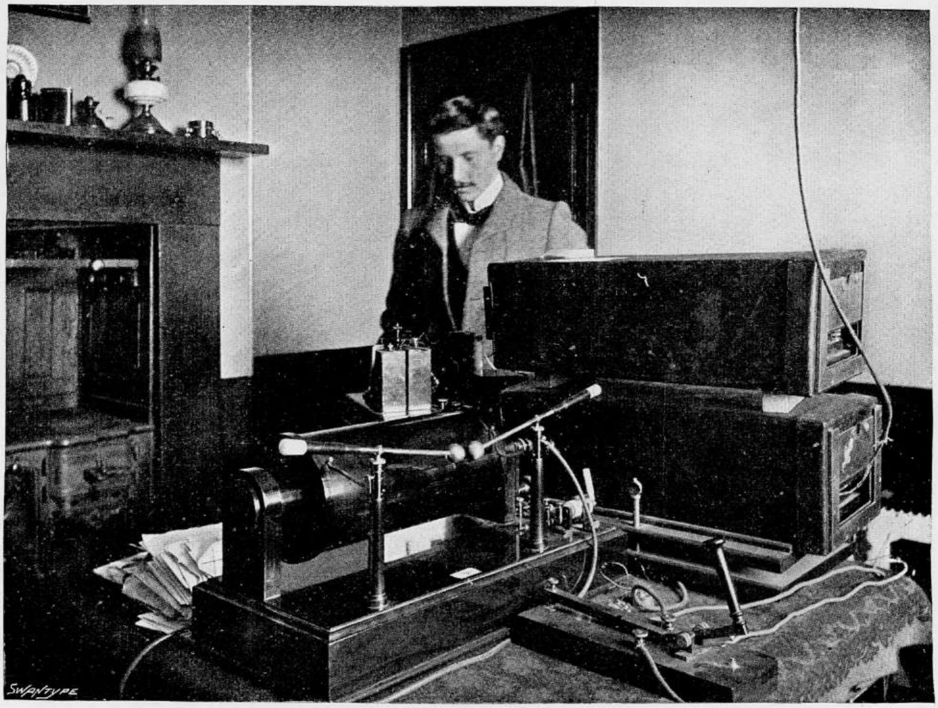
and these vibratory currents are sufficient to actuate a Morse recording instrument, which prints long or short dashes on a tape according to their duration.

This, briefly described, and without taking into consideration certain technical details, is all that the Marconi apparatus consists of; but scientifically the action is rather more uncertain and complicated than has been assumed. Thus the electrical radiations given off by the transmitter are probably of two kinds at least—electrostatic, due to the spark as a discharge, and electromagnetic, due to the action of the spark as an alternating current. In other words, induction plays an essential part in the radiation; and there may be transference of current by ordinary earth conduction as well.

It will be asked, what are the possibilities of "wireless telegraphy"? Will it supersede cables for telegraphing across the Atlantic? will it come into use on land? Well, at present there is no reason to think it will do either. In the first place, it has the obvious defect that, as electric radiations spread in every direction,

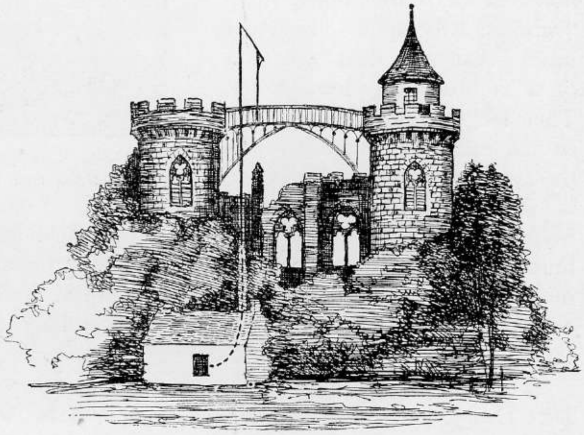

Slaby's receiving station at the Naval station, Potsdam.

and not simply in one straight line, anybody who sets up a pole of the proper height can read anybody else's message, if indeed the number of messages did not become so confusing as to prevent any being read at all. This can be got over in two ways: either by concentrating the radiations in a beam, by means of a suitable reflector, so that they do not spread in every direction, or by tuning the transmitting and



