SOUND AND ITS USES

By ARTHUR ELSON

"O father, I hear the church-bells ring;
O say, what may it be?"
"'Tis a fog-bell on a rock-bound coast—"
And he steered for the open sea.

IF Ralph (Rafe) Norman on the boat alluded to above had only known the location of the fog-bell, mentioned in "The Wreck of the Hesperus," there would have been no need for any wreck. It is on Eastern Point, at the mouth of Gloucester harbor, into which his ill-fated ship could have been brought. But according to the poem (and history, too), the skipper drove across to the Magnolia shore, and was wrecked on a rock projecting out from the land. This rock is now known as Norman's Woe; and a certain chasm near it is called Rafe's Chasm.

Fog-bells and fog-whistles are now well known to the coastwise skippers. It was claimed in jest that the early Yankee captains could tell their location by tasting the earth or mud brought up from the sea-bottom; but some modern writer would be nearer the truth if he described an old salt who could tell his whereabouts by the sound of the fog-bells and bell-buoys. Musicians are apt to think that the gift of absolute pitch is of no especial use; but to the fog-bound mariner it would certainly be of great practical value. The bells are not at present made to conform to any system of pitch; but the sailor who has come to know their haphazard pitches will certainly find that knowledge useful.

It is difficult when at sea to tell the direction of a sound by the ear alone. This is shown by the ease with which a man in a rowboat may lose his way when trying to follow guiding shouts, or any other noise, in a fog. A simple device, however, will remedy the trouble; for a megaphone, with the small end held to the ear, will enable the listener to locate the sound correctly. The writer remembers one foggy trip to Gloucester, on the little steamer of many years ago, when the inverted megaphone idea might have saved a little trouble. By some means the boat got outside the fog-bell mentioned by Longfellow. As the land curves around in a horse-shoe, it follows that we were passing the harbor, as if bound for Portland. The ship's superstructure acted as a sound reflector, and showed those who sat near it that the fog-bell must be on their side of the ship. In the pilot-house, however, there was no such guide. The boat edged in gradually until land was seen, and the vessel slid upon a sunken rock. She was backed off without other damage than upset crockery, and brought around properly into port; but the time and the crockery would have been saved if the pilot-house had been equipped with the inverted megaphone device, or some similar cone for receiving sound.

The sound waves do not entirely resemble light waves. They are rathermore analogous to the waves of the ocean. Just as the latter will swish up along a sloping rock, so the sound-waves will surge along a properly curved surface. As an illustration, the Salt Lake City Tabernacle will serve. It is semi-oval in shape, and the sound-waves rush along its gently curved roof and sides in a way that gives excellent acoustical results. The reverse is true of the Trocadero, in Paris. That edifice was built on the principle of reflection, such as light waves would have demanded; and it proved a failure acoustically.

Our lack of real knowledge in architectural acoustics has led to many surprises, both pleasant and unpleasant. Among the former sort are whispering galleries, such as the one in Saint Paul's Cathedral, London. Our own national Capitol reflects sounds from its dome with unusual ease. An unpleasant surprise came when a certain church in Boston was completed and turned over to its congregation; for it was found that every word spoken by the minister was followed by a perfect echo. The church was deemed useless, and sold. The new buyers remedied the defect only after lengthy experiments with galleries, interrupting wire screens, etc.

Fog-whistles are usually made in very deep pitches, as a deep tone carries farther than a high one.

Sirens, in which a revolving wheel allows jets of steam or air to pass through a series of small holes, one after another, may be made to vary in pitch by varying the speed of the wheel. If this variation is made definite, and repeated accurately, the resulting signal will always be the same. This procedure is followed by many light-ships.

A more recent development in marine signalling is the use of submarine bells. These have proven eminently practicable, for sound travels about four times as fast in water as it does in air. At present, each lightship along our coast has a special number of its own; and it rings that number on a submarine bell during thick or foggy weather. Steamers equipped to catch these signals are each provided with a pair of receivers, one on each side, below the surface of the water. Suitable wires lead from these to two telephone receivers in the pilot-house. The pilot, or other officer, holds one receiver to each of his ears. If the signal comes from one side, it will sound more clearly in the receiver on that side. By turning the boat until the sound is equally loud in both receivers, the pilot can make his ship head directly for the lightship. He can then proceed to that ship, and make it a new point of departure.

