RADIO

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PREFACE

THE main idea in publishing this book, is to convey to the reader a speaking knowledge of this highly technical subject.

All technical terms have been avoided and simplified as far as possible. Information on the subject has been gathered from the latest sources.

The chief thought has been to give descriptions and definitions in ordinary English, so as to enable the reader to acquire an intelligent, conversational knowledge of radio, also an understanding of the use and operation of the parts of the system.

If this object is accomplished, our labor shall not have been considered in vain.

Sincere thanks are extended to the New York Globe and to Harper & Brothers, for their kind permission to use extracts from their publications.

E. H. DION.

April, 1922.

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Chapter I.

Early Methods of Communication.

THE advent of wireless telegraphy marks a new era that has advanced most rapidly. It brings the world into a family circle in which the nations can freely converse. It reduces distance to a negligible factor. Inaccessibility is a word not known to a wireless wave. It has been the means of spreading civilization. It has made the sea practically as safe as the land.

Before beginning the study of a subject of such interest and magnitude, it may be well to lay out a background and introduce some incidents of past history.

Ever since mankind has settled in groups, ranging in size from a village to a nation, the necessity of rapidly sending and receiving news has been realized. Centuries have passed and it was left to the present age for the great discoveries resulting in the telephone, telegraph and radio, or wireless telephone and wireless telegraph.

Information for this chapter was obtained by the author from "Masters of Space" by Walter Kellogg Towers, New York, Harper & Brothers, 1917.

Fire, smoke and flags were used by the Egyptians and the Assyrians previous to the Trojan War. The towers along the Chinese Wall were more than watch-towers, they were signal-towers. A flag or a light exhibited from tower to tower would quickly convey a certain message agreed upon in advance.

King Agamemnon, as he besieged Troy, had to depend upon couriers to communicate with his native kingdom in Greece. One device the king hit upon was to have beacon fires laid on the tops of Mount Ida, Mount Athos, Mount Cithaeron and on intervening eminences. Beside them he placed watchers, who were always to have their faces toward Troy. When Troy fell, a nearby fire was kindled and beacon after beacon sprang into flame on the route toward Greece. Thus was the message of the fall of Troy quickly borne to the waiting Queen Clytemnestra by this preconceived arrangement.

Perhaps the earliest example of marine signaling of which we know is recorded of the Argonautic Expedition. Theseus devised the use of colored sails to convey messages from ship to ship of the fleet and caused the death of his father by his failure to handle the signals correctly. Theseus sailed into conflict with the enemy with black sails set, a signal of battle and of death. After emerging victoriously, he forgot to lower the black flag and set the red one of victory. His father, the aged Aegeus, seeing the black flag, believed it reported his son's death and flinging himself into the sea, was drowned.

In time, as their domains extended, it occurred to the monarchs to establish relays of couriers to bear messages. Such systems were established by the Greeks, the Romans and the Aztecs. Each courier would run the length of his own route and would then shout or pass the message to the next runner, who would speed it away in turn. Such was the method employed by our own pony-express riders.

An ancient Persian king thought of having the messages shouted from sentinel to sentinel, instead of being carried more slowly by relays of couriers, so he established sentinels at regular intervals within hearing of one another and messages were shouted from one to the other. The ancient Gauls also employed this method of communication. Caesar records that the news of the massacre of the Romans at Orleans was sent to Auvergne, a distance of nearly one hundred and fifty miles, by the same evening.

Though signaling by flashes of light occurred to the ancients, we have no knowledge that they devised a way of using the light-flashes for any but the simplest prearranged messages. We know the Persians applied them to signaling in time of war. It is reported that flashes from the shields were used to convey news at the battle of Marathon. These seem to have been the forerunners of the modern heliograph, which by the use of the dot and dash system of the Morse code can be used to transmit any message whatever. The ancients had evolved systems by which any word could be spelled, but they did not seem to be able to apply them practically to their primitive heliographs.

An application of sound signaling was worked out for Alexander the Great, which was considered one of the scientific wonders of antiquity. This was called a stentorophonic tube and seems to have been a sort of gigantic megaphone, or speaking trumpet. It is recorded that it sent the voice for a dozen miles. A drawing of this strange instrument is preserved in the Vatican.

An ancient system of camp signals from columns is especially interesting as showing a development away from the prearranged signals of limited application. For these camp signals the alphabet was divided into five or six parts and a like number of columns erected at each signal station. Each column represented one group of letters. Suppose we used our own alphabet, eliminating two letters, with six columns we would then have four letters for each column. The first column would be used to signal A, B, C and D. One light or one flag shown from column one would represent A, two lights or flags B and so on. Thus any word could be spelled out and any message sent. This system was slow and cumbersome, but without doubt, it was a step in the right direction.

The American Indians developed methods of transmitting news which compare very favorably with the means employed by the ancients. Smoke rings and puffs for the daytime and fire arrows at night, were used by them for the sending of messages. The Indian obtained his smoke puffs by placing a blanket or robe over the fire, withdrawing it for an instant and then replacing it quickly. In this way puffs of smoke may be sent aloft as frequently as desired. Fire arrows were made by dipping the head in some highly inflammable substance and then set on fire at the instant before it was discharged from the bow. Both smoke and fire arrows were used in connection with prearranged signals.

Very slight progress was made in message sending in medieval times and it was the middle of the seventeenth century before even signal systems were attained which were in any sense an improvement. For many centuries the people existed, devising nothing better than the primitive methods just outlined.

Chapter II.

Progress Made in Methods of Communication.

The ability of amber, when rubbed, to attract straws was known to the early peoples. How early this property was found, or how, we do not know. The name electricity is derived from elektron, the Greek name for amber. Little results toward improving the means of communication were obtained, until man discovered the application of electricity to this need.

Benjamin Franklin sent aloft his historic kite and found that electricity came down the silken cord. Franklin and others sent the electric charge along a wire, but it did not occur to them to endeavor to apply this to sending messages.

In the early days of the nineteenth century, the battery had come into being and thus a new source of electric current was available to the experimenters. The strange property of magnetism had been known since long before the Christian era and a connection of some kind between magnetism and electricity had long been suspected. Lightning had been known to magnetize knives and other steel objects, but almost all attempts to imitate these effects by powerful charges of electricity, or by sending currents of electricity through steel bars, had failed.

In 1819, Oersted, of Copenhagen, showed that a magnet tends to set itself at right angles to a wire carrying an electric current. Thus was electro-magnetism discovered. Ampère, experimenting further, discovered that when the electric current is sent through coils of wire the magnetism is increased.

The possibility of using the deflection of a magnetic needle by an electric current passing through a wire as a means of conveying intelligence was quickly grasped by those who were striving for a telegraph. This was later developed by others and it was still early in the nineteenth century when a model telegraph was exhibited in London.

It remained for an American, Samuel Morse, who was possessed with the practical genius and the business ability, to devise and introduce a thoroughly workable system of rapid and certain communication. The first successful test of his telegraph was made in January, 1838. Communication under water was also thought of by him. He laid an experimental cable, consisting of a wire wrapped in hemp soaked in tar and then covered with rubber, in New York Harbor between Castle Garden and Governor's Island, in the fall of 1842. The progress made upon the telegraph since then, is common history and known to all.

The reproduction of sound, upon which is based the modern telephone, also depended upon the progress made in the application of electricity. German scientists had caused tuning-forks to vibrate by means of electro-magnets and had combined the tones of several tuning-forks in an effort to reproduce the sound of the human voice. That an electro-magnet could vibrate a tuning-fork was the fascinating thought that started Alexander Graham Bell on his search for the telephone, about 1868, when twenty-one years of age. After many experiments he finally, in 1875, transmitted sounds over a wire. In 1876 he completed a telephone which carried and delivered an intelligible message. Today, as a means of communication, it is indispensable.

Chapter III.

Wireless.

Great as are the possibilities of the telegraph and telephone, still these instruments are limited to the wires over which they must operate. Before the telegraph and telephone had been achieved, men of science were already searching for an even better way.

The first suggestion that electric currents carrying messages might some day travel without wires seems to have come from K. A. Steinheil of Munich. In 1838 he discovered that if the two ends of a single wire carrying the electric current be connected with the ground a complete circuit is formed, the earth acting as the return. Thus he was able to dispense with one wire.

