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WIRELESS TELEGRAPHY.

ITS USES AND LIMITATIONS.

In this paper is presented a brief resumé of the history of wireless telegraphy, a statement of the principles on which it is founded, an attempt to explain its mechanism, and a discussion of its uses and the difficulties yet to be surmounted in its application.

HISTORICAL RESUME.

M. Guglielmo Marconi, the inventor of this method of communication, made his first experiments on his father's estate in 1895, having conceived the idea while a student under Prof. Righi who had taken up the work of Hertz in investigating the properties of electric waves.

Prof. William Crooke (best known as the inventor of Crooke's Tubes) had foreseen the possibility of utilizing electric waves to transmit intelligence, and in 1892 published an article from which the following extract is taken:

"Whether vibrations of the ether, longer than those which affect us as light, may not be constantly at work around us, we have, until lately, never seriously inquired. But the researches of Lodge in England and of Hertz in Germany give us an almost infinite range of ethereal vibrations or electrical rays, from wave-lengths of thousands of miles down to a few feet. Here is unfolded to us a new and astounding world - one which it is hard to conceive should contain no possibilities of transmitting and receiving intelligence.

"Rays of light will not pierce through a wall, nor, as is known only too well, through a London fog, but electrical vibrations of a yard or more in length will easily pierce such mediums, which to them will be transparent. There, then, is revealed the bewildering possibility of telegraphy without wires, posts, cables, or any of our present costly appliances. Granted a few reasonable postulates, the whole thing comes within the realms of possible fulfillment. At the present time experimentalists are able to generate electrical waves of any desired wave-length, from a few feet upwards, and to keep up a succession of such waves radiating into space in all directions. It is possible, too, with some of these rays, if not with all, to refract them through suitably shaped bodies, acting as lenses, and so direct a sheaf of rays in any given direction; enormous lens shaped masses of pitch and similar bodies have been used for this purpose. Also an experimentalist at a distance can receive some, if not all, of these rays on a properly constituted instrument and by concerted signals messages in the Morse Code can then pass from one operator to another.

"What, therefore, remains to be discovered is firstly, simpler and more certain means of generating electrical rays of any desired wave-length, from the shortest, say of a few feet in length, which will easily pass through buildings and fogs, to those long waves whose lengths are measured by tens, hundreds and thousands of miles; secondly, more delicate receivers which will respond to wave-lengths between certain defined limits and be silent to all others; thirdly, means of darting the sheaf of rays in any desired direction, whether by lens or reflectors, by the help of which the sensitiveness of the receivers (apparently the most difficult of the problems to be solved) would not need to be so delicate as when the rays to be picked up are simply radiating into space in all directions and fading away according to the law of inverse squares.

"Any two friends living within the radius of the sensibility of their respective instruments, having first decided on their special wave-length and attuned their respective instruments to mutual receptivity, could thus communicate as long and as often as they please by tuning the impulses to produce long and short intervals on the ordinary Morse Code."

This clear exposition of the methods and needs of wireless telegraphy, clear today, probably attracted momentary attention as a scientist's dream and was then forgotten.

However, the properties of electric waves continued to be an interesting field for investigation.

Branly, in 1891, had discovered their effect on various kinds of metallic powders or filings. These, which are normally in imperfect contact when in small masses and offer resistance to the passage of electric currents, become conducting when acted upon by electric waves of sufficient intensity and thus afford a valuable means of detecting them. They remain in this conductive state until tapped or shaken when their normal condition is restored.

Sir Oliver Lodge explained this action, improved the manufacture, called the completed wave detector a coherer, and used it in 1894 for detecting waves generated at a distance of 40 yards. Popoff, in 1895, invented an automatic tapper for restoring its non conductivity and (attached to short vertical wires) used the coherer as a wave detector for lecturing purposes and for indicating waves generated by the approach of ordinary thunder storms. He hoped "that his apparatus with further improvements would be adapted to the transmission of signals at a distance by the aid of quick electric vibrations." No one, however, had seen how to construct nor apparently conceived the commercial importance of a system of telegraphy without wires, except Crooke. The instruments were ready but their practical combination was not yet made. As previously stated, Marconi was a friend and pupil of Prof. Righi, a noted investigator of the properties of electric waves, and it was while assisting at Righi's experiments that he became convinced of the possibility of wireless telegraphy. He at once commenced experimenting, and in 1895 successfully transmitted intelligible messages up to a distance of 2 miles, using a Righi oscillator, a Branly-Lodge coherer, and a Popoff tapper.

In the summer of 1896 he conducted experiments in England for the British Postal authorities, covering a distance of 4 miles. His first British patent is dated July 2d of that year. In 1897 further experiments were carried on for both the English and Italian governments, messages being exchanged at distances up to 10 miles, and in August a company was formed in England to exploit the invention. These experiments attracted wide attention; other governments were not slow to perceive the value of this method of communication to their naval and merchant ships, and a host of investigators, stimulated by the attractions of a new science or the vista of commercial reward, plunged into the study of this fascinating subject.

Of so many now well known names, it seems invidious to mention any, but it appears that Prof. Braun of Strasburg and Lodge were the earliest to apply the known laws of electrical vibrations in conductors to wireless telegraphy, and possibly the most influential in pointing the way to the present practice of the art.

In 1898 messages were exchanged by the Marconi system up to 25 miles, and in 1899 to 70 miles. The great changes made in the Marconi apparatus about this time show the effect on his ideas of the work of other investigators, and the decided increase in range obtained shows that the changes were in the right direction. So radical were these changes that the apparatus brought out is sometimes called Marconi's new system, and it has been claimed in patent suits that he abandoned the material of his original invention, retaining only the <u>idea</u> and adopted the material of others as being better adapted to the commercial exchange of intelligence. In 1899, during the English Naval maneuvers, a maximum of 50 miles was obtained. M. Marconi came to the United States during the fall of the same year to superintend the use of his system in reporting the international yacht races off Sandy Hook. At the request of the Bureau of Equipment a Board of officers was appointed to witness and report on this use of the system.

Immediately after the yacht races Marconi sets were installed of the NEW YORK, MASSACHUSETTS and Torpedo Boat PORTER, and at the Highlands of Navesink. Tests between the NEW YORK and MASSACHUSETTS were successful up to 36.5 miles, and one way up to 47 miles, between the Highlands and a ship 16.5 miles, and between the PORTER and MASSACHUSETTS 8.5 miles. The Board recommended that the system be given a trial in the Navy.

In 1900 the British Admiralty made a contract with the Marconi Company to supply 32 sets of apparatus provided that messages were successfully exchanged between ships at Portsmouth and Portland, a distance of about 50 miles, with land intervening. This was done and the apparatus supplied at cost price and an additional royalty of 100 £ per year on each set of instruments installed. A similar offer was made about this time to the United States Navy Department, but a satisfactory agreement could not be reached, and it may be stated here that the policy of the Marconi company to retain control over its instruments - to license them, in other words, for particular uses - has up to the present time prevented that company from supplying any material to the Navy Department. Sometime subsequent to the tests of Marconi's apparatus, a Board appointed to consider the use of homing pigeons in connection with the transmission of messages, recommended that the use of homing pigeons be discontinued when some system of wireless telegraphy was adopted. This Board met at the War College, and I have here a blue print of wireless telegraph receiver connections for communication with Newport which shows quite unintentionally the union of these two methods of transmitting intelligence, the water mark of the paper (a bird with a letter in its beak) having printed as well or better than the diagram.

Other companies, in the meantime, entered the field and nearly all governments conducted experiments in wireless telegraphy. Notably, in the United States, the Signal Corps of the War Department, and Prof. Fessenden for the Weather Bureau of the Agricultural Department. About this time (1900-1) the effect of daylight in decreasing distance of transmission, the screening effect, in certain cases, of high land, and interruption due to atmospheric signals were noted.

In 1901, using Marconi's modified system, previously referred to, communication was obtained between the Lizard and the Isle of Wight, a distance of about 160 miles, with an expenditure of but 150 watts, about 1/5 of a H.P.