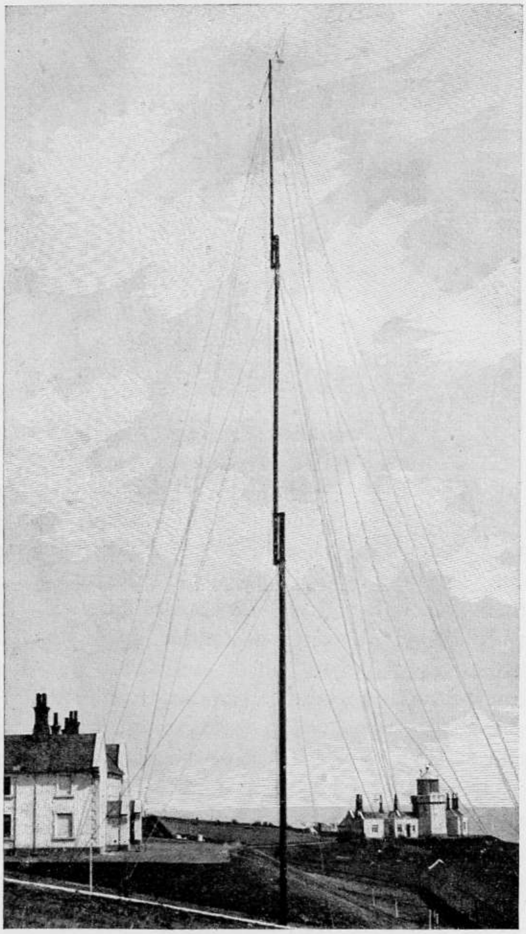
Marconi's assistant, Mr. Bullock, in the signalling room at South Foreland Lighthouse.

terminals are some minute grains of powdered nickel and silver, which have the curious property of being non-conductors until an electric vibration actually strikes them, when they "set" themselves, like iron filings under the influence of a magnet, and at once become a conducting body. A tap on the glass destroys their conductivity. Now when the waves transmitted through space, or through the earth, by the sparking apparatus, fall in their course upon a Branly coherer, they change it from a non-conductor to a conductor, and *this is all the action of which they are capable.* They cannot ring a bell, or work an instrument, or deflect a compass, or make signals in any perceptible way. All this is accomplished by a subsidiary apparatus consisting of an electric relay circuit, in which is a battery. The coherer forms part of this circuit, and is so placed that a vibrating clapper like that of an electric bell taps it with great rapidity whenever a current flows; thus a kind of vibrating action and reaction is set up between the coherer and the clapper, the current being rapidly made and broken by the coherer whenever the transmitted waves strike it;



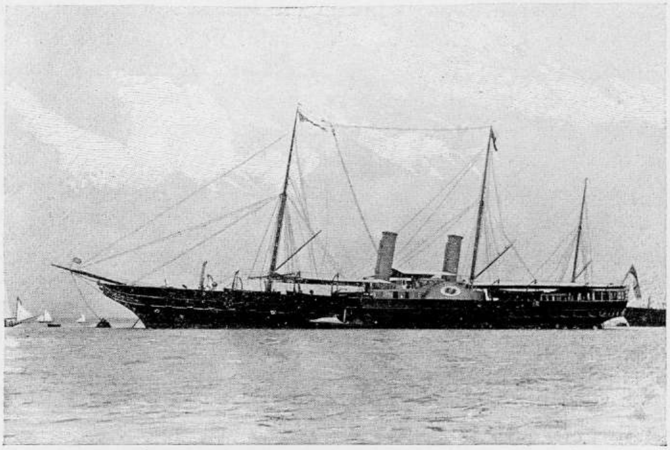
Slaby's sending station at the Castle on Pfaueninsel, Germany.