Prof. John Trowbridge made the first extensive investigation of this subject and furnished valuable information for those following. He demonstrated that when an electric current is sent into the earth it spreads from that point in waves in all directions, just as when a stone is dropped into a body of water the ripples widen out from that point, becoming fainter and fainter until they reach the shore. He further discovered that these currents could be detected by grounding the terminals of a telephone circuit. The earth as a conductor made telegraphy possible through it.

Thomas A. Edison first established communication with moving trains. A plate of tin-foil was placed on the engine or cars, opposite the telegraph wires, and currents induced across the gap, no matter what the speed of the train. The currents, traveling along the wires to the station, established communication. Many other experiments were carried on by Europeans, the most important being made by a German scientist, Heinrich Hertz.

Hertz found how to send out electrical waves that would travel to a considerable distance. He was working with two flat coils of wire, one of which had a small gap in it. When passing the discharge from a condenser into this coil, he discovered that the spark caused when the current jumped the gap, set up electrical vibrations that excited powerful currents in the other coil. These currents were noticeable, though the coils were a very considerable distance apart.

What carried these waves? The answer as evolved by Hertz and approved by other scientists, is that they travel through the ether, a strange substance which pervades all space and matter; a thin medium, whose highly elastic constitution enables it to convey to us the vibrations of light though it is millions of times less dense than air.

Although ether is invisible, odorless and practically without weight, it is not the fantastic creation of scientists and philosophers, but is an essential to our existence, just as the food we eat. The universe is a vast pool of ether. There is no void. It is diffused even among the molecules of which solid bodies are composed.

Ninety million miles away from our earth is the sun. This seething mass of flame and heat supplies the energy stored up in coal, plants, trees and mountain torrents. It gives us light, which is known to be vibrations of an extremely rapid period, called electro-magnetic waves, traveling at the rate of 186,000 miles per second. Ether is the medium through which this heat and light reaches us, over this inconceivable distance. Incidentally, it is also the seat of all electrical and magnetic forces.

Hertz discovered that light and his electrical waves traveled at the same speed and so deduced that light consists of electrical vibrations in the ether. We know that light will pass through a vacuum, and these electric waves would do likewise. It was evident that they did not pass through the air. Sound, on the other hand, cannot travel through a vacuum. The transmission of sound is, in fact, accomplished by a wave-like disturbance of air, or water, or other material medium.

With the knowledge that this all-pervading ether would carry electric waves at the speed of light, that the waves could be set up by the discharge of a spark across a spark-gap in a coil and that they could be received in another coil in resonance with the first, it yet remained for someone to combine these discoveries in practical form, to apply them to the task of carrying messages and to make the improvements necessary to make them available for use at considerable distances. The problem was solved by a youth, Guglielmo Marconi, an Italian.

CHAPTER IV.

Marconi.

Guglielmo Marconi was born at Villa Griffone near Bologna, Italy, on April 25, 1874. His father was an Italian and his mother an Irishwoman. He studied in the schools of Bologna and of Florence. He learned to speak English from his mother and attended English schools at Rugby and at Bedford, for short periods.

One of his Italian teachers was Professor Righi, who had made a study of Hertzian waves. From him he learned of the work which had been accomplished and of the then available apparatus. He was a student and a deep thinker and any scientific book or paper which came before him was eagerly devoured.

The boy saw the wonderful possibilities of the Hertzian waves, applied to telegraphy. He dreamed of how these waves might carry messages from city to city, from ship to shore and from continent to continent. It seemed to him that many others had the same vision and must be struggling toward its realization. For a year he dreamed, studied more about these wonderful waves and each week expected the announcement that wireless telegraphy had been accomplished. The news never came.

Marconi then decided to attack the problem. He began his experiments on his father's farm, by setting up poles at the opposite sides of the garden and on them mounted the simple sending and receiving instruments, then known. He used plates of tin for his aerials, set up a simple spark-gap, as had Hertz and used a little more elaborate receiving device. A Morse telegraph-key was placed in circuit with the spark-gap. By holding the key down for a short period a short spark passed between the spark-gap and a dot was thus transmitted. Likewise by holding the key down for a longer period, a larger spark resulted and a dash was sent forth. After much work, he finally was able to send a message across the garden, which was not unusual, as others had already accomplished this much, but to him this was but a beginning.

Marconi soon found that the receiver was the weak point of his apparatus. To make wireless telegraphy effective over any considerable distance, a highly efficient and sensitive receiving device is necessary. Some special means of detecting the feeble currents was necessary, for the waves spread in all directions from the sending station and become weaker and weaker as the distance increases.

The coherer was the solution. This consisted of a tube partly filled with metallic filings, inserted in circuit. The resistance of the filings is very great and little current flows, until an electric wave impinges upon the tube, when at once the filings conduct. A loose heap of filings scarcely conducts at all, owing to the want of cohesion, or to the existence of films of air or dust. But it instantly becomes a good conductor if an electric spark is allowed to occur anywhere within a few yards of it. The resisting films of air are broken down by minute internal discharges in the mass. A very slight agitation by tapping at once makes the filings non-conductive.

With this coherer as the basis, Marconi made improvements which resulted in a glass tube, filled with powdered nickel, mixed with a small proportion of silver filings. Silver plugs were placed at each end and platinum wires were connected to these plugs and brought out at the opposite ends of the tube.

Under the influence of the electric waves set up from the spark-gap these tiny particles so arranged themselves, that they would readily carry a current between the plugs. By placing these plugs with their platinum terminals in circuit with a local battery the current from this local battery was given a passage through the coherer by the action of the electrical waves coming through the ether.

While these waves themselves were too feeble to operate a receiving mechanism, they were strong enough to arrange the particles of the sensitive metal in the tube in order, so that the current from the local battery could pass through them. This current operated a telegraph relay which in turn operated a Morse receiving instrument. An electrical tapper was also arranged in this circuit, so that it would strike the tube a light blow after each long or short wave representing a dash or a dot, had been received. The particles were thus disarranged, ready to array themselves when the next wave came through the ether and so form the bridge over which the stronger local circuit could convey the signal.

Marconi further discovered that the most effective arrangement was to run a wire from one terminal of the coherer into the ground and from the other to an elevated metal plate or wire. He later discovered that this method of wiring also applied to his sending apparatus. The waves coming through the ether were received by the elevated wire and were conducted down to the coherer. Experimenting with his apparatus on the posts in the garden, he discovered that an increase in height of the wire greatly increased the receiving distance.

By 1896, Marconi had brought this apparatus to a state of perfection where he could transmit messages to a distance of several miles. This youth of twenty-two had mastered the problem he had dreamed of.

He applied for a patent on his system in England in June, 1896. The young inventor continued studying, experimenting and devising improvements until finally in March, 1899, he sent messages across the English Channel, without difficulty.

Chapter V.

Progress of Wireless.

The British Admiralty quickly recognized the value of wireless telegraphy to war vessels, so the battleships were equipped with wireless apparatus and a thorough test was made. A sham battle was held in which all of the orders were sent by wireless and communication was constantly maintained. Marconi's invention had again proved itself.

Its use for ships and lighthouses sprang in favor and wireless stations were established all around the British coasts. It early demonstrated its great value as a means of saving life at sea. Ships which were equipped, were warned of impending storms and could summon aid if sinking, or disabled.

Late in 1901, the first attempt was made by Marconi to communicate across the Atlantic. On the Coast of Cornwall, England, he built the Poldhu station, which was powerful enough to send a message to America. He replaced his single wire for an aerial by many tall poles and strung a number of wires from pole to pole. The weak batteries which had furnished the currents, were replaced with great power driven dynamos and converters were used instead of the induction coil. Signal Hill, near St. Johns, Newfoundland, was selected as the place for the American station and for this test the wires were sent aloft by means of kites. At the prearranged time the operator at Poldhu sent simply the letter "S" which was received successfully by Marconi. Later a large station was built at Cape Breton, Nova Scotia, and regular communication was established.

The wireless was soon established on a commercial basis. The first Marconi company was organized as early as 1897 under the name of the Wireless Telegraph and Signal Company, Limited. This was later displaced by the Marconi Telegraph Company, which operates a regular system of stations on a commercial basis, carrying messages in competition with the cable and telegraph companies.