Encouraged by this success Marconi boldly attempted to span the Atlantic, and during 1901 built two large stations, one at Poldhu, in Cornwall, England, the other at South Wellfleet, Mass. (on Cape Cod). Both stations were badly damaged by storms but the Poldhu station was rebuilt and Marconi having arranged a sending program with Poldhu proceeded to Cape Race, near St. Johns, Newfoundland, and attaching his receiver to a wire about 400 feet long suspended from a kite, announced to the world on December 12, 1901, that letters agreed upon had been received at the intervals agreed upon. This statement excited wide spread interest (and much controversy) and congrapulations and attentions were showered on M. Marconi.

While the Cape Cod station was being reconstructed, M. Marconi made a trip from Southampton to New York on the American liner PHILADELPHIA, which vessel had been provided with his best type of receiving apparatus. On his arrival in New York the announcement was made that a complete message had been received when 1550 miles from Poldhu, and letters at a distance of 2091 miles. During the same year the Italian Government placed the CARLO ALBERTO at his disposition for the purpose of conducting further experiments. Messages were received on the CARLO ALBERTO from Poldhu at intervals during the entire time of a voyage from Plymouth, England, to Spezia, Italy, and subsequently on a similar voyage to Cronstadt, and while lying in the harbor of Sydney, Nova Scotia.

During the summer of 1902 a station was built on Table Head, Cape Breton Island, and on December 21st three messages were sent to Poldhu. One from the Governor General of Canada to the

King of England, one from the Captain of the CARLO ALBERTO to the King of Italy, and one to the London Times from its special correspondent.

On the completion of the Cape Cod station in 1903, the following message was sent to Poldhu, January 19th:

"His Majesty, Edward VII, King of England.

"In taking advantage of the wonderful triumph of scientific research and ingenuity which has been achieved in perfecting a system of wireless telegraphy, I extend on behalf of the American people most cordial greetings and good wishes to you and to all the people of the British Empire.

THEODORE ROOSEVELT."

The reply was by cable.

Since that time, though both the Poldhu and Cape Cod stations are working in connection with steamers, and reports are occasionally received that liners are simultaneously in connection with both stations, no attempt has been made to conduct trans-Atlantic business. The Cape Eace station is being rebuilt and regular communication to compete with cable lines is promised.

The National Electric Signaling Company of Washington, D. C., is also constructing stations with this end in view.

The U.S. Navy Department, while watching and investigating the progress of wireless telegraphy abroad and at home, made no attempt to conduct experiments on its own account from 1899 to 1902. In the meantime, Fessenden and De Forest in the United

States, Slaby and Braun in Germany, Rochefort and Ducretet in France, and Lodge and Muirhead in England had developed and operated systems differing largely in instruments and methods, and to some extent in principles.

In August 1902, the Chief of the Bureau of Equipment directed the trial of sets from each of the above, (except Braun and Fessenden), which had been purchased for the purpose. These tests extended from August 1902 to July 1903, stations being established for the purpose at Annapolis and Washington and on the TOPEKA and PRAIRIE. The instructions to the Board were specific in the points to which particular attention was to be paid, which were as follows:

(a) Distance of reliable transmission for given height of aerial wire.

(b) Energy employed in transmission.

(c) Accuracy and reliability.

(d) Rapidity of transmission.

(e) Adjustments necessary for varying distance of transmission.

(f) Effect of heat, fog, rain, and general varying atmospheric conditions.

(g) Effects of vibrations due to neighboring machinery.

(h) Effect of interference from neighboring electric circuits or magnetic disturbances.

(i) Effect of rolling or pitching of ship.

(j) Danger from the sparks from sending wire.

(k) Interference from any cause whatever.

The best results between ship and shore were obtained with the Slaby-Arco apparatus, and were as follows:

Annapolis and PRAIRIE	- Annapolis 84 miles,	PRAIRIE	107 miles
" " TOPEKA	" 70 "	TOPEKA	70 "

The Board reported that the Slaby-Arco apparatus was the one best adapted to Naval use among all the systems tried, (not only on account of its greater range, but from its reliability, freedom from interference, adjustability, and ease of manipulation by unskilled or poorly trained operators), and recommended the purchase of sufficient sets for the equipment of vessels and shore stations.

About 55 sets in all were purchased and the work of supplying ships and shore stations was begun, and has been continued up to the present time.

These sets were guaranteed to give a range of about 50 miles regularly. This has been fulfilled and generally exceeded.

In 1904 another series of tests were conducted, using the stations at the Highlands of Navesink, Navy Yard, New York, and the TOPEKA. The instructions to the Board were similar to those issued to the previous Board, particular attention being devoted, however, to methods of preventing interference and ensuring secrecy in transmission otherwise than by the use of a cypher code. The systems tried were the Bull, the De Forest, Rochefort, Telefunken (formerly Slaby-Arco), Fessenden and Lodge-Muirhead.

In distance the best results were obtained with the Fessenden apparatus, between the Highlands of Navesink and the TOPEKA - 181 miles. One way from TOPEKA, 201 miles; words per minute, 27.

The Marconi Company, though at first signifying its willingness to submit apparatus for test, withdrew for reasons not pertinent to this discussion.

Special interference tests were made with the De Forest, Telefunken and Fessenden systems. The Fessenden Company presented a secrecy sender for test, but the test of this method of preventing interference and reading was inconclusive and further tests are desirable. The Bull system of selective signalling gave promising results but was slow in action. The Fessenden interference preventer also gave promising results.

In reference to preventing interference, it may be remarked that the operator in charge of the Department's Cape Cod station keeps his receiver so adjusted that he can receive messages from Boston on the coherer while the large Marconi station at South Wellfleet is sending.

In the meantime, the Signal Corps of the War Department and the Weather Bureau of the Department of Agriculture had been experimenting extensively with wireless telegraphy, and the Weather Bureau had in view the building of a system of coast stations.

The subject having been brought to the attention of the President, a Board was appointed to consider the entire question of wireless telegraphy in the Service of the National Government. The report of the Board was approved by the President July 29, 1904, and is in part as follows:

> "That the necessary steps be taken that the Navy Department shall install a complete coastwise, wireless telegraph system covering the entire coast of the United States, its insular possessions and the Canal Zone in Panama. That the wireless stations of the Navy Department shall receive and transmit to the ocean, or to islands, or to other places where the information can be made useful, the storm warnings of the Weather Bureau.
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> "That as fast as Naval wireless telegraph stations are put in operation the Navy Department shall be directed to receive and transmit, through these stations, free of charge, all wireless messages to or from ships at sea, provided such stations do not come into competition with commercial stations, until such time as Comgress may enact the necessary legislation governing this subject.
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> "That the Navy Department shall request all vessels having the use of its stations for the receipt of messages, to take meteorological observations of the weather at least once daily, when within communicating range, and transmit them to the Weather Bureau, and to transmit observations oftener when there is a marked change in barometer. That to prevent the control of wireless telegraphy by monopolies or trusts, that any legislation on the subject should place the supervision of private stations under the Department of Commerce and Labor."

Following out these recommendations, the Bureau of Equipment published a list of the call letters and names of its stations; adopted and published in Notices to Mariners rules governing the interchange of commercial messages; announced a standard wave length of 320 meters to which stations would be tuned for the present; and, through the Hydrographic Office, keeps the merchant marine informed as to the facilities for service, etc.. The most important service thus far is vessels reporting from the Nantucket Shoals Lightship via the Torpedo Station. A proposed bill incorporating the ideas recommended by the Board was prepared but failed to reach Congress.

The Bureau has now in operation 23 shore stations. 11 shore stations are under construction, most of which are nearing completion. 8 stations will probably be built on the Pacific Coast during the next fiscal year and several in the Philippines.

Outstanding contracts exist with five wireless telegraph companies and a sixth is installing three sets for test at its own expense.

Of the principal European countries in all of which governmental control of wireless telegraphy exists, Germany has adopted a wave-length of 365 meters for public service and announced the opening of 7 shore stations. These are supplied exclusively with Telefunken apparatus as is also the German Navy. None of the other countries have published the wave-length adopted. The English Post Office authorities have made arrangements with the Marconi Company for transmission to and from ships at sea through the company's stations of telegrams sent from any place in the United Kingdom. Special legislation providing for the licensing of all private wireless telegraph stations has been enacted there and in Canada. Italy has 16 shore stations in operation and others under construction, some for public use, others for military service only. Marconi's instruments are used exclusively in the English and Italian navies. The company enjoys an entire monopoly in Italy and a practical monopoly in England. France has a number of shore stations in operation and is building others.

