Why are these used? If we connect one end of our condenser to the spark gap and then to the aerial, the other condenser terminal to the spark gap and then to the ground, we are able to transmit electrical waves which would be much stronger than could be sent out from the condenser alone. An aerial at the receiving station is also necessary.

THE ETHER

Here we have shown in one city, say New York, a sending aerial. In Chicago, suppose we have located the receiving station. We

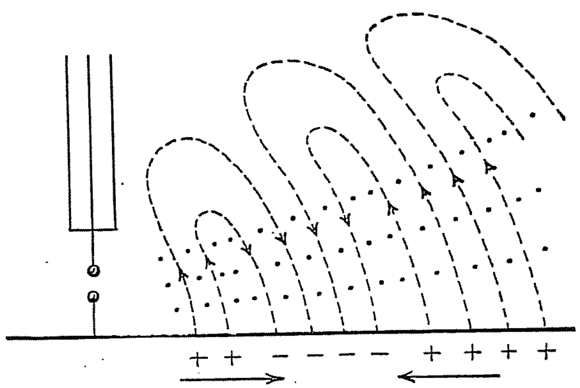


Fig. 5

can send waves from New York to Chicago without any wires. How are they sent? Scientific men never think of a **cause** and an **effect** without some connecting link. That is, we have the sending set in New York, which is the cause, and the receiving in Chicago, which is the effect. Where is the connecting link? We call it wireless, that is true enough, but there must be something on which we can send the wave. This something we call the **ETHER.** Scientists have assumed that all space is filled with a "something" to which the name of ether has been given. Wireless or electro-magnetic waves are transmitted through the ether, just as water waves are transmitted through water, or sound waves through air.

Let us look at Fig. 5 so we may get a picture of the wireless waves as they are sent out from the antenna. As the condenser

discharge runs up into the wires and down into the ground, a certain electrical field is made between the antenna and the earth. This strain is the beginning of a wave which extends out from the antenna in all directions to the receiving station. Fig. 6 illustrates the similar case of water waves which are sent out when a stone is thrown into a pond at A, being the sending point, and are received at B, which is the receiving.

THE RECEIVING

We have succeeded in following the waves as they branch from the sending station. Suppose they have reached Chicago. The waves strike the antenna because it is in their path. Do not think of the antenna as attracting the waves; it does not. As the wave strikes the wires of the aerial in Chicago, it creates in

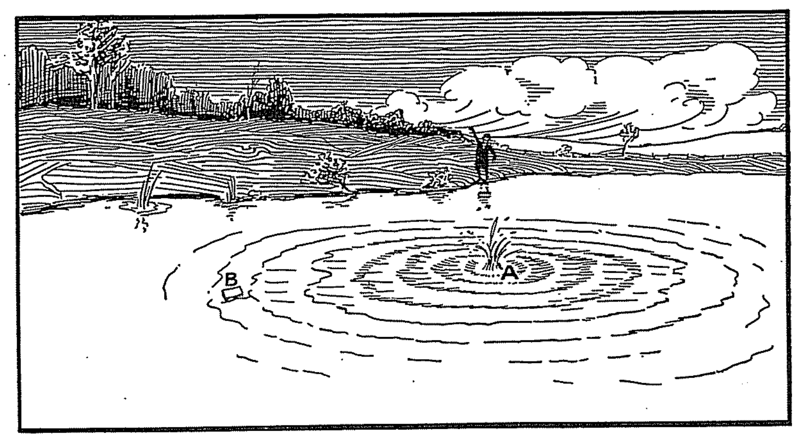


Fig. 6

them an electrical charge similar to the one which we put into the sending antenna. At the same time, the wave has proceeded through the earth connection, so that both the wave through the ether and the wave through the ground reach the receiving aerial at the same time, or, if you wish, you can consider the waves as

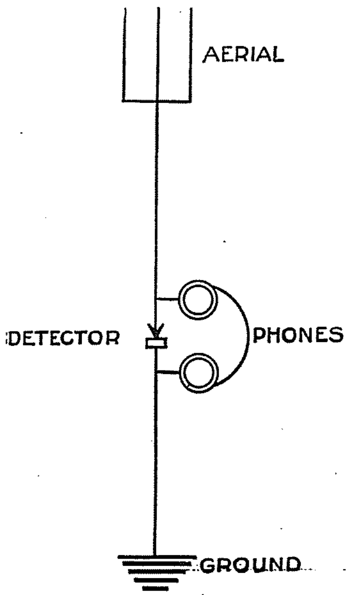


Fig. 7

reaching the receiving station through the ether and going back by way of the ground to the sending station to complete their circuit.

