AN INTRODUCTION TO RADIO

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An Introduction
to
Radio

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AN INTRODUCTION TO RADIO

Vol. 1

Vol. II

Chapter I

An Introduction to Radio

A short time ago, radio was a mysterious science to the layman, while today practically everybody is seeking knowledge of this branch of science. There is nothing difficult to understand about radio, and once an interest is awakened it does not readily abate.

Many are still prone to believe that radio impulses are made up of flashes resembling lightning which jump off something called an aerial, and speed away through the air until they bump into the station to which they are being sent.

We have probably all heard of wireless or electromagnetic waves. These are waves in the ether. But, what is ether? Ether is, we might say, an invention of scientists. Some years ago, when scientists attacked the problem of light, they found that it did not travel through the air. What it did travel through was not apparent. They decided that there must be some all-pervading substance, and they called this intangible something, "ether." Ether was a product of the resourceful imagination of scientists. We are told that ether is everywhere, the world is surrounded and soaked in it. It is all-pervading. It is neither a gas, liquid nor a solid. It is invisible, unweighable and odorless.

Now that we know all there is to know about the ether, let us go back to the subject of wireless waves. We have said that there are waves in the ether. Just as there are waves in the water, so there are waves in the ether. If a stone is dropped into a quiet pond of water, little waves spread out from the source of the disturbance in all directions, as shown in Figure 1. The size or length of these waves would depend upon the size of the stone that was dropped into the pond. If a larger stone were dropped into the water, it would create a greater splash and the length of the

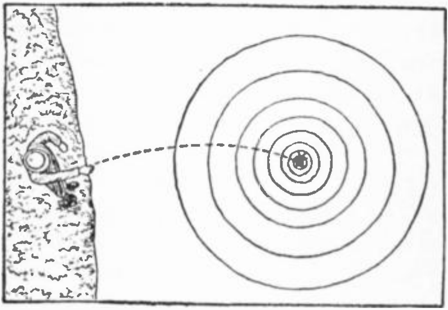


Fig. 1
Diagrammatic analogy of water waves and ether waves

resulting wave would be greater. The length of a wave is measured from the peak of one wave to the peak of another. The wave length in a small puddle might be no more than two inches, while ocean waves have a length ranging from fifty to three hundred feet.

From the foregoing paragraphs we learn that the length of waves will depend upon the number of them passing a given point in one second, or, we may say, their *length depends upon their frequency.* Small waves may have frequencies as high as ten or fifteen a second, while long waves may have a frequency of but one per second. We can understand *that the more waves that are crowded into a certain space the shorter the waves will be.* (See Figure 2.) We must impress upon our minds the fact that wave-length depends upon frequency.

We can assume that waves are produced in ether just as they are produced in water. Splashes in the ether result in waves just as do splashes in the water. (See Figure 3.) However, waves cannot be set up by dropping a brick in the ether, because the brick has no hold on the ether. Heavy electric discharges may be used to produce waves in the ether. We might liken these electric discharges to an "electric brick."

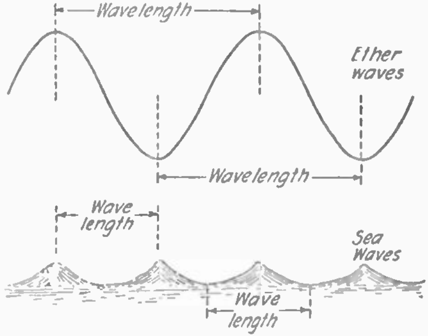


Fig. 2

Wave length depends upon frequency

Our understanding of ether waves brings us into many byways. It is now necessary to consider "alternating" and "direct" current. Many of us use alternating current for lighting purposes in our homes, while others use direct current. The difference between an alternating and direct current is simple. A direct current flows continuously in

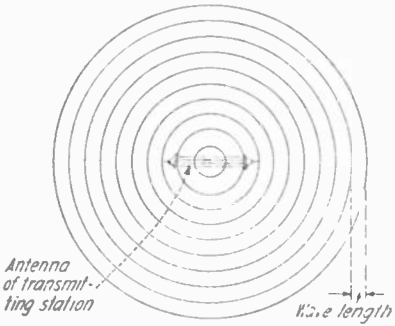


Fig. 3

The generation of ether waves

in one direction like water flowing through a pipe. An alternating current flows first in one direction and then in the other; it has a to-and-fro motion.

An alternating current can be said to vibrate and when a thing vibrates it always does so at a certain rate or "frequency." Alternating current used for lighting purposes is said to be of "low frequency." In some cases, it goes back and forth as many as 120 times per second and in other cases only 25 times. This frequency may be increased by suitable means, and as the frequency mounts higher and higher, the current grows wilder and wilder in its action until it is rushing back and forth several hundred thousand times a second. When this condition is reached the current is said to be of high frequency. Radio or wireless waves are generated by such high-frequency currents.

High-frequency currents are necessary for the production of wireless waves through space, or through the ether, in which they form electro-magnetic disturbances. The frequency (the number passing a given point in one second) of these waves is equal to that of the current that produces them.

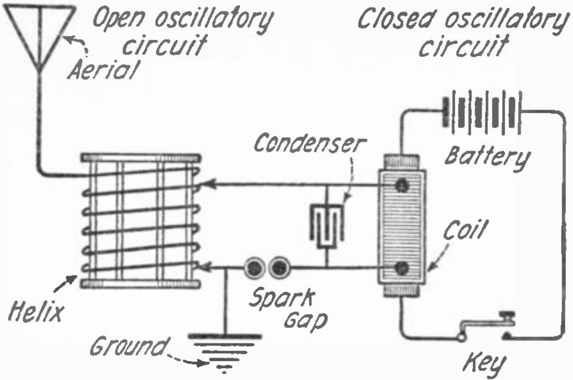
High-frequency alternating currents oscillate so rapidly that they entirely lose their hold on material things and leap off into the intangible ether. We might compare them with the little Jumping Jacks that we all played with when we were children. The monkey was so arranged on the stick that it would jump back and forth as rapidly as we could manipulate it. If the monkey had been attached in some way to a machine that could have speeded up its movements, it would have reached a point where it would have left the stick.

It has been said before that the length of the ether wave depends upon the frequency of the current producing it. If the frequency is extremely high, the resulting ether waves will be short and if the frequency of the current is low the waves produced will be long. The frequency of an alternating current depends upon the electrical properties of the circuit in which it is produced. First it depends upon the amount of wire in the circuit. We may say that the frequency of a current produced in a circuit with ten feet of wire will be twice that of the current in a circuit composed of twenty feet of wire. We will all realize that if the currents are travelling at the same speed (and they always do travel at the same speed), it would take the one travelling twenty feet twice as long to get around as it would the one with only ten feet to travel. From this we learn that the frequency depends upon the "inductance," and the "inductance" means nothing more than the amount of wire in a circuit. If a circuit has much wire, or inductance, the current will take such a long time to get around that its frequency will be comparatively low.

Resistance is another property of an electric circuit which is equally as important as inductance. Every moving thing, even electricity, meets with some resistance. To roll down hill, a ball must overcome a certain amount of resistance. Electricity flowing through a wire meets with resistance. The resistance met with here depends upon the nature of the metal making up the wire, the length and size of the wire. The size of the wire is important, because electricity will flow with greater freedom through a large wire than through a small one, just as in the case of water which flows more rapidly and easily through a large pipe than a small one. If the wire is small its resistance will be high. High-resistance wire is a deadly enemy to electric currents, since it tends to hold them back. When the resistance is too great the current loses some of its "pep" and cannot dart back and forth as strongly as under better conditions.

Electric circuits also have another property which influences the current flowing through them. This is called "capacity," but for the time being we will not attempt to enter deeply into an explanation of this property. It will be treated later.

We have now reached a point in our subject where we will consider the actual apparatus employed in producing electric waves or "splashes" in the ether. Before going into this angle of the subject let us study the accompanying sketch. (See Figure 4.) Here we will see what is known as a key, an induction coil, a condenser, a spark gap, a helix, an aerial and a "ground." The key is merely a hand-operated switch. It works on the same principle as the switches used in controlling lighting systems. It is so arranged that dots and dashes can be formed with it. By pushing the lever down the circuit is "closed," and current from the batteries flows into the



Open oscillatory circuit
Closed oscillatory circuit
Aerial
Condenser
Battery
Coil
Helix
Spark Gap
Ground
Key

Fig. 4

induction coil. We can simply look upon the induction coil as a device to increase or "step-up" the voltage of an electric circuit. A pressure of 5 volts may be increased to 50,000 volts. An induction coil might be regarded as a pump producing a high electrical pressure. When the current issues from the high voltage side of the induction coil, it has a good deal of vigor and sting to it.

The current produced by the induction coil passes into what is known as a condenser. A condenser is a receptacle which will hold just so much electricity at a given pressure. In other words, it has a definite "capacity." This brings us into a better understanding of capacity. The capacity depends upon the size of the condenser since a large one takes longer to fill than a small one. When a condenser is "filled" it acts in a peculiar manner. The condenser becomes "full" and discharges. The storedup electricty then rushes across the spark gap, from one side of the circuit to the other. This process of rushing back and forth is continued until all the energy is used up. When once fully charged, a condenser can discharge and recharge itself many thousand times in the space of a single second. Each successive charge becomes weaker than the preceding one.

Some of us, by this time, will have decided that the condenser when used in the circuit, as shown in Figure 4, is merely a device used to produce high-frequency alternating currents. This is quite true. The condenser referred to is simply a producer of high-frequency currents. These currents rush madly around what is known as the "closed oscillatory circuit." We may liken this to a circus ring.

We will all understand that the frequency with which the currents whirl back and forth around this oscillatory circuit will depend upon the size and nature of the wire (resistance), the length of the wire (inductance), and the size of the condenser (capacity). If currents of extremely high frequency and correspondingly small wave length were desired, we would use a small condenser and a small amount of extra large wire. The condenser would fill rapidly and the currents produced would meet with very little resistance in darting back and forth.

In glancing again at the diagram we notice the "open oscillatory circuit." We will not go into an explanation of the actual process undergone in inducing these currents into the open oscillatory circuit. The aerial, or open circuit, is tuned to the closed circuit, otherwise the currents could not be induced to leave the closed circuit.

We will now see what happens when our currents are playing around in the aerial circuit. The aerial circuit might be called the open door which leads out into the ether. The high-frequency currents jump from this circuit into space and they do so with great rapidity, reaching a speed of no less than 186,000 miles per second. So terrific is their pace that they are able to encircle the earth several times in the space of a second.

The wireless transmitter just described produces what are known as "damped" waves. We must go back to the condenser to discover the meaning of "damped" waves, since it is the condenser that creates them. We learned that the condenser produced currents that gradually faded out as they rushed back and forth from one side of the device to the other. In radio language, "they damped out." This "damping out" effect is noticeable in the waves they produce in the ether. The waves start out and swing back and forth in a lively fashion. Then they gradually fade away and another one starts. A damped wave train is shown in Figure 5. Many hundreds of thousands of these little wave trains are produced in the space of a second.

An undamped wave is continuous. There is no fading effect. This wave starts out with a certain swing and keeps it up until it is cut off entirely. Continuous or undamped waves are rapidly replacing the other variety for radio uses. (Undamped waves shown in Figure 6.) They are produced by a very special apparatus which cannot be confused with the crude instruments just considered.

There is another method of setting up ether splashes which is known as the "arc" method, shown in Figure 7. Waves propagated by an arc transmitter are of a continuous nature. Probably few of us understand how an arc light works. If two carbon rods are connected up to a source of controlled cur-

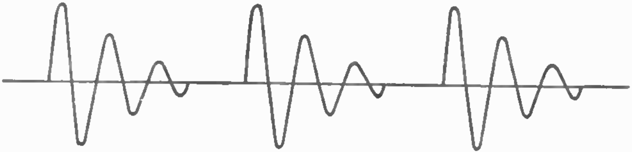


Fig. 5

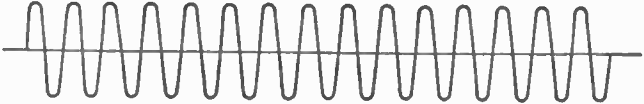


Fig. 6

rent, an arc will be produced between them when their ends are touched and then drawn apart. This arc produces a temperature as high as 7,500 degrees

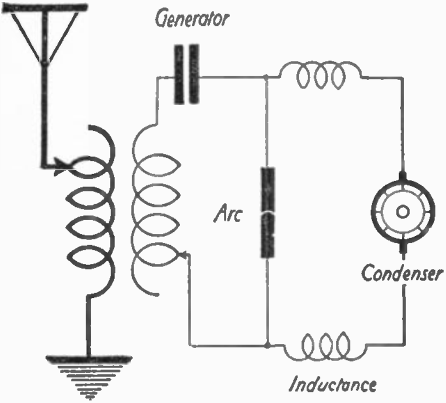


Fig. 7

Circuit diagram of an arc transmitter

Fahrenheit. However, this heat has nothing to do with its action as a producer of electric waves. Once the arc is established, current will continue to pour across the heated gap. Used alone, the arc does not create much of a disturbance in the ether, but when a condenser and inductance are connected around it, or "shunted across it," as the radio men say, it is no longer passive. It starts at once to charge the condenser, and when the condenser is "filled," it discharges. This discharge, however, is different from the discharge when the condenser is used in connection with an induction coil. If direct current is used in connection with the arc, a continuous discharge will be produced by the condenser. If the condenser is connected up to the aerial, a series of orderly waves will be sent off. These are known as "C.W." or continuous waves.

We will now consider another method of producing continuous waves which is of commercial importance. We have learned that the current that produces electric waves differs from the alternating current that lights our homes only in the matter of frequency. These low-frequency currents which we use for power purposes are produced by generators.

As wireless developed, the engineers at first reasoned that a mechanically driven generator could be used to produce the high-frequency currents. There were certain obstacles to overcome to do this, however. First, an alternator producing a high-frequency would have to be run at a terrific speed. To produce high-speed with large power generators such as those which would have to be used in long distance transmission of wireless waves, was a problem. A heavy piece of machinery, when brought to a high speed is very apt to fly to pieces carrying everything with it. The friction problem was also enormous. However, the efficiency of such a machine could not be denied, since it could be hooked right up to the aerial and the waves sent forth direct.

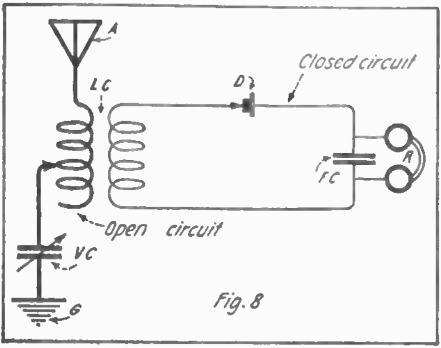
After engineers had worked on this problem for a number of years, it was finally solved. Ernest F. W. Alexanderson, of the General Electric Company, succeeded in designing a high-frequency alternator of the type invented by Fessenden. The machine which he produced is so powerful that it may be used to carry on continent-to-continent communication. This alternator is a triumph of engineering. Bearings had to be specially built to accommodate its rapidly revolving shaft, and its rotating member had to be machined to less than a hair's breadth of accuracy. Then, the method of driving this rotating member had to be invented. Motors of sufficient size would not operate at this speed. This brought up the necessity of connecting the driving motor to the alternator through a train of gears. This train of gears increased the speed in the same manner that the speed is increased in the kitchen egg-beater. Most of the American trans-oceanic stations employ the Alexanderson alternator, and its faithful performance in the transmission of messages reflects great credit on the engineering wisdom of the designer.

