WIRELESS TELEGRAPHY AND TELEPHONY SIMPLY EXPLAINED

WIRELESS TELEGRAPHY AND TELEPHONY SIMPLY EXPLAINED

A PRACTICAL TREATISE

Embracing Complete and Detailed Explanations of the Theory and Practice of Modern Radio Apparatus and its Present Day Applications, together with a chapter on the Possibilities of its Future Development

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PREFACE

Probably no marvel of modern science so grips the imagination as the mystery of those quivering impulses which go forth invisibly to link a ship sailing over the seas with the shores of the distant land.

The author has endeavored to furnish a comprehensive explanation, in simple language, of the theory and practice of this wonderful art, and to explain, as far as possible, the importance of the position occupied by wireless telegraphy to-day and the possibilities of to-morrow.

The title of this book naturally limits the amount of discussion that can be undertaken, and so, in the space at command, there has not been any real attempt made to enter into any engineering or constructive details further than is necessary to make the text clear.

Much that might properly be made a part of the preface has been embodied in the book, in order to avoid repetition, and to also bring certain matter to the attention of those readers who consider a preface to be merely an opportunity for the author of a book to express opinions very often quite foreign to the title, and so unconcernedly skip it with hardly more than a passing glance.

The author wishes to extend his sincere thanks to Mr. H. W. Young, Editor of *Popular Electricity;* to Mr. John Firth, to Colonel George P. Scriven, and to the *Scientific American,* for their kindness in supplying photographs for some of the illustrations, and to his friend, Mr. Safford Adams, who has kindly read the proofs and made many valuable suggestions. ALFRED P. MORGAN.

January, 1913.

TO

NIKOLA TESLA

WHOSE GENIUS HAS HARNESSED ELECTRICITY TO THE DAILY WORK OF MAN AND WHOSE INVENTIONS ARE THE BASIS OF ALL MODERN WIRELESS TRANSMISSION, THIS BOOK IS DEDICATED.

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Wireless Telegraphy

CHAPTER I.

INTRODUCTORY: WIRELESS TRANSMISSION AND RECEPTION. THE ETHER. ELECTRICAL OSCILLATIONS. ELECTRO-MAGNETIC WAVES.

Wireless telegraphy, that marvelous art which has made possible the instantaneous transmission of intelligence between widely distant parts having no apparent physical connection save that of the earth, air, and water, is one of those wonders of science which appeal to the average mind as either incomprehensible or only explainable through the use of highly technical language. Contrary to this general opinion, however, the whole theory and practice of the wireless transmission of messages is capable of the simplest explanation.

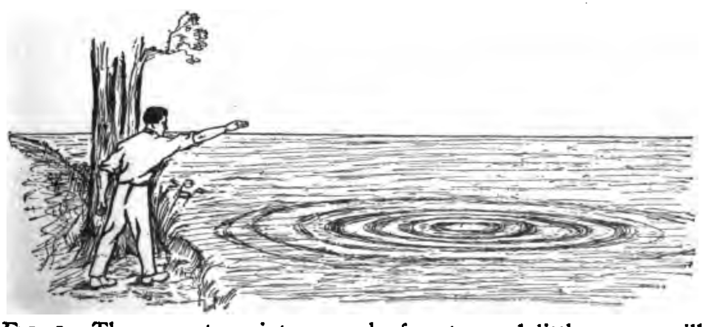

FIG. 1.—Throw a stone into a pool of water and little waves will radiate from the spot where the stone struck.

Throw a stone into a pool of water. A disturbance is immediately created, and little waves will radiate from the spot where the stone struck the water, gradually spreading out into enlarging circles until they reach the shores or die away. By throwing several stones in succession with varying intervals between them it would be possible to so arrange a set of signals that they would convey a meaning to one who is initiated, standing on the opposite side of the pool. The little waves are the vehicle which transmits the intelligence, and the water the ***medium*** in which the waves travel.

Wireless telegraph instruments are simply a means for *creating and detecting waves in a great pool of ether.*

Scientists suppose that all space and matter is pervaded with a hypothetical ***medium*** of extreme tenuity and elasticity, called *luminiferous ether,* or simply *ether.*

Although ether is invisible, odorless, and practically weightless, it is not merely the fantastic creation of speculative philosophers, but is as essential to our existence as the air we breathe and the food we eat. By imagining and accepting its reality, it is possible to explain and understand many scientific puzzles. The universe is a vast pool of ether. It is all-pervading. There is no void. It is diffused even among the molecules of which solid bodies are composed. The study of this substance is, perhaps, one of the most fascinating and important duties of the physicist.

Ninety million miles away from our earth is a huge flaming body of vapors and gases, called the sun. This seething mass of flame and heat furnishes us more than mere winter and summer and night and day, for we on this earth are not living on our own resources, and the real work of the world so necessary for even bare existence is accomplished by the energy of the sun stored up in coal, in plants and trees and mountain torrents.

Light is known to be vibrations of an extremely rapid period—*electromagnetic waves,* they are called. Heat can be shown to be of the same nature. Traveling at the rate of over 180,000 miles per second, these two great gifts of the sun come streaming continually down to us over the inconceivable distance of almost 100,000,000 miles. Both require a medium for their propagation. The ether supplies it. It is the substance with which the universe is

FIG. 2.—A Leyden jar is a glass jar lined inside and out with tinfoil for about two-thirds of its height.

filled. Incidentally it is also the seat of all electrical and magnetic forces.

In throwing the stone into the pool of water, muscular energy of the arm is transferred to the stone, and the latter, upon striking the surface of the pond, imparts a portion of that stored energy to the little waves which are immediately created in the water. In setting up electromagnetic waves for wireless communication the energy imparted to the ether is *electrical* energy, developed by certain interesting instruments explained further on.

Let us consider briefly how the *waves* are created in a wireless telegraph station. Almost every one has seen and heard the brilliant snapping spark produced by the discharge of a Leyden jar. A Leyden jar in its common form is a glass jar lined inside and out with tinfoil for about two-thirds of its height. A brass rod, terminating in a knob, connects below with the inner coating, usually by means of a loose chain. It may be described as a device which is capable of storing electricity in the form of energy and discharging this energy again in actual electricity.

This discharge has been the subject of many interesting investigations of direct interest.

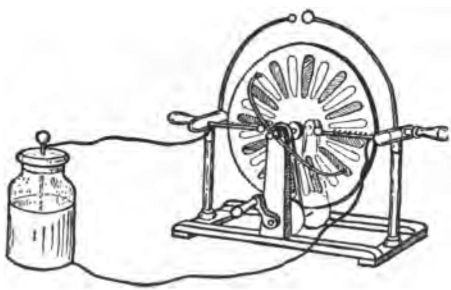

FIG. 3.—A static machine connected to a Leyden jar.

The inner and outer coatings are connected to the terminals of a static electric machine (an apparatus for generating electricity), and the machine set in rotation. After the jar has been charged, the electric machine is disconnected and one end of a coil of heavy wire connected to the outside coating, while the other end of the wire is made to approach the knob connected with the inner coating. Before the end of the wire reaches the knob a discharge occurs through the coil, producing a noisy brilliant spark between the wire and the knob. The discharge appears like a single spark, but in reality it is composed of a great many following each other in rapid succession. The jar discharges its energy, first by a tremendous rush of current in one direction, and then another discharge somewhat smaller than the first in the opposite direction. There

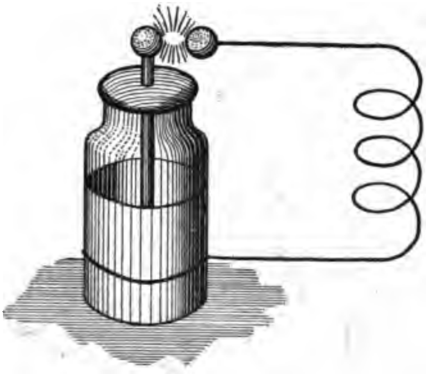

FIG. 4.—A Leyden jar discharging through a coil of wire produces a brilliant spark and *high frequency oscillations* are created.

is a series of these discharges in reverse directions, but each discharge is less and less, until the whole amount of

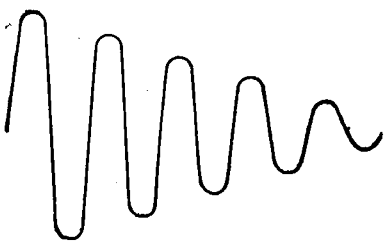

FIG. 5.—Curved line representing an oscillatory discharge of a Leyden jar.

energy is expended. The complete series of discharges takes place in an almost immeasurable fraction of time. It is from this phenomenon that the electrical term "high frequency oscillations," so often heard of in "wireless" parlance, is derived.

FIG. 6.—Navy type of Leyden jars. Coated with copper deposited upon the surface of the glass.

High frequency oscillations are the "pebbles" which, dropped into the vast pool of ether, everywhere, set up "ripples" called *electromagnetic waves* (identical with the electromagnetic waves of light, but *longer* and so beyond the limits of our spectrum and the vision of the eye). The manner in which this is accomplished may be explained by saying that the charge creates a state of strain in the surrounding ether, and then abruptly releases it. Ether possesses a high degree of elasticity, so that when the state of strain is thus suddenly released, it immediately returns to its former state. The sudden motion of the ether results in waves which spread out from their source in enlarging circles.

Wireless telegraphy, as it is practiced to-day, is based upon the fact that a system of wires or circuits, through which ***high frequency*** oscillations are surging, becomes a source of electromagnetic waves. Various methods have been devised for making the system more efficient and capable of giving better results with a given amount of power.

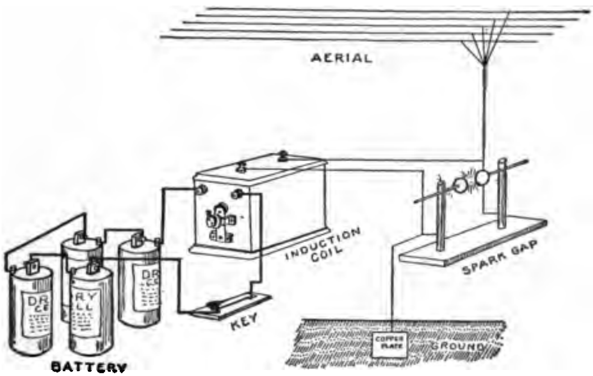

FIG. 7.—The simplest practical transmitter that it is possible to devise for the purpose of sending messages.

Fig. 7 is a diagram showing the simplest practical transmitter that it is possible to devise for the purpose of sending messages a sufficient distance to be of any value.

It would be impractical to use a static electric machine for wireless transmission, and so an *induction coil* or *transformer* is employed. These latter instruments are for the purpose of raising electric currents of a comparatively low voltage to the high potential, where they have the power of generating high frequency oscillations.

In the illustration the current from a battery is led into the primary of an induction coil. The *primary* is simply a coil consisting of a few turns of wire, which induces a high voltage in a second coil consisting of a larger number of turns, and called the *secondary.* The terminals of the secondary are led to a spark gap—an arrangement composed of two polished brass balls, separated by a small air space. One of the balls, in turn, is connected to a metal plate buried in the earth, and the other to a network of wires suspended high in the air and insulated from all surrounding objects.

As noted above, a Leyden jar consists of two metallic coatings, separated by a wall of glass. The purpose of the coatings is to form a *conductor* and carry an electric charge. A Leyden jar possesses a characteristic called, in electricity, *capacity.* Any two conductors separated by an insulating medium possess "capacity" and all the properties of a Leyden jar or condenser.

The waves generated by a Leyden jar would be somewhat weak and confined to its own immediate neighborhood, so recourse is had to the *aerial* and *ground,* in order to increase the area over which the oscillations exert their influence in setting up the electric waves. The aerial system corresponds to one coating of the Leyden jar, and the ground to the other. The insulating medium in between, corresponding to the glass, or *dielectric,* is the atmosphere.

When the key connected to the induction coil is pressed, the battery current flows through the primary and induces a high voltage current in the secondary, which charges the aerial and ground exactly as the static machine charges the two coatings of the Leyden jar. A spark then leaps across the spark gap and the current surges back and forth through the aerial, generating "high frequency oscillations" which, in turn, set up a state of strain in the surrounding ether, and cause the waves to travel out from the system.

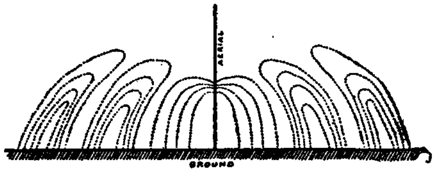

FIG. 8.—If a cross section of the aerial and atmosphere could be made in the same manner that an apple is sliced with a knife and the waves held stationary, they would appear as above.

These waves follow the contour of the earth, and so may cross mountains and valleys, and travel anywhere. They radiate from the aerial like the ripples from a pebble in a pool of water, in gradually enlarging circles. If a cross section of the aerial and atmosphere could be made in the same manner that an apple can be sliced with a knife, and the waves held stationary long enough to see them, they would appear as in Fig. 8. The curved lines represent the lines of strain induced by the oscillations. Each group of lines represents a wave. It will be noticed as they radiate farther from the aerial that they become larger and spread out.

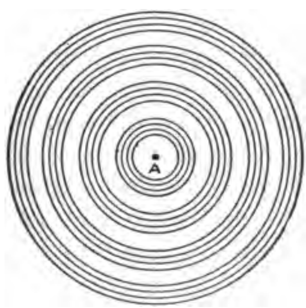

FIG. 9.—Under the same conditions, but when viewed from above, the appearance would be that of a series of concentric circles.

The electromagnetic waves have the power of exciting oscillations in a conductor on which they impinge. This is made use of for the purpose of receiving the messages. When the waves strike the aerial of a distant station they set up high frequency oscillations, which are usually too weak to make their presence known except with the aid of a sensitive device, called a detector.

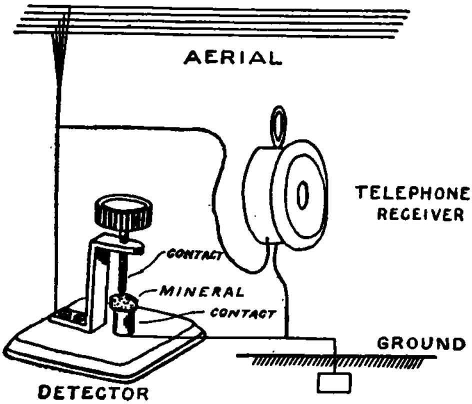

FIG. 10.—A simple receiving arrangement. The detector rectifies the oscillatory currents passing from the aerial to the ground so that they will flow through the telephone receiver and register as sound.

The most prominent type of detector in use to-day is a crystal of silicon, iron pyrites, zincite or certain other minerals. The mineral is placed between two contact points, one or both of which are adjustable so that the most sensitive portion of the mineral may be selected. A telephone receiver is connected across the terminals of the detector. When the electromagnetic waves from the transmitting station strike the aerial of the receiving station, they set up therein a series of high frequency oscillations, corresponding to the Morse signals emitted from the transmitter. The oscillations flow back and forth through the aerial and ground, striking the *mineral detector* on their journey. The high frequency oscillations are *alternating* currents, because they *reverse* their direction many thousand times per second. Such a current will not pass through the telephone receiver, because the little magnets contained therein exert a choking action on alternating currents of high frequency and effectually block their passage. The mineral detector acts as a valve, allowing the current to pass through in one direction, but not permitting it to return or go in the opposite direction. The result is a series of impulses flowing in one direction only, and therefore called a *direct* current. Such a current will flow through a telephone receiver and produce a motion of the diaphragm which imparts its motion to the surrounding air, the result being sound waves audible to the ear. By varying the periods during which the key is pressed and the oscillations are being produced, according to a prearranged code, the sounds in the receiver may be made to assume an intelligible meaning.

CHAPTER II.

THE MEANS FOR RADIATING AND INTERCEPTING ELECTRIC WAVES. AERIAL SYSTEMS. EARTH CONNECTION.

Every radiotelegraphic station may be summed up as comprising these elements: first of all, certain appliances collectively forming the transmitter and serving to create the waves; secondly, the receiving apparatus, whose function is to detect the signals of some far-distant sending station, and lastly, an external organ called the aerial, or antenna, consisting of a huge system of wires elevated high in the air above all surrounding objects, either vertically or sloping, or partly horizontal and partly vertical, which radiates or intercepts the electromagnetic waves, accordingly as the station is transmitting or receiving.

The antenna is at once both the mouth and the ear of the wireless station. Its site and arrangement will greatly determine the efficiency and range of the apparatus.

The site selected is preferably such that the aerial will not be in the immediate neighborhod of any tall objects, such as trees, smokestacks, telephone wires, etc., because such objects not only absorb an appreciable amount of energy when the station is transmitting messages, but also noticeably shield the aerial from the effects of incoming signals and limit its range.

The nature of the ground over which the waves must travel also enters into the question, and is always considered in locating a station. In gliding over the surface of the earth, the waves generate weak currents in the earth itself. If the ground is very stony or dry, these earth currents encounter considerable resistance, and the possible

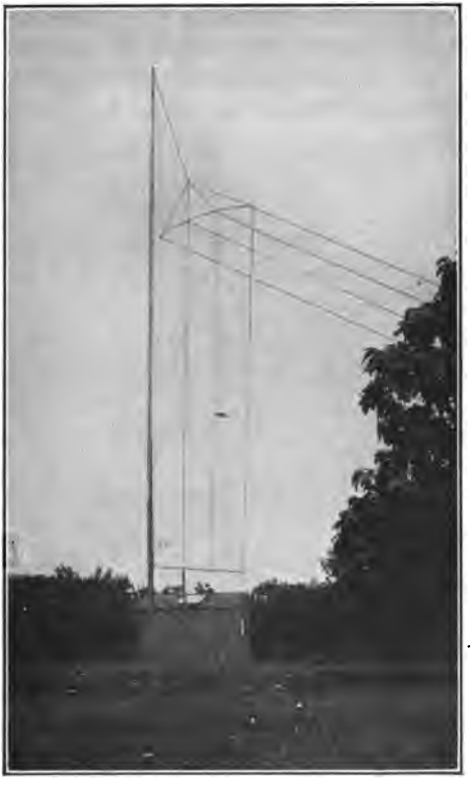

FIG. 11.—An amateur aerial and station.

distance of transmission over soil of this sort is very much less than if it were moist. Moist soil and water offer very little resistance, and the difference in the results obtainable at the receiving station when the waves travel over an area of this sort is very marked.

A station which can only send 100 miles over land can send messages three or four hundred miles over the ocean.

Forests exert a very decided effect upon the electric waves. Each individual tree acts as an antenna, reaching up into the air and absorbing part of the energy. The difference in the range of a station during the summer months and that of the same station in winter is considerable. In

FIG. 12.—The Army wireless station at Fort Gibbons, Alaska, showing steel lattice work mast and aerial system.

summer the trees are full of sap and, being much better conductors of electricity when in this condition, act in the capacity of innumerable aerials rising in the air, and able to absorb appreciable amounts of energy. During these same months the air becomes highly *ionized,* in which state the air molecules carry an electric charge, and are particularly opaque to the waves. This condition also usually exists in the presence of sunlight, the result being that the most favorable time for the wireless transmission of messages are the hours around midnight.

Locality is another factor which usually receives a fair share of attention in selecting the site. Certain sections of the country, for seemingly no apparent reason, are very hard to transmit messages, either to or from. Wireless stations located on the Pacific Coast, for instance, are more efficient than those situated along the Atlantic seaboard,

FIG. 13.—Lightning discharge near Montclair, N. J.

while those in the tropical regions are only able to send short distances in comparison to those farther north or south. Messages seem to travel better in the direction of the lines of longitude than along the lines of latitude.

"Static," that "bugbear" of the wireless operator, is very much more in evidence in the eastern parts of the United States and in South America than it is on the western coast of the country. If any one should ask a wireless operator what "static" is, he would probably reply, "a nuisance." In reality, it is caused by atmospheric electricity. When atmospheric electricity "jumps," it is called "lightning." A lightning discharge sets up very powerful waves in the ether, which strike the aerial of the wireless station and produce a peculiar rumbling, scratching sound in the telephone receivers, and sometimes seriously interfere with a message. In fact, it is possible for a wireless operator to predict a thunder shower by many hours from the sounds he is able to hear in his telephone receivers.

The cause of lightning is the accumulation of electric charges in the clouds. The electricity resides on the surface of the particles of water in the cloud. These charges grow stronger as the particles of water coalesce to form larger drops, because, as they unite, the surface increases proportionally less than the volume and, being forced to lodge on a smaller space, the electricity becomes more "concentrated," so to speak. For this reason the combined charge on the surface of the larger drop is more intense than were the charges on the separate particles, and the "potential" is increased. As the countless multitudes of drops grow larger and larger, in the process of forming rain, the cloud soon becomes heavily charged.

Through the effects of a phenomenon called "induction," a charge of the opposite kind is produced on a neighboring cloud or on some object of the earth beneath. These charges continually strive to burst across the intervening air and neutralize each other. As soon as the potential becomes sufficient to break down this layer of air, a lightning stroke from one to ten miles long takes place. The heated air in the path of the lightning expands with great force, but immediately other air rushes in to fill the partial vacuum, thus producing atmospheric waves, which impress the ear as the sound called *thunder*.

Wireless stations belonging to the United States navy

FIG. 14.—Photo of double lightning discharge passing to earth near the First Orange Mountain, Montclair, N. J.

and located on land are usually housed in a small building in the immediate neighborhood of the tall wooden mast which supports the aerial. Commercial stations are usually situated on the top floor of a high office building, or a hotel, and the aerials supported by a steel lattice-work tower. Amateurs place a small pole on the roof of the house, or in a tree, and locate their station in any convenient room near the top of the house.

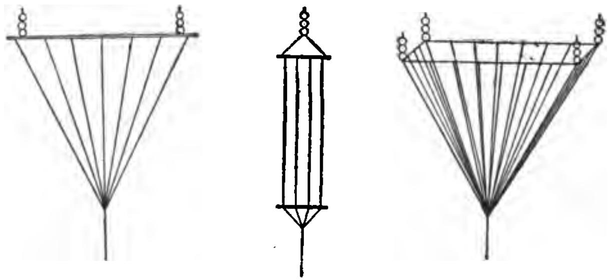

Fig. 15.—Vertical aerials of the "grid," "fan" and "inverted pyramid" types.

Aerials are of numerous classes and forms, but the most prominent types can be divided into two main groups, called respectively, the "flat-top" and "vertical" antenna.