"choppy" billows, so a vibration in the ether may consist of comparatively slow waves from a few feet to many miles in length, or of infinitesimally small waves following each other at the rate of millions and even billions per second. The physical effects of these waves differ according to their rapidity. The slowest that we are practically acquainted with produce magnetic and electrical phenomena of different kinds; more rapid and shorter ones produce heat; whilst waves varying from three to eight ten-millionths of a millimetre in length, and following each other at the rate of 400 to 800 million million per second, are the ones that produce upon our retinal senses the effect of light. Below and above these in the scale come the invisible but active chemical rays, and the mysterious radiations discovered by Lenard and Röntgen. According to their length and rapidity some of these waves can flow through metals, or through glass, or through air, or through the earth, whilst others are stopped and broken up. Sir William Crookes has drawn a fancy picture of what the universe would look like if our eyes were sensitive to electromagnetic vibrations of a lower quality than the so-called light waves. Glass and crystal would be opaque, metal would be transparent, a magnet would glow like a lamp, and a telegraph wire stretched across the air would appear as a gleaming hole in a dark body. In "wireless telegraphy" the ether waves that we deal with are of a comparatively low quality. Their length from crest to crest, as can easily be measured with the apparatus invented by Hertz, is about four feet, and their frequency is some 250,000 per second. Such waves have no effect upon the human eye, but there has been invented a remarkably delicate little instrument on which they have an effect, and this, whilst known scientifically as the "Branly coherer" from its inventor's name, has also been popularly called from its action the "electric eye."



Marconi's Installation at the South Foreland Lighthouse for communicating to the Goodwins and Boulogne.

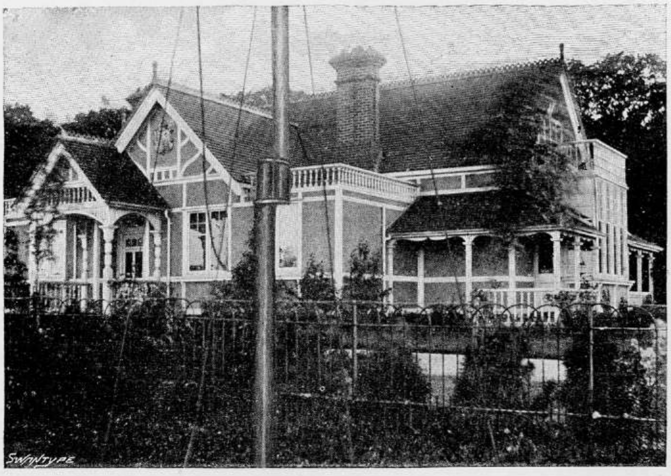
The coherer is the essential element in the receiving instrument employed by Dr. Lodge, Mr. Marconi, and all who have worked at spark telegraphy. It consists, in its improved form as used at present, of a tiny glass tube into which two platinum conductors are sealed. In the gap between the platinum



Royal yacht "Osborne" in communication at sea with Marconi's station at Ladywood.

Photo by Beken, W. Cowes.]

which consists of long and short dashes to represent letters, may be transmitted and reproduced. By connecting one of the spark terminals to earth and one to the long vertical wire, which is suspended from the top of a flagstaff, or from a stationary balloon, the space-penetrating power of the vibrations is enormously increased. Before we describe the receiving apparatus, this action had better be more fully explained. A spark, as Lord Kelvin has satisfactorily shown, is not merely a single discharge from one highly charged point to another. Like a spring suddenly released, it represents a series of oscillations or surgings, so rapid that what looks like a single flash to the eye in reality consists of many thousand backward and forward movements. Each of these oscillations starts a wave in the ether, which may be regarded as a continuous medium pervading all matter and all space: a jelly so thin that it flows between the molecules of glass, of metal, and of rock; so impalpable that philosophers have not yet discovered whether the earth as it rushes in its orbit cleaves it like a boat or lets it flow through like a sieve. A sudden jar upon this jelly-like medium sends a quiver through the mass, wave upon wave following in a rapid vibratory succession; and these waves spread onwards and outwards, as has been said, like the ripples caused by dropping a stone into a pond. Clerk Maxwell first established, from theoretical reasoning, that the ether waves set up by a source of electrostatic or electromagnetic energy, of heat, or of light, were all of the same kind, travelling at the same velocity of 186,000 odd miles per second, and differing only in frequency and length. Just as a rough sea may consist of long slow-rolling or of rapid