There is still another method of producing continuous waves. This is done with the vacuum tube, and is of such importance that we will not treat it here but will devote an entire chapter to the subject later.

Now that we have produced the electric waves and sent them out into the ether, we come to the problem of catching them again. Their production is only half of the battle. They must next be detected. How does a radio receiver "work"?

Let us now give our attention to the sketch of the receiving apparatus, shown in Figure 8. First and foremost we will notice the aerial and the ground.

This will indicate to us that an aerial and ground are necessary both in transmitting and in receiving. Connected to the aerial we will notice a tuning coil. This is also called a "tuning inductance" by wireless men. On this coil we will



Inductive coupled receiving circuit

see a slider. This slider is used to adjust the amount of wire used. If the slider is adjusted midway of the coil half of the wire in the coil will be active and half inactive, or, in other words, half of the wire will be in the circuit and half will be out. The tuning coil is an instrument with which we add wire to the aerial. It is this tuning coil that makes it possible to coax the oncoming electric waves into the aerial. If the tuning coil is not adjusted to receive it the wave will pass by the aerial.

The process of tuning in is a very simple one, and yet many amateurs or newcomers in wireless believe it to be a mystery. The wave length of wireless waves is measured in meters. A meter is 39.37 inches. A wave 200 meters long will be $\frac{39.37 \times 200}{12}$ or 656 feet long. When a 200-meter wave is approaching the aerial, there is only one way to receive it. We must have the aerial tuned to 200 meters. However, if we have a condenser in our aerial circuit this would also affect the receptivity of the system. This condenser must not be confused with the one which is used to set up oscillations. We can conclude that capacity in the form of condensers changes the wave length of a receiver. Receiving condensers are adjustable so that circuits can be tuned with them.

In the above mentioned case the condenser and the tuning coil will be adjusted until the "inductance" and "capacity" will be equivalent to 200 meters of wire. The size of the wire must also enter into the calculations, since too small wire would choke off the oscillations before they had half a chance. We will go on understanding that a wireless wave is coaxed into an aerial by adjusting the aerial through modification of the amount of wire, and the capacity until it is able to accommodate the incoming wave.

What would happen if a 300-meter wave came in contact with an aerial tuned to 250 meters? If the tuning was exact, the 300-meter wave would pass right by, as there would be no inducement for it to enter. If the tuning was sharp we would not get any interference. If it was not sharp, a 200-meter wave might be induced in and we would have more than one signal in the circuit and none would be clear.

The question of wave length is an important one. The Government awakened to this fact some time ago. When amateur radio was in its infancy, the experimenters were allowed to send their messages on any wave length and with any power. Finally their wave lengths grew until they were interfering with commercial stations. Then the Government took a hand and a law was passed limiting the amateur to a transmitting wave length of 200 meters. This eliminated the possibility of interfering with business traffic. Receiving can be done on any wave length which the set is capable of attaining. Commercial stations use from 600 meters up to several thousand.

When this electric wave is induced into the circuit, it is again an electric current. It started from the transmitter as a current of electricity and now after passing through space as waves we have it resuming an electrical form in the receiver. This current however, is an extremely weak one, and ultra-sensitive instruments would have to be used to measure its magnitude.

The current flowing in the aerial circuit induces a similar current in what has been noticed as the closed circuit in the sketch. We will assume that this closed circuit has also been tuned so that it is resonant or "in tune" with the other circuit. In the second circuit we will see a detector. In conjunction with this detector there is used a telephone receiver. The detector doctors the currents in such a way that they become audible in the telephone receiver. Here they are discernible as little humming noises, like the buzz of a bee.

Detectors are both interesting and important. To appreciate their importance we must first realize that we have an alternating current of high frequency flowing through the circuit. If this alternating current was allowed to go directly into the telephone receivers, the vibrations would be so rapid that there would be no audible sound produced. When vibrations go beyond 20,000 per second, the human ear cannot detect them.

This detector is composed of a small crystal, such as galena or carborundum, held in a metallic cup with a tiny spring or wire resting on its surface. This crystal acts like a water check valve. We all understand that a check valve on a water pipe allows the water to pass freely in one direction and cuts off its passage in the other direction. The crystal does the same thing with high-frequency currents. It allows them to pass in one direction but not in the other. As a result of this, we have what is known as an "intermittent direct current," which is made up of little jabs all going in one direction. This is due to the fact that the half of the current which tries to get back is entirely cut off. From this we will see that the frequency of the current, as far as its vibratory effect is concerned, is cut in half. It is brought from inaudible to audible frequency and allowed to pass into the telephone receivers where it produces a humming sound. It is in this way that the dots and dashes produced by the operator are heard at a distant receiving station.

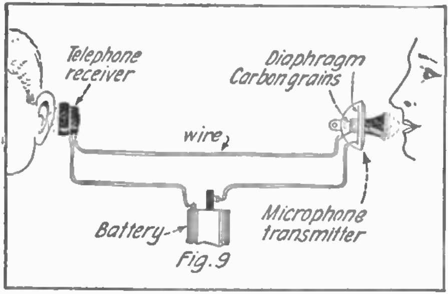
Before passing on to the next chapter, we must impress upon our minds the fact that wireless messages or waves travel in all directions. If the transmitting power of a station is fifty miles, every station with properly attuned receiving equipment within that radius will receive the message.

Chapter II

Radio Telephony

Radio telephony followed radio telegraphy just as Bell's telephone followed Morse's telegraph. When Bell listened to the human voice over the first telephone lines, he did not realize that it would some day be possible to carry on conversation without wires. However, science never stops, and almost before wireless telegraphy was perfected wireless telephony was anticipated. Today, everywhere about us the spirit voices of radio fill the ether. To hear these intangible voices we must have an electric ear, made up of various coils, detectors, phones, etc.

Before we go deeper into the subject of radio telephony, let us briefly consider the principles of voice transmission over copper wires. How is the man in San Francisco able to hear the voice of the man in Boston? He really doesn't hear



Operation of telephone transmitter and receiver

the voice of the man in Boston. The voice of the Boston man is translated into electrical impulses which are carried along the wire to the distant receiver where they are made audible.

There are two important parts of a telephone, the transmitter and the receiver. (See Figure 9.) The voice is directed into the transmitter and the receiver is held to the ear. An understanding of these two simple devices and their operation, is equivalent to an understanding of the fundamental principle of the telephonic transmission of sound.

When we speak into a telephone transmitter, the sound waves from our vocal organs strike against a thin metal diaphragm. Sound waves are tangible and they cause a momentary pressure when they strike the diaphragm. The diaphragm thus vibrates in sympathy with the voice of the person speaking.

A little compartment of carbon granules is placed back of the diaphragm and these little granules form part of the telephone circuit. The little grains are pinched together by the vibration of the transmitter diaphragm. This "pinching effect" occurs many hundred times per second. Electrically speaking, the pinching of these little grains together has the effect of making a better electrical contact between them, and this in turn lowers the resistance they offer to the passing current. With this simple carbon grain arrangement we are able to impress upon an electric current all the fluctuations that correspond to the human voice. The current is caused to "vibrate." This "vibrating" current enters the receiver at the distant station and there it produces an audible sound by causing another diaphragm to vibrate in unison with it. This is an extremely simple process, but very important.

In wireless telephony these voice vibrations are sent over the ether instead of over a conducting wire. However, there is still a use for the transmitter and receiver. In wire telephony, direct currents must be used. By direct current, we mean a smooth, steady current flowing in one direction that will carry the voice without distortion.

Some attempts were made to transmit the human voice through the ether with ordinary spark systems of wireless similar to that described in the last chapter. We have previously learned the difference between damped and undamped waves. We have been told that a wireless transmitter of the spark type sets up splashes in the ether that produce what are known as damped waves. We might call these discontinuous waves. These discontinuous waves are disconnected ripples in the ether. When we consider that the voice waves are uninterrupted, we will understand why it is futile to attempt to transmit the human voice with a spark transmitter. These waves will carry the voice, but there will be blank or "still" spaces between the waves when the voice waves will be lost, since there will be nothing to carry them. This can be readily understood by referring to Figure 10. Thus we will see that some other method must be used

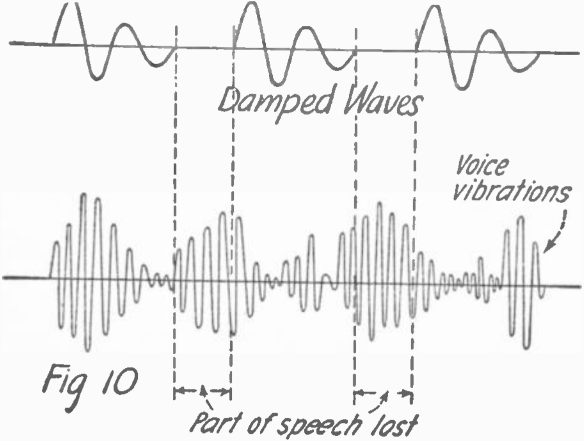


Fig 10

to carry the voice in wireless telephony.

This method will embrace the use of continuous waves. If the voice is properly superimposed upon such waves, they will carry it faithfully to its destination wherever that may be. In continuous waves there are no interruptions.

In a previous part of the course we learned something about continuous wave transmitters. An ordinary arc, when "shunted" with a condenser will produce continuous waves. The Alexanderson alternator and the vacuum tube are also used in continuous wave transmission. If we place a telephone transmitter in the proper part of a continuous wave transmitter, the voice will alter the waves in such a way that it will be audible at the distant receiving station. The voice is impressed upon these waves in the same way it is impressed upon the continuous current in a wire telephone circuit. This "impressing" process is known as modulation, and it is only during the last few years that engineers have learned the secret of good modulation.

Modulation is not a problem in a small, low-powered wireless telephone transmitter, but becomes one in the high-powered stations where heavy currents are handled. Here the telephone transmitter is found entirely inadequate. Comparatively weak currents are surging through it when it is used on a wire telephone, but in a powerful wireless telephone transmitter, it is called upon to handle extremely heavy currents. These currents are so heavy that they would render the device useless by fusing together the little carbon granules.

Modulation was a problem in wireless telephony for a number of years, and all the early engineers met and struggled with it. At that time the problem lay in producing a telephone transmitter that would handle heavy currents without "packing." Most of the early experimenters used the arc as a source of waves. One attempt, which at first proved encouraging, but later was found to be of little value, was to connect a number of telephone transmitters and arrange them in such a way that the person could speak into all of them. In this way it was possible to divide the heavy currents between the transmitters instead of letting one transmitter bear the burden.

One of the most successful experimenters in the early days of wireless telephony was Prof. R. A. Fessenden. Fessenden was instrumental in making a lot of very interesting wireless history. In 1901 he applied for a patent on "Improvements in apparatus for the wireless transmission of electromagnetic waves; said improvements relating more especially to the transmission and reproduction of words or other audible signals." In 1908, Fessenden constructed a high-frequency alternator, and, using this in connection with a special telephone transmitter, he was able to carry on radio telephonic communication over a distance of six hundred miles. Among the men who made valuable contributions to the art of wireless telephony, the following stand out as leaders: Duddell, Poulson, Bell, Dubilier, De Forest, Collins, Majorana, Vanni, Moretti and Valluri.

The problem of modulation was finally overcome by that useful little unit, the vacuum tube. The vacuum tube is so constructed that it is possible for it to cause a very weak current to control a very heavy current. Therefore, if the telephone transmitter is placed in the weak current circuit, the heavy current can be made to obey perfectly. The heavy current will vibrate in unison with the weak current when the transmitter is spoken into.

The successful application of the vacuum tube to radio telephony was only made possible after much experimentation.

Radio telephony can not yet be looked upon as a competitor of wire telephony, but rather as a helper. The radio telephone is fast becoming an important unit in our wire telephone system. It is being used to bridge gaps that cannot be covered by telephone cables. Today we can go to our telephone and ask the operator to get us a party in the Catalina Islands, which is about thirty miles off the Pacific Coast. This connection is made possible by the use of radio, which is employed to bridge the gap existing between the exchange at Long Beach, California and the exchange at Avalon, Catalina. At Long Beach, California, the voice would be passed into a wireless telephone transmitting apparatus which would, in turn, send it into the ether. It would travel through the ether a distance of thirty-one and one-half miles to a wireless receiving station at

Pebbly Beach. At this point the speech currents are shot back into the wire telephone lines and carried on to Avalon. The person talking, if uninformed of the radio link, would firmly believe that his voice and that of the person he was speaking with, were being carried by the usual wire system entirely. Two-way communication is carried on just as conveniently as it is in wire telephony. The installation of this system is not an experiment. It is an established unit of the telephone system of this country.

CHAPTER III

THE VARIOUS INSTRUMENTS USED IN RADIO TRANSMITTING AND RECEIVING OUTFITS

Chapter I has conveyed to us a brief explanation of the production, radiation, transmission and reception of these electromagnetic disturbances through space by means of the art of radio telegraphy, which we shall now try to study more in detail.

One knows very well that in the study of any new profession, science or art, he must first become familiar with the working tools, terms and parts which go to make up the complete mastering of the profession. For example, if we are to study a language we must learn what nouns, verbs and adjectives are. Then if we are to become a machinist we must learn what a hammer, chisel, drill and other various tools are and how to use them. Take another example, as for an accountant. We must learn the terms debit, credit, journal, ledger and what part they play in the system.

The same is true in the radio profession. In order to intelligently understand the workings of the complete system, we must become thoroughly familiar with the parts, how they are made and what part they play in the operation of the system.

We must first have a source of power for our production of radio waves and the electric current in its various forms is adaptable for this purpose. In our homes and cities we find two common types of current being furnished for power and lighting purposes. One is what is known as direct current, or a current which flows always in the same direction, just as the water in a brook

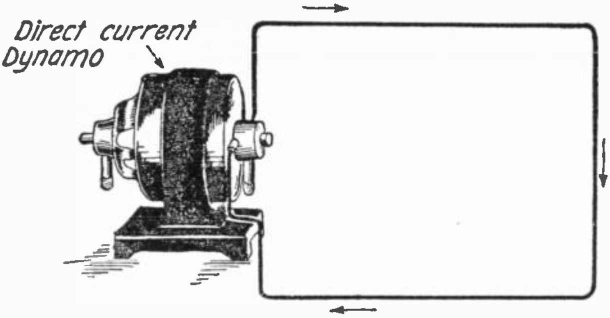


Fig. 11

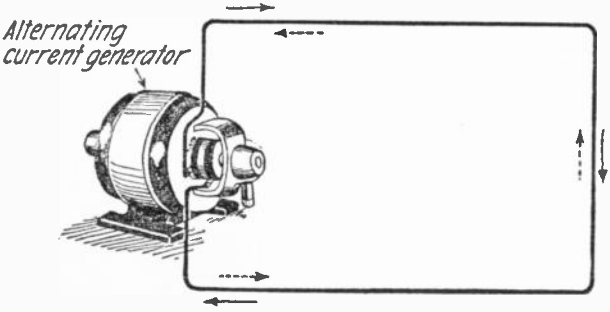
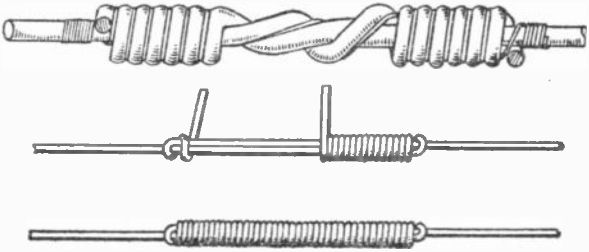


Fig. 12

is always flowing from the spring down into the river and is nearly constant in its value. In other cases we have what is known as alternating current, or a current which flows one way and then reverses and goes in the other direction, changing its direction very rapidly, as many as 50 to 120 times per second. This kind of current is furnished almost altogether, outside the very centers of our large cities, because it is much easier to transmit through wires without excessive losses. Figure 11 illustrates a direct current generator with the circuit, and Figure 12 is an alternating current generator.