The vertical aerials are the older form, and are usually employed for long-distance work or ultra-powerful stations. The aerials intended for transmission from Europe to America, installed by Marconi, consisted of huge inverted pyramids, supported by four heavy lattice-work towers, over 200 feet high. Vertical aerials also sometimes take the form of an umbrella, or fan, where only one supporting pole is available. Iron pipe masts may be employed for the purpose, by setting on an insulating base. The umbrella aerial is used extensively in the army and portable sets.

The flat-top aerials are gradually coming into very extended use. They are used to the exclusion of all others on shipboard. They need not be so high as a vertical type aerial in order to be as efficient. Flat-top aerials consist of a vertical portion and a nearly horizontal portion. The

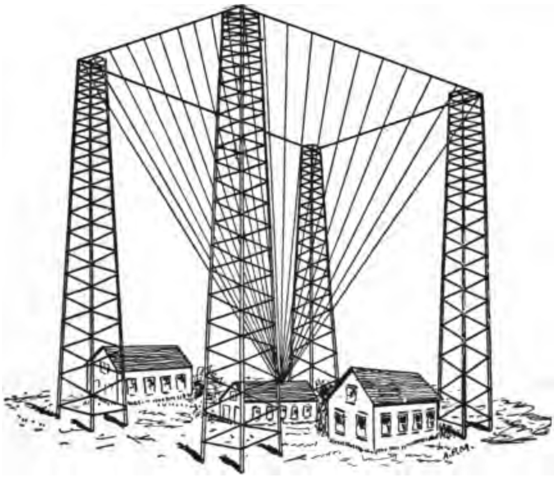

FIG. 16.—A diagram showing pyramid aerial.

horizontal portion is practically useless, as far as its work in radiating waves is concerned, it being used for the purpose of increasing the *capacity* of the aerial. An increase in capacity in an aerial means that more energy can be stored and radiated. Flat-top aerials have the objection, however, of possessing a *directive* action; that is, they receive, or radiate waves, better in one direction than in the other. A flat-top aerial always receives or transmits better in the direction that the ends point than in a direction at right angles to the wires.

The accompanying diagram is an illustration to show the effects of the directive action of a flat-top aerial. The black lines marked A B, and appearing very much like a little grating, represent an aerial of the inverted "L" type, looking down on it from above. B is the *free* end of the aerial, and A the *closed* end, or end to which the wires leading

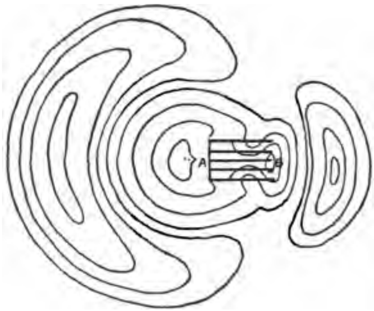

FIG. 17.—A diagram illustrating the directive action of a flat-top aerial.

down to the station are attached. If a snapshot of the lines of strain produced in the ether as the waves move away from the aerial could be taken, they would appear like the curved lines in the illustration. It can be readily seen that those passing outward from the aerial in a direction *opposite* to that in which the free end points are the strongest, and that the radiation in that direction is the best.

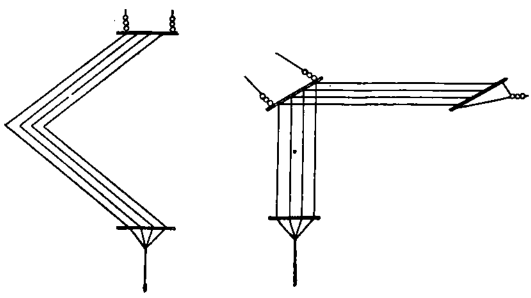

FIG. 18.—Aerials of the "V" and inverted "L" types.

The "V" aerial and also the inverted "L" type both receive waves much better when they come from a direction opposite to that in which the free end points.

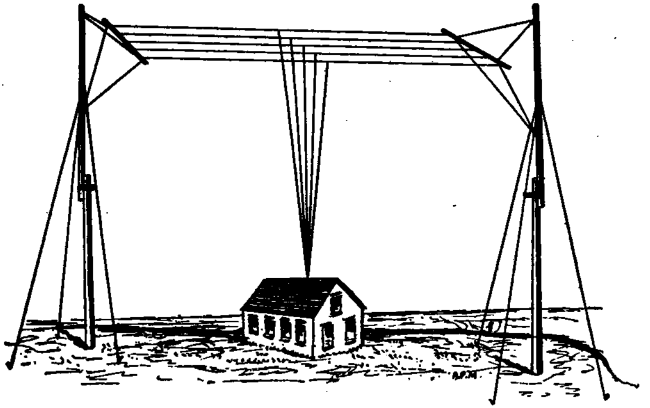

FIG. 19.—A diagram showing the arrangement of a "T" aerial.

Probably the most interesting feature of the directive action of aerials lies in the fact that a land station is able to determine the approximate bearing of a ship signaling with a horizontal aerial.

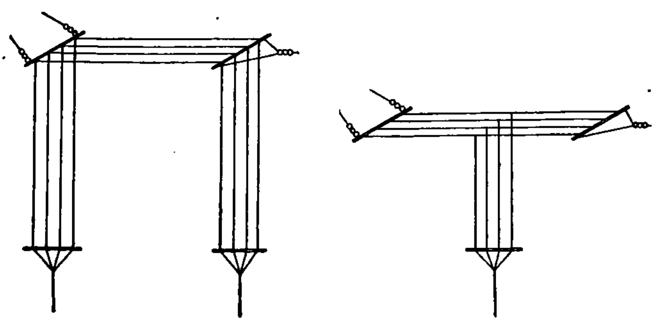

FIG. 20.—Flat top aerials of the inverted "U" and "T" types.

It is beyond the scope of the book to enter into all of the engineering details pertaining to the installation of a wireless station, but a few remarks and instructions for the benefit of those who may be interested in this phase of the subject may be appreciated.

The flat-top "T" aerial gives the best "all around" results. The vertical and umbrella forms are close seconds.

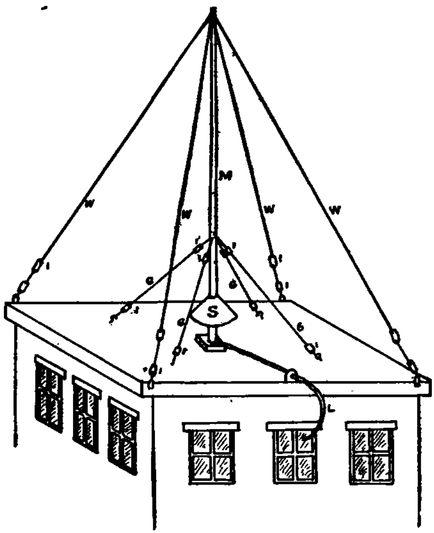

FIG. 21.—Umbrella aerial.

For the very best results, the top or horizontal portion of a "T" aerial should be slightly shorter than the vertical section.

The umbrella type of antenna is very efficient. Instead of a wooden mast, an iron pipe terminating above in a system of wires, inclining downward and serving both as part of the aerial and as guys to support the pole, is often used. The bottom of the pole is placed on an insulating base, protected from the rain by a small shelter. The wires are insulated near the lower ends by strain-insulators. The

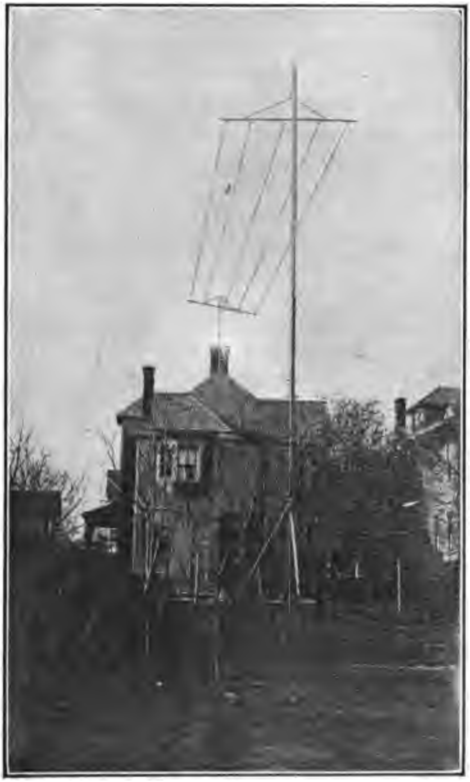

FIG. 22.—An amateur aerial (flat-top).

action of the wires is to serve as a capacity extension to the aerial.

Vertical aerials are not as efficient as either of those forms just mentioned. They require to be 50 per cent.

higher than a flat-top aerial, in order to be of the same value.

The "L" and "V" types are somewhat directional. They are used where the highest point must be near the station, with a lower point some distance away. It is possible to secure excellent results with either type.

The terms *straightaway* and *loop* denote the method of connecting the aerial wires. In the first form the upper or free ends of the wires terminate at the insulators. In the

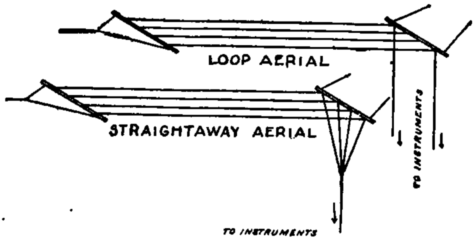

FIG. 23.—Diagram showing the difference between "loop" and "straightaway" aerials.

loop form they are all connected together, and divided into two sections, each of which is led separately into the operating room.

The straightaway aerial is the most efficient in most cases, but wherever great height cannot be obtained, or the aerial is necessarily short, the loop aerial will give the best results.

Bare copper wire is the best, and is generally used for aerials. Wherever the stretch is 100 feet or over, however, so that the wires are subjected to considerable strain from their own weight, phosphor bronze is used because of its greater tensile strength. Commercial and navy stations employ stranded wire. High frequency currents have the peculiar property of traveling near the surface of wires and conductors. They do not permeate to the center of the wire, as do normal currents. The surface of a stranded wire is greater in comparison to its cross-section than a solid conductor of the same diameter, and therefore is often employed because it offers less resistance to currents of this sort.

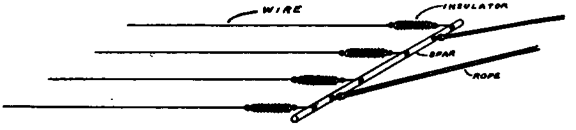

FIG. 24.—Showing how wires are arranged and insulated.

Aluminum wire is very light, and causes very little strain on the pole or cross-arms. It offers more resistance than copper, but some of the larger sizes may be used with equally good results.

Iron wire must never be used, even if galvanized or tinned. It possesses a certain reactance tending to choke off the high frequency currents.

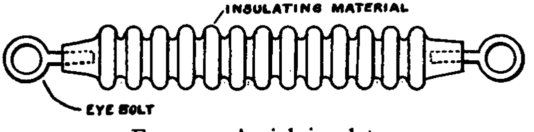

FIG. 25.—Aerial insulator.

The aerial is always very carefully insulated from its supports and surrounding objects by special insulators, capable of withstanding severe strains, made of a moulded material having an iron ring imbedded in each end.

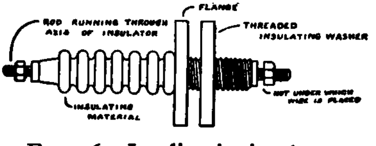

FIG. 26.—Leading-in insulator.

The wires leading from the aerial to the operating room are called the "rat-tail," or "lead-in." They must be very carefully insulated by leading through a bushing placed in the wall or window of the operating room.

One of the most important factors in a wireless station is the proper earthing arrangement. The usual method is to use large copper plates buried in moist earth, or thrown in the sea. On shipboard it is merely necessary to connect the earth wire to the metallic plates of which the hull of the vessel is built. Amateurs employ the water or gas pipes in the house, the former being preferred. Connections are established by means of a ground clamp.

In the country, where water-pipes are not available, the best way is to bury a sheet of copper three or four feet deep in moist earth.

A very efficient earth can be formed by spreading a large area of chicken wire netting over the ground. This method is the best where the earth is very dry or sandy, and no other way is readily convenient.

FIG. 27.—A side view of the aerial shown in Fig. 22.

CHAPTER III.

THE TRANSMITTING APPARATUS.

The principal instruments composing the apparatus used for sending the wireless messages comprise an *induction coil,* or in its place a *transformer,* a *key,* a *spark gap,* a *condenser,* and a *helix.*

THE CURRENT SUPPLY available will determine the type of the instruments, and whether an induction coil or a transformer is used. Unless current mains for light and power are already installed, it must be generated by an engine and dynamo, or recourse had to batteries. Induction coils may be operated on either direct or alternating current. Dry cells are most commonly employed to furnish

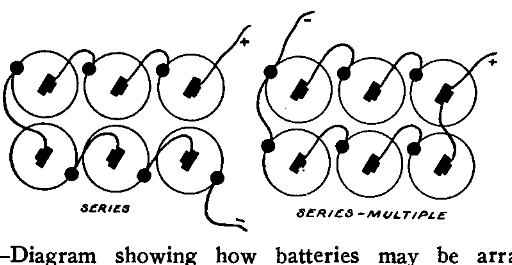

FIG. 28.—Diagram showing how batteries may be arranged in "series" or "series multiple."

the current for small induction coils, but a storage or some form of renewable primary cell, such as the Fuller and Edison, is necessary if the coil is a large one.

When dry cells are used, they should be connected in

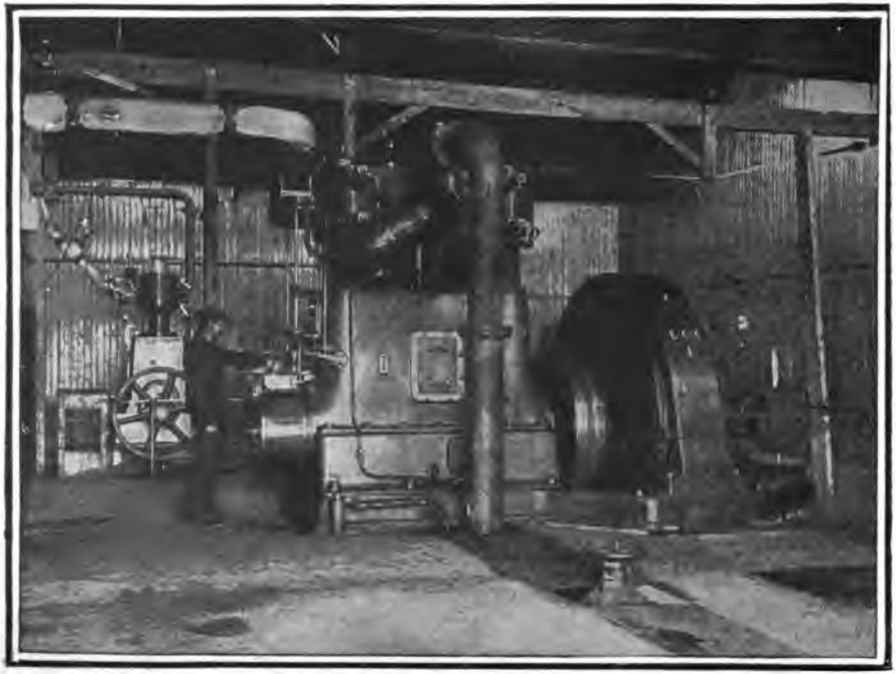

FIG. 29.—The power plant of a Marconi transatlantic station, showing engine and generator.

series multiple, as shown in the accompanying diagram. This method of connecting distributes the load, and considerably lengthens the life of the battery.

When the source of current supply is *alternating*, an induction coil may be operated as a *transformer*. Both induction coils and transformers are instruments for raising the voltage of the ordinary available current from a comparatively low value, 6-220 volts, to a quantity (15,000–

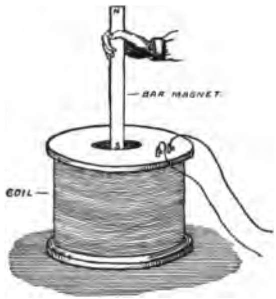

FIG. 30.—If a magnet is suddenly plunged into a hollow coil of wire a momentary electric current will be induced in the coil.

20,000 volts), where it can properly charge the aerial and create a *state of strain*, or, as it is called in technical parlance, an *electro-static field*.

Both the induction coil and transformer depend for their operation upon the principles of *magnetic induction*. In 1831, Michael Faraday, a famous English chemist and physicist, discovered that if a magnet be suddenly plunged into a hollow coil of wire, that a momentary current of electricity is generated in the coil. As long as the magnet remains motionless, it induces no current in the coil, but when it is *moved* back and forth, it sets up the currents. The source of electrical energy is the mechanical work done in moving the magnet. The medium which changes the mechanical energy into electricity is called the magnetic field. The magnetic field is a peculiar state or condition of the space in the immediate neighborhood of a magnet. Its real nature is very hard to explain and not easily understood. Suffice it to say, however, that the current is induced in the coil of wire only when the magnetic field *is changing,* either decreasing or increasing. *The change is produced by moving the magnet* because its influence on

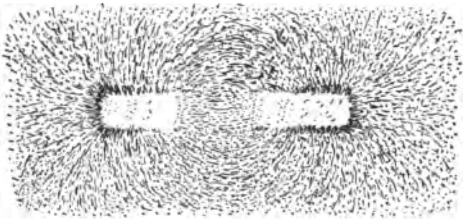

FIG. 31.—Magnetic phantom formed by bar magnet.

the coil will be great or small accordingly as it is near or far.

It is possible to show the existence of the magnetic field by placing a sheet of glass over a bar magnet and then sprinkling iron filings on the glass. They will settle down in curving lines as in Fig. 31, forming a *magnetic phantom.* The curved lines formed by the filings represent the direction of the lines of force which make up the magnetic field.

If we should examine the space in the immediate neighborhood of a coil of wire carrying a current of electricity it would be found that a similar state of affairs existed there and that the coil also possessed a magnetic field composed of lines of force flowing around it.

This is readily shown by punching a small hole in a piece of cardboard and passing a wire carrying a current of electricity through the hole. If iron filings are sprinkled on the cardboard, they will arrange themselves in circles

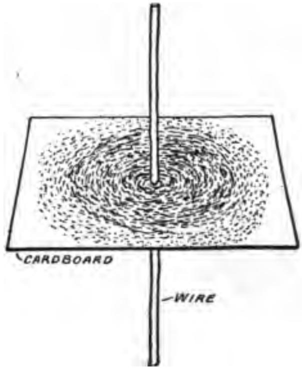

FIG. 32.—Magnetic phantom formed by wire carrying current.

around the wires, forming a magnetic phantom and showing that a coil of wire carrying a current of electricity generates a magnetic field in its vicinity. By forming the wire into a coil the magnetic field generated is much stronger, for the then combined effect of the wires is secured.

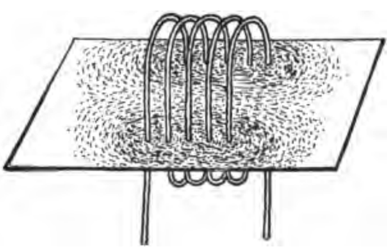

FIG. 33.—Magnetic phantom formed by coil of wire carrying current.

The induction coil and transformer are simply instruments utilizing the principle that a coil of wire carrying a current possesses a magnetic field which will induce a current of electricity in another neighboring coil.

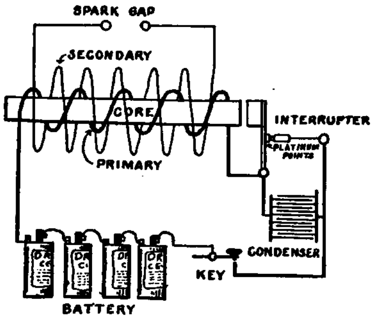

FIG. 34.—Diagram of induction coil.

THE INDUCTION COIL consists essentially of a *primary* winding of heavy wire wound around a soft iron core and surrounded by a secondary coil consisting of many thousand turns of fine wire, carefully insulated. The current from a battery is sent through the primary coil and sets up a magnetic field. The magnetic field induces a

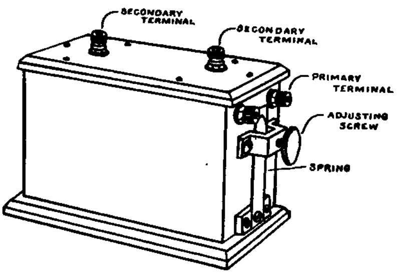

FIG. 35.—Induction coil for wireless telegraph purposes.

current in the secondary whose voltage is approximately proportional to the ratio of the turns of the secondary to the primary. Thus, if the secondary contains one hundred times as many turns of wire as the primary the induced voltage will be one hundred times the voltage of the original primary current. The purpose of the iron core is to concentrate the magnetic field and make the coil more efficient. Since currents are only induced in the secondary when the magnetic field is *changing,* an automatic device called an *interrupter* or sometimes a *vibrator,* is employed to rapidly turn the current flowing through the primary on and off. The interrupter consists

FIG. 36.—Induction coil, primary and secondary.

of a spring carrying a platinum point against which presses a second piece of platinum on the end of an adjustable thumbscrew. Platinum is necessary because the current of electricity would quickly oxidize and burn up any other material. The interrupter spring is placed near the end of the core so that the magnetism of the latter will draw it forward away from the thumbscrew and interrupt the current. As soon as the current ceases to flow the core loses its magnetism and the spring returns to its former position repeating the cycle very rapidly a large number of times per second. The interrupter is fitted with a *condenser* shunted across its terminals to stop sparking at the platinum points and also to make the currents in the secondary more intense.

The voltage of the currents in the secondary is high enough to leap across an air gap in a torrent of sparks. The spark of an induction coil intended for wireless work

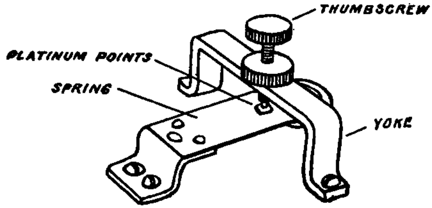

FIG. 37.—Interrupter for induction coil.

should be thick and heavy. It should be sufficiently hot and flâming to ignite a piece of paper. A rapid vibrator giving a high pitched spark is better than a slow one not only because it causes a more intense and powerful spark but because the human ear is the most sensitive to high pitched sounds and such a spark is more easily read at the receiving station.

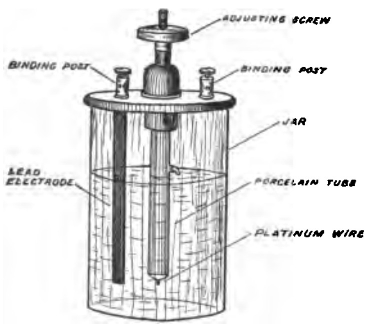

FIG. 38.—Electrolytic interrupter.