Submarine signals are being developed in various ways. The company controlling them has been working upon a submerged electric buzzer, of such a nature that its sound will produce an echo from any submarine obstruction within a certain distance. This, it is hoped, will prove useful in locating icebergs, even two or three miles off.

The practical uses of sound in marine work, however, are far surpassed in variety and interest by its various applications on land. Modern business life would have been wholly impracticable without the telegraph and telephone, for example; while in our daily life we take little notice of the cleverness shown in such inventions as the phonograph or the electric bell.

The phonograph, or gramophone, or victrola, is a machine that takes impressions of sound waves on waxy material, by means of a needle carried on a vibrating diaphragm. When the record is used, the process is reversed, the grooves on the finished surface moving the needle, and thus causing the diaphragm to reproduce its original vibrations. The recording material may be hardened for use if desired.

The phonograph devices, with the various sorts of player-pianos and pianolas, have been of great value in disseminating some knowledge of good music, in spite of the widespread desire for rag-time records. The only defect of the phonograph is its inability to reproduce the higher overtones, of shorter sound-wave length. This prevents it from recording the violin tone accurately; and the reproduction of that instrument sounds more like a flute than it should. Brass instruments, however, and piano tones, and voices, are reproduced excellently on the records. The original phonographs recorded sound on cylinders, while the more recent victrola forms use flat circular discs.

The telegraphone is an electrical and magnetic device for recording and reproducing sound. At the beginning of this century it was discovered (by the Dane Poulsen) that magnetism of varying degrees would localize itself on moving metal. In charging the telegraphone, a small telephone circuit is used, of direct-current type. The circuit is made to pass around two poles of an electromagnet. Between these poles, in the earlier instruments, was drawn the fine steel wire that was to receive and record the magnetism. This wire was drawn through at seven or eight feet per second. When a message or any other desired sound enters the transmitter, it produces the usual current fluctuations; and the resulting magnetic fluctuations are located on the wire. The latter is of steel, and is thus permanently magnetized, each part retaining the amount of magnetism given to it by the varying flux from the electromagnet. This magnetic record may be kept for many months, if desired, or may be erased at any time by the use of a stronger magnet. In reproducing the record, the wire is again drawn between the poles of the electromagnet, in the same direction, and at about the same speed. The varying magnetism of the wire now transmits its variations back to the poles of the electromagnet; and the variations of the latter cause the current variations that are recorded as sound in the receiver. The action of transmitters and receivers is explained on later pages. In more recent telegraphones, the drawn wire has been replaced by a revolving steel disc.

The type-reading optophone is an instrument that arouses interest, even though it has not yet come into general use. It aims to reproduce to the ear the letters of a printed line of type, so that blind people may be enabled to read ordinary print. The process depends upon the use of the metal selenium, whose electrical resistance is varied greatly by variations of light falling upon it. The selenium is included in an electric circuit, which contains also the receiver necessary to transform electric current variations into sound. The type, it will be seen, should be printed on one side of the page only. This type is then passed, line by line, over the selenium, so that the shadows of letters will fall upon it. Each letter, of course, casts its own special shadow, and influences the current (and the sound in the receiver) in a way different from other letters. As soon as the optophone user has learned to recognize the different letters by their various sounds, he can read the printed type aurally by passing it through the beam of light that plays upon the selenium. If the light is made to be reflected from the printed letter, instead of merely causing that letter to cast a shadow, the instrument will enable its users to read from any ordinary page, printed on both sides.

Practice will enable the optophone user to proceed at a fairly rapid pace.

The electric bell has come to be one of the commonplaces of modern life. It summons the reluctant bell-boy, for various purposes; it warns the railroad gate-man of approaching trains; it announces our arrival at many a house-door; and in a more advanced form, it summons us to the telephone.

The electric door-bell depends for its usefulness on what is known as a make-and-break device. Macaulay's schoolboy, and many more recent and less gifted members of that class, are all familiar with the fact that an electric current will flow through a closed metallic circuit. The bell is placed in circuit with one or more batteries of sufficient strength. Pressing the button at the door closes the circuit, i. e. makes it continuous, so the current can flow through it. The wires are so arranged that the current, in flowing through the bell, makes it for the time being a magnet. This property of currents to induce temporary magnetism in certain metals is of great use in various forms of the telegraph and telephone.