Now that we have spoken of our electric energy, which is developed by dynamos or generators, sometimes called alternators when they produce alternating current, we must turn our attention to the manner in which this power is conveyed to our radio apparatus. We all know it is through copper or other

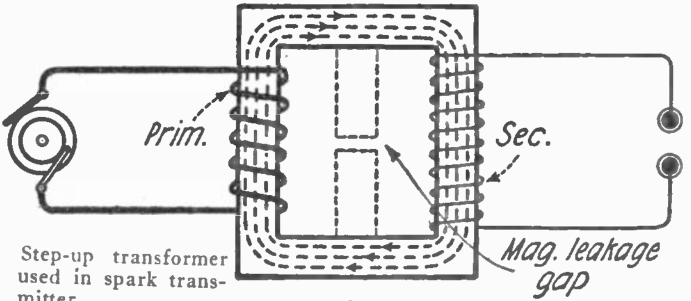


Method of splicing wire

Fig. 13

metal wires carefully insulated with rubber or some other non-conductor of electricity. These wires must often be connected together and in doing so the connection should be made very carefully so that the current will find a ready path from one wire to the other through the joint. The proper method of making the spliced joint by wires is shown in Figure 13. The two ends of the wire should be carefully cleaned by scraping the surface with a knife or some other sharp tool until it is bright and shiny, and then after they are twisted together they should be soldered, if possible, and then carefully wrapped with rubber, then cloth tape over this rubber to protect it against injury.

Now that we have found a source of power and means of conveying it to our radio transmitter, we should consider the important parts of the machinery for developing our high-frequency currents. Many times we must change the pres-



Step-up transformer used in spark transmitter

Fig. 14

sure of the electric current furnished for our transmitter and this is accomplished by means of what is known as a transformer, which is illustrated in Figure 14. It consists essentially of two coils of wire wound upon an iron core, the current entering one of the coils and creating in the other coil another current of a different pressure. The ratio of the pressures in the two coils is in proportion to the number of turns of wire in the coils. That is to say, if the pressure entering the first coil (the one on the left) was 100 volts and had 100 turns of wire, and the number of turns of wire in the other coil (at the right) had 1,000 turns, then the pressure would be 10 times 100 volts or 1,000 volts, due to the fact that the 1,000 turns coil had 10 times as many turns as the first coil of 100 turns. Where the pressure is increased by a transformer, it is called a step-up transformer and if the pressure is decreased, that is, reduced in value, it is called a step-down transformer. We shall find these transformers in use in other parts of our radio apparatus and so we should become familiar with the piece of apparatus known as a transformer.

In Chapter I the term "capacity" was used, which referred to the storing power which a body might have for electric current, and concerning which we spoke of the term "condenser," a particular piece of apparatus built for the purpose of holding a quantity of electricity. We use condensers in all the various types of radio apparatus, both in transmitters and receivers, and therefore we should study very carefully the various types of condensers employed in the art.

First, we have the fixed condenser, made to withstand high pressures. These condensers are used in transmitting equipment and are made in several different ways. One form is known as the glass plate condenser, shown in Fig-

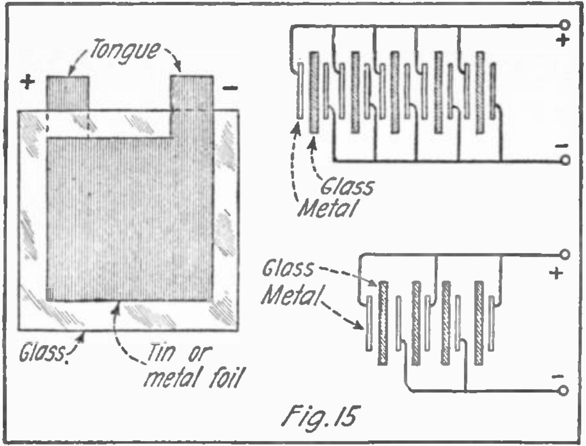
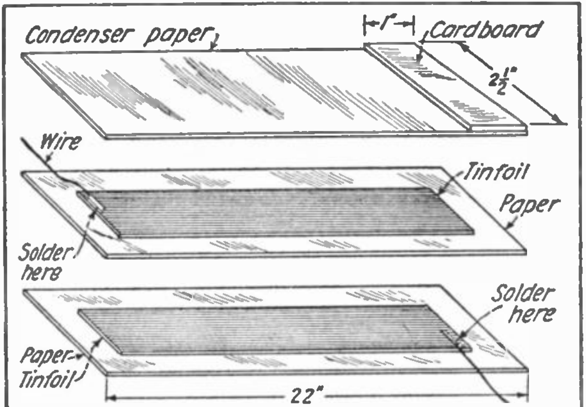


Fig. 15

ure 15. This condenser is made by placing alternate sheets of metal, tin foil, copper or aluminum with sheets or plates of glass to form an insulator between the metal conductors. This is well illustrated in the middle view of Figure 15. Every other sheet of metal is connected to one wire, while the other sheets are connected to a second wire. One set of these metal plates forms a positive of the condenser, when charged, while the other forms a negative of the condenser. When an electric generator or battery is connected by its two wires to the condenser, it will receive a charge of electricity which can be removed from it at a later period, just the same as we can store air in a tank by connecting an air pump to the tank, this air being removed at any time we wish. There are several different forms of insulators and conducting plates which may be used in condensers. For example, we may have oiled paper or mica for the insulator and very thin

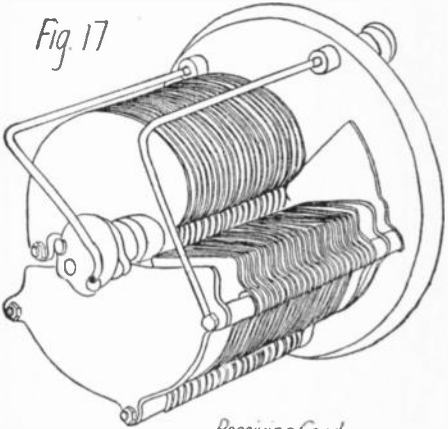


Condenser paper
1"
Cardboard
2½"
Wire
Tinfoil
Paper
Solder here
Solder here
Paper
Tinfoil
22"

Fig. 16

brass for the conducting plates and these may be tightly bound together in a very compact and condensed form. Another form of condenser is shown in Figure

Fig. 17



Receiving Condenser

Variable condenser used in receiving

16. In still some cases a condenser is made by separating alternate layers of steel plates, having air at a high pres-

sure, 200 lbs. per square inch, as an insulator between these steel plates.

Let us now turn our attention to another type of condenser known as the variable condenser, which is of great importance in receiving apparatus. This consists of two sets of semi-circular plates, one set of plates being carefully mounted or supported by some form of base with a small space between each plate, about ⅛-inch, with another set of revolving plates fastened to a shaft which move in and out between the stationary plates. This is illustrated in Figure 17, and the capacity of this condenser is increased by moving the rotating plates into the stationary plates, just the same as we might increase the capacity of a collapsible drinking cup by pulling the circular rings up one at a time, thus increasing the depth of the cup. When the rotating plates are entirely out from between the stationary plates the capacity is approximately zero.

This property of capacity is one of the two essential features in the tuning of all radio apparatus, either transmitters or receivers, and the construction and use of condensers should therefore be carefully studied in order to clearly understand the science of radio communication.

Carefully linked with the term "capacity" is the term "inductance," which is that property of an electric circuit which objects to any change in the value of the current in that circuit. We might say it is something like the property called inertia, possessed by a heavy body. For example, a large cannon-ball objects to having its motion changed. If the cannon-ball is at rest we find it very hard to start it in motion, while if it is in motion, rolling along a smooth surface, we find it very difficult to stop it or to change its direction of motion. This is due to a particular property which it has, called inertia. The greater the weight, the greater the inertia.

Electricity, however, has no weight, and in order to secure the effect of inertia we have to weight it, using a coil for the purpose. A current flowing in a short piece of straight wire, say ten or twelve feet long, is very easy to start and stop, while if we wind the same amount of wire around a stick, making a coil, we find that it is much more difficult to start and stop the current. The greater the length and number of turns of wire, the greater the resistance to changes in the current. That is why we have so many different kinds of coils in radio transmitters and receivers, and why each coil is provided with a method of changing the number of turns of wire in order to obtain the right amount or value of this property of "inductance."

Figure 18 is a helix or coil often used in small transmitting sets to vary the

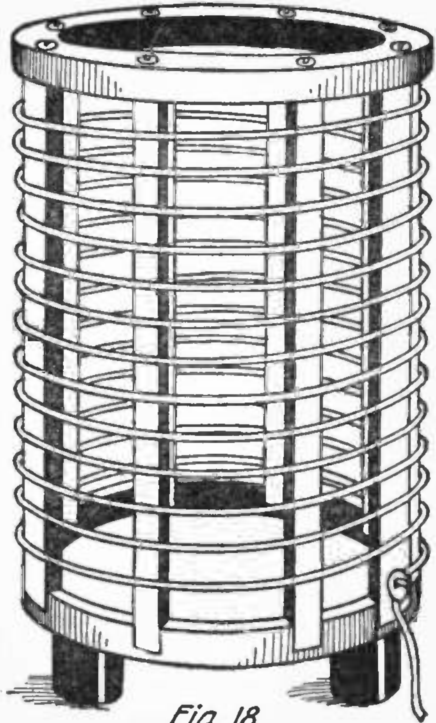


Fig. 18

Tuning coil for transmitting set

inductance in order to obtain the proper length of wave in transmitting.

Figure 19 illustrates a double slide tuning coil which is nothing more than a coil of wire forming an inductance, with a means of changing the number

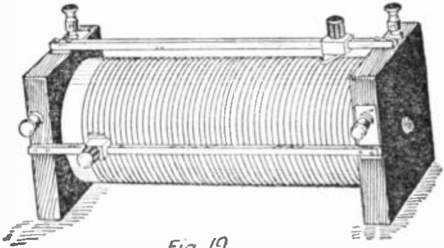


Fig. 19

Double slide tuning coil for receiving set

of turns by the two small knobs illustrated at the top and front side.

Another device for obtaining a very accurate variation of inductance is known as a "variometer," which consists of two coils of wire, one being mounted on a shaft so as to revolve within the outer

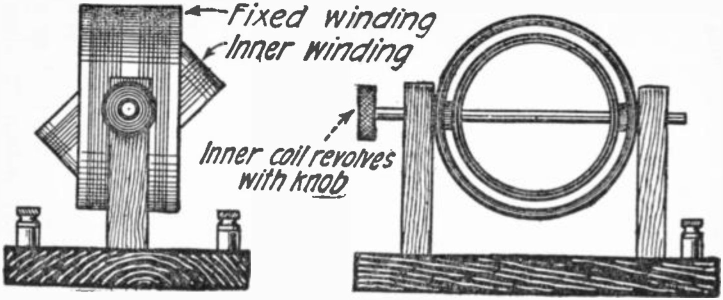


Fig. 20

Variometer used in a receiving set

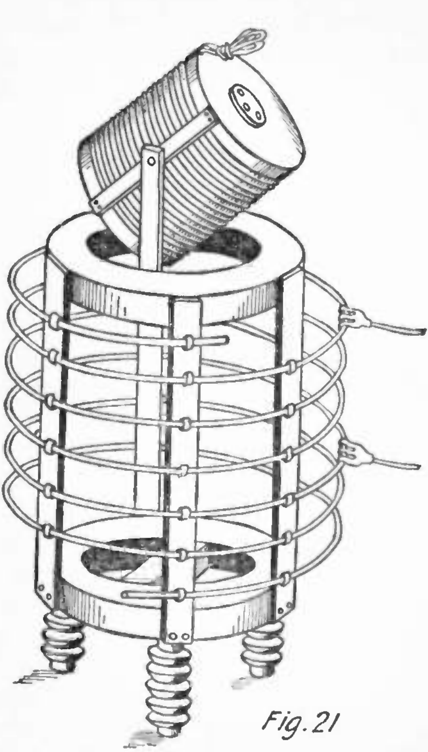


Fig. 21

Oscillation transformer for transmitting set stationary coil. This is well illustrated in Figure 20 and this form of instrument is in very common use in our modern types of radiophone receivers.

Another device which is very often

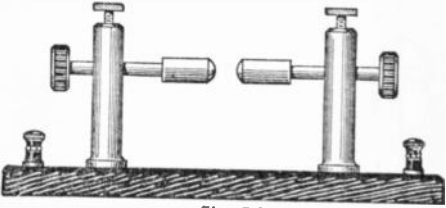


Fig. 22

Adjustable stationary spark gap

used in small and inexpensive radio transmitters is the spark gap, which serves in the production of high-frequency currents by means of discharging the condenser through a circuit consisting of a coil of wire and the spark gap itself. This gap serves to prevent the charge from running out of the condenser through the circuit, mentioned in Chapter I, as the "closed oscillatory circuit," until it has attained a sufficient force to jump across the gap and to form a

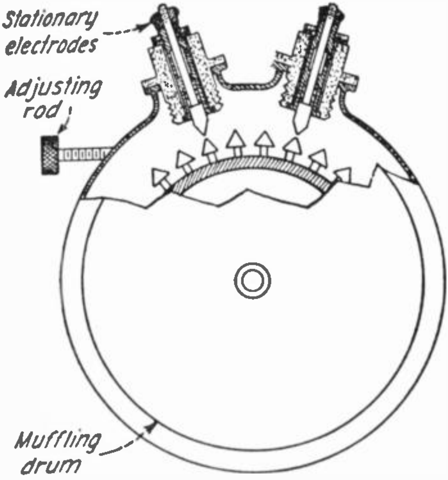


Fig. 23

Rotary spark gap

powerful discharge in the nature of high-frequency oscillations, which are

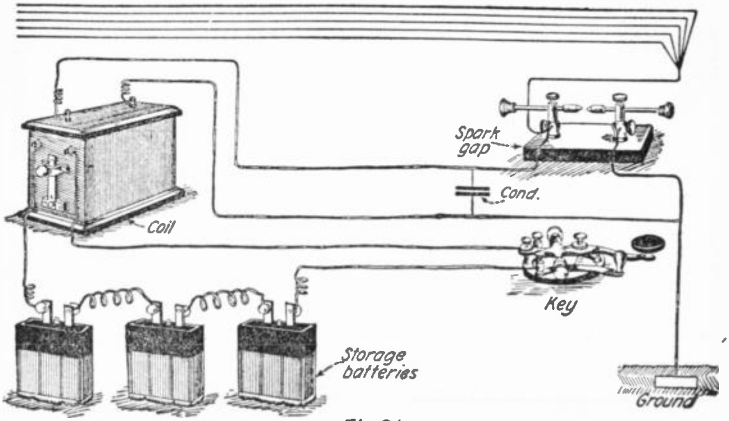


Fig.24

Spark transmitting set

transferred to the aerial or radiating circuit through means of another type of transformer known as the "oscillation transformer," shown in Figure 21. The various forms of spark gaps are illustrated in Figures 22 and 23.