When the coil is a very large one and operated on the 110 volt current an *electrolytic* interrupter is substituted for the mechanical type. One pole of the current is connected to a lead plate placed in a jar containing a mixture of sulphuric acid and water. The other side of the current is connected to a platinum wire placed in a porcelain tube so that only a small part of the lower end is in contact with the solution. When the current passes a bubble forms at the end of the wire shielding it from the liquid, and thus interrupting the current. The bubble is almost im-

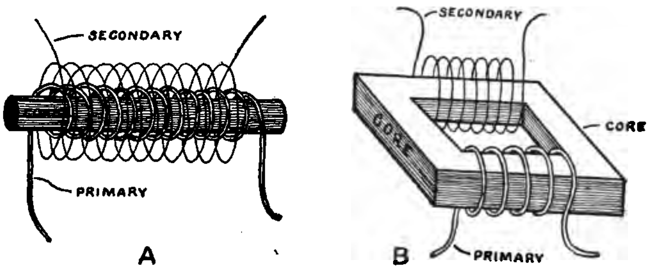

FIG. 39.—Open and closed core transformers.

mediately discharged however and the current allowed to flow an instant before a new one forms. This operation is repeated continuously at a frequency sometimes as high as a thousand per second. An electrolytic interrupter is both an expensive and a troublesome device. There are other types of interrupters of value in wireless service but the limitations of space prohibit any account.

THE TRANSFORMER is acknowledged to be the best practice as a means of stepping up the voltage of a circuit for wireless telegraph purposes. Alternating current is necessary to operate a transformer. There are two distinct types of transformers known as the "open" and "closed core" accordingly as the shape of the latter is straight like that of an induction coil or in the form of a hollow rectangle. The closed core transformer consists of two coils of insulated wire, forming a *primary* and a *secondary,* wound upon a rectangular core like that shown in Fig. 39B. The core is built up of sheets of iron called laminations, to reduce the heating and increase the efficiency of the machine.

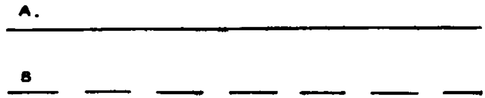

FIG. 40.—Lines representing direct and intermittent direct currents.

As noted above currents are only induced in a coil when the magnetic field is changing. The interrupter is employed to rapidly "make" and "break" the circuit. Every time that the circuit is made the primary coil creates a field and every time it is broken it is destroyed. A *direct* current is a current which passes in one direction only. It may be represented by a straight line as A in Fig. 40. Its voltage is usually very constant and does not vary greatly. In the case of electric lighting circuits the normal voltage is usually 110. If an interrupter is included in the circuit the current may be represented by a broken line, the spaces corresponding to the periods when the

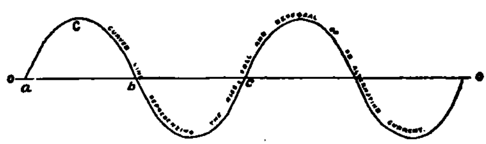

FIG. 41.—Diagram representing alternating current.

current is "broken" and the lines to the periods it is flowing. The interrupter creates an intermittent direct current.

An *alternating current* is one which reverses its direction and passes first one way and then the other. It may

FIG. 42.—High potential "Humming" transformer.

be represented by the curved line shown in Fig. 41. It starts at zero and rises to a maximum, gradually dying away to zero, then passes in the *opposite* direction, rising

FIG. 43.—High potential closed core transformer for wireless work.

to a maximum and dying away again. This is repeated a definite number of times per second; when the current rises from zero, reverses and returns to zero it is said to have passed through a cycle. From *a* to *c* represents a

FIG. 44.—Leyden jar set for oil immersion to prevent losses from brush discharges.

cycle—from *a* to *b* is an alternation. The usual *frequency* of commercial alternating currents is 60 cycles or 7200 alternations per minute.

From these facts we may readily see why the troublesome interrupter may be eliminated when alternating current is used. Every time that the current rises and falls the magnetic field *changes.*

Considerable care must be used in proportioning the windings so that they possess sufficient reactance. Reactance is the tendency of a coil to resist the flow of an alternating current. A reactance coil is sometimes placed

FIG. 45.—Oil immersed condenser.

in circuit with an open core transformer to prevent the spark from *arcing*. Arcing is the tendency of the spark to pass across the gap without charging the condenser and creating any high frequency oscillations.

THE CONDENSER, it will be remembered is the means of storing up the energy, which suddenly rushing across the spark gap, produces the *oscillations* necessary to generate the electric waves. A battery of leyden jars may be used as a transmitting condenser in connection with small induction coils. Their objection in large stations is that they are very cumbersome and some energy is lost by the brush discharges around the tops of the jars. The usual form of condenser consists of alternate sheets of

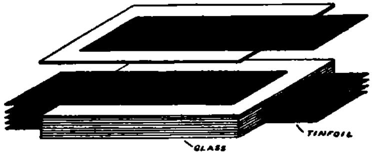

FIG. 46.—Diagram showing construction of condenser.

tinfoil and glass plates arranged in a pile. The alternate sheets of tinfoil are connected together to form the terminals of the instrument. The condenser is usually encased in a wooden box poured full of wax or oil to increase

FIG. 47.—Tubular condenser.

the insulation and efficiency. Condensers are arranged in units so that any desired *capacity* may be readily secured by adding the proper number of units. The capacity of a condenser is its relative ability to receive and retain an electrical charge.

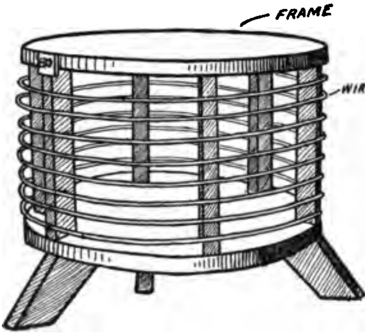

FIG. 48.—Helix.

THE HELIX is an instrument consisting of copper or brass wire wound around a frame of hard rubber or sea-

FIG. 49.—Close coupled helix.

soned wood. A certain amount of *inductance* is necessary in a wireless telegraph circuit in order to develop high frequency oscillations. Inductance is the property of an electric circuit by virtue of which lines of force are developed around it. The helix furnishes the inductance

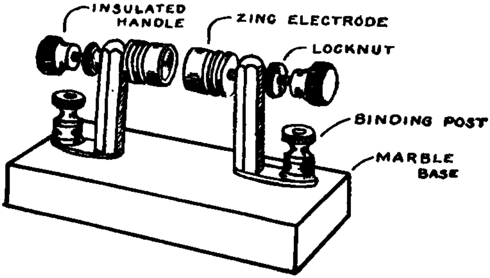

FIG. 50.—Spark gap.

in the circuit or at least the greater part. Connections are established to the turns of the helix by means of clips which snap on and off the wires.

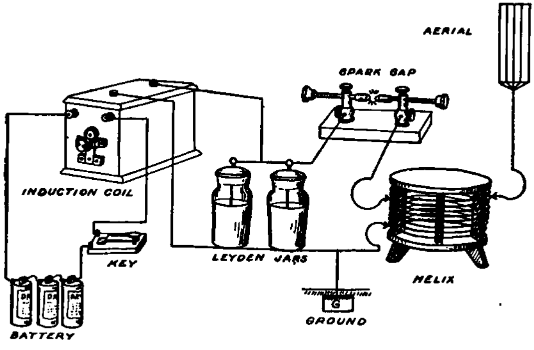

FIG. 51.—Circuit showing tuned transmitting system employing close coupled helix.

THE SPARK GAP is the medium for discharging the aerial and condenser and setting up the oscillations. It usually consists of a pair of electrodes supported by suitable standards and so arranged that the distance between the electrodes can be accurately adjusted. The electrodes usually take the form of hollow faced cylindrical rods having

FIG. 52.—Photo of spark gap.

flanges to radiate the heat generated and prevent the spark from arcing. Various metals are used for spark gaps. Silver is probably the best but its expense is prohibitive. A special hard zinc alloy is most generally used.

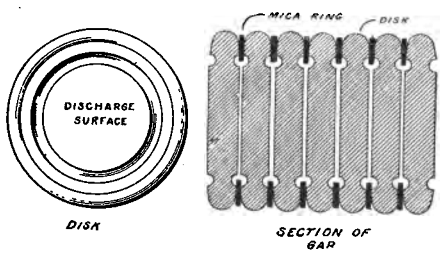

FIG. 53.—Quenched spark gap.

Spark gaps take other forms, two of which are interesting and important enough to describe here.

The first is the rotary gap. This consists of a number of small electrodes set around the periphery of a wheel mounted upon the shaft of an electric motor. Two other adjustable electrodes are so mounted that the small elec-

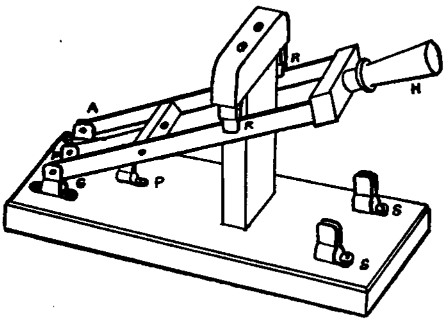

FIG. 54.—Diagram of aerial switch.

trodes on the revolving member pass between. When the motor is set in operation the wheel revolves at a high rate

FIG. 55.—Photo of aerial switch.

of speed interrupting the spark and causing a peculiar musical pitch to be emitted. A rotary spark gap almost entirely eliminates the arcing of the spark.

The quenched gap consists of a number of disks of brass about five inches in diameter having thin mica washers set between and arranged in a pile as in the illustration. The quenched gap radiates considerably more energy than any other form of gap and also has the advantage of being

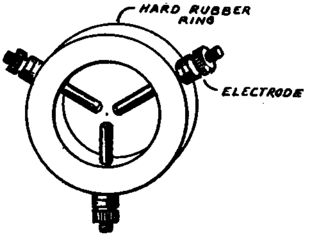

FIG. 56.—Anchor gap.

practically noiseless. The crashing discharge of an ordinary gap produces a very disagreeable penetrating noise hard to eliminate. In most commercial stations the spark is muffled to a certain extent by enclosing it in a cylinder of micanite or some other insulating substance.

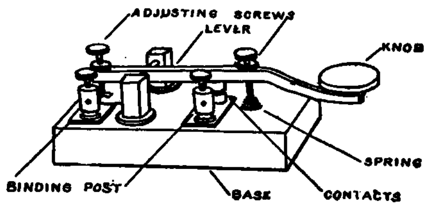

FIG. 57.—Wireless key.

THE AERIAL SWITCH is necessary for quickly connecting the aerial and ground to either the transmitting or receiving apparatus. Amateurs very often employ a small "double pole double throw" switch. The switch used in commercial stations is built in the manner shown in Fig. 55.

Fig. 58.—Photo of wireless key.

An anchor gap is a simple little device consisting of a hard rubber ring bearing two or three small electrodes

Fig. 59.—Key and aerial switch.

or sparking points. It is a necessary part of the transmitting apparatus wherever a loop aerial is used. One electrode is connected to the transmitting apparatus and the other two to the opposite sides of the aerial so that the currents divide between the two halves and equalize.

THE KEY is a hand operated switch which controls the electric currents passing through the transformer or coil shutting them on or off at will and so controlling the electric oscillations in the antenna to send out short or long trains of ether waves in accordance with the dot or dash signals of the Morse alphabet.

The key used in a wireless station is necessarily much larger and heavier than those employed in ordinary Morse line work, in order to carry the heavy currents used by the transmitter. In spite of their size and weight, however, such keys when properly designed may be handled with perfect ease.

CHAPTER IV.

THE RECEIVING APPARATUS.

The receiving instruments form the most interesting and ingenious part of a wireless station. They are the ears of the wireless station. They are wondrously sensitive but yet simple and incapable of much complication. The receiving station forms an exact counterpart of the transmitter, and the train of actions taking place are the reverse of those of the latter. The purpose of the transmitter is to change ordinary electric currents into electrical oscillations and thus set up *electric waves,* while the receptor converts the waves into oscillations and thence into currents which are capable of manifesting themselves in a telephone receiver. The instruments necessary for receiving comprise a

Detector	Fixed Condenser
Telephone Receivers	Tuning Device

Other instruments such as a potentiometer, test buzzers, variometers, variable condensers, etc., complete the outfit and improve its selectivity and sensitiveness.

THE DETECTOR forms the most vital part of the receptor. In explaining its action it may be well to recall and enlarge upon the description already set forth on page 11, where it was explained that electromagnetic or as they are more commonly called when identified with wireless telegraphy, Hertzian waves have the power of exciting *oscillations* in any conductor upon which they impinge. Electrical oscillations, it will be remembered, are alternating currents of

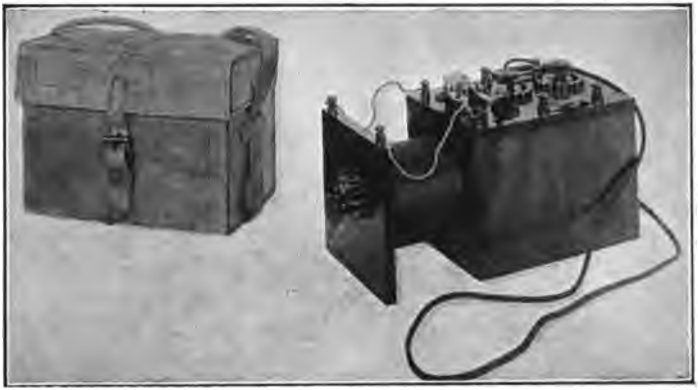

FIG. 60.—Portable receiving set and case.

very high frequency. They are generated in the aerial of the receiving station by the action of the waves coming

FIG. 61.—Complete receiving outfit.

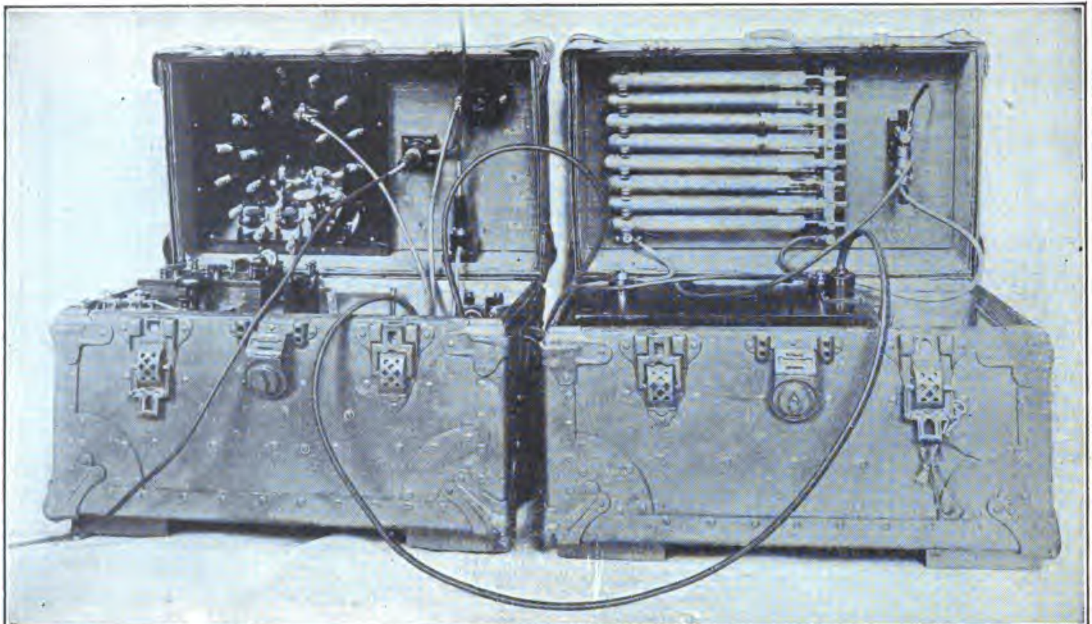

Fig. 62.—Portable pack set. The receiving outfit is contained in the left hand case; also the key and interrupter. The tubular condenser, spark gap, and induction coil may be seen in the right hand case.

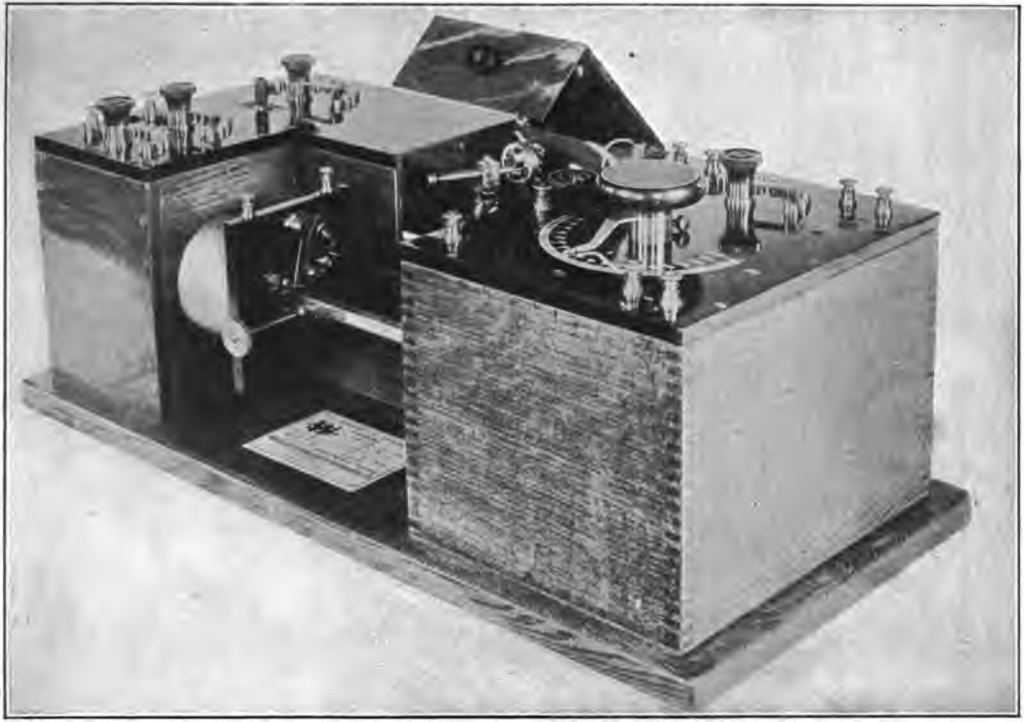

FIG. 63.—Complete receiving set, consisting of two "Perikon" detectors, potentiometer, loose coupler, variable condenser, etc.

from the distant transmitting station. These currents are exceedingly feeble, too feeble in fact to operate any form of electrical apparatus except a telephone receiver, which is one of the most sensitive instruments in existence.

There are probably more different forms of detector than any other piece of radiotelegraph apparatus. Those in most common use to-day are the mineral detectors. A small crystal of certain minerals, iron pyrites, silicon, ga-

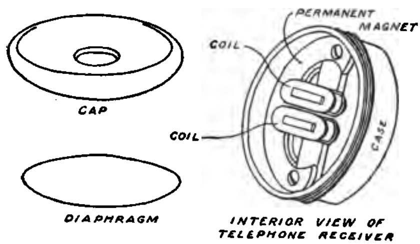

Fig. 64.—Showing construction of a "watch case" telephone receiver.

lena, etc., is placed between two contact points which are adjustable so that the pressure may be regulated and the most sensitive portion of the mineral selected. A telephone receiver is shunted across the terminals of the detector.

A telephone is shown in diagram in Fig. 64. It consists of a U shaped permanent magnet of bar steel, so mounted as to exert a polarizing influence upon a pair of little electromagnets, before the poles of which an iron diaphragm is mounted. For convenience these elements are assembled within a small cylindrical casing usually of hard rubber. The permanent magnet exerts a continual pull upon the diaphragm tending to distort it, concave inwards. When alternating currents are sent through the receiver coils, that part of the alternation which is flowing in the proper direction to form a magnetic field flowing in the same direction as that of the permanent magnet will strengthen the latter and assist it in attracting the diaphragm and causing it to further approach the magnet. That portion of the current flowing in the opposite direction detracts from the magnetic pull and allows the di-

FIG. 65.—Pickard adjustable telephone receivers for wireless purposes.

aphragm to recede from the magnet. The diaphragm thus takes up a vibrating motion corresponding to the electrical waves supplied to the coil and it imparts motion to the surrounding air, the result being *sound.*

It might reasonably be asked why a telephone receiver could not be directly connected to the aerial and ground so that it would respond directly to the high frequency currents generated by the incoming waves without the medium of a detector. There are two very good reasons why such a method would not be possible, the first being that the little magnet coils contained in the telephone receivers exert a choking action upon alternating currents of *high frequency* which effectually blocks their passage. Low frequency alternating currents, intermittent direct currents

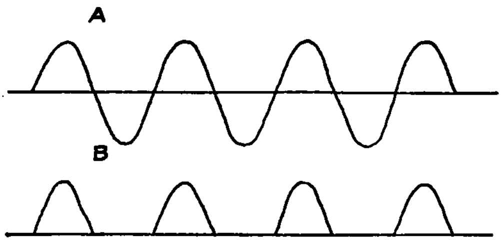

FIG. 66.—Illustrating the valve action of a rectifying detector.

and continuous direct currents will readily pass, producing a sound—each time there is any change in their value. The purpose and action of most types of detectors is to act as a valve allowing the current to pass through in one

FIG. 67.—A new type of silicon detector in which a crystal of *arsenic* may be brought to bear against the surface of one of several *silicon* crystals.

direction but not permitting it to pass in an opposite one. The high frequency oscillating currents may be represented by a curved line crossing and recrossing a zero line and gradually decreasing in amplitude as shown by A in Fig. 66.

The detector, *acting as a valve,* eliminates one half of the alternating current so that the result may be represented by B, in reality a pulsating direct current which rises and falls but is able to flow through the telephone receiver and produce a motion of the diaphragm with consequent sound waves audible to the ear.

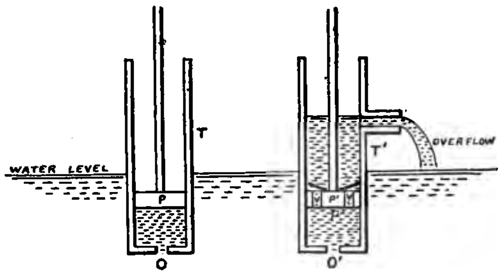

FIG. 68.—Diagram drawing analogy between rectifying action of a detector and a pump.