The visitor's push on the door-bell, and his completion of the path for the electric current, gives the bell so much magnetism that it at once attracts the hammer, or striker, towards it. The result is a single tap on the bell. Were this all, the hammer would rest against the bell until the visitor decided to release the button. The hammer, however, is placed on a long, springy arm; and when the bell pulls the hammer towards it, the springy arm is bent so much that it draws away from a certain wire with which it is normally in contact. The current has been so arranged that it flows through the wire and through part of the springy arm; so that when the arm is bent over to let the hammer strike, it loses contact with its neighbouring wire and thus interrupts the flow of current.

When the current is interrupted, the bell, no longer magnetized, ceases to attract the hammer, The latter, after having received momentum enough to hit the bell once, swings back to its original position. But as the arm swings back, it makes a new contact with the wire behind it, and allows the current to flow again. The bell is thus remagnetized, the hammer attracted again, the bell struck once more, and the circuit again broken by the movement of the springy arm, after which the hammer sways back again. This cycle is repeated as long as the button at the door is pressed in to close the circuit at that point. The cycle is completed so quickly that the bell receives a series of rapid blows. One of the most noticeable things about electricity is its speed; and the rate of a current is said to be nearly two hundred thousand miles a second.

Electromagnets are used in all telegraph work, and in very important ways for all telephone work. An electromagnet consists of a coil of wire, through which a current may pass; and inside this coil is a core, usually soft iron, which is magnetized only when the current passes through the coil of wire. The iron, when magnetized, attracts toward itself another metal piece, known as the armature. This armature is usually carried on some swinging bar, arranged to do certain things when the armature makes it move.

In telegraphy, the electromagnet (with two coils and two cores) is found in what is known as the sounder. When the current is flowing through the sounder, the coils magnetize their cores, which attract an armature and hold it against the magnet. When the current is interrupted, the armature is released by the magnet cores; and a spring draws it back. The bar on which the armature is carried strikes against projections at the end of its motion in either direction; and the sounds that it makes are the clicks which enable the operator to read a message. The letters, of course, are made by various combinations of dots and dashes, i. e. clicks that succeed one another quickly or slowly. Paper tape drawn slowly through a pointed contact will record actual dots and dashes.

The interruptions of current necessary to cause these clicks are made by means of a key, which is merely a lever attached to a spring, and arranged so that the contact and the circuit can be broken by pressing the key, and remade by releasing it, or *vice versa.*

On long lines, even with many batteries at each end, the force of the main current will not make the local sounders give a loud enough click. This is remedied by having an extra sounder in what is known as a relay, or relay circuit. This is simply a short local circuit, with one or more batteries, which is made to pass through the line sounder. It is so arranged that the touching of armature to magnet in the main circuit will complete the local circuit, and make the relay sounder act. The local circuit is strong enough to make the relay sounder click loudly enough for the operator to read messages with ease.

A repeater is a device that makes a sounder in one main-line circuit operate a key in another main-line circuit. The use of repeaters enables the operator to send a message to a great distance.

The length of a single circuit is never more than a very few hundred miles, even when dynamos replace batteries in furnishing the current.

In duplex telegraphy, two messages may be sent along one wire at the same time, in opposite directions. This is made possible by having the relay circuit at each end governed by a lever, and dividing the current. Each half of the current goes through an electromagnet, and the two coils are placed at opposite ends of the lever governing the relay circuit, which contains the sounder. Half the current is sent to the line, and the other half is allowed to enter the ground, through properly arranged resistances. The two stations at each end of the line are made similar. This is known as the Stearns duplex.

It has been shown above that the current from one office, dividing equally about the relay lever, does not influence it to sway in either direction. Any extra current, however, such as comes when the other end of the line is sending a message, influences only one of the two coils by the relay lever,—the one on the line, not the one on the ground connection. This extra current overbalances the lever, and makes it close the relay circuit, which contains the sounder. In this manner it is brought about that the key (transmitter) at each end does not affect its own relay, but governs that at the other end.

It is possible to connect the batteries at each end so that by shifting the connection only a part of them will be used, instead of all. This brings about a further variation in current streugth, used in quadruplex telegraphy.