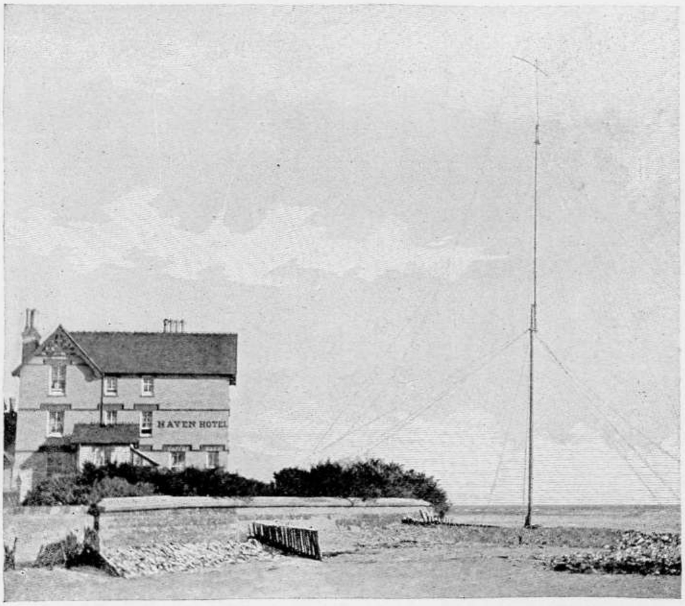


Marconi's station at Ladywood, Isle of Wight.

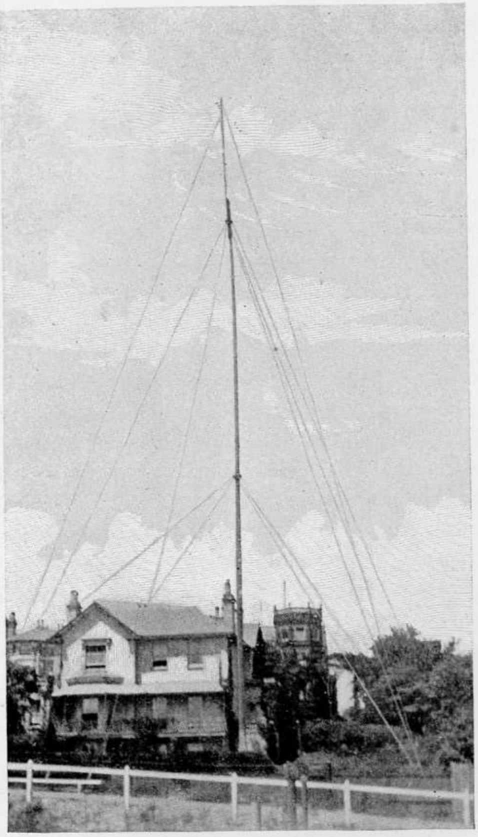
Photo by Beken, W. Cowes.]

the present maximum, obtained between two stations erected at the instance of the French Government on Dover cliff, close to the South Foreland lighthouse, and at Wimereux, near Boulogne. In addition to this, Mr. Marconi has made successful experiments in carrying on signals between ships and the shore, a permanent installation having been at work for some time between the South Foreland station and one of the Goodwin lightships; whilst in 1898, during the cruise that the Prince of Wales took round the Isle of Wight to rest his injured knee, constant communication was kept up between one of the Royal lodges at Ladywood and the yacht *Osborne*, even when seven-and-a-half miles of rising ground, as well as sea, intervened between the transmitting and receiving instruments. The newspapers have done such ample justice to Mr. Marconi's remarkable performances that it is unnecessary to dwell longer on them here. What may perhaps be of interest is a general description of the apparatus used in these trials, and a short account of the electrical problems involved. Mr. Marconi's instruments, as he would be the first to admit, have very few new or original features, the advance in results which he has made being due to careful observation and adjustment of details, with certain additional modifications which experience has proved to be important. In the first place, he may claim to have established the superiority of vertical over horizontal base wires, with an enormous reduction in the length necessary to signal over a given distance. Moreover, he has worked out a law showing the relation between the length of wire and distance, which is that the distance varies with the *square of the length*: thus, if twenty feet of vertical wire will suffice for signalling one mile, double that, or forty feet, will signal four miles, eighty feet will signal sixteen miles, and so on. In the case of horizontal base wires, according to Mr. Preece's experience, the length had to be of about the same magnitude as the distance to be traversed.