The accompanying sketches and the following analogy drawn between the electric currents and the flow of a stream of water may serve to render a better conception of how it is possible for the *valve action* of a detector to rectify an alternating flow, continuously reversing its direction to an intermittent current passing in one direction only. The illustration shows two pumps A and B. Each pump is immersed in a pool of water and consists of a cylindrical tube T and T′ having a small opening, O and O′, at the lower end to admit the water and a piston, P and P′, operating up and down inside the tube. Every time that the piston P is raised in the pump A it will draw in water through the small hole O. As soon as it descends, however, the water will reverse its direction and pass out. The action of the water represents that of an *alternating* current because it passes in first one direction and then in the other. The pump B is *fitted with a valve* whose action is to permit the water to flow in one direction only. The

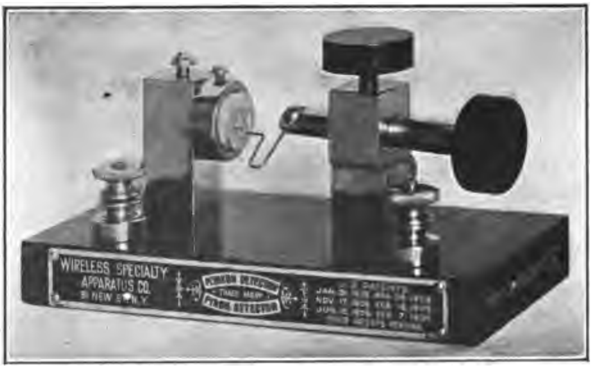

FIG. 69.—Pyron detector in which a fine wire is brought to bear against a crystal of iron pyrites.

valve is fitted to the piston P′. It is a little flap which opens a hole in the piston when the latter is descending and closes when it is rising. Suppose that the piston is raised. Water will be drawn in through the little hole O′. As soon as the piston reaches the limit of the stroke it commences to descend. In falling it exerts a slight pressure on the valve which opens and allows the water to pass through. The hole in the piston is larger than the hole in the pump and so there is almost none of the water forced back into the pool. The next up stroke of the piston draws more water in, that which is on top flowing out through the overflow. The nature of the stream passing through the hole O′ is ***intermittent,*** passing principally in *one* direction. It may be likened to the intermittent direct current produced by the detector.

Some of the many forms of detectors are interesting because of the ingenious manner in which equivalent results are attained. The illustration shows a type of detector known as the *"Perikon."* Two minerals, *zincite* (oxide of zinc) and *chalcopyrites* (copper-iron sulphide), are mounted in adjustable cups so arranged that the surfaces of the minerals can be brought into variable contact with one another.

FIG. 70.—Perikon detector.

Another very good rectifying detector is that consisting of a flat surface of highly polished silicon mounted in a small cup. A flat brass point mounted on the end of an adjustable thumbscrew is brought to bear on the silicon.

Other mineral detectors of value are the Pyron, molybenite and galena.

The carborundum detector is a form of crystal rectifier

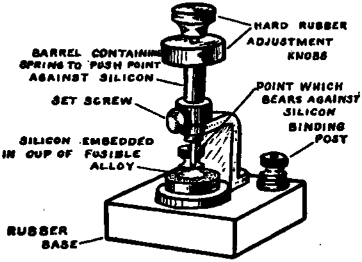

FIG. 71.—Silicon detector.

consisting of a fragment of carborundum held between two carbon blocks.

The electrolytic detector consists of a very fine platinum wire (.001-.0003 of an inch in diameter) dipping into a small cup of dilute nitric acid. A large platinum electrode

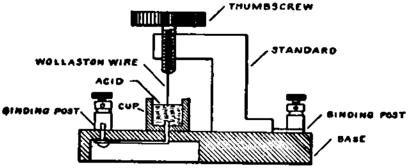

FIG. 72.—Electrolytic detector.

is sealed in the bottom of the cup so as to make an electrical connection with the liquid. This form of detector is exceedingly sensitive, probably more so than any other. The electrolytic detector requires a battery. When a slight current passes through the circuit, very minute bubbles are formed at the wire, insulating it from the liquid and thus shutting off the battery current from the telephone receivers. However, upon the arrival of any electric waves

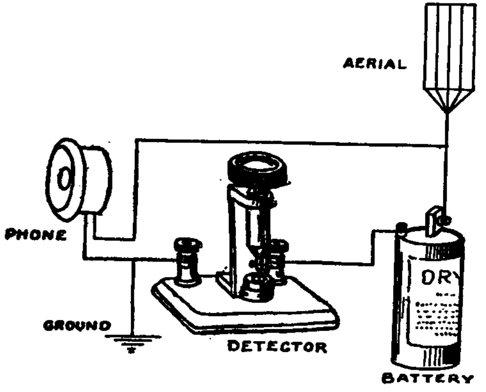

FIG. 73.—Electrolytic detector in circuit.

and consequent high frequency oscillations the latter destroy the bubbles clustering around the little wire and permit the current to flow. Upon the cessation of the high

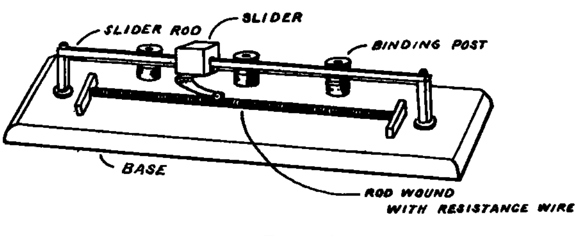

FIG. 74.—Potentiometer.

frequency currents the bubbles immediately form again, only to become broken down by each train of oscillations produced in the aerial. The intermittent currents can be detected by a buzz in the telephone receivers.

The carborundum detector also requires a battery although its action is somewhat different from that just described.

When a battery is used in connection with a detector, an instrument known as a potentiometer becomes necessary. A potentiometer is simply a device for accurately adjusting the voltage of a battery to a value where it will render the detector the most responsive to the incoming signals.

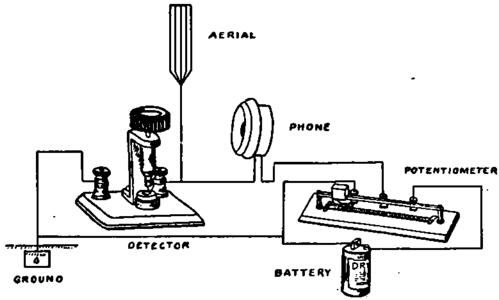

FIG. 75.—Diagram showing how potentiometer is connected in circuit.

The Tuning Coil is a device for accurately adjusting the oscillation circuits to receive the waves.

Its action may be illustrated to a certain extent by pressing down the loud pedal of a piano and at the same time whistling a note loudly and clearly. Listen carefully and some of the wires in the piano will be heard sounding the note whistled. At each vibration of the note of the whistle a wave of pressure went forth from the lips and reaching the wires gave them all a tiny impulse. The impulses followed each other rapidly at definite intervals giving each of the wires the same push each time. The wires which are tuned to produce the note on the piano corresponding to that of the whistle will vibrate energetically enough to produce a sound themselves. They are the wires to which the impulses are rightly tuned so that each one adds to the motion it has already acquired. We all know how a child sitting in a swing may be made to swing back and forth by giving a succession of little impulses properly timed. The small pushes are superimposed on one another, the result being a single large motion.

FIG. 76.—Analogy between swinging and tuning.

The "impulses" generated in the receiving aerial are exceedingly weak and in order to produce an effect must be timed so as to follow one another in proper succession. Tuning devices are for this purpose and by their means the receiving circuits and instruments may be carefully adjusted to the same wave length or "note" as the transmitter so that the high frequency currents in the aerial will arrive at the proper time to oscillate or surge back and forth to produce the maximum results.

In this way it is possible to convey intelligence over long distances by the repetition of small impulses without it being necessary to send any very energetic ones. By arranging the stations so that each one emits its own definite wave different in period or *length* from that of the others it is possible to operate several stations at the same time in

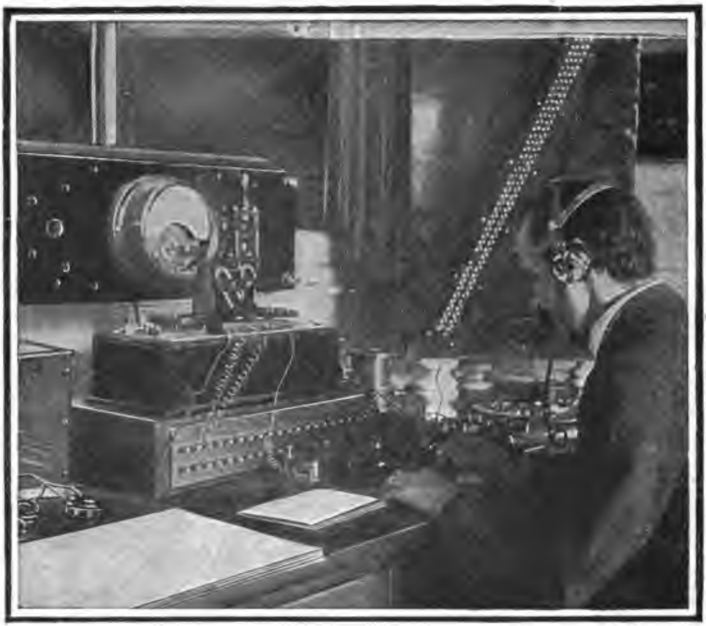

FIG. 77.—Receiving a message in a Marconi transatlantic station.

the same neighborhood without interfering with one another. The apparatus is then said to be *selective* because the instruments can be adjusted in a few seconds to receive from any desired station and to exclude others.

The tuning coil consists of a cylinder wound with bare copper wire spaced so that the turns do not touch one another. Variable contacts called "sliders" are so arranged that connection can be made almost instantly to any desirable turn of wire. The tuning coil is connected to the aerial and receiving apparatus in the manner illus-

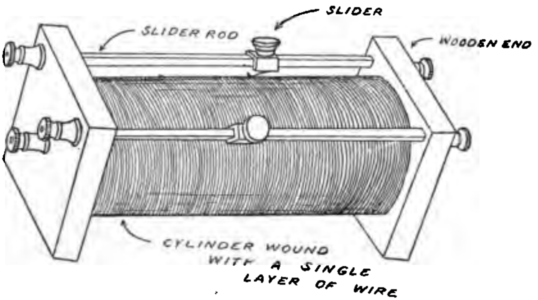

FIG. 78.—Tuning coil of the double slide type.

trated in Fig. 79. By moving the sliders back and forth the wave length of the system may be added to or detracted from and any desired "tune" quickly reached so that it is

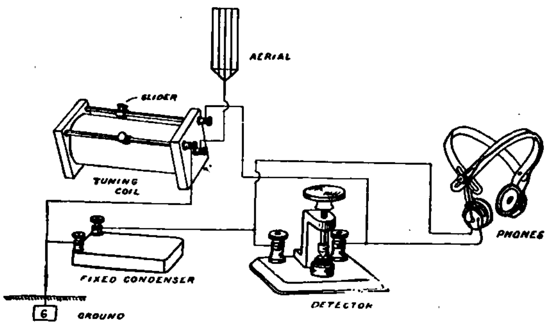

FIG. 79.—Diagram showing fixed condenser in circuit.

possible to listen to any station desirable and exclude the others. The cylinder over which the wire is wound usually consists of a thick cardboard tube treated so as to be moisture proof. Bare wire is preferable to all forms of insulated wire. The coil is usually three to four inches in diameter and eight to twelve inches long.

Tuning coils are known as "single slide," "double slide" and "three slide" according to the number of contacts they are fitted with.

The loading coil is a supplementary tuning coil used to furnish extra inductance in case it is desirable to obtain a greater range of resonance or tuning.

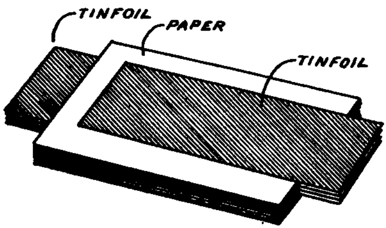

FIG. 80.—Fixed condenser.

It is merely a single slide tuning coil connected in series with the regular tuning device. It is not always a necessity but is often part of the equipment when it may be necessary to adjust the apparatus to receive long wave lengths.

Condensers are devices for collecting and storing electricity. They play a very important part in both the transmitting and receiving operations. Condensers and Leyden jars have already been described in connection with the transmitting apparatus.

The condensers used in receiving are very much smaller in size and *capacity* but are the same in principle. There are two general types of receiving condensers called "fixed" and "variable" accordingly as the capacity is alterable or not.

Fixed condensers consist of a few sheets of tinfoil interposed between sheets of paraffined paper or in some cases mica. The condenser is inclosed in a suitable case, usually a hollow molded block of insulating composition, and is provided with suitable terminals to facilitate connection.

When a conductor is charged with electricity it has the power of exerting an opposite charge in any adjacent con-

FIG. 81.—Rotary variable condenser.

ductors. The two halves of a condenser constitute adjacent conductors, the separating medium in between being called the dielectric. An alternating current will pass through a condenser because the charge on the plates keeps changing from negative to positive and back from positive to negative again. A direct current will not pass through a condenser.

These facts are utilized to considerable advantage in the receptor of a wireless station. As has already been explained, the high frequency oscillatory currents will not readily pass through the coils of the telephone receivers, but a path is provided through the condenser. The detector rectifies the alternating current into a direct current which the condenser opposes and forces to pass through the telephone receiver and produce sounds.

When a battery is used in connection with a detector a condenser is also necessary to oppose the direct current of

FIG. 82.—Interior of rotary variable condenser showing construction.

the battery and prevent it from flowing around through the tuning coil instead of through the detector. The capacity of the condenser may be smaller if the resistance of the telephone receiver is very great for the reason that as the wire grows smaller it offers greater impedance to the current. The opposite also holds true and condensers of large capacity are better fitted for use with telephone receivers of low resistance.

Variable condensers are divided into two general types, the "rotary" and the "sliding" plate, accordingly as the plates forming the condenser are adjusted with a rotary or a sliding motion. The rotary type consists of a number of movable semi-circular aluminum plates which swing between a series of fixed semi-circular plates of a slightly larger diameter. The plates must not touch one another and move back and forth with perfect freedom. The *dielectric* is formed by the air spacing between the plates.

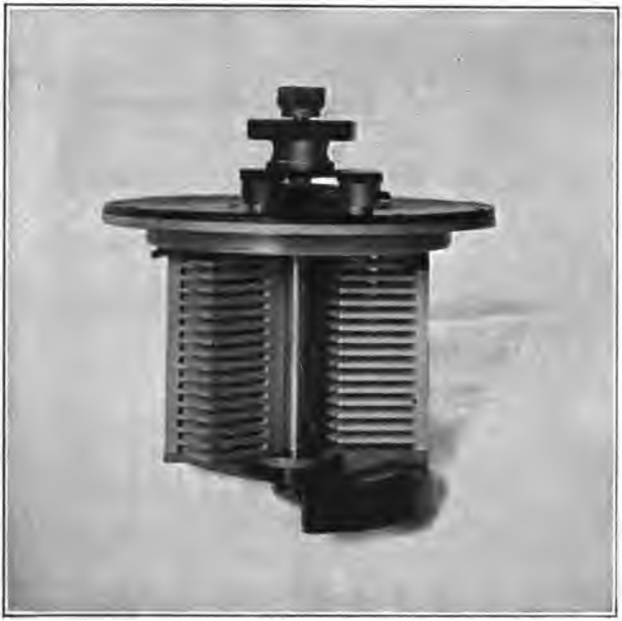

FIG. 83.—Dr. Seibt's rotary variable condenser. The plates are turned from a solid casting and the separation between is only .01 inch.

The advantage of an air dielectric is that no losses of energy take place through *hysterisis.* Hysterisis is the *lagging* which takes place in the process of charging and discharging. A thumb knob is fitted to the movable plates and provided with a pointer moving over a graduated scale so that the degree of capacity in use is indicated.

In the sliding plate type of variable condenser the plates are either square or rectangular in shape and move back

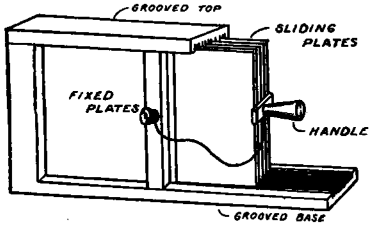

FIG. 84.—Sliding plate variable condenser.

and forth in grooves cut in a hardwood frame as shown in the illustration.

Variable condensers are used for tuning and adjusting

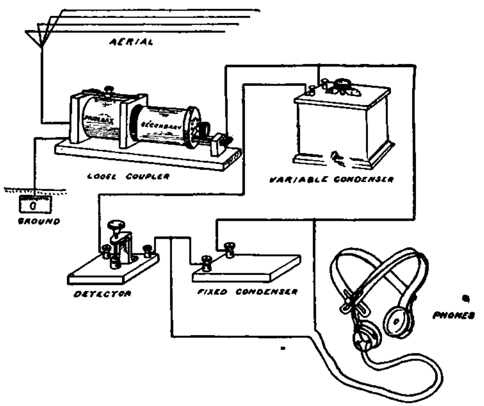

FIG. 85.—Diagram showing arrangement of rotary variable condenser in receiving circuit.

the receiving circuit in the same way that a tuning coil is employed, namely to increase or decrease the electrical length of the circuit so that it will respond to different wave lengths. The condensers are capable of finer adjustment than tuning coils because the change is gradual and even and is not in jumps from one step to another as from one turn to the next turn of the coil. If the desired point of resonance should happen to come between two wires of the coil and not in a position to be reached by the slider, the variable condenser can be adjusted to reach the exact degree of resonance and thus bring the circuit into finer adjustment than would otherwise be possible. The exact way in which this is accomplished and the effect upon the circuit will be left to the next chapter.

CHAPTER V.

TUNING AND COUPLING, DIRECTIVE WAVE TELEGRAPHY.

Tuning has been mentioned in several places but not explained in any greater measure than was necessary to render a conception which would enable the reader to follow the text intelligently in order not to depart from the subjects under discussion there and consequently defeat the purpose of clearness.

The great importance and value of properly "tuning" the circuit of radiotelegraphic apparatus cannot be overestimated and for that reason the subject can hardly be passed without some further explanation. Its effects are two-fold. In the first place it is always desirable and highly important that wireless messages should be, so far as is possible, *selective,* inasmuch as there are often several stations in the same immediate neighborhood operating at the same time. This result is reached by tuning and it is possible for them all to transmit different messages at the same time without confusion by the proper arrangement of the *wave length.* The second effect is the transmission of messages over long distances with the comparative consumption of small amount of power by adjusting the "period" or electrical length of the circuits until the oscillations "flow in harmony" with each other and resonance is secured.

Perhaps the only way that these results may be made clearly intelligible is by resort to a graphical example. Suppose that a very heavy weight were suspended from a chain as shown in the illustration and that it is struck at regular intervals, *once every* second, with a hammer. Every time that the hammer strikes the ball it will give it an impulse and cause it to swing slightly. If the chain is short, the ball will swing faster, while if it is long it will swing more slowly. We will suppose that the

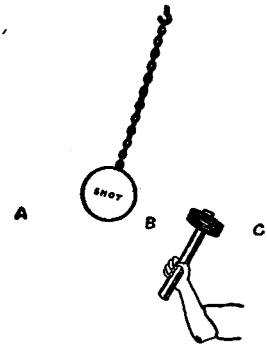

FIG. 86.—Chain and ball arranged to illustrate effect of tuning.

ball is struck from such a direction that it starts to swing over toward A. The ball is so heavy and the hammer so light in comparison however that the ball does not swing very far and soon commences a return journey. If it should return to the point B just as the hammer delivers another blow the force of the blow will be expended in stopping the ball rather than adding to its motion because they are both traveling in *opposite* directions. However if the chain is lengthened so that it has a period of swing lasting one second, the succeeding blow will strike the ball after it has reached the point C and is on its return journey, thus imparting fresh energy because both the ball and hammer *come together at the right time* when they are both swinging together. Proper adjustment of the length of the chain will make it possible for the hammer to always descend at the right moment to add its energy and motion to that previously given the ball. The result will be considerable increase in the amplitude of the swing.

From this we may easily perceive how it is possible by shortening or lengthening the period of an electrical circuit to so adjust it that resonance is secured and each succeeding oscillation will take place at the proper time to assist the

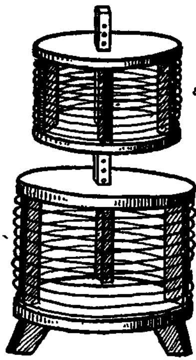

FIG. 87.—Loose coupled helix.

previous one, not dying away after one or two surges and becoming what is known in technical language as rapidly "damped."

The instruments for accomplishing these things consist as previously explained, in the case of a transmitter, of the *helix* and in the receiving station of various *tuning coils* and condensers.

Helix and tuning coils are divided into the "inductive" or "loose" and the "direct" or close coupled types. Inductive tuning coils are known as "loose-couplers" and "receiving transformers." Inductive helixes consist simply of two helixes, separated from one another as shown in the accompanying illustration. The upper helix, called the secondary, can be raised or lowered upon a central support. Varying the distance between the primary and secondary is varying the "coupling." There are several advantages

FIG. 88.—Hot-wire ammeter.

derived by using loose coupled sending helixes, the chief of which lie in the fact that it is possible to radiate larger amounts of energy and also decrease the "damping."

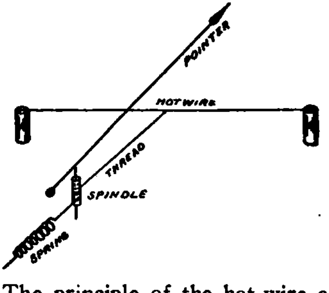

FIG. 89.—The principle of the hot-wire ammeter.

In order to tune a transmitter, the "hot-wire" ammeter is necessary. This instrument makes use of the property which electrical conductors possess to become heated and expand when a current is passed through them.