Rochefort and Ducretet with Captain Ferrie and others, developed the system in use in the French shore and ship stations, and Captain Jackson of the British Navy has been influential in adapting wireless apparatus to ship's use and has investigated atmospheric and other conditions which affect results.

The use of the De Forest system on the Hai Mun is the early part of the Russo-Japanese war is fresh in mind, and led probably to the announcement by both belligerents that persons in charge of wireless telegraph outfits on board private vessels captured in the vicinity of operations would be considered as spies.

Practically all of the larger vessels in all important navies are equipped with wireless telegrahp outfits, and its use in outlying parts of the world where it is not feasible to build telegraph lines or lay cables is rapidly extending.

Its usefulness on men-of-war previous to action is undisputed, but as to its actual usefulness in action only meagre and contradicting statements are yet available. This will be referred to in another part of this paper.

In the United States several companies have established stations for commercial and experimental purposes and distances comparable with the best overland results abroad have been covered.

At present the theoretical basis is fairly well established, but methods of application are still widely divergent, due largely to search for suitable combinations of material to achieve desired ends. Though progress has been very, one may say wonderfully, rapid in the ten years since Marconi's first experiments were made, the art of wireless telegraphy may fairly be described as still in the formative period.

THE PRINCIPLES OF WIRELESS TELEGRAPHY AND The Mechanism of their Application.

As an introduction to the mechanism of the art, I propose to review a few basic facts of electricity and magnetism.

Wireless telegraphy is closely connected with the very groundwork of both.

Everyone is familiar with pictures of the field surrounding a magnet as shown by the way in which iron filings place themselves when held over it. The curved lines which they form are the physical basis for the conception of magnetic lines of force, as showing the manner and direction in which magnetic force acts.

Figures similarly made show the magnetic field around a conductor carrying a current. The direction of the latter field, - that is, the direction a magnetic needle will take when free to move in it, depends on the direction of the current; but in every case the needle points at right angles to the wire, - to the right when placed above a wire in which the current is flowing away from the observer, to the left when placed below it. These directions reverse with the reversal direction of the current. Hence the statement that lines of magnetic force surround every wire carrying an electric current, increasing and decreasing in strength with the current and reversing in direction with it, and these lines enclose circles in planes at right angles to the direction of the current. These lines of force are of the same nature as those in the vicinity of a permanent magnet. They are produced by the current, and they in turn produce currents when moved in the vicinity of conductors, or when conductors are moved in their vicinity.

When magnetic lines of force cut or are cut by a conductor, a current starting at the cutting point is produced in the conductor and the result is such as to produce other lines of force opposite in direction to the inducing lines; in other words, to resist the motion. This is purely a mechanical illustration and may poorly represent the real facts. Just how the effect is produced is not known, but it appears that all magnetized and electrified bodies in the universe are connected to an elastic substance which transmits strains in all directions, so that movement in any one body produces movement in and is opposed by the inertia of all the others. This influence of one magnetized or electrified body on every other, however infinitesimal it is, always exists. This fact should be kept clearly in mind.

In relation to our subject we have then, that when lines of magnetic force cut conductors, currents are produced. It might better be stated that a tendency to current flow is produced. The rate of cutting is the measure of the force (is the force) tending to make currents flow, - the e.m.f. Currents actually do flow if the conductor forms a closed circuit, if not, sufficient manufacture, so to speak, of electricity takes place to produce electrostatic charges at the surface and ends of the conductor.

Electrification can also be produced by friction.

If amber is rubbed with silk an electrostatic charge is produced thereon, the presence of which can be shown by means of an electroscope or by its property of attracting light bodies. The silk is said to be positively, the amber negatively electrified. When separated, lines of electric force are set up between them, just as lines of magnetic force are set up between two opposite magnetic poles. They attract each other. If joined by a conductor the charges neutralize each other.

So in the conductor referred to in the preceding paragraph its ends are kept in states of opposite electrification as long as the cutting of or by magnetic lines of force continues, and lines of electric force are set up between these ends. They attract each other. When the cutting of lines ceases the charges on the ends neutralize each other through the body of the conductor. The electric lines of force joining these ends are at right angles to the circular lines of magnetic force produced when the charges flow towards each other.

Our ordinary view of the fields surrounding magnetized and electrified bodies is that these fields are limited, and for ordinary purposes they are limited; but for the discussion of wireless telegraphy it is necessary to bear clearly in mind the fact that they are really all pervasive, tenuous, but existing everywhere.

In magnets, lines of magnetic force join two points of opposite polarity, or magnetization, around electric currents they form circuits. Lines of electric force join two points of opposite electrification. Lines of force of either kind appear to be mutually repulsive, which may be the cause of their shape and of their pervasiveness, and they tend to contract in the direction of their length, which may be the cause of the attraction which exists between the bodies from which they proceed.

It is found that if two bodies oppositely electrified are brought within a certain distance of each other, that a spark passes between them and their charges disappear.

Theory indicated, and it was proved by the late Prof. Rowland of Johns Hopkins University, that an electric charge, if moved, creates and is surrounded by a magnetic field. Therefore when an electric spark passes a magnetic field is produced.

Electric charges moving in quick succession with the velocity of light, we call electric currents. This view of electric currents serves to explain their production by chemical action, as in batteries. The view previously given, of currents being generated by lines of force cutting conductors, - serves to explain the action of dynamo electric machines. Both views are suitable for our purpose.

I have just stated that moving electric charges are surrounded by circular magnetic lines of force and connected by electric lines of force. Now imagine two charges approaching each other; at a given instant the electric or electrostatic lines of force, as they are usually called, can be imagined as the meridians of longitude of a sphere of which the two charges are the poles and the magnetic lines of force the parallels of latitude, both electric and magnetic lines moving outward at the same rate (that of light) but the ends of the meridians moving toward each other; when the chanrges meet the spherical condition has been changed to that of a smoke ring, ever widening, progressing outwards. When the charges pass each other another sphere begins to grow but with oppositely directed meridians and parallels of electric and magnetic lines respectively. Having reached the ends of the conductor, the charges return, approach and pass, throwing off this time a ring in which all the lines are reversed in direction. It is thus that an attempt is made to imagine the way electric waves are produced.

It is found that spark limits between the same charged bodies can be increased, that is, the sparking possibilities or potential can be varied. Again, sparks between large bodies have greater volume, are fatter, so to speak, than between small bodies at the same distance. The larger bodies appear to hold more electricity; their capacity is greater. Capacity may be defined as the quality a body has of receiving an electric charge in proportion to its surface, without increasing its sparking distance or potential. Capacities may be said to be related to each other in the same way as rubber bags inflated with air. There may be more air in a large bag, but it is making no greater effort to escape per sq.in. than in a small bag at the same pressure. It will, however, require a longer time and more air to charge the large bag up to a certain pressure, and its power of doing work is correspondingly greater.

The charge or discharge of any capacity being a movement of electricity creates a current, and this current is surrounded by circular magnetic lines of force which are produced by the current, and which require work to produce. It might be stated that to produce (in air) or to cut one line of force requires one erg of work. With the same power (e.m.f.) to create the current, the time taken to create it will depend on the number

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of lines of force to be produced; in other words, the amount of work to be done. The number of lines of force produced or induced in a circuit when unit current is made to flow is called the self induction of the circuit. It represents the resistance of the circuit to change of condition. This we usually call inertia, and self induction is sometimes called electromagnetic inertia to distinguish it from the inertia of ordinary matter.

With the same e.m.f., that is, the same power to do work, the creation of a given current in a circuit of large self induction will take a longer time than in one of small self induction, and it will take longer to charge a large capacity than a small one. It will also take longer to charge or discharge any capacity through a circuit of large than of small self induction. It can be inferred from this that both capacity and self induction affect the time it takes to produce electrical effects in a circuit. All circuits have both induction and capacity.

Inertia represents resistance to change of condition, whether of motion or of rest and affects spark discharges in this way:- when two electrified bodies are brought within sparking distance, the passing charges may be likened to the sudden release of a compressed spring or of a taughtened bow string. Its inertia causes it to overshoot, so to speak, the mark, (which is the position of equilibrium); it passes from one condition of tension to another, and oscillates until the energy is lost in heat and vibration transmitted to other bodies, when rest ensues. So the two charges appear to fly past each other when suddenly released by the breaking down of the air gap.