Marconi's transmitter, like that of all who have employed the spark method of signalling, consists of an induction coil worked from a battery of cells. Every time that the signalling key is depressed a spark passes between the ball terminals of the coil, and according to Clerk Maxwell's famous theory, experimentally verified by Hertz, gives off a ripple of electrical vibrations which spread through the ether like waves of light, and may be intercepted at a distance by a suitable kind of receiver. These vibrations can be continued for longer or shorter periods, or interrupted altogether by simple manipulation of the key; and so the Morse code,



Marconi Installation at Poole, in communication with Alum Bay.



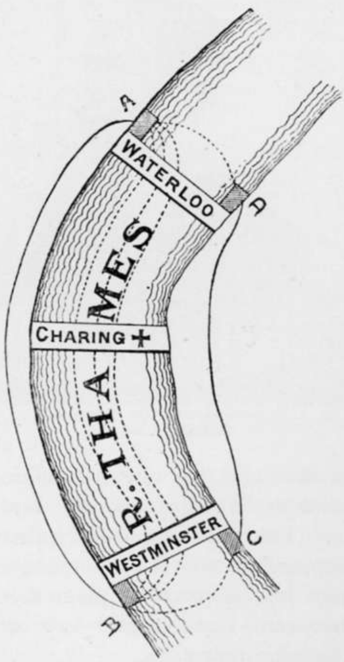
Marconi Installation at Bournemouth, in communication with Alum Bay.

has already been superseded by the "spark" method, which we shall next describe, are points it would be rash to pronounce upon definitely. Few men have had more experience in this branch of work than Dr. Lodge; and yet that eminent physicist, who has tried both systems, is still experimenting with huge coils of copper wire, between which he signals inductively across Liverpool; on the other hand a young rival, using the "spark" method, but employing much of the apparatus and ideas that other men have toyed with, has come forward recently, and in a sensational manner has wiped out all records for long-distance signalling without line wires by sending messages across the Channel with perfect ease and regularity. By the kindness of Mr. Marconi, whose system is here described, the writer was permitted, amongst the first, to inspect the successful working of his installation at the South Foreland Lighthouse, pictures of which are shown in this article; and, indeed, so simple and so regular does it appear, that a spectator has great difficulty in realising the significance of the achievement.

Mr. Marconi is a very young man—not yet thirty years of age, as his portrait shows. Born at Bologna, but of English parentage on his mother's side, he speaks fluent and perfect English, with a slightly foreign gravity of manner which belies his youth. He is, as he professes, an amateur electrician, and exceedingly modest as regards his accomplishments in comparison with some of the no doubt well-meaning chroniclers who have even unduly belauded them. He has been about four years at work on the particular subject of "wireless" telegraphy, carrying out many experiments on his family estate near Bologna before he discovered the important fact that electric waves generated by a sparking apparatus of the kind used by the lamented German physicist Heinrich Hertz, would not only carry to long distances, but were unaffected by intervening hills and natural obstacles. At this date, two miles was the maximum distance reached, whilst English observers had accomplished one mile and three-quarters. With his original apparatus for transmitting and receiving Hertz waves much improved, Mr. Marconi came over to England in 1896, and succeeded in getting the patronage of the British Postal officials, under whose auspices he carried out signalling experiments on Salisbury Plain and at Penarth. Since then he has gradually improved both his methods and his records; the distance traversed by his etheric signals being increased successively from fourteen-and-a-half miles, between Alum Bay and Bournemouth, to eighteen miles (Alum Bay and Poole), and thirty-two miles, wire, it causes a ripple of electro-magnetic waves in the ether pervading our universe; and if this ripple, spreading outwards, cuts another coil parallel to the first, it sets up, or *induces*, in it a corresponding momentary or alternating current. It is hardly possible to say, in these early experiments of Mr. Preece, how much of his result was due to earth conduction and how much to induction; but that the latter was at all events a potent factor he afterwards proved, at Newcastle and elsewhere, by signalling from point to point without the help of the earth at all, with two closed coils of insulated wire embracing a large area, and either laid upon the ground or carried upon poles. An ambitious attempt was even made once to send messages across the air between England and Ireland. A long circuit of telephone wires on either side was coupled up, so as to make a pair of huge single coils. The whole telephonic system of the country was stopped from midnight to 2 a.m. one Sunday in June 1895. Attempts were then made to signal, but failed on account of the wonderful, incessant, and strange sounds that filled the telephone and overpowered everything else. Mr. Preece was of opinion that the weird babel of noises which frustrated his attempt came not from earthly sources, but from primary electrical effects outside our globe, electrical radiations emanating from the sun, from Mars, from who knows what disturbing member of the celestial spheres!