The accompanying diagram serves to illustrate the principle of the "hot-wire" meter. A piece of platinum wire is stretched tightly between two rigidly fixed posts. A thread leads from the center of the "hot wire" to a small spindle around which it passes once or twice. The spindle is also connected to a spring which exerts a continual tendency to turn the spindle but is prevented from so doing by the

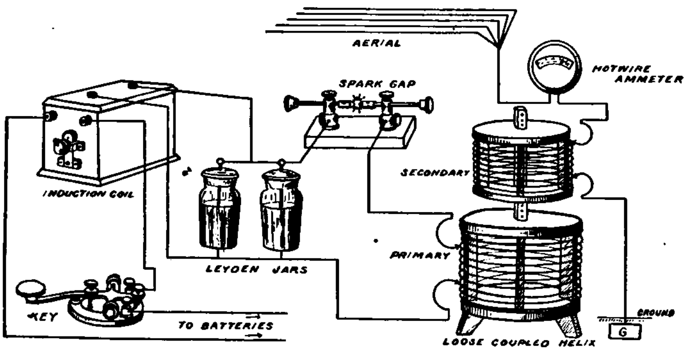

FIG. 90.—Diagram showing loose coupled helix in circuit.

thread attaching to the hot wire. Any tendency on the part of the string to slacken a little, however, will immediately permit the spring to turn the spindle. When a high frequency current is passed through the platinum wire it becomes heated and expands. The expansion of the wire allows the thread to slacken slightly with the immediate result that the spindle turns. The spindle carries a pointer at the upper end which shows the amount of turning. It is therefore easy to tell the comparative strength of current flowing accordingly as the deflection is great or small.

The meter is placed in series with the aerial and when the high frequency currents pass through it they heat and expand a fine wire, causing the needle to move over a graduated scale and indicate the amount of current passing. The apparatus is "tuned" or in resonance when the

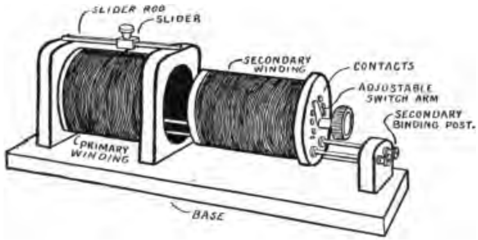

FIG. 91.—Loose coupled tuning coil.

length of the spark gap, the condenser and the helix have been so adjusted that the oscillations flow freely through the system and the maximum amount of current is indicated by the ammeter.

FIG. 92.—Loose coupled tuner.

The loose coupled tuning coil consists of two windings wound over two concentric cylinders, forming a primary and a secondary. The secondary is the smaller winding and slides in and out of the primary so that the "coupling" is variable. The primary is adjustable by means of a slider and the secondary by means of a multi-pointed switch. The slider is usually connected to the aerial and one end of the coil to the ground. The detector, etc., are connected to the terminals of the secondary. Variable condensers may be added with good results to both the primary and secondary circuits.

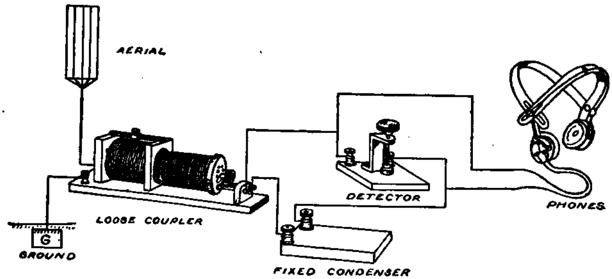

FIG. 93.—Diagram showing position of loose coupler in circuit.

Loose couplers also take the form of doughnut tuners in which the secondary revolves instead of slides. The coupling is variable in such an instrument by simply turning the secondary.

The wave emitted from a transmitter is in reality made up of two waves of different lengths. The variation in the lengths of these two waves is dependable upon a factor known as the coefficient of coupling. It is almost impossible to clearly explain the phenomenon and in order not to confuse and complicate by a rather lengthy explanation it may be well to simply state that its effect is to make selective tuning difficult unless the coupling of the receiving station can be varied to correspond with that of the transmitter and ask the reader to take it for granted. Varying the coupling adjusts the difference in the two

FIG. 94.—Fort Gibbons, Alaska, wireless station.

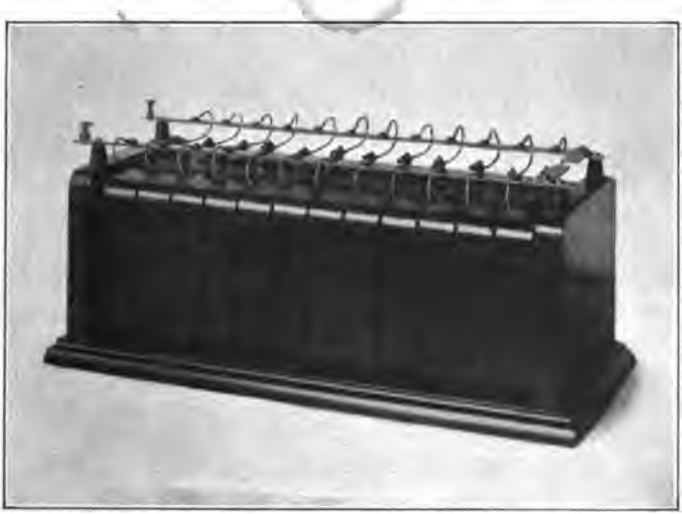

FIG. 95.—Transmitting condenser (molded dielectric).

wave lengths and when properly accomplished renders the apparatus highly selective.

Directive Wireless Telegraphy is an interesting phase of this new art which is receiving considerable attention in the hands of investigators and has resulted in the devisement of several successful systems for confining the propagation of the electric waves to certain directions.

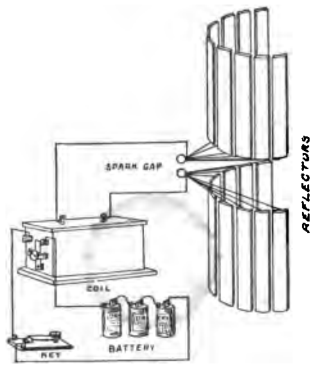

FIG. 96.—Braun's method for directing wireless telegraph signals.

A general diffusion of waves is often very undesirable for the reasons that the message may be received by an unfriendly neighbor or enemy and also because it is wasteful of energy. By so directing the waves that they may be sent over the earth to any desired point of the compass and only in that direction, it is possible to communicate without disturbing another station and also for a vessel at sea to secure its bearings and position by tuning its apparatus to respond to electric waves from two different known stations.

The manner in which the problem has been solved varies considerably according to the inventor. All are interesting and ingenious.

It will be remembered that electric waves possess all the characteristics and properties of light waves, etc., and may be reflected, refracted and polarized.

Ferdinand Braun has devised a system consisting of a number of metallic strips arranged to compose a parabolic surface. Another similar set of strips below the first set

FIG. 97.—Bellini-Tosi radio-goniometer for directive wireless telegraphy.

completes the arrangement. The two sets are connected to the terminals of a spark gap and induction coil. This apparatus acts as a huge reflector and sends out waves in one direction only, but however interesting and ingenious it may be is not entirely practical.

Another method devised by Braun employs two or more aerials at certain distances apart. The alternating currents used to excite the oscillations differ in *phase*, i. e. are so arranged that they have different comparative values at the same moment. It is possible to send very strong signals in a direction lying in the same plane as the aerials. By the use of three or more antennæ suitably differing in their phase of excitation and situated at the vertices of a

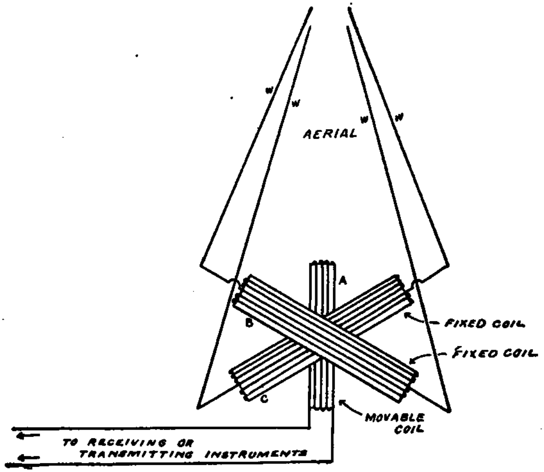

FIG. 98.—Arrangement of Bellini and Tosi for directive wireless telegraphy.

triangle it is possible to send strong signals in certain directions only.

Messrs. Bellini and Tosi have devised a very ingenious method of directively transmitting and receiving electric waves as shown in the accompanying diagrams. The antenna consists of two closed or nearly closed circuits of triangular shape arranged in two perpendicular planes. The two aerials each contain a circular coil of wire perpendicular to each other with their windings in the planes of the antenna circuits respectively. A third coil is connected to the receiving apparatus when the messages are incoming and to the condenser, spark gap and coil when the signals are to be transmitted.

Waves coming in from any particular direction produce oscillations in the two aerial circuits whose intensity varies according to the direction in which the waves come. These currents passing through the coils generate a magnetic field having a direction perpendicular to that from which the waves come. The strength of the currents in

FIG. 99.—Complete receiving and transmitting outfit.

the movable coil will depend upon its position in the resultant magnetic field and will be at a maximum when the coil embraces as many as possible of the lines of magnetic force.

By providing the movable coil with a pointer it is possible to thereby determine the plane in which the station producing the signals lies. Any ambiguity regarding the final position of the station, whether it is located in the same direction indicated by the pointer or in the opposite one, is only removed by general knowledge of the location of existing stations.

The processes involved in sending messages are the reverse of those entering into the receiving apparatus. The movable coil being connected with the condenser, gap and transformer or induction coil creates a magnetic field which induces oscillating currents in the other two coils and consequent waves in the aerial whose strongest exertions will lie in a plane determined by the third coil. Changing the position of the latter will send the messages in any direction desired.

CHAPTER VI.

THE DIGNITY OF WIRELESS. ITS APPLICATIONS AND SERVICE. WIRELESS IN THE ARMY AND NAVY. WIRELESS ON AN AEROPLANE. HOW A MESSAGE IS SENT AND RECEIVED.

Wireless telegraphy and that precocious infant, wireless telephony, have outlived all the speculative and tentative achievements of their early days and have established themselves in an important and settled position among our methods of conveying intelligence.

The field has been so greatly enlarged in recent years and the apparatus and methods so improved that the broadest possible view of its future development and importance

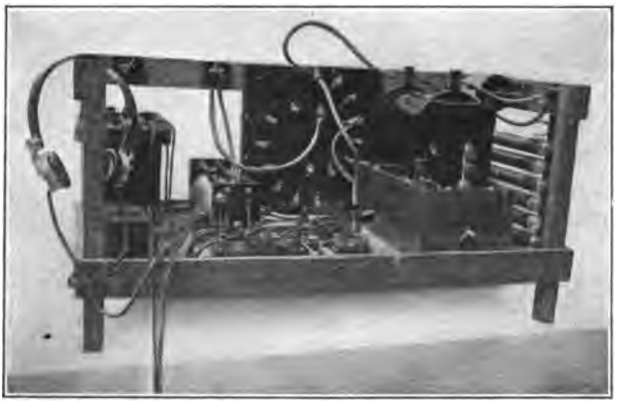

FIG. 100.—Special light weight wireless telegraph set for airship service.

is justified. And there must inevitably come the time when our merchant marine and wireless service will come under such reasonable regulation that it will be removed from any dependence upon stock jobbing wireless telegraph and telephone companies.

Official sources show that the equipping of sea-going

FIG. 101.—Telefunken wireless cart, showing transmitter.

vessels with wireless apparatus is progressing at a rapid rate and it is not difficult in the face of certain facts to appreciate the enormous volume of business that sooner or later will be handled by wireless. Three hundred and sixty-three United States naval vessels and about eight hundred merchant vessels are equipped at this writing. The large number of commercial shore stations, army forts and posts, and those used by corporations, isolated stations, etc., for various private purposes comprise a list which reaches an enormous total.

Whatever may have been the status of wireless previous

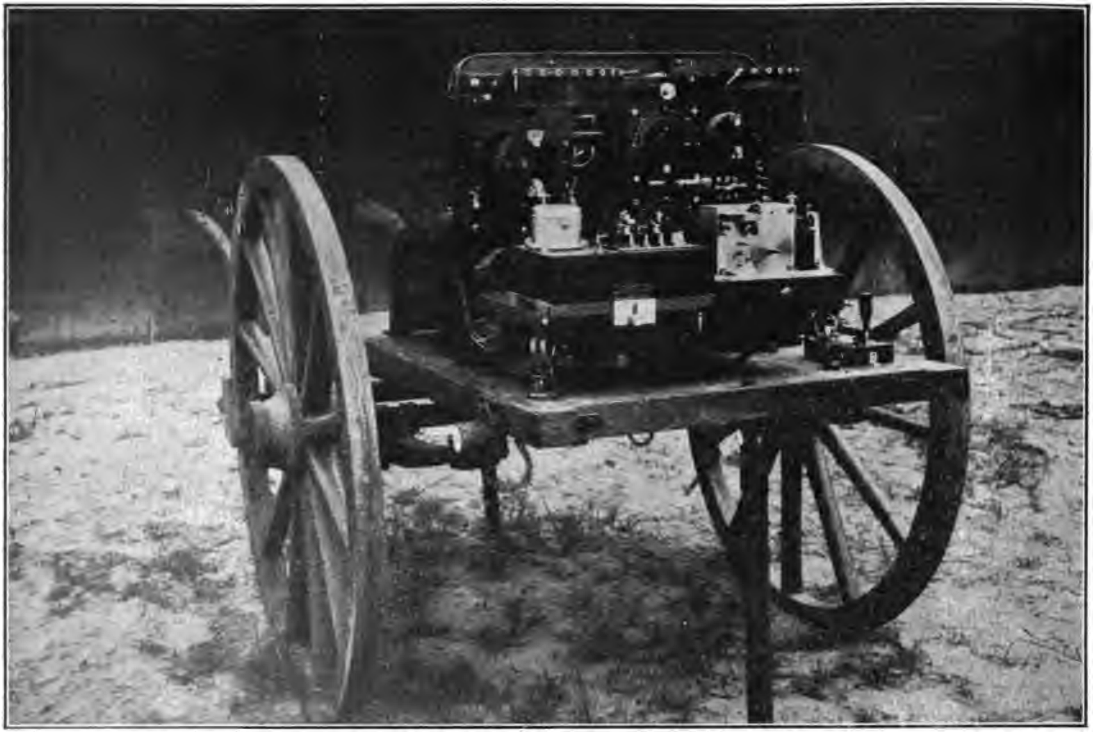

FIG. 102.—Telefunken wireless cart for military service, showing receiving apparatus.

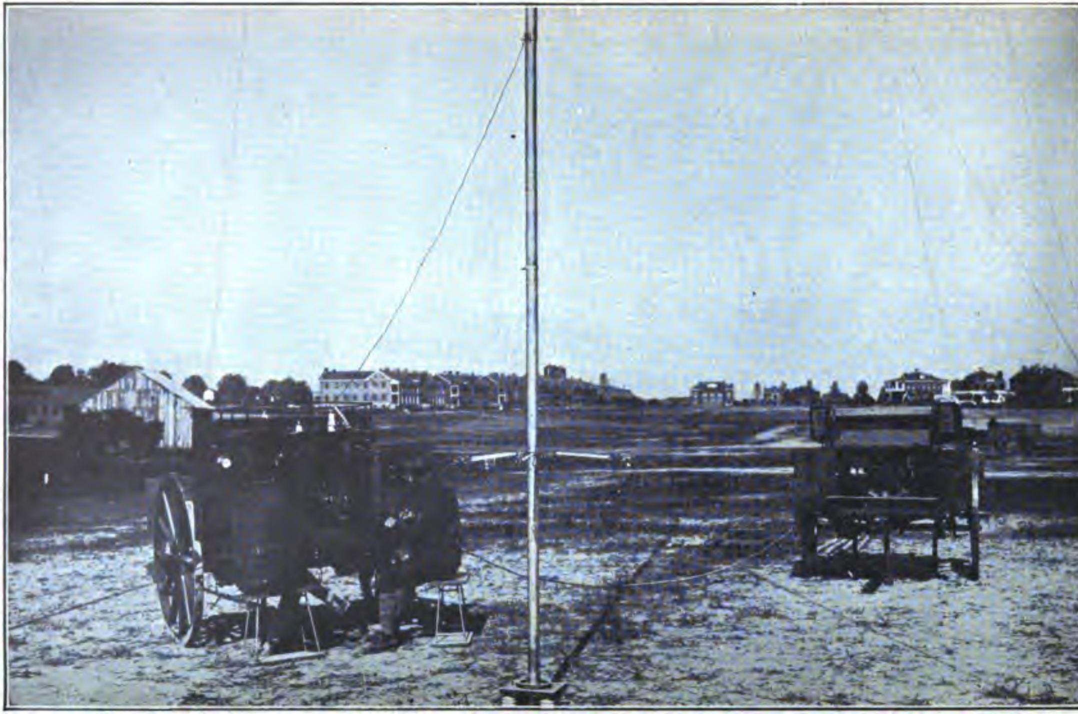

Fig. 103.—Telefunken wireless wagon set in operation at Fort Leavenworth, Kansas. The aerial is of the umbrella type supported by a steel pole resting on a porcelain base.

to the Titanic disaster, it now occupies a position far more important than that taken merely from any commercial standpoint, for it is no longer merely a convenience to business or a means of furnishing the latest news for the entertainment of passengers, but is a life-saving proposition taking its place with the elaborate and costly systems of railroad signals.

It is a curious fact that many of the most startling and newest inventions find ready and peculiar application as an aid in modern warfare. The nerves of every war vessel and fort are the wires of the telephones, telegraphs, telautographs, dynamos, storage batteries etc., that transmit orders by speech or in writing, find the range, fire the guns, explode the mines and seek out the enemy with a powerful searchlight.

Every battle-ship, cruiser, etc., of the United States Navy is now equipped and with the completion of the new ultra-powerful station at Washington the War Department will be enabled to issue instructions to a ship no matter where it may be on the ocean or in what harbor it may lie.

The government maintains an elaborate equipment at the Brooklyn Navy Yard where the future wireless operators of the Navy are given a course extending from seven to ten weeks. The first few days are spent in mastering the theory. The second week usually commences alternate study and practice of the Continental Code which lasts thoroughout the entire course or until thoroughly mastered. Each week some special branch of study is given out such as repairing and overhauling certain instruments. At the end of seven weeks the student can usually send and receive 15 words a minute. He is then given two weeks to prepare for an examination which if passed rates him as an electrician, third class, and qualifies him for active work.

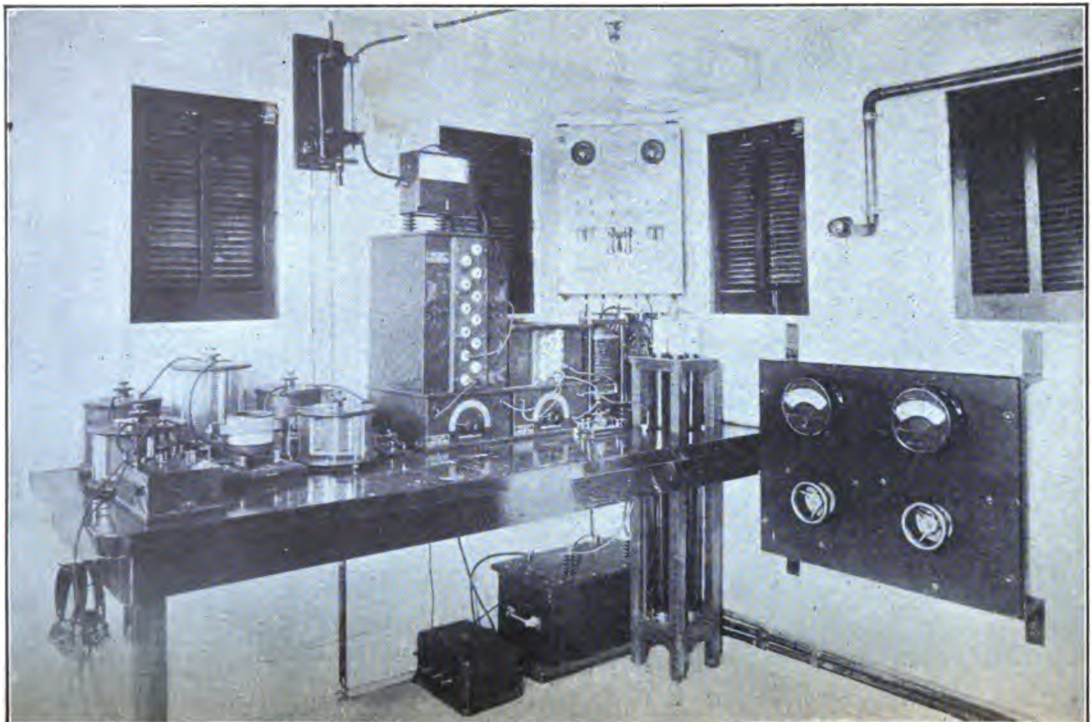

FIG. 104.—Wireless room aboard the U. S. transport "Buford."

It is certain that wireless telegraphy and telephony will be important factors in military campaigns of the future. For coast defense, wireless is as valuable as on the ocean.

FIG. 105.—The apparatus set up for operation.

This method of transmitting army orders is quite dependable. With the most recent developments and improvements it is now possible to direct the movements of a great army and navy simultaneously from a centrally located point.

One of the most interesting and spectacular applications

Fig. 106.—Wireless equipped automobile.

of wireless telegraphy in military service is the wireless telegraph automobile.

The automobile is a stock pattern touring car of 30 H. P. provided with a special body arranged to carry six passengers. The seats are elevated so as to afford storage space below for the entire wireless equipment and a truly astonishing amount of miscellaneous supplies.

FIG. 107.—Company D Signal Corps at San Antonio, Texas, 1911, showing pack sets and telescoping pole carried by pack mules.

The mast used to elevate the aerial is of light steel construction divided into eight sections which nest into one another with admirable economy of space. The socket for the foot of the mast is located in the center of the tonneau. Only a few minutes are required to raise the mast and aerial. The same gasoline motor employed to drive the automobile also drives a small dynamo which supplies the electric current for the transmitting apparatus.

Two of these cars have been experimentally operated over a number of the old battle-fields of the Civil War.