The so-called polar relay has at each end of the line bar magnets of soft iron, which will be magnetized when the current flows through wires coiled about them. Around each magnet are sets of wires, coiled in opposite directions. Current flowing through one coil will make the magnet active in one direction, and current through the other coil will cause an opposite effect, reversing its north and south poles. This current-shift is made to attract or repel an armature, which acts as the sounder. The current is divided as in the Stearns duplex, each end controlling the sounder relay at the other end, but not influencing its own sounder. This apparatus works by shifting the direction of its current.

A combination of the Stearns duplex and polar relay is used in the quadruplex, which may thus send four messages at a time over one wire, two in either direction. The polar relay is worked by about one-fourth of the total current, and the springs on the duplex sounders are made so strong that they do not act unless the entire current strength is used. The polar sounders act when the current is *reversed*, the duplex sounders working when the current is intermittently *interrupted*. Such interruption affects only the excess of current over that needed to work the polar relay, when the latter is in use.

Induction currents are those which one wire may generate in another wire, parallel to it, without any contact. Edison made use of an induced current for the purpose of establishing communication between stationary offices and moving trains. On the train was placed a long wire parallel to the road, and running the length of the train. The telegraph wires by the road-bed were placed on low poles, so as to be near the train. The induced current in the long train wire was then passed through a sounder. Similarly, a key on the train was used to send messages.

Prof. Dolbear, of Tufts College, used parallel vertical wires for pioneer work in wireless telegraphy and telephony; but he had no coherer, so the distance at which he could operate was only a very few hundred feet.

The simplest telephone is known as electro-magnetic. A horseshoe magnet, of the permanent variety, is provided near the diaphragm of the transmitter. The spoken voice makes the diaphragm vibrate to and fro, approaching the pole of the magnet and receding from it. Around the end of the magnet nearest the diaphragm is wound the wire of the line. The varying magnetic force resulting from the movement of the diaphragm causes a varying current to pass through the coil of wire. If this wire is extended to form the telephone circuit, the current will pass through the circuit. This current is of the alternating type, flowing one way as the diaphragm approaches the magnet, and the other way as the diaphragm recedes.

A second magnet and diaphragm, located at another place, will form a receiver. The vibrations of the first diaphragm are reproduced upon the second one. This telephone, known as the magneto telephone, was the early type used by Bell, its inventor.

The magneto telephone is successful at the receiver end; but as a transmitter, it cannot produce large currents from loud noises. For a practical transmitter, the principle of loose contact and varying resistance was brought into use. Carbon has been the material most successfully used. The current, often provided by a local battery in each transmitter circuit, is allowed to pass from the diaphragm through loose particles of carbon held against it. As the diaphragm vibrates, it alternately compresses and releases the carbon. Although the reason is not known, it is still a fact that the varying pressure on the carbon causes it to vary its electrical resistance considerably. The current for such a transmitter is not alternating, but direct, though it may produce an alternating current on the line.

Since a large electric force is needed for the long wires of the usual circuit, the transmitter current is allowed to produce this larger current in the wire extending to the central exchange. There are really a pair of wires, the telephone not using any ground connection. The current increase is brought about by the use of our old friend the core of soft iron. The wire from the transmitter circuit is wound around it, while the wire of the line circuit is wound around it also, but with a much greater number of coils. This excess in number of coils produces a more active current in the line circuit than in the transmitter circuit.

The variations of current produced by having the diaphragm work against a loose-carbon conductor are very great. For practical purposes, damping springs are put against the telephone diaphragms, so that the changes shall not exceed those of ordinary talking. In certain instruments, however, such springs are not used. The microphone, for example, has none; and as a result it can detect very faint sounds. One of the uses of the microphone has been in navigation. A weight is dragged over the sea-bottom; and the character of the sound enables the operator to tell what kind of bottom is below him—mud, weed, sand, or rocks, for example. The microphone is used also as a very sensitive stethoscope.

Another use of the diaphragm without damping springs is found in the telephonic ear-drums used for deaf people. The receiver is placed in the ear, the battery carried in the pocket, and the transmitter held at any convenient place. The ordinary telephone transmitter can record sounds some distances off, such as footsteps, near-by voices, etc. The loose-carbon transmitter without springs is much more powerful, enabling the user of such an ear-drum to hear voices at a greater distance, in spite of any partial deafness on his part.