Figure 24 shows the application of these various instruments previously described in a small transmitter, which is often assembled and used by the radio amateur. The storage battery furnishes the source of electric power, while the coil acts as a step-up transformer, the key for turning on and off the current to the coil, the condenser stores the high-pressure power from the coil, and the spark gap permits the discharge of the condenser in the aerial or radiating circuit. This is probably the simplest type and least expensive transmitter for the novice to build, and is capable of transmitting dots and dashes over a distance of 5 to 20 miles, according to the size of the spark coil.

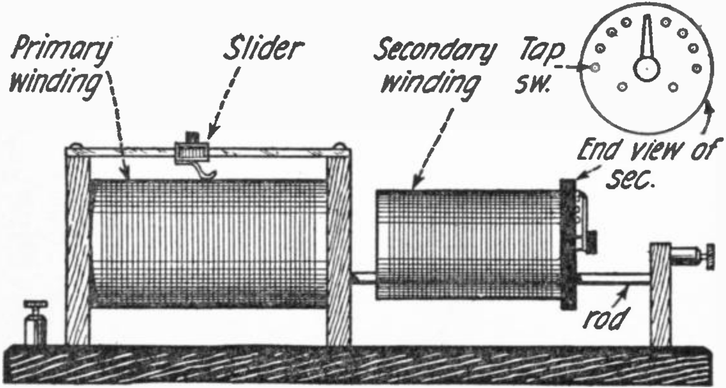


Fig. 25

Loose coupler used in a receiving set

We will now turn our attention to the application of some of the parts previously mentioned, along with some additional ones, to make up our receiving apparatus.

Again we come across the terms "transformer" and in this particular case it will be called the "receiving transformer," or sometimes called a "loose coupler," which is illustrated in Figure 25. As (the transformer), previously described, it consists of two coils of wire, but in this particular case the coils of wire may be moved away from one another and also the turns of wire in each coil may be altered so as to change the inductance of each and thus tune each of the circuits to the wave length which is being received. For more careful adjustment of the tuning of a radio receiver, we employ the variable condenser, which has already been described and which is illustrated in Figure 17.

Now that we have considered the instruments for carefully tuning the incoming radio message, we must find the necessary apparatus for changing these electric waves into sound waves which will make the messages audible to the human ear. This is accomplished through two important pieces of apparatus, the detector and the telephone head-set. The

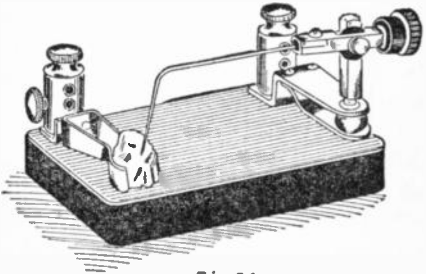


Fig. 26

Cat-whisker type of crystal detector

first and simplest type of detector to be described is known as the "crystal detector" and consists of a piece of mineral, say galena, silicon or perikon, supported in a metal cup and upon which rests the end of a small wire, or in other cases two pieces of mineral which touch one another. Several different forms of detectors are shown in Figures 26 and 27.

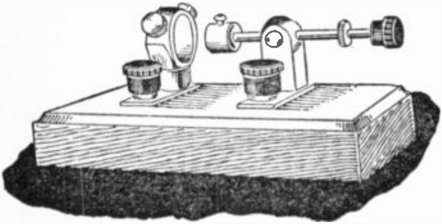


Fig.27

Compression type of crystal detector

As was told in Chapter I, these detectors act very much like the check valve in a water pipe leading to a boiler or tank. That is, they will allow the electrical current to flow in one direction but when it tries to reverse its direction the detector offers a very high resistance or impeding force to the passage of current.

Now that we have found a means of stopping the flow of current in one direction, we have at our disposal the half waves of these high-frequency currents, which number 10,000 to 1,000,000 per second, for the operation of the telephone receivers. These currents flow-

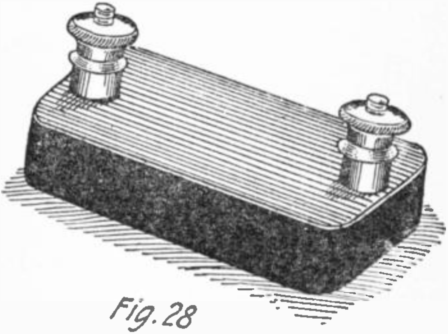


Fig. 28

Fixed condenser used in a receiving set

ing through at this rapidity would not be able to cause the diaphragm of the receiver to vibrate with this enormous rapidity and therefore, in order to have

Fig. 29
Telephone head-set used in receiving

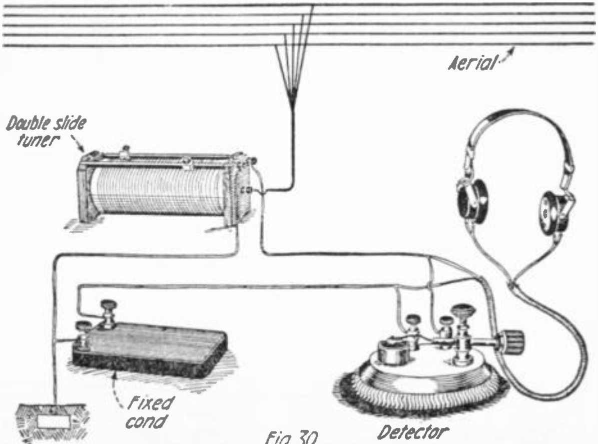


Fig. 30

Crystal receiving set

the telephone operate properly, we insert a small fixed condenser, illustrated in Figure 28, to store up these small rushes of high-frequency current and allow them to gradually discharge through the telephone receivers, shown in Figure 29, and thus make the diaphragm vibrate and convey the sound to the ear.

Let us now apply these few pieces of apparatus to a simple type of receiver, which is illustrated in Figure 30. We have the aerial, with the double-slide tuner acting as a receiving transformer, with the detector and fixed condenser, and the telephone receivers. This forms a simple and inexpensive type of radio receiver which is very well adapted for local messages, but would not be adaptable for long distance radiophone entertainments.

We will now mention a few miscellaneous devices which are used in the radio art.

We must have various forms of

switches for performing the different operations in changing from one device

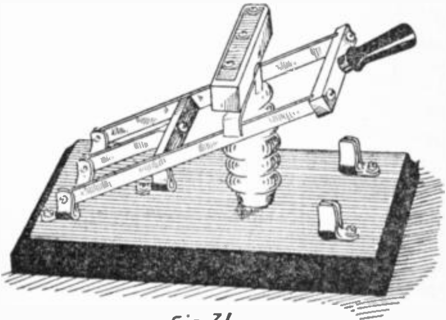


Fig. 31

Change-over switch

to another. For example, we have the "change-over switch," shown in Figure

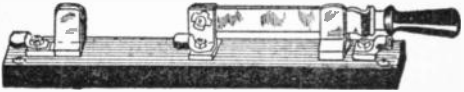


Fig. 32

Single-pole double-throw switch

31, in order to shift from the transmitting equipment to the receiving apparatus. Figure 32 is what is known as the "lightning" or "ground" switch and is usually located on the wall just outside the building where the lead-in enters the station. It is usually supported so that the blade is in a vertical direction and the middle point of the switch has the lead-in wire from the antenna connected to it, while the lower point of the switch has a large No. 4 copper wire leading directly to the ground, and the upper point of the switch has the wire leading into the station either for transmitting or receiving. The switch is thrown in the upper position when the aerial is being used for transmitting or receiving, and in the lower position when not in use, in order that any electrical disturbances created in the aerial or atmospheric conditions can be carried directly to the ground and thus protect the radio apparatus from lightning and other electrical disturbances.

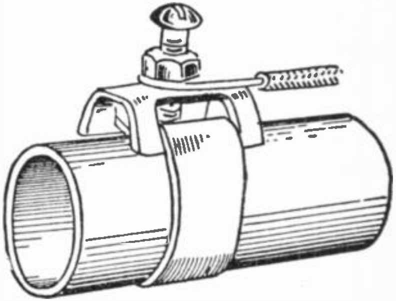


Fig. 33

Ground clamp

Figure 33 illustrates a ground clamp, which consists of a band of copper with a screw clamp for fastening it tightly around a metal pipe and also a means at the top for joining the insulated conductor to the metal band. It is used to connect the set to the ground.

Figure 34 illustrates the ammeter and voltmeter, often used in radio apparatus for measuring the amount of current and electric pressure.

Telephone Receivers

We are all acquainted with the telephone receiver which we place to our ears when communicating through our home telephone to the various stores and friends about the city. This is what is known as a simple receiver of low resistance, that is, the turns of wire are few in number and of fairly good size, which gives a resistance of 75 to 80 ohms.

When we come to the use of telephone receivers for radio messages it is customary to use a double headset, that is, a tight band which fits about the head and contains on each end a telephone receiver of a resistance usually 1,000 to 1,500 ohms making a total of 2,000 or 3,000 ohms per pair of phones. This high resistance is necessary in order that

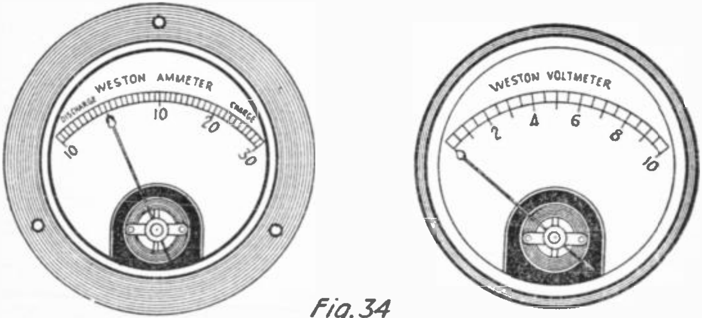


Fig. 34

Ammeter and voltmeter

the phones may respond to the very weak currents that are received. The amount of current available to operate the telephone receivers is very minute in value. These small currents, in order to be effective in moving the diaphragm of the receiver, which is placed over the magnets around which the coils are wound, must obtain their strength by means of a large number of turns of very small wire wound upon these small magnet cores. Due to this fact, that is, several thousand turns of wire in a very small space, it must be very small wire of great length which means a very high resistance. Of course we must bear in mind there is a limit at which we must stop, since if we get our resistance too great there will not be enough force to the radio currents to force even a reasonable amount of current through the coils and, therefore, it has been found, through long experience, that telephones of 2,000 to 3,000 ohms of resistance give best results.

Figure 35 illustrates the construction of the ordinary telephone receiver. "C" is an insulated case usually made of molded bakelite or some other material and in some cases aluminum is used, in which instance the magnets must be in-

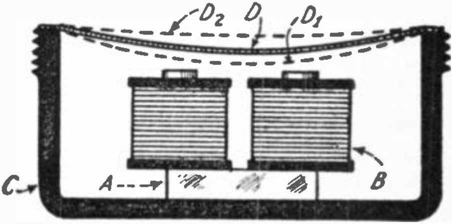


Fig. 35

Construction of a telephone receiver

sulated from the case. "A" is the magnetic core made, in this case, in the shape of a "U" of laminated iron in very thin sheets to reduce the iron losses. "B" are the two coils wound upon the iron cores and usually consist of several thousand turns of very small wire about the size of the finest silk thread. "D" is a thin sheet metal diaphragm separated from the ends of the magnets by about 1/32 of an inch and held in this position by means of a cap which is screwed over the threads shown in the drawing. In this cap there is a small hole about ½-inch in diameter which goes directly over the ear. In some makes of telephone receivers the diaphragm is adjustable to different distances from the magnets and this lends itself to fine adjustments.

The telephone receiver is a very important part of a high-grade radio receiver and too much stress cannot be laid upon the need for purchasing a reliable and high-grade make of telephone receiver to get good results in long distance radiophone reception.

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Chapter IV

Technical Terms Explained

There are many technical terms which must necessarily be used in the future explanation of the radiophone transmitter and receiver and which the following definitions cover sufficiently to give the beginner a clear and working knowledge of their meaning. We will now explain a few of these terms.

Radio Frequency: Radio frequencies refer to oscillating currents which have a frequency of from 10,000 to several million per second and are used exclusively for the transmitting of radio telegraph and radio telephone messages. Their frequency may be varied in any transmitter by changing the value of the inductance or the capacity which have been previously mentioned in this book.

AUDIO FREQUENCY: The term "audio frequency" refers to waves or oscillating currents below 10,000 oscillations per second. This frequency can be detected by the human ear and it is for that reason that it has the name "audio," which means to be able to hear. It is necessary to find some means of changing the radio frequency currents received by the aerial into audio frequency currents before they act upon the telephone receiver in order to be heard by the human ear. Certain types of transmitters, known as the damped wave type, break these radio frequency waves into groups which have an audio frequency when considered as groups.

TUBES: The term "tube" refers to the many types of vacuum bulbs constructed both for detectors in receiving, amplifying bulbs for increasing the strength of the signals, and power or transmitting bulbs used in radiophone transmission. At the present time there are several different names applied to the detector tubes, such as UV-200, as made by the Radio Corporation of America, and the Western Electric Company J tube. A detailed description of these tubes and the principle on which they operate is given in the chapter on vacuum tubes.

TRANSFORMERS: We have spoken in a previous part of this chapter about transformers. One already mentioned was the step-up power transformer.

BATTERIES: There are two common types of batteries in everyday use, both for radio and other electrical purposes. The first type is known as the primary battery or dry cell. These batteries must be thrown away and new ones purchased when the charge has been entirely taken from the cells. Each dry cell gives approximately 1.5 volts pressure when new, and drops off gradually to one volt or less as it becomes discharged. The second type, or storage battery, is made up of a type of cell which can be recharged by passing electrical current through it in the opposite direction from that in which it flows in discharging. This charging of the storage battery may be done in the home by direct current source of power or by a rectifying device attached to an alternating source of power. If the home does not have a means of charging the battery, it may be taken to a regular battery charging station. Storage batteries are usually made up in units of six volts each, which consists of three cells connected in series and enclosed in a wooden carrying case with handles provided on the sides or across the top. The six-volt storage battery is used almost entirely for supplying the current for lighting the filament of the detector and amplifying tubes in the radio receiver. What is known as a B battery, consisting of 15 or 16 dry cells connected in series and furnishing 22½ volts, is used to furnish the current in the plate circuit of the detecting or amplifying bulb. The life of the ordinary dry cell battery ranges from 7 to 12 months, according to the amount of use it receives, while the life of a storage battery may extend over a period of 2 to 10 years, according to the care which is taken of the battery. Detailed instruction regarding the care and operation of storage batteries will be taken up later.

RHEOSTATS: The term "rheostat" refers to a variable resistance which is placed in the filament circuit of the vacuum tube for regulating the amperes or amount of current flowing through the filament, and thus regulate the brightness of the filament. These rheostats are usually made of a coil of high-resistance wire, that is an alloy of nickel and iron wound upon an insulating rod and upon which coil a sliding or rotating metal arm makes contact with the various turns of wire.

POTENTIOMETER: A potentiometer is a very high resistance usually made of a small rod or stick of graphite or in some cases of many turns of very small high-resistance wire wound on an insulated rod, which device is connected across a source of electric pressure, usually a battery of dry cells of 2 to 80 volts, and makes it possible to obtain any voltage or pressure between zero and the maximum value furnished by the source of power.

Now that we have mentioned the various pieces of apparatus used in radio installations, we shall show the symbols which are used to illustrate these pieces of apparatus when making a complete drawing of a radio transmitter or receiver. Study very carefully the various symbols, or we might say abbreviations, of the different devices illustrated in Figures 36-A, B, C and D.