With the telegraph and telephone so well established and serving the needs of land communication, it was natural that wireless made but slow progress, as a commercial proposition. However, at sea, it had no competition and now almost all vessels are equipped. The United States Government by its laws now requires that passenger ships shall be equipped with wireless apparatus in charge of a competent operator.

Marconi has not been allowed to hold the wireless field alone. Others have devised wireless systems along more original lines, particularly two American experimenters, Dr. DeForest and Professor Fessenden.

Some of the railroads in the United States have equipped their trains as well as their stations. The speed of the fastest train does not affect the sending or receiving of messages. It has been found that even when passing through tunnels, messages passed without hindrance.

The world war gave wireless telegraphy great impetus. Although the German cables were cut early in the war, communication was easily kept up by the Allies by means of the wireless. Its use in the Navy was invaluable. Portable sets have been mounted and used successfully on aircraft and wireless control of boats and torpedoes do not startle anyone.

CHAPTER VI.

Wireless Telephone.

No sooner had Marconi placed the wireless telegraph at the service of the world than men of science of all nations began the search for the wireless telephone. But the vibrations necessary to reproduce the sound of the human voice are so infinitely more complex than those which suffice to carry signals representing the dots and dashes of the telegraph code, that the problem long defied solution.

The experimenters realized that future success lay in making the ether carry telephonic currents. They succeeded by using the same aerial, or antennae as used in wireless telegraphy and a microphone. The microphone, as its name indicates, serves to magnify minute sounds, such as the ticking of a watch, or the footfalls of an insect, and render them audible. In modern telephony, microphones under the name of carbon transmitters, are in general use.

The sending apparatus was so arranged that continuous oscillations are set up in the ether, either by a high frequency machine or from an electric arc. This unbroken wave train does not affect the telephone and is not audible in a telephone receiver inserted in the radio receiving circuit. But when a microphone transmitter is inserted in the sending circuit, instead of the key used for telegraphy, the waves of the voice thrown against the transmitter in speaking, break up the waves so that the telephone receiver in the receiving circuit will reproduce sound. This is the wireless telephone.

The engineers of the Bell organization, headed by John J. Carty, developed the wireless telephone to such an extent, that in October, 1915, spoken words at Arlington, Virginia, were heard at the Eiffel Tower, Paris.

To the devices of Carty and his associates was added the extremely delicate detector. This was the invention of Dr. Lee DeForest, an American inventor. His contribution was a lamp instrument, called an amplifier. This is to the wireless telephone what the coherer is to the wireless telegraph. It is so delicate that the faintest currents coming through the ether will stimulate it and serve to set in motion local sources of electrical energy so that the waves received are magnified to a point where they will produce sound.

Wireless telephony, despite the wonders it has accomplished is still in its infancy. With more perfect apparatus and the knowledge that comes with experience we may expect that speech will girdle the earth.

It is natural that one should wonder whether the wireless telephone is destined to displace our present apparatus. John J. Carty, a vice-president of the American Telephone and Telegraph Company and one greatly responsible for the wireless telephone's development, believes that radio telephony will supplement but will not supplant the wires as a general means of inter-communication and the present telephone system of the United States will always be the backbone of voice to voice communication.

The field for radio is limited to broadcasting communications with ships at sea, communication between airships and numerous other special services, both military and civil. There are too many limitations, such as the small number of channels for communication, the lack of secrecy, and the presence of atmospheric disturbances for it ever to be used wholly for voice to voice communication, but it has a remarkable usefulness in its own peculiar field.

CHAPTER VII.

The Possibilities of the Wireless Telephone.

Radio telegraphy is more than twenty years old, but radio telephony, in its present form, is a very recent product of inventive genius.

The radiophone is a new publicity agent which literally has everybody "by the ears." It immediately takes its place with the telegraph, telephone, post office, press, pulpit, school and theatre as a means of reaching the public, and its possibilities are obviously so great that it cannot be regarded as a plaything or a passing fad.

The great publicity field for radio is the broadcasting of information or entertainment designed to reach large numbers.

National news could be broadcasted from the few powerful stations and local news from the numerous local stations. The President of the United States might address the entire population from a high-powered central station; the Governor of the State of New York might address the people of the state through a local station. The message in either case would reach instantly localities not reached by telephone, telegraph, post office or newspaper.

The distribution of music and other forms of entertainment, and the broadcasting of educational and religious programmes will undoubtedly develop along similar lines.

Will the wireless telephone solve the farm labor problem and check the drift to the cities? Is the day coming when the farmer, his sons and daughters and "hired hands" will feel compensated for absence from the bright lights and diversions of urban life through the ability to turn a switch and instantly be in contact with musical comedy, opera or various forms of spoken entertainment?

The day is not far distant when every country home will have its aerial, and members of every household will have the whole day of lonely toil brightened by anticipation of enjoying in the evening the same things for which they formerly envied their city cousins.

Not alone in the way of amusement will the receiving set be useful to the farmer, however. The weather reports will be of inestimable value to him in planning his work Whether to cut his hay or grain now and tak a chance of having its quality impaired b heavy rainfall before it can be hauled to th barn is a question which may mean hundred of dollars to him, and one which the wireles report will help solve.

The installation of radiophone receiving an sending sets as a house-to-house proposition i as yet a dream that is far in the future. Whil there are many transmitting stations that ar using the radiophone, if this type of communi cation were generally adopted it would resul in terrific interference with the apparatus a used at present. However, there are many in stances where the amateur transmitting set ha been installed for inter-communication pur poses and some of them are working success fully.

Several sets are now in operation on som of the larger yachts that are used by the own ers to communicate with their homes, an there are several other cases where large firm use the radiophone to successfully carry o communication between the office and the fac tory. This may be easily worked out and i will be found very satisfactory as long as it is not generally adopted by the public.

It is a fact that, although the use of the radio telephone for broadcasting will probably continue as a permanent feature of national life, its future development will be directed along altogether different lines. Science has always tended to serve the interests of the government, both on its civil and military sides, and of business; it is in these directions that one must look for the new uses to which radio telephony will be put in the future.

It is well to remember here the distinction between the two dissimilar functions of wireless communication—its utility in reaching a definite place and in covering a more or less definite area. It is in the latter field that the greater and more recent exploitation has taken place. The line of development in this field is fairly obvious and certain, resting merely on technical perfection of the sending and receiving apparatus.

The greatly undeveloped field of radiotelephony—namely, place-to-place communication—will serve, however, more distinctly commercial purposes. The world of affairs is little interested in covering an area and intensely concerned with reaching a place.

Of course the wireless telegraph is able at the present moment to accomplish that end; but exactly as the wire telephone proved far more efficient and useful for many purposes than the wire telegraph, so the radiophone will assume exactly the same position with regard to its elder brother; that may be taken for granted. In the same manner that wireless telegraphy accomplished feats deemed impossible to the cable, for instance, such as the placing of a message in Berlin in less than five minutes from its dispatch from Long Island, so the radiotelephone will make it practical for a New York business man to consummate all the details of a transaction with his colleague in London in a manner impossible to the Marconigram. Combining the speed of the latter with the personal quality of the wire telephone, the new medium seems destined to be the basic agent of long distance business communication.

In the same manner, of course, it is evident that the radiophone must become an indispensable agent of contact between the branches of the government. Diplomatic business can be despatched with far greater speed and efficiency when the department head in Washington can come into immediate and personal touch with the representative abroad; military and naval movements can be carried out with greater facility for similar reasons. In the case of the navy, of course, the wireless is the only possible means of communication, and it is inevitable, of course, that the voice should for many purposes assert its superiority to the code.

Chapter VIII.

Electro-Magnetic Waves.

In wireless telegraphy and telephony, you constantly hear the terms "Hertzian waves" and "wave lengths". We know how Hertz discovered this phenomenon and how Marconi applied it to his wireless experiments. We know that these waves travel through the ether, a substance that exists in all materials, and even in what is commonly considered the above of nothingness—a vacuum. Who is amazed at seeing the sunlight streaming through a pane of glass? And yet glass is a solid substance that does not readily transmit sound. Light is an ether wave of slightly different nature, and in passing through a pane of glass acts somewhat as a wireless wave would in passing through stone or wood. Probably this very minute radio signals are passing in all directions through your own body.