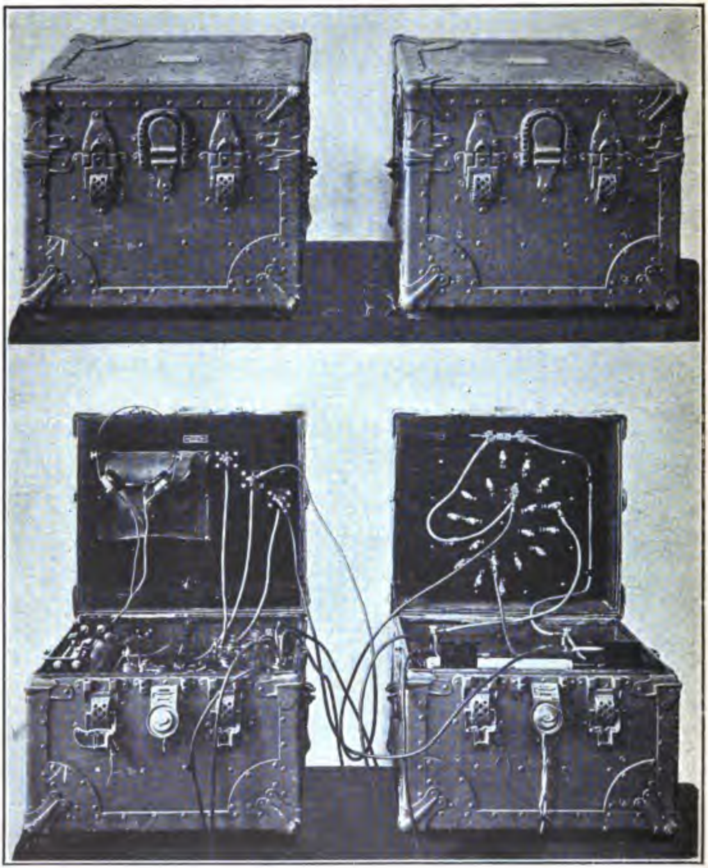

FIG. 108.—U. S. Signal Corps pack sets shown open and closed. Receiving apparatus on the left.

The tests were made under all sorts of road and weather conditions but no great difficulty was experienced in establishing communication over distances varying from 35 to 50 miles.

There is probably no application of wireless telegraphy, however, quite as picturesque as the combination of wireless and an aeroplane and the idea of a double seated aeroplane carrying an aviator and a wireless operator hovering over a hostile country to keep the commanding

FIG. 109.—The receiving apparatus of the airship "America" (Wellman expedition).

officer informed of all conditions and movements of the enemy.

The huge dirigible balloon Akron in which Melville Vanniman proposed to cross the Atlantic Ocean was fitted with wireless equipment in order to transmit news of the expedition en route to various of the daily newspapers of New York and London and also in case of an accident or emergency to summon aid.

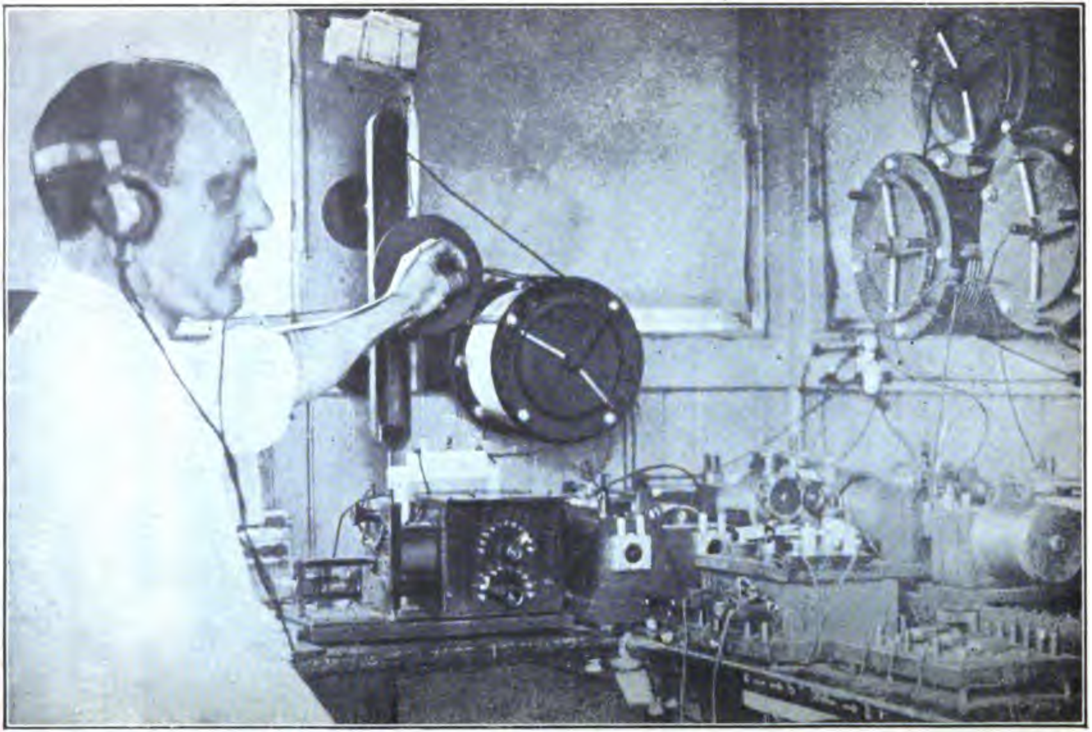

Fig. 110.—Interior of the N. Y. "Herald" (O. H. X.) press station.

The equipment is interesting because of the peculiar conditions imposed upon instruments to be used under such circumstances. A three kilowatt transformer, the latest type of musical rotary gap and a valve detector were included in the outfit. It was proposed to obtain the necessary ground connection by trailing a 1200 foot phosphor

FIG. 111.—Operating the U. S. Signal Corps airship wireless apparatus.

bronze ground lead in the ocean. The frame of the balloon was to be used as the aerial. Should it have become necessary to take the lifeboat which the balloon carried, a kite would have been raised and by substituting a copper wire in lieu of a string an aerial provided, and once more a C Q D and its appeal for aid would have gone vibrating forth through the ether.

Several enterprising newspapers have recognized the value of wireless telegraphy in collecting shipping news

FIG. 112.—The N. Y. "Herald" station, showing aerial.

Fig. 113.—Operator Jack Irwin overhauling the wireless apparatus for the dirigible balloon "America."

and have installed outfits for the assistance of their reporting bureau. This innovation in modern journalism has quickly developed into a useful feature of those publications which have seen fit to adopt it. When the baseball season is under way every steamship within calling distance wants the latest baseball scores or sporting results.

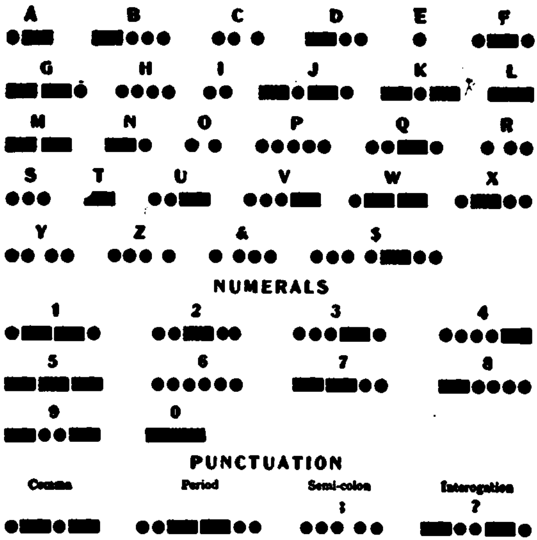

FIG. 114.—Morse code.

Railroads have found an auxiliary wireless service to be of the utmost value in relieving the heavily loaded wire lines between important centers. During some of the winter storms and blizzards, when miles of wires were down in all directions, wireless has been the sole means of communication in certain instances.

The process of sending a wireless message is very simple. The aerial switch is usually kept in such a position that the receiving instruments are connected to the ground and aerial so that the operator is always able to hear any one calling him. We will suppose for illustration that the land station at 42 Broadway, New York City, wishes to transmit a message to the steamer "Horatio Hall."

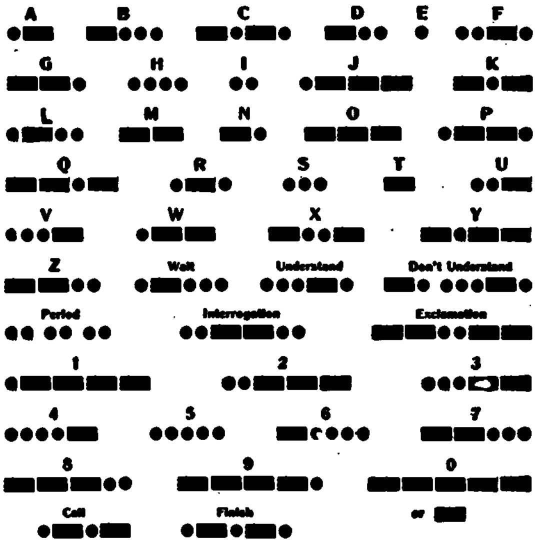

FIG. 115.—Continental code.

Every wireless station on land or sea has assigned to it two or more "call letters," which distinguish it from all other stations, and serve as the key to messages intended for it to receive and when signed to a message as an indication of its origin. The "call" of the land station in this case is N. Y., and that of the steamer, J. H.

In order to send the message to the ship, N. Y. throws the aerial into position for sending. This act also starts the motor generator set supplying current to the trans-

FIG. 116.—Transmitting equipment of the high power station at Nauen, twenty-five miles northwest of Berlin, Germany, showing six induction coils (in the foreground) arranged to charge the Leyden jars (composed of 360 units).

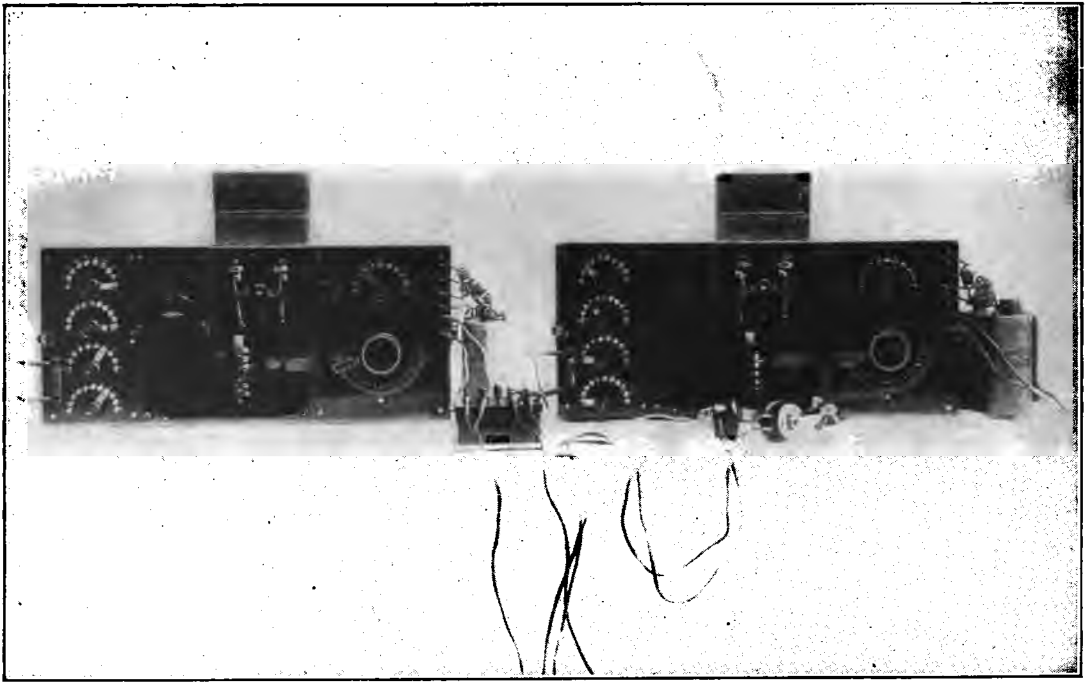

FIG. 117.—Duplex receiving apparatus. The set to the left may be adjusted to receive short wave lengths and that to the right to receive long waves. When the handle of the "listening" key, shown in the center of the illustration, is in the center, the left hand phone of the head set is connected to the instruments on the left and the right hand phone to those on the right, so that the operator is always ready to receive either short or long waves if received. Swinging the key connects both phones to either set at will.

former. Pressing the key, the operator then signals in the telegraph code J. H., J. H., J. H.—M. S. G.—N. Y.—and gives the "finish" signal. M. S. G. is the abbreviation for message. The N. Y. operator then throws his switch back into the receiving position and waits for a reply. If one is not forthcoming shortly the calling process is repeated.

As soon as the operator on board the steamer hears the call, he waits until the finish signal is received, and then

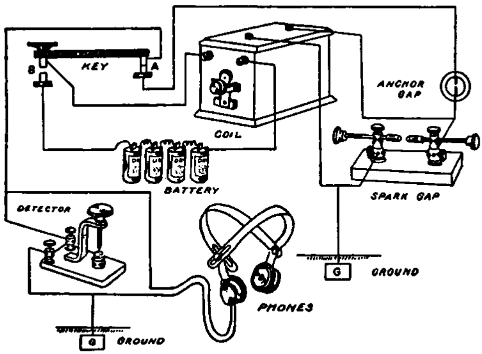

FIG. 118.—Breaking-in system.

responds in the following manner: N. Y., N. Y., N. Y.—J. H. —O. K., O. K.—G. A.—G. A.—N. Y., J. H.—and gives the "finish signal." O. K. is the abbreviation for "all right," and G. A. means "go ahead." Upon receipt of this, the land station transmits the body of the message, and signs its call and finish signal. If the steamer understands the message, she replies "O. K.," and signs.

There are two Codes in general use for wireless telegraph purposes, the Morse and Continental. It takes about five per cent. longer space of time to send a message in Continental than it does in Morse, but the former has the advantage of not containing any letters requiring proper spacing in order to be recognizable. American coastwise steamers use the Morse code; transatlantic ships use the Continental code.

One of the greatest disadvantages of most systems of wireless telegraphy lies in the fact that no arrangement is provided for simultaneously transmitting and receiving wireless signals. It is usually necessary for one operator listening to another to have to wait until the finish signal is given before he can reply or interrupt in case he cannot understand part of the message, because the receiving apparatus of the transmitting station is necessarily disconnected from the aerial and the ground during the period a message is being sent. If it were to be connected at this time the powerful currents of the transmitter would rush through the receiving apparatus into the ground without setting up any very powerful waves in the aerial and seriously injure the delicate receiving instruments.

The Breaking-in-System is a method of simultaneously transmitting and receiving wireless signals. This is accomplished by providing the transmitting key with a second set of contacts, so arranged that when the key is released between the dots and dashes of the code the aerial and ground are automatically connected to the receiving apparatus. When the key is pressed the receptor is automatically cut off. The advantages of such a system are more or less obvious. When interference or a misunderstanding occurs the fact can be immediately signaled to the sending operator, and the message commenced over again.

FIG. 119.—The receiving apparatus of the station at Nauen. The message is being printed on tape by a recording device.

CHAPTER VII.

THE EAR. HOW WE HEAR. SOUND AND SOUND WAVES. THE VOCAL CHORDS. THE STRUCTURE OF SPEECH.

On either side of the head, lodged in a cavity which they do not completely fill, and situated in the midst of a dense and solid mass of bone, entering into the base of the skull and forming the temporal bone, are two membraneous bags called the *membraneous labyrinth* and the *scala media of the cochlea.* Each bag is filled with a liquid, and is also surrounded and supported by a fluid which fills the cavity in which they are lodged. Certain small, hard bodies, free to move around, lie in the fluid of the bag. The ends of

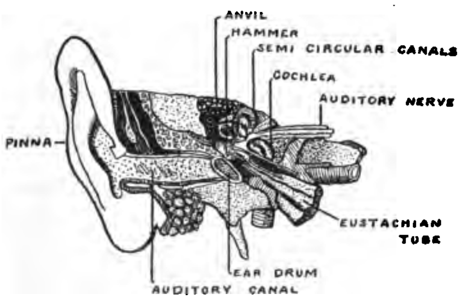

FIG. 120.—Diagram of the ear.

the *auditory nerve* of hearing are distributed around the wall of the sac, so that they are subjected to the blows of the little particles of calcareous sand, or *otoconia,* as they are called, whenever the fluid in the bags is disturbed.

The membraneous lining on which the ultimate ends of the nerves are spread is virtually a sensitive beach, and the little otoconia, showers of pebbles and sand, which are raised and let fall by each succeeding wavelet of sound. This wonderful mechanism constitutes the inner ear.

The ear, as a whole, consists of three parts: the *outer ear,* which is a trumpet-shaped passageway called the *pinna* serving to collect the sound waves and pass them on through

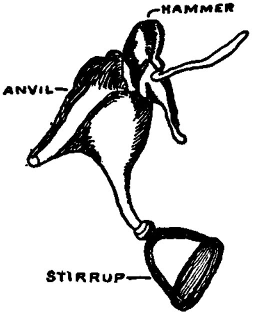

FIG. 121.—The ossicles.

the auditory canal to a small membrane called the *ear-drum;* the *ossicles,* a series of three little bones, the hammer, the anvil, and the stirrup, they are called; and the *inner ear* just described.

The foot of the stirrup is connected with an oval membrane, which closes a hole in the inner ear. Sounds passing through the auditory canal cause the drum to vibrate and send tremors through the bones to the liquid in the little sacs. The tumbling of the "pebbles" against the filaments of the auditory nerve sends the intelligence to the brain.

The impression which the mind receives through the organ of hearing is called sound. All bodies which produce sounds are in a state of vibration, and they communicate their vibrations to the surrounding air and thus set it into waves, just as a stick waved back and forth in a pool of water creates ripples.

Sound implies vibration, and whenever a sound is heard

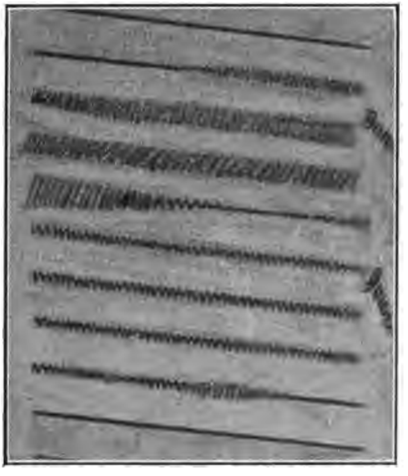

FIG. 122.—Bon jour ("good day" in French) as represented by a wave picture. The picture was made by a mirror arranged to move under the influence of the voice and to cast a beam of light upon a strip of sensitized paper.

some substance, a solid, a liquid, or a gas is in vibration and the surrounding air is in unison with it.

Sound has been likened to a picture painted not in the space and color of substance but in time and motion. What really passes out from the source is merely a rhythmical motion of the air particles, manifesting themselves as changes in pressure, spreading out in ever-widening spheres through the atmosphere. The order of these compressions is different for every sound. The musical sounds of an orchestra embody a different set of vibrations for each note of each particular instrument. If the fluctuations in pressure of a sound wave are irregular and non-periodic, the sound is called a *noise;* if they are cyclic, and follow a regular and sufficiently rapid periodic lag, the sound is *musical.*

We may easily satisfy ourselves that in every instance in which the sensation of sound is produced the body from

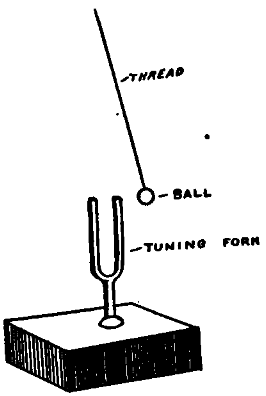

FIG. 123.—Experiment showing sounding bodies are in vibration.

whence the sound comes must have been thrown into a state of rapid tremor, implying the existence of a motion to and fro of the particles of which it consists.

If the face of a tuning fork prong be touched with a small ball of cork suspended from a fine silk fiber, after the fork has been struck and caused to emit its note, the cork will be violently repelled from the latter. *Why?* Because the prong of the fork *is in vibration.*

If a small wire or bristle is fastened to the prong of the fork and a piece of smoked glass drawn across it while the fork is giving forth a sound, the trace of the point will appear as a wavy line, showing that while the glass was drawn along the prong went to and fro many times.

The vibrations or disturbances set up in the air by a sound emitting body are known as sound waves. These waves consist of a series of condensations and rarefactions

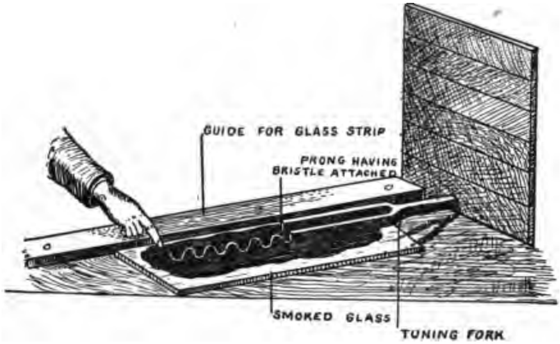

FIG. 124.—Method of registering vibrations of a tuning fork.

succeeding each other at regular intervals, each air particle swinging to and fro in a very short path.

Air waves cannot be seen by the naked eye, but their nature may be easily represented or illustrated. Fig. 126

FIG. 125.—Wavy line made by a bristle attached to a tuning fork prong in vibration when passed over smoked glass.

gives a pictorial representation of the crowding together of the air particles during the passage of a wave. The loudness of the sound depends upon the amount and suddenness of the change in pressure, and the note or pitch on the number of complete to and fro motions of the particles per second.

The *timbre* of a sound or the quality that distinguishes the note of a violin from that of a piano depends upon the smoothness or abruptness of the changes in pressure. Therein lies the difficulty of the production of sound by means of a phonograph or telephone, for the sound waves

FIG. 126.—Illustrating the action of air waves.

must resemble each other in every detail in order that the result may be like the original.

The mechanism with which we speak or sing is composed of two flexible membranes, stretched side by side across a small cylindrical box located at the top of the windpipe. The membranes are called the *vocal chords*, and the

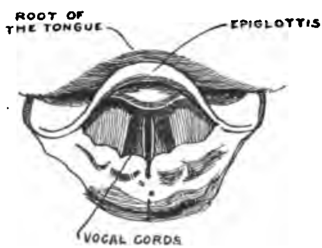

FIG. 127.—The vocal cords in position for making a sound.

box the *larynx*. The chords are so arranged and controlled by muscles that their tension may be changed at will. In breathing, the air to and from the lungs passes freely between the chords. When the controlling muscles are tightened, so as to stretch the chords, the edges are also brought parallel and quite close to each other. If the breath from the lungs is then forced through the narrow slit between them, they vibrate like the reed of a musical instrument, and produce the sounds of the voice. The multitude of sounds which it is possible for a human being to produce are the result of various degrees of stretching of the vocal chords, together with the movements of the mouth, lips and tongue.

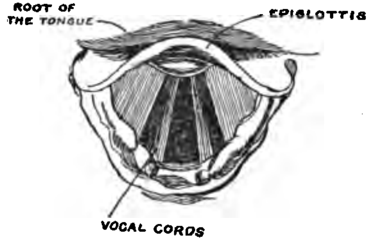

FIG. 128.—The vocal cords when relaxed.