Induction, like the genie of the "Arabian Nights," whilst capable of much useful and wonderful service, is as often as not the bugbear of the telegraph engineer. Applied to the "transformer," it enables us with very little loss of power to convert a dangerous high-pressure to a low-pressure alternating current; applied to telephone lines, it is responsible for much bewildering cross-talk and interference. Its serviceability as a means of communication was first impressed on Mr. Preece by the awkward fact that a telephone operator who knew the Morse code once found himself able to read off from his overhead line messages which were being sent on the telegraph wires buried underground. This inconvenience has been amply atoned for by the far-reaching results which have sprung from it under the hands of Mr. Preece, Dr. Oliver Lodge, and others. Whether the induction method of signalling will ever come to anything by itself, or whether it

Guglielmo Marconi.



now in use, is certainly destined to play a great part in extending their spheres of usefulness, and in making communication safe and easy between points where it is now difficult and uncertain. This is the so-called "wireless telegraphy," a misnomer in one sense, which has caused our more pedantic German neighbours to re-christen it "spark-telegraphy."

The feasibility of signalling without conducting wires is not by any means a new discovery. It was tried on a large scale by Morse, in America, as early as 1842, and by many others, the principle in all these early experiments being the use of land or water to carry current to the distant point. The attached diagram, shown by Professor Silvanus Thompson in one of his lectures, will explain this method.

A and B are metal plates sunk in the water at two points on one side of the Thames, and connected by an insulated wire. C and D are corresponding metal plates on the opposite side, to which it is desired to signal without laying a wire across the river. If a current is passed through the wire A B, it uses the earth and more particularly the water as a return circuit, spreading out in the manner shown by the dotted lines. A little of the current spreads as far as the metal plates C and D, and passing into the wire which connects them, will give faint but perhaps intelligible signals. When a storm once destroyed the cable connecting the island of Mull with the mainland, the telegraphists actually used this method of signalling, the ends of the overhead telegraph wire across the island being dipped into the sea, whilst from Oban a wire a mile and a half long was laid along the shore and dipped into the sea in a corresponding manner. Communication was kept up thus for over a week across a strait two miles wide.

An impetus was given to experiments of this kind by the invention in 1878 of the Bell telephone, an instrument so sensitive to even the smallest currents that it enabled much fainter signals to be detected than heretofore. One of the first to avail himself of this was Mr. W. H. Preece, whose name is associated with a long series of trials, beginning in 1882 with a successful attempt to communicate across the Solent. In this case the parallel wires were about fifteen miles long, whilst the width of the channel between them was, in parts, only one, so that there was no economy of wire, but rather the reverse. Later, Mr. Preece succeeded in telegraphing between Lavernock Point, in South Wales, and the island of Flat Holm, a distance of over three miles, using about a mile of wire only on each side, stretched along poles and with their ends carried to earth. Similar and equally successful experiments were made between Arran and Kintyre, and on the vast expanse of moist sand at Porthcawl, much valuable information being compiled as to the relation that the length of the wires should bear to the distance between them, and so forth. An interesting feature of these experiments was that in addition to depending on the *conduction* properties of the earth, Mr. Preece availed himself of *induction* across the air gap. When a current starts or stops, or when an alternating current pulses backwards and forwards in a closed coil of

The Delaney can keep six clerks and six receiving instruments busy at the same time. Its arrangement is, roughly speaking, as follows: a pivoted bar carrying a trailer is made to revolve over a disc divided into segments, each of which represents a separate instrument. As the trailer makes contact with each segment in turn, it gives up the line momentarily to a certain instrument, an intermittent current of a certain frequency passes and communicates its burden to one of the five or six instruments at the distant office. The trailer passes on to the next segment, sends a fragmentary message to the next instrument, and so on, serving each rapidly in turn. Distributors running synchronously are attached to both ends of the line, so that at every given moment a definite pair of instruments, say one in London and one in Edinburgh, are in connexion and can communicate. The moment after another pair is in connexion, and so on. In this manner six messages may be despatched practically simultaneously between London and two or three important provincial centres.