In order to get the idea firmly in mind a little analogy will have to be used. Consider the ether as a quiet pool of water into which is thrown a stone. As the stone sinks from sight a ring of waves will be seen receding from the spot. These waves will go on and on until the eye can no longer see them. The stone is the transmitting station and the size of the stone has much to do with the strength of the waves. A small pebble will only make a few ripples and this would correspond with some small boy experimenting with a "flivver" coil. As his power is so low the waves will only travel a little distance. However, throw a good-sized rock into the water and an idea may be gained of the disturbance caused in the air by a large broadcasting or commercial station.

It will be noticed that as the waves travel away from the spot where the stone hit the water that there may be several reeds or sticks that the waves will hit. These may be considered the receiving stations and it will be noticed that the waves will travel right on without the least hesitation. Practically the same thing happens in the ether when it is set in motion by a transmitting set. An unlimited number of receiving sets may be operated at the same time and the effect on the transmitted wave will be practically nothing.

Certain tall steel structures will have the effect of absorbing a great many of these waves, the same as the water waves would do if they hit up against a large rock. A certain number of the radio waves will penetrate beyond this obstruction, however, and if sensitive receiving apparatus is used the signals may be picked up despite the obstruction.

It will be noticed as the waves leave the spot where the stone hit the water that all the waves are a certain distance apart. Compare the distance between the waves made by the large stone and the little pebble. It will be seen that different sized stones throw out different sized waves and also that the difference between the crests of the waves will vary considerably. This distance between the waves is what is known as wave length, and in radio this wave length will remain constant, no matter how far the waves travel. It is even claimed that these radio waves travel on and on until even the little spark coil set has encircled the globe. It is simply a matter of perfecting receiving apparatus that is sensitive enough to hear these signals.

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 electro-magnetic waves for wireless communication the energy imparted to the ether is electrical energy.

How are the electrical waves created? Almost everyone 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 tin-foil 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.

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

High frequency oscillations are the "pebbles" which, dropped into the vast pool of ether, everywhere set up "ripples" called electro-magnetic waves. 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.

These waves follow the contour of the

earth and so may cross mountains and valleys and travel everywhere.

The wave-length is simply the distance from the beginning of one wave to the beginning of the next, or as stated before, from the crest of one to the crest of the next. It has nothing whatever to do with the distance covered. Wave length in radio corresponds to pitch in sound and with color in light.

The curiosity of all boys is aroused when for the first time they see a squad of soldiers break step as they cross a bridge, or when for the first time they spell out the sign on the bridge which reads "Driving Across This Bridge Faster Than a Walk Subject to Fine." They immediately ask why.

All bodies or structures, and all electrical circuits possess a "period of vibration." If the bell is struck it vibrates at a certain rate—a certain number of times per minute or second. If the bridge structure is set in motion it, too, has its own rate of vibration. If the force which sets the bridge in motion—the "exciting force"—recurs again and again, and if its recurrence is timed to be in exact agreement with the vibrations of the bridge structure, resonance exists, and by virtue of the resonant condition and the recurrence of the exciting forces, the vibrations in the structure may reach amplitudes sufficient to destroy it. Thus the precautions — for resonance allows the acting forces to overcome the resistance of the structure.

In the radio circuit advantage is taken of this principle. The period of vibration of the radiophone transmitter circuit is fixed. Its period of vibration is determined by its electrical length (inductance in the circuit) and by its electrical size (capacity in the circuit). Thus it must vibrate, electrically, at a certain rate. The inductance and capacity of the present day broadcasting station is so proportioned that the electrical vibrations surge through the circuit at a frequency of approximately 833,000 per second, creating disturbances in the electrical equilibrium of the surrounding medium which are radiated in ever widening circles at a speed of 186,000 mile per second—the speed of light; 186,000 miles are equivalent to 300,000,000 meters. Now if we divide the speed in meters at which these disturbances, or waves travel, by the frequence of their recurrence, we will know their length. Thus, 300,000,000 divided by 833,000 equals 360, approximately.

Different wave-lengths have been assigned various stations to prevent interference as much as possible.

Frequencies of 15 to 15,000 are spoken of as "audio frequencies," because vibrations, such as from a piano wire, can be heard, while those from 15,000 to 1,500,000 and higher are called "radio frequencies." They are most commonly used in wireless work, yet they cannot be heard.

The number of complete vibrations per second of a vibrating particle is called the "frequency" of the vibrations. The duration of one complete vibration is called the "period" of the vibrations. The whole distance through which the particle moves to and fro is called the "amplitude" of the vibrations.

Chapter IX.

Aerials.

Every station may be summed up as comprising, first, certain appliances collectively forming the transmitter and serving to create the waves; secondly, the receiving apparatus, whose function is to detect the signals of sending stations and lastly, an external organ called the aerial, or antennae, consisting of a system of wires, elevated high in the air above all surrounding objects, which radiates or intercepts the electro-magnetic waves, according as the station is transmitting or receiving.

The antennae 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 neighborhood 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 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 to four hundred miles over the ocean.

Forests exert a very decided effect upon the electric waves. Each individual tree acts as an antennae, 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 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 static 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.

For transmitting, a large aerial is required; a large station, such as the Radio Central at Rocky Point, Long Island, transmits across the Atlantic with an aerial comprising 16 wires 1½ miles long and 410 feet high.

That, of course, is exceptional. Receiving, on the other hand, requires only a small aerial. A single wire, insulated with ordinary porcelain knobs or cleats such as are used in exposed wiring, stretched 100 feet long between a house and a clothes pole or a tree, should be ample.

Two wires may give better results, and longer wires should certainly stand for better results since more energy is intercepted the greater the aerial. For best results the aerial should be elevated as high as possible above nearby objects.

The question of a receiving aerial is much the same as that of distance. Given a better grade of receiving apparatus, naturally a smaller aerial is required for a desired result.

For a ground connection, a wire connected to a water pipe, radiator, or leader pipe may be used.

In case there is no room available to install an average size aerial, one may suspend the aerial wire from a window, care being taken that the wire does not touch the wall; or a loop may be formed with the wire around the moulding of a room.

The thing to aim for in a receiving aerial is length, in one direction, and also height, but mostly length. A single wire is all that is necessary, but the wire should be straight, or at least as near straight as possible. A four-wire flat top aerial, 50 feet long, is much inferior to a 200-foot single wire aerial. Winding a lot of wire inside a room does not give the effect of length.

One of the wonders of present-day radio is the so-called loop. Instead of employing an aerial and a ground connection, a simple frame with a half dozen turns of insulated wire may be employed. This frame can be used indoors, and it simplifies the problem of radio reception in many instances. However, since the loop does not begin to intercept as much energy as the usual aerial, it is necessary to fall back on amplification so as to bring up the signal or sound strength.

Indoor aerials, as a rule, are very disappointing in the results they give. Unless several stages of vacuum tube amplification are employed, very little will be heard. The same applies to the loop aerial. The outdoor aerial is the only thing that gives any real results.

Amplifying apparatus makes use of vacuum tubes which differ but slightly from detector tubes. The difference is merely a matter of the degree of vacuum in the bulb, and detector and amplifier tubes can be used interchangeably if necessary. In conjunction with the vacuum tubes various pieces of apparatus are used, such as closed-core transformers, sockets, small condensers, and so on.

Another development in the art of radio is the perfection of the aerial that will throw most of the waves in a certain desired direction. This has been worked out to a high degree in the stations that are used to send messages across the Atlantic. While not all the waves are sent in one direction, it will be found that the strongest waves are sent to the east, or west, as the case may be.

The direction in which the aerial points, as well as the location, has a lot to do with its efficiency. The direction will not make a great difference in the receiving, but in radio receiving the currents dealt in are so small that anything that will help in the least to make the signals any louder may well be looked into. The direction that the aerial should be pointed in is, of course, toward the station to be received.

In a radio receiving set the energy is very small and all precautions should be taken to prevent unwarranted losses.

Copper ranks highest among conducting materials and is, therefore, used in all wiring where resistance must be kept down.

