ÆTHERIC OR WIRELESS TELEGRAPHY.

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PUBLISHERS' PREFACE.

Experiments in wireless telegraphy are by no means new, but previous to the discovery of the telephone they consisted entirely of making earth or water, or both combined, part of a telegraphic circuit. Bell's discovery led to experiments which proved that the telephone could be acted upon at a distance inductively, but there was no commercial practicability in the various schemes devised. The development of knowledge relating to Hertzian waves really led us to what the moderns term wireless telegraphy. This little book deals almost exclusively with these later developments.

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Ætheric or Wireless Telegraphy.

INTRODUCTION.

Scientific men are often accused of being too optimistic—of dreaming dreams which are never likely to be realised. Some listeners, no doubt, characterised as of this nature Prof. Ayrton's memorable statement made in 1897 (when speaking of telephony): "There is no doubt the day will come—maybe when you and I are forgotten—when copper wires, guttapercha coverings, and iron sheathings will be relegated to the museum of antiquities." . . . In that day "when a man wants to telegraph to a friend he knows not where, he will call in an electromagnetic voice which shall be heard loud by him who has the electromagnetic ear, but will be silent to everyone else. He will call 'Where are you?' and the reply will come, 'I am at the bottom of a coal mine,' 'I am crossing the Andes,' 'I am in the middle of the Pacific,' or perhaps no reply will come, and he may conclude his friend is dead." Making due allowance for mere rhetoric, few dreams of scientists have reached such a stage of fulfilment in so short a time. Five years only have elapsed, and we read in the daily papers Marconi's message to the King which has been flashed across 2,500 miles of Atlantic ocean without the aid of an intervening wire or metallic conductor. Prof. Ayrton's dream is likely to become to a considerable extent a reality even whilst he himself is young and vigorous enough not only to rejoice at, but also to participate in, the triumphs of the science he loves. To whom is the wonderful advance of the last few years due? Well, to many workers. To Faraday, Maxwell, Henry, Hertz, Branly, Lodge, Preece, and, most of all, to Marconi, the man who reduced theories and experiments to practical realities.

Early Attempts.—Passing over the "anticatelephor" of Edwards (1829), in which air or water in pipes was probably the medium employed, we find Mr. Edward Davy in 1838 preparing to send waves "by the conjoint agency of sound and electricity," to be received in the focus of an electromagnetic receiver at a distance. Prof. Morse in 1842 gave a practical demonstration of an ordinary submarine insulated wire telegraph to connect Governor's Island with Castle Garden in New York, a distance of one mile. The accidental breakage of his wires by a passing vessel caused him to so arrange his wires along the banks as to use the water itself as a conductor—at least that was his own explanation. Sir W. Preece in recent times has carried out this method much more perfectly.

James Bowman Lindsay, of Dundee, about 1843 elaborated somewhat the same idea. Lindsay, who was born in 1799, was, without doubt, a remarkable man. He was appointed lecturer in mathematics at the Watt Institution, Dundee, in 1829. He saw far in advance of his time, but was prevented by want of means and a strange hyper-modesty from carrying his ideas out to perfection. A sort of walking encyclopædia, he spent a great part of his life trying to compile a dictionary in fifty languages with the object of finding out the time and place of man's origin. He lectured in electrotechnics, including electric lighting, and proposed in 1843 a submarine telegraph across the Atlantic. In March, 1853, he delivered a lecture in the Thistle Hall, Dundee, in which he proved by experiments that with suitable arrangements of apparatus and wires laid along the banks of a river, the water itself could be made to transmit the electrical impulses. Many experimenters have tried the same method, using the earth or water as a conductor. It cannot be said that all these are on the wrong track, but certainly most of their experiments show very little knowledge of the capabilities of high-frequency etheric transmission.

Practical Period.—We come now to the time of the telephone. The invention of the telephone gave a new receiver of extraordinary sensitiveness for very feeble interrupted or alternating currents, and experimenters were not slow to make use of it. Prof. Trowbridge, of Harvard, in the United States, carried out elaborate researches on the propagation of electric currents through the earth or water. He found, like many others since, that if the terminals of a telephone receiver be connected to a separate metallic circuit, two points of which are earthed at two places not at the same potential as regards the metallic circuit, sounds will be heard in the telephone due to the current passing through it. By inserting an interrupter and a key in the circuit of the battery, the uniform noise or hum heard in the telephone can be cut into long and short periods to give signals in accordance with the Morse alphabet. Thus messages may be sent over considerable distances without intervening wires. Prof. Trowbridge even put forward the view, originally promulgated by Lindsay, that it might be possible to signal in this way from the United States to Europe.

Intercommunication between ships at sea was proposed, and in 1882 Graham Bell tried the experiment with boats on the Potomac River, and succeeded in sending messages over a distance of $1\frac{1}{2}$ miles.

Prof. Dolbear, of Boston, made some useful suggestions in 1883. He used an induction coil having in its primary circuit a microphone transmitter with wire dipping into the earth, and he even in some cases used an elevated wire, or "aerial," not unlike that now employed.

Mr. T. A. Edison, in 1885, invented, or rather perfected, in conjunction with Messrs. Gilliland Phelps and Willoughby Smith, a method of signalling to and from moving trains. This method is based on the principle that a magnetic field, if varied, has the power to affect a second electrostatic system and create, in air-gaps, displacement currents sufficient to affect a telephone receiver.

Prof. Trowbridge, again, in 1891 proposed the use of the magnetic induction system, using two separate and insulated circuits. He found that if a primary circuit consisting of a large coil of wire with a battery and interrupter be employed, and a secondary circuit consisting of a coil and telephone receiver, the interruptions of the current in the primary circuit give rise to induced currents in the secondary circuit which make themselves heard in the telephone. Sir W. Preece has carried out many experiments with a combination of this and the conduction method, and, in conjunction with Mr. Marconi, in 1897 had considerable success, a distance of over eight miles being traversed without intervening conductors.

Dr. (now Sir) Oliver Lodge has, probably more than any other Englishman, worked successfully at this subject. He has shown the way, has written much, and formulated nearly all the known laws governing the transmission of signals without conductors. He has recently (in conjunction with Dr. Muirhead) elaborated a system which is likely to rival those now in use.

Later success has been due mainly to Mr. Marconi, who, with true youthful elasticity combined with genius, "has never known when he was beaten," but, when seemingly defeated, has taken up the fight with renewed ardour, always to conclude with success. For instance, the lengthening of his vertical wire and the discovery of a so-called "law of distance" when failure seemed certain, and later the insertion of a step-up transformer in the transmitting circuit, the use of a split transformer in the receiving circuit, and the invention of the magnetic receiver, can only be regarded as strokes of genius. The support of a powerful company has, no doubt, been of immense value to Mr. Marconi, but he has had many detractors, and even some who appear to be opponents.

Unscientific opposition has been a rather unseemly feature of early wireless work, both in this and other countries. It is said that there are stations where considerable time and money have been expended in trying to interfere with, or decipher, another's messages, with the object, presumably, of showing that the competing system is of little commercial value through its messages not being secret. Whether these experiments are undertaken in the interests of science or from a desire to conserve certain monopolies, one can only say that Englishmen love fair play, and we are sure desire that a work of world-wide importance shall not be unduly hampered on account of any interests, however powerful. When Mr. Marconi, Mr. Bull, and others have time to thoroughly work out this problem of secresy, it is quite possible they may be able—if they have not already done so—to negotiate it as successfully as the 2,500 miles of Atlantic Ocean have been traversed. On the other hand, a new system should be thoroughly tested before being adopted officially, and the inertia which is our national characteristic may be, in this respect, no more an altogether bad thing than is the physical inertia which, though often troublesome, is, on the whole, such a boon to the engineer.

Of the future of the system who can predict? Five years have done so much, that the next five may witness revelations of hidden etheric force and its transmission such as none of us even dreams of, especially if it be possible to project the waves in a given direction. The system as it at present stands has its defects. These have been very well summarised by Mr. Bright. He says the objections or hindrances to success are mainly: (1) *the earth's curvature* (this did not stop Marconi inside 2,800 miles); (2) *the coherer is extremely sensitive*, liable to derangement, and to be influenced by "stray" vibrations (the coherer may be to a large extent replaced in the future by the electromagnetic receiver, or a better class of coherer may be employed, like the new one of Dr. Lodge); (3) *slow speed*, comparing badly with the one hundred words per minute of duplex cable (but thirty-five words per minute will do—remember an Atlantic cable has cost over half a million sterling, and cables get out of order); (4) and, worst of all, *messages are not secret*—as compared with cables he thinks its inferiority is as marked as would be the delivery of our letters on the pavement—to be picked up by anyone—instead of in our letter boxes. But even if these be true, its advantages are many, and for many purposes are of far greater weight. It is the only system by which we can keep in touch with a moving body, such as a ship; in fact, it will soon be the case that no ship of importance will put to sea without a wireless outfit. The saving of shipping alone, and of perishable goods consigned thereby, will probably quite justify the existence of the Marconi and similar companies. Then if an enemy gets possession of our cable or cables, we are at his mercy as far as communication is concerned; but there is no monopoly of the ether, and, even if a secret code be necessary, no enemy can stop wireless messages, or prevent us from communicating with *suitably equipped* friends.* Also our locality is of little consequence—we have not to find our way through hundreds of miles of tangled forest, or over leagues of arid plain, in order to receive or send a message. The post office of wireless telegraphy is always open, and, if we have suitable apparatus, always at hand.

* This statement is to be read in the light of such discoveries and successes as those referred to later.

CHAPTER I.

Fundamental Facts and Notions.

In order to study in an intelligent manner the various systems of so-called "wireless" telegraphy to be referred to in these pages, the knowledge of a few preliminary facts and hypotheses may be necessary, and these must be borne in mind.

Electricity.—Some people have thought it a pity that ever the name "electricity" was invented. It answers well enough for the penny-a-liner in a daily paper who wishes to describe some occult occurrence of which there is no very material or visible cause. He describes the event, and says it is due to "electricity" —a sort of common explanation when no other is ready. What is electricity? There are various kinds of electrical phenomena and evidences of electrical disturbances, but whether it is necessary to think of electricity as a concrete and material thing is questioned. In this respect the text-books — especially cheap elementary text-books, in which the reader is taught to think of an electric current as a fluid like water moving through a pipe—are to blame. The books tell us of frictional electricity, positive electricity, negative electricity, voltaic electricity, electricity in motion, and so on. Is there really something called electricity which exhibits itself under aspects deserving all these different titles, or are there all these different kinds of electricity? No very good proof has been adduced for the necessity of the existence of any such thing or things—if an entity be assigned. Electrical phenomena can be explained on the assumption of peculiar molecular states or peculiar conditions of the ultimate particles of bodies and of the ether surrounding them. But the term is convenient, and, if not absolutely necessary, at least aids us in the formulation of our laws and in the concretion of our ideas. The objections to the term urged with particular force a few years ago have lost some of their force during the last few months, and the term is now freely employed by the highest authorities. But whilst we use the term we must not forget that it does not represent some material thing like water or air.

Just as electric energy is probably transmitted through the dielectric (or insulator) surrounding a wire, so probably the state of the ether and the ultimate particles of a body give rise to the phenomena which we call electrification, etc. The word "electricity" is derived from *ἤλεκτρον*, the Greek word for amber, because this material, like many others, possesses the property of attracting or repelling light bodies when rubbed with certain rough substances. May it not be that the friction causes a state of strain in the ether which, in the case of the particles of the amber, is not readily propagated, since it is what we call a bad conductor? The electronic idea, referred to later, is no doubt a reasonable explanation of how this strain is induced and propagated. So-called positive and negative electricity may be opposite phases of strain, or opposite whirls if the vortex theory be adopted. A condenser has the property of entrapping or holding its molecules with such a distribution of strain that each little particle has + strain on one face and − strain on the other. Other electrostatic phenomena have also been accounted for in this way in conjunction with the newer electronic development. In regard to a *current* of electricity, the electrical disturbance is propagated, we are told, mainly through the dielectric surrounding a wire or conductor, somewhat as light vibrations are propagated from the sun to us, and we say, loosely, that electricity travels along the wire. The disturbance travels, energy is propagated, and we call this a *current of electricity*. But the gross idea, so readily imbibed from text-books, that some sort of material substance moves along or through the wire as water flows through a pipe, is, of course, quite untenable. Why, then, it may be asked, must the sectional area of the wire be sufficient to carry the given current if the dielectric has the work to do? Because the area must be sufficient to carry off the energy in the form of heat, so as to save the dielectric from rupture, and the heat-carrying property depends on the cross-sectional area of the conductor (Lodge's "Modern Views of Electricity").

Then, again, in *magnetism* it may be that every particle is surrounded by an electric current or whirl in the ether, and as there is probably *no* or *very little* resistance to the continuance of these whirls they continue, and the bar is *permanently* magnetised. We must initially make the whirls face one way, or cause polarisation, by some outside means. The whirls were there before—how started we cannot tell. It may be that the earth's existence as an immense reservoir of electricity is as explainable as the starting of the whirls referred to.

Electricity has been likened to a fluid—we have had one-fluid and two-fluid theories of electricity. But, apart from these now out-of-date conceptions, electricity *behaves like* an imponderable (massless) incompressible fluid. The ether is incompressible—is electricity then the ether or the ether electricity? We do not say so, but electrical phenomena are probably due, mainly, at least, to peculiar states or motions of the ether. Light is propagated by vibrations of the ether. In the propagation of electrical displacements the vibrations are in directions at right angles to the direction of propagation, and in every way are similar to the vibrations by which light is propagated. Electric displacement produces a (magnetic) force at right angles to itself, and it also produces by induction (an electric) force which is propagated at right angles to both the electric displacement and the other magnetic force. Further, the rates of propagation are practically the same. However we may regret the erroneous material notions of electricity, there is no doubt, however, that it behaves, in many respects, *like* a material substance. It is *not* energy, yet it can be transformed, and moves in a closed circuit. Electricity in motion and under pressure can do work; but this is true of water, and no one will say that water is energy. Electricity is plentiful, but usually inert; for every quantity of positive electricity we can detect, there must be somewhere an equal quantity of negative electricity. This is proved by the fact that inside a closed room of conducting material, well insulated, electrical experiments of various kinds may be performed, long sparks may be drawn from Ruhmkorff coils, etc., but yet the outside of the room exhibits, to even the most delicate tests, no trace of electrification. Or if the outside of the room were electrified so that sparks 8 in. long were taken from its surface, no effect would be detected inside the room. It seems, therefore, that we cannot create or destroy electricity, though we can *move* or *strain* it. We may say, then, that we live in a great sea of this all-prevading, perfect fluid, yet we do not know of its existence, normally, or unless something is done to it. But there are in other respects striking differences between the behaviour of any ocean we have knowledge of and the actual ether-electricity we experiment with—especially in regard to the propagation of wave-motion. The motions connected with light propagation are at right angles to the direction of propagation, are, in fact, transverse disturbances, and a perfect fluid cannot transmit such vibrations—unless we can conceive it to be almost as rigid as a solid. How can a fluid have such properties? Rapid motion is one way, and Lord Kelvin's vortex motion would give the necessary rigidity. *Strain* is another way, and Larmor's hypothesis may be the true one. But before going further, having mentioned the ether so frequently, it may not be out of place to devote a short space to its consideration.

The Ether (or Æther).

The ether (not the anæsthetic) is a very imponderable medium supposed to exist in all space and between and around the ultimate particles of all bodies. Indeed, the particles themselves may be centres of strain in the ether. The old theory, "Nature abhors a vacuum," rendered the existence of the ether a very necessary conception, but it is not so easy to see the necessity from that point of view now. It still exists, however; nay, it is more imperative now than ever. Newton endeavoured to account for his great generalisations about the laws of gravitation, attraction, etc., by supposed differences of pressure in the ether. He did not publish his idea, not did he in any way verify it by experiment. The ether of to-day is that of Huygens—a conception used by him to explain the propagation of light. Light is *not* a substance, but is due to a disturbance or wave-motion which, acting on the optic nerves, gives rise to the sensation associated with the term. Light is propagated with a velocity of about 3×10^{10} centimetres (nearly 186,000 miles) per second in a vacuum. It must have *some* medium for its propagation, hence the necessity for the conception of the ether. The vibrations or disturbances follow a sine law, and the physical process involved in the propagation of light is a vector quantity, but one capable of having its direction reversed, and this vector is at right angles to the direction of the ray. The process may be—is believed to be—an electromagnetic one, and in this case the electric displacement and the magnetic disturbance are at right angles.

If it be true (as assumed by Lord Kelvin) that the density of the ether is about $9{\cdot}36 \times 10^{-19}$ and its coefficient of rigidity $842{\cdot}8$ (the coefficient for steel being $2{\cdot}4 \times 10^{11}$) and the density of air near the earth and at 0 deg. C. is $\cdot 001293 = 12{\cdot}93 \times 10^{-4}$, the air, then, under these conditions is about $1{\cdot}38 \times 10^{15}$ times as dense as the ether ($1{\cdot}38 \times 10^{15}$ is 138 followed by 13 ciphers). On the other hand, in interstellar space the ether is much more dense than the very attenuated air there. For if the atmosphere were all at 0 deg. C. and at rest, the earth also being at rest, its density at a distance which for calculation purposes may be called infinite would be about 3×10^{-346}, and since the ether density is $9{\cdot}36 \times 10^{-19}$, the ether in these remote regions is about 3×10^{327} times as dense as the attenuated atmosphere there. Vibrations in the air (sound-waves) travel about one million times slower than the transverse vibrations of the ether (light). Solid bodies, it is true, transmit transverse vibrations, but comparatively slowly. The velocity of light varies in different bodies, therefore the particles of the body are vibrating, and take part in the transmission of light. Opaque bodies also are probably permeated by this all-prevading ether, though in dense bodies it must be somewhat loosely connected with the particles of the body. Light is transmitted at the same rate as an electromagnetic disturbance, hence we may conclude that the medium through which light is transmitted is identical with that through which the electromagnetic disturbance is propagated. This has been proved by Boltzmann and many others. Whether Lord Kelvin's "theory of vortices" or molecular whirls be true or not (and it seems a little difficult to reconcile the vortex theory with all known phenomena, and to account for the energy required to keep up the whirls), it is, nevertheless, pretty well established that the ether pervades interstellar space, and is probably the most uniform and generallly disposed of all the things of which we can form any conception.

The question suggests itself, Does this vast isotropic ocean not only exist as a medium for the interchange of physical action between bodies at a distance, but also to perform other functions of even a higher order? Certainly a study of the subject inclines one to the belief that an affirmative answer is probable.

The Ether and the Propagation of Electric Disturbances.—If a vibrating body vibrates in a medium capable of taking up and transmitting the vibrations, it, itself, gradually comes to rest if left alone, as it has to make waves in the medium which are transmitted to a distance. The energy of the vibrator is thus gradually conveyed to a distance through the action of the medium. The *rate* at which the disturbance travels through the medium depends merely on the medium itself, but the *length of a wave* depends partly on the medium and partly on the rate of vibration of the vibrator. Only some media can convey such a disturbance—in fact, a medium may not be able to take up and convey the motions of a particular vibrator at all.

The commoner fluids, such as air and water, radiate or propagate wave disturbance in a way well known to us, as in the case of sound—the velocity of propagation being proportional to the square root of the elasticity ÷ density. The elasticity here is the volume elasticity coefficient, and if this be high, the density being low, the rate of propagation is high. In the ether this coefficient is enormously high, and as the density is so low the rate of propagation is exceedingly great. To get an idea of this velocity we have only to consider the fact which Dr. Lodge states in "Modern Views," p. 276, that when the earth receives a spark, as from a flash of lightning, its charge may oscillate between the antipodes and back seventeen times in a second. Evidently, if we wish to send messages rapidly, the ether is so constituted as to fulfil that condition at any rate. In fact, we know that it takes only one-sixtieth of a second for the signal to travel from Cornwall to America. The velocity with which electromagnetic disturbance is propagated by the ether is $2{\cdot}9857 \times 10^{10}$ centimetres per second, and the velocity of light in air is practically the same. The following deductions have been made by scientists and mathematicians: Good conductors of electricity are opaque to light, and for transparent media (transparent or both) the specific inductive capacity or "specific inductivity" is found to be about equal to the square of the index of refraction. [*Note.*—The specific inductive capacity of a condenser depends not only on its dimensions, but on the inductive power of the dielectric used, and is the ratio of its capacity to that of an air condenser of equal size at 0 deg. C. and 76 cm. pressure. The index of refraction is the ratio which the sine of the angle the incident (or entering) ray makes with the perpendicular to the refracting surface bears to the sine of the angle which the refracted (or emerging) ray makes with the same perpendicular.] Some bodies conduct electricity better in one direction than another, and the opacity to light differs accordingly; crystals which conduct better along one axis than another show a corresponding difference in the case of light. In fact, light is propagated by vibrations in the ether, and electric disturbances such as those by which messages are conveyed "wirelessly" are exactly similar, but differ in wave-length from those of light.

What is Electricity? The Electronic Answer.

The various answers which have been given to this question at different times by different authorities prove, by their diversity, very confusing to the student. At one period electricity is a single fluid, at another two fluids called positive and negative. Positive electrification at one time is supposed to be due to an excess of a single fluid, just as negative electrification is evidence of a deficit. An electric charge has been regarded as something put upon or transferred to a conductor, and, again, it is a state of strain of the surrounding non-conductor or dielectric.

As a matter of fact, no complete answer to the question, "What is electricity?" has yet been given, though many things have recently been found out about electric phenomena, and we are beginning to see our way to an answer. We have already referred to the ether, and suggested that certain states or motions of the ether account for all electric phenomena. Something, however, is wanting to complete the connection—something through or by which the ether may be acted upon, and the electronic theory comes to our aid.

Lord Kelvin and others have taught us that matter is atomic in structure (see Dr. Fleming's "Electronic Theory"); that, in fact, the smallest free portion of a compound body, such as a salt, is a molecule, which in turn is made up of *atoms*. These atoms were supposed to be the smallest particles or portions into which the molecules could be divided, and Lord Kelvin approximated to the size of a molecule (the smallest portion, say, of a salt which retains all the properties of the salt), and gave its diameter as between $\frac{1}{100}$th of a micromil and two micromils. A millimetre is about $\frac{1}{25}$th of an inch, a micron the $\frac{1}{1000}$th part of a millimetre, and a micromil the $\frac{1}{1000}$th part of the micron. From this it follows that an atom may be taken as that exceedingly small portion of a body, approximately one micromil, say, in diameter, which according to old conceptions it is impossible to subdivide into small portions. Various authorities have estimated that the number of molecules in a cubic centimetre of air at ordinary temperature and pressure is from 10^{18} to 10^{21}, the molecules themselves occupying about one-thousandth of the space. The mind fails to grasp the significance of these figures, but some idea of the greatness of these numbers may be formed by considering that, small as these molecules are, so great is the number of them in the cubic inch of air that they would, if placed in a row and each given its own free path, *reach nearly from the earth to the sun and back.* Now there are two atoms of hydrogen, say, to the molecule, though as to the relative sizes of atoms of different substances we are at sea. We have, then, some idea of the size of the supposed atom in a given case. But now comes on the stage the newer "electronic theory," or hypothesis, that the atoms may be composed of yet more minute portions, called corpuscles, each with its charge of one electron of electricity, and itself often called an electron. The electron charge is really an exceedingly small quantity of electricity, being equal to about $22/10^{20}$ of a coulomb, or in other words, the coulomb is nearly five million million million electrons, the British Association unit of quantity — viz., that quantity which, placed on a very small sphere, repels a similar sphere similarly charged, when the centres of the two spheres are 1 cm. apart, with a force of one dyne—being equal to 1,540 million electrons.

Now, the electronic theory attempts to answer our question, "What is electricity?" These electrons constitute what we call by the name "electricity," the atom of matter in its neutral condition consisting of a shell or envelope of negative electrons with a core or matrix of positive electrons. If an electron be withdrawn from the atom, the latter is left positively electrified. Thus the neutral atom *minus* one electron may be considered as the natural unit of positive electricity. In this theory conductors are substances in which electrons free to move exist, a current of electricity being due to a movement of electrons, an electron in motion being a moving centre of ether strain. An electron in *vibration* creates an ether wave.

In good conductors it is supposed that the atoms are broken up into positive and negative ions, or electrons and remainders of atoms. There may be constant divorce and remarriage of the ions going on, one electron forming now part of one and then part of another group or atom. In non-conductors the ions are much restricted in their movements—if pulled apart a little, they spring back when released. The application of electromotive force to a conductor causes migration of the ions, for conductors are mostly simple substances whilst non-conductors are complex. According to this theory, what takes place when we rub a glass rod with silk is that the double layer of electrons and co-electrons on the surface of the silk is roughly treated and broken up, the majority of the positive co-electrons getting left on the glass and the negative electrons on the silk. On the whole there are just as many positive and negative ions as before, but their distribution is altered. This theory explains why the air in the neighbourhood of a fresh-water cascade is charged negatively and near salt-water spray it is charged positively due to the breaking up of the double layer of ions on the surface of each drop when it touches the ground. The theory also explains many of the known facts of chemical decomposition under influence of an electric current, voltaic action in its turn being due to some force which drives electrons across the boundary between, say, copper and zinc, this diffusion constituting what we call the current. Again, when a conductor is moved across a magnetic field of force a current is produced in it. We must remember that an electron in motion causes a magnetic force, and the field may be considered as if due to a moving sheet of electrons. The cutting of a conductor through it is accompanied by the same reactions as if a movement of electrons were started in it in certain directions depending on the direction of motion across the field. This sudden starting involves the backward reaction or push on surrounding electrons which we call induction, which tends to hinder the current. Similarly, the reaction at stopping will tend to make the current flow on. Many interesting explanations of thermo-electric effects have also been advanced by the exponents of this theory. Briefly, then, the theory assumes that: (1) at exceedingly small distances the electrons repel each other; (2) at greater distances positive electrons repel positive, and negative repel negative, or unlike electrons attract; (3) that all *atoms* attract each other at distances very great in comparison with this size, an atom being in many respects like a planet of which the satellites are electrons.

The question may now be asked, How does this theory fit in with our conceptions of the ether, and the part it plays in electrical phenomena? The matter may be explained, in one case at least, as follows: The corpuscle, with its charge of negative electricity—*i.e.*, the electron—creates an *electric* force in the space around it; if the corpuscle moves, it creates a condition of strain in the ether, to which we give the name *magnetic* force. If we know the difference in the values of the electric force at two near points, we know the time-rate at which the magnetic force is changing between them, and in a direction at right angles to the line joining them. Thus electrons and the movements of electrons give rise to forces, but it is equally true that these forces move electrons. Now suppose we take two insulated conductors, one with a spark-gap in it. To charge the one rod positively and the other negatively, we must force more negative electrons into the latter and remove some from the former. A dynamo, or induction coil with battery, or any "electron pump" will do this. The excess of electrons in one causes a strain in the surrounding air or insulator, the air in the spark-gap having the greatest strain; and if the electron pressure be still further increased, the strain becomes so great that the insulating qualities of the air in the gap breaks down, and a spark passes. Too many electrons rush across the gap through the passage thus formed, and we have an electric current, but some of them come back, giving us the backward current, and this is repeated, giving rise to a surging current in the conductor and a series of electric oscillations, or rapidly reversed electric and magnetic forces giving rise to ether waves. The electron has some kind of grip on the ether; in fact, it is itself, according to Dr. Larmor, a centre of convergent strain in the ether, so that its sudden starting or stopping produces a disturbance in the ether which Dr. Fleming has called "a splash" (see "Waves and Ripples"). If a multitude of electrons are suddenly set moving in one direction, the effect on the ether is like that on the air caused by a number of men simultaneously striking drums with sticks or firing off rifles at the same instant. The more sudden the first rush of electrons across the air-gap the greater the disturbance in the ether, and this may be the reason why, with high frequencies, want of polish or roughness of surface of the spark balls reduces the ether wave effect of the discharge, as it probably prevents the first rush of electrons from being so sudden and vigorous by allowing premature migration of some of them. Compression of the air in the spark-gap, on the contrary, *increases* the suddenness of discharge.

The electron, then, is the connecting link; is itself, in fact, a centre of strain in the ether. At rest it constitutes an electric charge, but in motion an electric current. If isolated, it is negative electricity; groups of electrons in proper combination with co-electrons form the atoms of matter. Steady flow of electrons in one direction, with co-electrons in the opposite direction, constitute a steady or continuous electric current, but the current may be alternating if the electrons merely oscillate. The oscillations of the electron, if sufficiently rapid, produce ether waves, and by the aid of these communication may be made between places hundreds—even thousands—of miles apart without the aid of a connecting metallic conductor.

Seeing its many functions and all-pervading nature, the reader may be inclined to ask, "Is there, then, any form of matter not composed of electrons, and, if not, how are the different characteristics of different forms of matter accounted for?" We leave the question for the *savants* to answer. The new theory agrees with Maxwell's mathematical deductions and supplements them. The inertia of matter is probably due to the inductance of the electron, just as moving electrons constitute an electric current and rotating electrons give rise to magnetic phenomena. The theory also explains much in optics hitherto only vaguely guessed at, and it shows how the ether may be strained or set oscillating in accordance with previous hypotheses explaining known electric and magnetic effects, but it is yet very incomplete. What has here been given is but a brief outline of some of the ideas of prominent workers in this fruitful field of research, especially in their relation to the laws and phenomena of the formation and propagation of the ether waves by which "wireless" messages are usually conveyed.

CHAPTER II.

Telegraphy.

The Old Plan—The Function of a Telegraph Wire. In order to estimate the chances of success of the new systems, and to understand the disadvantages under which they work, we may consider briefly some points in the older system, and see whether the ancient and modern systems have much in common. In the old system the electrical influence is transmitted by means of a wire. A magnetic field is created all round and inside the wire by the passage of a current. The lines of force (convenient, but entirely imaginary lines) are circles round the centre of the wire as a common centre. They are closer and closer together as we go out from the centre of the wire till we get to its circumference, then outside they again thin out, and become more and more distant as we go from the wire. This is especially the case where an *oscillatory* current is employed, in which case the lines have to be built up each time the current *grows*—this building up giving a back electromotive force due to *self-induction,* which *opposes* the current — and as they collapse each time the current dies away, they give rise to a direct electromotive force, tending to make the current flow on. With an oscillatory current of high frequency, such as that used in wireless work, the variation in the distance apart of the lines is very marked, the circles being crowded towards the circumference of the wire, so that its *surface* is the important thing. But with steady currents the self-induction effects are negligible usually, and the *area* of the cross-section of the wire is of importance. The magnetic whirls (represented by the circular lines of force) are set up at one end, and all along the wire they are propagated with a velocity which would be that of light but for modifications introduced by metals in the neighbourhood, and by other effects due to capacity, etc. Is

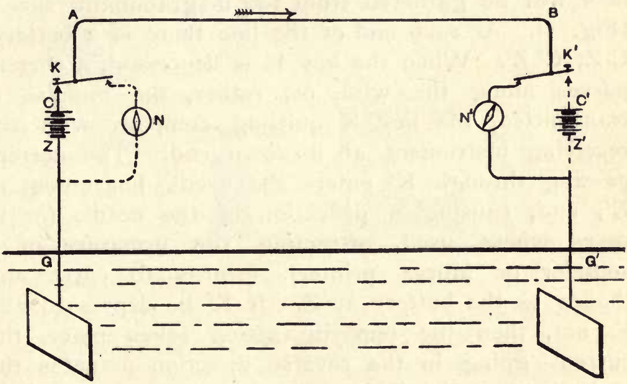


FIG. I.

the wire really necessary? Some authorities tell us that the wire does *not* convey the impulses—that they are sent through the ether or ether and dielectric (or insulator), the wire only *guiding* them. That the wire is not absolutely necessary our wireless friends have shown, though for the sake of *certainty* and economy of power it may pay to have the wire, even if it be expensive. As Dr. Lodge, in "Modern Views," clearly shows, we could, for instance, avoid the immense loss by radiation if we inserted a wire directly between the optic nerve and the source of light—say, the filament of an incandescent lamp—but we put up with the great loss for the sake of comfort and certainty, besides the radiated light does good all round. Reasoning the opposite way, it may be well in many cases to go to the expense of a wire for the sake of certainty, comfort, and because the electric radiations are not likely to do any good to anyone else.

The way in which an ordinary telegraph installation acts will be gathered from the diagrammatic sketch (Fig. 1). At each end of the line there is a battery, C Z, C′ Z′. When the key K is depressed, a current passes along the wire, or, rather, the impulse is transmitted, the key K quitting company with the receiving instrument at its own end. The current passing through K′ enters the needle instrument at N′, and, causing a deflection of the needle (or in cases where used, attracting the armature of a sounder or Morse printer), returns to earth and thence to the battery at Z. If K′ be depressed and K not, then the opposite action takes place, the current going in the reverse direction actuates the instrument at N. This arrangement also suits where a relay is employed to work a Morse instrument; the stronger auxiliary current passes through the coils of the electromagnet of that instrument as soon as the weak current closes the relay circuit, and the armature is attracted for a short or long period of time, thus printing a dash or dot on the moving ribbon in a way which will be understood from Fig. 2, where a somewhat old form of relay and Morse printer (an embosser) are shown, the action of the relay being here more easily traced than in newer forms. The key B being open, the faint current from the line energises the electromagnet of the relay, which attracts the armature, *a*, the upper end of which leaves F and moves into contact with E, completing the circuit of the local battery, which gives a more powerful current to the electromagnet of the Morse instrument, the armature of which, being attracted, stamps or embosses a mark on the ribbon of paper moved by clockwork. In the case of a Morse inker of the type now most in use, the armature when

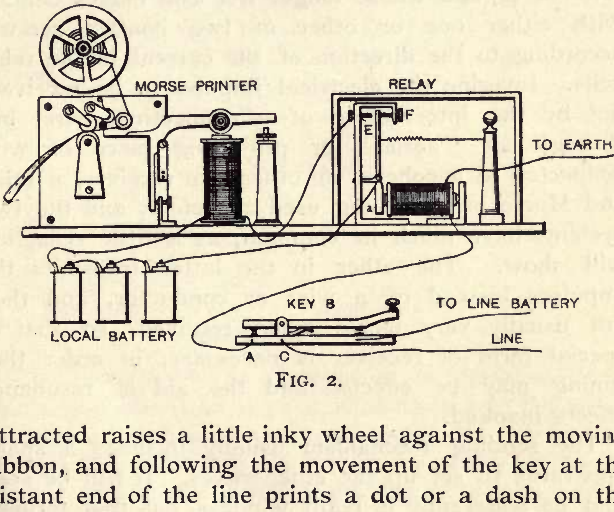


FIG. 2.

attracted raises a little inky wheel against the moving ribbon, and following the movement of the key at the distant end of the line prints a dot or a dash on the ribbon. In sending a message the key B, when depressed, closes the circuit connecting the line and line battery, allowing the impulses from the latter to flow to the distant station; the other end of the key B being raised, the relay and Morse at the sending station are cut out of action.

The modern relay, such as that used by the Post Office, has two complete electromagnets alongside of each other, and so wound and connected that when a current is passed round their coils their opposite poles are adjacent. Two soft-iron armatures are fixed to an axle near the magnets, and play between the soft-iron pole-pieces of the magnets, being kept permanently magnetised by a permanent magnet. Upon the same axle is mounted a German-silver tongue, which moves with the armatures already referred to, and whose longer free end makes contact with either one or other of two contact screws, according to the direction of the current in the relay coils. Imagine the electrical impulse to be received, not by the intervention of a connecting wire, but through an "aerial" or projecting piece of wire connected to a coherer or other like receiver, a relay and Morse printer being used as before, and the two systems have much in common, as a little reflection will show. The ether in the latter transmits the impulses instead of a wire or conductor, and they are usually very feeble when received, so that a special form of receiver is necessary, in order that tuning may be effected and the aid of resonance effects invoked.

The sending mechanism usually includes a spark apparatus to set up the ether waves. It will be seen that *no* telegraphy is really wireless, but that term is now in common use for systems in which *connecting* wires are dispensed with. In the latter case, the electrical impulses being very faint when received, the relay is usually modified; a single cell is placed in series with it. In ordinary circumstances the relay cannot act, as the coherer resistance overcomes the tendency of the cell to send a current round the relay electromagnet coils. When the impulse is received the coherer is made conducting, the balance is upset, and the cell sends its current round the relay coils, attracting an armature and closing an auxiliary circuit in which is a stronger battery sufficient to actuate the Morse instrument, where such instrument is used. The Morse dot-and-dash alphabet as used in wireless telegraphy is given below.

continental

THE MORSE ALPHABET.