These illustrations contain an alphabetical arrangement of symbols of the various instruments which cover not only those in common radio practice, but those which might possibly come to the attention of the radio enthusiast who may care to read technical papers and books on the subject.

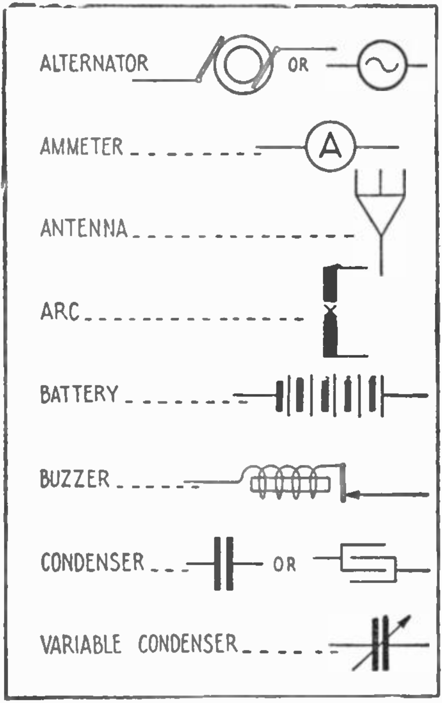

ALTERNATOR
OR
AMMETER
A
ANTENNA
ARC
BATTERY
BUZZER
CONDENSER
OR
VARIABLE CONDENSER

Fig. 36-A

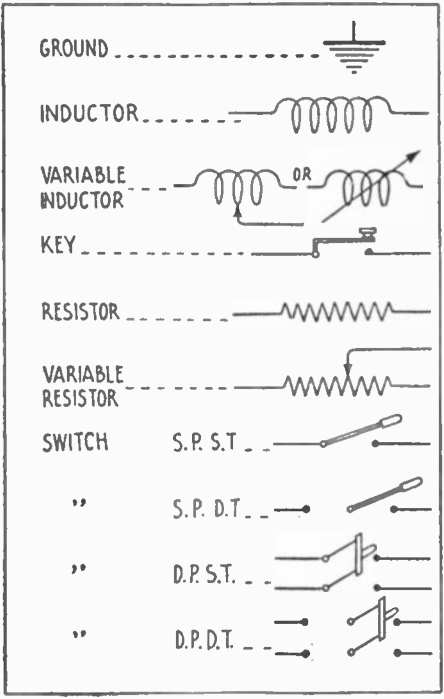
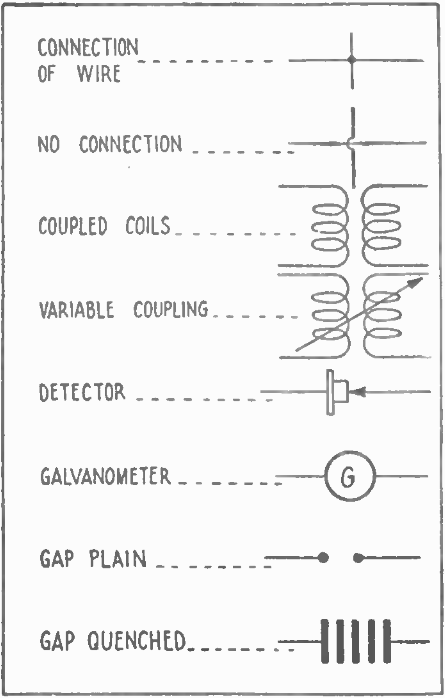

GROUND
INDUCTOR
VARIABLE INDUCTOR
OR
KEY
RESISTOR
VARIABLE RESISTOR
SWITCH
S.P. S.T
S.P. D.T
D.P. S.T.
D.P. D.T.

Fig. 36-B



CONNECTION OF WIRE
NO CONNECTION
COUPLED COILS
VARIABLE COUPLING
DETECTOR
GALVANOMETER
G
GAP PLAIN
GAP QUENCHED

Fig. 36-C

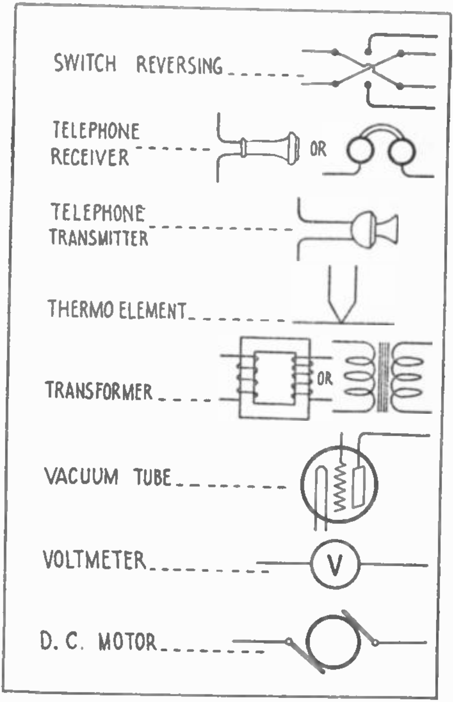

SWITCH REVERSING
TELEPHONE RECEIVER
OR
TELEPHONE TRANSMITTER
THERMO ELEMENT
TRANSFORMER
OR
VACUUM TUBE
VOLTMETER
V
D. C. MOTOR

Fig. 36-D

Chapter V

How to Set Up Receiving Outfits

Radio can no longer be called a hobby, but rather a "malady." Every day the Radio-mania claims new victims among both young and old. Little Willie, age 11, now chats volubly with Grandpa about tuning coils, detectors, etc.

In 1912, the Government passed a law restricting amateurs to a sending wave length of 200 meters. Other conditions were also placed upon amateur transmitting. Among these conditions was one that prohibited an amateur from using a power of over 1 kilowatt. However, one kilowatt is no mean amount of power. In fact one kilowatt is close to 1½ horsepower. Stations located within five nautical miles of a naval sending station were restricted to the use of ½ kilowatt.

The law further states that an operator's license as well as a station license must be obtained for transmission over the boundary lines of the state in which the station is located. To obtain an operator's license (which is issued in 1st and 2nd grade form) it is necessary to be able to transmit and receive a certain number of words per minute. Under the Radio Communication laws of the United States, the country is divided into nine districts. Every licensed amateur station is given a number or call that corresponds to the district. For instance, in Chicago and vicinity, the call is started with nine, and stations within this territory are designated as 9GC or 9EE or whatever the letters assigned may be.

Transmitting licenses can be readily secured and it is advisable for all amateurs to obtain them if they decide to operate a transmitting station. Owing to the increased sensitivity of the receiving outfits these days, the smallest transmitting apparatus is likely to be heard over a considerable distance. For information regarding station licenses, a letter should be addressed to the Radio Inspector of the district in which the applicant is located. The various districts and headquarters are as follows:

1st district........Boston, Mass.
2nd district........New York, N. Y.
3rd district........Baltimore, Md.
4th district........Norfolk, Va.
5th district........New Orleans, La.
6th district........San Francisco, Cal.
7th district........Seattle, Wash.
8th district........Detroit, Mich.
9th district........Chicago, Ill.

All licenses issued are listed in a book called "Amateur Radio Stations of the United States." This book is published by the Department of Commerce, Bureau of Navigation, and copies of it may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. A charge of fifteen cents is made. This book gives the name and address of the owner of the station, the call letter, and the power of the transmitter.

All these restrictions were made necessary because of amateur interference with commercial messages. A few amateurs with fairly powerful transmitting sets filled the air with all kinds of jargon, just for the pleasure of hearing themselves "send." When asked to stop for a few minutes to allow commercial messages to get through without interference, they became indignant and refused.

Since receiving stations cannot become a nuisance, no restrictions have been placed upon them. Receiving stations can employ the most costly and sensitive receiving apparatus without seeking permission from the government. There is only one law concerning receiving stations, and this states that operators of stations must keep all messages they receive from commercial stations secret. This is simply a protection for those who transact business by radio.

Radio offers an unlimited opportunity to the hobbyist who feels the creative urge. There is no set way in which receiving and transmitting apparatus may be connected up. Practically every amateur has worked out some pet "hook-up," as the various methods of connecting the apparatus are called, and every amateur naturally believes his way to be the best.

There are two well known national associations of radio amateurs, and practically every amateur is connected with one or the other. One is the American Radio Relay League, of Hartford, Conn., and the other the National Amateur Wireless Association, of New York. These bodies have been organized largely for the purpose of relaying messages. For instance, an amateur station owner in the east can start a message which will be relayed across the country until it eventually finds its way to a party in California. Twenty-five or thirty stations may participate in the relaying of such a message.

The word "amateur" has a distinctly limited application in the minds of some people, who believe it to be a name given to any one who dabbles around with things in an unprofessional way. During the latter part of the year 1921, certain events took place which must change this belief. At that time the American Radio Relay League held its trans-Atlantic amateurs' test. With transmitters that required little more power than a cluster of 40-watt electric lights, several amateurs succeeded in getting messages across to England. The amount of energy used was but an insignificant fraction of that employed by the trans-Atlantic commercial stations. Of course, the conditions were favorable and an ultra-sensitive receiver was used on the other side. Hiram Percy Maxim,

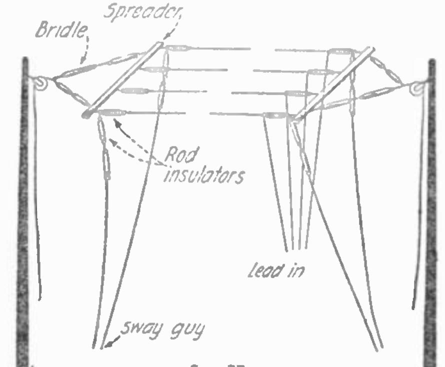


Fig 37

Inverted L-type aerial

President of the League, said in this regard: "These tests mean the coming of the day when Americans can carry on unrestricted conversation with their cousins across the sea."

The first difficulty which an amateur wireless man encounters is the construction of his aerial. It is upon the aerial that much of the efficiency of the station depends. Figure 37 shows an ideal aerial. The first thing we must impress upon our minds when starting out to build an aerial, is that it must be kept entirely insulated from everything surrounding it. We must make it a sort of island of copper wire, suspended in the air. The aerial must be made electrically "tight" (well insulated), and the number of insulators used will depend upon the power of the transmitting apparatus. Receiving aerials do not have to be so thoroughly insulated. If we are to operate a transmitting station care must be taken to get our aerial of the proper dimensions and height, since this affects the wave length, and the Radio Inspector is apt to get peevish when he comes around with his little wavemeter and finds our wave beyond

200 meters. There is a simple rule which will help us to keep in the good graces of the inspector. For two-hundred meter transmission, the length of the aerial plus its height should not exceed one hundred feet. This holds true for the inverted "L" type of aerial, which is illustrated. It will be easy to understand that the height of the aerial affects the wave length of a transmitter since the length of the lead-in wire to the instruments is determined by the height. The lead-in wire is, of course, considered as part of the aerial, and the wave length cannot be limited to 200 meters if it is too long.

Since the small aerial necessary for transmission does not lend itself to the reception of long wave lengths, many amateurs who have plenty of space at their disposal like to put up a special receiving aerial. The higher this aerial goes the better, but since the higher it goes the deeper the amateur must dig into his pocketbook, it is usually made up of a single wire several hundred feet long. If the student does not care to put a large aerial up, he may use a single wire about 80 or 90 feet long. This size will be sufficient for reception from the Broadcasting Stations.

When putting up the aerial, the joints of the aerial wires must be made with the greatest care. They should first be scraped scrupulously clean and then soldered. To prevent corrosion, friction tape should be wrapped around the joints. Either phosphor bronze or copper wire should be used for the aerial. Soft copper wire, although electrically good, is apt to break when subjected to slight strain.

The insulation of the lead-in wire, where it enters the building, is a very important thing. We must come to consider the lead-in wire as a bridge which connects the aerial with the instruments. Lead-in insulators may be purchased from any radio dealer, and these will give service which cannot be expected from a makeshift. If an inefficient insulator is used we may be losing 50 per cent of our transmitting energy. All energy lost through leaks subtracts that much from the efficiency of the station. We should always remember the fact that electricity takes the path of least resistance, and if it can find a way out through a faulty insulator it will take it.

Every radio receiver and transmitter must be "grounded." By this we mean that a connection must be established with the earth. No effort should be spared to make the ground connection a good one since it is of utmost importance. There is on the market a device (see Figure 33) called a ground clamp. This is a little clamp that is made especially for use in connection with a ground that is made on water pipes, and may be purchased for a few cents.

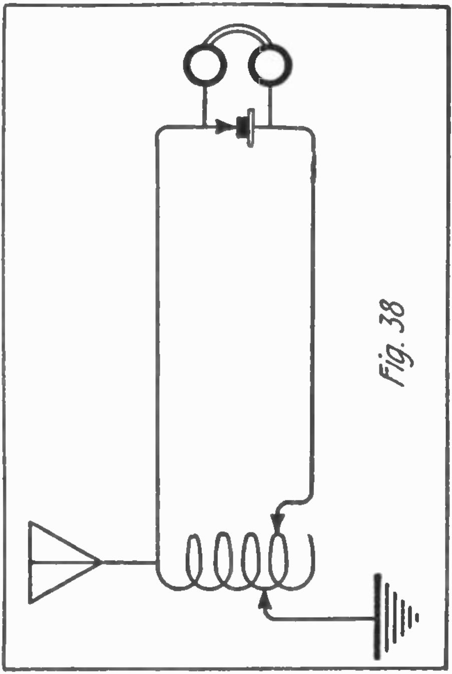


Fig. 38

Where water pipes are not available, a good ground can be made by burying an old copper wash boiler filled with charcoal.

Now that we have learned a little more about aerials and grounds, we will turn our attention to receiving apparatus. About the simplest kind of a practical receiving outfit is made up of a tuning coil, a crystal detector and a pair of phones. The method of connecting these instruments is shown in the diagram. (See Figure 38.) We will call this Outfit No. 1. "How far can I receive with such an outfit?" will be one of the first questions to arise in our mind. The only way in which we can answer this is to say that for an outfit of given sensitivity, the distance over which it will be able to receive will depend entirely upon the power and distance of the transmitting stations. Then too, the atmospheric conditions affect reception a

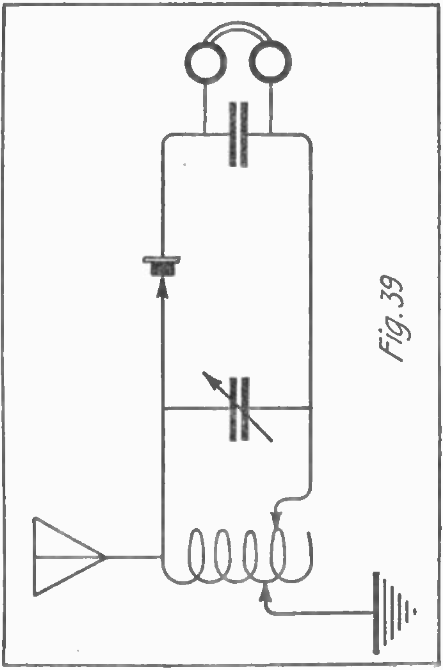


Fig. 39

great deal. All these things must be considered.

Outfit No. 1, shown in Figure 38, can be greatly improved by the addition of what is known as a variable condenser connected across the tuning coil and a fixed condenser across the phones, as shown in Figure 39. By moving the plates the capacity of the condenser can be adjusted as explained in a previous chapter. We were told there that changing the capacity of a wireless circuit affected its wave length. Hence, it will be easy for us to understand that the variable condenser will help us to tune in signals. The variable condenser is operated by means of a knob on the top. If this knob is turned while the sliders on the tuning coil are moved to and fro a position will be found at which signals will be heard, if the detector is in a sensitive condition.