Speech is the sound produced by the vocal chords of a human being, modified by the movements of the lips, tongue, and cavity of the mouth. The consonants are made by

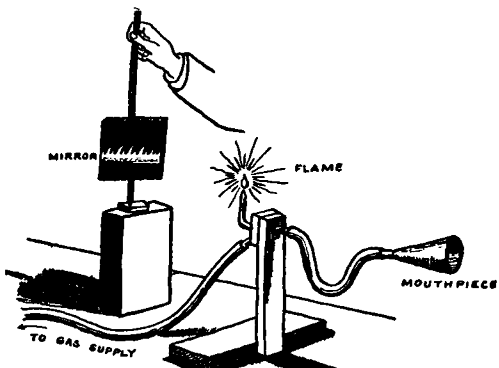

FIG. 129.—Koenig's manometric flame apparatus.

movements of the tongue and lips obstructing the sounds at their beginning or end, while the vowels are formed by a steady voice modified by the resonance of the different shapes or sizes given the parts of the mouth. The waves produced in this manner are transmitted to the ear, and the sensation of sound is caused by the impact of the *otoconia* against the auditory nerve, giving a series of impressions, musical or unmusical, pleasing or displeasing, as the case may be. Many interesting experiments showing the nature of the sounds of the human voice may be performed by means of a simple apparatus invented by Koenig of Paris. A box is separated into two compartments by a rubber membrane. Gas is led into one of these compart-

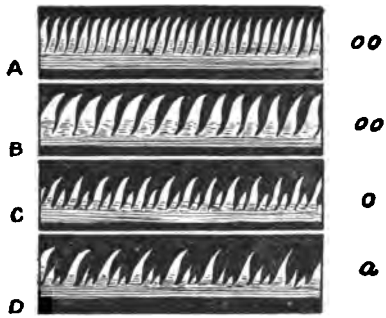

FIG. 130.—Appearance of manometric flames in a revolving mirror.

ments by a rubber tube, and then allowed to issue to a burner. The other compartment is connected to a megaphone.

Two pieces of mirror are arranged so as to revolve in front of the lighted jet or burner. When the human voice is produced in front of the megaphone, the air waves strike the membrane and cause changes of pressure in the gas. The height of the flames varies with each change in the pressure, and when viewed in the mirror resemble a band of light having an edge like a saw. The teeth are faithful representations of the changes in the voice, and immediately take on a new appearance when a new sound is emitted. The shape of the teeth changes with the tone, and the number of teeth with the pitch. Fig. 130 shows the flames produced by singing the sound *oo,* as in *tool.* The same sound an octave lower in pitch will show as in B, where there are just one-half as many teeth or vibrations. The sound of *oo* is a simple sound. If *o* on the note

Fig. 130 a.

is sung into the megaphone, the image in the mirror will appear like that shown by C, being made up of alternating large and small teeth, the former corresponding to every alternate vibration of the octave of the higher sound coinciding with a vibration of the octave below.

The sound causing the flame to appear, as in D, is made up of two simple vibrations combined.

CHAPTER VIII.

THE TELEPHONE TRANSMITTER AND RECEIVER. THE PHOTOPHONE. THE THERMOPHONE. THE SELENIUM CELL. THE SPEAKING ARC.

The telephone is an instrument for the transmission of sounds to a distance by the agency of electricity, wherein the speaker talks to an elastic plate of thin sheet-iron, which vibrates and transmits its every movement, electrically, causing it to vibrate in an identical manner and emit the same sounds.

The transmission of the vibrations depends upon well-known principles of electricity, and consists, not of an actual transmission of the sounds, but the passage of electric waves, or impulses, which keep perfect accord and agree in phase and period with the atmospheric waves produced by the voice. These in turn, through the medium of an electromagnet, cause vibrations of a plate or membrane, which agitates the air in a manner similar to the original disturbance, and thus emits sounds.

The parts of the apparatus which take up the sound waves and change them into electric currents compose the *transmitter*. In the form of transmitter most commonly used, the motions of the diaphragm cause variations in the strength of a current flowing from a battery by varying the resistance in the path of the electric current.

The sounds are directed to the mouthpiece, which causes the vibrations of the air to strike the diaphragm, on the back and center of which is fastened a small cup-shaped piece of carbon. A second cup is mounted in a rigid position directly in back of the first. The space between is filled with small polished granules of carbon.

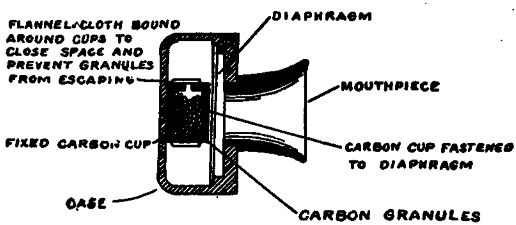

FIG. 131.—Diagram of a telephone transmitter.

When these are in a perfectly free and loose state their resistance to an electric current is very great, and they allow almost none to flow.

When slightly compressed their resistance is greatly lowered, and they permit the current to pass. The vibrations of the diaphragm exert a varying pressure upon the gran-

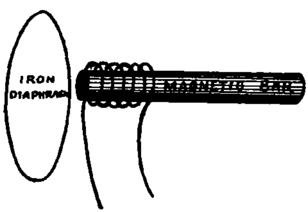

FIG. 132.—Diagram showing the principle and construction of the telephone receiver.

ules, with a corresponding variation in their resistance and the amount of current flowing.

The receiver, as has already been explained, consists of a thin iron disk, placed very near but not quite touching the end of a small bar of steel, permanently magnetized, about which is wound a coil of fine insulated wire. The ends of this coil are connected to the wires leading from the transmitter and battery. The varying currents of electricity, produced by the transmitter, generate corresponding changes in the magnetism of the receiving instrument, and thus, by alternately attracting and repelling the diaphragm, cause it to vibrate and emit sounds.

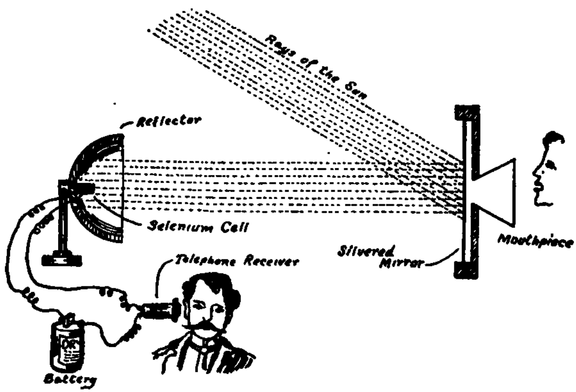

FIG. 133.—The photophone.

Alexander Graham Bell, the ingenious inventor of the telephone, with the aid of Sumner Tainter was the first who achieved success in the attempts to transmit speech without the aid of connecting wires between the source of intelligence and the receptor.

In 1873 Willoughby Smith announced that the element *selenium* possesses the abnormal property of changing its electrical resistance under the influence of light. Bell and Tainter took advantage of this discovery, and devised *selenium cells,* in which selenium is formed into narrow strips between the edges of broad conducting plates of brass. The resistance of the cell in the darkness is approximately twice the resistance when illuminated.

This property of the cell was immediately applied to the

Fig. 134.—Photophone receiving apparatus.

FIG. 135.—Photophone transmitting apparatus using acetylene flame to furnish light.

construction of the *photophone,* an instrument which transmits sounds to a distance by means of a beam of light reflected to a distant spot from a thin mirror thrown into vibration by the voice. Over fifty different forms were devised but the most successful consisted of a transmitter composed of a glass disk, silvered to reflect a pencil of light focused from the sun, or an arc lamp. This glass disk was used as a diaphragm similar to that of an ordinary telephone transmitter, except that the rear side of it was made free to reflect the beam of light. Bell used for this purpose disks about two inches in diameter and the thickness of ordinary paper. The receiver consisted of a parabolic reflector, with a selenium cell placed at its focus. In series with the cell was placed a battery and telephone receiver.

When the membrane was set into vibration by the sound waves, it became alternately concave and convex, the normally parallel rays of light correspondingly converging and diverging. The receiving station was thus under the influence of light rays of rapidly varying intensity in perfect phase with the vibrations of the voice. The reflector concentrated the rays on the selenium cell, and their varying strength changed its resistance and caused a pulsating current to flow through the receiver and reproduce the speech produced at the transmitter.

In another arrangement employed by Bell and Tainter, they used the rays of a powerful electric arc lamp, and by varying the electric current supplying the arc caused the light to fluctuate and produce the same results at the receiver.

These ingenious inventors also devised a method of transmitting speech called the *thermophone.* The transmitter remained the same as in the photophone—a thin silvered membrane, or glass diaphragm, stretched across the back of a mouthpiece, and arranged to reflect the rays of the sun, or the light of an arc lamp.

The receiver was a small glass bulb containing a plate of mica covered with lampblack, or little charred pieces of

Fig. 136.—Powerful searchlight arranged to transmit speech over a beam of light.

cork. The glass bulb was placed in the focus of a reflector, which collected the rays and concentrated them. The variations in the intensity of the heat radiations caused the air in the bulb to expand or contract with each vibration. Rubber tubes extended from the bulb to the ears of the observer, and the pulsations of air, traveling through the tube as sound waves, would strike the ear-drum and reproduce the speech.

Both of these methods were later very much improved by the employment of Koenig's manometric flame in place of the silvered mirror as a transmitter. As explained in the last chapter, speech delivered into the mouthpiece causes the gas to become compressed or rarefied in direct accordance with the sound waves, and the flame rises and falls with a rapidity too great to be detected by the naked

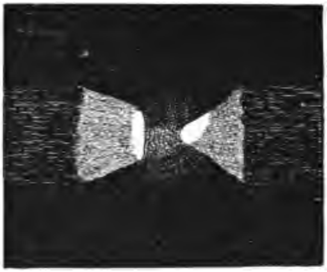

FIG. 137.—The Electric arc.

eye. These rapid alterations in the intensity of the illumination of the flame act on the selenium cell, and reproduce the original voice perfectly in the telephone receiver.

It is obvious, however, that such methods as these are only capable of transmitting speech over very limited distances, and if greater ranges are to be traversed much more powerful transmitters must be employed for the purpose.

Ernest Ruhmer, after long and laborious researches, finally succeeded in transmitting speech many miles by taking advantage of the *speaking arc,* discovered by Simon, who observed that an arc lamp gave out a loud rattling noise if its current supply was interfered with. An electric arc consists of two carbon rods, connected to a generator.

When the carbons are brought into contact for a moment and then drawn apart to a short distance, a kind of electric flame or *arc* is produced between the points of carbon, and a brilliant white light is emitted by the white hot points of the carbon electrodes.

Ruhmer immediately made the arc serve as a telephone receiver and *speak* by utilizing the pulsating current of a telephone transmitter to vary the current supplying the arc.

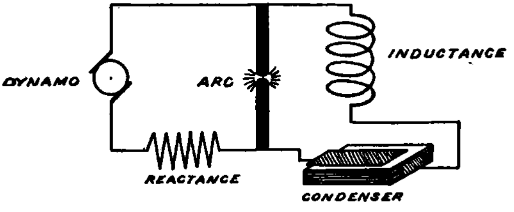

FIG. 138.—Circuit showing how a singing arc is arranged.

The arc could thus be made to sing, whistle or reproduce music and the human voice perfectly, if the sounds were clearly conveyed into the transmitter. Further investigations showed that every alteration of current caused by the action of the transmitter also caused an alteration in the intensity of the light and radiation of the lamp. The speaking arc could therefore be used as a perfect photophone transmitter by directing the rays toward the receiving station with the aid of a parabolic reflector.

In 1902 Ruhmer performed a series of experiments in Germany on the Wannsee, near Berlin. A large motorboat, the *Germania,* was fitted with an electric searchlight connected with a microphone, so as to form a speaking arc. The receiving station was located on the shore, so that the distance between the stations could be easily enlarged by moving the boat.

The receptor was an ordinary selenium cell, placed at the focus of a large reflector and connected with a telephone receiver and battery. No difficulty was encountered in reproducing the speech over varying distances up to about three miles.

CHAPTER IX.

THE WIRELESS TELEPHONE.

The applications of any of the wireless telephone systems thus far described are very limited, for at the best they only operate under the most favorable conditions, and then over rather limited distances. In the case of any system whereby the speech must be transmitted over a beam of light, the great resulting limitations are that the transmission can only take place in a straight line over water or clear country, and that stormy weather or a fog will interrupt communication.

None of these objections are present, however, when recourse is had to Hertzian, or electromagnetic waves. Wireless transmission of speech has therefore followed in the wake of wireless telegraphy, and the methods and apparatus employed are very similar.

Some who have followed the text closely might reasonably ask why it would not be possible to establish wireless telephony by simply connecting a telephone transmitter in some manner to an ordinary wireless telegraph, and by directing speech into the latter, vary the strength of the oscillations emitted.

Such a system, at first thought, seems very plausible, and many experimenters have devised countless methods trying to attain this result, only to meet with ultimate failure. The reason is very simple.

Suppose that an induction coil, having a high-speed interruptor, and therefore able to produce a very rapid stream of sparks at the gap, is connected to the aerial and ground in the usual manner and a telephone transmitter placed in series with the ground wire. When the coil is set in operation the sparks jump across the gap, each spark setting up a train of oscillations. If speech is conveyed into the

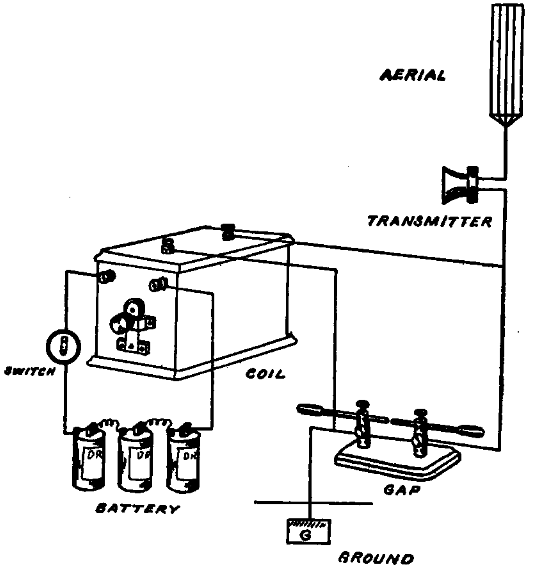

FIG. 139.—A "logical" form of wireless telephone which is impracticable.

transmitter, the resistance in the path of the oscillations will be varied and correspondingly also the strength of the waves emitted. The sounds will be reproduced to a certain extent by the receptor. Whistling, certain musical tones, and words containing many vowels are sometimes heard in the receptor, with sufficient distinctness to be recognizable. The voice cannot, however, be heard at all times, and the system is of no real value other than an interesting experiment.

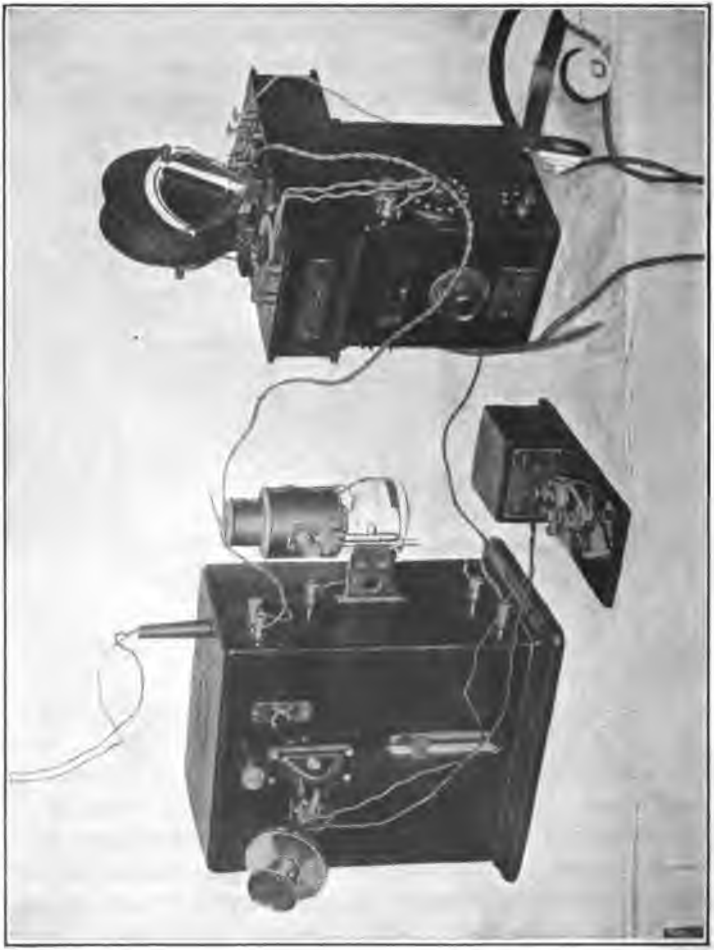

FIG. 140.—De Forest wireless telephone equipment.

The reason is very simple and readily explained. For the sake of clearness we will suppose that the speed of the interruptor attached to the coil is 100 per second. It will therefore produce 100 sparks per second at the spark gap if the electrodes are close together. The passage of the

FIG. 141.—Wireless telephone receiving apparatus (induction method).

sparks is not continuous, each one only occupying a very small space of time. The pause between each is very distinct, although it could not be detected with the naked eye. The ten straight lines in Fig. 141 represent ten sparks which cover a period of one-tenth of a second, since they pass at the rate of 100 per second. Each spark produces a train of oscillations, which surge back and forth in the aerial, rapidly dying out, however, or becoming *damped* in the manner already explained.

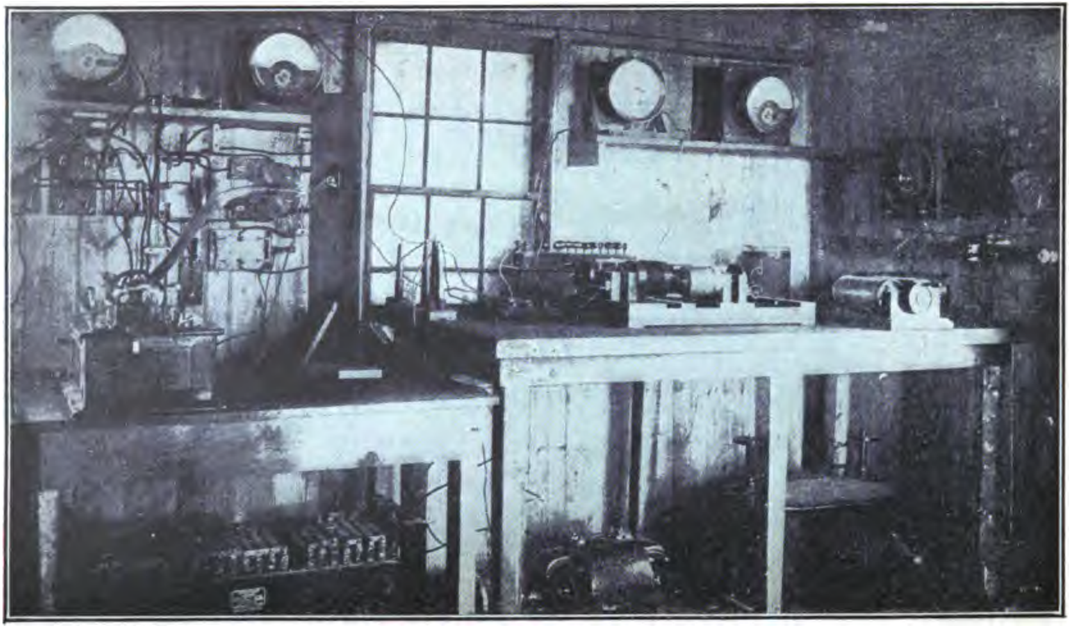

FIG. 142.—Fessenden wireless telephone transmitting phonograph music.

It may now readily be realized that there are long pauses between the sparks when there are no oscillations in the aerial, and, consequently, no electromagnetic waves passing between the transmitter and receptor during those periods.

The wavy line, C, represents the vibrations of the human voice when producing speech. Part of it has been represented by a continuous line, and part by a dotted line. The portions represented by the dotted line occur when there are no oscillations in the aerial, and consequently these

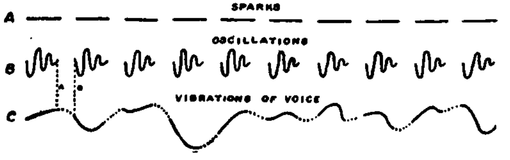

FIG. 143.—Diagram illustrating the reason why damped oscillations will not carry the voice.

portions are not transmitted. The continuous portions are the only ones reaching the receptor. Literally, there are "holes in the voice," and the result is a jumble of sounds, sometimes bearing a resemblance to speech, but usually untranslatable.

The fault lies in the method of producing the oscillations which are *damped* and therefore do not exist continuously. If they could be made to keep on swinging and at a sufficiently high speed so that their tone would be inaudible and not confuse the speech, the problem would be solved. In other words, three things are necessary for the successful operation of a wireless telephone.

1. A means of producing and radiating a stream of *undampened* electrical waves sufficiently continuous to transmit the *upper harmonics* of the voice, on which the quality and recognition of the speech depends.

2. Means for varying or modulating the stream of electrical waves in accordance with the sound waves.

3. A receiver, continuously responsive and capable of corresponding with sufficient rapidity to the speech harmonics.

In order to obtain the desired result, recourse is had to an arc lamp as a generator of *undamped high frequency oscillations.*

When an arc is properly connected with a condenser and

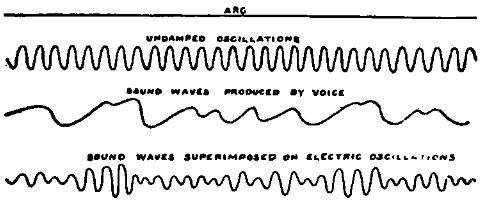

FIG. 144.—How the sound waves of the voice are impressed upon undamped oscillations.

an impedance coil it will emit a musical note. The note is due to rapid changes in the arc, a very important factor which led to its recognition as a value in wireless telephony.

When the condenser and inductance are shunted across an arc supplied with direct current, the condenser immediately becomes charged, and the current through the arc is diminished. The potential difference across the latter is therefore instantly increased, tending to further charge the condenser. This increase of charge reacts on the arc, increasing its current. The condenser discharges, through the inductance coil, and becomes charged in the opposite direction, just like a spring, which released, goes beyond its normal position and then returns.