A . —	**F** . . — .	**K** — . —	**P** . — — .	**U** . . —
B — . . .	**G** — — .	**L** . — . .	**Q** — — . —	**V** . . . —
C — . — .	**H**	**M** — —	**R** . — .	**W** . — —
D — . .	**I** . .	**N** — .	**S** . . .	**X** — . . —
E .	**J** . — — —	**O** — — —	**T** —	**Y** — . — —
				Z — — . .

NUMERALS.

1 . — — — —	**5**	**9** — — — — .
2 . . — — —	**6** —	**0** — — — — —
3 . . . — —	**7** — — . . .	
4 . . . . —	**8** — — — . .	

Full stop . . . . . . **Call up** . . . — . . . —

Understood . . . — .

The New Plan—The Function of an Aerial.—When an electron leaves an atom it is connected to the latter by lines of electric strain, and hence the function of an aerial may be diagrammatically represented as in Fig. 3, where the vertical wire with spark-gap has sent off a wave, and is being again charged, the electron pressure becoming higher and higher towards the top of the aerial at the instant considered by the surging back of some of the electrons which had before been released, as well as by the entrance of those sent in by the "electron-pump." The *pressure* is greatest at the top, but the movement of the electrons (therefore the current) is greatest at the spark-gap. The magnetic flux due to the action of the aerial would be shown by circles at right angles to the lines of strain. The action on the ether has been likened to that on the air in an organ pipe, and it has been shown that whilst in an elementary aerial with spark-gap the pressure rises gradually towards

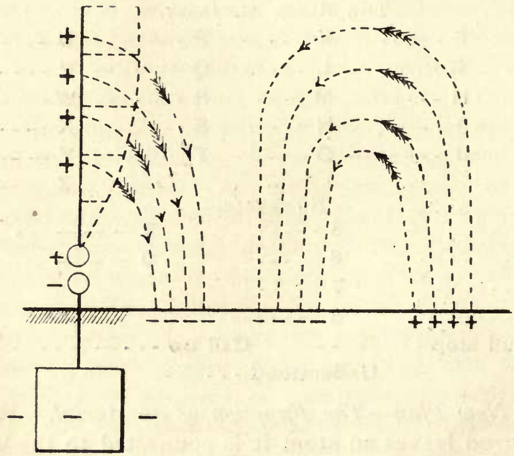


FIG. 3.

the top, as shown in Fig. 3, it is possible by the introduction of capacity and suitable alteration of the induction of the circuit to produce overtones, so that there may be two or more points of maximum pressure in the aerial; but whilst it is easy to produce overtones in an organ pipe—in fact, it is difficult to get the fundamental note alone—the opposite is the case with the aerial, and overtones are only produced with difficulty.

Overtones may be set up by having the aerial in the form of a loop, like a tall U upside down, one side being earthed, but it is necessary that the loop be unsymmetrical, and Prof. Slaby has tried this form, in which one of the legs of the loop contained a grid consisting of several parallel or nearly parallel wires In this way a first odd harmonic may be produced with a potential node at the lower end of each leg of the loop.

The energy stored in an aerial when charged to its maximum pressure is comparatively small. Dr Fleming* gives the formula

$$F = \frac{3\ C\ V^2}{8 \times 10^6}, \text{ or } F = \frac{27\ C\ S^2}{8},$$

where F is the energy stored in foot-pounds; C the capacity in microfarads; V the charging voltage; and S the spark-length in millimetres. Roughly, the voltage is 3,000 volts per millimetre spark. The energy stored in an ordinary aerial when the pressure is 30,000 volts is only about $\frac{1}{14}$th of a foot-pound, and this will give a signal clearly recognisable at a distance of 100 miles. If, however, we consider the number of times the aerial has to be charged and discharged in a second, we see that whilst the *energy storage* of the aerial is small a considerable *amount of power* may be necessary, especially where condensers and multiple aerials are employed.

Methods of Signalling.

Ordinary methods of signalling, such as by waving flags, moving a semaphore arm, or flashing the sun's rays by means of a heliograph, are, of course, known

* Cantor lectures on "Hertz-Wave Telegraphy."

to all readers. It may be stated in passing that any method in which light waves are employed to convey the signal is a species of ether-wave telegraphy. These can be used, however, only over comparatively short distances and under favourable conditions. There is no doubt that many oriental and even some savage peoples are able to convey information for considerable distances, in some unknown way, with astonishing rapidity. Many stories regarding this are related by travellers and others. One is to the effect our officers in Afghanistan were greatly puzzled as to how the intended military movements of the British could be so clearly known to the enemy in distant places so shortly after they were determined upon. Not the swiftest horses in the British lines could have covered half the distance in the given time, and a strict watch failed to detect any heliographic or beacon-light signals. The offer of bribes was ineffective—money could not purchase the secret, nor could the fear of death extort it—it remains in the possession of the natives till this day. It is said that on the day on which that good man General Gordon was murdered in Khartoum the event was known in the bazaars of Cairo. This may not be true, for his murderers had probably few sympathisers in Cairo ; but, if true, it is a mystery how the news travelled so quickly, seeing that there was then no railway and no telegraph to Khartoum, and even had there been a railway, a train running at 60 miles an hour would have taken something like 16 hours to accomplish the journey. It may be that the sensitive oriental nervous organisation is susceptible to etheric influences which we cannot detect, and that in this way two similarly endowed persons are affected so as to be able to emit and receive impressions more or less tangible. That this power of rapid communication is shared to some extent by the Kaffirs is shown by a recent writer (Mr. D. Blackburn on "Kaffir Telegraphy" in the *Spectator*), and the Matabele have often astonished our officers in the same way. These stories have really little interest for us to-day, except to excite wonder and speculation, since modern science has furnished us with surer and swifter, if more expensive, methods. Messages have been transmitted without the intervention of a metallic conductor for a distance of over 2,500 miles, and greater wonders are said to be in store for us.

In considering some of the modern methods of "telegraphing without wires," we may divide them into three classes—I., earth conduction; II., induction; and III., ether-wave systems.

CHAPTER III.

I.—Earth Conduction Systems.

The success of these systems depends on the fact that when one terminal of a battery or dynamo is connected to earth at a point A (Fig. 4) near to it, the other at a distant point, B, the current does not all flow back from the distant point through the earth or water to the battery by the most direct path, but part of it takes circuitous routes, and may be detected by

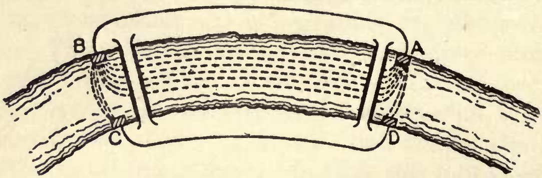


FIG. 4.—The Principle of Earth Conduction. A and B, C and D, metal plates sunk in a river; A and B are connected by an insulated wire; so, too, are C and D.

a sensitive receiver even at distances of a few miles from the straight path. Some of these "stray" currents may be caught by a second wire, C D, preferably nearly parallel to the first, at a distance from it which varies with the conducting power of the earth or water at the place and the kind of apparatus employed to generate and detect the currents. Looking at the matter from the historical point of view first, we see that this system is comparatively old. Mention has already been made of Lindsay's experiments, and the method has been practically employed in emergencies on several occasions. A storm having destroyed the cable connecting the island of Mull with the mainland, the ends of the overhead land wire on the island were dipped into the sea, and at Oban on the mainland a wire 1½ miles long was laid along the shore and immersed in the sea at the two ends in a similar manner. Telegraphic communication was thus kept up for over a week across two miles of sea until the cable was repaired. The introduction of the telephone by Graham Bell in 1877-8 provided experimenters with a very sensitive receiver. The experiments of Prof. Trowbridge, another eminent worker in this field of research, have already been referred to, and Prof. Dolbear, of Boston, in 1883 introduced an induction coil having in its primary circuit a microphone transmitter, with its secondary coil connected to earth.

Prof. Dolbear's Method.—Dolbear's method, interesting mainly from the use of condensers and, in some cases, elevated antennæ or aerials, is represented, as regards its use of the apparatus employed, in Fig. 5. According to his patent specification published in the *Scientific American* Supplement of December 11, 1886, Dolbear used a telephone transmitter, T, with a coil, H, and condensers, C_1, C_2, and C_3. The vibrations of the diaphragm of the transmitter, T, disturb the electric condition of the coil, H, varying the potential of the ground at K, which causes corresponding variations at L, and the receiver, R, reproduces sounds spoken into the transmitter as if the wires, K L, were in contact instead of being earthed or connected to gas or water pipes. K, which is connected to the secondary coil of H, may be "electrified with a positive potential of

100 volts or more"; L will then be at a corresponding negative potential—at least, this is the explanation of the action given by the professor. The condensers, C_1, C_2, and C_3, are used with good effect. C_1 is charged to give the desired potential; C_2 and C_3 are not essential, but are of value. Prof. Dolbear prefers to charge all three. He found, furthermore, that heightened effects were obtained by grounding one wire from one terminal of the induction coil and projecting the other into the air free, using a kite

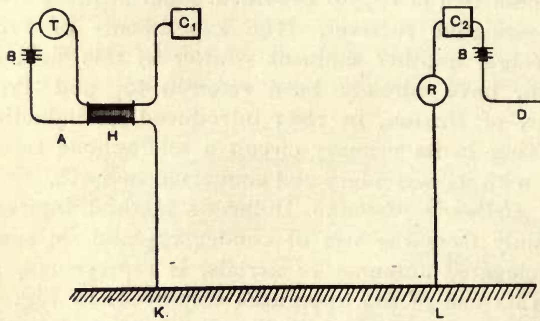


FIG. 5.

to carry the free end of the wire. Thus even in 1883 the modern vertical antenna or "aerial," so much used by Marconi and others, was tried with good effect by at least one experimenter, though his method is quite different from Marconi's, electrostatic induction playing, probably, the most important part in the results obtained. The distance of signalling was, as might be expected, small. To show the utility of a long base line in such cases, it may be mentioned that Prof. Rubens and Dr. Rathenau in 1894, using a base line 550 ft. long, transmitted signals for three miles across the open waters of the Wannsee, near Potsdam, obtaining the current from seventy-five accumulators, using a rotating interrupter and a telephone receiver; and this is probably near the limit which can be practically attained in shortening the base lines.

With leakage induction methods a long series of experiments were conducted by Sir W. Preece between the Isle of Wight and the mainland, at Penarth and between Kintyre and the Isle of Arran. Messages were transmitted to distances of from four to six miles, but the base lines were longer than those of Profs. Rubens and Rathenau.

Prof. Silvanus P. Thompson in 1898, struck by the fact that an accidental "earth" at the Ferranti electric light station at Deptford caused disturbances, easily detected as far north as Leicester and southwards to Paris, offered, if £10,000 were forthcoming to establish base lines and generating apparatus, to telegraph to the Cape without using a connecting metallic conductor. If the conduction method were employed, however, he pointed out, serious interference with existing electric agencies might result from the powerful stray currents in the neighbourhood of the transmitter.

The earth conduction system is, as a rule, not economical, and these experiments are interesting mainly from the historical point of view.

The Armstrong-Orling System.—This is a system which in some quarters has lately attracted considerable attention. Whether the writer is correct in classifying the system with those in which earth conduction is the feature it is difficult to say, for the inventors claim that "by a make-and-break mechanism forming part of the transmitter" (which has not yet, so far as he knows, been fully described) they are able to combine with simple earth conduction currents "high-tension discharges which vastly enhance the capabilities of the apparatus." The system is the device of a young Swedish electrician, Mr. Axel Orling (inventor of the Orling dirigible torpedo), who in conjunction with Mr. James Tarbotton Armstrong, a well-known London electrical engineer, has formed a company to supply apparatus, and, it is said, to bring the advantages of wireless telegraphy and telephony within the reach even of those who can only afford to pay the modest royalty of, say, £1 per annum. No very expensive or bulky apparatus are required, and aerials are not used for distances under five miles. The method of proceeding in telegraphy is to run a pair of wires from the terminals of the transmitter—which only requires a few cells giving a pressure of about eight volts—to two iron stakes driven into the ground some 10 ft. or more apart (according to the distance to be traversed), connecting the receiver to earth in the same way. In telephony the transmitter is connected to the gas or water pipes, the receiver being similarly connected. How the many disturbing "stray currents" which are usually meandering round—at least in most of the thickly populated parts of this country—will affect the telephone, one is not told, but it may be that the apparatus is constructed to get over this and other difficulties.

The important part of the invention seems to be the new electro-capillary relay, which is shown complete in Fig. 6 and in section in Fig. 7. This comprises a coherer, relay, and decohering device. By this apparatus, it is said, the most feeble electric impulses are able to operate a receiving apparatus. The liquid (shown in Fig. 7) is mercury, and a means is provided of maintaining the level of the mercury in the chamber *c*, and of adapting the apparatus to operate a relay. A lever, *k*, is delicately poised at a point, *l*,

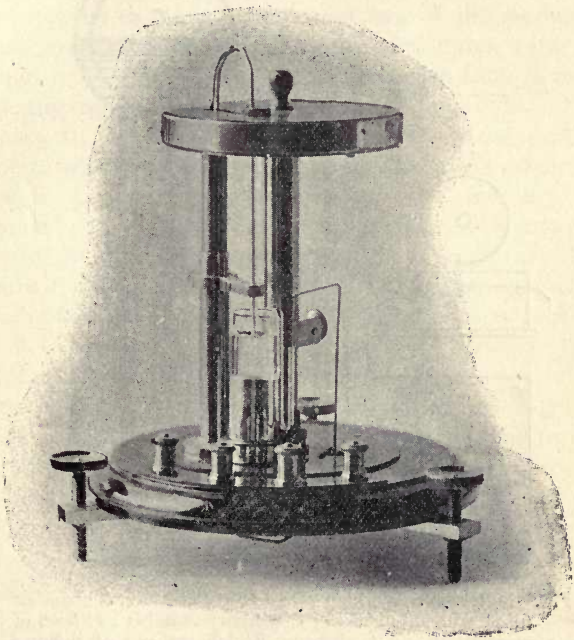


FIG. 6.—Armstrong and Orling Receiver, with case removed.

near the delivery end, *h*, of the siphon, *f*. One of the ends of the lever (marked *m*) extends beneath the surface of dilute acid in the chamber *b*, so that any mercury delivered by the siphon, *f*, may fall upon *m*, and so cause its other end, *n*, to make contact at *o*, and thereby close the relay circuit, *p*, which may operate a Morse instrument. Both ends of the siphon, it will be seen, are constricted to prevent the mercury from con-

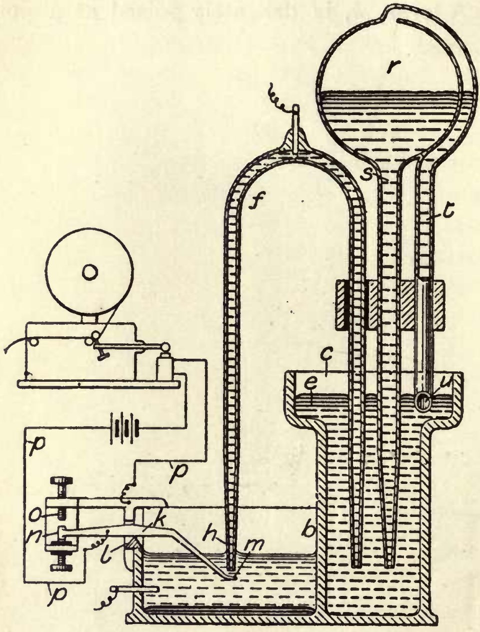


FIG. 7.—Receiver Working with a Morse Printer. *b*, chamber filled with dilute acid; *c*, mercury chamber; *e*, level of mercury in *c*; *f*, siphon; *h*, delivery end of siphon; *k*, lever; *m* and *n*, ends of *k*; *o*, point of contact; *p*, relay circuit; *r*, reservoir; *s* and *t*, legs of reservoir; *u*, aperture.

tinuing to flow after the electro-capillary force set up by the passage of the current has ceased. When the current does flow, electro-capillary force is set up, which displaces the fluid from positive to negative, and the lever is actuated, the relay being brought into action as described. To preserve the level of the mercury, *e*, in chamber *c*, a reservoir, *r*, is provided, which has two tubular legs, *s t*, the former of which extends beneath the surface, where its lower extremity is constricted to prevent too rapid flow of the mercury, whilst the latter is shorter, and terminates with an oblique or V-shaped aperture, *u*, in order that it may gradually open as the level of the liquid falls. The mercury in the reservoir, *r*, is retained by the partial vacuum, which is gradually destroyed as air is admitted through *t*, owing to the fall of the mercury in chamber *c*. By this means sufficient mercury is allowed to leave the reservoir, *r*, to maintain the level in *c* and close the vent in *t*. Other arrangements are adopted in which the fine droplets passing out of the hole make a momentary contact between two metallic points, so causing the relay and receiving instrument to work. The droplets, after passing the points referred to, drop on the lever, which performs the function of *de-cohering*. This instrument has been worked before numerous observers through a high resistance with an extremely small current, and it is said that its sensitiveness is very remarkable. The working of a receiver with Morse printer is shown in Fig. 7, whilst a receiver to be used for long-distance telegraphy (in which, by the way, elevated aerials and a system of relays at given distances apart are employed) is being experimented with. Fig. 8 shows the form of capillary receiver designed for cable work, in which the moving masses (mercury, etc.) have been very much reduced so as to admit of high speed in signalling.

There is an ingenious application of the system for the purpose of preventing collisions at sea. The writer believes, however, it is assumed that all ships likely to collide with that carrying the apparatus specified are equipped with similar apparatus, so that communica-

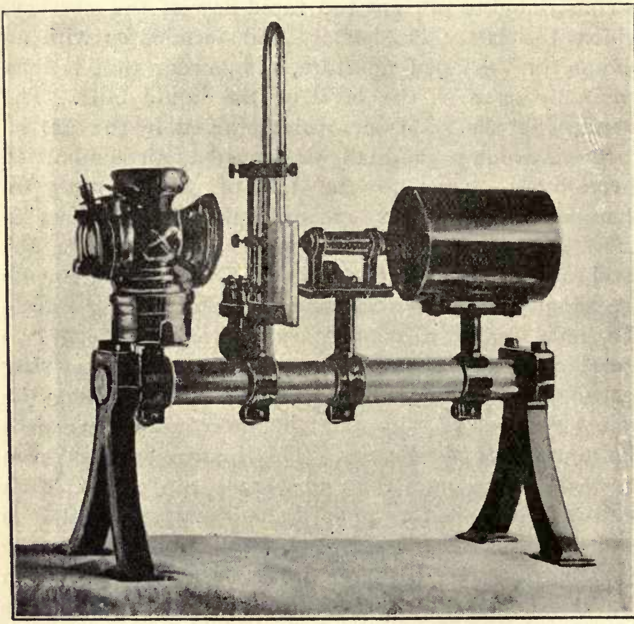


FIG. 8.—Latest Capillary Receiver as arranged for Cable Work.

tion may be effected within a given range of distance. Before Press representatives and others demonstrations of the use of the apparatus referred to above have been given. Mines have been fired at a distance, a boat has been steered, railway signals worked, an unseen volunteer firing party communicated with, and, in fact, some very wonderful things have been accomplished. The writer is not aware, however, of what success has been attained where greater distances have been attempted. It seems to him that, in all earth conduc-

FIG. 9.—Apparatus for Preventing Collisions at Sea, referred to at p. 50.

tion systems, to cover considerable distances long base lines are necessary, but the mention in the patent of the use of aerials shows that the inventors have not overlooked the possibility of greater success in the Hertz-wave domain. With these sensitive relays at given distances apart, and by the use of ether waves for the transmission of signals, there seems to exist some ground for anticipating greater success than has hitherto been achieved.

II.—Induction Systems.

Induction systems depend for their success on the fact that a current is induced in a coil or circuit when the current in a neighbouring coil or circuit is started, stopped, or varied. Faraday in 1831 discovered that currents are *induced* in a closed circuit by moving magnets near the circuit or by changing the strength of the current in another circuit near the first. Let the first be called the primary, and the latter the secondary circuit. Then a momentary inverse current is induced in the secondary, when the current in the primary is approaching, beginning, or increasing in strength; and a momentary *direct* current is induced in the secondary circuit whilst the current in primary is receding, ending, or decreasing in strength. In fact, a decrease in the number of imaginary lines of force passing through a circuit produces a *direct*, and increase in the number of lines of force produces an *inverse*, current in the circuit, the total electromotive force induced being equal to the rate of change in the number of lines of force through the circuit. Faraday thus laid the foundation of all modern progress in dynamo construction and application.

Sir W. Preece made many experiments on signalling without connecting wires, taking advantage of these laws. He used apparatus differing but little in main features from the earlier systems, but with the following important additions and improvements. By means of a revolving contact breaker the current at the sending station was interrupted rapidly—thus a discontinuous current of high frequency was obtained. He used a telephone in the receiving circuit instead of a galvanometer or relay, and long and short "dot-and-dash" signals on the Morse code were transmitted. In this case probably leakage currents play an important part, but induction has, at any rate, *something* to do with the result. He also used a microphone, which in its elementary form consists of a pencil of carbon supported loosely between two blocks of carbon fixed on a sounding board of thin pine, the blocks being connected with the collecting wire or line and a telephone. The microphone serves to magnify very minute sounds, and is the invention of Prof. Hughes (1878). When the microphone was used, conversation was conducted over considerable distances. On one occasion at least insulated copper wires were laid in squares and used so as to preclude the use of earth currents, and signals were transmitted inductively over a distance of a quarter of a mile.

An elementary induction arrangement consists of two coils of insulated wire (Fig. 10), one with a battery, dynamo, or other source of current in it, also a contact breaker or interrupter if the current be continuous; the other coil may be at a considerable distance away, should be parallel to the first, and should contain a telephone or other suitable receiver. The interruptions or renewals of current in the first (or primary) coil will give rise to a varying magnetic field round that circuit, which will induce secondary currents in the second coil, these affecting the telephone or other receiver.

Sir Oliver Lodge, who has been the most persistent and successful English experimenter in connection with etheric and induction signalling, described in 1898 some of his work in connection with a system of electromagnetic induction telegraphy. Some of his patents of about that date are very suggestive, and well worth careful study.

In a transformer the alternating current in the primary circuit induces currents of higher electro-

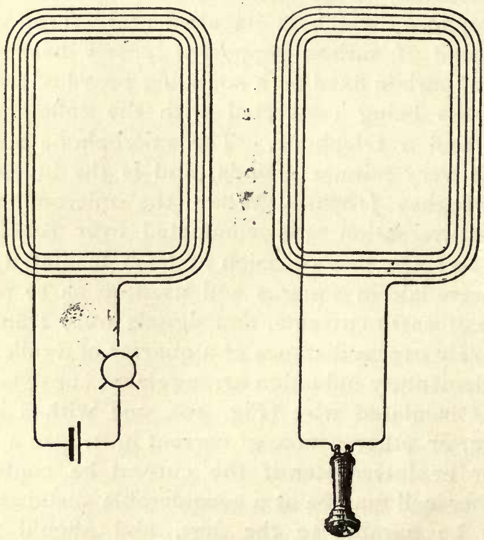


FIG. 10.—An Elementary Induction System. This comprises two coils of insulated wire, one with a battery, and a circuit breaker, if the currents are not alternating.

motive force in the secondary circuit. In this case the circuits are packed closely together. In telegraphy the two circuits are placed as far apart as possible. In one of Dr. Lodge's experiments he used a coil passing right round his college at Liverpool, having a controllable alternating current circulating in it.

A similar coil was placed some distance off and connected to a magnifying telephone and to a condenser of such capacity as to make the period of the circuit synchronise with that of the transmitting circuit. In the magnifying telephone the coil was the moving part instead of an iron diaphragm as in the ordinary telephone, the coil being suspended over the telephone magnet on the end of a tuning fork, which was carefully tuned to the same period or frequency as the current. On one prong of the tuning fork a single-carbon microphone was attached, and this was connected to a second and exactly similar telephone with a battery in circuit. This again was connected to a third, and so on, the vibrations becoming stronger at each step. In this way very feeble vibrations, which would not excite the ordinary ear, were increased till they were audible at some distance. In using a system of this kind, or, indeed, any wireless system, a call bell or alarm actuated by the vibrations sent from the distant station is valuable. Mr. Evershed's call relay is an important auxiliary where telephones are employed, and will be described later.

Dr. Lodge's Induction Experiments (1898).*—In 1898 Dr. Lodge read a paper before the Institution of Electrical Engineers describing at length his "magnetic induction" method of signalling. The system depends on electric "resonance." It had already been shown that two similar Leyden jars in similar circuits may be "syntonised," or tuned, so that one responds to electric oscillations in the other, the lines of force of the one circuit crossing the other and by their fluctuations producing in the second an alternating

* *Proc.* I.E.E., vol. xxvii. Fig. 11 copied by permission of the Council of the Institution.

electromotive force. The Leyden jar in the distant circuit may, for practical telegraphy, be replaced by a condenser of greater capacity, the circuit being in each case a large horizontal coil of wire; thus the frequency of the electric impulses may be reduced to that of sound. Instead of a coherer to detect the induced vibrations, an ordinary telephone receiver may be used as a shunt to the condenser circuit. An alternating or intermittent current of considerable power may be employed—in fact, Dr. Lodge used a Pyke and Harris low-frequency alternator to give the current. The cable or horizontal coil used was about a quarter of a mile long, and enclosed a rectangular area of 150 × 30 square yards. When a condenser of 28 microfarads capacity was used with the thick wire of a hedgehog transformer in circuit the induced frequency was as low as 384, and gave rise to a pleasant note in the telephone. The sounds could be heard over 100 miles away, even in Cheshire towards the Dee, from Liverpool (the sending station) in the ordinary National Telephone Company's telephones. When, however, a condenser was employed, and the sending and receiving circuits were *properly tuned*, the signals were not audible to outsiders more than two miles away. The importance of *tuning* was thus forcibly shown, as well as the great possibilities of, and some of the difficulties connected with, induction telegraphy and telephony. Several of Dr. Lodge's arrangements of apparatus are shown on another page, and in passing something may be said as to the uses of the words "induction" and "conduction" in this connection. Experiment can answer, in some cases at least, the question as to the relative part played by induction and conduction in a given case. In one experiment Mr. Gavey stretched an insulated wire between two boats at sea, dipping the ends of the wire into the sea. Signals were sent from the land—from a similar wire—and could be heard distinctly in the wire when it was above water, but not when it was below water, showing that *induction* was the chief factor in this case. However, conduction probably plays some part in most of these experiments, where no special arrangement is made to eliminate this part altogether. At the time of the reading of Dr. Lodge's paper signalling was regularly carried on by the Post Office authorities

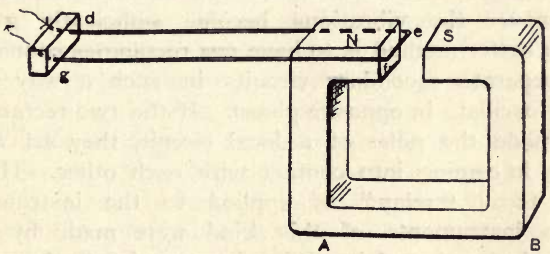


FIG. 11.—Evershed's Call Relay.

between Lavernock Point and Flat Holm, across 3·3 miles of water, Mr. Evershed's call relay being invented to get over the call difficulty.

Mr. Evershed's Call Relay.—Mr. Evershed found that an indicator working at a lower frequency than that necessary for telephonic receivers was a necessity. In principle his call apparatus (Fig. 11) illustrates what all vibratory indicators for minute alternating currents must more or less conform to. It consists of a rectangular loop of fine wire, *d, e, f, g,* fixed in an insulating block in such a position as to allow its end, *e f,* to move freely in the air-gap between the poles, N S, of a magnet, A, B. When the rectangle is traversed by an alternating electric current, the loop vibrates up and down the fixed end, *g d,* and if the rectangle be tuned so that its free period of vibration is the same as that of the current, it becomes a very sensitive alternate-current indicator or voltmeter, the amplitude of the vibrations being proportional to the impressed electromotive force at the terminals of the rectangle. In fact, it forms a simple alternate-current synchronous motor. A fixed contact screw may be placed adjacent to the free end of the rectangle, so that a local circuit may be closed whenever the vibrations become sufficiently great. Or a better method is to have *two* rectangles connected to separate secondary circuits in such a way that they oscillate in opposite phase. If the two rectangles be made the poles of a local circuit, they act as a relay in coming into contact with each other. Hence the term "relay" as applied to the instrument. Two instruments of this kind were made by Mr. Evershed and used in 1896. Later on (1898) they were used with perfect success by the Post Office authorities in the experiments between Lavernock and Flat Holm already referred to. They were used as relays for closing the call-bell circuit, the primary current being derived from a small alternator with a heavy flywheel, which was driven by hand to a speed above the synchronising frequency, the exciting current was switched on, and the alternator allowed to gradually come to rest, thus passing through the synchronising speed, so that the two rectangles of the distant relay had time to act. The rectangle (at 16 periods per second) gave a visible indication with about one five-hundredth of the power required for a telephone of frequency 400 per second.

Telephonic Difficulties — Important Experiments. — Induction systems have, however, special difficulties to contend with, as the following experiment shows: An attempt was made by Mr. Preece some years ago to communicate, by induction mainly, between England and Ireland. A circuit was made up from Carlisle to Haverfordwest, in England, and another from Belfast to Wexford, in Ireland. The whole telegraphic system of the country was stopped from midnight to 2 a.m. on one Sunday morning in June, 1895. Attempts were made to signal, but it was impossible to distinguish the signals on account of the strange incessant babel of sounds which filled the telephone receiver. The hum of two or three alternate-current lighting stations was clearly distinguishable, but the strange medley of weird noises due, it may be, to electrical effects outside the earth prevented the experiment from succeeding. The difficulty is not confined to induction methods, for Dr. Lodge has recently observed in experiments on wireless telegraphy, where a sensitive telephone receiver was connected in a low-resistance circuit, the ends of which dipped into the sea, and ordinary inductive influences were inoperative, that certain earth-current disturbances were strongly in evidence. These have been classified into noises like (*a*) uniform flowing of rushing water; (*b*) intermittent crackling; (*c*) bubbling and boiling water; (*d*) rocket-like disturbances; (*e*) high-frequency disturbances, not detectable by the telephone, but appreciable by the coherer. The rocket-like disturbances are like a shrill whistle dying away in pitch. They may be due to meteorites, which, rushing through the atmosphere, produce electrical disturbances which diminish in frequency as the velocity of the meteorite increases. They are observed more at night than during the day, not because meteorites are more plentiful at night, but because the highly ionised air in daytime screens the effect, by absorption, from the telephone receiver.

III.—Hertz-Wave Systems.

Hertz Phenomena—The Electric Voice.—Perhaps no single worker has done so much to make success in modern ether-wave signalling possible as the great Heinrich Hertz, who died on January 1, 1894, in his thirty-seventh year. Up till his time the "action-at-a-distance" theory had prevented advance in Germany. Following the beautiful theory of Maxwell on the transmission of vibrations in the ether, and the state of stress in that medium under certain electromagnetic conditions, Hertz took the matter up at the instigation of his master and friend Von Helmholtz. He used at first short flat coils, called Reiss' spirals, and found that the discharge of a Leyden jar passed through one spiral was able to excite induced currents in the other, provided a minute space or spark-gap was left in the latter. In his researches he found, among other things, that the velocity of electromagnetic waves *in air* was the same as that of light, but was much smaller *in wires*, the ratio being about 4 : 7. He also showed that ether waves could be reflected, refracted, polarised, and diffused like light. In fact, the work of Hertz was the first great advance towards long-distance wireless telegraphy, and the account of his work surprised and delighted the scientific world in 1887-88.

In the famous Hertz researches the condenser plays an important part. A condenser consists of two conducting surfaces with a non-conductor or dielectric between. A Leyden jar is the commonest form of condenser, but much larger condensers of special form are used in wireless telegraphic work. Some of these will be illustrated in a later chapter. Most readers are familiar with the Leyden jar, which is merely a glass jar with a coating of tinfoil up to a certain height, both within and on the outside. A brass knob over the cork or stopper communicates through a stout wire with the inner coating. To charge the jar, this knob is held to the prime conductor of an electric machine giving a high pressure or voltage, the outer coating being connected to earth; or the knob may be connected to the positive pole of an electric generator, the outer coating being connected to the negative pole, thus the inner coating obtains a so-called negative charge, the dielectric being strained. The higher the pressure, the more the dielectric or insulator is strained.

The condenser has been likened to a spiral spring, the extension of which is proportional to the force acting on it, and also to the "stretchiness" or weakness of the spring. The electric displacement is proportional to the electromotive force, and also to the capacity of the condenser, which, in turn, depends on the areas of the conducting plates, the distance between their surfaces, and on the nature of the dielectric. When a weight is suspended from the spring and is set moving up and down, the spring and weight oscillate with a simple harmonic motion, which gradually diminishes in amplitude till the weight finally comes to rest. The discharge of a condenser has similar effects, causing oscillatory motion in the ether, which gradually dies out. The inertia of the spring has its analogue in the self-induction of the electric current in a circuit, which produces a magnetic field round the conductor, this self-induction tending to cause the current when flowing to continue to flow, and to oppose it at starting. A long wire has more self-induction or electric inertia than a short one of the same material, whilst with two similar wires of iron and copper the iron has more self-induction than the copper.

In the case of the condenser the discharge obviously occupies only a short time, and it is necessary to recharge it. In wireless telegraphy, not a single impulse, but a train of ether waves is wanted, and the induction coil, due originally to Ruhmkorff, is used, or an alternator with large condensers for great distances. The Ruhmkorff coil consists of soft-iron wires of considerable diameter fixed into a disc of the same material at each end. Round this core the primary coil of copper—say, 2 mm. in diameter—is wound. The secondary coil consists of specially insulated fine copper wire of great length, and usually in sections, in large coils as much as ninety-four miles of wire being sometimes used, but for an ordinary 10-in. spark coil seventeen miles of wire will do; this is wound outside the primary coil. The two ends of the primary go to two terminals on the base of the instrument, and the ends of the secondary to two separate terminals, through which pass two brass rods with spark-knobs at the ends. The primary coil has a battery and a condenser in its circuit. The condenser is usually in the base of the apparatus, and is made of alternate layers of tinfoil and paraffined paper; into this the current flows when the circuit is broken. The object of the condenser is to make the break of circuit more sudden by preventing the spark of the "extra current" in the primary, due to self-induction, from leaping across the gap of the interrupter, and also to store up the electricity of this "extra self-induced current," so that when the circuit is again made the current shall attain its full strength more gradually, and thus serve to reduce the inductive action at "make" in the secondary circuit.

This making and breaking of circuit is performed automatically by an interrupter, which in coils made in this country often consists of a vibrating strip of metal similar to the trembler of an electric bell. This, however, is not a good form of interrupter. For one thing, the frequency cannot be very readily varied, or, if so, only within narrow limits ; there is also some difficulty with the platinum contacts, which are, moreover, expensive. For very large coils a Foucault mercury contact breaker or interrupter is used, in which a metallic arm attached to a pointed platinum wire alternately raises the point of the wire out of, or depresses it into, a cup of mercury, the arm being attracted towards the coil whenever the latter is magnetised, the arm being drawn back again by a spring when the circuit is broken and the coil ceases to be a magnet. An interrupter somewhat on the same principle—not actuated, however, by the coil itself, but by two outside coils acting reciprocally—has recently been introduced by Drs. Lodge and Muirhead, and is described elsewhere. Mercury turbine interrupters are also used, as described later, and electrolytic interrupters, as shown in later figures. The coil—in laboratory instruments—has also usually a commutator for breaking the circuit or reversing the direction of the primary current. The discharge of the coil is more violent and produces a greater effect on the ether if it takes place in air under pressure, and some gases are even better than air. Thus the suddenness of break is three and a half times as great when the pressure is 80 lb. per square inch as when it is 50 lb. per square inch.

To get a sufficient store of energy for modern work, as well as for purposes of tuning, it is necessary that condensers be inserted in the secondary circuit, but for

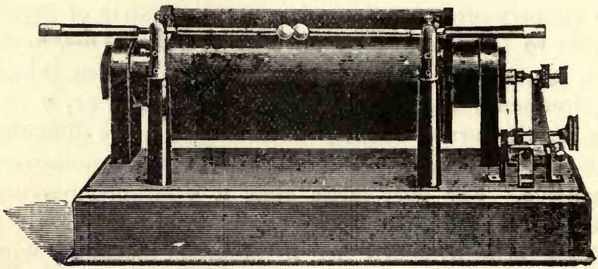


FIG. 12.—A Marconi 10-in. Induction Coil. There are seventeen miles of wire in this "coil."