It had been suspected by various scientists that spark discharges consisted of several sparks in alternate directions instead of a single spark in one direction only, before Lord Kelvin in 1853 deduced the equation governing them; showing that if the resistance of the circuit in which the spark discharge takes place is greater than $\sqrt{\frac{4L}{C}}$, that it is gradual; but that if the resistance is less than $\sqrt{\frac{4L}{C}}$, which is usually the case, the discharge is oscillatory. He showed further that time time of the oscillation depends entirely on the self induction and capacity of the circuit, and is equal for a complete oscillation to $2\pi\sqrt{LC}$. Therefore, the time for any electrical action to take place in a circuit depends entirely on the self induction and capacity of that circuit.

This has been called the fundamental equation of wireless telegraphy.

In 1863 Prof. Clerk Maxwell, from theoretical considerations predicted that light and electricity are both forms of ether vibrations, differing only in length. He died before his theories were proved, but they had made a profound impression on many scientific minds, and in 1886 Henrich Hertz, a German scientist, then Professor of Physics in the Technical High School at Carlsruhe, proved the entire truth of Maxwell's theory, showing that the oscillating spark discharges referred to produce true ether waves, similar in all respects except length, to light waves and sibject to all the laws of light waves, such as reflection, refraction, diffraction and polarization. He further proved that these waves coming in contact with conductors, produced oscillatory currents in them which he could detect by means of the minute sparks produced in a nearly closed circuit by waves from spark discharges in another circuit at a distance.

Hertz laid the foundation of wireless telegraphy by producing ether waves and detecting them. These waves are called Hertzian waves, and it has been proposed to call the method of transmitting intelligence by their means Hertzian Wave Telegraphy. Hertz showed that substances opaque to light, except conductors, are transparent to electric waves. It was with these facts at command that Marconi began his experiments in 1895. His wave producer was what is known as a Righi oscillator, which consisted of an induction coil whose terminals charged (by means of sparks) two spheres a short distance apart, the short waves produced by the oscillating spark discharges between these spheres being used for transmission. The spheres were placed in the focus of a parabolic mirror and the waves sent in any desired direction. Marconi's wave detector was the coherer of Branly-Lodge and Popoff connected by means of a relay to a recording apparatus.

The operation of all coherer recording receivers is briefly this: Current from a single cell in circuit with the coherer and a sensitive relay actuates the relaytongue when the coherer is rendered conducting by the impact of electric waves. The movement of the relay tongue closes a stronger circuit which starts the Morse tape and inker, and also actuates a bell tapper which strikes the coherer, rendering it non conducting. The movement of the tapper tongue should be arranged to break the tapper recorder circuit before the coherer is tapped, so that there will be no break and consequent spark and injury to the relay tongue. The coherer is protected by a condenser in shunt with it.

It was soon found that better results were obtained when capacity plates were added to the spark balls of the Righi oscillator and to the coherer. This increased the wave length to such an extent as to render a reflector impracticable, but improved reception despite this loss. Further experimenting to increase distance brought about the substitution of the earth for one capacity plate, and the elevation of the other both for sending and receiving. Then it was found that the added capacity due to increased height of vertical wire compensated for the elevated capacity plate, or, rather, that the desired capacity could be obtained by increasing the number of vertical wires (see Fig. 5).

Theory showed no reason why wave propogation should depend on an earth connection to the air wire. Prof. Braun long after Marconi's use of an earth connection constructed artificial earths or capacities of various forms which, like Marconi's first sets, were successful for short distances.

The exact role of the earth in the production or transmission of electric waves is still the subject of controversy; but the weight of authority is in favor of the view that electric waves have the further property of being guided by conductors, and that when ground connections are made the electrostatic lines of force (which join points of opposite electrification in the elevated wire and the ground) keep one foot on the ground at all times, so to speak, and when snapped or crowded off from the wire are guided over the earth's surface as loops or half waves following its curvature, and can therefore be detected at points far distant from what would be possible if they were propogated like light, in straight lines only.

Marconi had always in mind the fact that, other things being equal, reception should be better if the natural time periods of the sending and receiving circuits were the same. We have seen that when the resistance is small the time in seconds of one complete oscillation in any circuit is $2\pi\sqrt{LC}$ L + C being given in practical units, and the wave-length of the circuit in meters is this fractional part of 300,000,000 meters (the velocity of light per second).

The inductance and capacity of a straight wire are so related that when the wire is placed vertically at a distance from other capacity bodies its electrical length is equal to its natural length, and the wave-length is twice the length of the wire for a complete oscillation. If one end is held (attached to the earth) its wave-length is four times the length of the wire, following in this respect the wave-lengths produced by closed and open organ pipes.

The waves produced, whether propogated like the smoke rings referred to or gliding as half waves over the earth's surface, have, when generated in a vertical wire, their magnetic lines of force in circles parallel to the earth's surface, and therefore at right angles to the vertical receiving wire. Currents are produced in this wire when it is cut by the advancing lines of force and the higher the wire the greater the number of lines which are cut by it and consequently the greater current flow. This is one explanation of the greater efficiency of elevated wires. Another is that the longer wave-lengths, up to 2,000 meters or more, seem to travel with less attenuation over land than the comparatively short waves of 200 to 500 meters, and longer wires produce longer wave-lengths.

When the period of the waves producing oscillations in the receiving wire is equal to the natural electrical period of the wire, the current impulses produced are timed so as to increase the effect, just as timed pressure on a spring board produce vibrations which increase until the dissipation of energy per vibration is equal to that received. It will thus be easily seen that waves properly timed can build up currents in the receiving wire which can be detected when a single impulse would give no indication. Marconi's tuned circuits up to 1900 were as shown. (See Fig. 1).

There are two defects in a sending circuit with elevated straight wire and spark gap in series with the wire and the ground, and usually called plain aerial. One is that its low self induction gives it less inertia and makes it in consequence a less persistent vibrator. The oscillations die out quickly, three or four sparks at the most passing. All of the energy is radiated in a few rapidly diminishing waves. The other defect is that its small capacity combined with its small self induction gives a correspondingly short wave-length and high frequency; that is, number of oscillations per second. Now capacity of a body decreases as the oscillations per second increase. Within limits, the higher the voltage used and the longer the spark gap, the greater the wave energy produced; but with any high frequency a limiting voltage can be reached beyond which the capacity body spurts electricity (in the shape of brush and glow discharges) in all directions like dry linen fire hose suddenly subjected to water pressure. The dielectric breaks down everywhere; the directed energy that it can transmit is limited.

As we have seen, properly timed vibrations can build up the current in a receiving wire to a point where it can be detected when any single wave cannot. The limitations on number and amplitude of single waves from a straight vertical wire with a spark gap in series have just been pointed out.

Many inventors have claimed the distinction of first inductively connecting a persistently vibrating circuit to a good radiating open circuit so as to be able to take advantage of the resonant current which can thus be built up in the receiving wire and increase the radius of transmission without reaching the limiting voltage. Such persistently vibrating circuits consist of comparatively large capacities and inductances arranged in a small space, so as to give low resistance and small heat loss. The lines of force generated by the current vibrations in the closed persistently vibrating circuit, cut the open circuit (air wire) and produce equivalent currents in it, which are rapidly dissipated by radiation, but the loss is continually supplied from the closed circuit. Advantage can be taken here also of resonant or properly timed impulses to increase and maintain the amplitude of the outgoing waves.

Specially designed appliances to give comparatively large capacities in small spaces are called condensers, the most familiar example of which is the Leyden jar, - a glass jar with inner and outer coatings of tin-foil.

Two capacities charged at a distance from each other to the same potential and then brought near each other show a lowered potential as if the pressures were reduced or the charges condensed, - hence the term condenser. The amount of this effect depends also upon the material between the charges, glass and other insulators producing a much greater effect than air. The best glass for this purpose having 9 times the effect of air at atmospheric pressure in increasing capacity. In fact, the charge is in the glass and the best glass has 9 times the storing capacity for electricity that is possessed by air at atmospheric pressure.

The tin-foil being a conductor is used only to convey the charge to and from, and spread it equally over the glass. As stated above, the charge is in the glass or other material used as a dielectric, and subjects it to a mechanical stress which is shown by the change of shape when charged. Glass of the best quality has the highest known capacity for storing energy in the shape of electricity, but micanite, paraffine, oiled paper, air under pressure, etc., are all used for condensers, and when so used are called dielectrics.