While speaking of simple receiving outfits, it is well to mention the detector. Various minerals can be used in them, but the beginner will find that galena is very satisfactory. Handling the crystal with the fingers should be avoided. Such handling will cover the mineral with an invisible layer of greasy matter, which will reduce its sensitivity.

Great care should be used in the selection of the phones which are to be used with any set. It is in the receivers that the weak currents are transformed into audible sounds, and if these currents are not handled efficiently by the receivers, the outfit will be robbed of its sensitivity.

Outfit No. 3 introduces what is known as a loose coupler or a tuning transformer, as shown in Figure 40. This is made up of two tuning coils, one sliding within the other. In the language of radio we say that the coils are "inductively coupled." Such coupling increases the selectivity of the outfit; it helps us to "tune out" stations we do not want to hear. The side of the receiving transformer that is connected to the aerial is called the primary. The

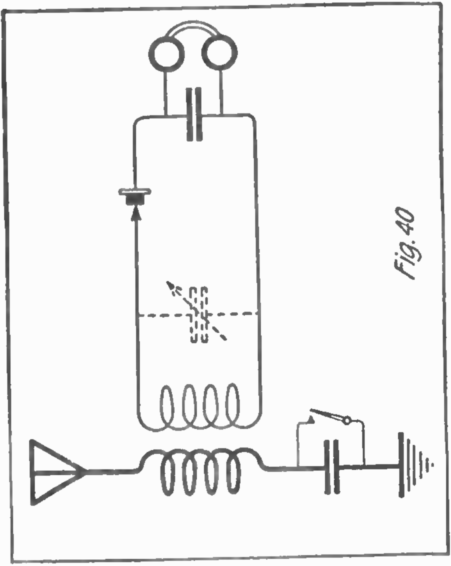


Fig. 40

other side is called the secondary. The secondary slides into the primary so that the "coupling" between the circuits can be varied. This sliding is done during tuning. The primary and secondary of the transformer must always be adjusted as well as the variable condenser.

By adding another variable condenser to the outfit, as shown by the dotted lines of Figure 40, we will have Outfit No. 4, which has a greater selectivity than No. 3.

The receiving outfits just described can be connected up in many different ways, although the connections shown will probably give as good results as any. However, since connecting and disconnecting outfits is part of the fun of radio, practically everyone owning a set will do a little experimenting himself. It is well to do this, since it is by practice of this sort that we really get to know our instruments, and gain actual experience.

Almost everyone interested in radio reaches the point where he is no longer satisfied with a crystal detector, but wishes to replace it with a vacuum tube. Increasing the sensitivity of an outfit, will, of course, bring a greater number of stations within range.

Vacuum tube receivers, although widely different from crystal detectors, are not difficult to manage. However, it will be wise for us to start out with one vacuum tube and a simple circuit so that we may become familiar with it. The first one described we will call Outfit No. 5, and a glance at the diagram of connections (shown in Figure 41), will show us that the vacuum tube adds little complication to the outfit. To operate the vacuum tube we must first light the filament. We then adjust the rheostat to regulate the current passing through the filament. It is best not to burn the filament of the tube too brightly as this does not bring the best results and tends to shorten the life of the tube. After the tube is set in operation, the tuning transformer and variable con-

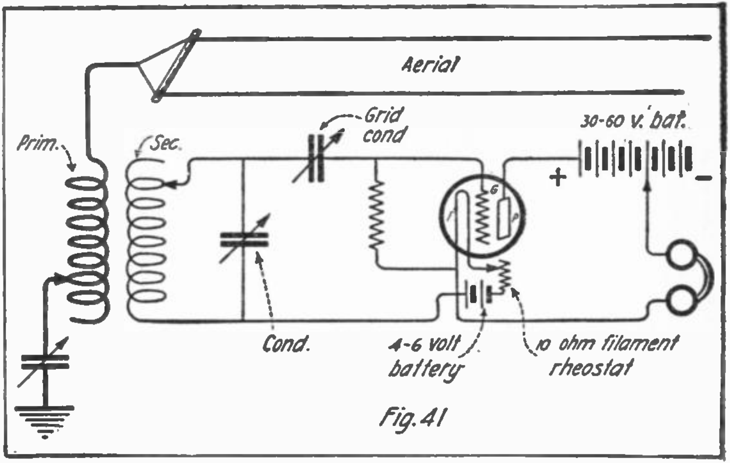

Aerial
Prim.
Sec.
Grid
cond
30-60 V. bat.
+
–
G
P
Cond.
4-6 volt
battery
10 ohm filament
rheostat

Fig. 41

denser are manipulated and the signals tuned to maximum loudness. When this

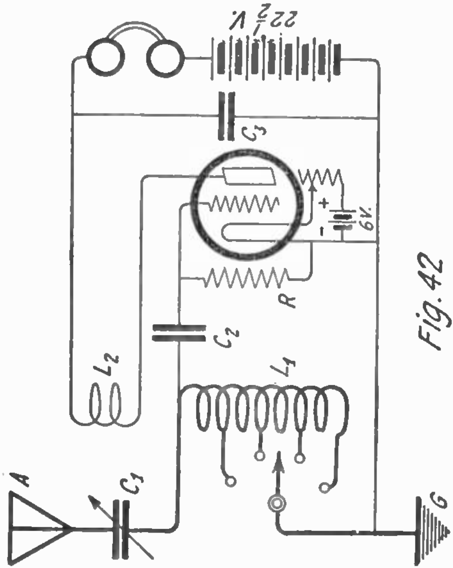


Fig. 42

is done the filament rheostat of the vacuum tube can be further adjusted.

With the signals in the phones to be guided by, it will be an easy matter to bring the tube to its most sensitive point. With this outfit we will be able to hear stations that were previously beyond the range of our instruments.

The next outfit we will call No. 6. This is a regenerative receiver as illustrated by Figure 42. The regenerative or feed-back feature was developed by E. H. Armstrong, and our first experience with it will convince us of its usefulness. This simple contrivance greatly amplifies the signals which come in. This circuit contains the grid leak which is mentioned in a later portion of the book. To operate the regenerative receiver we adjust the detector in the usual manner and then tune the signal in with the variable condenser, the tickler coil and the receiving transformer. We will also observe that it is possible to vary the voltage, or we might say the "positiveness" of the plate battery. After becoming familiar with the Armstrong regenerative circuit, nothing will be too hard for us to tackle.

Chapter VI

Primer of the Vacuum Tube

Since the birth of the vacuum tube into the wireless family, about six years ago, it has become an instrument of boundless utility. The vacuum tube is coming to mean to wireless what the lever means to mechanics. In short, the development of wireless is centering around this little instrument.

To understand fully the operation of the vacuum tube we must delve into what scientists call the "Electron Theory." In 1896 the electron theory came into existence. Previous to that time scientists had believed all matter to be composed of little particles which they called atoms.

We have all heard of molecules. Molecules are so small that even the most powerful microscope cannot bring them within the range of our vision. Atoms are still smaller. Sir Oliver Lodge has said that there are as many atoms in a glass of water as there are glasses of water in the ocean. For a long time the atom was reckoned as the smallest unit of matter, but since the conception of the electron, the atom seems a giant in comparison. Atoms vary in size. Each of the ninety-two elements that go to make up this earth has an atom of different size, ranging from the atom of hydrogen, which is the smallest, to the atom of uranium, which is the largest.

When the early chemists said that the atom was the smallest particle of matter, indivisible and unchangeable, some people did not agree with them, and set out upon researches of their own. This research led to the discovery of the electron. However, we have neither space nor time to explain the exact nature of the experiments that led up to the discovery of the electron.

Atoms are made up of electrons. We also know that electrons are pure negative electricity. Most of us will recall that when we were back in the physics class at High School we were taught that there were two kinds of electrical charges, positive and negative. We were also taught that like charges of electricity repel one another and unlike charges attract each other. We must get firmly settled in our mind the fact that the electron is a particle of negative electricity.

Some of us will now ask, "How can atoms be built up with negative particles, when the negative particles will repel one another?" To answer this question, we must introduce another unit which is known as the proton. This is a positive nucleus or sphere in the center of each atom which attracts and holds the electrons of negative particles within its influence. Electrons revolve rapidly about this nucleus, traveling in regular orbits. Their speed is terrific.

The electron theory has made possible the explanation of many things that have heretofore been mysteries. The weight of each element depends upon the number of electrons that go to make it up. For instance, the hydrogen atom is the smallest and lightest known, as it contains only one electron. The atom of nitrogen has sixteen electrons and the atom of uranium has 239 electrons.

With the electron theory the chemist is able to account for chemical activity between the various elements. The physicist pointed out the way. He told the chemist that chemical activity was simply the result of an interchange of electrons between the various atoms. In some atoms the positive charge or proton dominates, and in others the electrons or negative charges dominate. Or, we might say, that some atoms are lacking a few electrons and are reaching out for more, while other atoms have too many and tend to release the excess. When an electro-positive and an electro-negative atom come together, there will be a chemical action. There is an interchange of electrons and a new chemical compound will result. Probably most of us are wondering what all this has to do with the vacuum tube. We are coming to that shortly.

In 1883, Thomas A. Edison, while experimenting with his electric light, discovered what is today known as the "Edison effect." In conducting some of his experiments, he noticed that the space about a heated filament was a conductor of electricity. Further research lead him to discover that this heated space had the property of conducting electricity with greater facility in one direction than in the other. Technically speaking, this heated space he found to possess "unilateral conductivity," or conductivity in one direction only. However, for once in Edison's life he failed to find a practical application for this discovery.

Had Edison known about electrons at the time, he probably would have been able to explain the phenomenon. Today it is accounted for by the electron theory. It is found that when we boil water the molecules are set into motion and finally become so energetic that some of them break away from their moorings and sail off into space. When a poker is heated to a red heat, the electrons do the same thing, and it is this jumping off into surrounding space that gives the space about a heated body the property of conductivity.

Dr. H. A. Fleming, of London, England, was the first to find a practical use for the Edison effect. In 1904, Dr. Fleming brought out his "oscillation valve." He called it a valve because it allowed a current of electricity to pass

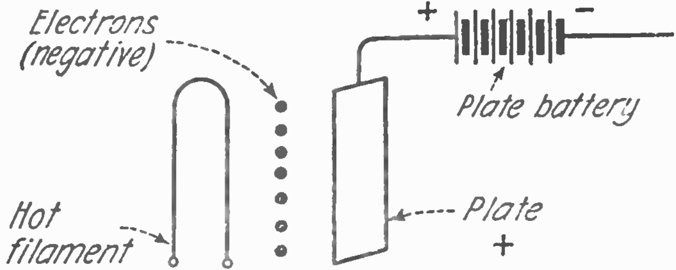


Fig. 43

in one direction only. That is the function of a valve. The valve on an automobile tire allows air to go in but it does not allow it to turn around and come out. The "vacuum valve" or vacuum tube, however, allows electricity to enter and pass out, but it must continue always in the one direction.

Up to the time of Fleming's invention of the vacuum valve, the devices used in the detection of wireless waves were crude and inefficient. The new valve was little better, but it opened up a line of research which has since borne much fruit. Today the vacuum tube is one of the most sensitive detecting instruments known to man.

Figure 43 will give us some understanding of the operation of a simple two-element vacuum valve. Here we see that the filament is kept heated by a battery, and the current from this battery is regulated by a rheostat or variable resistance. The temperature of the filament may be adjusted by regulating the current passing through it, and this, in

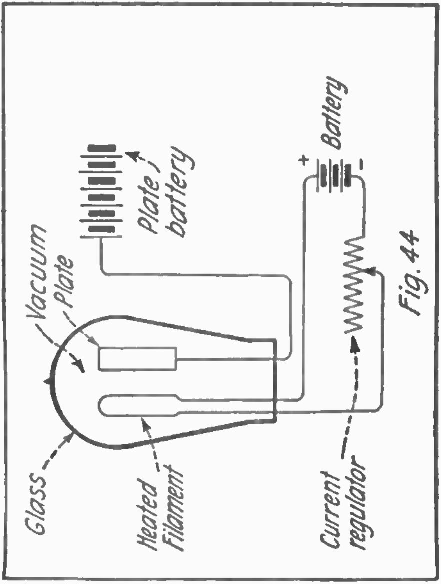


Fig. 44

turn, controls the electrons that evaporate from its surface. The conductivity of the space about the filament will, of course, depend upon the number of electrons that gain their freedom.

Figure 44 will show us that there is a battery "B" connected to what is known as the "plate" in the vacuum tube. If we will look closely we will see that the positive pole of the battery is connected to the plate and the negative pole to the filament. Under these conditions the plate in the vacuum tube is positive. We will understand from the foregoing, that the plate will attract the negative electrons as they leave the hot filament. The attraction which the plate has for the negative electrons will depend upon the voltage of the battery. If the voltage is high the electrons will be drawn away from the filament with greater speed. To permit the tube to function properly it is necessary that this plate be adjusted to the proper potential. If the potential is too low the electrons do not move away rapidly, but remain in a cloud about the filament. The space around the filament thus accumulates a charge of negative electricity. This charge becomes so powerful that it holds back other electrons that desire to come out. This is known as the "space charge." If the conductivity of the space between the plate and the filament is to be kept at proper value, the plate must have a positive charge strong enough to keep these electrons from remaining near the filament. A certain number of electrons are emitted every second, at a certain filament temperature, and these must be drawn away. The electric field created by the positive plate can be looked upon as an electric suction that draws the electrons away from the filament as fast as they are free.

In a previous chapter we said that crystal detectors were used to render high-frequency radio oscillations audible. We also said that the crystals used in the detector had the property of unilateral conductivity. A vacuum tube performs the same service as the crystal de-

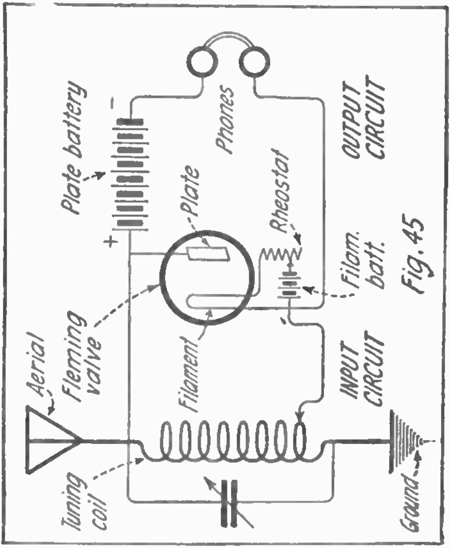


Fig. 45

tector, but it performs this service more efficiently. When high-frequency currents pass through a detector, one-half passes freely while the other half is entirely cut off. This action or rectification has the effect of changing the inaudible high-frequency current into a series of direct current impulses which are audible in the telephones. The vacuum tube does the same thing.

In Figure 45 we see the vacuum tube in use in a wireless circuit. Let us study this sketch for a few minutes. We will see that the signals or high-frequency currents come down through the aerial to the tuning coil. Both the tuning coil and the variable condenser are used to adjust the circuit so that it will respond to the incoming wave. After the circuit is properly tuned, the currents rush along to the vacuum tube. One-half of the incoming current is allowed to flow freely from the plate to the filament of this device, but the other half of the cycle is effectively cut off. The current that is allowed to pass causes an increase in the current that flows in the telephones. Thus, the current passing through the telephones is composed of a number of impulses coming very close together. This causes the diaphragms of the telephone receivers to vibrate in sympathy at an audible rate.