Transatlantic work these condensers, often of great capacity, are charged, not by a coil, but by an alternator. A modern induction coil, as used by Mr. Marconi for ship work, and giving a 10-in. spark, is shown in Fig. 12. Employing the rule "3,000 volts per millimetre of spark," we see that the highest instantaneous pressure in the secondary coil must be in that case something like $3,000 \times 25{\cdot}4 \times 10 = 762,000$ volts. The vibrations of the ether set up by such a coil are very rapid, thirty or forty taking place during the passage of a spark, and as many as hundreds of millions sometimes in a second. It may be asked, "What determines the frequency or time-period of the oscillations?" The capacity and self-induction of the circuit are the determining factors. This may be simply illustrated by the Hertz oscillator (Fig. 13), consisting of two metal plates attached to

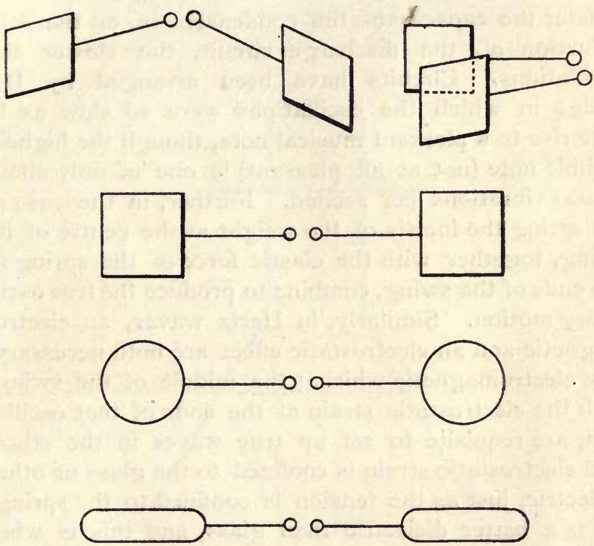


FIG. 13.—The Development of the Modern "Oscillator."

two wires which have spark-knobs at their ends. The knobs being not too far apart for discharge to take place, then the oscillator has a certain capacity due to the metal plates and air dielectric between, whilst the wires have a certain self-induction. The periodic time, T, is give by the equation $T = 2\pi\sqrt{LC}$, where L is the self-induction and C the capacity. Of course, the frequency, n, is the reciprocal of T, and knowing the velocity of light, v, the wave-length, λ, of the oscillations in the ether may be calculated from $\lambda = T \times v$.

Returning to the analogy of a spring, it is well known that a weak—*i.e.*, non-stiff or slack—spring vibrates more slowly than a stiff one, so also the greater the capacity of the condensers in, or the self-induction of, the discharge circuit, the slower the oscillations. Circuits have been arranged by Dr. Lodge in which the oscillations were so slow as to give rise to a pleasant musical note, though the highest audible note (not at all pleasant) is one of only about 38,000 vibrations per second. Further, in the case of the spring the inertia of the weight at the centre of its swing, together with the elastic force of the spring at the ends of the swing, combine to produce the true oscillatory motion. Similarly, in Hertz waves, an electromagnetic and an electrostatic effect are both necessary. The electromagnetic whirl at the middle of the swing, with the electrostatic strain at the ends of that oscillation, are requisite to set up true waves in the ether. The electrostatic strain is confined to the glass or other dielectric, just as the tension is confined to the spring. Air is a better dielectric than glass, and this is what Hertz employed. An ordinary condenser may consist of two sheets of tinfoil with glass between, but if we imagine the tinfoil sheets to be opened out till they finally take the shape shown in Fig. 13, we reach the "Hertz oscillator," which in some cases had sheets of zinc 40 cm. ($15\frac{3}{4}$ in.) square with a distance of 60 cm. (23·6 in.) between them, the spark-gap being 1 cm. long. Two spheres may be employed or two cylinders with hemispherical ends.

As a rule, it may be stated that the smaller and dumpier the arrangement, the quicker the vibration or the shorter the period. Spheres give quicker vibrations than plates. However, we cannot by these arrangements get up to a speed of anything like a billion per second, and yet to affect the retina the vibrations require to be at the rate of at least 400 billions per second (see Lodge's "Modern Views,"

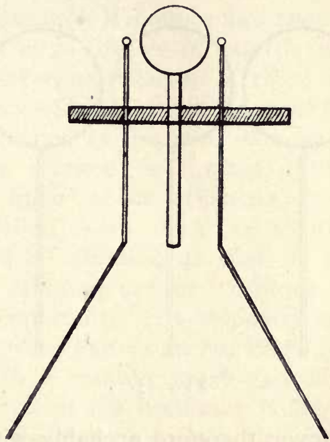


FIG. 14.

p. 341). Thus if the vibrations of the ether, started as above, convey readable messages to distant lands, they must be very much lower in frequency than the vibrations of light. A small oscillator used by Prof. Lodge, consisting of two spheres, gave a frequency of 300 millions per second, whilst a large oscillator of the shape shown in the third sketch of Fig. 13, when excited by a very large coil, had a frequency of ten millions per second, and produced such marked effects that most of the gas and water pipes of the building, and even neighbouring wire fences, gave off sparks to conductors brought close to them. These oscillators might be charged by an electric machine such as a Wimshurst or Voss machine, but a coil is better. Also, it has been found that light rays (especially ultra-violet rays) falling on the cathode discharging knob caused the spark to pass too easily and with less

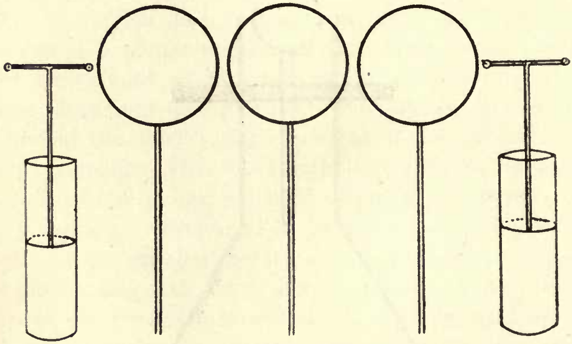


FIG. 15.

sudden breakdown, therefore probably with less effect on the ether. Dr. Lodge has tried many forms of oscillators, some being very powerful. What is sometimes called the "Lodge standard" type is shown in outline in Fig. 14, whilst the triple-sphere oscillator is depicted in Fig. 15. The oscillations of the larger type of Lodge apparatus are much more damped, dying out more quickly than those from a Hertz apparatus, giving in some cases only 1½ periods.

CHAPTER IV.

Different Forms of Oscillators and Resonators.—The Modern Receiver.

Hertz's Resonator.—Reference has been made to the Hertz oscillator, or starter of electric waves. Hertz called his receiver, or detector of these waves, by the name "resonator," evidently thinking of the analogy of tuning or resonance in the case of sound, because he found that it worked best when "tuned" to the oscillator—in other words, when its circuit's capacity and self-induction were such as to give the same natural period of vibration as that of the oscillator. This question of resonance, or "syntony," has recently become very important. His resonator consisted of a ring of round wire, like an anchor ring, 35 cm. ($13\frac{3}{4}$ in.) in radius, with a minute spark-gap in it (Fig. 16). Etheric waves from the oscillator falling on this ring set up electric oscillations in it, which, if the tuning or syntonising were good enough, grew larger and larger till they finally burst across the gap, causing a minute spark. The spark is more visible if the ring be held in the horizontal plane with its gap towards the oscillator, the reason probably being that the waves from the oscillator are to a certain extent polarised horizontally, and the ring, acting as an analyser, receives best the vibrations when placed in this plane. With his resonator, or "electric eye," Hertz made very important investigations. Interference of the fundamental waves with those reflected from a large sheet of iron (which is opaque to these vibrations) gave rise to stationary waves, and the distance from node to node was measured. Thus the wave-length, and hence the frequency, being obtained, since $v = n\lambda$, where v is the velocity of propagation, n the frequency, and λ the wave-length, the velocity of propagation was found to be that of light, which has since been calculated (by Michelson) as $2 \cdot 991 \times 10^{10}$ centimetres per second, or

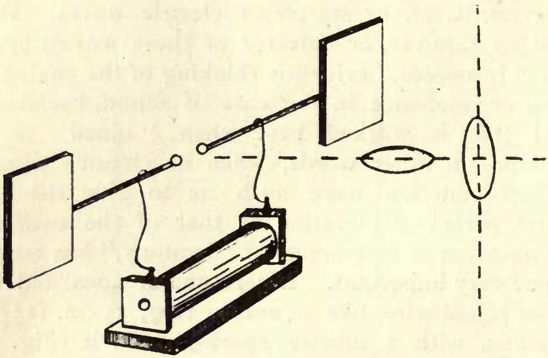


FIG. 16.

186,364 miles per second (Newcomb's number is 186,333). The curve for an oscillator and one for a resonator as used by Hertz are shown in *a* and *b* (Fig. 17).

Dr. Bose found that two minute beads at a short distance apart used as spark-balls formed a satisfactory oscillator, as the accumulation of dust or dirt did not much reduce the intensity of the radiation. The question of the cleanness and polish of the spark-balls in oscillators has been the subject of discussion and experiment. It is found that with low frequency discharge, such as from a Leyden jar, the efficiency is *increased* as the balls get dirty. But, going higher in the scale of frequency, the balls have to be polished frequently, especially when, as in the Hertz apparatus, the frequency goes so high as 50 or 100 millions per second. Dr. Lodge, going as high as 500 or 600 millions per second, found it more necessary still to have high polish ; and Dr. Bose, at 30,000 millions per second, found that the slightest deterioration of the surfaces was fatal to the production of ether waves,

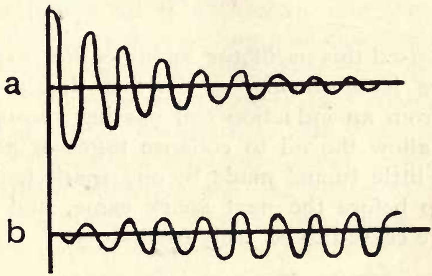


FIG. 17.—Curves for Hertz Oscillator and Resonator.

and he finally made his spark-balls of platinum. At these high frequencies any deterioration or dirt gives rise to a fizzing off or conduction of the charge before sparking occurs. The large capacity of low-frequency apparatus probably accounts for the absence of ill effect due to fizzing off through dirt.

In some very successful oscillators oil is employed. They are usually constructed with three spark-gaps—one in oil and two in air. A typical one, due to Prof. Righi, is shown in Fig. 18, where the oil is enclosed in a small vessel like a jar. A more modern type of

Righi oscillator is depicted in Fig. 19, where large solid balls of brass, 5in. or 6in. in diameter, are employed. The function of the oil seems to be to make the discharge more sudden, owing to the comparatively high dielectric properties it possesses. Mr.

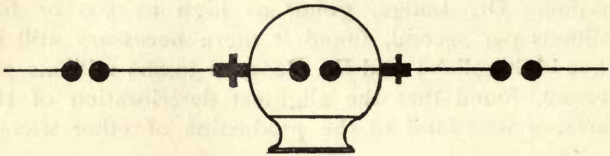


FIG. 18.

Marconi used this oscillator in his earlier experiments, but gave it up owing to the fact that a shower of sparks from an induction coil passing through the oil did not allow the oil to collapse together properly, so that the little tunnel made by one spark had not time to fill up before the next spark came, and hence the discharge ceased to be truly oscillatory.

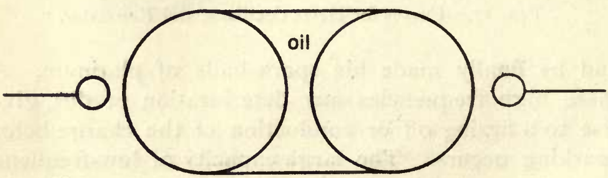


FIG. 19.—Righi Oscillator.

It should be noticed that the magnetic disturbance of an oscillator is one-quarter period in advance of the electrostatic disturbance, or when the rush of current is at its maximum the magnetic whirl is greatest, and the electrostatic difference of potential between the two ends of the oscillator is zero. Returning to our illustration of a spiral spring, when the motion of the weight is greatest—*i.e.*, at the centre of the swing—the strain in the spring is least. A quarter of a period, or a half-swing, later the spring is most extended and the weight is momentarily at rest. For the propagation of ether waves the electric and magnetic effects must be in phase with each other. They start one-quarter period out of phase, but the lag in time of the electric effect is compensated by its lead in space. After the first quarter period the two travel into space together as a true radiation, but during the first quarter period all is confusion, and the energy which does not succeed in getting past this first quarter returns into the circuit and partly helps to keep up the oscillations. Thus the more powerful a radiator is the more damped are its oscillations, and if an ordinary alternator of frequency 100 periods per second were used to radiate directly, the wave-length—as Dr. Lodge shows—would be about 2,000 miles, and no true radiation would occur at distances of less than 500 miles, and then the intensity of the radiation would be small. Mr. Marconi in Transatlantic telegraphy uses an alternator (that at Poldhu being of about 120 h.p.), and the wave-length is probably 600 ft. to 1,000 ft. But as he does not radiate his alternator current directly, but uses condensers and high-tension spark discharge, the frequency of the alternator is not of importance in calculating the wave-length on account of the other radiating apparatus employed. Following are some of the wave-lengths of most interest to the student: shortest ultra-violet waves, ·0001 mm.; violet, ·00043 mm. to ·00075 mm.; dark heat, ·0008 mm. to ·051 mm.;

shortest Hertz waves, 4 mm.; ordinary Hertz waves, 13 mm. to 13,312 mm.; ether waves used in wireless telegraphy, 500 ft. to 1,500 ft.

Modern Receivers.

Detectors or Receivers.—Having shown how Hertzian vibrations may be set up and propagated, it may not be out of place now to refer more fully to various modern methods of *detecting* or receiving these impulses. The various detectors may be classified under different heads, such as electric, thermal, electrostatic, microphonic, and chemical. There are also other effects, many of them peculiar and obscure, of etheric vibrations on the nerve centres which may be called physiological, but it is not necessary to refer further to them here. Some are detectors only, others are receivers such as may be employed in telegraphic work. We need not enter into the delicate question as to what constitutes a detector and how it may become a receiver.

Electric Detectors.—A ring with a spark-gap has already been referred to. It is one of the most elementary of electric detectors. Two rods may be used in the same way. Telephones have also been employed, being automatically brought into circuit with a battery when the spark passes. Prof. Boltzmann, by momentarily connecting the spark to a dry pile, used it to charge an electroscope, and Dr Lodge caused the induced spark to make a path by which a charged electroscope discharged itself. A vacuum tube has also been employed, as it can be made to glow by the induced vibrations, or the induced electromotive force may be made to help a high-voltage battery to cause the tube to glow.

Prof. Righi used a relay in circuit with such an arrangement as that just described. He found this method almost as good as the coherer, to which reference will be made presently.

Electromagnetic Detectors.—Mr. Sydney Evershed's call relay is a remarkable instance of an electromagnetic detector. As used in connection with induction signalling it has already been described.

Marconi's Magnetic Receiver.—The action of this receiver is based on the decrease of magnetic hysteresis (inertia) which takes place in iron when exposed to Hertzian oscillations. This matter was experimented on by Mr. E. (now Prof.) Rutherford at Cambridge (*Proceedings* of the Royal Society, 1896, and patent specification No. 10,245 of 1902). A bundle of very fine steel wires was surrounded by a coil. The steel was magnetised, and it was found that when the coil was put in series with a receiving circuit for Hertz waves, the oscillations set up in the circuit demagnetised the steel, this effect being produced even when the transmitter was half a mile distant. Mr. Marconi's magnetic detector or receiver has a band, B (Fig. 20), consisting of iron wires kept moving by the pulleys, P_1 and P_2, which are revolved by clockwork. The band passes through the coil, O O. This coil is connected at one end to the aerial, A, and at the other end to the earth. The portion of the band in the coil, O O, is magnetised by the magnets, M M, and in consequence of the magnetic inertia of the band this magnetised condition is not immediately removed, but a portion of the band beyond the coil, in the direction in which the band is moving, retains its magnetism, but is in a very unstable condition. The incidence of electric oscilliations from the aerial through the coil, O O, has the effect of demagnetising the band, especially affecting the magnetism in that part outside the coil, which was there on account of hysteresis, and this magnetism, so to speak, slips back into the coil each time the waves come down the aerial to O O. That part of the band inside the

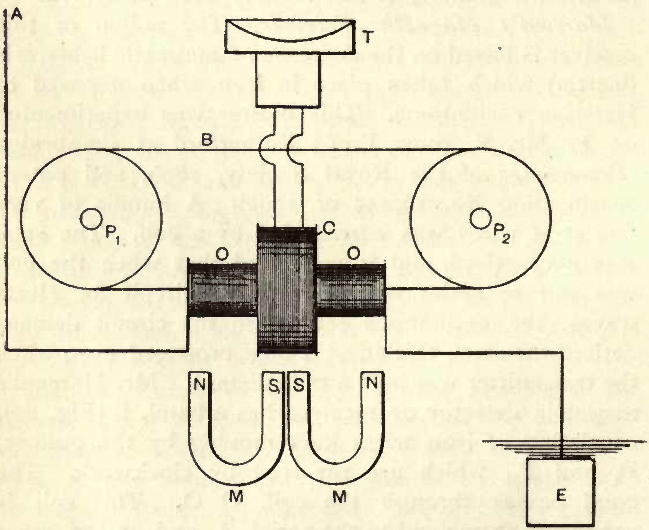


FIG. 20.

coil is also subjected to the effect of the waves, but is under the influence of the magnets, M M. Around the coil, O O, is a second coil, C, connected to the telephone receiver, T, and the disturbance referred to of the magnetism in a portion of the band causes a sound to be heard in the telephone, which is either short or long according as the incident waves from the aerial persist for a short or long period. In this way dot-and-dash signals are obtained. The receiver is much more sensitive than a coherer, and is more suitable for use in a syntonic wireless system. This form of receiver was used by Mr. Marconi in recent Transatlantic transmission, and was that by which President Roosevelt's message to the King was read after having traversed more than 2,800 miles.

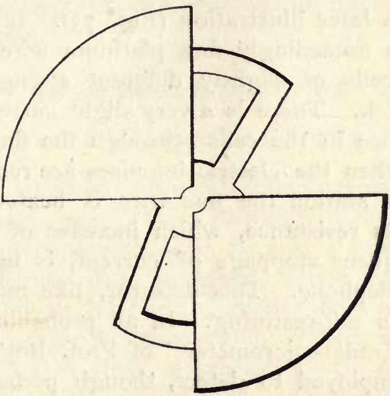


FIG. 21.

Electrostatic Detectors.—If, in a nearly closed circuit, a tuned receiver like a kind of one-sided electrometer (Fig. 21) be inserted, the needle being at zero and each quadrant connected to one terminal, successful results may be obtained. Bjerknes used such an apparatus, and other inventors have used electrostatic methods.

Thermal Detectors.—The oscillatory currents set up inductively by Hertzian waves may be employed to heat junctions of different metals, and thus give rise to thermo-electric currents from which with suitable apparatus readable indications may be obtained. The late Mr. Gregory, of Cooper's Hill, invented a very remarkable detector of this kind, which, on somewhat the same principle as the Cardew voltmeter, was really a sensitive arrangement for showing the minute rise in temperature of a fine platinum wire due to Hertzian vibrations.

Fessenden's Receiver or Responder.—A good example of these thermal detectors is that of Prof. Fessenden, shown in a later illustration (Fig. 73). It really consists of an exceedingly fine platinum wire in circuit with two cells of slightly different strengths placed back to back. There is a very slight current—due to the difference in the cells—through the fine platinum wire, but when the electric impulses are received from the distant station the fine wire is heated, and this increases its resistance, which increase of resistance, and consequent stoppage of current, is heard in the attached telephone. This detector, like most thermal detectors, is self-restoring. In all probability the very sensitive "radio-micrometer" of Prof. Boys might be similarly employed to detect, though perhaps not to regularly telegraph by means of, Hertzian waves. This remarkable instrument is really a combination of thermo-electric couple and sensitive-coil galvanometer. A tiny antimony-bismuth couple is connected at one end to a very thin piece of blackened copper foil. The outer ends of the strips are connected to the one end of a long narrow coil consisting of a single loop of wire suspended at its other end by a quartz fibre. The coil hangs between the poles of a powerful magnet, and the quartz fibre constrains the coil to remain, when no current circulates in it, in the plane of a line joining the poles of the magnet. When any heat radiations fall upon the copper foil, the latter is heated and the current flowing round the loop causes it to turn through an angle, which motion being participated in by the quartz fibre, or rather by a small mirror fastened to a fine capillary glass tube connecting the loop and fibre, deflects a ray of light falling on the mirror, which is reflected and travels along a scale, as in the case of a reflecting galvanometer. Prof. Boys has shown that if the temperature of Jupiter were as high as 100 deg. C., its heat would be detected by this apparatus.

Coherer Detectors or Receivers.

I.—Non-Restorative Forms.

In these detectors chemical action plays a certain, though obscure, part. Lord Rayleigh in 1879 observed curious phenomena with dusty air and jets of water due to what we now call "coherer" action; and Signor Calzeechi Onesti, of Fermo, about 1885 noticed the decreased resistance of metallic filings when small sparks passed in their neighbourhood. About 1878 Prof. Hughes used a microphonic contact as a detector. He was really the first in this country to employ Hertz-wave methods, but was discouraged by an explanation of the action given by the late Sir G. Stokes, and made little practical use of his discovery. In a paper read before the Royal Society in 1878 he described "a tube filled with loose filings of zinc and silver," which served as a detector of electrical impulses or influence, the decrease of resistance when acted on by these impulses being very marked. In 1880 Prof. Hughes actually demonstrated the transmission of signals and the detection of the same by his microphonic detector to the President of the Royal Society and Profs. Huxley and G. Stokes. Prof. Stokes thought the results were due rather to electromagnetic induction than to ether vibrations, an explanation which is said to have discouraged Prof. Hughes, who himself correctly interpreted the action as due to the latter cause.

PROF. EDOUARD BRANLY.

When Hertz by his masterly researches during 1887-9 solved the problem, Prof. Hughes, as stated by him in a letter to the *Electrician* in 1889, "was forced to see others re-make the discoveries he had previously made as to the sensitiveness of the microphonic contact and its useful employment as a receiver of aerial waves."

Prof. Edouard Branly, of Paris, may be said to have invented the modern coherer about 1890 (*Comptes rendus de l'Academie des Sciences*, November 24, 1890, and *Bulletin de la Société Française des Physique*, April, 1891). His apparatus, which consisted of a glass tube partly filled with metallic filings, with metallic conductors at the ends, was used by him as a *detector* only, but was afterwards adopted and improved by Lodge, Marconi, and others, and used by them as a receiver in Hertz-wave telegraphy. In Branly's experiments he connected his tube of filings in circuit with a Daniell's cell and a galvanometer. No current traversed the circuit on account of the high resistance of the filings, but as soon as a spark from a Wimshurst machine or a Ruhmkorff coil passed in the neighbourhood, the resistance fell from several millions ohms to perhaps only 100 ohms, and a current was shown by the galvanometer. This action was early found to take place even when the coil or machine was 60 ft. or 80 ft. away, and in another room. It was also found that the tube was effectually screened from electrical influences by being enclosed in a metal box, but that if two wires connected to the terminals of the tube projected from the box (but were not connected to anything outside the box), the action took place as before. Thus we have, probably, the origin of the antennæ or aerials now used in all Hertz-wave systems. The properties of the early coherer to receive and indicate etheric oscillations naturally came to an end after the first impulse. Dr. Lodge applied an automatic tapping arrangement to the coherer which restored to it its original receptiveness. Prof. Branly made many experiments with different materials, as well as with rods and pastes made of Canada balsam, sulphur, guttapercha, etc. He also found that a row of iron or steel balls 1 cm. in diameter formed a very sensitive coherer.

Dr. Lodge improved on Branly's form, not only by introducing the tapper already mentioned, but by improving the sensitiveness of the tube by placing the grains of metal in a vacuum, or sometimes in hydrogen. Metal collectors, or "antennæ," were also used to intercept a larger range of vibrations, and the sender and receiver were "tuned" to a certain extent by means of these antennæ. Dr. Alexander Muirhead, co-patentee with Dr. Lodge, applied the automatically

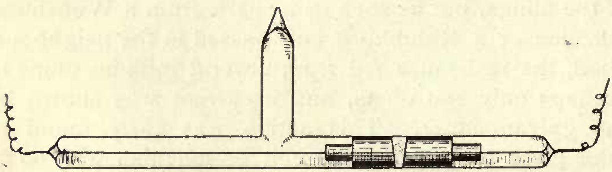


FIG. 22.—Marconi Receiver.

tapped or "decohered" coherer to a Morse telegraph instrument, so that regular dash-and-dot signals might be transmitted and received, and Mr. Marconi also introduced the Morse printer at an early date.

Marconi's Coherer.—Mr. Marconi made numberless experiments with various kinds of filings in coherers, different forms of tappers, and, in fact, very varied arrangements of the apparatus. He found that even at the best the coherer is somewhat erratic in its action, and for long-distance work the magnetic detector, already referred to, is much superior. Mr. Marconi's coherer as now in use is shown in Fig. 22. It is made by inserting filings between two silver plugs in a glass tube from which the air is exhausted. The plugs should be a fairly tight fit, but not so large as to burst the tube from expansion when they are heated. The plugs should be slightly amalgamated at the tips. The gap between the plugs, which is about 1 mm. wide, tapers slightly, and is about half filled with filings, consisting of 95 per cent. of nickel, 5 per cent. of silver, and sometimes a trace of mercury. The vacuum is about one-thousandth of an atmosphere, and the tube is exhausted through a projecting side portion, which is seen near the middle of the tube, this part being sealed up by melting the glass at its extremity as soon as the requisite vacuum is obtained. The connecting wires are fixed to the silver plugs. So sensitive is the coherer that it is best to keep it short-circuited by connecting its wires when it is not in use. It is fastened to a bone handle so as to be easily carried or moved into a required position.

Blondel's Regenerative Coherer.—This coherer with M. Emile Guarini's tapper is shown in Fig. 23. It consists of the usual glass tube with metal plugs, the space between which has a certain amount of filings in it. This space is connected with a side reservoir in which is a reserve store of filings, the idea being to alter the sensitiveness or restore the action of the coherer should it become insensitive, by introducing a further or new supply of filings from this reservoir.

Lodge's Single-Point Coherer.—Dr. Lodge used a single-point coherer, consisting of a needle resting with its point on a smooth aluminium disc. When the electric impulse is received the needle adheres to the disc, and the contact becomes conducting. The difficulty with such a coherer is that the fine point is liable to injury by the passage of too large a current.

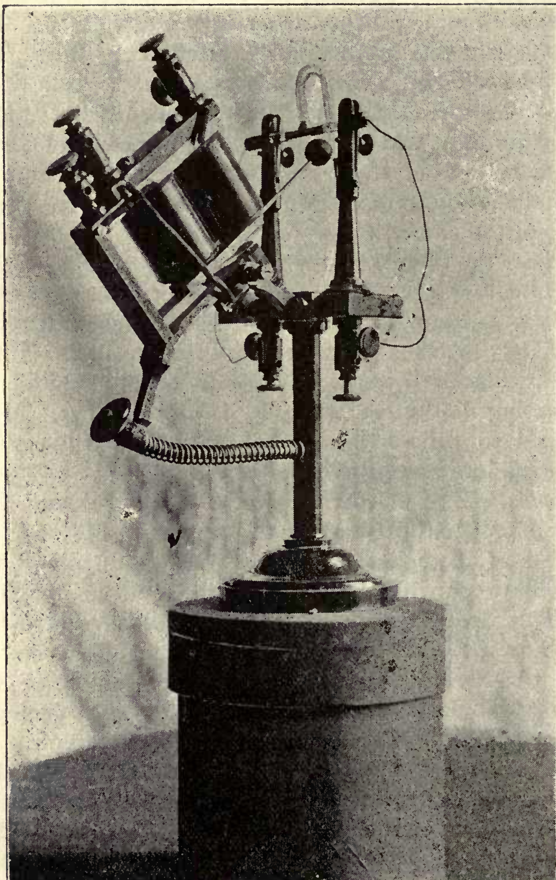


FIG. 23

Dr. Lodge also used this in another form, consisting of a fine spiral of iron wire inside a cylindric box. This spiral can be turned by means of a lever outside the box, and its pressure of contact with an aluminium plate varied. When the electric waves reach the coherer the contact becomes conducting, or, rather, the resistance of the contact diminishes greatly. A slight tap restores the coherer to its original state. The filings coherer used by Drs. Lodge and Muirhead up till the time of the introduction of their new mercury and disc coherer, consisted of an exhausted glass tube with two ordinary darning needles inserted in it point to point. Between these points the filings were placed, and whilst one needle was fixed, the other had an iron armature at its exterior (or eye) end controlled by a small permanent horseshoe magnet outside the tube. This coherer, we are informed, acted well, remained in good order for months, and was easily adjusted.

Prof. Branly's New "Radio-Conductor."—In most of the coherers in use up till recently metal filings or fine particles have been employed. This form of coherer is comparatively easy to construct, but is not altogether satisfactory. The numerous contacts and the modifications introduced by tapping render the apparatus somewhat fickle. Prof. Branly has recently devised a coherer or radio-conductor made by the contact of three tempered steel legs with oxidised points resting like a three-legged stool on a disc of polished steel. The oxidation is effected at a fixed temperature, and the degree of oxidation, as well as the polish, play an important part in the result. The thin layer of oxide remains intact for months. In the primary circuit of the receiver a cell of half-volt is joined by one of its poles to the upper terminal of the Morse register. The current goes through the terminal, then through a thin sheet of platinum to the pallet of the Morse, then to the relay through a variable resistance, and finally to the steel disc. The current goes through the contacts between the polished metal and oxidised metal, and returns to the battery. In the secondary circuit there is one cell of a battery or an accumulator, the contact being closed by the relay. A spark having passed at the transmitting station, the first circuit is closed by the contact of the polished and oxidised metals, which becomes a conductor. The second circuit is closed by the play of the relay ; the pallet of the Morse being attracted, the circuit opens between the upper screw of the Morse and the soldered plate of the pallet. The pallet continues its movement owing to its inertia, and strikes the lower screw of the buffer, and by this shock, which may be very feeble, operates the return of the tripod to its original state. When the opposing spring of the Morse has reapplied the pallet against the upper screw of the buffer, a new spark can act. The weakness of the shock enables the stroke of the pallet to be reduced, and greater speed of transmission to be attained. The radio-conductor is protected from the action of the sparks of the transmitter at its own station by an auxiliary electromagnet.

Theory of the Action of the Filings Coherer.

The action of the coherer may be briefly described as follows. Suppose a sending and receiving plate on the top of a pole, connected through a single spark-gap to the earth—this is like a Hertz vibrator with its axis vertical, and its lower plate replaced by the earth—or a pair of plates may be used, one charged and the other at zero potential. Some of the lines of force due to the one plate no doubt extend to the other. The spark passes with a sudden discharge, which is in effect like the rush of an opposite charge into the sending plate, disturbing the electric equilibrium to a great distance, and having an effect—very small, it is true—on the distant plate and conductor. If the latter plate is separated from the earth by a coherer, the minute jerk or sudden disturbance of electric equilibrium is felt by the coherer, it is rendered much more conducting (some investigators think that small sparks passing between the particles of filings aid in this effect), and a current passing works the relay, giving a signal. A tapper to give mechanical shocks to the coherer, so as to restore it to its original condition, is provided for instruments of the non-restorative class. Dr. Lodge suggests that the eye has a sensitiveness of the coherer order, some part of the retina maintaining an electromotive force which is prevented from stimulating the optic nerves by an intervening badly conducting material, which in turn is made much more conducting by the ether waves of light falling upon it.

Dr. Bose's Theory of the Coherer.—It is only right to add that Prof. Jagadis Chunder Bose, the great Indian scientist, who has made a special study of Hertzian vibrations and coherer action, gives a different explanation of the action from that usually accepted. He says the alteration of resistance is due to a kind of allotropism, and not to cohesion or the formation of vapour arcs. The metal filings in a coherer are like a metal in a very unstable condition, which only requires a slight strain to throw it off its balance. In most cases the effect of the strain due to Hertzian waves is to *lower* the resistance of the coherer, but, as Dr. Bose points out, coherers can be made in which the resistance *rises* on receipt of the vibrations—this being especially the case with metals like potassium, sodium, lithium, etc. Coherers formed with these metals tend to de-cohere themselves. It is only right to add that Dr. Bose has been found to be right, as regards decrease of resistance being limited to some metals only, and his theory may be the correct one. It is very similar to that given by Prof. Minchin for his cells.

Cell Detectors.

These are often classed with coherers, and certainly there are many points of similarity. Some are self-restoring (as the De Forest electrolytic cell), but others, such as those now to be described, are not. Prof. Minchin, working at Cooper's Hill with his sensitive photo-electric cells, found that they behaved curiously when Mr. Gregory worked an electric Hertz radiator in the next room, and that an electrometer connected to his cells responded to the discharges of the radiator. He was able in this way to signal over considerable distances without connecting wires even at that early date (1888-9). The reason of the action of the cells is obscure—it may be a chemical one, though Dr. Lodge classes it with that of the coherer. The cells are described on p. 90 under a separate heading. The sensitive photographic plate has also been used as a detector. Explosive gases may be ignited by the spark due to Hertz waves, and form another, though not practically important, chemical means of revealing the incidence of such waves.

Selenium cells, which are very sensitive to light, have also been tried, but, so far as we know, without success. The reader may wish to know what a selenium cell is. Crystalline selenium has its resistance considerably reduced by the action of light Selenium in narrow strips, arranged between broad conducting plates of brass, giving a large surface for exposure to light, forms one kind of selenium cell. When in the dark, a new type of this cell may have a resistance of, say, 120,000 ohms, but after exposure to light its resistance is only 1,500 ohms, and later cells have even a wider range. This curious property of selenium has been used in the *photophone*, an apparatus which transmits sounds to a distance by means of a beam of light, reflected to the distant station by a very thin mirror vibrating under the influence of the voice like the diaphragm of a telephone. The reflected beam falling with varying intensity on a selenium receiver in circuit with a small battery and a telephone, sounds are reproduced in the telephone by the variation of the current due to the variations of resistance in the selenium.

A young German scientist, Herr Ernst Ruhmer, has recently greatly improved this method of transmitting intelligence, and has invented a cell having a variation of resistance of about 1 : 200 between darkness and light, and whereas the older cells required from ten to twelve hours to return to their original condition, the new cell is restored in a few minutes. These cells are cylindric in form, and can be placed in the focus of the receiver, which is a parabolic mirror. Thus the cell receives the light uniformly, being enclosed in an exhausted thin glass tube or globe. The transmitting light consists of an arc searchlight. Herr Ruhmer uses a telescope in combination with the transmitting reflector, and by this means, having the optical axes of the two instruments parallel, gets over the difficulty of keeping the positive crater of the arc in proper focus.

He has been able to convey articulate messages over a distance of about ten miles.

It is also worthy of note in passing that Prof. Garbasso, of Turin, has recently found the action of sunlight to be such as to greatly facilitate the passage of electric sparks. The effect of the light continues for some time after the light is cut off. Focussing the light on the negative electrode gives a nearly continuous current at a distance at which sparks would hardly pass in the dark. Screens of mica, glass, or alum solution check the action of the light, but plates of quartz or Iceland spar allow the action to take place through them.