Condensers formed of batteries of Leyden jars are commonly used in wireless telegraphy as well as those composed of interlaced plates of glass or micanite covered with tin-foil. Metal plates are used for variable condensers either in oil or air, the insulator being the dielectric; these are connected with inductances made of several turns of wire of comparatively large diameter.

The lines of force produced by the current in each turn cut all other turns and in so doing produce additional lines of force which also cut each turn so that the total number produced for unit current, and therefore the self induction, is largely increased over what it would be in the same length of straight wire.

As has been stated, the time of a complete vibration depends on the product of self induction and capacity, so that it is possible to get (by using condensers and coiled wire) a long wave-length in a small space; this is combined with the open circuit inductively as shown (see Fig.), and its equivalent is used by practically all wireless telegraph companies both for sending and receiving.

At the receiving end the wave detector is placed on a persistent vibrating circuit and inductively connected with a vertical open circuit which will respond to waves of any length, but the current set up by it and in its attached persistent vibrating circuit tend to oscilate in their natural period; if this does not coincide with the oscillations produced by the passing waves, the resultant currents will be weakened and may neutralized. The more persistent the vibrations of the receiving circuit the more marked will be the effect, so that persistent vibration both for sending and receiving tends to selectivity (that is, persistent vibrating circuits respond well only to those waves whose length is nearly the same as theirs) as well as to increased radius.

Adjustment of sending and receiving wave-lengths to each other is called tuning and the precise wave-length assigned to a station may be called its tune.

Proportioning the time periods of vibration of the various circuits to each other, is of the greatest importance in wireless telegraphy and wave meters have been invented and are in use for this purpose.

For communication with stations using the same tune, selectivity is very advantageous, but when it is necessary to be ready to receive from stations having different or unknown tunes, as an explorer, so to speak, a strongly damped vibrator is best, - as has been explained, but the distance of reception is thereby cut down. So in sending to stations having different or unknown tunes, highly damped waves are more likely to be received but the receiving distance is decreased.

The sending apparatus consists of a current source in circuit with the primary of a closed or open core step up transformer (an open core transformer is called an induction coil). The secondary of the transformer is in circuit with the condenser which it charges. The current in the secondary is induced by its turns being cut by the lines of force produced by the primary current.

There is probably no difference in fact, and there is very little difference in theory, between the way the current in the primary produces a current in the secondary of an induction coil, and the way electric waves affect a receiving wire at a greater distance. Great stress is laid on the difference between effects produced by electric waves and by magnetic induction, and Marconi has stated that without the electric spark there is no electric wave. But it is submitted that no current is made or broken without setting up surgings not only in its own conductor but in all others, so that it appears that the difference is one of degree and not one of kind.

It is commonly stated that all the energy returns to the wire with the reverse of current when it is reversed without a spark, while when electric waves are produced it does not, and that this is due to some peculiarity about spark-produced surgings; but patents have been granted for wireless telegraph senders in which no spark is used, an alternating current generator being directly connected to the sending wire. It is probable, therefore, that in particular forms of circuits more non returnable energy, so to speak, is sent out than in others, by reversing currents.

Fleming states that to detach a free electric wave from a radiator it is necessary to have a certain high frequency, not sharply defined, but involving a relatively very sudden reversal of the electric force, but he gives no lower limit of frequency.

To return to the sending apparatus, of which elementary diagrams of the principal systems are shown (see Figs.), the primary of the transformer may be supplied with interrupted or alternate current. The current induced in the secondary (which has a high voltage on account of the greater number of turns compared with those on the primary) charges a condenser which is in circuit with the inductance and the spark gap. The length of the latter depends, to a certain extent, on the potential of the secondary which must be greater than the amount necessary to cause a spark to pass across the gap. This potential for short gaps is about 4500 volts per millimeter, but voltage per millimeter decreases as the length of gap increases, being for a gap of one centimeter about 30,000 volts, that is, 3,000 volts per millimeter.

The resistance of the spark gap is so high that no current passes until the strain on the dielectric (the air between the spark electrodes) is brought to the point of rupture by the increasing potential. This same strain exists between the faces of the dielectric forming the condenser. When the air gap breaks down, its resistance (in the time it takes light to travel its length) drops to, in many cases, a fraction of an ohm, and thus removes the only obstacle to the uniting of the charges on the condenser and other parts of the circuits. Thus suddenly released their inertia causes them to fly past each other. The condenser becomes charged in the opposite sense and the action is renewed in the opposite direction. A spark passes at each reversal, until the potential drops below the sparking point, when the visible surgings cease.

The high self induction due to the iron core of the induction coil or transformer prevents these surgings from being communicated to the secondary and reactance coils are put in where leads are long. The secondary is out of resonance; in other words, its inertia is too great to permit it to be set in motion by the rapid blows given by the oscillatory currents, so that the circuit formed by the condenser, inductance, and spark gap oscillates in practically its own period until the potential drops below the sparking point, when, as stated, the visible energy ceases, the circuit is again charged by the secondary to the sparking potential, and the action commences again.

Suppose a spark gap of 5 millimeters, which requires a potential of 20,000 volts to rupture it; suppose further that the maximum secondary potential is 40,000 volts and that the cycles or interruptions are 80 per second.

Spark discharges begin about 1,320 of a second after the voltage begins to rise; i.e., as soon as difference of potential across the gap is 20,000 volts. If the oscillating circuit has a wave-length of 300 meters, its frequency is 1,000,000 per second, and if 8 sparks pass in each train (i.e., before the potential falls below the sparking point) the duration of a train is 1/250000 of a second. As many as 200 sets of oscillations have been measured by Prof. G.W. Pierce of Harvard University in one alternation or half cycle of current; that is, the condenser was charged and discharged 200 times in a certain fraction of a second, producing 200 trains of waves in that time, each wave train (if the circuit above described were the case in point) consisting of four complete waves, lasting 1/250000 of a second; intervals between trains 1/16000 of a second. The sparking and silent intervals are as 1 to 15; long intervals of silence, so to speak, between trains and much longer intervals (about 1/160 second) between groups of trains. Successive sparks have been photographed and the intervals between them measured.

The vibrations of the closed sending circuit are inductively or directly impressed (by means of an air core transformer of a few turns) on the open radiating circuit, and waves in trains and groups of trains sent out in all directions. The current in the primary, and thus the production of the waves in the manner just described, is controlled by the sending key, by means of which it is closed at intervals to correspond in length with the dots and dashes of any desired code. A dot, therefore, is made up of many waves in trains and groups of trains, and a dash of a still greater number.

We are accustomed to think and speak of electrical action as being instantaneous, though we know it is not. This habit produces confusion of thought, and in order to consider the subject of wireless telegraphy understandingly, time must be kept clearly in mind. The time rates of vibration, that is, the number per second, is given here as a matter of interest in this connection, for a number of different phenomena.

We perceive air vibrations, which we call sound, by means of the ear, a special sense organ for the purpose. The ear distinguishes notes of from 16 to 40,000 vibrations per second as sound, though the ordinary human voice has a range of but 3 octaves, from approximately 100 to 1000 vibrations per second.

With the eye we perceive ether or electromagnetic vibrations, which we call light, from 430,000,000,000 to 740,000,000,000 per second - a little less than one octave, i.e., from red to violet light.

By means of their action on certain substances (that is, by photography) we perceive vibrations from 870 trillions to 1500 trillions of vibrations per second and beyond - ultra violet and X rays.

Between 430 and 300 trillions of vibrations per second we have what is known as the infrarouge rays, which are known for their medical effects.

Below 300 and down to 20 trillions of vibrations per second, we detect ether vibrations by our sense of feeling, ether vibrations through these four octaves being known to us as <u>heat</u>.

45 octaves lower down on the same scale are the ether vibra-

tions which we call electric waves and which are used in wireless telegraphy. The shortest of these yet measured are .2 of an inch in length; the longest ones over one million miles. The latter have a period of 6-1/2 seconds and give evidence of electric displacements in the sun.

We have, therefore, the gamut of ether waves, running from the infinitely small to the infinitely great, with an unexplored range of 45 octaves between the longest heat waves and the shortest electrical waves yet measured.