The line-circuit produced by the use of the transmitter and doubly-wound coil has an alternating current. An increase of direct current in the local circuit gives an impulse in one direction in the main line, while a decrease of the local current gives a main-line impulse in the opposite direction. Many telephones, however, use direct battery current on the line: in which case the impulses caused by the transmitter are added to or subtracted from the main current, making it fluctuate. It will be seen that the magneto receiver is not suited for use on direct-current lines; and a new type of receiver was developed for direct-current use. Such a receiver lacks the permanent magnet of the magneto receiver, the current being allowed to magnetize the cores by flowing through coils about them. Sometimes a single coil and core is used. The current fluctuations move the receiver diaphragm by the greater or lesser attraction that they give to the magnetic core.

The ordinary telephone bell is what is known as a polarized ringer. This consists of two electromagnets, mounted side by side. An armature is placed below these, and magnetized by a permanent magnet. The armature is pivoted so that when not in use it does not touch the end of either core of the electromagnet, the pivot being on a line between the two cores. The electromagnet coils are wound in opposite directions; so that when a current flows through them it will make one core north in polarity, and the other south. Attached to the armature is one pole of a permanent magnet. The armature, being of one polarity, will be attracted toward the reverse pole, which is one of the two cores in the electromagnet. When the current is reversed, the polarity of the cores is reversed also; and the armature is now attracted toward the other core. The armature carries a rod with the bell striker, which is placed between two bells, and thus strikes them both alternately.

A biassed bell, used with the fluctuating current, is built on similar lines. The bell-striker is made to press normally against one of the two bells, by means of a spring or other device. The current is supplied in direct but short impulses, which attract the armature and pull the striker toward the other bell. As each impulse releases the striker, it drops back to its original position. Each attraction and each release thus means one bell-stroke.

In the old telephones, the subscriber turned a crank when calling central. This crank was attached to a horseshoe magnet, the rotation of which operated the polarized ringer. Now-a-days the mere lifting of the receiver off the hook, allows springs inside the telephone box to complete the circuit that will make the call.

Central office is usually called by the lighting of a lamp, in the circuit made by the subscriber's lifting his receiver. Formerly, and in some cases at present also, the signal consists of some sort of gravity-drop, in which the moving of an armature at the subscriber's office terminal allows a white strip to drop into the operator's view. Similar drops inform the hotel bell-boy what number is ringing.

Large offices now have multiple switchboards, in which each line has several terminals. This enables the operator to make the connection (by a flexible cord containing wires and ending in plugs) with much less movement than if each line had one terminal. Even with this aid, the service is somewhat wearing, and we should not grow impatient with the hard-working telephone girl.

The use of a battery and local circuit for each transmitter becomes rather expensive for a large exchange; and it is customary now for such exchange to have its batteries in the office. The completion of the circuit is made by the rising of the hook when the receiver is lifted off it. The office batteries may be connected to serve for more lines than they could supply if used locally.

Party lines, with several instruments on a line, may be called by using the proper number of rings agreed upon for each subscriber. In these, all bells ring together. There are, however, selective and lockout party lines, in which only one bell responds to the call. In the latter classes, polarity systems are those in which a bell responds to current in one direction, but not in the other, sometimes by the use of oppositely biassed bells. Harmonic systems give to each bell-hammer a different rate of vibration, and each bell has a rate at which it will ring while the other are silent, the operator giving current impulses of the desired frequency. The step-by-step system depends on parts of ratchet wheels at each subscriber's station, the wheels moving one tooth (by escapement pawls, etc.) for each current impulse, but the bell contact being made by a different number of impulses for each station. The broken-line system has a switch at each station, which may be used for its own station or subjected to a current impulse which connects it with the wire for the station beyond and cuts off the station where the switch is thrown. For selective lines, two or four stations are usually included. Lockout lines are used for more than four stations, either the ratchet or the broken-line system being employed.

In telephone train dispatching, instruments known as selectors are used, to call individual stations. These depend uponthe use of ratchet wheels, each station making contact after the wheel has been moved the requisite number of teeth. Such wheels work on the usual escapement principle, but differ from clock escapements in having the power supplied by a pushing pawl, operated by the usual electromagnet. There are, of course, similar magnets and pawls at each station.