Prof. Minchin's Impulsion Cells.—These constitute one of the most interesting, as they were among the earliest, forms of detectors for Hertzian vibrations. They were constructed of strips of pure stiff tinfoil, 1 in. long and $\frac{1}{8}$ in. broad, which, having been cleaned first with sodic hydrate, then with dilute hydrochloric acid, and thoroughly washed in distilled water, were then coated with a solution containing 500 cubic centimetres of distilled water, three cubic centimetres of pure nitric acid, and 15 grm. of nitrate of ammonia. When the plate is covered with the solution, a whitish deposit is thrown down on its surface, the deposit being allowed to form for about four minutes. The glass plate on which the tinfoil rests is uniformly heated with a spirit lamp until the liquid on the tinfoil is evaporated. Continuing the heating process, the surface of the tin on which the deposit is assumes first a dull slaty look, then a whitish aspect, rapidly changing to a dark colour with a tinge of green as the heating goes on, until finally the green shade having passed over the foil, the dark surface changes to a strong white, when the plate should be plunged into alcohol. It is now in a very sensitive condition. If suspended from a platinum wire, and placed in an alcohol cell in front of a similarly suspended clean tin plate—the plates being connected to the poles of an electrometer, whilst the cell is screened from light—a small difference of potential is observed, the sensitised plates being positive to the unsensitised, but this difference of potential disappears in a short time. The plates and liquid, if sealed up in a glass tube, form a cell, and if connected with the poles of an electrometer, a rise of electromotive force is observed. Six such cells were connected in series, and a "standard" candle placed in front of them, the cells being connected to a Thomson quadrant electrometer. The curve of increase of electromotive force with time was shown, the maximum electromotive force being 0·566 of that of a Minotto cell. The electromotive force curve followed a logarithmic law, $E = A + B\,\epsilon^{-Kt}$, where A and B are constants, E the electromotive force at time t. It sometimes happens that a few days after the cell is mounted an exposure produces no electromotive force at all, but a slight tap (even if scarcely audible) given either to the support of the cell or the table on which it rests makes the cell sensitive to light once more, whilst another tap makes it insensitive again, and so on. This action is not due to any gas formed in the cell, but probably (as Prof. Minchin states) to some molecular alteration either in the sensitive surface, or the liquid, or in their layer of contact.

Prof. Minchin found that when a Voss machine was worked some distance off, the cell being in its insensitive state, *the moment a spark passed between the poles of the Voss the insensitive state altered to the sensitive.*

The same effect was produced at a much greater distance when the spark was from an induction coil. In fact, when a Hertz oscillator was taken into the grounds of the college, the cell being inside at a distance of 60 yards, the insensitive cell was at once rendered sensitive by the discharge of the oscillator. The opposite change, that from the sensitive to the insensitive state, was readily accomplished by taps administered to the base of the cell, or was even produced by dropping small pieces of cork on the base of the stand on which the cell was mounted. It seems as if the change we call de-cohering is readily produced by slow vibrations, whilst the opposite change (cohering) is due to rapid vibrations. The length of the waves has also something to do with the matter, for when capacity was added, and so as to lengthen the waves sufficiently, they ceased to effect the change. To show that the changes *were* due to electromagnetic disturbances, the cell with its connecting wires was shut up in a metal box, when it was found to be unaffected by any electrical discharge. When the wires projected outside the box, but were not connected to anything except the cell, it was affected as if exposed in the open, immediately becoming sensitive on discharge. Here we have the use of embryo antennæ demonstrated. Remember this was in 1888. Branly's coherer was not discovered, or, at any rate, not described, till 1890 or 1891. If Prof. Minchin had attached a long vertical wire to one pole of his cells and connected the other to earth, with an automatic tapping arrangement, he might have signalled "wirelessly" to considerable distances even at that early date. The action of the filings coherer is very similar to that of the impulsion cell, and it is worthy of note that the explanation of the action of the latter given by Prof. Minchin is very like that given by Dr. Bose for the former. Prof. Minchin also constructed sensitive films somewhat similar to his cells.

II.—Self-Restoring Coherers.

The foregoing all require some "de-cohering" device. The following coherers do not require such an addition, but are self-restoring. The *microphone* of Prof. Hughes is one of the earliest of this class.

Mercury Coherer.—Dr. Bose and Mr. Rollo Appleyard proposed the use of mercury long ago, but it is said a signalman in the Italian navy was the first to construct a practically successful mercury coherer. It consists (according to Mr. Marconi) of a globule of mercury between an iron and a carbon plug. The mercury wets the iron, or adheres to it, only when under the influence of Hertzian vibrations. It is far more sensitive than a filings coherer, and has the valuable property that it is self-recovering. It was used by Mr. Marconi when receiving signals at Newfoundland from Cornwall, 1,800 miles away. A balloon or kite was used to carry the aerial wire, but, owing to the varying capacity, an ordinary coherer was found unsuitable. Mr. Marconi says it was shown to him by Lieutenant Solari, of the Italian navy, and was baptised with the name "Italian navy coherer," as it was the fruit of the work of several individuals, and not of one.

Lodge-Muirhead New Coherer.—A new coherer has recently been perfected by Drs. Lodge and Muirhead, in conjunction with Mr. E. E. Robinson. It is said to be by far the best yet constructed. It is not disturbed by shaking, requires no tapping back, and is extremely sensitive and dependable. Dr. Muirhead recently picked up signals with it (not intended for him, however) when on the Atlantic 800 miles from land. It consists of a little disc, or wheel, with sharpened edge, running in mercury. This wheel is turned at a medium speed

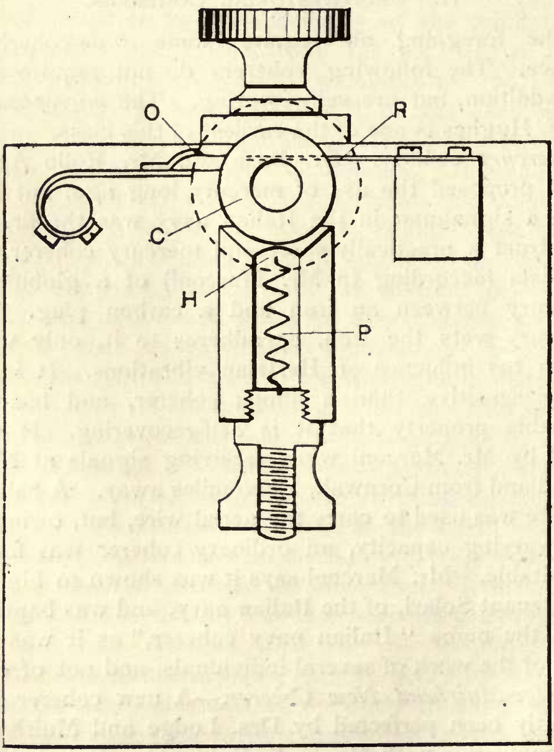


FIG. 24.—New Lodge-Muirhead Coherer (Elevation).

by clockwork, and a small pad with a supply of oil keeps the little wheel's sharp edge always oiled. Thus there is a slight film of oil between the wheel and mercury where the former dips into the latter. The wheel is connected to one terminal of the apparatus and the mercury to the other. The incidence of ether waves breaks down the insulating properties of the thin film of oil, making the coherer conductive, but

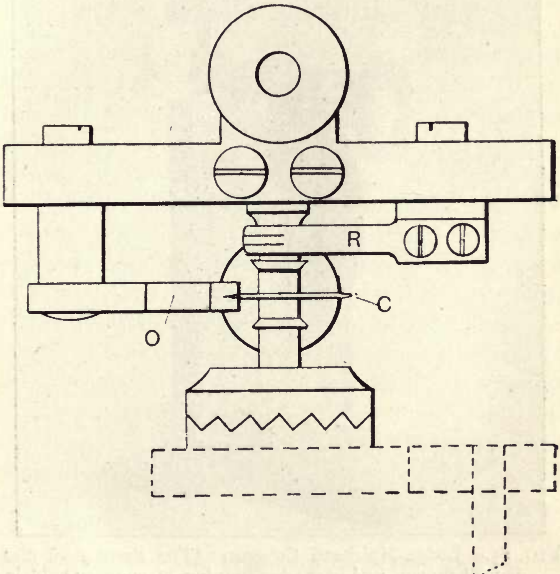


FIG. 24A.—New Lodge-Muirhead Coherer (Plan).

the continued motion of the wheel immediately brings another portion of its surface with its film into action, so that no decohering device is necessary. This coherer requires no relay and no tapper, but operates a siphon recorder direct. It is said to be so sensitive that in the long stroke or dash which the recorder prints can be detected the oscillations showing the frequency of the sparking apparatus. The record given is strong and clear, indeed equal, it is said, to the best cable records. The coherer is shown in elevation and in plan in

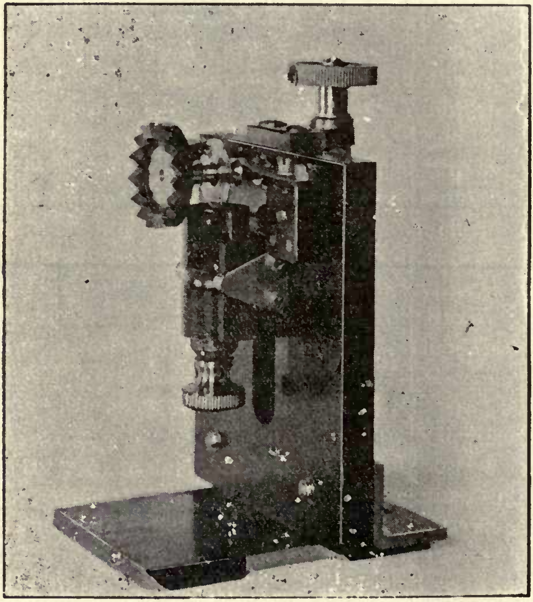


FIG. 25.—Lodge-Muirhead Coherer. (The sharp steel disc is well shown, its lower edge running in mercury held in an ebonite cup. The clockwork for driving the coherer disc acts through the serrated wheel.)

Figs. 24 and 24A. C is the steel disc, H the mercury, P a platinum spiral connecting the mercury to one terminal, O is the pad which keeps the coherer clean and supplies the oil, R a spring to hold the coherer in place. Should any injury happen to the coherer disc—

the only likely one is mechanical injury to its sharpened edge—it is easily removed and another disc substituted. The oil film breaks down in resistance at a very low pressure (probably under 0·4 volt), but if not acted on by ether waves the resistance is high. A photograph of the actual apparatus is shown in Fig. 25.

Electrolytic or Chemical Detectors.

These in some cases act in the opposite direction to coherers; in other words, their resistance goes *up* instead of *down* when subjected to the influence of Hertz waves. Prof. Neugschwender used a detector consisting essentially of a cut on a silver-on-glass mirror, with rods, rings, or wires attached. When the mirror was slightly breathed upon, its resistance immediately went up when acted on by etheric vibrations of the proper frequency. If connected to a telephonic receiver and battery, a click was heard for each discharge of the radiator no matter how quickly these discharges followed each other, showing that this detector—unlike the ordinary coherer—is self-recovering. The inventor attributes the increase of resistance to the break up of electrolytic trees which form across the cut or gap when the current flows, this break up being coincident with and due to the influence of Hertz waves. The break up increases the resistance very greatly.

The cut-on-glass receiver of Neugschwender referred to above is sometimes called a coherer, but is really an anti-coherer, as the resistance increases on the incidence of ether oscillations.

Schäffer Anti-Coherer.—This receiver, the invention of the son of the leading electrical engineer of Budapest, acts on the same principle as that of

Neugschwender, and consists of a piece of silvered glass—an ordinary mirror will do—having the mercury backing divided by one or two grooves or scratches.

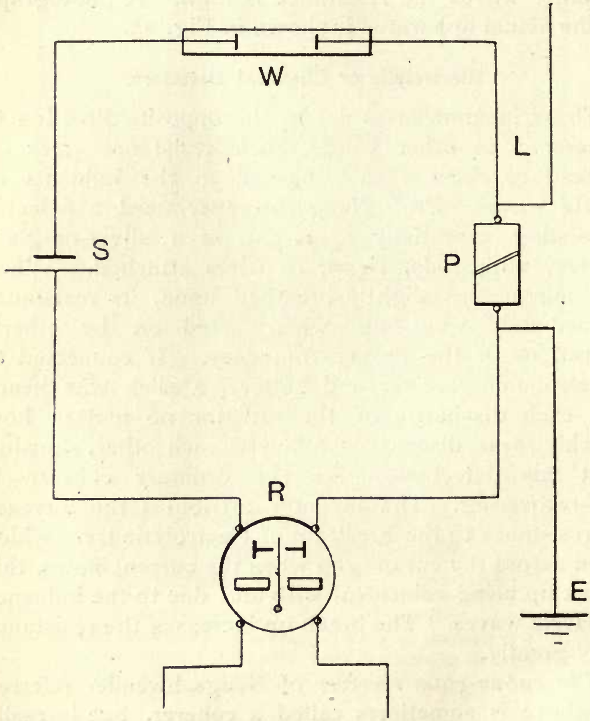


FIG. 26.

The action of the ether waves—electrolytic or chemical—is to increase the resistance of the apparatus, and careful trials by Dr. Joseph Tuma, professor of physics at the Imperial University, Trieste, as well as others conducted between Lavernock Point and Weston-super-Mare (1899), at Bremen (1901), and Frankfort (1902) showed this receiver to be equal in point of sensitiveness to the ordinary filings coherer then in use, with, of course, the advantage of requiring no de-cohering, since the resistance drops to normal amount as soon as the ether waves cease. A specially prepared glass is found to give best results, and an air-tight covering is advisable to prevent interference by atmospheric influences. These and other improvements have been carefully thought out by Prof. Schäfer. The circuit employed by him is shown in Fig. 26, where L is the aerial, E the earth, P the anti-coherer, W a water resistance, S a battery, R the relay.

The De Forest Detector or Responder is really a little electrolytic cell consisting of the hollow or spherical-shaped space between two screws in a tube. The liquid in this space is probably composed mainly of glycerine and water, but with other ingredients not very clearly specified. The ends of the screws are coated with peroxide of lead. The electrolytic action has the effect of building up chains of particles across the space between the two screws, but the incidence of an oscillating current from the aerial breaks up these chains, the result being that a click is heard in the telephone. The responder is, of course, self-restoring.

New Schlömilch Indicator.—This is a "cell of decomposition or polarisation" with platinum electrodes, which becomes in a high degree sensitive to electric waves, when a feeble auxiliary current is passed through the cell so as to produce a regular development of gas at the electrodes—the impressed electromotive force being slightly greater than the counter electromotive force of the cell. Unlike the De Forest receiver, this one is said to act so as to give an *increased* current under the incidence of electric waves. "When the wave effects meet the cellule the bubbles of gas produced by the decomposing current disengage themselves more quickly from the electrodes, are more closely together, and in greater number." If there is an intense action of the electric waves, "one is able, so to speak, to signal, through the Morse machine, by the simple disengagement of gas." If, instead of platinum, two metals widely apart on the galvanic tension scale be used, an auxiliary current may be dispensed with, the cell being then like a primary element without current on account of polarisation, but which depolarises itself immediately under the action of the electric waves. The cell, indeed, resembles a small Wehnelt interrupter, with, after the manner of the Fessenden bolometer, several reserve positive electrodes, which may be put into circuit one after the other if necessary. Any such step is, however, said to be little necessary, owing to the constancy of the cell, which is stated to be greater than that of a filings coherer, and the intensity of the action varies in some degree with the intensity of the received waves. It works best when the positive electrode is *very* small—even microscopic in dimensions. These particulars were furnished by the Gesellschaft für Drahtlose Telegraphie, Berlin.

Optical Detectors.

Hertzian Heliography. — Herr R. Blochmann (November, 1902) used mirrors with high dielectric constant to concentrate the electromagnetic radiations on a distant receiver, which is itself a lens. Mirrors of 80 cm. diameter sufficed for waves 20 cm. long, and signals could be sent and received correctly over several miles. The apparatus was practically a heliograph for *invisible* light waves, used much in the way in which an ordinary heliograph is used for visible light. The receiver is in this case, of course, not the eye, but a suitable sensitive Hertz-wave receiver, which may be made to print a message if necessary. These *invisible* rays are not intercepted by fog or by non-conducting solids, but mountains do act as obstacles, which, however, can be overcome by a series of relays. The direction in which the rays come to the receiver can be distinguished with considerable accuracy, and thus several messages may be received at the same time, or sent out at the same time in different directions.

Classification of Detectors.

Dr. Fleming suggests the name "kumascope" (from κυμα a wave), as a better term than detector or receiver, for the instruments used to give evidence of the presence of Hertzian vibrations. The term, however, is too suggestive of a toy to be likely to meet with general scientific approval. A classification of the detectors, or responders, here described, somewhat on the lines suggested by Dr. Fleming, is given below.

Microphonic or Coherer Types.—Non-restoring: Branly (coherer); Blondel (coherer); Marconi (coherer); Minchin (cell). Self-restoring: Hughes (microphone); Lodge-Muirhead (coherer); Castelli-Solari or Italian Navy (coherer).

Magnetic.—Marconi.

Electric.—Hertz.

Electromagnetic.—Evershed.

Electrolytic.—De Forest ; Neugschwender ; Schäfer ; Schlömilch.

Thermal.—Boys ; Gregory ; Fessenden.

Optical.—Boltzmann.

CHAPTER V

Syntony.

A body vibrating in a medium usually gives rise to waves, the intensity of the waves depending on the rapidity of the alternation. Thus we may have a very slow pulsation, say of the air, of great amplitude, producing little effect except perhaps the alternate rise and fall of a sensitive pressure gauge, whereas a rapid pulsation of the air gives rise to a loud noise or a musical note. The pulsations may even be so rapid that our ears fail to distinguish the sound produced; thus at each end of the scale we fail to perceive the effect of the vibrations. So it is with etheric vibrations. A magnetic alternation of sufficient rapidity induces an alternating electrostatic field, and energy is given out, whereas a slow alternation gives rise to practically no electrostatic effect. In the latter case little or no energy is emitted, or, rather, it nearly all returns to its source. For a progressive wave half its energy must be static and half kinetic—in ordinary current induction the energy is all kinetic. It seems, therefore, that the rapid vibrations are the most advantageous if we wish to transmit a message to a distance, but for great distances the rapid waves of small length are too easily prevented from reaching their destination by "screening," whereas for slow vibrations obstacles, if not of *iron,* have little effect, even conductors not having a serious screening effect if the vibrations are slow enough. To detect the electric vibrations, a form of detector is necessary, and some of these have already been referred to. But the importance of the receiver being in *tune* with the vibrations it is intended to detect was pointed out by Dr. Lodge in 1890, as deduced by him from an experiment with Leyden jars. For telegraphic purposes the Leyden jar is replaced by a condenser, the circuit of the jar being replaced by a large horizontal coil of wire, the frequency being lowered by this means to some thousands or even hundreds per second, so that an ordinary telephone might be used as a receiver in a shunt to the receiving condenser. Instead of the etheric oscillation produced by the spark of a coil, an alternator or source giving an alternating current may be employed. The importance of accurately tuning the receiver to its alternating dynamo or source is now recognised by all, and was fully explained by Dr. Lodge, who illustrated the matter by noting the analogous quantities as follows: electric—self-induction, resistance, capacity; mechanical—inertia, viscosity, elasticity (*Proc.* Inst.E.E., vol. 27, p. 809).

A mechanical idea of an alternating circuit without condenser is given by Dr. Lodge. It is that of a truck on level rails pulled and pushed alternately by a piston. To vary the resistance the truck could be braked, to increase the self-induction the truck might be loaded, but to represent capacity we must imagine the truck fitted with a spring recoil tending to return the truck to its mean position. The truck has now—by the insertion of the springs—a period of vibration or oscillation of its own, and if disturbed it will swing to and fro a certain number of times per minute, gradually coming to rest. To keep it in alternation without springs a great amount of energy was required and wasted, and a very strong push and pull by the piston; whereas with the springs, if only the push and pull are in tune or synchronism with the natural period of oscillation of the truck, comparatively little energy is required, that stored in the springs at each compression being nearly all given out again at the next forward movement. So even a very slight push, if given at proper intervals, could set the truck in violent oscillation. Thus, in the electric circuit, the analogue of force of the springs is the voltage at the terminals of the condenser; the analogue of current is velocity of the truck as it passes the mean position. Without the condenser the oscillations are feeble if there is considerable self-induction in the circuit, and without plenty of self-induction the magnification of voltage at the right frequency is small. With large self-induction and small resistance it would be possible (as in an enormous copper coil) to multiply the applied voltage thousands of times, so as to burst any condenser. Dr. Lodge concludes that in an unaided self-induction process it is impossible to work well over really long distances without proper syntony or tuning unless an extravagant amount of power be employed. The elements of the mathematical side of the theory are also given by Dr. Lodge, who describes some methods whereby the tuning may be effected. As regards receivers, if the current is of the *interrupted* kind, a coherer may be employed as a shunt to the receiving condenser, and a relay worked by the signals so obtained. For the more sinuous law current of an alternator the ordinary coherer is hardly sensitive enough. Thus when an alternator is employed to produce the etheric oscillations, the receiving circuit must be modified, as a filings coherer is unsuitable. A telephone may be used.

One method suggested by Dr. Lodge is shown in Fig. 27. M is the magnifying telephonic arrangement, K a condenser of about 20 microfarads capacity, H the thick-wire winding of a hedgehog transformer inserted as extra self-induction. The telephonic magnifiers were not found so satisfactory as reed or tuning-fork magnifying telephones with only a single pair of carbon contacts. The coil is here hung to a reed or fork of definite pitch, and also carries a

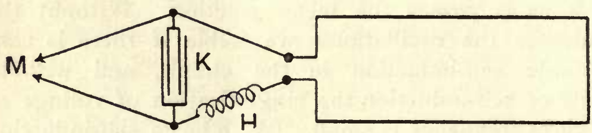


FIG. 27.

pellet of carbon which presses lightly on another fixed pellet, thereby acting as a single-contact microphone.

The tuning-fork telephone, which responds only to one definite note, is an apparatus which seems to promise the much-wanted secrecy for ether-wave telegraphy. The vibrations of a telephone diaphragm may be magnified and used to ring a bell or work a Morse printer, as in the phonophoric receiver of Mr. Langdon Davies.

Another important improvement introduced by Dr. Lodge is shown in Fig. 28, where a condenser is shunted across the terminals of the receiver, R, to take up the extra oscillations. The syntonic responder, M, is also used.

Marconi's Methods of Securing Syntony.—Mr. Marconi read a paper before the Society of Arts in May, 1901, in which he described various methods by which tuning could be effected. With simple vertical wires connected directly to the coherer at receiver, and spark-gap at the transmitter (Fig. 29), no tuning of any

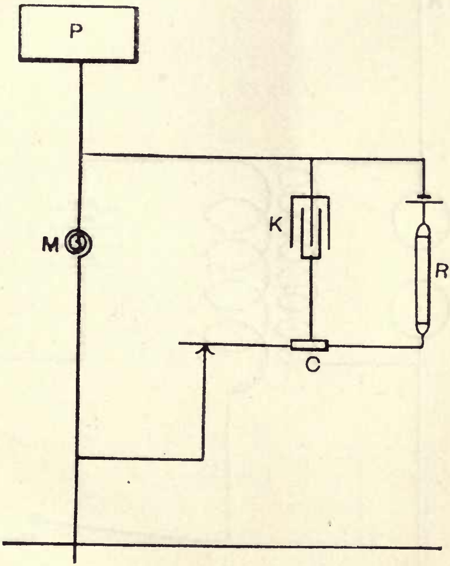


FIG. 28.

consequence is possible. If the aerials were very different in length, a certain amount of selection was possible. Thus two stations five miles apart, using aerials 100 ft. long, would not interfere with two other stations, with aerials 20 ft. long, two miles from one of the first-named stations. The method adopted by

Mr. Marconi in or after 1898 of connecting the receiving aerial to earth through the primary of an induction coil or transformer instead of to the coherer, and of connecting the ends of the coherer to the

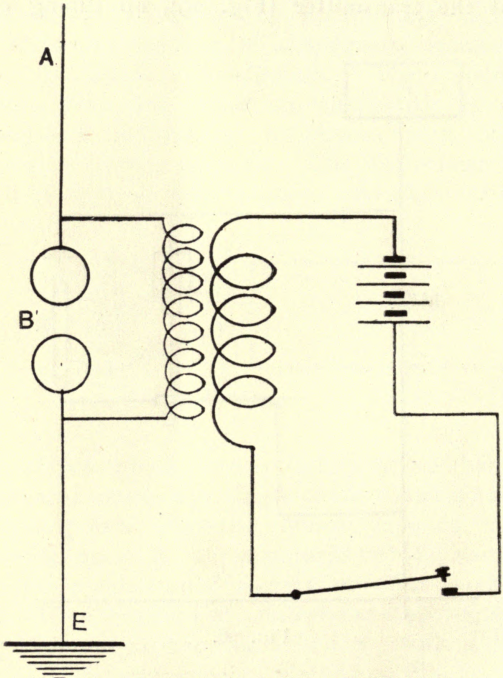


FIG. 29.—Early Form of Marconi Transmitter.

secondary of the same, also shunting across the coherer an adjustable condenser, the whole forming a resonator tuned to respond to the given waves, was an important advance. This method is shown in

Fig. 30. The importance of this tuning was illustrated by Mr. Marconi by an example in which bellringers gave their impulses to the ropes in proper time, and

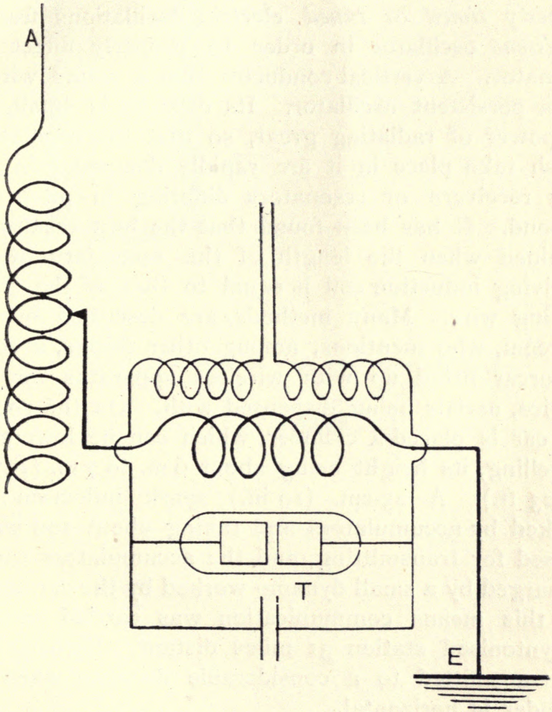


FIG 30.—Syntonic Receiver (Marconi).

thus succeeded in ringing heavy bells with a comparatively small expenditure of energy. The heavier the bell the slower the impulses had to be. If the impulses were wrongly timed—*i.e.*, untuned—the bell did not ring. The same sort of thing happens in a very small fraction of a second if we try to induce electrical oscillations in a good resonator. If the resonator be of the *persistent* kind, we must apply a large number of properly *timed* or *tuned* electric oscillations from a *persistent* oscillator in order to properly affect the resonator. A vertical conductor like a round wire is *not* a persistent oscillator. Its capacity is small, and its power of radiating great, so that the oscillations which take place in it are rapidly damped. In this case receivers or resonators differing in pitch *will* respond. It has been found that the best results are obtained when the length of the secondary of the receiving induction coil is equal to that of the transmitting wire. Many methods are described by Mr. Marconi, who mentions, among other things, a steam motorcar fitted up with wireless apparatus for field service, aerials being dispensed with. On the roof of the car is placed a cylinder, which can be lowered in travelling, its height being about 6 m. to 7 m. (19·7 ft. to 23 ft.). A 25-cm. (10 in.) spark induction coil, worked by accumulators and taking about 100 watts, is used for transmitting, and the accumulators can be recharged by a small dynamo worked by the car motor. By this means communication was carried on with a syntonised station 31 miles distant. Signals may be transmitted to a considerable distance when the cylinder is horizontal.

Cylinders Instead of Aerials.—Mr. Marconi has found, as already stated, that good radiators can be constructed with cylinders of moderate height instead of aerials. Fig. 31 shows these copper cylinders, the inner being connected to earth with an air space between the cylinders. The outer cylinder is connected to one side of the spark-gap through a variable inductance, the other side being connected to the

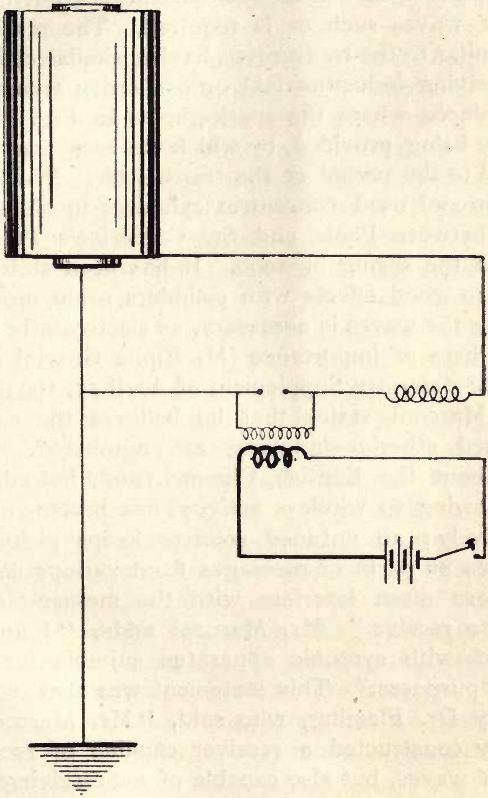


FIG. 31.

earth-wire of the inner cylinder. The source of energy is in the primary circuit of a transformer, the secondary of which is connected to the two sides of the spark-gap as shown. The capacity of the radiator is large, and the energy set in motion by the spark discharge cannot be all radiated in one or two oscillations, but forms a train of waves such as is required. The receiver is very similar to the transmitter, having similar cylinders, the receiving induction coil or oscillation transformer being placed where the spark-gap is in Fig. 31, and capacity being provided, by which the receiving circuit is tuned to the period of the transmitter. We believe Mr. Marconi used concentric cylinders in his experiments between Poole and St. Catherine's Point (31 miles) in the spring of 1900. It has been stated that to secure good effects with cylinders some means of directing the waves is necessary, as electrostatic induction is here of importance (M. Emile Guarini in the *Scientific American* Supplement of April 25, 1903).

Mr. Marconi states that he believes the days of non-tuned etheric signalling are numbered. "The ether about the English Channel, and, indeed, elsewhere, owing to wireless activity, has become exceedingly lively; an untuned receiver keeps picking up messages or parts of messages from various sources, and these often interfere with the message one is trying to receive." Mr. Marconi adds, "I am now prepared with syntonic apparatus suitable for commercial purposes." This statement was also authenticated by Dr. Fleming, who said, "Mr. Marconi has not only constructed a receiver capable of receiving trains of waves, but also capable of *not* receiving those not adapted to it." Yet people about the English Channel are said to give trouble in connection with Mr. Marconi's messages. They also say that they can pick up the said messages. The explanation of the latter probably is that a "slack" system with small capacity is like a very weak spring, and will respond to oscillations of almost any wave-length. Such a system will, probably, receive almost any message sent out within a certain radius of it, but if two or more messages are sent out simultaneously in its neighbourhood, it will receive all, and the result will be an unintelligible jumble. Remarkable experiments carried out at Poldhu in March, 1903, under the supervision of Dr. Fleming, showed that messages dispatched simultaneously from the large Transatlantic station and a small ship station near were received perfectly correctly and distinctly on the same aerial of a properly tuned station a few miles away. This is one of the most remarkable instances of perfect tuning yet made public. One should imagine that the great station sending out waves of great length, and the smaller station with its probably very different wave-length radiation, offered a particularly good opportunity for tuning with success. It would be interesting to know how far it is possible to tune in this way, say, the apparatus of a number of ships of a squadron, and whether it is possible by this method of syntonisation to communicate with one of the ships without the others detecting the message. Also whether the working of a transmitting apparatus within a few miles of Poldhu interferes at all with the messages received from America, the oscillations conveying which must be very much attenuated when they reach our shores.

Harmonic Telegraphy.

The Johnson-Guyott System.—Evidently syntony, if perfectly carried out, gives the secrecy which remains up till now a hoped-for future improvement rather than an assured present success. The system now to be referred to is claimed by the patentees as a satisfactory solution, though the distances traversed have been as yet comparatively small. Its object is to secure immunity from the tapping of messages, and the means of sending messages to one or more of a fleet of vessels, without the others being able to detect or read the messages. One weak point of wireless telegraphy so far has been the want of a perfect method of discriminating between messages when a number are being received at the same time, and ensuring that they shall not interfere so as to confuse the receiver. The point of the patent lies in the employment of combinations of musical notes with electricity (the possible combinations being very great in number), and the patentees claim to have discovered a method or methods of combining these so as to give a system of wireless telegraphy or telephony of a secret kind, and capable at a small cost of meeting commercial requirements. No high poles are required by this system.

The instruments consist of a Ruhmkorff coil transmitter and a receiver (Fig. 32, with a disc on which are mounted the vibrators, consisting of tuning and speaking reeds). By the aid of these the electrical waves are produced and tuned, and messages are transmitted through the earth. The two ends of the receiving instrument are placed in the earth at distances varying according to the size of Ruhmkorff coil used, roughly about two hundred times the sparking distance of the coil. This, it will be seen, is a small distance compared with other systems of a similar kind as regards the use of the earth. The armature

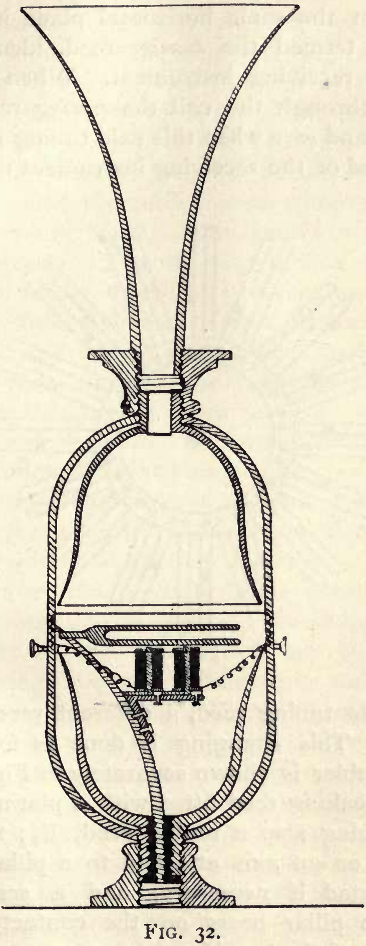


FIG. 32.

of the coil consists of a brass reed (Fig. 33), with soft-iron head acting as a vibrator, and just below this—*i.e.*, in the same horizontal plane in Fig. 32—is what is termed the *tuning* reed, identical to the reed in the receiving instrument. When the current is passing through the coil the *tuning* reed is caused to vibrate, and *only* when this said tuning reed vibrates does the reed of the receiving instrument respond. By

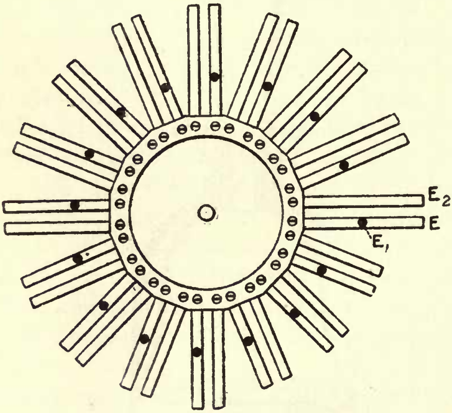


FIG. 33.

changing the tuning reed, a different receiver may be spoken to. This changing is done as follows. The musical trembler is shown separately in Fig. 33, where E is the speaking reed fitted with a platinum contact, E_1, there being also a tuning reed, E_2; the trembler is mounted on an axis attached to a pillar, so that it can be rotated if necessary, and a screw passing through the pillar bears on the contact, E_1. The tuning reed of the trembler acts as contact breaker of a Ruhmkorff coil forming part of the transmitting apparatus. The operator at the transmitting station, having ascertained the frequency to be employed, rotates the trembler till the proper tuning and speaking reeds (E_2 and E, Fig. 33) are in front of the cores of the electromagnet; he then turns the screw before referred to until it bears on the platinum contact, E_1, on the speaking reed, closes his circuit, and turns a tuning screw until the tuning reed vibrates in unison with the speaking reed. This shows him that the electrical impulses are really sent out in unison with the speaking reed. They are received at the other station by a vibrator similar to that shown in Fig. 33. A Morse key and Morse printer or sounder may be employed to give long and short signals in the usual way. When the tuning reed at the transmitting station does not "speak," it shows that the reed at the distant station will not receive the impulses. The ingenious arrangement of keys and circuit with battery for sending the current, and actuating the coil and trembler, need not be further referred to here. No reed or vibrator can possibly make another respond unless the distant one is properly tuned to it, so that messages sent by this means can only be tapped by receivers having a proper vibrator in tune with the sending instrument. Some recent experiments with this system were carried out on the Thames between two launches, but owing, it is said, to a defect in one of the coils, the messages were only conveyed about 700 yards, but it is hoped that before long, with improved coils, the messages may be sent a very much greater distance. The method is, we understand, to be tried by the Admiralty if found successful experimentally. This description should have been given under an earlier heading as regards the use of the earth, but as *tuning* is the important part of the invention it is inserted here.