For electric waves before the researches of Hertz, we had no detector. His micrometer spark gap, in which tiny sparks were produced by the impact on its circuit of electric waves, was the first made for the purpose. The coherer of Branly and Lodge we may call the second, and this last still does duty for the purpose, but since its invention many others have been discovered - first, those of the various forms of carbon whose extreme sensitiveness to pressure (even to the extent of registering the movements of a fly's foot -) in its electrical properties) had long been known and utilized in the various forms of microphones and telephones.

The action of all forms of imperfect contact wave detectors or kumascopes, as Fleming proposes to call them, in which are included all coherers and microphones, can be explained on the principle of electrostatic or magnetic attraction, whether self restoring or otherwise.

The heating effect of the induced oscillating currents has also been utilized for the purpose of detecting electric waves, notably in the hot wire barretter of Fessenden.

In 1896 the action of electrical oscillations on iron was investigated by Rutherford who devised a form of magnetic wave detector which has been perfected by Marconi. The magnetization of iron always lags appreciably, in time, behind the cause which produces it. While being magnetized it is extremely sensitive to any change in the magnetizing force, any sudden increase in which produces a disproportionate increase in the magnetization of the iron. In Marconi's form of magnetic wave detector, a band of iron wire is revolved continuously in front of a magnet, so that its magnetization is always changing. The receiving wire is in circuit with a coil surrounding the moving band, and the oscillatory currents due to the passing electric waves produce sudden changes in the magnetization of the band. These changes induce currents in a coil of fine wire surrounding the band and in series with a telephone, in which they are heard as dots and dashes. Different forms of imperfect contact, thermal, and electrolytic wave detectors (the latter yet to be described) will act only as relays to increase or diminish current in a local circuit, and thus require in connection with their use local batteries and means for adjusting their strength.

The magnetic detector is free from these accessories and therefore simpler to use.

The best form of electrolytic or chemical wave detector is just now the subject of important patent suits. These hinge, I believe, somewhat on the character of the action in the detector.

It consists of a cup of acid or alkaline solution having an anode of fine platinum wire and a kathode of heavier platinum wire in circuit with a local battery, and an adjustable resistance. The sensitiveness of the cell is said to depend on the area of the anode exposed. This consists generally of a fine platinum wire sealed in glass so that the point only is exposed to the electrolyte. A very good form is quickly made by taking out the filament of an instrument lamp, leaving the platinum leading in wires intact and covering them with a dilute solution of sulphuric or nitric acid. This form is due to the ingenuity of a Chief Electrician in the Navy (Delaney).

Its action appears to be that the gas generated at the anode by electrolytic action in the cell, due to the current from the battery, is momentarily pushed away by the oscillating current; in other words, the cell is momentarily depolarized, and the current thereby increased. It is stated to be not reversible; that is, that the small wire must be the anode. In the instrument lamp receiver just referred to, both anode and kathode are of the same size but neither very small. It is also claimed that the heat generated at the anode by the oscillatory current renders the electrolyte surrounding it, momentarily, a better conductor and thus produces sounds in the telephone.

The latest form (from which excellent results also have been obtained) has the local battery and the detector combined in the same receptacle and requires no adjustment. On account of the extremely small change in resistance produced in electrolytic detectors by the impact of electric waves and the consequently small current change, better reception is obtained by the use of telephones with a great many turns of fine wire, which increases the magnetic effect on the diaphragm of the telephone. These are called high resistance telephones.

Marconi states that he has perfected a call for his magnetic detector, but though promised, no one has yet produced a satisfactory call for the electrolytic detector.

Under the same circumstances that an ordinary coherer will receive messages up to 90 or 100 miles, the best electrolytic detector will receive up to nearly twice that distance. With the latter, readiness to receive depends on the telephone strapped to the operator's ear, while with the coherers an electric bell attracts his attention, or the tape will receive without attention.

Electrolytic detectors lend themselves more readily than coherers to selectivity; that is, are more suitable for use in persistently vibrating circuits, and the use of the telephones permits that of a still more highly selective instrument, - the human ear, which has very high qualities as an interference preventer, and can select the note it desires to receive from a number of others occurring at the same time.

The kind of spark, i.e., whether produced by interrupted or an alternating current, also affects the wave sent out. An alternating current spark is preferred; it seems to be clearer and sharper. With a certain voltage current and length of spark gap an arc may be formed. A spark gap so short that it is necessary to use a current of air across it to prevent forming an arc sometimes gives good results. Adjustment has much to do with the performance of both sending and receiving stations.

ENERGY USED IN TRANSMISSION.

It has been calculated by Dr. Kennelly that a vertical wire 100 feet high, charged to 30,000 volts and suddenly and completely discharged, would have an output, if conversion were perfect, of about 3.5 foot lbs - 46,000,000 ergs - of energy, and that, if no losses of any kind occurred, the energy of the wave would be capable of producing an e.m.f. of 1 volt at 1,000 km. in a wire of the same height. This postulates perfect radiation and conversion.

Fleming states that 40 to 50 foot lbs. per cubic foot is the greatest amount of electrical energy that can be stored in glass when arranged in the best manner. The maximum amount of power yet installed in any wireless telegraph station is about 50 K.W., equal to somewhat over 2,000,000 foot lbs. per minute, or 35,000 foot lbs. per second. i.e. 460,000,000,000 ergs per sec.

If the wave-length of a station using 50 K.W. is 3,000 meters its frequency is 100,000 per second, and if radiating 5% of the time, that is, if the interval between wave trains is 20 times the length of the trains, the total energy in each wave train, (if conversion were perfect) is equal to about 7 foot pounds. There is no known means of accumulating wave train effects when produced by spark discharges. The outlook in this direction is toward the high frequency alternating current, impressed directly on the sending wire. Poincaré, Fleming and Marconi, all high authorities, unite in saying that such alternations

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without the spark do not produce electric waves.

Turning now to the receiving end, Prof. Fessenden states, as the result of quantitative experiments, that the relative sensitiveness of various forms of detectors are as follows:

1. Marconi - nickel, silver, mercury coherer,	4	ergs per
2. Gold 95%, bismuth 5% alloy	1	dot.
3. Solari receiver and various types of carbon steel, steel aluminum and steel mercury receivers	.22	"
4. Magnetic hysteresis receivers	.100	"
5. Hot wire barretter	.08	"
6. Liquid barretter	.007	"

The following record of calls and messages heard by the operator at the wireless telegraph station in the Washington Navy Yard, between 8 and 10 p.m., May 18th and 19th, is interesting as showing the carrying powers of the small amount of energy set free in any one wave train under favorable circumstances. Two or three foot pounds of energy set free in Portsmouth, N.H., making itself intelligently felt in Washington, borders on the marvelous. I may add that these reports have been verified. (See reports). (Not being in Massachusetts, I venture to relate than a few months ago I spent a night in Salem, having in my possession a wave-meter. Imagination fails to picture the effect the possession of such an instrument would have had on the inhabitants of that now peaceful city some hundreds of years ago.)

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May 18, 1905.

Heard "BA" (Bermudian) calling "G" (Galilee, N.J.) at 8 p.m.

" "JH" (Horatio Hall) " "N.Y." (42 Broadway, N.Y.) at 8:04 p.m.

" "BA" " "HA" (Cape Hatteras) at 8:09 p.m.

" "G" " "JH" at 8:17 p.m.

" "WA" (Philadelphia) Pa. " "N.Y." at 8:20 p.m.

" "JH" " "VN" (New Haven, Conn.) at 8:22 p.m.

* " "CG" (U.S.S. COLORADO)" ? "PG" (Boston N. Yd.) at 8:25 p.m.

" "JH" " "N.Y." at 8:31 p.m.

" ? " "VN" at 8:41 p.m.

" "JH" " "VN" at 8:45 p.m.

" "JH" " "RV" (Fall River boat PURITAN) at 8:57 p.m.

" "G" " "BA" at 8:57 p.m.

" "JH" call "VN" at 9:01 - "VN" replied "Nothing doing. "JH" replied "O.K." "G.B." (Good bye) "JH."

" "JH" call "RN" at 9:04 p.m.

" New York Yard communicating to some station at 9:09 p.m. talking about some one being in the class there. (May have been talking to Highlands, N.J., or to Newport, R.I.)

" "G" calling "FB" (City of Atlanta) at 9:33 p.m.

" (?) " "PK" (Newport, R.I.) at 9:38 p.m.