When the old two-element (plate and filament) form of vacuum tube was in use, certain adjustments had to be made before it was brought to a point of maximum sensitivity. The voltage of the battery which was connected to the plate had to be adjusted so that it would draw the electrons away from the filament at the proper speed. The current flowing through the filament also required adjustment to give off just the proper number of electrons. The maximum response in the telephone receivers is brought about by these adjustments.

After some experimentation, Dr. Lee DeForest added another element to the vacuum tube which he called a "grid." This grid was nothing more or less than a small piece of wire bent in a zigzag

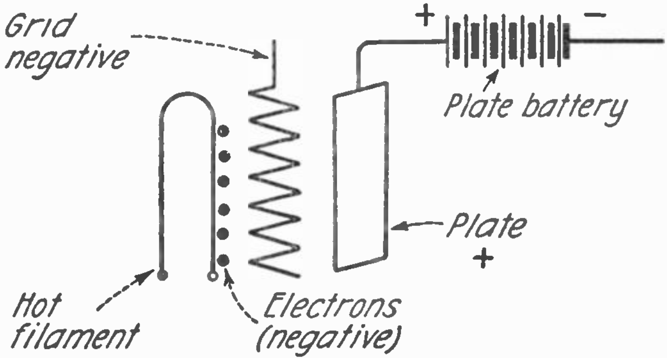

Grid
negative
Plate battery
Plate
+
Hot
filament
Electrons
(negative)
+
−

Fig. 46

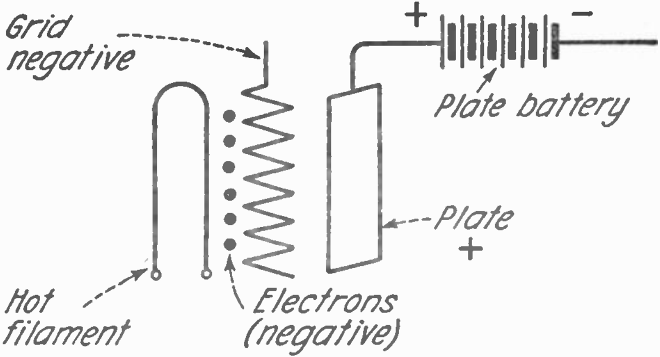

Grid
negative
+
−
Plate battery
Plate
+
Hot
filament
Electrons
(negative)

Fig. 47

fashion. The grid was inserted between the filament and the plate as illustrated in the Figures 46 and 47. The addition of this grid made the vacuum tube a more practical device, capable of rendering a greater service.

We can picture the Fleming tube as a device containing a red hot filament which generates electrons (negative particles). These electrons we know are at once carried away by a positively charged plate, this plate being merely a piece of sheet nickel. Naturally the introduction of a third element is going to cause some change in the performance, but what this change is we will not learn at this time. This three-element tube is made up of a glass bulb exhausted to a high degree of vacuum, containing the three essential elements which are known as, first, the filament, similar to that of the ordinary lamp, second, the plate and third, the grid. There are two connections for the filament, one to lead the

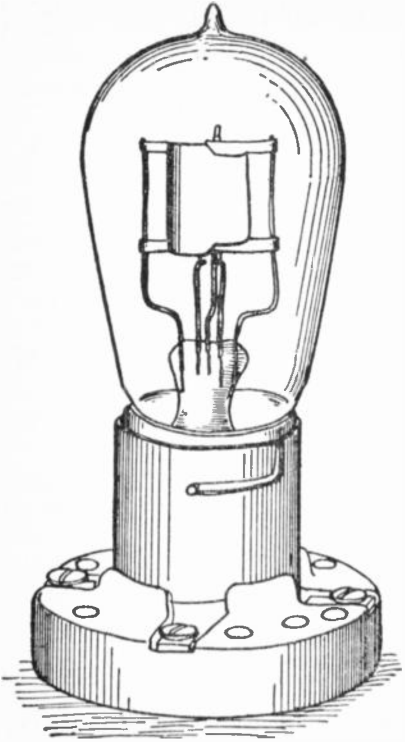


Fig. 48

current in and the other for the current to pass out. Then there is one connection for the plate and one for the grid, making four terminals for the tube. These terminals are brought out through the base, which is similar to the ordinary lamp, but instead of having the metal screw threads, it is a simple brass cylinder surrounding a porcelain insulator through which the four terminals protrude in the form of four cylindrical pins.

Before going further with the explanation of the three-element tube, we will pause and consider more radio terminology. It is absolutely neces.ary that everyone who wishes to thoroughly understand radio should become familiar with the various terms that are used in connection with it.

From our former description of electric circuits, we will see that three independent circuits must be used with a vacuum tube receiving outfit. These are shown in Figure 49. One of these circuits, which is called the grid or input

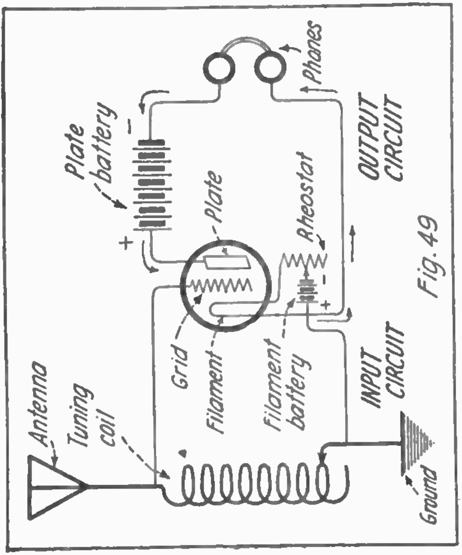


Fig. 49

circuit, involves the tuning coil condenser, filament and grid. There is another circuit which involves the plate, high potential battery, the telephones and the filament. This is called the plate or output circuit. The third circuit is called the filament circuit and involves simply the necessary battery and rheostat that supplies the filament with the proper amount of current.

The grid circuit is also known as the input circuit, since the weak currents that are received come in over this route. The high potential battery which keeps the plate of the vacuum tube positively charged is usually referred to as the "B-battery," while the battery supplying the current to light the filament is called the "A-battery." We must have these terms and their meanings firmly implanted in our minds before we resume our study of the vacuum tube.

It will now be assumed that a high-frequency current is flowing in the grid circuit (input circuit). We know that these currents alternate or change their direction many times a second. This results in the grid becoming charged, first negatively and then positively, to keep pace with the changing high-frequency current. Let us keep this fact also in mind.

A current is always passing through the plate or output circuit which contains the telephones. This current is a unidirectional one, which means that it will flow from the positive side of the "B-battery" through the telephones across the space between the filament and the plate and back into the negative side of the battery. This current will produce no sound in the telephones, as long as it is uniform and non-pulsating. This is another fact that we must keep in mind.

Now we are ready to return to the function of the grid. We remember that it is interposed between the plate and the filament with its charges changing rapidly from positive to negative. We also understand that something is going to happen to this stream of negative electrons from the filament when the grid is negatively charged. The negative charge of the grid will have the effect of pushing back the electron stream. Thus, an interruption in the uniform current that is passing through the plate or output circuit will be caused. The grid will become positively charged when the current in the grid circuit again changes its direction. This causes the electrons, which shoot off the filament to be attracted by the grid and they pass with renewed vigor and speed to the plate. When the grid is positively charged there is an increase in the current flowing through the telephones since the current passing between the filament and the plate meets with less resistance. This increasing current in the telephones is periodical, keeping pace with the changing currents in the grid circuit. The current in the output circuit, while still flowing in one direction, loses its uniformity. The changes in the strength of the current produce corresponding changes in the magnetism of the coils in the telephone receivers, and the signals thereby are made audible.

Since only one-half of the high-frequency current flowing in the grid input circuit affects the current flowing in the plate or output circuit, the effect is in general the same as that produced by a rectifying crystal, but more pronounced. The vacuum tube is unlike the crystal detector in that we do not hear the actual incoming radio currents, but simply the effects they produce in the local battery circuit.

Figure 47 illustrates the effect which the grid with the positive charge from incoming radio waves will have upon the negative electrons formed by the hot filament. This positive charge on the grid will attract the electrons.

Figure 49 shows the complete hook-up for a simple type vacuum tube detector in a plain receiver. The aerial circuit contains a tuning coil which assists in tuning the detector circuit by moving the arrow point up and down on the turns of the tuning coil. The oscillations from the incoming waves are impressed upon the grid and filament. When the grid receives a positive charge from the incoming waves it assists in the flow of electrons and causes the B-battery current to increase, and when the incoming waves, place a negative charge on the grid, the flow of electrons is retarded and the B-battery current decreases. This increase and decrease of the battery current causes the telephone diaphragms to vibrate and make the signals audible to the receiving operator.

The essential adjustments of this receiver are, first, the brightness of the filament, which is regulated by the rheostat, and second, the plate battery voltage which is usually changed by taps on the battery itself, and third, the tuning of the detector circuit by moving the sliding contact on the tuning coil.

Radio engineers look upon the vacuum tube as a sort of trigger. When the trigger of a revolver or a shotgun is released it sets off the detonating cap of the bullet. The energy that is required to operate the trigger is insignificant when compared with the amount of energy that is released by the exploding powder. In the same way, the little "trigger" currents in the grid circuit of the vacuum tube are quite insignificant when compared with the increases which they cause in the current flowing in the plate or output circuit of the tube. Hence the vacuum tube is also an amplifying device, since the plate current governed by the grid is far greater in strength than the high-frequency grid current.

The function of any detecting device, such as a vacuum tube or rectifying crystal, is to make a radio frequency current produce an audible sound. We have previously been told that a radio frequency current "vibrates" or "oscillates" so rapidly that it is inaudible. A crystal detector, for instance, simply cuts off one-half of these oscillations and produces a unidirectional, pulsating current of audio frequency. All we need to know about this is that we cannot hear radio-frequency currents, while we can hear audio-frequency currents.

We shall now touch again upon the subject of damped and undamped oscillations. We will recall that damped oscillations are those that gradually die out. They are produced by wireless transmitters of the spark type. To make a vacuum tube detector responsive to such oscillations we must insert in the grid circuit what is known as a grid condenser. Our previous mention of the condenser left us with the understanding that it is a device capable of storing up electrical currents in the form of charges.

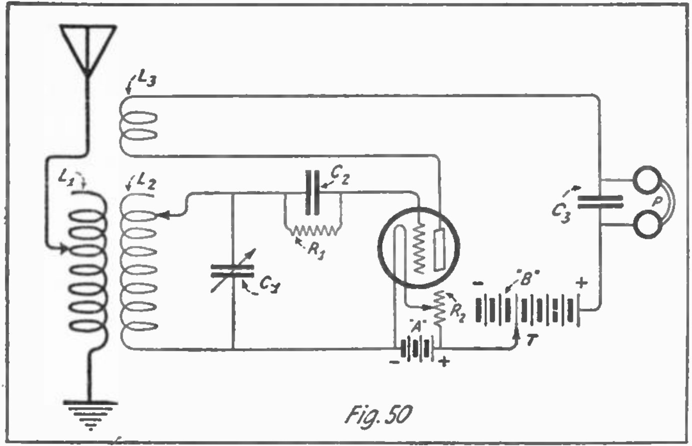


Fig. 50

In Figure 50 we see where this grid condenser is placed. It is the work of this condenser to store up the currents which are rectified by the valve action which takes place between the grid and the filament. Each group of incoming oscillations charges the grid condenser. When the charge reaches a certain point it either discharges through the vacuum tube or through what has become known as the grid leak. To explain this grid leak, we may say that it is like a small hole in a barrel which will allow water to run out slowly while the barrel is being filled to a certain level. (The grid leak is really a piece of high-resistance material.) As the condenser becomes charged, the charge leaks slowly away through the resistance. Thus the cumulative effect of a whole group of incoming oscillations is allowed to act upon the vacuum tube. It is in this way that the telephone current (current passing through the plate circuit), is varied with the spark frequency of the distant transmitter. The diagram of connections showing the grid condenser is one that can be used to receive either damped or undamped signals.

In the diagram of the circuit just referred to we will notice an extra coil which has not as yet been explained. This little coil forms the basis of a patent that has had a profound effect upon the wireless art. A few years ago, Edwin H. Armstrong, one of the greatest authorities on the vacuum tube, discovered what has become known as the principle of "regeneration." We have seen how a variation of the grid charge changes the strength of the plate current. A very slight change in the grid charge brings about a relatively large change in the plate current. If we could change this grid charge above or below the maximum value that is supplied by the incoming radio signal, a still greater change would take place in the plate circuit.

If we are to fully understand the following, we must concentrate the whole of our attention upon it. We know that the plate current varies in step with the frequency of the incoming signals. We will understand that if this plate current can be impressed upon the grid circuit in step with the incoming signals, the charge of the grid will be increased. This increased charge on the grid will in turn cause a greater effect in the plate current. This is the principle of regeneration.

The coil shown in Figure 50 is the regenerative circuit with a "tickler coil," marked L-3. This coil inductively connects the plate circuit with the grid circuit. The current flowing in the plate circuit will pass through the tickler coil. Thus, part of the changing current in this circuit is inductively impressed upon the grid circuit.

Just how much the regenerative principle has increased the efficiency of vacuum tube receivers, is hard to realize. However, we can gain some idea of the value of this principle when we learn that the original strength of the signals can be amplified several hundred times. Previously inaudible signals can now be received with ease. Any device that will increase the sensitivity of receiving apparatus really increases the efficiency of transmitters as well, since it allows their signals to be heard over greater distances. Armstrong's regenerative circuit stands next in importance to the invention of the vacuum tube.

We will perhaps wonder why we cannot connect up several vacuum tubes in such a way that the output of one tube will be amplified by another tube and so on until the signal strength will be built up to a point where it will be thousands of times greater than its original value. This is entirely possible and is being done every day. A circuit in which three vacuum tubes are used is

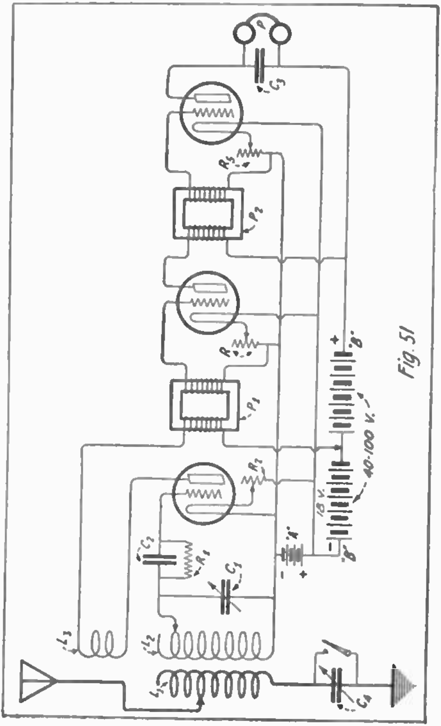


Fig. 51

shown in Figure 51. Although the connections look extremely complicated at first glance, they are really very simple. The first vacuum tube shown is made especially for detection. The two following tubes are used for amplification. There is placed with each amplifying tube a tiny transformer. To outline the function of the transformer would take a long time, and the outcome would be uncertain. We will merely say that the amplifying tubes are always connected through transformers. We do not need to know much about the construction of these transformers since they can be purchased ready-made together with the vacuum tubes and other parts.