A conductor is a material that will admit the flow of an electric current with great ease, and an insulator is a material that offers extremely great resistance or opposition to a current, in fact, for all practical purposes an insulator may be considered as entirely stopping the current flow. The terms are only relative, however, as there are no perfect conductors or any perfect insulators. All materials allow some current to pass, and all materials offer some resistance to its flow.

For small aerials hard-drawn bare copper wire will serve very well. The advantage of hard-drawn over soft-drawn wire is its greater strength. Cable, made up of several strands of copper wire, is better for larger aerials and where greater conductivity is wanted. It has been found that radio currents travel only on the surface of a conductor. This phenomena may be illustrated by taking a pan with a little sand in the bottom and whirling it on a spindle. It will be noticed that the faster the pan rotates, the nearer the edge the sand will fly.

Practically the same thing happens in the realm of electricity—the higher the frequency of the current, the nearer to the surface of the conductor it will stay. A cable composed of several strands offers more surface than a single round one of the same cross section, and is, therefore, more efficient. Some copper wire is tinned to prevent corrosion. This tinning also makes it easier to solder and does not in any way lower its efficiency. Bronze, phospher bronze, and silicon bronze cable is used in large stations where extremely great tensile strength is needed, especially on very long spans. The conductivity of these wires is lower, however, than that of copper, and should not, if possible, be used for receiving aerials. Aluminum wire was used quite extensively by amateurs at one time, but is very unsuitable for the work, owing to its weakness, low conductivity, and the almost impossibility of soldering joints.

If possible, all joints on the aerial and apparatus should be soldered, as metals corrode and form an oxide that is only partially conductive. Dust, dirt, and grease are also poor conductors.

Good insulation is all-important, for the energy in a most perfect conductor may be entirely lost through faulty insulation. Aerial insulators are made of a number of materials, the most common of which are glazed porcelain and a composition known as "electrose." Porcelain insulators are cheap, and for receiving purposes give fair results. The insulating qualities of such insulators depends on the glaze. If the glaze is chipped they absorb moisture, thus lowering their value as insulators.

You may wonder why some insulators are corrugated or "bumpy." Such insulators are used on transmitting stations, where high voltages are used. As was noted, high frequency currents travel on the surface of a material, therefore by lengthening the surface by the aid of corrugations, you do something that has the effect of lengthening the insulator, only at less cost.

There is a general idea, that an aerial makes an excellent target for a lightning bolt. In reality, if the aerial is properly connected, it is a protection against this hazard. There is not a single fire on record in New York City, that has been caused by lightning striking an aerial.

Chapter X.

Tuning.

The theory of tuning is a long and complicated study. In the first place, every transmitting station has a certain wave-length upon which the transmitted signals or voice is transmitted. The receiving set, however, is capable of receiving several wave lengths. A transmitter can also be made to transmit on several wave-lengths, but cannot be tuned as fast as a receiver. When a receiving set is tuned to receive a certain transmitting set it is in "resonance" with the other station.

"Resonance," as applied to mechanics and to the electrical sciences, may be better understood, by the following experiment, which will demonstrate the principle. If a piano is available place the foot upon the "forte" pedal, stand or sit before the instrument and sing or whistle some note. After production of the note has ceased you may hear one of the strings in the instrument vibrating quite audibly, without any key having been struck. Continue this experiment on different pitches, allowing the voice or whistled note to slide gradually up and down just above and below some particular note. You find that the string which is being "excited" vibrates with greatest amplitudes when the voice note is in exact agreement with the pitch of the string. This is mechanical resonance, and it is this phenomenon which sometimes causes the disagreeable vibration of metal ornaments on or near the piano.

This can be again illustrated by holding down a note on a piano and then quickly striking another note an octave away. The first note will be heard to ring as the other note dies out. This is exactly what happens in tuning a station. The two notes are in tune and one responds to the note sent out by the other one.

The violin string is another example which will serve the purpose. If a violin string is plucked it will vibrate and emit a sound of a definite pitch. If another string of the same length and tension is brought near to it, it will vibrate in harmony with the first string, but if the length or tension is not the same, the second string will be affected, but slightly or not at all. When the strings vibrate in harmony they are said to be in "tune."

If you wore a pair of special glasses which only permitted a given shade of pink light to pass through to the eyes, you might say you were "tuned" for that shade of pink light. Blue light, yellow light, green light, purple light, and all other colors and shades save pink would not be seen by you, providing it were possible to make such accurate color filters.

Now in radio the same situation holds true, and with great precision. The radio waves are of different values, and these values are expressed in terms of meters of wave length. A station for instance transmits on 360 meters. When you manipulate the tuning knobs of a receiving set so as to have the 360 meter adjustment, you can hear this station. Tune down to 200 meters, and you hear some nearby radio amateur. Tune up to several thousand meters, and you hear the high-power transatlantic stations.

For the purpose of further illustration, we might compare four radio transmitting stations located in the same vicinity to four singers on a single stage. As long as the quartet sang together everything would be fine—but suppose that the tenor sang "Mother Machree," the soprano "Dixie," the basso "Asleep in the Deep," and the contralto "Margie," all at the same time. The result would be what, in radio parlance is called "interference."

Now suppose that you had in your pocket a little device that, when placed against your ears and properly adjusted, would exclude the basso, contralto and tenor voices, but would allow the soprano voice to pass, the result would be that you would hear only the clear soprano strains of "Dixie" unmarred by the bedlam of "Asleep in the Deep," "Mother Machree," and "Margie." But suppose that the man alongside of you wanted to hear "Margie." He would simply turn the knob on his little device so that it would exclude the basso, tenor and soprano, but pass the contralto voice, and he would hear his favorite song, undisturbed by the soprano "Dixie," or any other.

If the singers are compared to radio stations, and you should call the basso voice a "200 meter wave length," the contralto a "360 meter wave length," the tenor a "600 meter wave length," and the soprano a "1,200 meter wave length" and your little pocket device is compared to a radio receiver, the analogy will be complete.

Hence it is the tuning of the transmitter and the tuning of the receiver which makes "selectivity" possible in radio communication. This enables the owner to "select" the wave length suited to his individual apparatus.

In order that a number of radio stations in the same vinicity may transmit signals at the same time, and not interfere with one another, one will transmit on a 200 meter wave length, another on 360 meters, another on 600 meters, another on 1,200 meters, and so on. In order that a radio receiving station may listen to any station at will, the receiving instrument is provided with one or more adjusting knobs or switches, so that the "wave length" of the receiver may be tuned to correspond with the wave length of the station it is desired to hear.

All radio receivers, however, are not capable of adjustment to all wave lengths. When we say that a receiver has a wave length range of "160 to 600 meters," we mean that it can be adjusted to hear any station that sends on a wave length between 160 and 600 meters, but that a station sending out a 1,200 meter wave, for instance, could not be heard.

Most receiving sets receive radio telegraph and radiophone waves alike.

The great importance and value of properly "tuning" the circuit of radio apparatus cannot be over-estimated.

CHAPTER XI.

Transmitting.

At the sending station, electric energy is generated, stored up, and released into the air, in the form of electro-magnetic waves.

To transmit radio signals it is necessary, therefore, to first create waves in varying groups and of varying strength and second to intercept them with apparatus capable of changing them to sound waves.

To create the waves it is necessary to have two surfaces, separated by a distance of from ten to several hundred feet, and to create between them an electrical pressure which changes its direction (first toward one surface, then toward the other) hundreds of thousands of times a second. It is the common practice to use the ground for one surface and provide another surface by erecting an antennae insulated from the ground and suspended many feet above it. Between these, by means of suitable transmitting equipment we create an electrical pressure of from one to one hundred thousand volts which starts waves radiating out in all directions.

These pressure waves are, however, only part of a radio wave. From any wire in which current is flowing are radiated electro-magnetic waves and radio waves are made up then, of both electro-magnetic and electro-static (pressure) waves.

The creation of these waves may be compared to the action of hurling a large rock into a pool of water The amperes of current put into the antennae correspond to the size of the rock, while the volts of electrical pressure are equivalent to the force with which the rock is hurled. The larger the rock and the greater the force behind it, the bigger the splash and consequent waves. The more amperes of current flowing in the antennae circuit and the greater the pressure (volts) between antennae and ground, the stronger the waves radiated.