The automatic central station for telephone exchanges is certainly one of the great achievements of the human mind. Such stations are in use in many places, and their principles have been employed largely in many others to lessen the work done by operators. Selectors and connectors impart to a vertical bar first a step-by-step rising motion, and then a rotary motion. The bar (selector switch) carries an arm which moves along contacts set in horizontal lines along the inner surface of part of a cylinder. The contact is not made until the "up-and-around" motion is completed, when a little plunger rod is drawn to the contacts. The operations of the automatic exchange are so varied, and the means for bringing them about so intricate, that space forbids anything more than a mere mention of them. The number is called by moving a plate on the transmitter to figures representing the successive digits of the number called. The thousands digit operates a line switch, and after it a first selector, giving contact to a trunk leading to the proper thousands group. A second selector gives the proper hundred, while the connector, on the same principle, picks out the proper ten and unit. At the beginning, each line-switch is made to take care of eight or ten subscribers. The circuit for automatic work has a ground connection, and the transmitter outfit contains certain springs enabling the operator to send impulses over either of the two wires, which are both retained. The use of electromagnets is illustrated at its very best in automatic exchanges, for they perform nearly all of the many necessary operations.

In operating a telephone with automatic central, the subscriber has only to take down his receiver and rotate a plate to successive numbers forming the digits of the number he wishes to call. The plate-release after each rotation allows it to return to its original position by passing over contacts that give the desired number of current impulses for the up-and-around motion at central. The electromagnets do the rest, flashing back a signal if the line is busy. (For a full description of telegraph and telephone apparatus of all sorts, the reader is referred to the Cyclopedia of Telephony and Telegraphy.)

The real development of "wireless" is quite recent, although its principles were foreshadowed in part many years ago. Wireless telegraphy is brought about by electric waves travelling through the ether, at a rate of 186,000 miles a second. Such waves seem to follow the earth's curvature by preference. They are generated by current impulses in an aerial wire, these impulses being made very rapidly in succession by the use of a recurring spark. The impulses in the ether are known as Hertzian waves.

The sending apparatus has some form of current generator, with an induction coil and a "step-up" to increase the current force, the induced circuit having many more windings about the coil than the primary circuit. The spark-gap is in the induced circuit. The key for sending messages is larger than an ordinary telegraph key, to avoid undesired sparks before or after contact; and the wireless key is often immersed in a bath of insulating oil. With this key, dot-and-dash messages are sent through the air. The ether-waves are best sent and received by the use of areial wires.

The relay at the receiving end must have some delicate form of detector, influenced by the electric ether-waves to close a local circuit of sufficient strength to operate the receiving sounder. To speak more accurately, the ether-waves produce a slight curren- in the receiving aerial wire, and this current influences the detect tor. The great variety of detectors in use bears witness to the development of this field of electric work.

The first detectors were coherers, consisting of loose iron filings. The slight current from the aerial was strong enough to make these filings cohere, and serve as a circuit-closer, for the relay current. These coherers are not now in practical use.

The Lodge-Muirhead system has a mercury-contact detector, a drop of mercury between steel discs being insulated by a film of oil, but making a contact through that film when influenced by the aerial. The mercury-contact detector is used by other firms in various forms, and may properly be called a coherer.

Valve, or rectifier, detectors, change the oscillations from the aerial into a steadier current, sometimes by the use of substances like silicon, which conduct in one direction only. This type of instrument is very simple, and much used by amateurs. Another rectifier device is the glow-lamp of Prof. Fleming. This is merely an incandescent bulb, in which negative impulses of electrons from the filament cause a one-way current action. In the bulb is a metal plate, connected to the outside circuit.

De Forest's audion lamp uses similar one-way impulses of electrons from filament to plate; but he has made the process much more delicate by introducing wire grids between filament and plate. Any variation in the charge of these grids causes a much greater variation in the filament-plate current, magnifying the effect from six to ten times.

Marconi uses a magnetic detector, in which endless loops of wire drawn past a magnet tend to hold their magnetism except when a message is being received.

Best among the so-called electrolytic detectors is Fessenden's liquid barreter. Contact in this is made through a fine platinum wire electrode dipped into nitric acid. The oscillations from the aerial pass through this path easily, while small local currents do not. Prof. Fessenden has been one of the most intelligent investigators in the wireless field, which the public mistakenly regards as the domain of Marconi alone. Fessenden has invented also an electrodynamic detector, consisting of a suspended metal disc, which tends to swing into a plane at right angles to the current from the aerial whenever a message is being received.

Thermo-electric detectors respond to the heat caused in very fine wires when a current passes through them.