There is little doubt that systems of this kind will be more heard of in the future, and it seems likely that what has been described contains the germs of successful syntony or selective transmission in wireless work. If the inventors were to use Hertz-wave methods—and the mention in the patent of the transmission of messages through earth, *air,* or water seems to foreshadow this—instead of earth conduction, they would be much more likely, in the author's opinion, to attain that success in regard to *distance* which they have already achieved in regard to secrecy, or selective working; especially if a telephone the diaphragm of which has the same natural period of vibration as that selected for the transmission of the message were employed in the receiving apparatus.

Mr. Anders Bull's Selective System.—Herr Anders Bull, of Christiania, Norway, has invented a selective system which is based upon mechanical principles, and which gives promise of affording a solution of the selective problem in wireless telegraphy. The transmitting and receiving of the signals is done in the usual way by means of induction coil, aerial wires, coherer, etc. Thus, for obtaining the electric connection, this system may be combined with any one of the existing systems based on electric resonance. The distinguishing feature of Herr Bull's system is the manner in which the wave impulses are sent out and received. In the case of other systems the signals are dispatched as rows of impulses, each impulse following another in regular rapid succession; a short row standing for a dot, a long row for a dash. By the system now referred to, however, rows or series ot impulses are used, each series consisting of a fixed number of impulses succeeding each other at prearranged short (and usually *unequal*) intervals of time.

The transmitting station is provided with an adjustable mechanical arrangement for forming the series. Suppose, for instance, the apparatus is adjusted to send out a certain series consisting, say, of four impulses, the intervals of time between them being one-twentieth, one thirty-fifth, and one fifty-fifth of a second respectively, then it is not possible by this apparatus, without readjustment, to send out impulses except in series of the said form. The apparatus is connected up with a Morse key, which is used in the ordinary way. In sending a dot the key is pressed for a short interval of time, whereby the mechanism is released for a moment and sends out one series of wave impulses. In sending a dash the key is pressed for a longer time, which causes the mechanism to transfer a sequence of uniform series of the kind referred to.

The receiving station is fitted with an apparatus for transforming the series into legible signals. The receiving apparatus acts in the following way: Every wave impulse striking the aerial causes an electromagnet to work a movable mechanism. The apparatus is adjustable, and has to be adjusted to correspond with the series dispatched. When thus adjusted, the mechanism will close a local circuit containing a Morse inker each time a series of the given shape arrives One series is registered by the Morse inker as a dot, a sequence of series as a row of dots (a dash). Any incident wave impulses having other time intervals than the series for which the receiver is adjusted, will not be registered by the Morse inker at all. In this way the inker of a receiving station, A, will merely record dispatches intended for this station. When signalling to another station, B, a differently shaped series is used, and the wave impulses transmitted through the ether in the form of this new series affect only the receiver at B, which has been properly adjusted to receive this series. In like manner, the one transmitting station may, by using a third series of different shape, communicate only with a third station, C, which has been apprised beforehand of the series adopted for its use. As the variety of series which may be employed is very great, many different stations may be communicated with, and without risk of the several stations receiving messages not intended for them.

It is even possible to interchange different signals simultaneously between different stations without mutual interference. The mechanism by which this result is attained is rather complicated, and would require for its full description many drawings. It may, however, be stated, in passing, that the author of the system has used various devices. One way in which he secures the desired result is by having at the transmitting station a *disperser*, consisting of a horizontal disc which can be rotated at constant speed about a vertical axis. To this disc are attached a large number of vertical steel springs, arranged concentrically round the circumference of the disc, their upper ends protruding through radial slits in a second disc mounted above the first. There is a ring and ∩-shaped guide for the upper ends of the springs, so that in a revolution the springs glide either within the *ring* or in the ∩-shaped groove. A portion of the ring is cut away at one place and a bronze piece fitted, which deflects the springs towards an inner electromagnet, the coils of which are constantly excited by a battery. A number of contact pieces arranged at predetermined intervals round the outside of the disc make contact with those steel springs which are within the U-groove, but do not touch those within the ring. Another electromagnet, excited when the sending key is depressed, determines the springs which shall be within the ring. Thus, when the key is held down for a very short time, all the springs—which under normal circumstances of non-transmission are within the ring—remain in the ring, except one which is brought within the groove, and makes contact successively with each of the outside contact pieces during a revolution. This contact allows current from a battery to excite the interrupter magnet, the armature of which is attracted, causing current to flow through the sending induction coil, and on subsequent opening of the circuit of the latter, a spark discharge takes place between the secondary terminals of the cell, causing a wave impulse to be sent out through the ether. At the receiving station the wave impulses strike the receiving aerial, lower the resistance of the coherer, causing the relay to become excited. The collector magnet is shunted with the tapper of the coherer (in cases where a coherer requiring tapping is employed), the collector being constructed similarly to the transmitter, a steel spring for every wave impulse being brought into the groove and by contact completing a circuit in which is the Morse inker. The angular distances between the springs brought into the groove are proportional to the time intervals between the impulses, and the contact pieces outside being set for a certain series with given intervals, the arriving impulses will affect the contact pieces simultaneously if at the proper time intervals apart, in which case only is the Morse inker affected and brought into action. Thus, when impulses of the prearranged kind are received, all the springs make contact and a dot (-), or if the sending key is depressed for a longer period a succession of dots equivalent to a dash (—) is received, and hence a readable message is obtained. A series of any other form will not affect the Morse inker at all. There are various ways of rendering messages unintelligible to an outsider who has set up an ordinary sensitive (non-tuned) receiving apparatus. One way is to send two series of different time intervals, one for the dots and another for the dashes. These are received by properly arranged disc receivers, but, being very much alike, cannot be distinguished if registered by an ordinary receiving device.

Another way is to use a short series and send out, in the spaces between the dots and dashes of the message, a series of such a form as will not affect the receiver telegraphed to. This latter series is used merely as a blind, but completely puzzles the person who receives it on the ordinary apparatus of a receiving station; or one series only may be used, the duration of which is relatively long. In sending a dash the individual series are made to succeed each other at time intervals which are shorter than the duration of a single series. In this way the series overlap each other, and the signals become quite illegible if recorded in the usual way.

It may be pointed out, in conclusion, that it is not at all necessary that the apparatus of the transmitter and receiver shall move synchronously. Fair working is conditioned only by an approximate isochronous speed of the propelling device. The system has lately been tried successfully in the neighbourhood of Frinton-on-Sea and Chelmsford. The more important portions of the apparatus used in those experiments are, by the courtesy of the inventor, depicted in Fig. 34.

The circuit employed successfully, after various alterations, is shown in Fig. 35, taken from illustrations kindly supplied by the inventor, and where

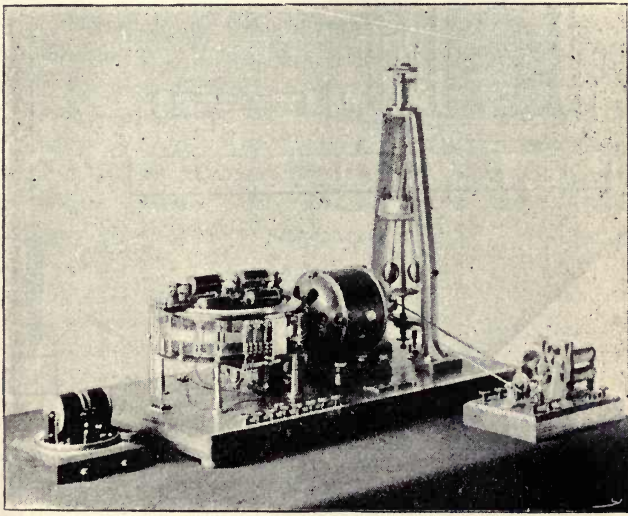


FIG. 34.

quickness of action is secured by having the coherer, C, attached at one end to a T-piece fastened to the armature of the electromagnet, M. This armature is held by the insulated spring, S, against the contact screw, P. Thus the movement of the armature is limited to about 1 mm. On the coherer becoming conducting, owing to the incidence of the electric waves from the distant station received through the earthed aerial, A, current from the cell, E, flows as indicated by the arrows, magnetising the relay, R, which closes the secondary circuit, including the stronger battery, B, the collector magnet referred to in the foregoing, and the electromagnet, M. As

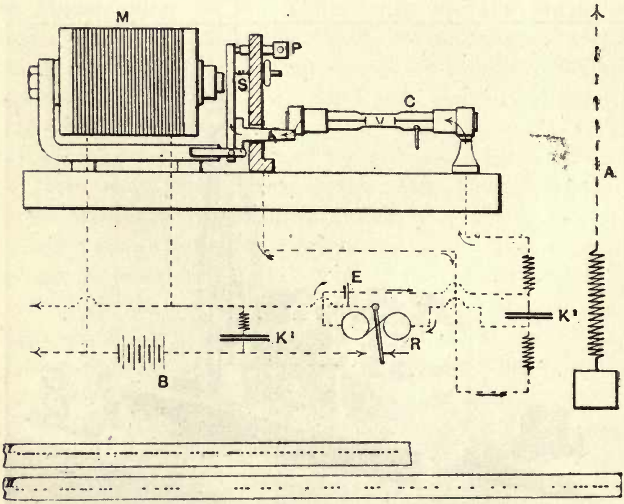


FIG. 35.

soon as M is magnetised it attracts the armature, interrupting the relay current, its tongue or switch going back to the "off" position almost before the coherer has ceased to vibrate. The coherer is tapped *twice*, first on the armature striking the core of M, and again on the armature coming back into contact with P under the pull of the spring, S. Thus the decoherence is rendered complete, and extra vibrations are to a large extent avoided, moving parts being light. After the proper adjustment of the apparatus—it being found advisable to "earth" the end of the coherer nearest M, so as to prevent the extra capacity of M from having the usual evil effect due to want of symmetry when M is connected to the coherer—messages from Chelmsford were received perfectly at Frinton, the distance being about 35 miles, whilst the ordinary Marconi receiver printed the message as an unintelligible jumble. Tapes I. and II. (lower portion of Fig. 35) are exact reproductions of the message, "Do you (u) get this?" as received and printed by Mr. Bull's apparatus and the ordinary receiver respectively. The reader can easily read the first by referring to the Morse alphabet previously given. The message as printed by the ordinary receiver is unintelligible.

CHAPTER VI.

The Work of Marconi.

Marconi's System.—This system has already been referred to in several places throughout the preceding pages. Guglielmo Marconi, a young Italian (whose mother, however, was an Irishwoman), came to England in 1896. He had previously made experiments at Bologna, and brought with him to England a patent the originality of the claims in which has been the subject of some discussion. Some critics have asserted that most of the things therein described were already well known to workers at this subject. Be this as it may, Marconi was the first to really show us what Hertz-wave telegraphy could accomplish, and whether he be original or not is of little interest to the ordinary reader. He had what, to an inventor, is far more valuable than any patent—viz., indomitable perseverance and a thorough belief in the ultimate success of the system or systems (for he has introduced many changes and modifications) he advocated. There is no doubt that the aid of a powerful company has been of the greatest value to him ; it has enabled him to experiment on a stupendous scale and to *create records.* The public likes a man who creates records ; hence Mr. Marconi, at twenty-nine years of age, attained a place in fame and history such as few men reach even at twice that age. Mr. Marconi was welcomed by Mr. (now Sir W.) Preece, then electrical engineer to the

Post Office, and the authorities gave all facilities for his earlier experiments, which were carried out on the roof of the General Post Office, London, later on at Salisbury Plain, and between Lavernock Point and Flat Holm in the Bristol Channel.

SIGNOR MARCONI.
(By permission of the Biograph Company.)

Deferring for a moment a consecutive history of his success, reference may be made to his system, and to some of the apparatus employed by him with such success. One of the earlier arrangements is shown diagrammatically in Fig. 36, where E is the elevated wire or aerial, which is cut, and in the space thus provided is placed the spark-gap, G, of a Ruhmkorff coil, the primary circuit of which has the usual battery and key by which a longer or shorter series of impulses may be sent out. The receiver is equally simple, consisting

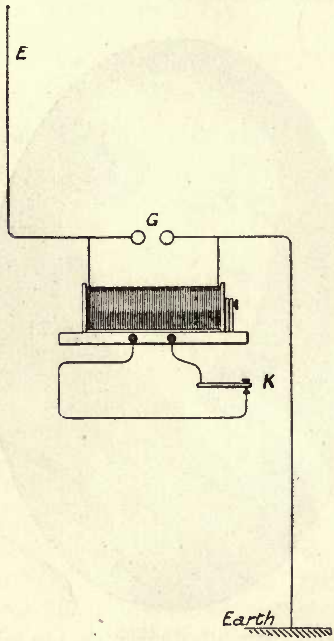


Fig. 36.

of the aerial, E (Fig. 37), one end of which, as in the transmitting apparatus, is earthed. The aerial has a space in it in which is the coherer, C, relay, R, and battery, B. It will be noticed that the ends of the coherer are joined to inductance or choking coils, S S, to confine the oscillations to the coherer.

The newer arrangement is much more complicated, especially that used for long-distance work. Very powerful impulses are radiated at high pressures. So far as we can ascertain, the transmitting apparatus

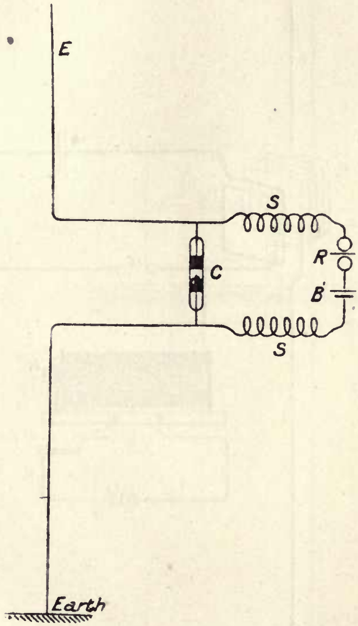


FIG. 37.

may be depicted in outline somewhat as in Fig. 38, where E is the aerial (for long-distance work usually of multiple form, as shown in Fig. 40), with the secondary coil, P_2, of an oscillation transformer (probably more or less like a large Tesla oil transformer) in it, the primary coil, P_1, of which is connected to a condenser or series of large condensers, C_1, and to the spark-balls, G, of a powerful coil with mechanical break. The source of power is here represented by a battery, B, but is really an alternator in the case of

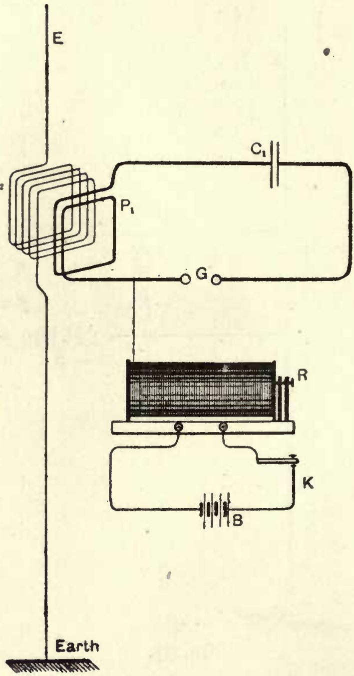


FIG. 38

large stations such as those at Poldhu and Cape Cod. There is also a key of special form, by which the length of the impulses or trains of waves may be varied to give definite signals. The receiving apparatus (Fig. 39) has the aerial, E, with the primary coil of an oscillation transformer in it, the secondary coil of which is split and contains a small condenser, H, the coherer, C (or magnetic receiver when a coherer is not employed) and another condenser, D. The two

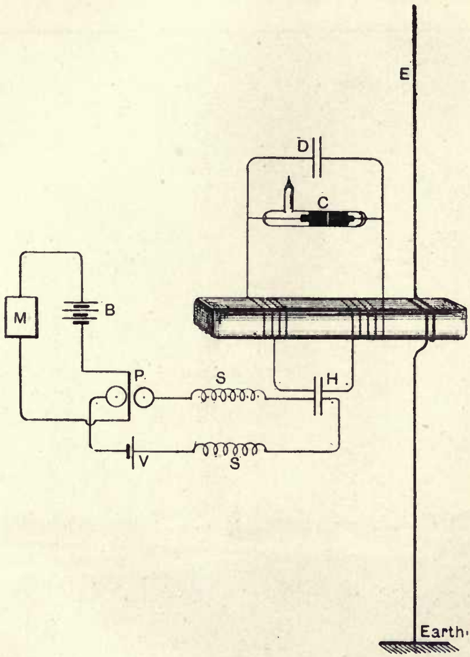


FIG. 39.

sides of the small condenser, H, are joined to another circuit containing the choking coils, S S, the single cell, V, and the relay, P, which, when actuated by the feeble impulses received through the coherer, closes the auxiliary circuit in which is a more powerful battery, B, capable of working the Morse machine, M. There is also close to the coherer tube, and as a shunt to the Morse printer, a tapper actuated by a small electromagnet after the manner of the trembler or

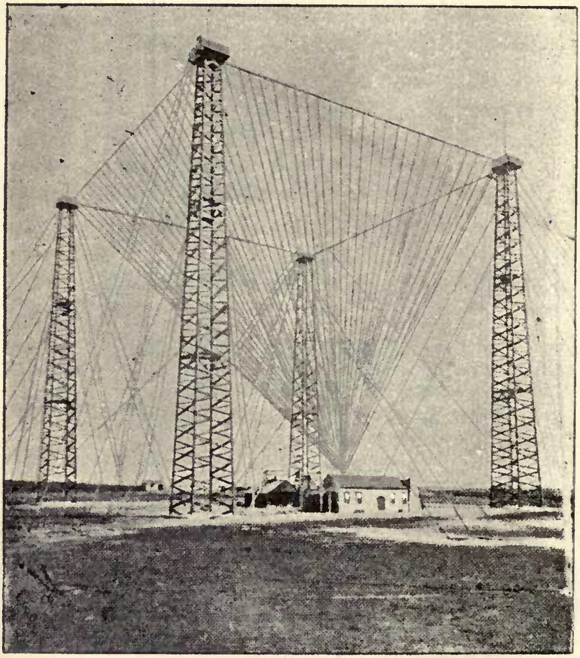


FIG. 40.—The Poldhu Wireless Telegraphy Station.

armature of an electric bell. This tapper taps or de-coheres the coherer, so as to render it again a bad conductor. However, for long-distance work the coherer is replaced by the magnetic receiver, in which case the Morse printer is not required, the records being read by telephone.

The main features of later improvements will be gathered from the foregoing. Of course, for large distances large amounts of energy must be radiated. This energy depends on the capacities employed in the exciting circuit and on the discharge potential. It is evident that aerials should have large surface, a single wire has not ; hence the multiple forms of aerial used by Mr. Marconi, as shown in Fig. 40. Then, again, where induction coils are used, a certain capacity only may be employed in the exciting circuit without interfering with the working of the coils. Since the discharge potential is nearly inversely as the capacity, the available energy would seem to be nearly constant in cases like those referred to, and it is usual to tune the aerials to two or three turns of the Tesla secondary.

Marconi's solution of the difficulty is said to be to first devote all the available energy to produce oscillations of any period in a primary circuit of the highest possible capacity. These oscillations are then brought to a high potential by means of the first Tesla coil, which charges another capacity, so that its period of discharge can be adjusted to the aerial by a second Tesla coil. M. Ferrie proposes to divide all the capacities which the transformer can charge into two or more groups placed in different oscillating circuits, but mounted on the same oscillator. All these circuits, adjusted to equal periods, act on the aerials through as many Tesla coils whose secondaries are mounted in series or parallel. Adjustment is made by trial with a thermal ammeter which must show the maximum reading. By the introduction of syntonisation and the use of the magnetic receiver, Mr. Marconi has been able to signal—indeed, to telegraph on many occasions—across 2,500 miles of ocean lying between Poldhu and Cape Breton in Nova Scotia, and more recently between Poldhu and Cape Cod in Massachusetts, over 2,800 miles, thus achieving a triumph for wireless telegraphy deemed impossible a few years ago.

At Poldhu (see Fig. 40), if report speaks correctly, an alternator of about 120 h.p. generates the current, which is interrupted by a magnetic or mechanical interrupter. The radiator consists of naked wires 200ft. long, arranged in a sort of inverted pyramid suspended from horizontal wires which stretch between two pairs of towers $65\frac{1}{2}$ m. (215 ft.) high and 60 m. (196·8 ft.) apart, the apex of the pyramid being connected to the power house. The wires are about 1 m. apart at the top, and they can be used in sections. The potential to which they are charged is so high as occasionally to cause sparking between the top of one of them and an earthed conductor 7 ft. or 8 ft. away.

History of Marconi's Success.—Marconi's first trials of wireless telegraphy were carried out at Bologna, and those being successful, he came to England and applied for a patent on June 2, 1896. He submitted his plans to the Post Office authorities, and they were taken up with the greatest promptitude. His first experiments were from the General Post Office, London, to a station on a roof 100 yards away. Later there were trials at Salisbury Plain, where two miles were accomplished, roughly-made parabolic reflectors of copper being here used. In 1897 the British Channel was the scene of experiments, and between Lavernock Point and Flat Holm 3·3 miles of distance were successfully negotiated. Next near Weston-super-Mare 8·7 miles—in this case the reflectors were not used. On May 11 and 12, 1897, the fate of Marconi telegraphy seemed to some observers to hang in the balance. The experiments were failures. An apparent inspiration, such as comes to the true genius, however, saved it. On the 13th the receiving apparatus at Lavernock Point was carried down to the beach at the foot of the cliff, and the vertical wire was thus lengthened by 20 yards, making 50 yards in all. The result was now a success, and the signals were perfect. Prof. Slaby, who assisted at these experiments, describes graphically the almost painful suspense of the first few minutes after the new and higher wire had been arranged, and whilst the experimenters were awaiting the signal, which, however, came with perfect distinctness a few minutes afterwards, "the Morse instrument visibly printing the signals borne to us by the mysterious ether from the island station, scarcely visible in the distance." This is how the matter appeared to those present, but a glance at Marconi's fundamental patent 12,039 of 1896 discloses the following lines: "The larger the plates of the receiver and transmitter, and *the higher from the earth the plates are suspended*, the greater is the distance at which it is possible to communicate at parity of other conditions." Probably Mr. Marconi was not insensible to the value of dramatic effect. Prof. Slaby has since become, himself, one of the most successful workers in this field, but in his book he handsomely acknowledges his indebtedness to the pioneer work of Marconi. The next trials were at Spezia, by request of the Italian Government, in July, 1897. Fairly good signals were received at a distance of 16 km. (10 miles). The screening properties of iron funnels of ships, and to some extent even of land, were here observed. In these experiments Mr. Marconi worked out more fully his law of distance which he thought proportional to the square of the length of the vertical conductors. Parallel conductors may be employed. The Marconi Company was established in July, 1897, and in that year a distance of 34 miles at Salisbury Plain was reached, and a permanent station established at Alum Bay, Isle of Wight. A director of the Donald Currie line of steamers asked that the passing of the "Carisbrook Castle," a steamer of that line, might be signalled to Bournemouth, and this was done, being the first use of wireless telegraphy in connection with the mercantile marine. Lloyd's now had signalling between Ballycastle and Rathlin Island established (7½ miles). The Marconi Company has since secured a monopoly from Lloyd's for fourteen years. Shortly after this, Mr. Marconi put up a station at Osborne for telegraphing to the Prince of Wales's yacht. The more important events from May, 1898, are given in chronological order.

1898.

May.—Experiments in connection with Lloyd's between Ballycastle and Rathlin Island, a distance of 7½ miles.

July 20 and 21.—Experiments in Dublin Bay; Kingstown regatta reported from "Flying Huntress" for *Dublin Daily Express.*

August 3. — Wireless communication established between Osborne House and Royal yacht at Cowes, I.W. Mast of yacht 83 ft., pole at Ladywood Cottage 100 ft., messages transmitted. Communication maintained uninterruptedly for sixteen days.

September. — Bournemouth installation removed to Haven Hotel, Poole Harbour.

December 24. — Communication established between East Goodwin lightship and South Foreland lighthouse, 12 miles ; 80-ft. mast on ship.

1899.

January.—Bulwarks of East Goodwin lightship carried away during heavy gale ; accident reported by wireless telegraphy to Trinity House.

March 3.—East Goodwin lightship run down by s.s. "R. F. Matthews" ; accident reported by wireless telegraphy to South Foreland lighthouse, lifeboats promptly put out, and lightship was saved.

March 27.—Communication established between Châlet d'Artois, Wimereux, near Boulogne, and South Foreland lighthouse.

September.—Chelmsford and Dovercourt installations erected. British Association meeting. Experiments in connection therewith between Town Hall, Dover, and Wimereux. Communication made possible between Wimereux and Dovercourt and Chelmsford, and Chelmsford to Wimereux—85 miles over sea, 35 over land.

October.—International yacht race reported between "Shamrock" and "Columbia." After the conclusion of the yacht race, experiments were carried out for the U.S.A. naval authorities, and messages interchanged between cruiser "New York" and battleship "Massachusetts," over a distance of 35 miles. On the return journey from America, Mr. Marconi fitted the s.s. "St. Paul" with wireless telegraph apparatus, and on November 15 established communication with the Needles station when 35 miles distant. The progress of the war in South Africa was reported by wireless telegraphy, and communications published on board the s.s. "St. Paul" in a leaflet entitled the *Transatlantic Times.*

October 31.—Agreement entered into with Mr. F. J Cross for the connection by wireless telegraphy of five Hawaiian islands—viz., Oahu, Kauai, Molokai, Maui, and Hawaii. This work was begun in 1900, and completed successfully by the commencement of 1901.

1900.

March.—The Marconi system was adopted by the Norddeutscher-Lloyd Steamship Company, and by agreement with this company Marconi apparatus installed on the Borkum Riff lightship and Borkum lighthouse, and on board the L.M.S. "Kaiser Wilhelm der Grosse."

April 25.—The Marconi International Marine Communication Company, Limited, incorporated with offices in London and Brussels, and agencies in Paris and Rome, for the maritime working of the Marconi system of wireless telegraphy.

July 2.—Contract entered into with the Admiralty for the installation of the Marconi apparatus on twenty-eight of H.M. ships and four coast stations.

Many plants have since been installed on ships of H.M. navy and at Admiralty coast stations. In addition to these installations, the six installations supplied to the War Office for field operations in South Africa were transferred to H.M. navy, and are still being employed by the latter in South African waters.

October.—High-power station at Mullion commenced.

November.—The Belgian Royal Mail Steam Packet "Princess Clementine," plying between Ostend and Dover, fitted, and a Marconi wireless telegraph station installed at La Panne, on the Belgian coast, near Ostend.

1901.

January 1.—"Princess Clementine" reported barque "Modora," of Stockholm, waterlogged on Ratel Bank.

January 8. — Wireless telegraph experiments on "Princess Clementine" carried out during storm, communication being maintained the whole way from Ostend to Dover.

January 19.—"Princess Clementine" ran ashore at Marikerke during a thick fog; intelligence of the accident conveyed to Ostend by wireless telegraphy.

February.—Communication established between Niton station (Fig. 41), St. Catherine, I.W., and the Lizard station, a distance of 106 miles. The Marconi system of wireless telegraphy was largely used during the voyage of the Duke and Duchess of Cornwall and York to Australia in 1901.

March 1.—Marconi system began to work commercially throughout Hawaiian Islands.

April.—Demonstration of the Marconi system arranged for the French Government, communication being successfully established and maintained for some time between a station at Calvi, Corsica, and another at Antibes, in the Riviera. The Prince of Monaco's yacht also fitted with Marconi apparatus at the same time for the purpose of demonstrating to the delegates of Congres International

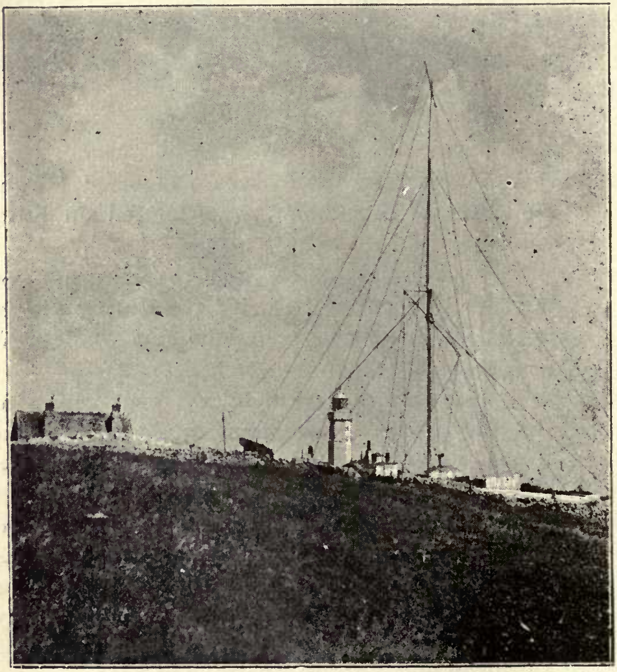


FIG. 41.—Marconi Wireless Telegraph Station at Niton, Isle of Wight.

de l'Association de la Marine the value of the Marconi system for maritime communication. Order received from the Canadian Government to instal Marconi apparatus at two stations on the Straits of Belle Isle.

May 21.—A series of Marconi wireless telegraph stations having been erected round the coasts of Great Britain and Ireland, the following were opened on this date for commercial telegraphic communication with ships at sea: Crookhaven, co. Cork; Rosslare, co. Wexford; Holyhead; Withernsea, near Hull; Caistor, near Yarmouth; and North Foreland.

Marconi stations have also been opened for communication with ships at sea at the following places: Borkum Riff lightship and Borkum lighthouse, Germany; La Panne, near Ostend, Belgium; Belle Isle and Chateau Bay, Canada; Nantucket Shoals lightship and Siasconsett, Mass., U.S.A.; Oahu, Molokai, Kauai, Hawaii, and Maui, Sandwich Islands. Stations are being erected at Banana in the Congo Free State and at Ambrizette (St. Paul de Loando) in Angola. Other stations are also to be erected in various parts of the world to meet the requirements of the large shipping companies, and in accordance with the agreement entered into by the Marconi companies with Lloyd's.

The first vessel of the British merchant navy to be fitted with wireless telegraph apparatus was the Beaver line s.s. "Lake Champlain," which left Liverpool on her first voyage fitted with wireless telegraph apparatus on May 21, 1901. The apparatus was transferred from this vessel when she was chartered for transport service, and is now on board the s.s. "Lake Simcoe," belonging to the same line. The Marconi apparatus is installed on the following steamers: Cunard Line — "Lucania," "Campania," "Umbria," "Etruria," "Ivernia," and "Saxonia"; Beaver Line—"Lake Simcoe"; Royal Belgian Mail—"Princess Clementine"; Norddeutscher-Lloyd—"Kaiser Wilhelm der Grosse" and "Kronprins Wilhelm"; Cie. Générale Transatlantique—"La Savoie"; American Line—"Philadelphia";

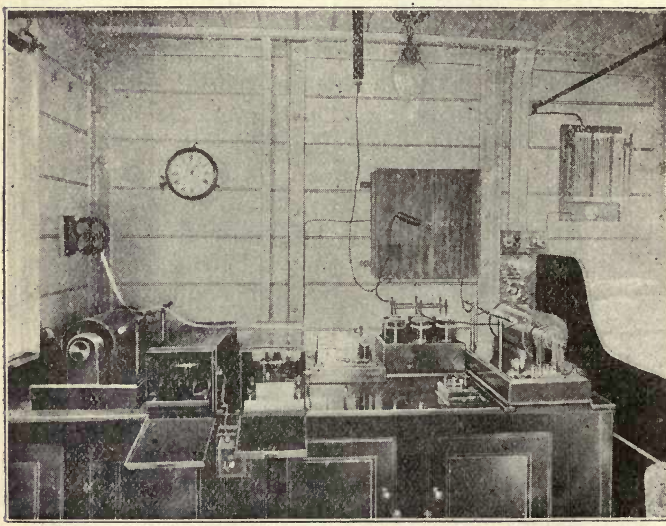


FIG. 42.—Interior of Marconi Cabin, Atlantic Transport Line s.s. "Minnetonka."

Atlantic Transport Line—"Minnehaha," "Minneapolis," and "Minnetonka" (for interior of signalling cabin of the "Minnetonka" see Fig. 42. The fore deck with aerial from sprit is shown in Fig. 43, the Marconi signalling cabin being conspicuous); Allan Line—"Parisian," "Tunisian," and "Ionian."

June 1.—Agreement entered into between Marconi Wireless Telegraph Company, Limited, and the *New York Herald* Company for the installation of

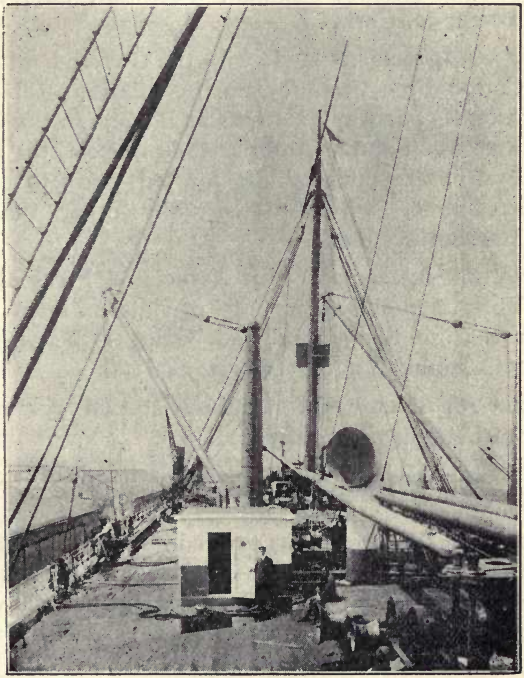


FIG. 43.—Fore Deck of Atlantic Transport Line s.s. "Minnetonka," showing Marconi Cabin and Aerial Sprit on Foremast.

Marconi apparatus at Siansconsett lighthouse, Nantucket Island, and on the Nantucket Shoals lightship for communication with ships at sea, interchange of shipping and other news between ships at sea and *New York Herald* office, and transmission and receipt of service and passenger telegrams.

June.—Wireless communication established between Poldhu station, Mullion, Cornwall, and Crookhaven, co. Cork.

July 23.—Agreement made with the Government of the Congo Free State for the installation of Marconi wireless telegraph stations at Banana in the Congo Free State and at Ambrizette in Angola, the Congo Free State undertaking for ten years to use no system of wireless telegraphy other than the Marconi system.

August 8.—Agreement with Associated Press at New York for the reporting of international yacht races in September and October between the "Columbia" and "Shamrock II."

August 16.—Nantucket wireless station commenced working commercially.

September.—The company opened school for training its technical staff at Frinton-on-Sea.

September 26.—Agreement entered into with Lloyd's for the installation of Marconi system of wireless telegraphy at Lloyd's stations throughout the world, and whereby Lloyd's agree for a period of fourteen years not to use or permit to be used at or in connection with any of their stations any system of wireless telegraphy other than the Marconi system.

October 1.—Stations for commercial wireless telegraph communication opened at Niton, St. Catherine, Isle of Wight, and Lizard, Cornwall.

October 26.—La Compagnie de Télégraphie formed, with its head office in Brussels, to develop and work the Marconi system on the Continent.

November 7.—Agreement made with the Government of Newfoundland for installation of wireless telegraph stations in Newfoundland and Labrador.

December 12.—Signals received by Mr. Marconi at Signal Hill, St. John's, Newfoundland, from Poldhu station, Cornwall, a distance of 1,800 miles across the Atlantic.

December 21.—Stations for commercial wireless telegraph communications opened at Malin Head and at Innistrahull.

1902.

January.—Mr. Marconi sailed for America on s.s. "Philadelphia," which vessel was fitted with his system of wireless telegraph apparatus, and during the voyage he succeeded in receiving legible messages up to 1,551½ miles and Morse signals up to 2,099 miles from Poldhu station, Mullion, Cornwall.

March 17.—Agreement entered into with the Government of the Dominion of Canada, whereby the Canadian Government agreed to subsidise the Marconi companies for the establishment of a station in Canada for wireless telegraphic communication between Canada and the United Kingdom, provision also being made for the erection and working of wireless telegraph stations in other parts of the Dominion of Canada. A station for transmission and receipt of Transatlantic messages at this time in course of erection at Glace Bay, Cape Breton

April 28, 29, and 30.—Demonstration arranged and attended by the chief officials of the Dutch Government, communication being established and maintained between the Dutch warship "Evertson" and Scheveningen. Agreement concluded with the Belgian Government for the installation of the Marconi system on nine of the Ostend-Dover Royal Mail boats and at two coast stations.