The current supply in a transmitting station must be generated by an engine and dynamo, unless current mains for light and power are already installed from an outside source. Recourse is also had to batteries.

This current is an alternating current, which is one which reverses its direction and passes one way and then the other. It may be represented by the roll of an ocean wave.

Sparks were once exclusively employed in telegraphing through the ether, but sparks die out very quickly. They produce what are called "damped waves." Vibrations are said to be "damped" when they die out quickly. This is generally due, in part, to the dissipation of energy in the body in the form of heat, as it is repeatedly distorted, and in part to the giving up of energy to the surrounding air. A heavy tuning fork performs several thousands of perceptible vibrations when struck. A drum head performs only a very few perceptible vibrations when struck. The waves beating on the sea shore, may be called "damped waves" for they rise and then expend their energy upon the sand.

In radio telephony, a continuous vibration is wanted, an "undamped wave." Undamped waves, continuous waves, or continuous oscillations, all refer to the same thing. If you were in a boat at sea, each wave passing would appear to move on, one after another, steadily, each wave of equal strength and size. Those would be "undamped waves."

From ten thousand to thirty million vibrations per second are required to generate Hertzian waves.

A Danish engineer, Poulsen, discovered a way of producing the alternations, necessary for a continuous arc. This displaced the old spark method of radiating waves, as used in the earlier experiments.

High frequency alternators, running at speeds of 10,000 revolutions per minute, or more, are employed to generate undamped waves and most of the high powered stations have Poulsen arcs, some working on 500 and even 1000 kilowatts.

To radiate waves, as we have seen, many thousands of alternations per second are required. Ordinary alternating current dynamos or generators cannot turn fast enough to produce any such number of alternations. Special dynamos have been invented which meet the requirements and some stations have been equipped with them. A new invention called the "vacuum tube," "electron tube," or "therminoic valve," replaces this large apparatus in most cases.

In the spark set the waves vary in amplitude

—that is, the height of the waves gradually become less. This is called decrement, in wireless. With the continuous wave set this decrement is very small, and with some sets that are used for continuous wave telegraphy only, it cannot be measured. While all waves are very high frequency it will be seen that the continuous wave is made up of many alternations spaced very closely, while the spark transmitter has an entirely different looking wave train. Each spark as it jumps the gap sets up a separate wave, while with the tube transmitter or continuous wave set these alternations are so close together that it makes a continuous wave.

Reverting to the previous analogy of the quiet pool of water, the spark set would correspond to the waves caused by throwing in one stone and a moment later throwing in another. The two sets of waves would follow each other. Now as you watched these waves, the smaller and smaller they got, the farther would they be from you. This corresponds to the decrement. If the stones were thrown in almost together, the resulting waves would resemble one continuous wave and would correspond to the alternations spaced very closely, of the continuous wave set.

These waves are sent out in the form of alternating current of very high frequency; that is, the current is changed from positive to negative at very frequent intervals. This is also called the frequency of the current, and, owing to the great many times that the current changes every second, it is known as high frequency. The ordinary house current has a frequency of sixty cycles, or has sixty changes per second. In wireless telephony this frequency mounts up to about 100,000 cycles per second. These high frequency waves are produced by the vacuum tubes or an arc transmitter.

The development of the vacuum tube as an amplifier, rectifier and oscillator has made it possible for anyone having an antennae to transmit signals, music and the human voice by means of continuous waves of radio frequency.

Continuous wave transmission has many advantages over that of spark discharges, as with continuous wave the supply of energy to the antennae is continuous, undamped and of one sharp frequency, while with spark discharges it is intermittent, damped and of more than one frequency.

The continuous wave transmission is similar to allowing water to flow through the garden hose without a nozzle. If the faucet is kept open, you will get a steady discharge and further, if the hose is held steadily a short distance from the ground, the water will curve to the ground in practically a steady stream. The spark discharge corresponds to manipulating the faucet, so as to open and close it, thus giving an interval between discharges into the air. This discharge will vary in amount and will be in spurts. The great advantage of continuous wave transmission lies in the receiving end, which, being tuned to one frequency, receives all the available energy, as it exists at one frequency only, and being a persistent oscillator is more easily affected by a continuous supply.

The solution of the problem of interference in amateur radio lies in the use of continuous wave transmission, as it is possible for stations in one neighborhood to communicate simultaneously at frequencies which differ by only a few per cent. With spark systems it is necessary to work at widely different wave lengths for success, and even then there is in all probability a longer wave length with sufficient energy to be heard at some distance, all of which energy is lost to the station with which communication has been established.

With these advantages, coupled with the small losses in vacuum tubes compared with spark gaps, it is possible to communicate over greater distances with continuous wave transmission than with spark systems.

For transmission, an alternating current source of sufficiently high voltage for the oscillating tubes is the only source of power needed.

When an alternating current is rectified, it becomes a direct current, that is, the lower half of the wave is eliminated. A commutator, added to an armature, as seen in any power station, produces this effect. When rectifying alternating currents for the production of direct current, it is necessary to have choke coils and condensers for smoothing out pulsations. The pulsations in current are smoothed out with choke coils and pulsations in voltage with condensers.

The vacuum tubes as soon as they are lighted, by the generated current, start to send out continuous waves of high frequency. As soon as an operator starts to speak, the waves formed by the voice, are carried out on these waves, in other words, the voice mounts and rides the radio waves.

When the United States Government began to license amateur stations the power for transmitting was limited to one kilowatt and to one-half kilowatt for stations that were located within five miles of a government station. Some used powers up to five and ten kilowatts, with disastrous results to all who happened to be anywhere near them. The amateur has now refined his apparatus to such a degree that he is able to squeeze the last ounce of energy out of the transmitting set.

A Madza lamp of 25 watts is considered a very small one, yet some are covering one-half the country on one-fifth of this power.

The government and commercial stations are still using high power for all long distance work, while the amateur is doing almost the same thing on comparatively low power.

During the recent Transatlantic tests Mr.

Godley, who went to Scotland to receive the signals, was fairly overcome with the strength and great number of American amateur stations received. Mr. Godley used a ten-step amplifier and some of the signals were heard 200 feet from the receivers. In all, Mr. Godley reported twenty-six stations, but at times he says that he heard so many stations that it was impossible to separate them and make the necessary identification. Out of all that he heard he could be sure of only twenty-six.

In these tests very few of the stations used powers that were anywhere near the 1000 watts as allowed by the law. The average station used about 250 watts or one-quarter kilowatt.

Chapter XII.

Receiving.

Radio communication comprises three definite operations: First, a suitable source of radio energy, known as the transmitter, which is capable of imparting this energy to space, or ether. Secondly, the radio energy, converted into vibrations of the ether, is propagated through space by means of the antennae. These waves have a definite period of vibration. They spread out in all directions, but as with the sound waves and the violin strings, they manifest themselves to full advantage only in those stations that are in "tune." Thirdly, a receiving set, which is an instrument capable of detecting these waves. The receiving antennae at the station picks up these high frequency waves.

For the purpose of bringing about harmony of vibration with the different stations, one or more tuning coils made either, flat of a single layer of wire—narrow but thick and wound in what is called "honeycomb" style—or of two spherical structures of wire one of which revolves within the other and known as a variometer, are used

The high frequency waves known as radio frequencies are inaudible, consequently a means of changing the frequency of the incoming signals from radio to audible frequency is necessary. This is accomplished by what is known as a "detector."

There are two types—"crystal" or "vacuum" tube. The high frequency waves, 20,000 to 6,000,000 changes of direction per second, are thereby rectified to pulsating direct current traveling in one direction only, and the voice becomes audible in the receivers. This process of rectification is what makes the voice or music audible, for the intercepted waves, which have been tuned in, have been transformed into audible signals or sounds, in the telephone receivers.

In order to make a finer and more accurate adjustment of the circuits to the incoming waves, than is possible with the tuning coils alone, a "condenser" is used.

The telephone receivers are the means of changing the electrical impulses to sound waves, which are audible to the ear. In order to make the circuit complete the return current is carried back by the "ground," which is as necessary as an aerial.