The sending station of a direct-current wireless outfit has usually an interrupter, acting on the electric bell make-and-break principle, or some other deivce that will produce rapidly recurring current impulses. By regulating this, and by altering the size of the spark-gap, and in some cases by still other means, it has been found possible to tune the waves to any desired rate. These waves are quite long in comparison with sound waves. Thus if 186,000 waves per second are generated, each wave will be a mile long. The Fessenden system has used the tuning principle most frequently. Alternating current generators are now sometimes used for spark production, in which case no interrupter is needed.

In the primary circuit of a sending station is a condenser. This is really a break in the circuit, consisting of two plates with some insulating material between. The electricity seems to store itself up in such plates, one positive and the other negative; and the rest of the circuit acts in many ways as if it were completely closed, with current flowing. Such a circuit will cause a current in the secondary circuit by means of the induction coil. A Leyden jar is practically a condenser.

To sum up briefly, the mechanism for transmitting consists of key, current generator, induction coil, an interrupter, all in the primary circuit, with a spark gap in the secondary (induced) circuit, and an aerial wire, grounded at one end, to take the spark-impulses, either directly or through another induction coil. The receiving outfit consists of the same aerial wire used for sending, a detector, a local circuit which the detector completes, and a sounder or other receiver.

The Marconi system for ships and comparatively short distances now uses an induction coil with mechanical interrupter to charge from six to twelve Leyden jars, connected to a spark-gap, two coils and two sets of jars being often supplied for different wave-lengths. The magnetic detector is used. Shore stations for the best work may have various supplies of current, and do have the horizontal antennae placed with the grounded end in the direction of sending, and the free end in the opposite direction. The magnetic detector, often with the Fleming glow-lamp, is used here.

The Fessenden system, which signalled from Massachusetts to Scotland in 1906, is used by the National Electric Signaling Company. This system is most advanced in the field of selective tuning. The sending key does not break the current, but cuts out a part of the circuit resistance, raising the resulting wave frequency. Receiving stations are tuned to respond to the raised frequency. It is claimed that a frequency alteration of less than one per cent. is enough for the sending of intelligible messages. An interference preventer takes unexpected disturbances from earth or air away from the receiver. The liquid barreter is used for detector purposes. An intensity regulator enables the operator to cut down the oscillatory force for communication with nearby stations.

The Telefunken system of Germany sells its instruments outright, and they are noted for excellence of workmanship. It uses a direct-current generator, interrupter, condensers in both primary and spark circuits, a direct-coupled aerial, and an electrolytic detector. The company has recently adopted very small spark-gaps, increasing the power considerably, and a newly invented detector of its own.

The Von Lepel system uses for its spark-gap two copper boxes separated only by a layer of paper with a hole in it. The sparks burn the edges of the hole, but the paper is easily replaced. This arrangement is directly in the aerial, with a condenser between it and the ground.

The Lodge-Muirhead system has large capacity areas connected with the (multiple) spark balls, to facilitate tuning. The transmitting circuit is coupled directly to the aerial, the receiving circuit taking its aerial impulses through an induction coil. This system has used perforated tape for sending messages, the compressed key making a contact whenever the tape permits.

DeForest's system uses a detector much like Fessenden's barreter, which is made very sensitive. It employs also a syntonized system, using the so-called Lecher wires, which reflect waves having a definite ratio to the wire's total length.

The Clark system makes portable instruments, such as are used in the United States army. The sending apparatus is of the induction-coil type, with condenser and alterable inductance in the spark circuit. The aerial is influenced by induction. The aerial may be switched rapidly from the transmitter to the receiver circuits. Between this point in the aerial and the ground is a variable inductance coil. The coherer has carbon granules between two conducting blocks of steel. One dry cell is put in series with the telephone receiver. Four oak cases contain the entire outfit.

The Stone system, important in America, though little mentioned, has a key that breaks the circuit when used, so that an interruption of the operator, distracting his attention, is not mistaken for the end of the message. After the message is finished, the current is shut off.

The Massie system has an imperfect-contact detector, consisting of an ordinary needle laid upon two edges of carbon, and sometimes held in place by a small magnet.

The Poulsen system employs a carbon-copper spark-gap (carbon making the so-called singing spark), and a magnetic blowout, in hydrogen, i. e., magnets on each side of the spark-gap.