May 28.—Torpedo destroyer "Recruit" struck in Brissons in fog. Cruiser "Hyacinth," destroyer "Vigilant," and two tugs dispatched to render assistance. "Hyacinth" sent message by wireless telegraphy to Devonport advising the floating of the "Recruit.'

July 14-16.—Mr. Marconi received messages from Poldhu on Italian battleship "Carlo Alberto" at Cape Skagen, a distance of 800 miles, and at Kronstadt, a distance of 1,600 miles.

July 24.—Practical demonstration of Marconi system of wireless telegraphy on steamer "Koh-i-Noor" and at North Foreland station. Communication established with Southend-on-Sea, Frinton-on-Sea, Chelmsford, North Foreland, and Nieuport, in presence of Right Hon. J. R. J. Seddon, Earl Onslow, Lord Charles Beresford, the Belgian Minister, and other representative gentlemen.

August 30.—Mr. Marconi received messages from Poldhu on Italian battleship "Carlo Alberto" at Ferrol.

September 10.—Messages received from Mr. Marconi, stating that he had received messages on Italian battleship "Carlo Alberto" at Gibraltar, at Spezia, and throughout Mediterranean voyage

December 21.—Messages transmitted by wireless telegraphy from Cape Breton, Nova Scotia, to Poldhu, Cornwall.

1903.

January 19.—Message sent from President Roosevelt to the King, *viâ* Cape Cod and Poldhu (over 2,800 miles). Message clearly received at Poldhu and forwarded to Windsor.

March 18.—Remarkable experiments on tuning carried out by Dr. Fleming and Mr. Marconi between Poldhu and the Lizard (six miles); also Poole (200 miles). Two different sets of messages, one from the large station at Poldhu and the other from the small ship station at the same place being received *simultaneously* and on the same aerial at the Lizard, the former being checked by the Poole station.

Ships and Stations Fitted.—The following are some details giving the number of ships equipped by the Marconi Company up to date: British Admiralty, between seventy and eighty; Italian Navy, between forty and fifty; Cunard Company, eleven; Norddeutscher Lloyd, four; Allan Line, three; Atlantic Transport Company, three; American Line, four; Compagnie Transatlantique, six; Belgian Mail Packet, nine; Red Star Line, four; Hamburg-American Line, three; Isle of Man Steam Packet Company, one; Navigazione Generale Italiana, five ships already fitted and contract signed under which Marconi's have a right to equip (if required) the whole of this company's fleet, numbering about one hundred and twenty vessels; yachts, one ("Samaritan," Royal Yacht Squadron). Their recent contract with the Admiralty covers the use of the apparatus of this company on all ships of war which the naval authorities may decide to equip. They have also thirteen land stations in the United Kingdom, one in Belgium, two in Germany, four in America, two in the Congo Free State, six in Hawaii, two in Canada—twenty-nine in all. Three stations in Alaska, one in Havana, and one in Florida are being equipped, whilst seven shore stations have been erected in Italy, and seven more are to be in operation shortly; also six are on order for Newfoundland. The company by its contract with Lloyd's of September, 1901, has the right to equip any of the one hundred and twenty or so stations belonging to Lloyd's which it may be thought necessary to equip. A number of these stations have already been fitted, and are at work as wireless stations for communication with passing ships. There are also, of course, the three high-power stations at Poldhu (England), Glace Bay (Canada), and Cape Cod (U.S.A.), already referred to. That a ship, if properly equipped, need never lose touch with land (at least on a voyage from England to America) is shown by the journal published on board the "Lucania" on her voyage to America, October 12, etc., 1903, and other similar journals which have since been published. On October 14 messages were received from both sides of the Atlantic, the "Lucania" being then in mid-ocean. It is said to be the intention of the Cunard Company to fit their principal ships in a similar way with high-power apparatus, so that a daily journal containing news of current events on land may be produced on board. The daily "Atlantic weather" reports are also an important feature of recent wireless enterprise.

CHAPTER VII.

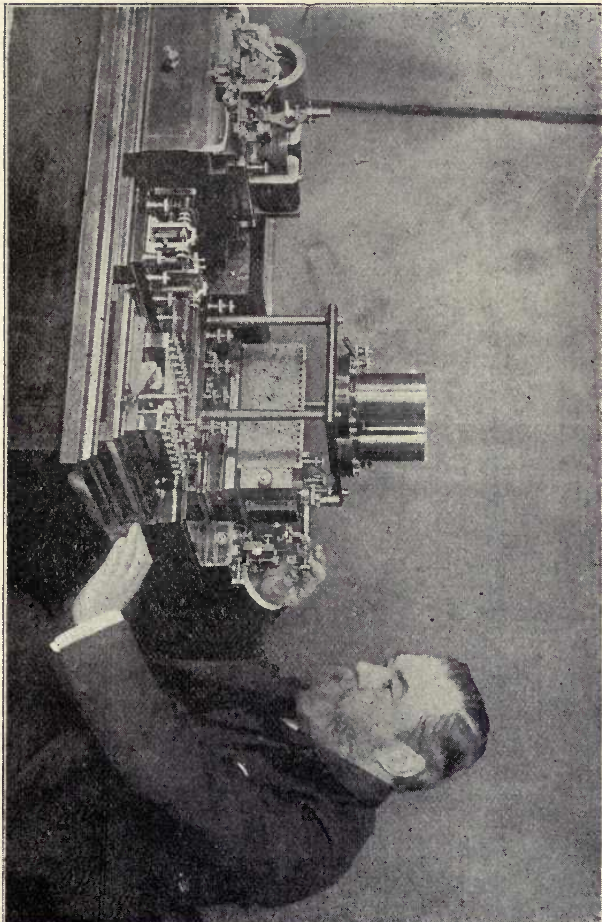
The Lodge-Muirhead System.

The work of Dr. Lodge in connection with space telegraphy has already been referred to frequently. He was the first, or one of the earliest experimenters, at any rate, to apply Hertz-wave methods to actual telegraphic signalling and—at the suggestion, it is said, of his collaborator, Dr. Muirhead—to use the former in the production of printed records as in cable work. Whilst Dr. (now Sir Oliver) Lodge has been very busy in other ways, the development of his wireless inventions has been in good hands; though progress has not been rapid it has been solid; every arrangement and detail of apparatus has had to pass the severest practical tests before being adopted. Hence the solidity and workmanlike design, excellent finish, provision for easy renewal of parts, as well as great simplicity of manipulation which characterise the apparatus of this system. The system has not been tried over very long distances, but up to 60 or 100 miles it has shown its excellence in many practical and searching tests. A coherer is used, and whilst for long-distance work other forms of receiver may be better, a coherer has the great advantage that it can be used with a printer to give a printed record, which is not the case with receivers employing a telephone.

Referring briefly to the special characteristics of the system, they are: (1) A coherer which is extremely sensitive and constant in action, requires no tapping or decohering, and very little, if any, alteration for long and short distances. (2) The elimination of the relay and the use of the siphon recorder, with consequent diminution of complication, increased speed of working,

SIR OLIVER LODGE.

and the use of less power. (3) And subordinate to the others, the use of a simple and effective form of interrupter by which the frequency can be varied at will by merely turning a screw. This is likely to prove of great value in the future if certain methods of tuning reach the importance we anticipate. (4) The provision



DR. ALEXR. MUIRHEAD.

of an automatic transmitting arrangement by which even the unskilled may send perfectly clear and well-spaced messages. Referring more fully to these in turn, we first notice:

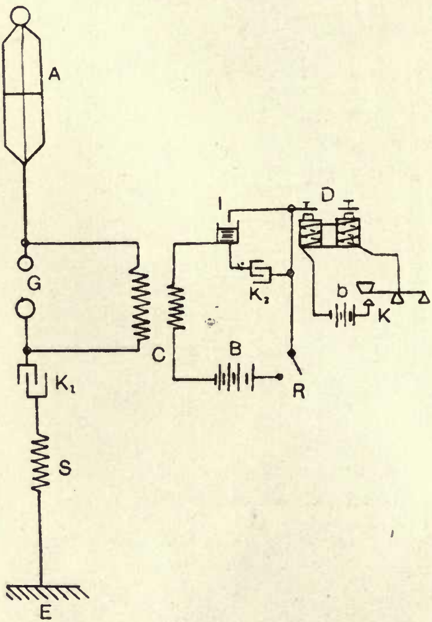


FIG. 44A.

The Transmitting Circuit.—The arrangement of this circuit is shown diagrammatically in Fig. 44A, where A is the aerial with wire-cage capacity, which can readily be varied by merely pulling a rope reaching to the ground. G is the spark-gap, having at its lower extremity the capacity, K_1, inductance coil, S, and earth capacity, E. C is a 10-in. spark induction coil of special construction, the primary of which has the

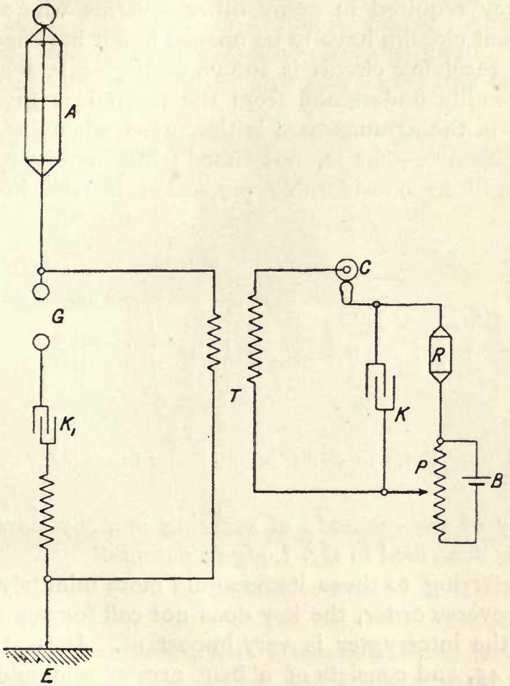


FIG. 44B.—A, Aerial ; E, Earth Capacity ; G, Spark-gap ; T, Transformer ; C, Coherer ; K, Condenser ; R, Recorder ; P, Potentiometer ; B, Battery.

sending battery, B, in its circuit, the primary switch, R, the capacity, K_2, and the interrupter, I, actuated by the "buzzer," D (consisting in effect of two Post Office sounders working reciprocally). There is also the sending key, K, and the local battery, *b*, which usually consists of a box of secondary cells. It will be noticed that the key only breaks the circuit of the *local* battery which is weak, hence the special form of key required in many other systems where heavy-current circuits have to be opened is not here necessary. The receiving circuit is shown in Fig. 44B, which will be readily understood from the references given. As shown, the arrangement is that used when the station is "open"—that is, not tuned; but tuning has been brought to considerable perfection by the inventors,

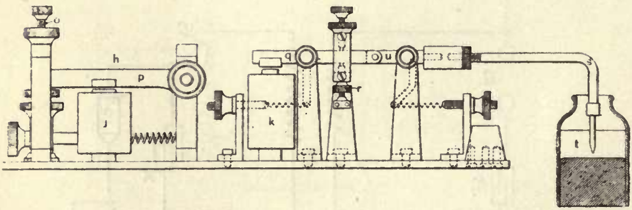


FIG. 45.—Elevation of "Buzzer Interrupter."

many of the methods of securing syntony now in use being described in Dr. Lodge's patents.

Referring to these items again more minutely and in the reverse order, the key does not call for any remark, but the interrupter is very important. It is shown in Fig. 45, and consists of a bent arm of aluminium with the vertical sharpened end of copper dipping into mercury, being alternately lifted and depressed by the action of an electromagnet, shown in the centre of the figure, controlled in turn by the buzzer—consisting of two Post Office sounders—which, of course, cost little, and remain for a long time in good order. The action will be understood from an examination of the figure.

The vibrator, *t*, is shown lifted out of the mercury, which is covered with oil. When the current passes, it energises the electromagnet, *k*, attracting the arm, *q*, which, being pulled down, depresses *t*, owing to the hinge at *u*. As soon as *t* makes contact with the mercury, the circuit through electromagnets, *j*, is completed, and *p* is pulled down, breaking the former

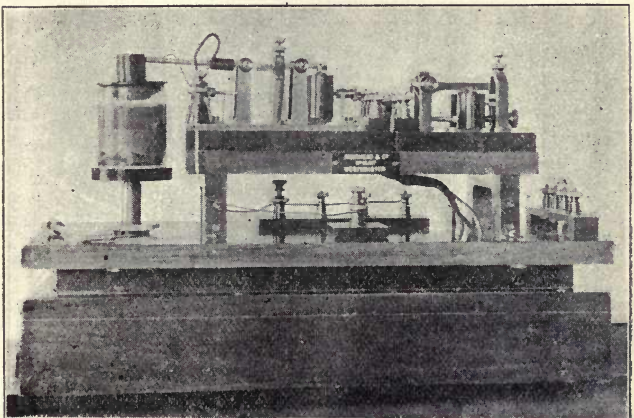


FIG. 46.—"Buzzer" Interrupter.

circuit, when the point, *t*, is lifted out of the mercury by the spring. This action takes place with great rapidity, a wide variation of frequency being possible. Adjustment of the speed of interrupter can be made, mainly by the milled screw to the left of *j*, and also by the other similar screws, near *k* and *s*. This can be effected whilst a message is being transmitted if necessary. A photo of the actual apparatus is shown in Fig. 46; the sparking apparatus is shown in Fig. 47, and it will be noticed that knobs or discs are not used, but simply two cylindric brass pillars with rounded ends.

The automatic transmitter is a very ingenious piece of apparatus, which is intended for use where the station is not under skilled supervision. As the system is one likely to come largely into private use, this is an important matter. A novice in sending a message

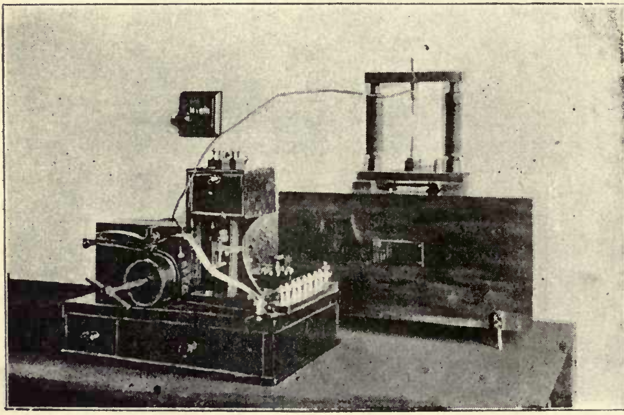


FIG. 47.—Receiving Apparatus with Siphon Recorder.

according to the Morse dot-and-dash alphabet finds great difficulty in *spacing*. He may very slowly pick out his letters correctly—so many dots, then a dash, and so on—but the spacing gives great trouble, and if wrongly done spoils the message. By means of the automatic transmitter, shown in Fig. 48, this difficulty is completely obviated. The sender sits down in front of the apparatus, which is provided with little vertical buffers, on which he impresses his message by means of blows. There are three little buffers shown to the right—the centre one giving the punched spacing for moving the strip, the left the dots, and the right the dashes. Seated in front of this apparatus, with a little hammer in each hand, or with the fingers merely, he spells out his message—dot, dot, dash, dot, etc.—by blows on the little buffers, paying no attention to spacing at all; the apparatus does this for him, and

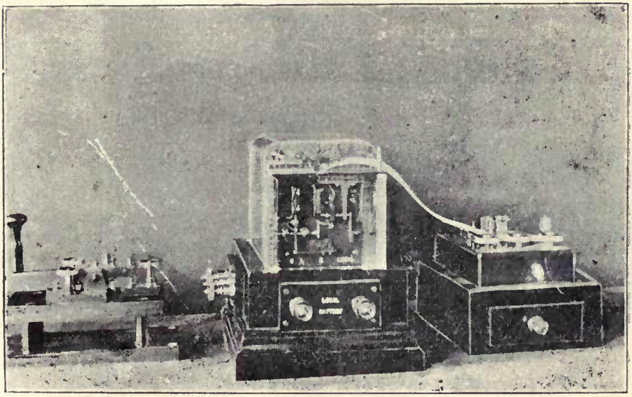


FIG. 48.—Automatic Puncher, Transmitter, and Key.

the message comes out punched on a moving strip of paper with perfect spacing. He has only now to lead the punched ribbon into the machine shown in the centre, and having closed his transmitting switch, sit down and watch the scintillations of the sparking apparatus as his message is sent automatically with a precision that no operator could exceed. A similar apparatus is used in cable work.

Receiving Circuit.—The circuit arrangements at the receiving station have already been referred to. A complete station outfit is shown in Fig. 49. By changing a plug over from the sending apparatus to the receiving portion, the operator joins the aerial to one terminal of the primary of the transformer, T (Fig. 44B), the other being connected to earth or the earth capacity, E. The secondary of the transformer is connected to the steel disc of the coherer, C, the mercury of the coherer being joined to the siphon recorder, R. The coherer has already been fully

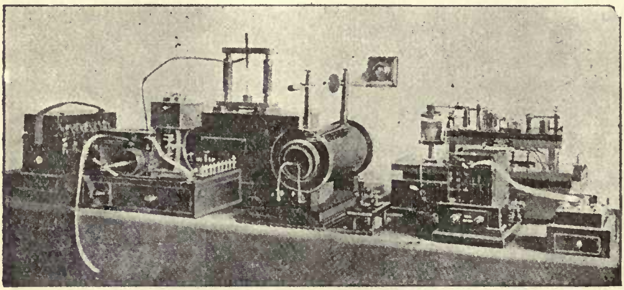


FIG. 49.—Complete Station Outfit (Sending and Receiving) Lodge-Muirhead System.

described. Shunted across the terminals of the recorder and battery is the capacity, K. The recorder having high inductance, the extra oscillations go by the capacity, and not through the recorder. The potentiometer to regulate the potential at the coherer terminals, and the battery, B, are also shown. This arrangement is that adopted when the station is not tuned. The putting of the plug into the position for *sending* a message automatically short-circuits the coherer, so that it is not necessary to shut it up in a metal box in order that it may be uninfluenced by the sparks of the transmitting apparatus. When *receiving*, the plug is placed as shown in Fig. 49, where the moving ribbon is seen on which the message received is recorded. The ribbon moves by clockwork, and the siphon of the recorder squirts a tiny stream of ink on it, the undulations of the line thus traced giving the message. The siphon is really a tiny tube of glass which is attached to the moving coil of a sensitive D'Arsonval galvanometer. The motion of this coil can also be made to close the circuit of a call-bell, so that the bell warns the attendant in charge of the station to be ready to receive a message. As, however, the message is printed, it can be read afterwards, even if the attendant be not present during the whole time of its reception.

Nothing which the author has seen in successful use in wireless work can exceed in compactness, excellence of finish, and reliability in working of the apparatus of this system, the cost being comparatively low. The power required for distances up to 100 miles is usually obtained from three 30 ampere-hour boxes of secondary cells ; but in many cases secondary cells are not now used, an ingenious combination of alternator and exciter being employed instead. If cells are used, they are readily recharged (if no other means be at hand) by a small dynamo driven by a tiny oil-engine kept in a hut adjoining the signalling station. A 150-ft. mast with wire-cage capacity was formerly used for distances up to 100 miles. The aerial, or aerial grid, has recently been greatly reduced in height. Up to twenty or thirty miles transmission, it is now not more than 46 ft. in height, and is of the form of an ordinary pyramid—the reverse of the inverted pyramidal form adopted by Mr. Marconi. It consists of four triangles of wire, with planes inclined to the horizontal, which form the sides of the pyramid, the eight ends of contiguous sides of the triangles being threaded through wooden battens, and thence to the apparatus below. The battens are fixed to the top of a central pole through the medium of insulators. The earth capacity used as the lower extremity of the system is formed by copper netting and plates laid on the ground. The width or span of the upper capacity area or grid is 120 ft., but the lower or earth capacity extends 6 ft. further out.

In receiving messages the aerial grid is connected to the primary of the "jigger" or transformer, the other terminal of which is connected to the wire netting or plates referred to above, an adjustment being possible by changing the "jigger."

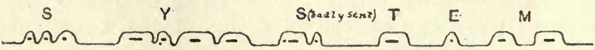


FIG. 50.—Tape Message Received by Siphon Recorder, Lodge-Muirhead System.

The term earth capacity has been used in the foregoing to designate the lower extremity of the spark circuit. It should be understood that in this system the earth is not used directly, as a rule. A capacity, such as a plate of metal laid on the earth, or the iron roof of a hut, is used instead. This gives a radiating system more in accordance with Hertz's original arrangement, and less subject to atmospheric influences than that in which the aerial is earthed. Recent experiments between Holyhead (Wales) and Howth in Ireland showed that the system worked perfectly over that distance, a 3-in. spark being sufficient. In fact, the attendant had no more difficulty in reading the messages than in the case of those received at Elmer's End from a distance of eight miles with intervening hills ; nor did the spark require to be much longer. Very successful working has also been carried on between Elmer's End and Aldershot, Aldershot and Portsmouth, etc. The extreme sensitiveness of the coherer and siphon recorder is such that any defect of the spark apparatus, such as the collection of dust or dirt, is at once evident to the receiver, and a message is sent back to warn the sender of the defect. The word "system"—telegraphed wirelessly and printed by the recorder—is photographed in Fig. 50, the second letter "s" having been badly sent. The wavy line is that traced by the recorder ; the dashes and dots were inserted afterwards by hand as explanatory of the siphon's record

CHAPTER VIII.

Wireless Telegraphy in France.

France has not been behindhand in this matter. We have already referred to the classic experiments of Prof. Branly in connection with phenomena previously noticed by Prof. Hughes and Prof. Calzecchi Onesti—viz., the fact that an imperfect contact (microphonic or that of filings) becomes comparatively a good conductor under the influence of electrical pressure, due (amongst other things) to ether waves from a distance. Onesti introduced his filings into the secondary of a Ruhmkorff coil, Branly found that the spark of a coil or condenser at a distance rendered his coherer or "radio-conductor" conducting. Since this important discovery was made many experimenters have been at work at various times in France.

In 1898 M. Ducretet made experiments between the Eiffel Tower and the Pantheon in Paris, a distance of 4 km. ($2\frac{1}{2}$ miles), and found that the Eiffel Tower worked well as a receiving station, but not as a transmitting station. In 1899 M. Ducretet made other experiments between Sacré-Cœur and the Pantheon, and also over the fortress of Bicêtre, between Villejuif and the station in Rue Claude-Bernard ($5\frac{1}{2}$ km.). These experiments attracted little attention as the distances were small, and they were undertaken in a city. M. Ducretet used different kinds of apparatus, patenting most of them either in his own name or in conjunction with Prof. A. Popoff, whose important work deserves special notice.

In 1899 M. Tissot (a naval lieutenant) made experiments with the Ducretet apparatus between the lighthouse at Trézien, in Corsica, and that at Stiff (Ushant), the distance being 32 km. (20 miles); also between Stiff and the lighthouse at Vierge Island, 42 km. ($26\frac{1}{4}$ miles). Further reference to M. Tissot's results will be made presently.

Experiments of Popoff.—In 1895 Prof. A. Popoff, the distinguished physicist of Cronstadt, made many experiments on atmospheric phenomena. He connected a coherer fitted with an automatic tapper to a lightning conductor, and with a relay and Morse printer in the circuit obtained important records of electrical disturbances at a distance. Prof. Popoff has made many experiments since that time, and has lately brought out a new coherer which has been successfully employed in conjunction with a telephone receiver. In this coherer little bands of platinum are placed in proximity to each other in a small tube of glass or other insulating material. In the interior of the tube, and in the spaces between the bands, are grains of steel. The distance apart of the platinum bands is determined by the fineness of the grains. The state of oxidation of the surface of the grains assures great sensitiveness in the apparatus. The novel point in the coherer seems to be that the surfaces of the platinum are lengthwise in the tube instead of across it, as in most coherers. Thus, the surface exposed to the action of the steel dust is greater, and the sensitiveness is correspondingly increased. The general form of the coherer may be gathered from Fig. 51, which also shows the arrangement of receiving circuit adopted. A is the aerial or antenna, having in its prolongation the primary coil of the transformer, T. B is a battery and C the coherer. The secondary coil of the transformer has the telephone receiver, S S, in its circuit. The battery is not indispensable, but strengthens the received impulses. Prof. Popoff, using

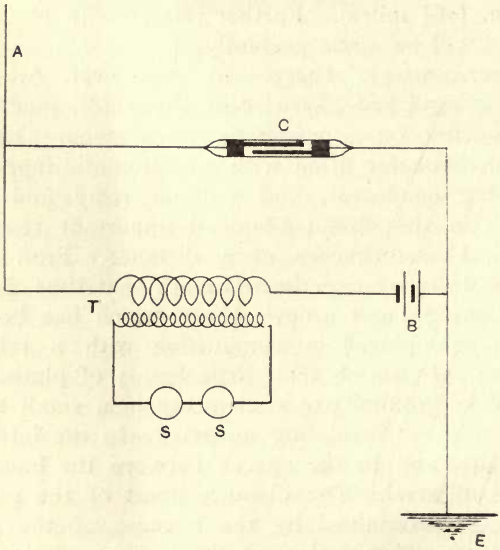


Fig. 51.

this method, has been able to attain regular transmission of messages over distances of from 36 km. to 50 km. ($22\frac{1}{2}$ to $31\frac{1}{4}$ miles). For instance, communication has been established since February, 1900, between an island in the Gulf of Finland (Hogland) and the continent. One of the stations is placed near a country wood, and several islands intervene between the stations. The masts carrying the antennæ are 48 m. ($157\frac{1}{2}$ ft.) high, and a regular service of communication is carried on.

The Ducretet System.—M. Ducretet, as already stated, has made many experiments and tried various systems at different stations in France. In Fig. 52 one of these is represented in outline as far as regards the receiving circuit and apparatus. The waves received

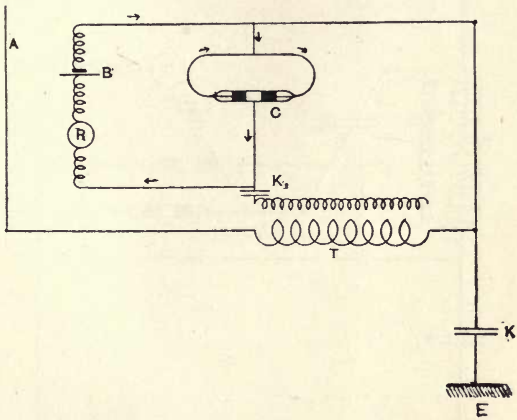


Fig. 52.

by the aerial, A, traverse the primary coil of a transformer, T, and are directed towards the ground through a condenser, K, the secondary coil of the transformer being in communication with the coherer, C, through an intermediate condenser, K_2. The coherer forms part of a circuit comprising the relay, R, and cell, B, which circuit communicates with the earth through the condenser, K. Another arrangement is shown in Fig. 53, where the coherer has *three* terminals instead of two, as before. The filings or metallic dust used in this coherer are of steel mixed with silver or rhodium. The arrangement will be understood from the figure. There is the transformer as before, the two condensers, the coherer, and

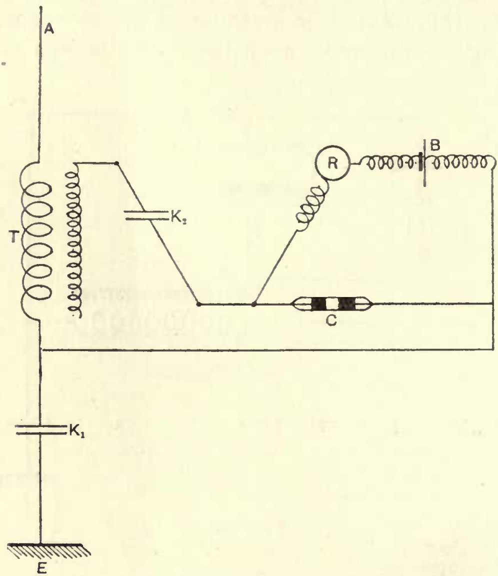


FIG. 53.

choking coils to prevent the vibrations received through the antenna being wasted in the cell or relay.

Experiments of M. Tissot.—Many of M. Tissot's important experiments deal especially with syntonisation. He has tried to realise syntonic transmission by utilising the arrangements described by Mr. Marconi, especially that including the "jigger." Although he has tried to follow scrupulously the indications furnished by Mr. Marconi in connection with the subject, he has not been able to realise the hoped-for results as far as regards syntony, neither at Trézien nor at the station at St. Martin, where the experiments were carried out. M. Tissot concludes that if Mr. Marconi

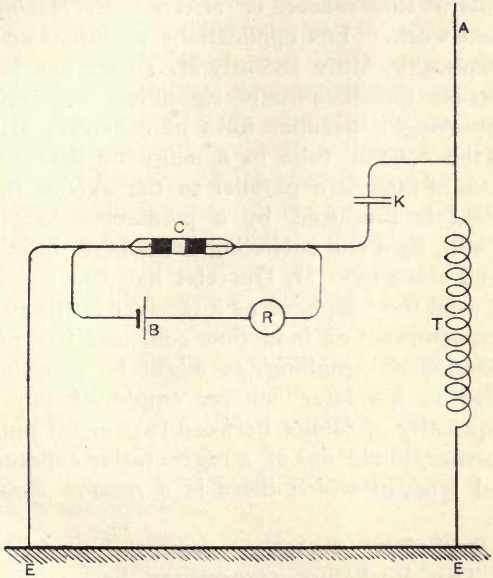


FIG. 54.

has realised the transmissions which have solved the problem of syntonisation, it has been by the use of methods other than those described. In the course of his experiments M. Tissot was led to adopt an arrangement which, if not solving the problem of syntonisation, at least augmented the security of selective reception. His arrangement is shown in Fig. 54, where A, the antenna, is joined to earth through the primary of an induction coil, T. A wire from the antenna goes to one terminal of a condenser, K, of which the other is connected to earth at E through the medium of the coherer, C. A shunt from the ends of the coherer contains a cell, B, and a relay, R. (For further particulars the reader is referred to M. Turpain's excellent work, "Les applications pratiques des Ondes Electriques.") More recently M. Tissot has been able to increase the distance of signalling very appreciably by employing a peculiar form of coherer. M. Tissot places the coherer tube in a magnetic field, of which the lines of force are parallel to the axis of the tube. The field is produced by a permanent magnet, or, better still, by a coil encircling the coherer tube.

In and since 1900 M. Ducretet has to a considerable extent used the telephone as a receiver in the secondary of a transformer or induction coil, and has increased the distance of signalling, as might be expected. He has also in his later coherer employed only a very small quantity of filings between two metal plugs, and has, further, made use of a regenerative coherer of the Blondel type, in which there is a reserve chamber of filings.

M. Rochefort is another successful worker in this field. The Rochefort transmitter has such special features as the Rochefort rotary interrupter and the Rochefort unipolar transformer. In the latter, the whole of the pressure is on one side of the pole—viz., on that side connected with the antenna. He has a receiver, the sensitiveness of which can be regulated by a magnet, and he uses the automatic Morse machine of the French Government type, with a resistance in circuit with the coherer to regulate the sensitiveness of the (Claude) relay. This arrangement has been very successful. Twenty-four stations in and at the disposal of the French navy have been fitted with Rochefort apparatus. Stations have also been installed on the French coast fitted with Rochefort-Tissot apparatus. The average distance of signalling between vessels and these stations is about forty or fifty miles. Vessels fitted with the above apparatus are said to be able to read messages sent out by vessels of the German navy, and also by vessels fitted with Marconi apparatus as well as from the Marconi station at the Lizard. M. Rochefort has found out a very important thing—viz., that a coherer can be made to decohere automatically by the passage of a small current through it. When the coherer has been influenced by ether waves, if a current of n milli-amperes be sent into it, then under succeeding waves the needle of the ampere-meter in series oscillates between values greater and less than n, returning to about n when the waves have ceased. The value of n depends on the resistance in circuit, the intensity of the waves, and the difference of potential applied to the terminals of the coherer.

Marconi's Experiments in France.—In March and April, 1899, Mr. Marconi established communication between a station at Wimereux in France and the South Foreland, a distance of $28\frac{2}{3}$ miles, also with a third station at the lightship "Goodwin." These experiments were very successful, clear signals being obtained at all times. Experiments were also tried between the stations named and two vessels, the "Ibis" and "Vienne." The distance of the "Vienne" from the South Foreland was on one occasion 52 km. ($32\frac{1}{2}$ miles), and messages were received *by the ship.*

Experiments on screening, and also on syntony, were carried out, but an accident prevented the final tests from being carried out. However, between the "Vienne" and Wimereux some experiments showed that messages could not be received by one from the other when they were differently tuned *as long as the distance apart was greater than a certain amount,* but when nearer than this signals could be read just as clearly as if syntonised to suit each other. M. Ferrie, himself an expert in this subject, superintended these experiments for the French Government. M. Ferrie also installed a provisional station at Dunkirk on the occasion of the departure of the French squadron for Russia. He was able to receive telegrams from a number of English Marconi stations, and gives it as his opinion that syntony, as practised at that time, is no protection, or, at least, only a very limited protection against messages being read.

CHAPTER IX.

German Systems.

The Arco-Slaby System.—This system, which has been in successful use not only in Germany, but in various other countries for some years, is the product of Prof. Slaby—who was present at some of Mr. Marconi's earlier experiments in England—and his assistant, Count Arco. Many of the ships of the German navy and German mercantile marine have been equipped with the apparatus of these inventors, and over fifty new stations on this system have been installed during one year. The various arrangements described by Prof. Slaby cannot be fully discussed here, but the principal features of the receiving and transmitting circuits will be given.

Fig. 55 shows one form of the receiving circuit, in which A is the aerial, M a coil "of special form and winding, producing at the coherer, F, a tension loop whose amplitude is considerably larger than at A." This coil, M, is called by Prof. Slaby a tension multiplier. Probably the reason for its use is the fact that at the top of an aerial the pressure is greatest (as shown in Fig. 3 (p. 38), and hence the coherer ought to be placed there. This is, however, not convenient, and Mr. Marconi got over the difficulty by introducing the transformer or "jigger" (nautical term for "hoister," used here because it hoists or raises the potential) at the foot of the aerial, where the pressure is least, but the current greatest. Prof. Slaby by stretching a wire horizontally from the base of the aerial and making this wire of the same length (or inductance) as the aerial, gets a similar arrangement of pressure as in the aerial, and is thus able to place his coherer at a point corresponding to the top of the aerial. It is not necessary that this wire should be all stretched out straight, some

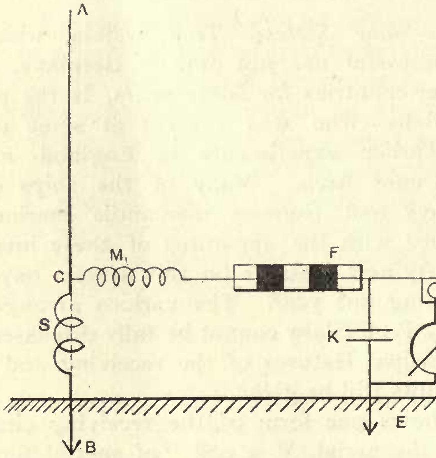


Fig. 55.—Receiver Circuit, Arco-Slaby System.

of it may be in the form of a coil, and this coil is probably that to which Prof. Slaby refers in the passage quoted above. K is the condenser inserted parallel to the battery, P, of the relay, R. The capacity of K is about one hundred times that of the coherer. Other arrangements are possible; for instance, in some cases two coils like M are employed, the coherer being connected to a point on the wire between them.

One form of the transmitting circuit, as used on warships, is shown diagrammatically in Fig. 56. The exciting circuit is earthed at E, and contains the variable self-induction, S_1, the condenser, K, the spark-gap, F_1, and the insulated connecting wire, C D. In a watertight chamber on the deck is placed the multiplier, M, complete with spark-gap, F_3, and trans-

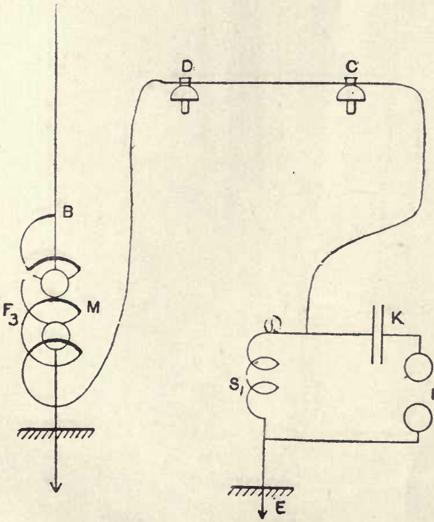


FIG. 56.—Transmitter.

mitting aerial, B. In the insulated wire, C D, there is, therefore, only the potential of the 15-mm. spark-gap, F_1. In the aerial this is increased by the multiplier and spark-gap, F_3, to that of 150 mm. or 200 mm.