The tuning coil is connected to the aerial. As has been previously noted, the purpose of tuning coils is to secure an adjustment of the receiving apparatus such that the circuits are responsive to, and will receive signals from any station desired. Two types are in use in the majority of stations, the single layer of wire wound on a tube and the "honeycomb." The first is varied either by tapping it every few turns and bringing the tap wires to points on a switch or by scraping the insulation from the wires for a width of ¼ inch the length of the coil and causing a movable contact to slide along this bare strip. Individual "honeycomb" coils, which take their name from the method of winding them, are not variable; different size coils being used for various ranges of wave lengths, i. e., one coil for wave lengths 145-150, another for wave lengths 150-225, etc. These coils have contact pins in the bakelite block attached, and are "plugged in" into receptacles mounted on a panel. Tuning coils are known as "single slide," "double slide" and "three slide" according to the number of contacts they are fitted with.

There have, in the evolution of radio, been many types of detectors, each having a short period of popularity, only to be replaced in desirability, by another more sensitive. Coheror, carborundum, electrolytic, pyrites and silicon—each had its day, in about the order named, and was discarded. We now find two in general use; that employing a piece of galena (lead peroxide) and that using a vacuum tube.

Galena crystals possess the property of changing high frequency radio currents (20,000 to 6,000,000 changes of direction per second) to impulses of varying strength traveling in one direction only, and for that reason we find them, in radio work, mounted in a small block of soft metal with one surface exposed. A short spring made of fine phosphor bronze wire is mounted directly in front of this surface and so attached to the base of the instrument that one end can be made to touch any point of the exposed surface of the galena crystal. This is necessary as all points on the surface of a piece of galena will not give the results described above and a little maneuvering of the phosphor bronze spring is necessary to find "sensitive" points. Once such a point is found, and the detector is not jarred, readjustment will not have to be made for some time.

This type of detector is very satisfactory if a good piece of mineral can be secured. The crystals all look alike and the only way to tell a good piece of mineral is to actually try it out. Some crystals will give results almost as loud as a vacuum tube detector, but they are hard to locate. However, it is well worth the trouble if you can pick up a good piece of galena.

The vacuum tube, as a "detector" or "amplifying" tube is nothing more than a highly exhausted incandescent lamp containing a plate and a grid. In fact, Edison made his first tube by inserting a wire in the top of an ordinary electric lamp.

Tubes used for receiving may be generally divided into two classes, those used for detector and those used for amplifiers. The latter tubes are known as "hard" tubes, and are exhausted to a very high degree, while the former, or detector bulb, usually has some small amount of gas left in it. Experience has taught that the tubes will work best this way.

The vacuum tube detector gives louder, clearer signals in the receivers than does the galena crystal detector because a small battery made up of flashlight cells and known as a "B" battery is connected in what is called the "plate circuit" and a very small current is constantly taken from this battery and added to the signal currents. Thus the signals from this type are much stronger and cause greater vibration of the diaphragms in the head telephones.

In the case of the crystal detector, it is necessary to adjust one of the members of the set until a sensitive spot is found on the large crystal. This detector has to be readjusted each time it loses its sensitiveness. In comparison with this, the vacuum tube is far more constant and positive in its operation, and is adjusted by means of a rheostat, which controls the flow of filament current. The vacuum tube is far more sensitive than the crystal, and is always more satisfactory.

Vacuum-tube sets are twenty-five to fifty times as efficient as are crystal sets.

There are three general classes of receivers of which the crystal set is the cheapest. Next comes the vacuum-tube set, and finally the vacuum-tube set employing the regenerative principle. This last-mentioned receiver is the most saisfactory, although of course it is the most expensive. In a regenerative set, amplifiers are added to the tuner and detector and the increase in sensitiveness will make for louder signals over a greatly increased distance.

The detector does not perfectly rectify, for a small amount of high frequency energy flows on. This energy passes through the condenser, instead of having to pass through the high resistance of the telephone receivers.

Condensers are of two types—fixed and variable. They have what is called "capacity" and will contain electricity, just as a jar has capacity for water. The capacity of a "fixed" condenser is definite and unchangeable, but the capacity of a variable condenser may be changed at will.

The tuning coil, enables an operator to vary his circuit so that it will catch the transmitted waves, but the tuning is not sufficiently fine, so a variable condenser is used, to secure a more precise degree of accuracy and to enable the operator to hear even weak signals. When the single layer, movable contact type of tuning coil is used, a "fixed" condenser is employed in the circuit. The condenser is usually connected across the phones. Its purpose is to store the energy of the individual oscillations and discharge it at the proper time.

The ear is so constructed that it will not hear sounds that vibrate with a frequency above 10,000 a second.

Now, radio currents "vibrate" at a point far beyond the range of human hearing The problem is to cut this rate of "vibration" down to a point where our ear will respond. That is the function of a detector.

Radio currents dash back and forth in a circuit many thousand times a second. They alternate, going first in one direction and then in the opposite direction. The detector has a peculiar property of allowing a current to pass freely in one direction, but not allowing it to turn about and pass in the opposite direction. It acts as a sort of one-way door.

If an alternating current is allowed to pass through the detector half of it will be cut off.

This will have the effect of cutting the frequency of the current in half—we cut its rate of "vibration" in half, bringing it from the range of inaudibility into the range of audibility. The resulting current if allowed to pass into an ordinary telephone receiver affects it in such a way that they produce sound.

The amplifier is not a necessary piece of equipment in a receiving set, but is very desirable.

The word amplify means to increase, to add to, to exaggerate and that is exacly what this piece of apparatus does to the radio signals after they have been tuned in and have gone through the detector—it increases and adds to the strength of the signals.

With the aid of a little glass tube, half an inch thick and scarcely an inch and a half in length, you may talk around the world without the use of wires. Attached to your receiving instrument, it magnifies sounds so wonderfully that the steps of a house fly on a piece of paper sound to your ear like the roll of the kettledrums in an orchestra. The audion detector was first brought out by Dr. Lee De Forest and is the most interesting instrument developed, during the progress of radio development. With special variations in design, it is used for detecting minute currents, amplifying and for the generation of undamped waves.

Long distance wireless telephony would not be possible without the little giant vacuum tube amplifier. One of the most interesting and important features of the little giant amplifier is its ability to handle with ease radio waves of such length as have heretofore been the despair of electrical engineers and wireless experimenters. No less an authority than William Marconi has said that he did not know of any wave length in use anywhere on earth greater than 23,000 metres. No instrument invented can accommodate itself to anything greater than that.

Yet the amplifier can absorb wave lengths of 100,000 metres and even more and repeat them to the listening ear with a magnified strength of a million. To make it plainer why a long wave length is necessary for long distance conversation without wires, it should be understood that high-frequency currents produce short wave lengths. Such a current does not penetrate as satisfactorily as one of low frequency, but the trouble with low frequencies is their weakness after traveling long distances. The ordinary instrument cannot pick them up and the message is lost in the illimitable ether.

The vacuum tube amplifier fills this long-felt want and makes it possible to chat around the earth on wave lengths of five, six, or more times the greatest length now in use and not interfere with anybody else.

It was previously stated that when a vacuum tube is used as a detector that a "B" battery made up of flashlight cells was connected in the circuits and that current from this battery was added to the signals. When this is done the action of adding to the signals is very small. Due to its having other characteristics than those utilized in detecting, the vacuum tube is also used to strongly amplify or increase the signals. A tube, when properly connected in the circuits, will not change the form of signals passing through it as it did when detecting but will add large amounts of current to them and so increase the audibility about 10,000 times. This multiplication of sound is accomplished by passing the original through several amplifiers, until the degree of sound desired is reached.

A single tube, with its controls, thus used is known as a "one step amplifier" or as one stage of amplification. If another is added, the two are called a "two step amplifier" or as two stages of amplification.

Now, it must seem quite evident that the more powerful the transmitter employed, the more far-reaching must be the radio waves. Conversely, the more sensitive the receiving set, the greater its ability to receive weak radio waves. In fact, with a given receiving set the radio waves from a transmitter four hundred miles away may be too weak to be detected, while the same waves can be readily detected and heard with an elaborate receiving set which includes suitable sound-amplifying apparatus.

Chapter XIII.

Broadcasting.