" "PK" " "PG" (Point Judith?) at 9:50 p.m.

From Wireless Station. Rec'd May 19, 1905, 8 to 10 p.m.

8:06 p.m. Heard "N.Y." (42 Broadway, N.Y.) calling "VN" (New Haven) and sending message in rapid Morse code.

8:08 Heard "PC" (Portsmouth Navy Yard, N.H.) making signature and finish after making call to some station or sending message.

"N.Y." calling "VN" 8:11 and 8:13 p.m. No reply from "VN".

At 8:23 p.m. "HA" (Cape Hatteras) calling "QN" (Cape Henry).

At 8:27 p.m. Heard "CD" calling "CS". Am certain of the calls but not certain as to where they came from as "CD" is the BROOKLYN and "CS" the CHATTANOOGA, and both are in Haitian or Domingoan waters I think. (Operator here received letter from CHATTANOOGA this a.m. mailed in Tompkinsville yesterday). I know of no other ships or stations using these calls. At 8:47 heard "CS" called again but did not get sig. of station calling.

At 8:34 "PG" (Boston Navy Yard) called "PE" (Thatcher's Island) and sent:

"Will u pls. give me that msg. u said u got from Portsmouth this p.m. I forgot to get a copy of it. "PG, PG, PG."

At 8:39 & 8:45 "PG" repeated the above message. It came in clear and distinct tho' not loud.

"PG" called "PE" again at 8:46, 9:03 & 9:05 p.m.

At 8:40 p.m. "MO" (S.S. MONROE) calling "QN"; called again at 8:45 p.m.

At 9:13 p.m. "N.Y." calling "AX" (Atlantic City).

At 9:15 p.m. "HE" (U.S.S. MAINE) called "QN" & sent msg. but too weak to read as slight atmospheric was interfering.

At 9:36 p.m. some station calling "PV" & "HN" (New & old call for Highlands, N.J.).

Much difference of opinion still exists as to the best forms of ground connection. As has been stated, theory shows no necessity for ground connections at all, and if I am not mistaken, two of the leading investigators still believe that better results are obtained by using large capacity bodies at the base of the air wire without earth connection. However, thus far ground connections are generally used, and the more points of good contact with moist earth that can be obtained the better the results, generally speaking.

The shape of the open radiating circuit, the aerial as it is usually called, has passed through many changes from the capacity plate at top connected with a single wire, to a single vertical elongated wire, then through the Slaby-Arco squirrel cage and rattail and De Forest looped aerials (excellent, by the way), to elevated grid of horizontal wires connected tomone or more vertical wires leading to the sender or receiver, and this is the form now generally used. So also different forms of single and multiple spark gaps and compressed air spark gaps are used, the object of all being to find a more efficient way of radiating larger quantities of energy. Improvements are constantly being made.

Selectivity, and therefore pervention of interference, is no as easy to secure in practice as in theory. The waves we send out are not pure but have impressed on them overtones, humps and ripples, to an extent that will require a liberal application of Fourier's theorem to analyze them completely, if this is ever done.

Investigation of the manner, sequence and causes of the effects produced are daily increasing knowledge of the subject and placing the art on a firmer basis.

Mr. John Stone Stone and others have patents on arrangements of successive persistent vibrating circuits for filtering out irregularities in order to impress a pure wave on the radiating circuit. He also announces a fool proof receiver.

It appears that a wave form more nearly approaching the theoretical can be obtained and at the same time loss of energy, due te reflection, secondary vibrations, heating, etc., can be avoided, by care in the design of circuits so as to avoid abrupt changes of resistance, self induction, capacity and direction in the different parts. In other words, by making circuits more nearly if not wholly electrically homogeneous.

USES OF WIRELESS TELEGRAPHY.

Many of its uses have appeared incidentally in the course of this discussion; new and unexpected ones are constantly being discovered. One novel idea, which has possibly not been utilized (but is patented, and is certainly unexpected), is for lighting by means of electric waves kerosene torches in orange groves to protect the fruit from frosts.

However, its most important use and principal application thus far has been to maintain communication with and between vessels at sea. It is now vital to all navies, if they are to fulfil the object of their existence, and is spreading rapidly in the merchant marine.

In addition to its use as an ordinary means of conveying private information between individuals, ashore and afloat, it adds to the safety of sea voyages by enabling masters of vessels to be forewarned - which is forearmed - of approaching weather and to assist in predicting the weather by furnishing their own local observations from points hitherto inaccessible to the Weather Bureau. In distress, they can call for assistance; their approach or departure is reported; noon time signals can be received from shore; chronometers compared at other times - between ships or between ships and shore stations. Destination of ships that have left port can be changed.

Though I am not aware that it has yet been done, I wish to point out the fact that the International Signal Book lends

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itself as readily to assist communication by wireless telegraphy as by flags. Operators of any nationality cam converse by its use, and it is no stretch of the imagination to state that navigation laws will sometime require mates and masters of vessels to be, not experts, but able to send and receive the alphabet by wireless, just as they are now required to be able to signal by flags, and that its use will be required by the same laws, or forced by the marine insurance companies.

All modes of application to the merchant marine of this method of signaling are equally applicable to the Navy, and in addition, it enables a commander-in-chief to keep in touch with his units, at all times, regardless of weather, place, hour, and to a certain extent, distance; and in this lies its great and peculiar advantage over other forms of signaling, and therefore its value to the Navy. In one view of the matter it may be said that it lessens the chance for individual initiative, but this field is still wide. Cable catting is now useless; the last hope, the only relief for an admiral - to get to sea and be let alone - is, or soon will be, gone. A separated fleet no longer becomes instantly a lot of unrelated units. Or, in another view of the matter, it gives the ability to control and direct from a distance, which multiplies the value of an army or a fleet. It also calls for the highest qualities in the director, as having the means, he must also have the knowledge to direct. It is in the hands of the commander-in-chief, a new tool, which will assist him best, who knows best how to use it. It is not possible in the limits of this paper to refer more than briefly to its particular uses, as in scouting, but it may be pointed out that a 20 word message relayed from ship to ship at 100 miles apart and allowing 5 minutes for receiving and re-dispatching - which is ample - will travel towards its destination at the rate of 1200 miles per hour. It is expected that reliable communication between ships at 100 nautical miles will soon be an accomplished fact. Six sets of apparatus guaranteed to exchange messages at 250 nautical miles have recently been installed and a distance of 225 miles has been obtained. There is every reason to believe that 250 miles will be obtained under favorable circumstances with an expenditure of not more than 3 horse-power. The working radius of the sets first installed was 40 to 70 miles.

As is well known no reliable information as to its use during action has yet been made public; experiments during target practice indicate the ability of a properly mounted recorder to operate during actual firing, but reception by telephone is difficult, and with more than one gun firing, impracticable, unless a sound proof booth can be constructed. Of course stations that are useful in action should be behind armor, though the range of reception is thereby decreased. Further experiments will be undertaken at the first battle efficiency practice.

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In the Army, portable wireless telegraph sets will replace to some extent the present field telegraphs and telephones. Combined land and sea operations will be assisted by its use. The Signal Corps in its line to Alaska has filled one gap of 107 miles with wireless telegraphy which is working daily on commercial and governmental business. Major Squier, of the Signal Corps, has recently discovered the value of trees as receivers.

The Artillery use it in long range target practice. Also its commercial use is extending in outlying parts of the world, where cables or land lines are difficult or too expensive to construct. Stations are being built on the Amazon, the coasts of Central America and elsewhere by companies having large interests in those quarters.

It will form an integral and important part of the coast signal systems of all maratime countries in peace and war.

Its promoters firmly believe that it will compete with cables on the Atlantic. It is proposed to have central sending stations in large cities to supply news and market quotations to receivers in outlying cities and towns. New mining camps can be connected with wireless, prior to building the regular means of communication.

Enough has been said to show that wireless telegraphy has a wide field of usefulness, public and private. Its use of the ether is bound to extend and mutual arrangements, legislation and international agreement will all in time be necessary to secure the greatest efficiency.

LIMITATIONS.

Many of the limitations as well as the uses of wireless telegraphy have appeared elsewhere in this paper. Some, or most of them, we hope will pass away, as our knowledge increases. Our distance limitations are, at present as has just been stated, about 250 miles with 3 H.P. between ships. We can devote more power and space and aerial wire to this service and this distance can be greatly increased, but probably not without interfering somewhat with other equally important functions of the vessels. 250 miles achieved under favorable conditions should give a working radius of 125 miles at all times.