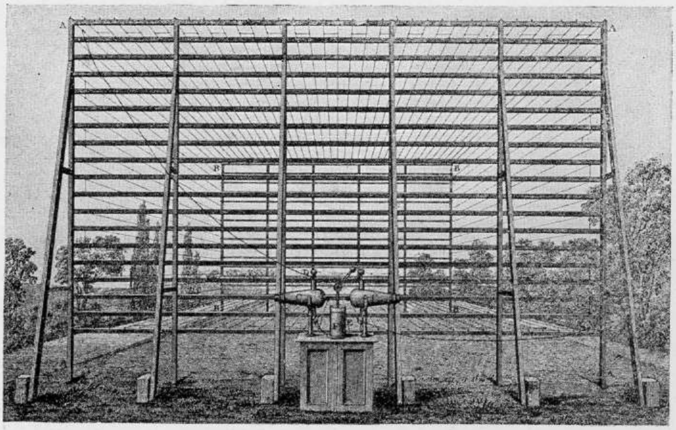
Heinrich Hertz.
By permission of "The Electrician" Publishing Company.

Mr. W. H. Preece, C.B., F.R.S.

Here we have for the present the high-water mark of land telegraphy, so far as speed is concerned; though even as these lines are being written there comes from Vienna—the home of scientific marvels nowadays—a sensational announcement of *sixty thousand words per hour* achieved by some new form of apparatus over a single wire. If true, this threatens once more to eclipse all previous records.

In the development of sub-oceanic telegraphy, which has not yet been touched upon, speed plays a secondary part as compared with the difficulties of laying and working a long insulated cable, in which currents smother and strangle themselves, and which is open to every sort of insidious risk, from the chafing of rocks and tides to the boring of tiny insects. Triumphant as the story of submarine telegraphy is, as a record of perseverance and pluck (mainly British), this is not the place to tell it, especially as it has been dealt with very voluminously of late by some of those connected with the early history of the movement. Our object is to describe the last new development of telegraphy—a development which, without superseding or revolutionising either the land or submarine systems

Dr. Oliver Lodge, F.R.S.

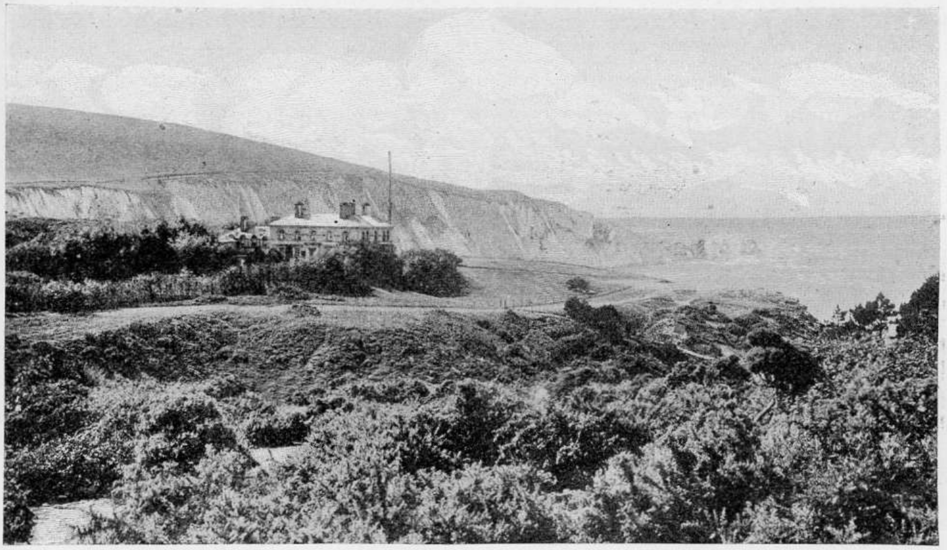


Ronalds' Telegraph at Hammersmith.