A number of stations have been engaged in broadcasting since before the war, but these efforts were of a more or less experimental character and were unknown to the general public.

On election night, 1920, the Westinghouse Electric and Manufacturing Company sent out from its station at East Pittsburgh, Pa., the results of the Harding-Cox balloting. This undertaking was so well received by the thousands of radio amateurs who heard the reports, that it was decided to broadcast a definite programme every night from then on. This programme consisted first of "canned" music, but within a very short time artists were invited to perform in person. Then news, sporting events, speeches by prominent men, and other features were added, and in February, 1921, arrangements were made to broadcast the services from Calvary Church, Pittsburgh, regularly every Sunday night.

By this time the general public began to hear about the etherial music and news. Interest in it was immediately aroused, and grew so rapidly that by the fall of 1921 it was decided to establish broadcasting stations at Newark, N. J., Springfield, Mass., and Chicago, Ill.; and shortly thereafter the Radio Corporation opened its station at Roselle Park, N. J., while many others were established in other parts of the country. With the opening of these stations, broadcasting lost its local character and became a national affair.

Today, etherial concerts can be heard by sensitive receivers in almost every part of the United States. The trapper in Canada and the rancher of Texas alike ask to be provided with the daily programmes of the various stations.

The term "broadcasting station," is well known to thousands. The music and speaking voices are sent out daily to an unseen audience. The audience is familiar with its receiving set but wonders how the broadcasting is done.

Upon entering the broadcasting station the first thing that strikes the observer is the apparent lack of complicated apparatus. Over against one wall is a black cabinet standing possibly four and a half feet high and as many feet across the front. This is known as the transmitting panel. Over the piano will be seen a curious hornshaped affair with a twisted wire running up to the ceiling. Another one of these horns will be seen on a pedestal in front of a phonograph of the latest type. Over the place where the singer is to stand will be seen another horn, usually much larger than the others. A receiving set is on a small desk. The room itself is fitted up nicely, with comfortable looking chairs and an expensive rug.

At the scheduled time, the sending set is put in operation, the knobs on the transmitting panel are adjusted. With a few clicks a distant hum of a generator is brought to the listener's ears. Immediately all talking ceases in the room, because the sensitive transmitter over the piano will pick up every word that is uttered and the thousands in the unseen audience will hear possibly something that is not on the programme. In the upper half of the transmitting panel four lights burn brightly, and upon closer inspection they will be found to be big brothers to the vacuum tube that is used by so many amateurs for receiving. Now the operator motions to his assistant, who immediately winds up the phonograph. A record is selected and the second operator holds it up to his chief. The chief now has what appears to be an ordinary desk telephone in his hands and he is seated comfortably before the desk. He speaks slowly and distinctly into this telephone transmitter and the announcements are sent out that are already so familiar.

Broadcasting of information wide in range and priceless in its educational value is given freely to the people of the United States—and even over the borders into Canada and Mexico.

The moment one or two large corporations interested in the manufacture of radio apparatus hit upon the plan of popularizing wireless communication by establishing broadcasting stations and sending news, market reports, sermons, bedtime stories and concerts through the ether, free to any and all who have an apparatus and care to listen in, the new industry, for such it is, jumped ahead in amazing fashion.

Government forces, led by Secretary Hoover, are following the rapid developments in radio without partiality, and with an eye to conserving the full benefits of the new art for the whole public. Mr. Hoover sees no future for radio if we attempt to use it for promiscuous intercommunication. It is his idea that the wireless telephone has one definite field, which is for the spread of certain predetermined material of public interest, from central stations. The matter sent out must consist almost entirely of features that are of importance to large groups at the same time. He holds the opinion that the number of sending stations must be definitely limited, and that the big problem is to determine who will do the broadcasting and what will be his purpose.

Communication without wires has been quite highly perfected, but the future holds much in store. We do not yet realize what the result of a discovery of the really basic cause of the manifestation of electric waves and an understanding of the medium through which they travel may mean. It may mean the changing of all existing theories of life and motion.

ACTIVE BROADCASTING STATIONS OF THE COUNTRY

Where Located	State	Station Call
Newark	N. J.	W O R
Newark	N. J.	W J Z
Jersey City	N. J.	W N O
Jersey City	N. J.	2 A 1
New York	N. Y.	W J X
New York	N. Y.	W D T
New York	N. Y.	W Y C B
New Haven	Conn.	W C J
Hartford	Conn.	W Q B
Springfield	Mass.	W B Z
Medford Hillside	Mass.	W G I
Washington	D. C.	W D N
Washington	D. C.	W D W
Washington	D. C.	W J H
Washington	D. C.	N O F

WESTERN STATIONS

Pittsburgh	Pa.	K D K A
Pittsburgh	Pa.	W P B
Indianapolis	Ind.	W L K
Toledo	Ohio	D W Z
Cincinnati	Ohio	W M H
Detroit	Mich.	W B L
Chicago	Ill.	K Y W
Madison	Wis.	W H A
Omaha	Neb.	W O U
Minneapolis	Minn.	W L B
Kansas City	Mo.	9 Z A B
Lincoln	Neb.	9 Y Y
Denver	Col.	9 Z A F

PACIFIC COAST

Los Altos	Cal.	K L B
Pasadena	Cal.	K L B
Los Angeles	Cal.	K Q L
Los Angeles	Cal.	K Y J
Los Angeles	Cal.	K Z C
Hollywood	Cal.	K G C
Oakland	Cal.	K Z M
Oakland	Cal.	K Z Y
Sacramento	Cal.	Z V Q
San Francisco	Cal.	K D N
San Francisco	Cal.	K G B
San Francisco	Cal.	K Y Y
San Jose	Cal.	K Q W
Stockton	Cal.	K J Q
Stockton	Cal.	K W G
Sunnyvale	Cal.	K J J
Seattle	Wash.	K F G

Most of these operate on a 360 meter wave length.

GLOSSARY

Aerial, or Antennae:

The wire, or wires used to radiate energy into the ether, or to receive this radiated energy.

Alternating Current:

A current which flows in one direction and then in the opposite. Similar to an ocean wave.

Alternator:

An electrical machine used to generate alternating current.

Alternations:

This term is used to express the frequency of an Alternator.

Amplifier:

An instrument used to increase the volume of sound.

Amplitude:

The distance from the center to the crest of a wave, or one-half the distance from the hollow to the crest of the wave.

Audio frequency:

Vibrations audible to the human ear.

Audion:

A trade name for one form of vacuum tube.

Broadcasting:

Sending either telephone, or telegraph communications through the ether.

Capacity:

An electrical term, relating chiefly to condensers, which are used to store up electricity.

Choke-coil:

Coils used to impede alternating currents.

Circuit:

The continuous path of an electrical current.

Coherer:

A device for detecting the presence of electric waves, usually consisting of metallic filings, inclosed in a glass tube.

Condenser:

An instrument, consisting of alternate layers of a conductor and non-conductor used to collect electric energy.

Continous wave:

A wave in the ether; similar to an ocean wave.

Damped waves:

Electric waves that die out quickly. The action is similar to waves breaking on a beach.

Detector:

A device which changes the electrical vibrations received from the ether into audible vibrations.

Direct Current:

An electric current, flowing constantly in one direction, like water in a pipe.

Ether:

A medium which pervades all space.

Frequency:

The number of complete vibrations per second.

Ground:

A connection to earth, river or sea, is called a ground.

Hertzian waves:

Electro-magnetic waves.

Kilowatt:

1000 watts. An electrical term denoting the quantity.

Loop antennae:

A form of aerial, consisting of wire wrapped around a small frame.

Oscillator

An apparatus used to start electro-magnetic waves.

Period:

The duration of one complete vibration.

Radio Frequency:

Frequencies above audibility.

Rectifier:

A device which converts alternating to direct current.

Resonance:

When a receiving set is tuned to receive a transmitting set, it is in resonance.

Selectivity:

To select any wave length to the exclusion of others.

Static:

Uncontrolled electric discharges in the atmosphere.

Tuning:

To select wave lengths.

Undamped waves:

Continuous waves.

Vibration:

To move to and fro, as a pendulum in a clock.

Wave length:

The distance, usually in metres, from crest to crest of two succeeding waves.