The operation is repeated many times per second (usually over 1,000,000), setting up *persistent undamped oscillations.*

Perhaps a better conception of how it is possible for a

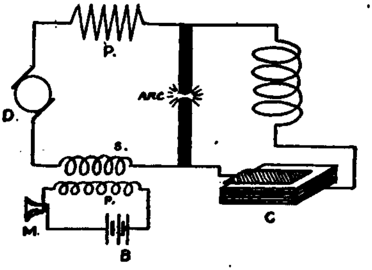

FIG. 145.—Arrangement of the speaking arc.

continuous current, such as that which supplies the arc, to change into alternating current, vibrating backward and forward, may be gained by comparison with the steady forward motion of a violin bow, which produces a to and fro motion of the strings.

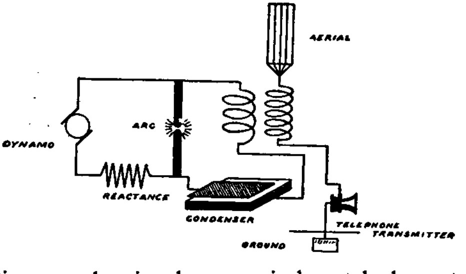

FIG. 146.—Diagram showing how a wireless telephone transmitting system is arranged.

It was later discovered by Poulsen that if one of the arc electrodes was kept cool by making it of copper and passing water through it that the efficiency was greatly increased. A further improvement was obtained by burning the arc in an atmosphere of coal gas or hydrogen. By surrounding the arc with a powerful magnetic field, its resistance is greatly increased and the voltage raised.

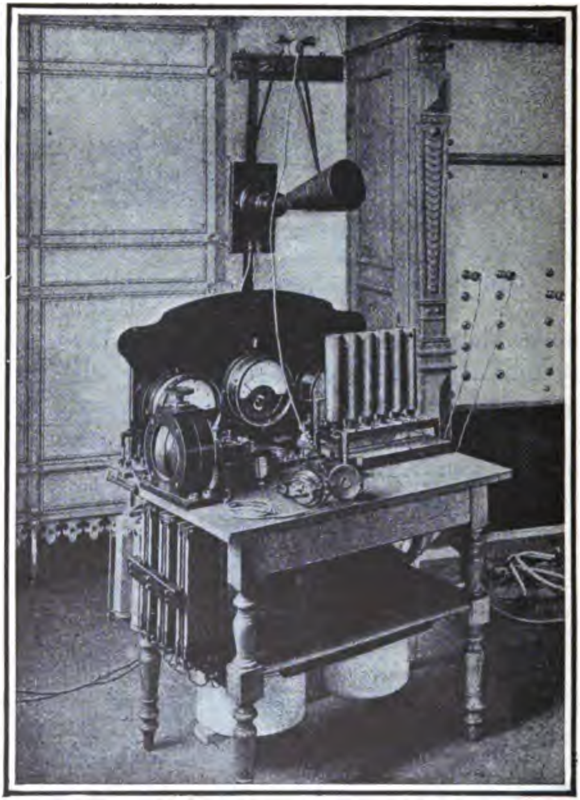

FIG. 147.—Poulsen wireless telephone equipment.

The condenser shunted around the arc usually consists of a number of metal plates, placed above one another in a tank of insulating oil. The inductance is simply a single helix or bare wire.

By connecting a telephone transmitter to the arc in the same manner that it is connected to the speaking arc, the oscillations can be varied in accordance with the vibrations of the voice. The apparatus is connected to the aerial and the earth through the medium of a loose-coupled helix, formed by providing the helix in series with the arc and condenser, with a secondary winding.

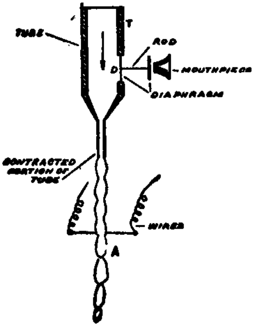

FIG. 148.—The Majorana wireless telephone transmitter.

The ordinary carbon transmitter, in its common form, is unsuited for wireless telephonic work, on account of its inability to handle large amounts of power. Many modifications have been designed, the usual procedure being to make it on a larger scale.

One of the most interesting forms, and also probably the best, is that devised by an Italian inventor, Majorana.

Its action will be clear from the illustration. T is a tube in which water or some other liquid is allowed to flow in the direction of the arrow. The bottom of the tube is contracted so that the stream will issue in a fine jet. The tube is made of strong, rigid material, except at one point, D, where an opening is covered with a thin elastic diaphragm. This diaphragm is connected by means of a short rod to a second diaphragm, which is provided with a mouthpiece. The water normally flows out of the jet in a smooth, unbroken column, breaking into drops at about the point A. As soon as it is disturbed in any way, however, the distance from the outlet of the tube and the point where the drops commence becomes shortened. The vibrations of the voice, thrown into the mouthpiece and striking the diaphragm, are transmitted to the membrane through the medium of the little rod, and so cause corresponding changes in the pressure of the fluid in the tube. Each variation or disturbance in the pressure increases or decreases the length of the stream before it breaks into drops.

A pair of fine wires are inserted in the stream where the contractions are the strongest. Connection is established between the wires by the liquid. If the stream is narrow its resistance will be greater than if it were expanded at that point. The contracted portion of the liquid will jump up and down with the vibrations of the voice, and thus alter the amount of current flowing.

The receiving apparatus consists of some form of detector and a telephone receiver and battery. The usual form of detector employed is the electrolytic. The currents generated in the receiving aerial by the incoming waves vary in amplitude with those of the transmitting aerial, and, being in perfect accordance with the vibrations conveyed into the transmitter, cause the detector and telephone transmitter to reproduce the speech perfectly.

Experiments in wireless telephony have developed an interesting type of detector, known as the "Audion." This consists of a six-volt, low-candlepower, incandescent lamp, having a small, nickel plate fastened a short distance from the filament, and a "grid" bent from wire placed midway between the two. When the filament is lighted from a battery, it throws off a stream of extremely small particles charged with electricity and called "ions." These ions pass through the grid and discharge against the plate. When the aerial is connected to the "grid," and the plate to the ground, the stream of ions carries that part of the alternating current in the aerial which flows in the same direc-

FIG. 149.—Showing the brush discharge from a Marconi transatlantic aerial at night.

tion, across, but does not allow the current tending to pass in the opposite direction. In reality it is a valve, or "rectifier," opening one way and closing the other; thus changing the current into an intermittent, direct current, capable of manifesting itself in a telephone receiver.

The Audion is a very sensitive device, and is much employed for wireless telephone purposes.

With such a system it has been found possible to transmit speech and music to a distance of two hundred miles. In fact, even greater distances have been covered, and there does not seem to be any good reason why it is limited to any range.

Transmission by wireless telephone is considerably more distinct than by wire line, and the fine inflections of the voice are brought out much better.

Unlike the ordinary line telephone, no rumbling or roaring noises are heard which confuse the speech, and there is absolute silence in the wireless telephone receiver, except when talking is going on. Any noises or sounds produced in the transmitting station, such as walking about the room, or the breathing of the person speaking into the transmitter, are reproduced faithfully at the receiving station many miles away.

CHAPTER X.

REMARKS. ACCOMPLISHMENTS. MAXWELL'S THEORY. HERTZ'S DISCOVERY. THE FUTURE.

The history of wireless telegraphy and telephony is a striking example of how it is possible for scientists laboring in the field of pure research and stimulated by accumulated knowledge and imagination to arrive at discoveries of the most vital importance. Heinrich Hertz and Clerk Maxwell in experimental effort to attain other results unwittingly laid the foundation of this art.

In 1867 Maxwell proposed the theory that light is not mere mechanical motion of the ether, but consists of electrical undulations. These undulations are partly magnetic and partly electrical. Moreover, according to the theory, the phenomena of electromagnetism and also that of light are due to certain modes of motion in the ether, electric currents, and magnetism, being due to whirls, or body displacements in the substance of the ether, while light is due to vibrations to and fro.

Twenty years later Hertz discovered the most convincing experimental proofs of Maxwell's wonderful theory, and succeeded in producing electromagnetic waves in such a manner that their propagation through space could be examined, and it readily showed that while they were much longer than the ordinary waves of light, they possessed the same properties, were capable of being reflected, polarized, refracted, etc., and traveled at the same speed.

The waves that Hertz produced are the *electromagnetic* or *Hertzian* waves of radiotelegraphy.

Many thousand commercial wireless stations dot the face of the earth. Daily time signals, weather reports and storm warnings flash to ships far out in the ocean from government observatories. Late at night, in the midnight hours,

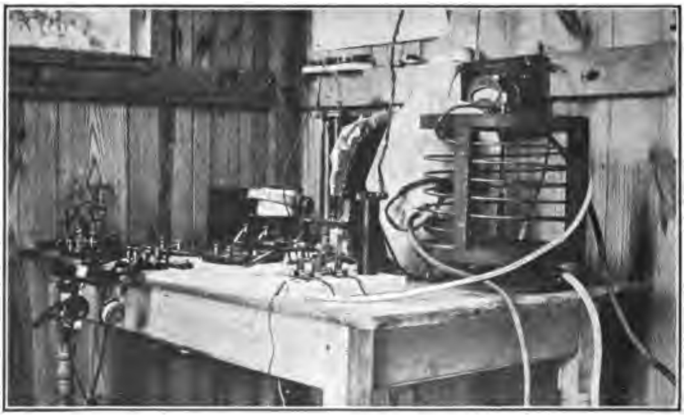

Fig. 150.—An amateur wireless telegraph station.

when the world is asleep, powerful land stations commence to whisper press dispatches, and the next morning the ocean daily, containing the same news as our morning paper, is laid on the breakfast table of the ocean greyhound. A distress signal sends revenue cutters scurrying along the coast, and brings rescue to hundreds of imperiled lives. The Navy Department issues an order, and a few minutes later it is in the hands of the commanding officer of a fleet, a thousand miles away. Wireless links two continents across a table, and yet this wonderful apparatus is so simple that a sixteen-year-old boy can build instruments with a

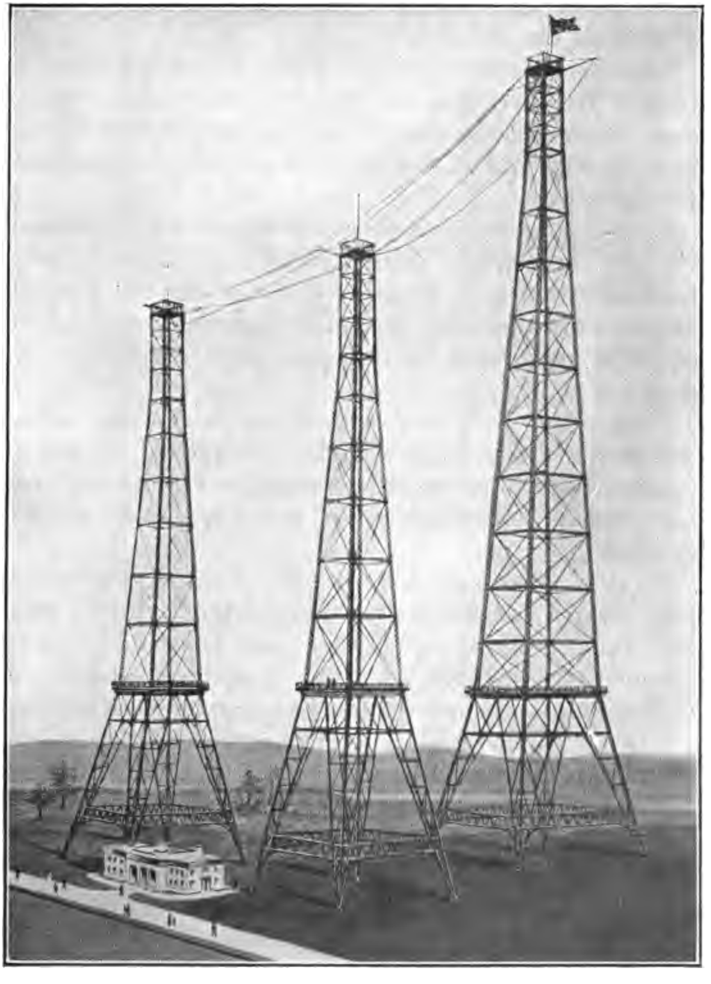

FIG. 151.—The high-power Naval wireless telegraph station under construction at Washington, D. C.

little guidance and listen to a far-distant station, 1,500 miles away, spell out its news.

Wireless telegraphy is part of the established order of things. The wireless telephone is practical for limited distance, but is not a commercial rival of the telegraph. Great distances are claimed, but they are matters for proof and speculation.

There is no immediate possibility that wireless telephony will take the place of local exchanges. If the time ever does come that it in any way tends to supplant the line telephone for some uses, it is more than probable that each subscriber must have his own generating station and call up direct.

There is a very decided field of opportunity for wireless telephony for long-distance work. The present systems of long-distance wires are very expensive to construct and maintain, and are subject to the whims of storms and the elements.

Wireless telephones will not only transmit the speech more clearly and distinctly, but have the further advantages that the initial cost is very much lower than that of wire lines, the maintenance is almost nil in comparison, the depreciation is smaller, the number of employees required is less, and a break-down is limited to the inside of the station, where it could be quickly remedied by the substitution of a duplicate spare piece of apparatus.

Furthermore, no franchises or rights of way would need to be purchased. No serious difficulty would be encountered because of interference.

Wireless telephony, like wireless telegraphy, but to an even greater extent, is peculiarly suited for the conveyance of marine intelligence. Wireless telephony occupies a unique position in this regard—no operator is required. The additional expense of an operator is an objection to

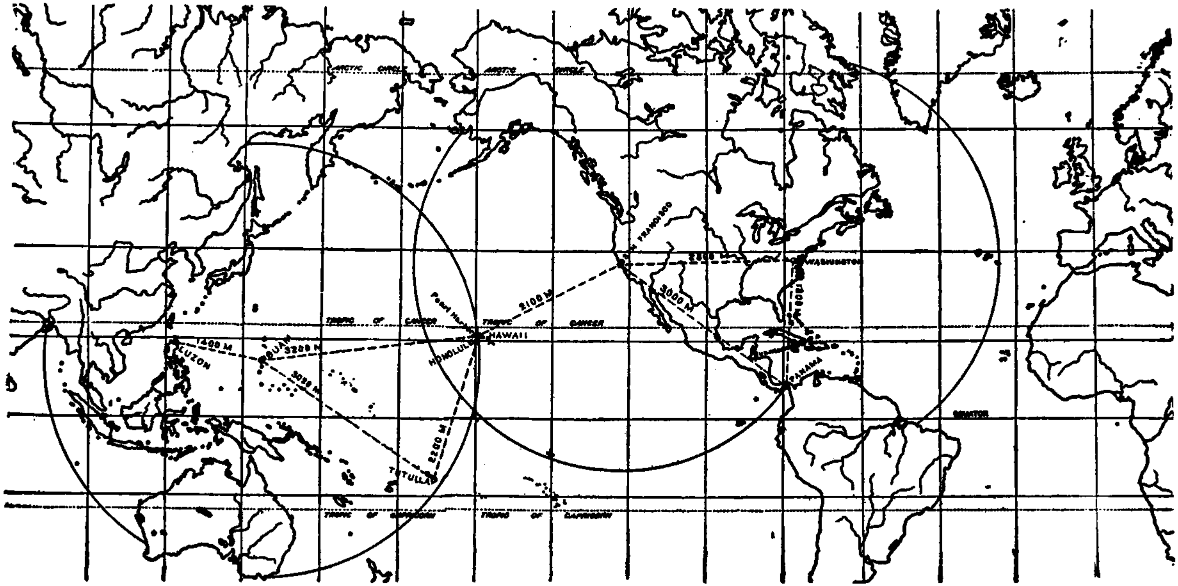

FIG. 152.—The curved lines represent the radius of the government high power wireless stations and show the zones over which direct communication may be had with ships.

the wireless telegraph in many cases, and forbids its installation. Anybody can operate the wireless telephone. It is also much quicker—words can be spoken more rapidly than they can be put into Morse signals and translated.

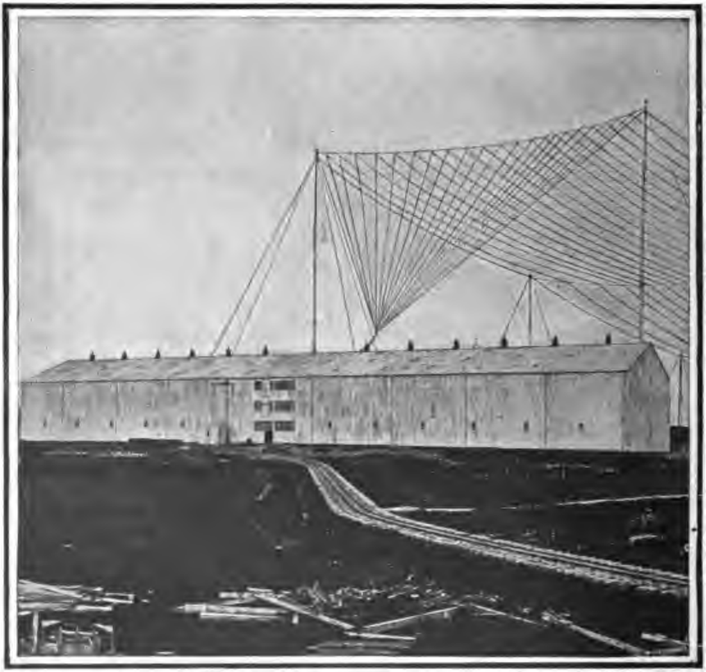

FIG. 153.—The aerial system of a transatlantic station.

The wireless telephone enables a passenger on board ship to communicate direct with his home by relaying the message over the line wires. By the same means the captain of a ship can call his home office and communicate with the owner of the vessel.

Telegraphs and telephones are the nerves of the world, carrying swift messages from its brain centers to its hands, annihilating distance in thought. All differences between men as individuals and people as nations can be traced to the lack of close contact. Reduce or annihilate all distance in thought and action, and mankind would possess unbounded opportunities for peaceful economic and healthful development. No force more vital than the possibilities of wireless has ever presented itself or could be demanded to attain such an end. Such a statement, in the light of actual developments, might even be considered conservative, and is neither absurd nor the dream of a vivid imagination. The greatest obstacle to all efforts in radically new directions is the resistance of the human race. The antagonism of prejudice and skepticism can only disappear when the world as a whole grasps a new proof and learns to appreciate it. Inertia must be overcome, and the great masses set to thinking and striving toward an end before the aweing genie finally bursts forth and amazes the Aladdins of science.

Within the memory of older men and women are primers of science, which speculate about the developments of electrical force, and guardedly discuss its possibilities.

And now, electricity—this mysterious agent—has multiplied the muscular strength of man a billion times. The tasks of Hercules are now but chores to be accomplished by the closing of a switch. Mighty rivers roar through intake and turbine to drive the wheels of industry in a distant city and turn the night into day. Any attempt to chronicle all the applications of this wondrous power would be absurd. Such is electricity to-day.

Only a few years ago Langley launched his famous aerodrome over the waters of the Potomac, while the world stood by and sneered, ridiculed a man whose work is now one of the classics of aeronautical literature, and scoffed at a machine whose principles embodied the conclusions of years of careful thought and scientific effort.

A decade later and aeroplanes have become a living reality. A man and a little frame of sticks and canvas can

Fig. 154.—Fong Yee, a Chinese amateur wireless operator at Oakland, Cal., who is also an aviator and has been summoned home by the republican Chinese government to demonstrate apparatus of his own invention to the Chinese army.

throw off the fetters of gravity and go soaring dizzily two miles up into the blue sky, and daring more, come skimming and diving back to earth with motor dead. Such wonders only came to pass, however, when numbers of men accepted the problem as one to be solved by trying, and bent their energies toward its solution. Science has not reached the limits of its resources. It never will. The art of wireless may always be embarrassed by novelty in many directions.

One of the greatest steps forward toward the day when

FIG. 155.—Tesla world power plant (experimental station).

methods and appliances regarded as permanent as the mountains will pass and be considered only as the curious remnants of a cruder age is the interest of 200,000 wireless amateurs in the United States. Some of these will develop into men who will bring some of the wonders of the future to their full fruition.

What is this great change that can be coolly and precisely forecast? Along what lines will these wonderful developments come? The answer is "wireless"—not the wireless of a Marconi or a De Forest, but the wireless of a Tesla—of "high potential magnifying transmitters"—of "nodes" and "loops"—of oscillatory currents that leave their conductors behind—the "wireless" of the day when a system is introduced enabling any person to reach any other on the globe, not simply through a spoken word or thought conveyed, but visually a perfect transmission of images which will enable one person to see another, as though that other were by his side—"wireless" of a time when the great operations of commerce and industry will be vitalized by huge wireless power stations, turning the machinery of factories, lighting cities, or sending swift aeroplanes and ships darting to the farthest points of the earth.

Of course, there may be something of the dramatic in such assertions, but they are founded upon scientific facts, and, if imaginary, are scientifically imaginary. The wonderful mysteries of oscillatory currents, whose natural medium is the ether, currents which object to being confined to wires and cables, and defy all ordinary laws; currents that will melt masses of metal with the violence of an explosion, but yet pass through the human body without producing any sensation; currents that will instantly manifest themselves 2,000 miles away from their source, with no visible means of propagation, are the open sesame to the treasures of a wonderful future.

There are many places in the world where water power is available capable of generating almost unlimited electrical energy. The present difficulty lying in the way of its utilization is the limitation of electrical transmission by wire, for not only is the cost of long lines of copper tremendous, but power can only be carried in this manner for limited distances. Central distributing wireless power stations could send the power of Niagara, which alone might be made to supply a fifth of all the power in the

FIG. 156.—Twenty-five foot sparks from a Tesla transformer.

United States, and the energy of Victoria to the ends of the earth with little loss. The Great Falls of Zambesi, in the heart of Africa, could be made to run the subway trains, the factories, lights, railroads, ferries, trucks, heaters, etc., in that vast, most complex, most bewildering and inspiring city of the Western World, the City of New York. Ocean vessels would no longer carry thousands of tons of coal, locomotives would not wheeze and cough a trail of soot and smoke through the country, chimneys would cease to belch, and aeroplanes would travel silently and swiftly overhead.

It is easy, in the face of certain facts, to conjure up situations which would be pleasant and make for the betterment of the world. Any one whose imagination is vivid enough can make a prediction, but when the great truth is accidentally revealed, or experimentally confirmed, as the case may be, and rendered absolutely sure of accomplishment, will its incalculable consequences continue to baffle the imagination and carry us further into the land of wonderment? Only the future knows.

THE END.

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