On shore the distance is, we hope, practically unlimited, but this has yet to be fully proved.

The Department's shore stations will be spaced so that ships with a communicating radius of 125 miles will be practically at all times in touch when within 100 miles of the coast, and be able to <u>receive</u> (from powerful stations) practically anywhere in the West Indies or Philippines.

The precise number of wave lengths, or tunes, which will be necessary for the use of a fleet, so that its different squadrons and divisions can communicate with each other and the flag without mutual interference, depends on the size of the fleet. The precise interval between tunes which will prevent interference is not yet definitely known for all cases. Interference from waves varying 3 per cent from the standard has been successfully prevented.

Interference prevention has been, and is being, made the subject of much study and experiment. If in general practice a wave variation of 3 per cent will suffice to prevent interference, a range of tunes which will accommodate all classes of business can easily be provided. Then the problem of successful intercommunication between stations having different tunes must be solved, in order that sharp tuning (extreme selectivity) will not prove as embarrassing as universal responders.

Stations are already provided with tuning curves, showing within their limits the wave lengths of both the open and closed circuits, so that these can be adjusted to any tune within the range of the apparatus; but means of quickly making these adjustments have not yet been installed, except in two or three shore stations. If the method adopted there proves satisfactory its use will be extended. All this implies graduated variable condensers and variable inductances in both open and closed circuits, preferably graduated in wave lengths.

There are several very convenient and well graduated forms of condensers and inductances, both variable, but an entirely satisfactory scheme of rapid of rapid and certain tuning is not yet the property of any one system.

Having solved the problem of interference by providing resonators which will pick out each its own note from complex ether vibrations, the further problem of interference by vibrations sent out in the same tune by the enemy must be attacked. This may be done by clockwork, using Greenwich time, or some cypher or other pre-arranged system of tune changing, which will block interference until it is useless.

Malicious interference in time of peace can be prevented in the courts, and secrecy assured by cypher codes.

Just at present, in applying wireless telegraphy to Naval purposes, much embarrassment is caused by the multiplicity of codes. It has been deemed necessary, in order to make signalling by wireless conform with other Naval codes, to use the Wig-Wag Code in dots and dashes for official Naval use. With private shore stations and U.S. steamships it is necessary to use American Morse. With foreign vessels and shore stations Continental Morse. Occasionally an operator, expert in all three codes, can be developed, but the use of three militates strongly against expertness in any, and hampers very greatly the organization of an efficient corps of operators, the possession of which, it cannot but be evident, is absolutely essential in order to utilize the capabilities of wireless telegraphy.

Continental Morse is used by all cable companies, and universally abroad. It is probably easier to read, if not as rapid to send, as American Morse; it is more rapid than the Navy Code and is as well adapted for use in the Wig-Wag Code. American Morse, on account of spacing, is not well adapted for wig-wagging.

In international telegraph code is greatly to be desired and I hope in time will be forced by ships' use of wireless

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telegraphy. In the meantime, with three codes forced on our operators, the development of the art in the Navy will continue to be greatly hampered and retarded. This is especially true in sending and also in receiving when the telephone is used.

This brings us to the question of audible vs. visible reception.

We learn that the strong waves sent out by the Poldhu station are read on the coherer in the interior of Germany many hundreds of miles distant; but the fact remains that the coherers now in use decrease the receiving range nearly 50 per cent, as compared with the telephone, and they have not the selective qualities of the human ear. Any vagrant wave that impresses itself on the coherer will make as good a mark on the tape as any dot or dash ever regularly sent out.

Bearing in mind the fact that practically all telegrams received in the United States are read by sound, a record, though very desirable, cannot be considered necessary, especially as the range of communication is thereby much decreased when compared with telephonic reception.

A coherer operated station requires a smaller force and is less fatiguing than where the telephone is used, since the latter, having no call, requires unremitting attention. A call that will work to the greatest distance of the telephone is greatly needed.

During bright sunlight or hot sultry weather much greater energy is required to send a given distance than is needed to send the same distance at other times, and this is often a serious limitation. Transmission in daylight is always poor in comparison with transmission at night, but the amount of difference is very variable.

At some stations atmospheric discharges produce serious interference. At Dry Tortugas, for instant, during certain hours of the day reception is impossible. These discharges are the product of vagrant waves of various kinds which have their own periods of recurrence and occurrence in different latitudes at different seasons of the year, and though they may be partially selected out, they cannot be enjoined.

There are further limitations due to local conditions at stations which we are not thus far able to foresee, and not always able to overcome. An imperfect reflecting screen only occasionally lifted, seems to surround some localities. Little comes in, and little goes not. They remain in the shadow continually. Other stations, again, appear to be the meeting point of electric waves of all kinds from all quarters, and are exceptionally good both for transmitting and receiving. The screening effect of high land or heavy undergrowth and tall trees in the vicinity of a station is well settled, but is not definite in amount.

In fact there is a great deal more qualitative than quantitative information available concerning wireless telegraphy, but a number of expert investigators are now conducting experiments which cannot fail to add greatly to our knowledge of the actions that take place, and to indicate the direction in which improvements can be made.

For instance, Professor Pierce of Harvard has shown that when the ordinary spark gap is replaced by a Cooper-Hewett mercury interrupter, the received energy is increased four times, other things being equal.

This shows how great the loss in the ordinary form of spark gap must be, producing as it does sound, light, heat and electric waves simultaneously.

Wireless telegraphy has not yet been duplexed. More than one message can be received at the same time at the same station. Two messages can be sent from the same station at the same time also, but no station is yet prepared to send and receive at the same time.

This practically limits the capacity of wireless telegraph stations to approximately 35 words per minute, one way, under the most favorable circumstances, with one sender and one receiver. If arranged to send or receive two or more tunes at the same time, the capacity is increased but is still only one way.

A company has recently been formed for the purpose of exploiting an invention to detect the direction from which the waves proceed. This, if successful, will be directly applicable to navigation for the plotting of ships' positions.

Prof. Artom, an Italian scientist, has recently made extended experiments in the production of eliptically polarized waves in which the energy predominates in the longer axis of the ellipses. This is an effort, - and it is said to have been successful, - to direct the wave energy.

As has been previously stated, the length of the waves now used prohibits the idea of using reflectors to direct them. Marconi's first apparatus generated waves approximately 10 inches in length, which were directed by means of a parabolic mirror.

We have inefficient means of producing waves of any desired length, of breaking them up so as to form signals, and of receiving these signals at great distances. But due to the only partial selectivity of our receivers we are liable to interruption and confusion when two or more wave trains of the same or different periods arrive at the same place at the same time.

We have no practical means of directing the waves produced so as to intensify their action in the desired direction and prevent their detection out of the plane of transmission. But with good selectivity this is not essential. I have pointed out, in attempting to describe the way in which the waves are produced, that the oscillating discharge of a condenser spreads the energy, small in any case, over a series of waves which is called a wave train and that the interval between wave trains is great in comparison with their length. So great that no vibratory effect produced in the receiver is likely to last over from one train to the next.

If the wave detector is such that it operates by virtue of the potential or current effect produced and not by the heating effect of the current, any number of oscillations per wave train, beyond that necessary to produce a maximum in the receiver, for the energy per oscillation received, is wasted, and the same energy had better be concentrated in a less number of waves, just that number necessary to produce a maximum in the receiving circuit. The waves per train are a function of the length of spark gap and potential as well as of the capacity and inductance of the circuit. For instance, if there are 20 waves in a train and the maximum effect in the receiver is produced at the passing of the 10th wave, the energy in the remaining 10 waves is wasted.

It would be better to have the same energy concentrated in 10 waves, each of greater amplitude, and thus produce a higher maximum in the receiver.

Again, as Dr. De Forest has pointed out, the receiving circuit can be so designed that it will have produced in it by equally spaced vibrations, stationary waves, such as are produced in Lecher wires, with alternating nodes and loops of potential and current, and the wave detector can be placed at points of maximum current or potential according to its mode of action.

Production, Transmission, Reception, all present some unsolved problems, but the progress made in ten years gives assurance that in another decade Wireless Telegraphy will be established on a firm theoretical and practical basis.