Morse in America, the sounder of Steinheil in Germany, and the semaphore of Breguet in France, were just struggling into existence. The double needle was the principal instrument in use in this country, its construction being based on the elementary fact that whenever an electric current passes through a wire in the neighbourhood of a magnet, it causes the latter to take up a position at right angles to the wire. The instrument was a wonderful work of art. Enshrined mysteriously in a miniature oak temple, it pursued (for the time) a useful but erratic career, to the everlasting agony of the operators and the occasional mystification of the telegram-reading public. Still, men of the "old school" profess to have loved the Cooke and Wheatstone instrument, and look back with fondness to the time and ingenuity expended in conquering its whims. "Duplexing" was the first important advance after the original instruments had been sufficiently perfected. This consists in sending two messages in opposite directions at the same time along one wire. At first sight it might appear as if the two currents crossed. In reality no current passes along the wire at all, the needles being simply affected by the upsetting of the balance in a pair of counteracting coils with which they are surrounded. "Diplex" telegraphy, by which is meant the use of two instruments depending on a different class of currents, next permitted two messages to be sent along a wire simultaneously in the *same* direction; and the combination of this with the foregoing gave "quadruplex" working, which for many years was considered the ultimate possible advance to be made in telegraphy.

Clerk Maxwell.

Experience, however, has shown, and the purpose of this article is to prove, that in telegraphy nothing can be called ultimate. The Wheatstone automatic system very soon lowered the record of quadruplex working. In this, mechanism to a large extent supplants manual dexterity. The messages are not transmitted directly by hand, but are punched on paper first. A clerk can punch at the rate of forty or fifty words a minute; the machine can transmit at the rate of 450, and so one instrument can take off the work prepared by several clerks. This is *simple* automatic working. By means of duplexing and other devices an actual 600 words per minute has frequently been recorded along our postal telegraph lines. The acme of telegraphic working at the present day is not, however, the automatic Wheatstone, but the Delaney distributor, which first came over from America in 1886, and has been enormously improved, and in fact rendered practicable in the English service,



Marconi's Station at Alum Bay.

"WIRELESS TELEGRAPHY," ITS HISTORY AND DEVELOPMENT.

AMONGST the triumphs of what Mr. Wallace has christened "The Wonderful Century," none stands out with greater distinctness than the invention, development, and rapid perfection of electric telegraphy. A tablet upon the wall of Kelmscott House, Hammersmith, so long known as the residence of William Morris, commemorates the fact that there, in 1816, Sir Francis Ronalds, F.R.S., erected the first electric telegraph, eight miles long. Having succeeded by the aid of pith balls in sending intelligible signals through this great length of wire, and invented a species of code, Ronalds sat down and wrote to the Admiralty, inviting Lord Melville to come and witness his performance. The telegraphic system of the country in those days was entirely dependent on the old semaphore, a costly arrangement which for one hundred days out of the year, as statistics show, was incapacitated on account of the weather. Ronalds, however, was at that time not well known, and the Admiralty officials received his communication with a laconic indifference which is characteristic of Government officials when confronted with a novelty. In other words, the secretary, Mr. Barrow, presented his compliments to Mr. Ronalds, and informed him that "*telegraphs of any kind are now wholly unnecessary, and no other than the one now in use will be adopted.*" Mr. Barrow lived to become Sir John Barrow, and by an irony of circumstance wrote the article on "Telegraphy" in a subsequent edition of the *Encyclopædia Britannica.* Ronalds' telegraph, consisting of eight miles of wire partly laid underground in glass tubes and partly suspended between two large frames, is illustrated on the following page, from an old engraving in his book, published in 1823.

Telegraphy proper did not begin until nearly the middle of the century. In 1852, when Mr. W. H. Preece, F.R.S., the late respected Chief Engineer to the Post Office, joined the electrical profession, it was still in its infancy. The needle system of Cooke and Wheatstone in England, the electro-magnetic recorder of