A complete station outfit for low-tension work is shown in Fig. 57, having the inductor (shown high up on the wall), the primary condenser, turbine interrupter, Morse instrument, three-step regulating resistance, and lightning arrester. None of these call for special remark, except the mercury turbine interrupter (seen to the right on the table), which consists of a small

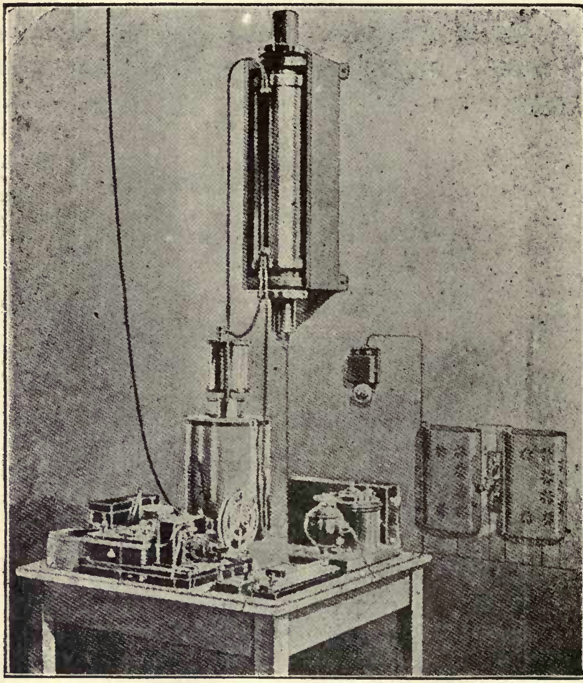


FIG. 57.—Complete Outfit for Wireless Telegraphy—Arco-Slaby System.

turbine driven as a centrifugal pump by an electric motor. It squirts mercury through a small opening, two square millimetres in area, in a horizontal plane. A metal segment ring is placed on the turbine shaft, and the mercury strikes against this ring during a part of every revolution. The mercury is connected with one pole of the current supply and the segment ring with the other; the circuit is by this means opened and closed automatically with any desired frequency, which may be varied by varying the speed of the turbine. The turbine casing is filled with alcohol, to quickly extinguish the sparks caused by the break of circuit. For use on board ship the turbine is mounted on trunnions, so as always to remain with its axis vertical. This interrupter works very satisfactorily, but the use of several pounds of mercury is somewhat of a disadvantage, and to get over this difficulty another form has been devised, in which a disc provided with copper segments runs under carbon brushes, being driven by a motor, the variation of the speed of which gives the required variation of interruption.

For large electrical outputs the Grisson rotary converter is employed. This gives a true alternating current instead of the interrupted direct current, due to the turbine interrupter. It is shown in Fig. 58. P is the inductor, which has besides its two main terminals, P_1 and P_2, a third terminal, P_3, which is connected to the winding of the coil as shown. Direct current is sent into coil P_1 P_3, and is kept on till it reaches a maximum. When this is reached the current is passed through the circuit of a second coil, P_2 P_3. The coils have a common iron core, which they magnetise in an opposite sense, so that when the current is sent through P_2 P_3 a back electromotive force is induced in the first coil, P_1 P_3, reducing the current flowing in it nearly to zero. At this moment the first circuit is interrupted, and the current in P_2 P_3 immediately rises to its maximum. These operations are performed automatically by a device consisting of two commutators, U_1 and U_2, insulated from each other and mounted on a common shaft, being fitted with col-

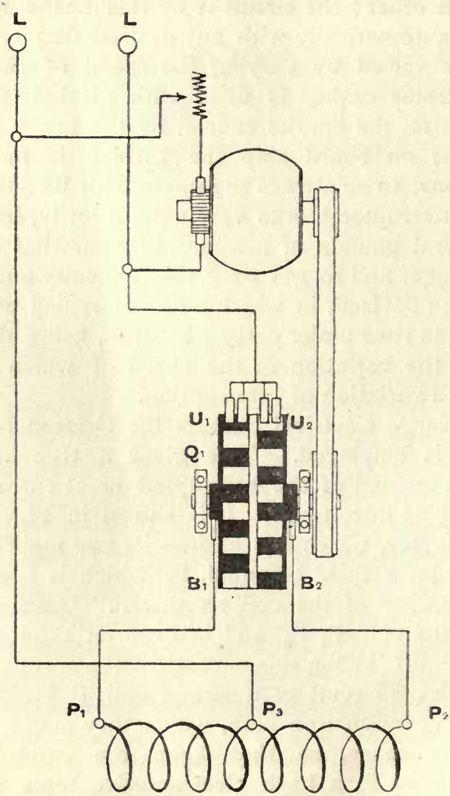


FIG. 58.—Connections of Grisson Converter.

lector rings, B_1 B_2, and on the other hand with a common brush, B_3, which makes contact alternately with the segments U_1 and U_2, or connects them with one another. The contact device is driven by a small electric motor. This apparatus gives a pure alternating current, the frequency of which can be varied from 15 to 100 cycles per second. All the standard inductors of this company can be used with these converters by the addition of the connection P_3.

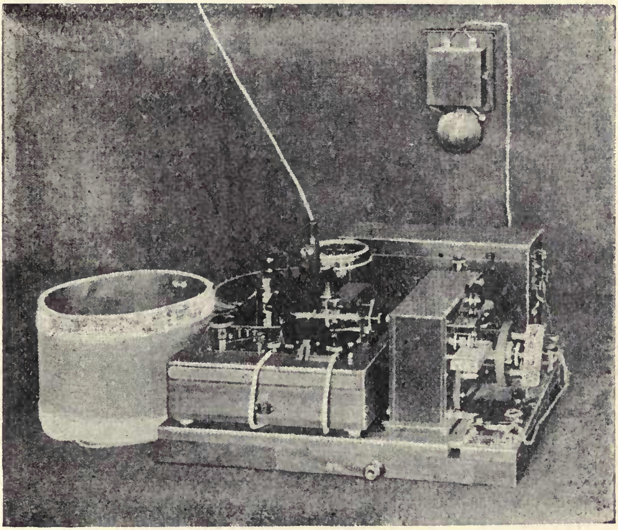


FIG. 59.—Receiving Apparatus.

A view of the receiving apparatus for high-tension work is shown in Fig. 59. The receiver here consists of two separated circuits, which have been designated the weak current circuit and the heavy current circuit respectively. The weak current circuit includes the coherer (Fig. 60), interrupter, coherer cell, relay, condenser, regulating resistance, and make and break switch. The coherer is of special form (patented) which permits its sensitiveness to be varied at will. The ends of the silver plugs are *not* parallel, but taper.

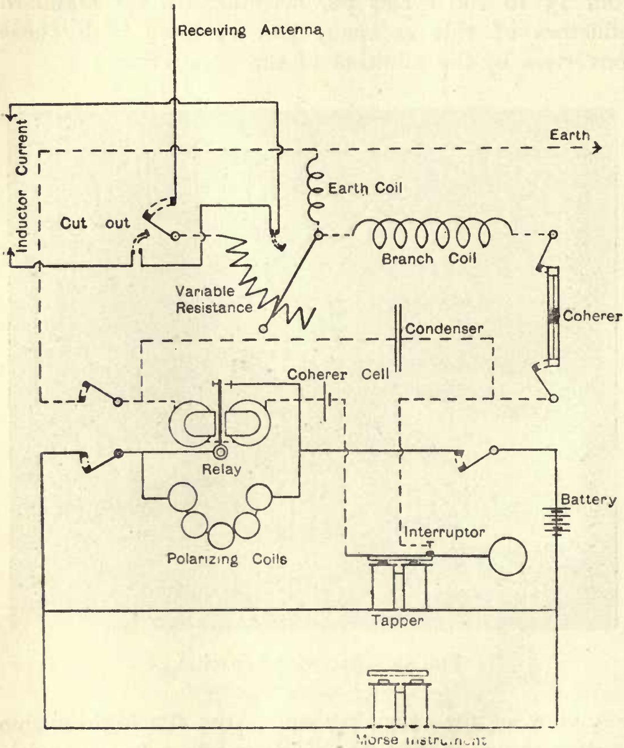


FIG. 60

If placed with the smallest part of the opening downwards, the filings fill up the greater part of the space, and the coherer is then most sensitive If the widest part of the slit is placed downwards, the powder is divided over a large surface, and the sensitiveness of the coherer is least. The "fritter" can be turned on its axis by a thumbscrew, so that any desired degree of sensitiveness can be given even when telegraphing. (The tapering ends are quite common, but the convenient means of turning the slit into any required position may be new.) The weak current circuit is shown by dotted lines and the heavy current circuit by light continuous lines in Fig. 60. The latter includes the heavy current battery (not shown), the tapper, the relay, relay working contact and tongue, polarising elements, Morse magnets, and the alarm (not shown). A microphone receiver of an interesting kind is employed when telephones are used.

The patents of this system are, or were until recently, owned by the Allgemeine Elektricitäts-Gesellschaft, by whose permission these illustrations are shown. The combination of this system with that of Braun, Siemens, and Halske under the title "Telefunken" is referred to later on. The owners publish full information, and show a fac-simile reproduction of a Morse message received from the steamship "Deutschland" when at a distance of 150 km. (94 miles).

A warship of the German navy fitted with an installation of this system is shown in Fig. 61. The receiving and transmitting aerials will be seen attached to a sprit on the foremast.

In connection with this matter of long-distance work, Prof. Slaby gives a curve showing the height of masts or antennæ required for a given distance. From this curve the author has deduced the following approximate *law of distance*, $h^2 = 25{\cdot}6\, d - 112$, where h is the height of aerial in metres, and d the distance of transmission in kilometres. (A kilometre is about five-eighths of a mile.) This law must not be used for values of d less than 10 or greater than 140, and holds good only for distances measured over water. It gives the height of aerial slightly in excess of the correct value (as shown by the curve) for intermediate distances. Mr. Marconi gives the law $d = c h^2$, where d is the distance at which the signal may be received, h being the height of the

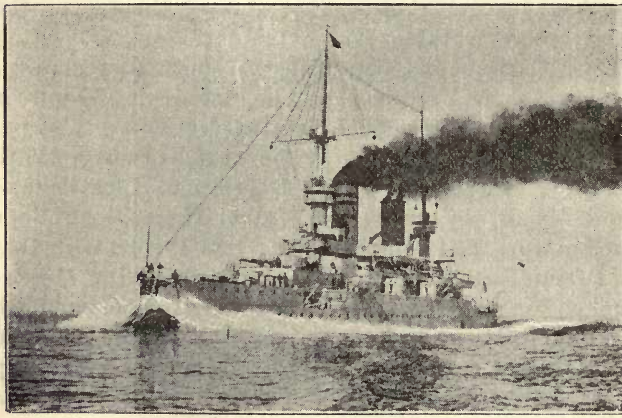


FIG. 61.—S.M.S. "Kaiser Barbarossa."

aerial (both in metres), c a number varying from 30 to 1,000, according to the nature of the receiver and transmitter employed. Recent researches by Mr. Marconi and others seem to indicate the possibility of tall masts and aerials being dispensed with to a large extent, or at any rate to the material lessening of their height in the near future.

Installations on the Arco-Slaby system have been established for the following countries: Austria, Sweden, Norway, Portugal, Russia, Denmark, and Chili, mainly in connection with their marine requirements. A very interesting station has been fitted up; it is situated on the Zugspite, the highest mountain in Germany, from whence communication is kept up with a station 2,000 m. (6,650 ft.) lower down.

DR. BRAUN.

The Braun-Siemens and Halske System.—In this, one of the most successful and, in some respects, most novel and interesting of the Continental systems, a closed circuit is employed, in which oscillations are set up, which may by a proper choice of self-induction and capacity be adjusted to a determined period. An open resonator is employed, and this transmitter sends out waves of a known length, the circuit of the receiver being tuned to respond better to this length of wave than any other. The inventor of the system is Prof. Braun, of Strasburg, and it has been acquired by the great German electrical firm of Siemens and Halske. Symmetry is observed in both the transmitting and receiving apparatus, and—unlike some other systems—there is not any earth connection, this fact causing the apparatus to be very little affected by atmospheric disturbances. The transmitting circuit is shown diagrammatically in Fig. 62, where J is the inductor, S

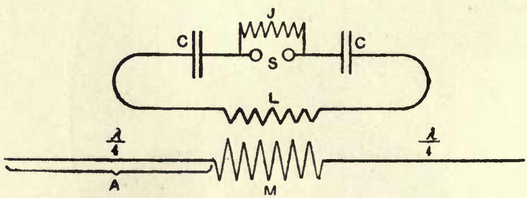


FIG. 62.

the spark-gap at the secondary terminals of same, L the self-induction, C the capacities. It is not difficult to show that in a circuit of this kind the discharge sets up oscillations of which the periodic time T is, according to Lord Kelvin =

$$\frac{2\pi\sqrt{LC}}{\sqrt{1-\frac{CR^2}{4L}}}$$

and if $\frac{CR^2}{4L}$ is small in comparison with 1, as is usually the case, then $T = 2\pi\sqrt{LC}$, very nearly; or $L = \frac{T^2}{4\pi^2 C^2}$ which enables the self-induction to be calculated if the other quantities are known ; or C to be obtained if L and T are determined. If λ is the wave-length since $\frac{\lambda}{T} = V$ (the velocity of light), then $T = \frac{\lambda}{3 \times 10^{10}}$ where λ and the velocity are in centimetres and centimetres] per second respectively.

Referring to Fig. 62, the oscillations of the closed circuit of the resonator are forced upon the secondary coil, M, and in order that the intensity may be a maximum an amount of wire or capacity must be added to

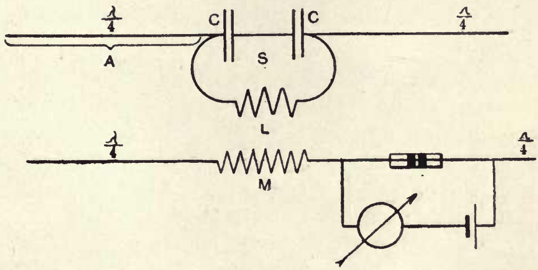


FIG. 63.

each end of M to put this secondary circuit in resonance with the closed circuit. The length of this secondary circuit on each side of M is found to be $\frac{\lambda}{4}$ if the best results are to be obtained. One of these lengths includes the aerial ; the other may be coiled into a coil (but shortened owing to increased self-induction), or it may be replaced by a suitable capacity. The receiver circuit, shown in Fig. 63, is very similar to that of the transmitter, but the action is reversed, the etheric oscillations being received in the open circuit, A, and forced on the closed circuit, which in this case affects through M the circuit containing the coherer, relay, and indicator or Morse machine.

Referring more fully to the apparatus, the inductor or induction coil (Fig. 64) differs considerably from others in use, since the aim is not so much the high pressure necessary to produce sparks across the gap as a large current output. This is attained by the use of a special iron core, a larger primary and a shorter and

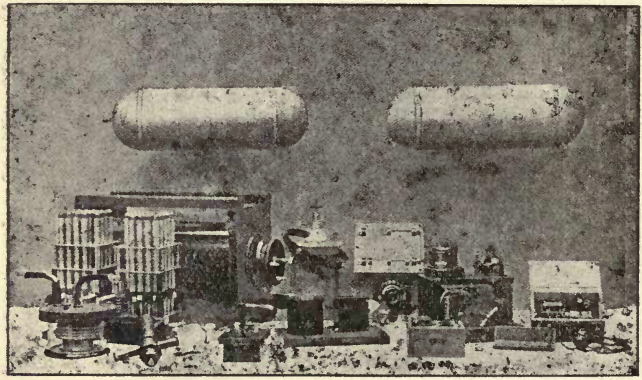


Fig. 64.

thicker secondary winding than is usually employed. The insulation is also double that of the ordinary coil, and hence it will work well even in damp places. The primary has three terminals, giving different lengths of primary for different interrupters. With these inductors large capacities can be charged in a short time. The interrupter is of the "Wehnelt" electrolytic type. This electrolytic break, brought out in 1899, employs for one electrode a lead plate immersed in dilute acid, and a platinum wire passing through the bottom of a porcelain tube for the other. In a circuit containing inductance the current passes intermittently from the platinum to the lead, the interruptions being very rapid, as high as several thousand per second in some cases, and being to some extent variable, depending on the amount of protrusion of the platinum wire. It has been found to work best at a potential difference of 60 to 80 volts, and gives usually from 100 to 2,000 interruptions per second. The interruptions are not, however, under such exact control as in some of the other breaks already referred to. In the form shown the upper part of the platinum pole above the surface of the liquid is also protected from acid vapours by the porcelain tube. A peculiar form of Morse key is necessary to take the heavy currents—as much as 50 amperes. A magnetic blow-out is fitted, which quickly extinguishes the spark. The Leyden jar capacities are of elongated cylindrical form. To provide a capacity to balance the aerial in the secondary wire of the transmitter, round-ended cylinders are employed. Two of these are shown suspended above the apparatus in Fig. 64, where the inductor with three projecting terminals is seen to the left, with the Leyden jar capacities in front of it, and the transformer, M, already referred to, in front of that again. The interrupter is distinguishable (in the centre) by the peculiar inclined hoop with which it is surrounded, the remaining apparatus being the Morse key, etc. The receiving apparatus is shown separately in Fig. 65, the coherer consisting of an ebonite tube containing hardened steel particles of a uniform size between two polished steel electrodes. It is known that a coherer becomes magnetic by use, and whilst this to a certain extent aids the coherer in the performance of its functions, too much magnetisation renders it unreliable. To obtain the requisite amount of magnetisation, and to render the coherer adjustable as to sensitiveness, a permanent ring magnet is fitted to it. Where a *record*

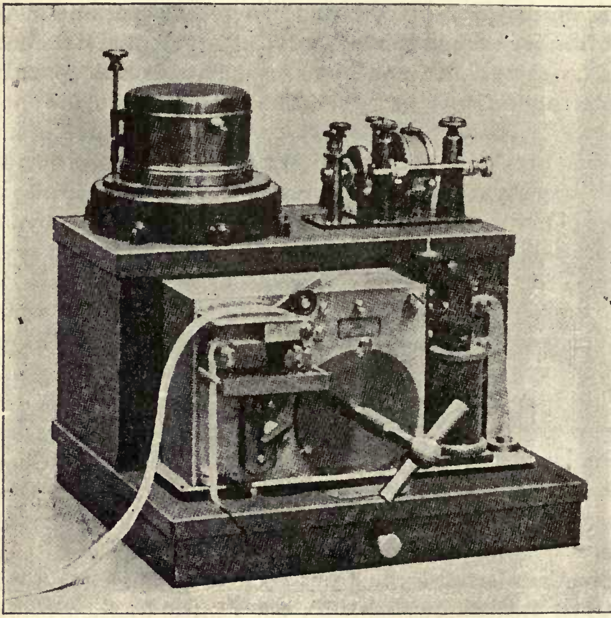


FIG. 65.—Receiving Apparatus.

is not wanted, where syntonising is not of importance, and for great distances, a telephone receiver with microphonic attachment is employed. The microphone consists of a steel disc pressed against a carbon or steel point. By means of a screw the pressure of the disc on the point, and hence the sensitiveness of the receiver, can be varied at will. The microphone telephone and dry cell are shown in Fig. 66. A view of the installation in one of the principal stations in Berlin fitted up with the apparatus of this system is shown in Fig. 67.

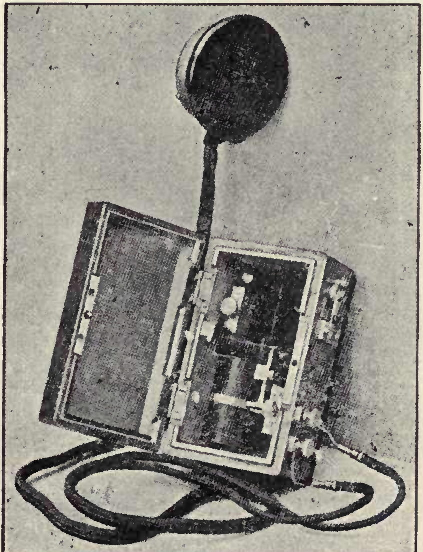


FIG. 66.

Wireless telegraphy is destined to play a very important part in modern warfare, and the field equipment shown in Figs. 68 and 69 is interesting in this regard as showing what is being done in the Germany army.

The New Wave-Meter (Arco-Rendal System).—Early in the history of wireless experiments inventors set to work to improve the effects due to electric waves, using

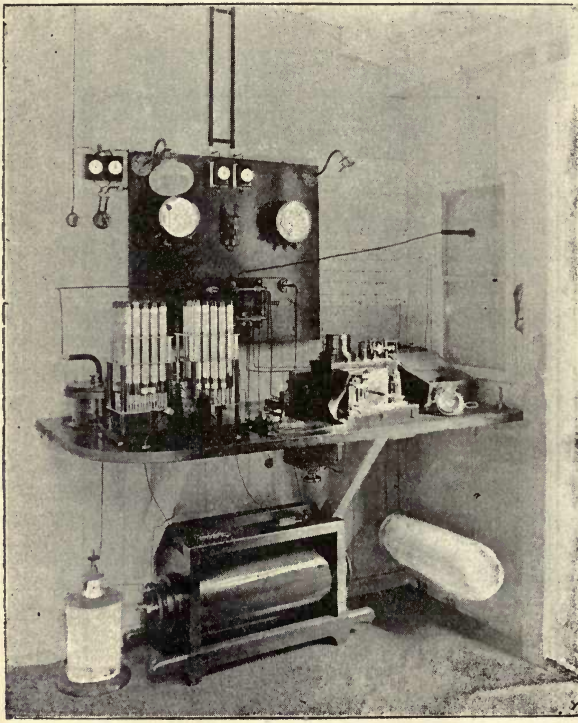


FIG. 67.—Braun-Siemens and Halske System. Interior of the "Hochbahn" Station, Berlin.

the well-known laws of electric resonance. But new difficulties accompanied the new improvements, definite dimensions and dispositions were necessary to suit each wave-length. Hence the difficulty of tuning, say, a dozen stations so as to properly respond to the same wave-length, though their installations may be quite different. The wave-meter, therefore, becomes a necessity.

The principle of this apparatus consists in establishing a normal open or closed system, in which the inductance and capacity are both variable. The variations are indicated on a scale, and the scale may be

FIG. 68.—German Army Wireless Field Equipment.

calibrated to directly indicate lengths of waves. The simplest form consists of a coil covered with one layer of wire. The number of turns put in circuit can be easily regulated by a slider, which allows the short-circuit of a certain number of turns. The principle was initiated by Count Arco, and developed by Mr. Rendal. The apparatus is attached to the system to be indicated, and the number of windings put in circuit changed until the coil comes into resonance, which is recognised by observing the maximum rise of potential at the terminals of the coil, which in turn may be measured by the length of spark obtainable. The number of turns in circuit being noted, the wave-length is found from a curve. This apparatus, though simple, is not exact enough for up-to-date technical work.

FIG. 69.—German Army Wireless Field Equipment.—Detachment on the March.

The precision of a measuring operation depends essentially upon the damping conditions as well of the wave-meter as of the oscillating circuit to be indicated. The measuring coil shows less damping than a long conductor, because it emits less of its oscillating energy, but more than a closed circuit. The closed-circuit form of the apparatus was originated by Herr Dönitz and Dr. Franke, and is patented by the Braun, Siemens, and Halske Company. A closed circuit has a very definite time period, as already noticed, this time period being defined by the inductance and capacity of the circuit. By modifying one or other of these, the electric oscillations of the circuit, and through it the wave-length in that circuit, can be altered. In the coil apparatus the resonance was determined by observing the highest potential, as shown by the spark-length. In the closed-circuit apparatus, however, resonance is recognised by observing the current intensity by means of a hot-wire ampere-meter. The circuit is composed of an inductance and a plate condenser, the latter being adjustable. It is composed of two series of metallic half-round plates equidistant from each other, one of the series being fixed, the other movable round a spindle. If the spindle is turned, the movable plates come into the spaces between the fixed ones. The half circle described by the handle which turns the plates is divided into 180 deg. By putting the handle to, say, 160 deg., a capacity is obtained four times as large as that when the handle is at 40 deg. Thus by variation of the capacity only, it is possible to obtain a range from λ to $2\ \lambda$. The inductance can also be altered, three coils are added to every apparatus, so that the ratio between the inductances may be as $\frac{1}{4} : 1 : 4$. To every one of these coils a special scale is fixed, from which the wave-length can be read directly, for lengths varying between 140 m. and 1,120 m. (460 ft. and 3,674 ft.). In using the apparatus it is placed near the circuit to be indicated, in such a way that the field of the latter excites the coil of the wave-meter inductively. Having chosen the most suitable of the three coils, the capacity is varied till the ampere-meter shows maximum current. The wave-meter is then in perfect resonance with the circuit under examination. From the scale the wave-length is read directly. By shifting the handle to the left or right of the resonance point, it is possible to form an idea of the clearness or damping of the wave by observing whether the current changes rapidly or slowly. To permit the measurement of the natural oscillations of a simple aerial, auxiliary coils are added. Accuracy within 1 or 1½ per cent. is obtainable, and the instrument is portable and convenient. These particulars have been kindly furnished by the Gesellschaft für drahtlose Telegraphie, Berlin.

The New German System—" Telefunken."

This system of wireless telegraphy arises from the amalgamation of the two systems already described—the " Braun-Siemens " and the " Slaby-Arco "—the one owned by the Gesellschaft für drahtlose Telegraphie, and the other by the Allgemeine Elektricitäts-Gesellschaft. This fusion of systems took place in the summer of 1903, the apparatus of the new system being constructed in the workshop of the two companies, but for alteration and repairs required on short notice, and for the production and *testing* of new models, a special workshop employing about a hundred carefully trained workmen and assistants has been established. For outdoor experiments with aerial conductors, and in relation to syntonising and carrying distance tests, six stations in and around Berlin have been established.

The two systems have over twenty patents in Germany alone. Amongst these may be mentioned that of 1898 for the transmitter arrangement, in which an oscillation circuit with condensers and a spark-gap with a large amount of energy, excites the aerial conductor slightly deadened to self-oscillations. A similar arrangement for the receiver was patented in 1901, consisting of a closed oscillating circuit, which by a clear and pronounced self-period renders the receiving apparatus sensitive to a definite transmitter frequency only, thus eliminating to some extent disturbances emanating from foreign transmitters. A patent reserving to the company the resonance arrangements of four oscillation circuits of transmitter and receiver for certain modes of mounting has been followed by others, granted or applied for, in connection with transmitter arrangements for reducing loss by deadening in the spark-gap—the first successful attempt, it is claimed, made by any company to deal with this hitherto chief cause of loss of energy. The patent electrolytic wave-detector or coherer (Schlömilch) already referred to (see page 99 *ante*) is, no doubt, one of the chief sources of success. It is claimed to be the simplest and most reliable receiver yet produced.

The fact that 250 stations on this system are (according to information supplied to us from Berlin) now working, and that the number is rapidly increasing, shows the importance of the system. The annual cost of working in warships amounts, we are told, to about £20 (we presume this means £20 per ship). A great feature of this system is the portable station (see page 189). Concerning the reliability of these stations and their use in war, an officer of the general's staff, referring to the manœuvres in an article in the *Militär-Woehenblatt* of November, 1902, says: "The telegraphists employed the Braun-Siemens system of spark telegraphy, which worked exceedingly well. The transportable station was daily in great requisition: it transmitted orders and reports between the general in command of the fifth army corps and the cavalry division. . . . With the Morse printer the stations worked reliably at a distance of two days' march, with other receivers at a distance of three or four days' march.

Distance of Signalling.—The distance of successful signalling by this system is determined by the size of the aerial conductor net and the magnitude of the source of electric energy necessary for radiation into the ether. As early as 1902 some experiments by the company were made from the Oberspree works of the Allgemeine Elektricitäts-Gesellschaft. Four chimney stacks, each 70 m. (229½ ft.) high, were used to support a square aerial net consisting of about a hundred wires running down in funnel shape to the generator. An alternating-current supply of about 15 kw. was taken from the engine-room. This current, converted to a pressure of about 50,000 volts, supplied the exciting system. The enormous oscillations with a frequency of about 900,000 per second excited the aerial net. On the very first day of the reconstructed trials legible messages were transmitted to Karlskronain, Sweden, 450 km. (about 281 miles), the receiving wires being only 35 m. (82ft.) high. The company now guarantees communications over distances of upwards of 1,000 km. (625 miles). Especially in summer it is, however, a well-known fact that the distance of successful signalling varies much with the state of the atmosphere. Hence a large *factor of security* is necessary to ensure successful communication at all times. Thus to cover successfully a distance of 100 miles under all conditions, it may be necessary to utilise energy sufficient to cover 300 miles under favourable conditions.

The Province of Wireless Telegraphy.—The owners of this system have made many experiments, and give it as their opinion that in the immediate future neither absolute exemption from disturbance nor complete secrecy—at least for comparatively long distances—is to be expected. Even if this be true—and it is disputed by some authorities—wireless telegraphy has in numberless cases already done excellent work. The first primitive contrivances of wireless apparatus were sufficient for short distances and under favourable conditions, and various navies introduced them on their ships. Now, however, an important problem presents itself. A company supplying such apparatus as are used on board, say, the ships of a large navy, is required to make the range of all the instruments as nearly alike as possible; in other words, they are all to be as nearly alike as possible in the time period and wave-length adopted, so that intercommunication may be easy and interference from outside workers, to some extent, at least, secured. To do this, a wave-meter becomes a necessity, and this the system here referred to supplies. This apparatus has already been described at pp. 187-192, and by its use a station may be erected in any part of the world with apparatus suitable to receive messages from any other given station. Further, if it were desirable, this apparatus could be used to determine the wave-length employed by any other rival station, or station in the hands of an enemy. The necessary alteration being made in the receiving circuit of the station supplied with the wave-meter, the messages from the rival or enemy could easily be read if dependence were placed merely on the security given by resonance effects. Of course, a code might be employed to get over this difficulty, but apart from this suppositious case the utility of the wave-meter is evident.

This very weakness of wireless telegraphy—viz., the fact that it is necessary to radiate into space, and hence all within a given distance may read who care to suit their stations to the radiations—proves, in some cases at least, its most desirable feature. In army work, for instance, the fact that the telegram may be *simultaneously read by many receivers* is of the greatest value, as the orders of a commanding officer can thus be received *simultaneously* at many quarters, and combined movements of large bodies of troops in scattered positions may thus be made with the greatest precision. This feature has been fully worked out in Germany, and the excellent portable sets there used testify to the ingenuity displayed in taking advantage of the above peculiarity of wireless signalling. Light military wagons have been constructed to carry not only the whole apparatus of a station, but also the necessary supply of current, kites or balloons being used to carry the aerial wires. The use of wireless signalling to and from railway trains in motion has been advanced by this company. With horizontal aerials on the trains and the ordinary telegraph wires on the line the military railway from Berlin to Zossen has been equipped for wireless telegraphing, and it has remained in uninterrupted use since since the close of 1903.

The use of the system in the Imperial and commercial navy is very striking, the shores of the North Sea and Baltic being netted by an unbroken series of stations belonging to the German navy. *All* telegrams are taken up and sent off within a range of 150 km. ($93\frac{2}{3}$ miles) at the low tariff of $9\frac{1}{2}$d. per ten words, irrespective of the nationality of the dispatching vessel or of the system employed on it. The shores of the United Kingdom are surrounded by many similar stations, but we may have some disquietude as to whether these stations will soon be under State control, and whether State resources will be used to further commercial enterprise as in Germany.

There is another little disquieting statement that one may mention. The owners of this system in their pamphlet say that "On September 26, 1903, their Lloyd-Hall station at Bremerhaven exchanged telegrams with the Marconi station on the fast steamer 'Kronprinz Wilhelm,' 257 km. (161 miles away." They also say, "In like manner we can catch up, on the North Sea coast, telegrams which the Marconi apparatus at Poldhu strives to fling across the Atlantic. Similarly, we can force the Marconi receiver at Poldhu to take up our telegrams together with the messages coming from America, so that when the two arrive simultaneously . . ." The writer desires to avoid controversial matters, so prefers not to give the remainder of the sentence, and distinctly desires to state that he has no knowledge of the truth or otherwise of the statements. The first part of the pamphlet ends with the pregnant words, "all we need is to work with a like wave." The disquieting part of this matter is that as our navy is equipped with Marconi apparatus, one cannot help wondering whether our German friends are as successful in connection with the reception of our naval messages as they say they are of the messages referred to, and whether a code would be of much use in time of war.

Spanish Experiments.

The Cervera System.—Spain has also recently added her quota to successful research in this branch of science and invention, and we find the system of Señor Cervera adopted and giving good results. In some respects this system differs from those already described, especially in the construction of the coherer. The transmitter has the usual vertical aerial with earthed connection, and the usual induction coil with spark-gap, a condenser being inserted in each arm of the oscillator near the spark-gap. The same antenna is used both for receiving and transmitting, there being a changing switch which cuts out the condensers and spark-gap when receiving. The antenna is earthed through the primary of a small transformer, as before, the secondary of this transformer being divided by cutting out one spiral of winding at the centre of the coil and inserting a condenser between the terminals thus formed, after the manner of the Marconi "jigger." The terminals of the condenser are in turn connected to the terminals of the coherer, which consists of two small *ivory* discs, which may be adjusted by micrometer screws, having between them the conductors, which are in this case plugs of soft annealed iron with the usual powdered metal between them. The Cervera receiving apparatus has *four* separate circuits, which in turn fulfil the following functions: (1) operating the Morse machine, (2) making and breaking the coherer and relay circuit, (3) actuating the tapper, (4) interrupting the circuit of an electromagnet, the function of which is to alter the sensibility of the coherer. The whole receiver, with its various circuits, is somewhat complicated, but is said to work well. The system has been successfully tried at various stations, and also across the Straits of Gibraltar, a distance of 34 km. ($21\frac{1}{4}$ miles).

CHAPTER X.

American Systems.

The De Forest System.—This system is due to Dr. Lee De Forest and Prof. C. E. Freeman, of the United States. The transmitter is not of the usual cell and Ruhmkorff coil type, but is much more powerful. A 110-volt continuous current from a dynamo or accumulators is transformed by a rotary transformer into an alternate current at a pressure of about 500 volts, which is further increased to 25,000 volts in an oil transformer, 3 (A, Fig. 70). This high-pressure but low-frequency alternating current is used for charging a series of condensers, represented by 7, 8 in the illustration. The discharge of these condensers through the spark-gap, 6, gives rise to the ether waves necessary for the transmission of the message. The aerial, 4, is connected to one spark-ball or disc, the other being connected to earth. The pressure being high, great disturbance of the ether takes place, hence long distances may be traversed and yet the effect be sufficiently powerful to give a readable message. A key, 2, working in oil is used to make and break the circuit of the transmitter. The receiver circuit is shown diagrammatically at B (lower figure). Its circuit includes the aerial, which is connected to the primary of a small transformer, the secondary of which is in the local circuit, the latter including the responders, 1′ 1″, inductance coils, 2′ 2″, resistance, 3′ (about 5,000 ohms), the condenser, 5′, and the telephone receiver, 6′. There are keys, 9′ 9″, for relieving the responders. There is also a battery, 4′, the current from which flows through the telephone all the time the apparatus is in use.