The circuit to which we have just referred has two stages of amplification. Each amplifier tube and transformer is a stage. Although more than two stages of amplification can be used, it is not advisable for the beginner to attempt to take on the control of too many vacuum tubes. Two stages of amplification can be easily handled by an amateur, but more than this requires the services of a seasoned veteran.

The vacuum tube is not only a detector of radio currents, but can be used as a generator of them as well. When functioning in this manner it works silently and efficiently. It is able to convert a direct current into a high-frequency radio current which is able to set up ether splashes. It is quite probable that sometime in the near future a few transmitter vacuum tubes, or power vacuum tubes, as they are called, will take the place of much of the elaborate mechanism that is now employed in the radio station. The vacuum tube is indeed a radio Jack-of-all-trades, and it is quite possible that still other applications will be found for it in the future.

Chapter VII

How to Set Up Radio Transmitters

When a radio "bug" has gratified his desires along the receiving line, he is usually not quite satisfied until he has a transmitting outfit as well. After all, to be complete, a wireless station must be able to "speak" as well as "hear." Let us now consider a few transmitting outfits.

Transmitter No. 1, shown in Figure 52, uses a spark coil as a generator of the high-frequency currents. There is used in connection with the spark coil, a spark gap, a heavy glass plate condenser, and what is known as an oscillation transformer. Every time the telegraph key in the primary circuit of the spark coil is pressed a spark will flow

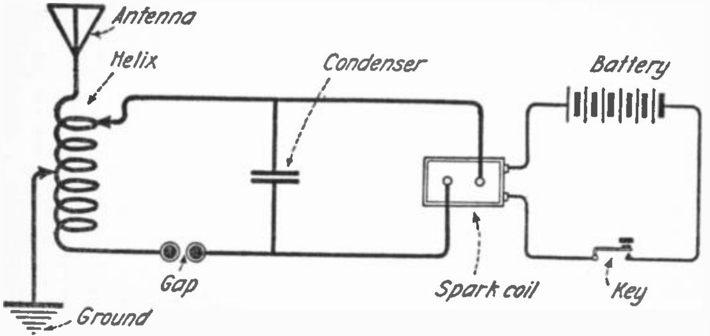
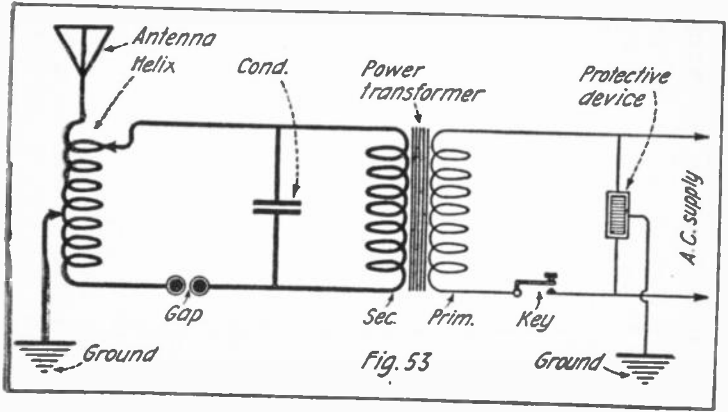


Fig. 52

across the gap and waves will be propagated. When operating such a set we must be careful not to come in contact with the spark gap while the coil is in operation. This would give a very uncomfortable shock as the voltage produced by the spark coil is very high.

If we want to graduate from the spark coil class we may get a transformer which will operate off the lighting circuit. Transformers must be operated with alternating current, however, and before we purchase one we should make sure that the house is supplied with alternating current, and also we should know the frequency of this current. It may be 25 cycle or it may be 60 cycle, and the transformer must be designed for a certain frequency. Transformers come in various sizes or powers. We can get a ¼ kw. transformer, a ½ kw. or a 1 kw.

Transmitter No. 2, shown in Figures 53 and 54, includes besides a transformer



Antenna
Helix
Cond.
Power transformer
Protective device
A.C. supply
Gap
Sec.
Prim.
Key
Ground
Ground

Fig. 53

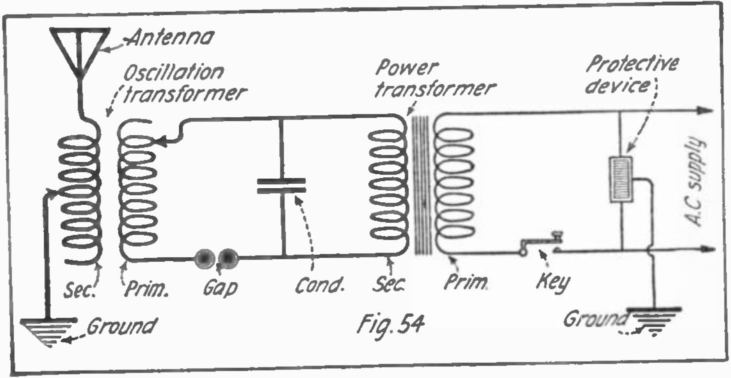

Antenna
Oscillation transformer
Power transformer
Protective device
A.C supply
Sec.
Prim.
Gap
Cond.
Sec.
Prim.
Key
Ground
Ground

Fig. 54

a rotary spark gap which is driven by an electric motor. The rotary gap gives the signal of the station a musical tone, and it also allows the signals to be read with greater ease through interference. The tone produced is quite pleasing to the ear.

When we buy parts for our transmitting outfit, we must depend upon the electrical dealer to the extent of having him provide us with the proper kind of rotary spark gap, key, condenser and oscillation transformer to be used with the transformer we buy. A condenser that would be suitable for a ¼ kw. transformer would not be capable of handling the power developed by a 1 kw. transformer. In the same way, a rotary spark gap designed for use with a 1 kw. transformer would not be suitable for use with a ¼ kw. transformer. A key used with a ½ kw. transformer has a heavier current to break than one used with a ¼ kw. transformer.

We will also see that a line protecting device is used with transmitter No. 2. Such a device is necessary if we wish to keep on good terms with the local electric light company and fire inspector. This little device is inexpensive and comes already assembled. We must use this because at times our transformer is very apt to get unmanageable and send a high voltage surge back into the power line. If the protecting device is not used a fire is apt to be started or damage will result to the wiring. The protective device allows the excess current to pass off harmlessly to the ground.

It would seem that the spark coil and power transformer transmitting stations have had their day. They are both troublesome and inefficient. For 200-meter work the transformer is a great waster of energy.

The vacuum tube has taken the place of the spark gap in the transmitting station. This little tube produces a high-frequency current and in this work it has no rival in efficiency. It produces a perfectly clear note that can be read with ease through static and interference. The vacuum tube produces no local noise, but at the distant receiving station the signals it produces for a given amount of power make a noisy spark transformer set appear ridiculously weak in comparison. A vacuum tube outfit using 10 or 15 watts of energy is often able to transmit signals over a far greater distance than a transformer using as much as 250 watts. The cost of the vacuum tube outfit is no more, if as much as the transformer.

Vacuum tube transmitters are known as C.W. transmitters. We will remember that C.W. means "continuous waves," and that vacuum tubes produce these waves. The spark coil or transformer is used in damped or discontinuous wave transmitters.

Transmitter No. 3, shown in Figure

55, is a simple, little vacuum tube outfit suitable to begin with. The tube is

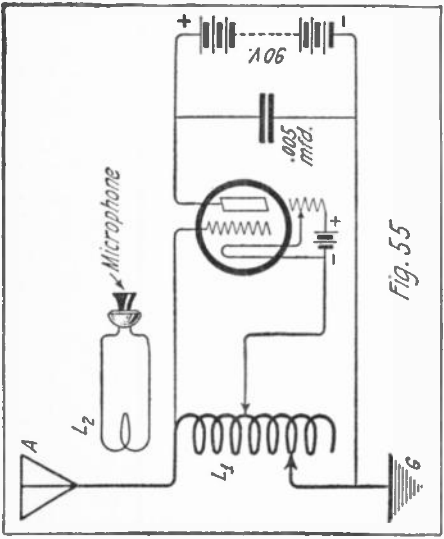


Fig. 55

made especially for transmitting purposes, and is able to handle five watts of power. Such a tube, if properly cared for, will last a long time, and the initial cost is little more than that of a receiving tube. The power of such a transmitter can be increased by adding more tubes. Every time a tube is added, five watts of power are added to the outfit. If more than 15 watts are desired, it is advisable to get a 50-watt tube, since three five-watt tubes would cost nearly as much, and necessitate more attention. With a 50-watt tube we would have only one tube to watch. For still more powerful outfits there are 250-watt tubes, and we may keep adding tubes until we have built up any power we wish. The great Marconi station at Carnarvon, Wales, which communicates with Australia, has forty-eight tubes.

We will now learn how a single aerial and ground may be used to serve both the transmitting and receiving unit of a station. To use one aerial and one ground, it will be necessary to purchase a double-pole, double-throw switch.

This is simply a single switch which takes the place of two. The receiving outfit is connected to the aerial and ground when the switch is in one position, and the transmitting outfit will be connected to the aerial and ground when the switch is in the other position. Thus, when we are about to receive, the transmitting instruments are entirely disconnected, and vice versa.

Many beginners ask, "Is there any danger of my aerial being struck by lightning?" If an aerial is properly grounded when not in use, it will act in the capacity of a lightning rod and actually offer protection to the shed or house upon which it is located. To have an aerial serve in the capacity of a lightning rod, we must be careful to have certain details faithfully carried out. The ground wire must be a heavy one, well supported on insulators. No. 4 insulated wire should be used. When the outfit is not in use, a heavy single pole, double-throw switch is used to connect the aerial directly to the ground. When connected in this way, if lightning strikes the aerial, the heavy charges will immediately flow off to the ground without doing any harm. If such a ground switch is not used, serious damage is apt to result. When a low-resistance conducting path is established between the aerial and the ground, the danger of the aerial being struck is greatly reduced, since the small static charges of electricity which accumulate in the neighborhood of the aerial will be conducted away as fast as they are formed. No one should make the mistake of trying to receive or transmit during a heavy storm.

The real radio enthusiast, after getting his station in operation will want to learn the international code. For this purpose he may purchase a small buzzer practice set which will help him to become familiar with the characters.

This practice set consists of a small buzzer, key and a single dry cell. Besides helping the operator to become familiar with the characters, this little set will teach him to send correctly.

Learning to receive is much more difficult than learning to send. Good receiving is developed only through perfect familiarity with the code characters, and, as in everything else, practice makes perfect. At the start we will probably be able to receive only two or three words a minute or less. Gradually this speed will increase until we reach fifteen or twenty words a minute. Commercial operators seldom go over twenty-five words a minute, and more usually send around twenty.

On the radio market today, there are a number of automatic code transmitters. These devices will transmit messages to us automatically and at varying speeds. They can be adjusted to send from three to forty words per minute.

To develop a good "sending fist," as it is called in the radio world, we must practice diligently with the key and buzzer. In practicing the code we should remember that the dash is just three times as long as the dot. The beginner should try not to send in a jerky fashion. If he starts out in a uniform manner, he will find it less difficult to send at higher speeds.

The International Morse Code and Conventional Signals are given. This is the universal wireless code in use by all big commercial stations. We must learn it if we are to hear what is passing through the ether about us.

Unless the beginner also acquaints himself with the list of abbreviations used in wireless, he will hear some very mysterious things. One radio man may say to another, "Your signals are very QSA." He may also say, "QRZ," "QRU," "QRW," or "QRO." An examination of the accompanying list of abbreviations will show us just what the various letter combinations mean.

List of Standard Abbreviations Used in Radio Communication

PRB Do you wish to communicate by means of the International Signal Code?
QRA What ship or coast station is that?
QRB What is your distance?
QRC What is your true bearing?
QRD Where are you bound for?
QRF Where are you bound from?
QRG What line do you belong to?
QRH What is your wave length in meters?
QRJ How many words have you to send?
QRK How do you receive me?
QRL Are you receiving badly? Shall I send 20?
QRM Are you being interfered with?
QRN Are the atmospherics strong?
QRO Shall I increase power?
QRP Shall I decrease power?
QRQ Shall I send faster?
QRS Shall I send slower?
QRT Shall I stop sending?
QRU Have you anything for me?
QRV Are you ready?
QRW Are you busy?
QRX Shall I stand by?
QRY When will be my turn?
QRZ Are my signals weak?

List of Standard Abbreviations Used in Radio Communication

QSA Are my signals strong?
QSB { Is my tone bad? / Is my spark bad?
QSC Is my spacing bad?
QSD What is your time?
QSF Is transmission to be in alternate order or in series?
QSJ What rate shall I collect for ......?
QSK Is the last radiogram canceled?
QSL Did you get my receipt?
QSM What is your true course?
QSN Are you in communication with land?
QSO Are you in communication with any ship or station (or: with........)?
QSP Shall I inform..........that you are calling him?
QSQ Is..........calling me?
QSR Will you forward the radiogram?
QST Have you received the general call?
QSU Please call me when you have finished (or: at ......o'clock)?
QSV Is public correspondence being handled?
QSW Shall I increase my spark frequency?
QSX Shall I decrease my spark frequency?
QSY Shall I send on a wave length of.... meters?
QTE What is my true bearing?

Getting acquainted with the other radio "bugs" in our vicinity is another thing which most of us want to do. This is very easy. All we need to do is to go out and walk the streets until we find a house with an aerial on it. If it is a good aerial with high poles and carefully strung wires we can rest assured that it was put up by a brother "ham" and it is just like a welcome sign on the door. We can walk right in and ask for the "fellow who owns the wireless." Then we can chat with him to our heart's content about variometers, microhenries, radio frequencies and all the other mysterious terms that we are bubbling over with. We can also take advantage of his knowledge of radio to progress more rapidly with the perfection of our station. We can sometimes learn a great deal from the experiences of other "hams."

We sometimes learn things that will do us no good in this way also. Every amateur has a different idea about hook-ups and apparatus, and he naturally tries to win over other amateurs to his way of thinking. It is probably best that we do a little experimenting on our own, because the real enjoyment of radio comes through this experience. We must learn to use our own judgment in selecting the worth-while hints from the other amateurs who insist on giving us advice.

When we learn how to handle the code, and get our station in operation, it is easy to get acquainted. This will be especially true if our signals are strong and our sending passable. The radio fraternity greets with open arms any new member who can send fairly well and whose instruments have a good, clear note. From the official call book, we can obtain the calls of stations that should be within our range. We can then call them until they answer, and usually when they answer we have gained a new friend. He will want us to tell him all about our outfit, our location, etc., and will tell us all about his. These conversations usually end by an ·ppointment for another call at some ıture time.

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

To be Used for All General Public Service Radio Communication

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A • —	Ä (German) • — • —
B — • • •	Á or Å (Spanish-Scandinavian) • — — • —
C — • — •	CH (German-Spanish) — — — —
D — • •	É (French) • • — • •
E •	Ñ (Spanish) — — • — —
F • • — •	Ö (German) — — — •
G — — •	Ü (German) • • — —
H • • • •	1 • — — — —
I • •	2 • • — — —
J • — — —	3 • • • — —
K — • —	4 • • • • —
L • — • •	5 • • • • •
M — —	6 — • • • •
N — •	7 — — • • •
O — — —	8 — — — • •
P • — — •	9 — — — — •
Q — — • —	0 — — — — —
R • — •	
S • • •	
T —	
U • • —	
V • • • —	
W • — —	
X — • • —	
Y — • — —	
Z — — • •	

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

To be Used for all General Public Service Radio Communication

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Attention call to precede every transmission	— • — • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

To be Used for All General Public Service Radio Communication

Warning—high power	— — • • — —
Question (please repeat after......) — interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report (to precede all position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

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