A new system, invented by Anders Bull, makes the receiver respond only to a set of impulses with unequal but prearranged time intervals between them. The timing of the impulses is done by a dispenser, and they are received by a collector operating a Morse recorder. The apparatus is complicated, but the results excellent.

Wireless telephony has been suggested by nearly all who have had much to do with the wireless telegraph, and by others as well. But before it began to develop much, the so-called light telephony was used. In Bell's photophone, light was reflected from the transmitter to a selenium cell, the latter being in a circuit with batteries and a receiver. Prof. Simon noted that a direct-current arc may be made to give a musical note when telephone currents are superimposed upon it. The arc was therefore used in place of a transmitter, and operated in conjunction with powerful search-lights and very sensitive selenium cells. Ruhmer developed this apparatus until it became practical enough for use in the German navy, twenty miles being the maximum operating distance.

In telephony by means of the Hertzian waves, which the wireless (radio) telegraph uses, the waves are first formed, at a desirable high frequency, and then modified by voice currents from some transmitting apparatus. Fessenden has used high-frequency alternators, while Poulsen has employed the oscillating arc as a source for the waves. Poulsen varied his method by using several arcs in series, which is known as the multiple-arc system. In general, the transmitter is made to affect the energy of the waves, and these are made to reproduce the sound on the receiver diaphragm. In the methods mentioned above, the maximum variation of energy probably does not exceed eight per cent.

To adapt the transmitter idea to wireless conditions, Fessenden made the so-called "through," or condenser, transmitter. It is placed in a circuit connected to the aerial above and below a high-frequency generator. The transmitter is practically a condenser, the diaphragm vibrating toward or away from a fixed plate, from which it is insulated by the air.

Radiotelephony, as wireless telephony is called, needs a detector that will not merely react to the impulses in the receiving aerial, but will be sensitive to varying intensity in these impulses. Such detectors are thermo-electric, depending on the amount of heat produced by the varying current intensity; or they may be electrolytic, silicon valve, or ionized gas detectors. The latter form resembles the electrolytic in principle, variations in the condition of atomic change in the gas causing variations in resistance. If the waves received are continuous and steady, the current sent to the telephone receiver is also steady, holding the diaphragm in one position. Variations in this current cause audible sounds in the receiver. Fessenden's so-called heterodyne receiver has two coils, one on the diaphragm, and the other on a fixed core close by. A high-frequency alternator sends through the fixed coil impulses about in tune with the waves received; while the waves cause impulses that are led through the diaphragm coil. Fluctuations in the waves received thus cause variations in the attraction of the two coils. The use of this instrument as a radiotelegraph detector enables the operator to tune it slightly below the wave frequency; and the "beats" between these varying vibration rates make a musical tone in the receiver, the tone being stopped when the waves are interrupted.

For two-way transmission, it is necessary for a switch to be thrown from the sending to the receiving apparatus at each station. Fessenden patented a commutator which alternated the connection with the transmitter and the receiver very rapidly. The calling may be done by an ordinary coherer in circuit with a bell, the circuit being disconnected before conversation is begun.

The Fessenden system, with high-frequency alternators and heterodyne receivers, has sent messages from Brant Rock to New York,—about two hundred miles. The Telefunken system, developed abroad, has operated at fifty miles' distance. The Poulsen system, with umbrella-like aerials 225 feet high, sent messages from Lyngby to Berlin,—325 miles. The Marjorana system, in Italy, is another that can cover over 300 miles. The last-named system uses a very original transmitter. A circuit-breaking gap is closed by dropping water; and the diaphragm, by making this tiny jet vibrate, causes it to vary the connection it makes in the broken circuit, and thus influence the current.

DeForest has recently made practicable a system of telephony without wires that has given remarkable results. Vacuum tubes are used in the sending circuit, in a way not definitely made public. These, often used in Physics, are tubes from which the air is almost wholly exhausted, and which have an electric terminal sealed through the glass at each end. The use of the audion lamp as a relay has already been explained, the grid between the filament and an outer plate influencing by its varying charges the current of electrons passing from the filament to the plate. All this is enclosed in the lamp bulb. This device has proven practicable as a relay in ordinary long-distance telephony. The wireless system is now owned by the United States Government and has been operated between Washington and Mare Island Navy Yard, if memory serves,—a distance of about three thousand miles.

It is not probable that wireless service will come into popular use at all quickly; but that should not detract from the credit due to those who have brought it to its present remarkable state.