The responder deserves special notice. It is of the

DR. LEE DE FOREST.

anti-coherer type, as its resistance is *increased* under the influence of impinging ether waves, and thus the current flowing normally through the circuit of the responder is interrupted. The responder is really a little electrolytic cell ; the electrodes being of soft metal are placed in a paste composed of metallic particles, and a liquid which can be electrolysed by the current. The current flowing normally detaches minute particles of metal, causing them to pass from one electrode to

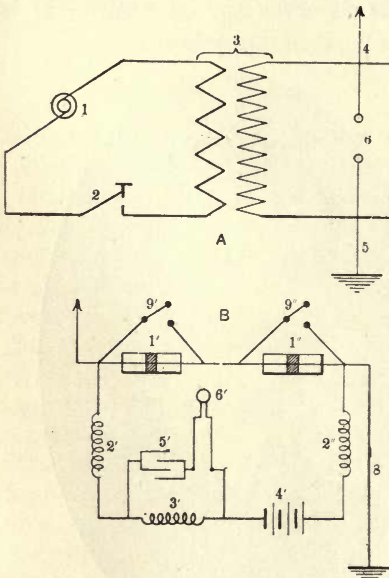


FIG. 70.—Diagram of De Forest Wireless Telegraph System. A, Transmitter; 1, Alternating-Current Generator; 2, Key; 3, Oil Transformer; 4, Antenna; 5, Ground; 6, Spark-Gap; 7, 8, Condensers. B, Receiver; 1′ 1″, Responders; 2′ 2″, Choke Coils; 3′, Resistance 5,000 ohms; 4′, Battery; 5′, Condenser; 6′, Telephone Receiver; 7′, Antenna; 8′, Ground; 9′ 9″, Shunt Switches.—*From "The Engineering Magazine."*

the other, the normal resistance of the cell being small. When the ether waves set up by the transmitter reach the responder, hydrogen bubbles are generated at the kathode, and form a cushion which increases the resistance of the cell, momentarily interrupting the current, causing the telephone diaphragm to be momentarily released from the pull of its magnets, and a sharp click is heard in it. A series of impulses sent at proper intervals give rise to a series of clicks arranged to convey a message in accordance with the Morse code.

The system has been very successful. On December 11, 1902, the Coney Island station of this company caught messages from the "Philadelphia" when the latter was 100 miles away, the vessel having Marconi apparatus. No tuning device is used at Coney Island. The "Philadelphia" was overheard calling up the Babylon station, and later the Sagaponack station. The aerials at Coney Island are simple two-stranded copper wires 210 ft. high. In the dock at New York, with miles of metal warehouses intervening, conversation was carried on with the "Deutschland," which is equipped with apparatus of the Arco-Slaby system, but it was found necessary to replace the coherer of that system by the responder of the De Forest system. Messages have been received by a De Forest pocket receiver measuring 5 in. by 4 in. by 3 in. from a distance of 100 miles. Recent war messages to *The Times* newspaper are due to the success of this system installed on a special dispatch boat, which has been brought prominently before the public. The equipment of trains has also been taken in hand, and we understand that the "Twentieth Century Limited" express on the New York Central Railroad is to be fitted with the apparatus of this company to communicate with stations near the track 100 miles or so apart. The system has now, it is said, been adopted, after severe tests, by the United States army and navy.

A photograph of a complete De Forest transmitter set is shown in Fig. 71, kindly sent by Dr. De Forest—the key to the right, variable inductance or resistance in the centre, the oil transformer and spark apparatus to the left, where it will be seen discs are employed.

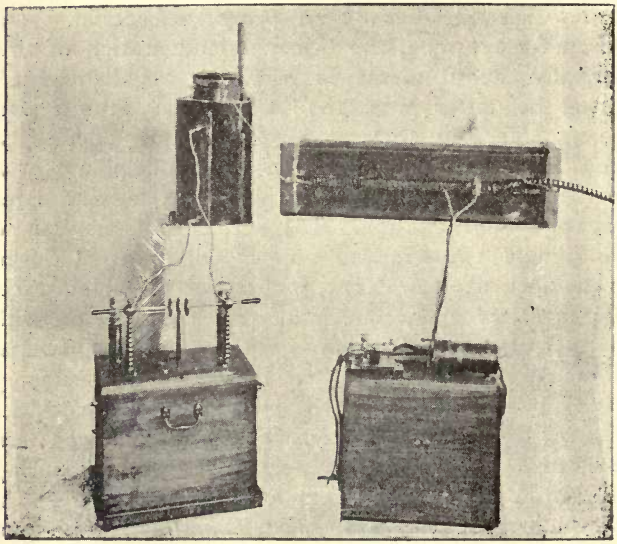


FIG. 71.—The De Forest System.

American papers tell us that before the possibility of Transatlantic wireless telegraphy was demonstrated, this company had completed plans for establishing stations by which not only America, but the Pacific, could be spanned. One of the latter is to be at the southern end of California, another (a relay station) at the north end of Hawaii, one near Manila, and one at

Hong Kong. The towers at Manila and Honolulu are to be 250 ft. high. They will support three screens of vertical wires at each station. The distance between Manila and Hawaii will be 3,500 miles, that between Hawaii and California 2,200 miles. Stations at Cape Hatteras, Key West, Havana, etc., are now being equipped or are in working order. Should Dr. De Forest succeed in negotiating these long distances, he may claim a place in the very front rank in regard to wireless invention and enterprise at the present time. Like Marconi, he is young — only thirty. He is graduate (Ph.D.) of Yale.

The Fessenden System. — This system has been successfully developed by Prof. Reginald A. Fessenden, of the United States Weather Bureau. Prof. Fessenden claims to use, not free Hertz waves, but "semi-free" waves. In his patent specification the professor says: "In the Lodge waves the electrical energy is a maximum when the magnetic energy is a minimum, and all the energy not absorbed by resistance is recoverable; with the form investigated by me the electrical energy is a maximum at the same time as the magnetic, and none of the energy radiated is recoverable except by deflection." The "aerial," A (Fig. 72), may have several wires in parallel, and there is usually a secondary conductor joined on to these, which may be carried in a horizontal direction over buildings, etc., being earthed at each end. The length of each arm of this secondary conductor is approximately one-quarter of the wave-length employed. The mast to which the aerials, A, are attached is guyed from the top by wires having a different period of oscillation from that of the aerials, the object being to eliminate as far as possible the influence of waves the lengths of which are not in tune with the receiving apparatus. The induction coil, I, is kept continually in action when messages are being transmitted, a

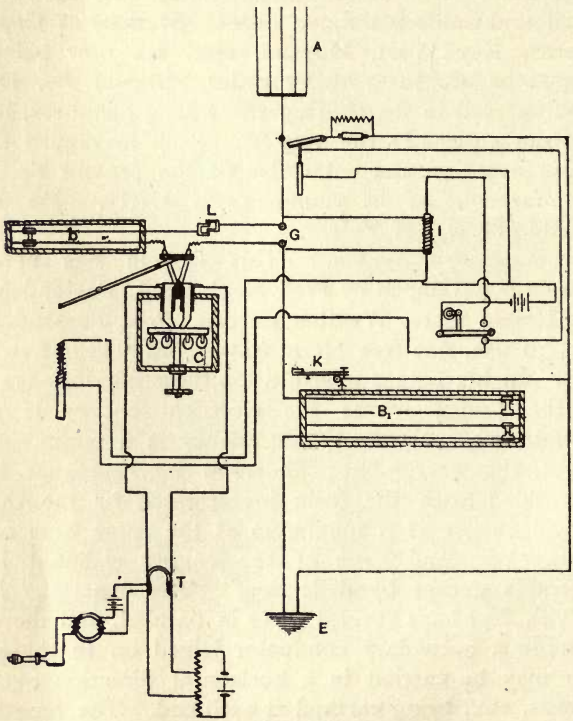


FIG. 72.—Fessenden Apparatus.

key, K, being employed to throw the aerials in and out of tune with the receiving station. The key, in fact, short-circuits the tuning device, which is shown at B_1, and consists of parallel strips or wires immersed in oil and fitted with sliding contacts. The capacity and inductance of the tuning device is arranged to give a true sine wave, and to agree in period exactly with the natural period of the oscillator system, including the aerials. The receiver system includes the aerials, the condenser, L, tuning grid, *b*, electromagnetic wave detectors, C, and the earth, E. There

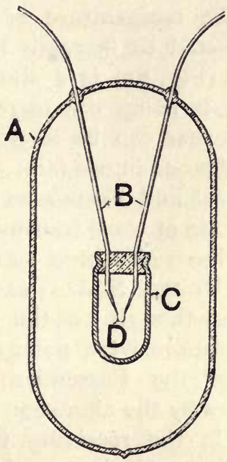


FIG. 73.—Fessenden Electromagnetic Receiver.

are also head telephones, T, and other details, as shown in the illustration.

The electromagnetic detector or responder, C, is of special interest, and is shown in section in Fig. 73. It consists of a short loop of fine silver wire, D, ·002 in. in diameter, with a core of platinum wire ·00006 in. in diameter, and is fastened to the terminal wires, B, which are sealed into the glass bulb, A. The tip of the silver loop is dissolved or eaten away by nitric acid, leaving the platinum wire exposed, and to decrease the loss due to radiation, the loop is enclosed in the silver shell, C. The action of the receiver is practically that of the bolometer, and has already been referred to. The radiating or absorbing surface is here, however, very small compared with the mass. The heat capacity is therefore small, and a very small—in fact, nearly infinitesimal—quantity of heat suffices to raise, and sufficiently raise, the temperature of the wire. The glass bulb is exhausted to increase the sensitiveness of the receiver. C (Fig. 72) is a stand for a number of these detectors, it being considered best to have several, so that another can be immediately switched into circuit should the one in use fail.

Both the De Forest and Fessenden systems are said to admit of a high rate of word transmission telephones being used. They have also been subjected to severe tests during the United States naval manœuvres, and at other times, though on the occasion of the manœuvres the distances were not great. One very important phase of the Fessenden system is the possibility of syntony by the alteration of the frequency of the diaphragm in the receiving telephone. Prof. Fessenden found that a diaphragm clamped all round its circumference had a natural period of vibration, which could readily be varied, say, by altering the radius of the clamping ring. In this way the telephone could be made to respond to ether oscillations of its own frequency better than any other, and that frequency could be varied by the simple device referred to. Thus tuning or syntony, and to a certain extent secrecy of transmission, may be secured.

CHAPTER XI.

Inventions and Experiments of M. Guarini.

The Guarini Repeater and Guarini Wireless Fire-Alarm.—With a good and economical system, it may be that for land transmission, at any rate, great power and expensive stations are unnecessary; the use of an automatic repeater like that of M. Emile Guarini, of Brussels, may yet solve the problem of wireless telegraphic intercommunication. The object of the apparatus is to receive messages from a station and repeat or re-telegraph them on automatically to a further station or stations. The circuits of the apparatus are shown diagrammatically in Fig. 74, where 1 is the aerial, 2 conductor connecting aerial to negative pole of relay 4, 5 conductor (placed in metallic tube) joining armature 6 of relay 4 to primary 7 of little transformer 8, 13 is a condenser, 14 the coherer, 24 tapper of same, 15 inductance coils, 16 a cell, 17 coils of the relay 18, 20 and 21 terminals of the same, 22 source of electrical energy, 23 shunts, 25 the table on which the apparatus rests, 26 inductance, 28 a metallic box joined to the other metallic envelope 11, 29 are coils of relay 4, 30 source of electrical energy, 31 induction coil, 32 the oscillator or spark-gap, 33 the earth or a capacity. In the case where it is necessary to register the signals repeated, relay 4 works a Morse printer.

Action of the Apparatus.—Suppose that between two stations (transmitter and receiver) there is a single repeater, the Morse dot-and-dash code being used. At the transmitting station an electromagnetic wave

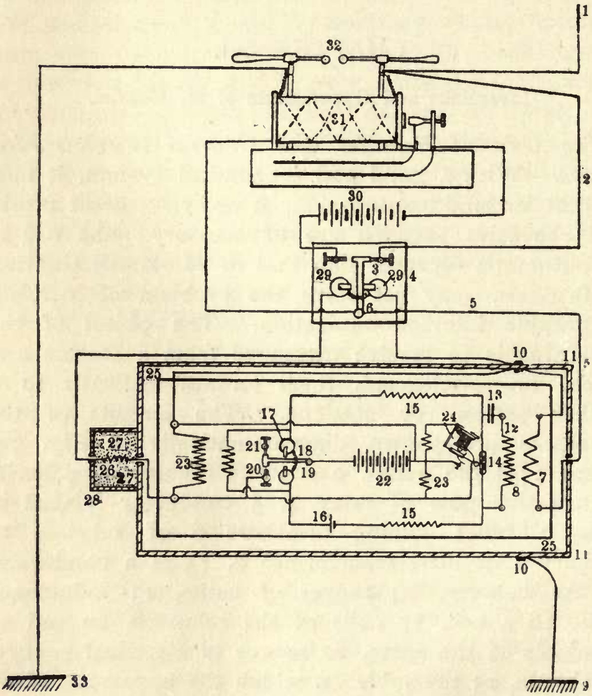


FIG. 74.—Guarini Repeater Circuits.

of short duration is produced, say, by an oscillator like 32. This wave projected into space is too feeble to reach the receiving station, but is strong enough to affect the aerial, 1; is collected by 1, but is not able to traverse the secondary of coil 31, and reach the earth (or capacity), 33, on account of the great impedance of the circuit. The wave, therefore, traverses the conductor 2, the terminal, 3, of the relay, 4, the conductor, 5, of the primary, 7, of the transformer, 8, and reaches the ground (or capacity) at 9. On account of induction in the secondary, 12, of the transformer, 8, the coherer, 14, is impressed so well (the self-induction coils, 15, hindering the waves from following the circuit of the cell, 16) that the coils, 17, of the relay, 18, are energised, the armature, 19, of the relay is attracted, and leaving the position of rest, 21, applies itself against the buffer, 20; the current of the cell, 22, acting on the tapper, 24, the latter decoheres the coherer, 14, at the same time that a current circulates round the coils, 29, of the relay, 4. The armature, 6, of the relay, 4, is attracted. It leaves its position of rest, 3, and places itself against the working buffer of 4 at the same time that the armature, 6, closes the circuit of the source of energy, 30, of the primary of the coil, 31, and a spark leaves the oscillator. It will be noticed that at this instant an interruption has been caused between the terminal, 3, and the conductor, 2, going to the receiving antenna. Thus the relay, 4, sends on the signal received, and it may also print it through the agency of a Morse printer. The lower part of the apparatus, being enclosed in a metallic box, is not affected by the spark of the oscillator, hence the apparatus is again ready to receive a fresh signal. A number of dots sent in quick succession form a dash, and so on, as usual, by the Morse code. There may be a number of repeaters between the extreme transmitting station and the final receiving station, but the action is the same: No. 1 repeater repeats the short and long signals to No. 2, No. 2 repeats them to No. 3, and so on, till they finally are received at the extreme station. There is no danger that the signals of one repeater may react on another, for when a signal is reproduced to No. 2, the circuit of the receiving antennæ, 1, of repeater No. 1 is interrupted. It is only when the signal arrives at repeater No. 3—*i.e.*, out of

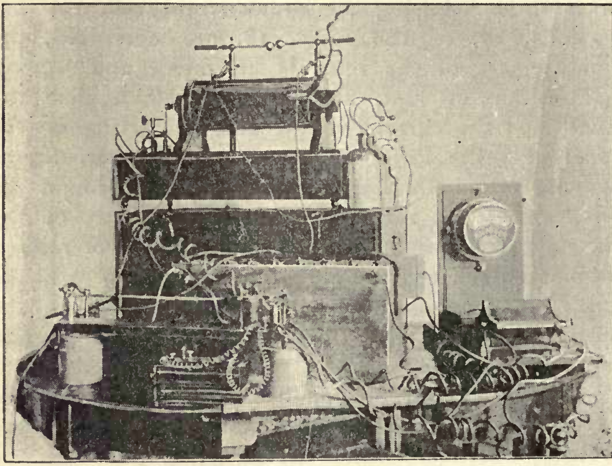


FIG. 75.

reach of No. 1—that receiver No. 1 becomes capable of receiving and retransmitting a new signal from the extreme transmitting station. In practice, all this takes place as rapidly as if there were direct communication, for by diminishing the distance of transmission, the capacity of the station, the size of the induction coils, and hence the time constant, are all reduced.

An illustration of the apparatus is shown in Fig. 75.

Other forms of the apparatus which have been employed by M. Guarini need not be further referred to here. The apparatus has been thoroughly tried. Experiments were made between Brussels and Antwerp, with a repeater at Malines, in order to test the value of the repeater over considerable distances. The experiments proved very successful. An observer at Malines—Lieutenant Fernand Poncelet, of the Belgian Artillery—had simply to note, watch in hand, the time of the passing of certain signals, and the printed records of these signals made by the repeater were, after the experiment was finished, compared with the records received direct from Brussels at the extreme receiving station at Antwerp, as well as with those sent out from Brussels. The printed records were found to be absolutely identical. All the messages sent out from Brussels were not received at Antwerp, but the latter station received correctly every one of the messages received at Malines and passed on by the repeater. The absolute fidelity of the repeater was thus proved conclusively.

M. Guarini has also made some experiments in the direction of securing the radiation of electric waves in any required direction only. Evidently this, if successful, will greatly aid other efforts to secure secrecy in transmission. M. Guarini attempted to do this by limiting the issuing waves to a narrow band directed towards the receiver he wished to communicate with. To effect this he carefully covered his central antenna or core with insulation, and enclosed it in a metallic sheath cylindric in form, with a vertical slit in one side, the slit facing in the direction in which the distant receiver was situated. The central core was connected to one of the oscillator or spark knobs, the outer sheath being connected to earth. It was supposed that by this arrangement only that portion of the core opposite the slit would send out Hertzian radiations into space. Considerable success attended this effort, we believe, especially when the screen was connected to earth, but it has been tried mainly for

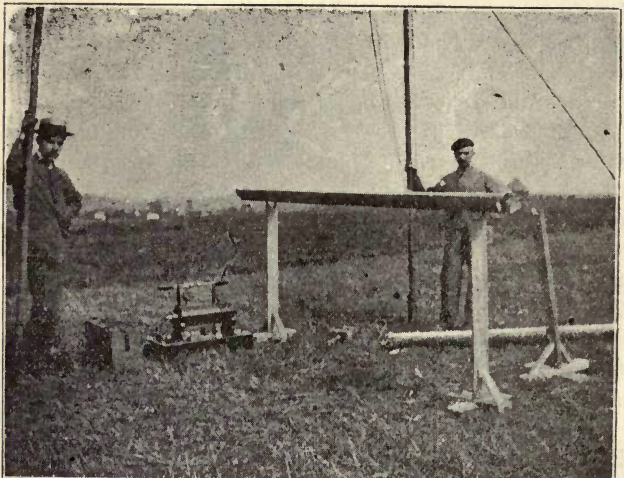


FIG. 76.—Experiments of M. Guarini on "Limitations de l'espace" (with Metal Envelopes.)

short distances. The matter, however, is of great importance, and is worthy of further research. Fig. 76 shows some of M. Guarini's experiments in progress.

Wireless Fire-Alarm.—The importance of automatic fire-alarm systems, especially in centres of population, is obvious. That this importance is recognised is evident from the high prices at which shares in some companies owning patents for appliances of this kind stand. But an ordinary fire-alarm fails to indicate exactly the position of the fire. That of M. Emile Guarini, using the known laws of ether-wave signalling, accomplishes this very important function, at the same time being automatic.

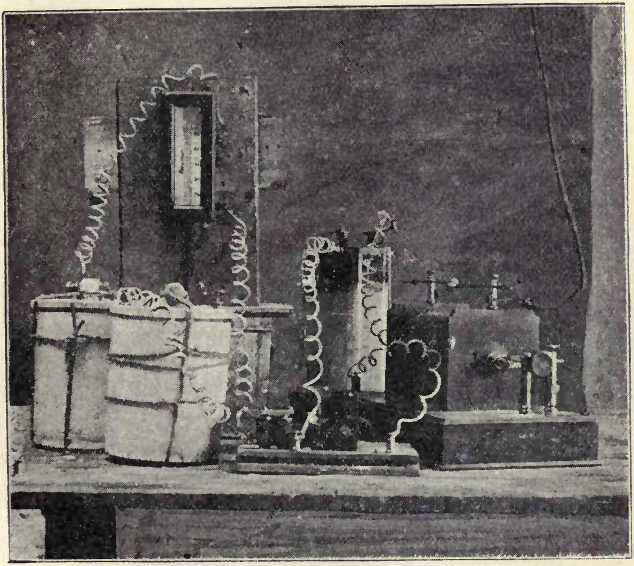


FIG. 77.—Guarini Wireless Fire-Alarm Transmitter.

The principle of M. Guarini's system is that of most automatic fire-alarms, in that a mercurial thermometer acts as the basis of the alarm. Two platinum contacts fused into the glass walls of the thermometer tube are in a circuit including a battery and relay. The circuit is completed by the expansion of the mercury in the thermometer when exposed to the increasing heat of the fire. The circuit may be arranged so that the alarm shall act when the temperature reaches any fixed limit, which, of course, must be above that of any ordinary summer temperature. The novelty of M. Guarini's system, however, lies in the fact that communication between the thermometer in the premises protected and the fire station is accomplished by

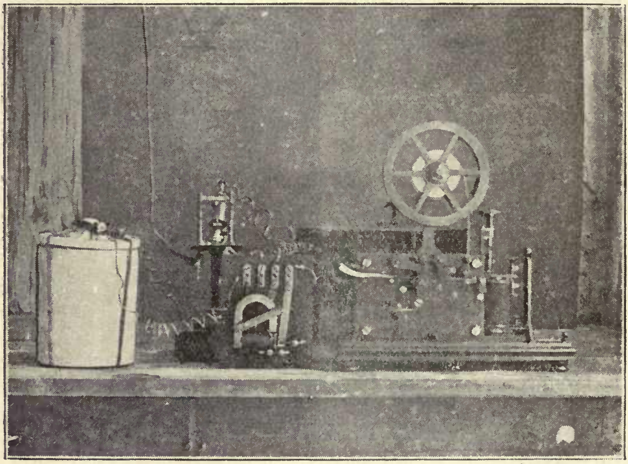


FIG. 78.—Guarini Fire-Alarm Receiver.

Hertz-wave telegraphy. Thus no connecting wires are necessary, and the distance up to twenty or thirty miles is of little consequence. The alarm circuit includes a battery and relay, the armature of which acts as a detent, preventing, under normal circumstances, a contact wheel driven by clockwork from acting. When the circuit is completed, through the expansion of the mercury, the armature of the relay is attracted;

this wheel is released, and the latter revolving makes a series of contacts with a fixed brush which is connected through a battery with the primary of an induction coil transmitter. The induction coil secondary is connected with the usual oscillating circuit and aerial with earth connection. The transmitting apparatus is shown in Fig. 77. The various parts of the apparatus, it will be seen, are well protected, so that the alarm may have a considerable time in which to act before the temperature is so high as to destroy the transmitter itself. The receiver is shown in Fig. 78, which has the usual coherer battery, Morse printer, etc. The first incidence of the ether waves rendering the coherer conducting, closes a circuit including a call bell. The contacts on the wheel of the transmitter determine the signals, and thus not only an alarm is given, but the name and address of the premises or even the *room* protected by a given instrument are repeated again and again and registered by the receiver. The same receiver can be made to serve for different thermometers placed in distinct buildings or in different rooms of the same building.

This up-to-date application of wireless signalling appeals to all who wish to avail themselves of the most recent advantages resulting from scientific research. As fires are more numerous and more dangerous by night than by day, it is as well to remember also that wireless signalling can be carried on with more certainty at night than in the daytime, and over longer distances.

CHAPTER XII.

Signalling to and from Moving Railway Trains.

Mr. T. A. Edison in 1885 invented, or rather perfected, a method of doing this, said to be due to Mr. Willoughby Smith (see Edison and Gilliland English patent No. 7,583 of 1885). He had a large board 8 in. wide, covered with tinfoil, placed along the roof of each car. He used static electricity, thus, to use his own words, "making the electricity jump 35ft., and transforming every running train of cars into a telegraph station accessible to every other telegraph station on the road, as well as to the passengers." "When the train is telegraphed to," he adds, "the message jumps from the ordinary telegraph wire at the side of the track and alights on this board, being conveyed to the apparatus in the train below." The board is well insulated from the carriage by blocks of glass, all the boards, or rather strips of metal, being electrically connected. A wire is connected with this board or condenser, and through the carriage body to the earth. The apparatus required is an induction coil, the secondary wire of which is of very high resistance, and is in the circuit of the grounding wire referred to, in which may be also a telephone of high resistance. In the primary of the induction coil are a local battery and a revolving circuit breaker. The circuit breaker is shunted by a back-point key, which normally short-circuits it and prevents it from affecting the induction coil. A switch is provided which short-circuits the secondary wire of the induction coil when receiving a message and opens it on transmitting one. The ordinary telegraph wires on poles at the side of the line, and earthed at their ends, are used collectively for conveying the signals—they, in fact, form the other surface of the condenser, the metal strips on the carriages being one surface, whilst the air between is the dielectric. In signalling between *trains* the key in one telegraph office upon one train is worked; this causes static impulses at the condenser surface on this train which affect the wires, and these in turn affect the condensing surface on the other train, and cause audible signals in the telephones there. At each signalling station by the side of the line a large metallic condensing surface is provided, a wire running from this condenser surface to the station, where it is earthed through similar apparatus to those in the carriages, or a separate wire may be run from each telegraph wire to the station, where it is connected to one side of a condenser. The ordinary telegraph Morse keys are shunted by condensers, which do not, it is said, interfere with the ordinary telegraph work, at the same time forming constantly closed paths for the induction impulses. The trains and stations were connected inductively with the line wires in "multiple arc," signals being transmitted as described, Morse characters being employed. The system was put in operation first at Staten Island, United States; next on the Chicago, Milwaukee, and St. Paul line, and by October, 1887, also on the Lehigh Valley line. Messages were sent and received perfectly even when the trains ran at speeds of sixty miles an hour, over four hundred messages being sent during one run, and the same winter all the snowed-up trains on the latter line were in constant communication. The system soon fell into disuse, as nobody seemed to want it much.

The De Forest Company is, we understand, at present making arrangements to equip the "Twentieth Century Limited" express on the New York Central Railroad with their apparatus, so that communication may be kept up with "wireless" stations near the line and about a hundred miles apart. The same thing is also being tried in Germany, the train aerials being horizontal and occupying a position similar to that of the communication cord on English lines. Experiments on wireless telegraphy to moving trains have also recently been carried out in Canada on the Grand Trunk Railway there by Profs. Rutherford and Barnes, of McGill University. Probably their system is not like that of Mr. Edison, but on more modern lines, following Marconi and De Forest; in which electrostatic induction is the prominent feature, or whether it has any distinctive features the author does not know; in any case, the matter is not one of great importance, as it was found in the United States, and probably will be found elsewhere, that very few people, even in America, wish to devote themselves to business to such an extent as to require telegraphic communication during a train journey. It would scarcely pay a railway company, on the other hand, to instal such a system unless a considerable number of passengers require the communication.

Wireless Railway Signalling in England and Belgium. Experiments in connection with wireless intercommunication between moving trains, and between trains and fixed stations along or near the line, have been carried out in England with the Marconi system, in America with the De Forest system, in Germany with the Braun-Slaby system, and in Belgium with the Guarini system (Belgian patent, No. 167,023, November 29, 1902). These experiments have shown one thing at any rate—viz., that great power is requisite even for comparatively short distances. It takes (on the authority of M. Guarini) an expenditure of no less than 1 h.p. to communicate "wirelessly" with a moving train only six miles distant. The distance of successful wireless signalling depends, with good apparatus, not only on the power supplied, but on the length of aerials used. In the case of moving trains tall aerials are inadmissible, and horizontal aerials have not proved very successful, their rapid displacement in space having apparently a prejudicial effect. It has been proposed to place a special continuous horizontal aerial near the track, influencing this first by the transmitter, and thus allowing it to act on the receiver connected, say, to a horizontal wire laid along the roofs of the carriages. This special wire by the track would involve considerable expense, and it is doubtful if the utility of wireless intercommunication is, in this case, such as to warrant the expense. M. Emile Guarini, assisted by M. Cesar and Lieutenant Poncelet, made some interesting experiments recently on the Belgian State line, using the ordinary telegraph wires and (unlike Edison, who tried the use of these wires in 1886) a true Hertzian-wave system. In addition to the telegraph wires, intermediate wires were employed to communicate with the transmitter and receiver respectively. M. Guarini, in fact, created at a fixed point, say a station, or at a moving point (on a train) an electromagnetic disturbance by using an oscillator. Such a disturbance is readily detected by a coherer or like receiver at the other fixed (or moving) point near the telegraph wires. The latter take up the Hertz-wave disturbances and radiate them after the manner of aerials.

The energy employed in some of these experiments was 40 watts, the aerial at the fixed station consisting of 40 strands of wire 32·8 ft. long, communication being successfully maintained through a distance of 10·4 miles. With energy equivalent to only 15 watts and $\frac{1}{10}$-in. spark, a good coherer being employed on a car at a distance of $2\frac{1}{2}$ miles, successful telegraphing was accomplished; the aerial on the car being only $6\frac{1}{2}$ ft. long, and consisting of an iron tube 4 in. in diameter. Signals were successfully transmitted both ways even when the car was 100 ft. to 130 ft. away from the telegraph wires, but no data are furnished as to what effect the speed of the car, when moving, had on the distance successfully traversed. No disturbance of any sort was observed in any of the telegraph or telephone instruments connected to the wires along the line. This fact is of interest, and agrees with the results obtained by Profs. Slaby, Turpain, and others. In fact, the high-frequency oscillating currents employed in wireless work do not interfere with the ordinary currents of telegraphic work. It was not even necessary in the experiments of M. Guarini to connect one pole of the oscillator to earth, as it was found that a condenser or simple capacity, consisting of a tube laid parallel with the earth, was sufficient.

M. Guarini tried how the rails would do instead of the telegraph wires. With power equal to 100 watts and a sensitive Blondel coherer, signals were successfully sent, but over a very much shorter distance than before. M. Guarini thinks that a cheap and effective block system might be established by using the telegraph wires to communicate with the *engine* of a moving train. What means would have to be adopted, however, to prevent half a dozen different engines from receiving a given message it is difficult to say, but it might be possible to ensure that a given engine (or van) should be able to communicate only with the train immediately preceding or following—possibly the distance itself would ensure this in most cases. M. Guarini thinks that submarine cables might perform a similar function to that of the telegraph wires in the above experiments. Thus without interfering with the ordinary cable business it might be possible to communicate readily with ships within a certain distance of the cables or with certain portions of coast at present remote from ordinary telegraph stations. In fact, without using the enormous amount of energy required for Transatlantic wireless signalling, the cables might be used as intermediaries, the news being radiated both by land and sea by the wireless methods now so common.

CHAPTER XIII.

Screening—The Effect of Obstacles, Weather, Light, etc.

Captain Jackson, F.R.S., of the British navy, read a very interesting paper on "Some Phenomena affecting the Transmission of Electric Waves over the Surface of the Sea and Earth" before the Royal Society in May, 1902. This paper gave the results of most important observations respecting the intercepting power of various obstacles. For instance, in regard to various kinds of rock, soft sandstone, shale, etc., together with hard limestone, and iron ores transmit electric vibrations with completeness represented by the numbers 72, 58, and 32 per cent. respectively. Barometric variations were also studied and their effect on, or, rather, connection with, the distance of signalling noted. His results may be summarised briefly as follows: he found that, contrary to some of Mr. Marconi's statements, an electrical state of the atmosphere *diminishes* the distance to which signals can be transmitted, although in one case such a state momentarily increased the distance *by nearly 50 per cent.* Mist or dust-laden air *diminishes* the distance, and a want of synchronism in the oscillatory discharge of the transmitter, when proper syntonic apparatus are not used, causes zones of silence at the receiver. The irregularity of the trains of waves causing interference at different points of their path may account for this. Captain Jackson's results hardly bear out the extremely optimistic views of some experimenters who stated that bad weather and obstacles had no ill-effect on the signals sent out by the wireless system.

Mr. Marconi's observations on the effect of day and night are interesting; they are given in a paper read by Mr. Marconi before the Royal Society in June, 1902.

The Effect of Daylight on Wireless Signalling.—It is found that signals transmitted by night carry much farther and better than during the day. Up to 500 miles little difference was detected by Mr. Marconi, but for greater distances the difference became more and more marked as the distance increased. Aerials 12 m. high sufficed at night, but, other things being equal, a height of 18·5 m. was required by day. Mr. Marconi suggests that the effect may be due to the diselectrification of the transmitting aerial or elevated conductor by daylight, the electrical oscillations being, therefore, prevented from attaining the large amplitude they would attain by night. The effect is probably more noticeable where, as at Poldhu, a very high potential is necessary in the elevated conductors. The true explanation is probably that referred to by Prof. J. J. Thomson and others—viz., that the sun sending out streams of electrons gives rise to what has been termed an "electron fog," which acts on the long-wave impulses of wireless messages much in the same way that an ordinary fog does in the case of light waves. The ionisation of the air in sunlight is the now generally accepted cause of the difficulty experienced in sending messages over long distances by day.

The Effect of Electrical Storms.—The effect of atmospheric electrical conditions were observed by Captain Jackson. The effect of lightning discharges was to make a record in the receiver even when no lightning was visible to the observer at the receiving station. The approach of electrical disturbances is usually denoted by the printing of a few dots at intervals on the receiving tape, the most frequent record being three dots, the first being separated from the other two by a slight interval like the letters "e i" in the Morse code, this record being that of *distant* lightning. There are other irregular signs—often spelling words on the Morse code—probably due to the same cause. These disturbances are most frequent in summer, and also most frequent near high mountains. They are most frequent at night and between 8 and 10 p.m. When they are present, the distance of successful signalling is reduced by 20 to 70 per cent. as compared with that under the most favourable atmospheric conditions. Many electrical disturbances or magnetic storms which give rise to severe earth currents do not affect wireless instruments, as the following letter, referring to the great disturbances to ordinary telegraphy experienced on October 31, 1903, shows: "Marconi Wireless Telegraph Company, Limited, Finch-lane, London, November 3, 1903. Dear Sir,—In reply to your letter of 2nd inst. we beg to inform you that, from all reports to hand at time of writing, the recent electrical disturbance has had no effect whatever on wireless communication. This is only natural, as these disturbances are apparently oscillations of so long a period as to be altogether outside the range of wireless apparatus operated on the Marconi system.—Yours faithfully, ANDREW GRAY (for the Marconi Wireless Telegraph Company, Limited)."

The Difference between Sea and Land.—Ether vibrations of the wave-length used in wireless telegraphy, say 500 ft. to 1,000 ft., are much more readily transmitted over sea than over land. This seems to be due to the fact that the sea acts as a sort of mirror, reflecting these waves, but not allowing them readily to pass through it ; whereas the earth does allow them to diffuse themselves through it more readily. Hence over the sea the waves may be bent or diffracted, so as to adapt themselves to the curvature of the earth much more readily than over land. There will be a mountain of water something like 150 miles high between Cornwall and Cape Cod, so that the ether waves conveying Mr. Marconi's recent messages between the two places must have suffered considerable bending or reflection without extinction. In regard to the speed of ether waves, Dr. Fleming gives a very interesting comparison between water, air, and ether waves. A water wave, at the speed of usual ocean waves, would take one hundred hours to reach America, a sound wave four hours, and an ether wave about *the one-sixtieth part of a second.* The results of the experiments of Captain Jackson and others may be summed up in a few sentences as follows : (1) Signalling is much more successful over sea than over land. (2) Signalling is much more successful by night than by day. (3) *Intervening* land or mountain reduces the distance of signalling. (4) Particles held in suspension, such as dust, saline vapour, etc., also reduce the distance. (5) Electrical disturbances act as adverse factors, and give rise to false signals, known as "strays." Some severe electric storms, however, have no effect on wireless apparatus. (6) With certain transmitting apparatus there may be zones of silence due, perhaps, to interference effects.

Conclusion.

Of the future of this wonderful system of message transmission with its many modifications, who can predict? Whilst fully alive to its defects, and to the uncertainty as to results, especially over land, which render it a still not very formidable rival to the older cable systems, one cannot but reflect that the rapidity of advance in the last few years warrants the belief in still greater achievements in the near future. The good work already done must not be minimised by reflections as to unaccomplished possibilities. It may be that in a short time the earth shall be girdled with a complete system or systems of stations, so that all nations may thus be linked in a community of interest—let us hope for universal advancement and peace. An important message sent out by a powerful station in England or America may then be read, not only on multitudinous ships at sea, but by lonely missionaries in the swamps of Africa, and by trained mountaineers amid the eternal snows of polar climes. Thus the savage and sage alike, though far from the haunts of civilisation, may at any rate *read* the message eternal love, and sojourners may learn from friends at home how each is remembered in the "dear homeland." Thus may all be encouraged by brotherly help to follow the way which leads "upward every day"; and so through the ether, by means of a new wave-length which man has only recently found eyes to see, may the old command receive further fulfilment: "Let there be light."

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