The electrical current set up in the receiving antenna is brought into the operating room, where we make the signals audible by means of a telephone receiver and what is called a detector. Fig. 7 shows the connections at the receiving station. It will be necessary to pause here to tell you what the detector does.

The detector is a device for making the wireless signals audible. Under the description of "Wireless Waves," page 9, you were told that a condenser oscillates with a frequency in the neighborhood of 1,000,000 sparks per second. This is so rapid that it cannot be heard by the human ear. To make the signals audible, we must cut out some of the million sparks. This is what the detector does, and the connecting phone gives us the instrument in which we hear the wireless signals.

SUMMARY

You have seen how it is possible to send out a wireless wave from one antenna through the ether to another, induce a current in this, have it operate through a detector, and a phone, and back through the ground to the sending station. In order that you might more easily understand this first principle of wireless transmission, we have purposely left out a great many terms, which might only confuse you. The apparatus described is the simplest with which we can explain wireless communication. In order that we may exchange ideas by wireless, we send the waves out in a series of long intervals or short ones. The long one is a dash when received or sent; the shorter, a dot. In this manner, by means of a code, we are able to transmit words and messages by wireless telegraphy.

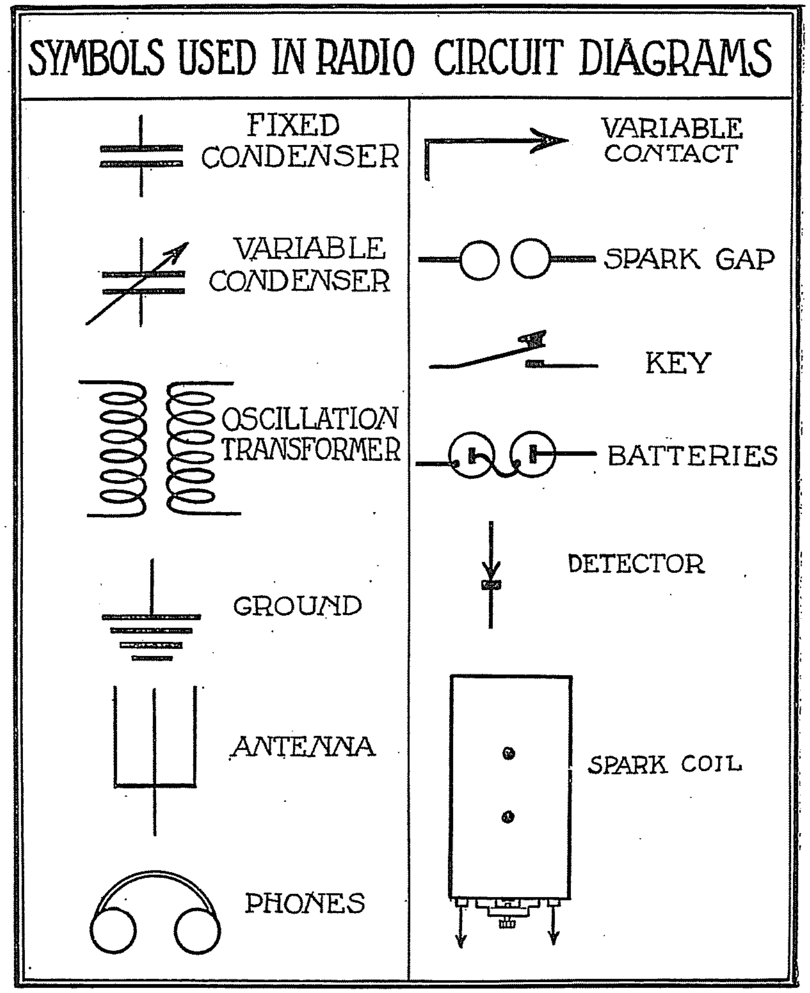


Fig. 8

APPLICATION OF THEORY TO APPARATUS

As it has been explained, not all the apparatus was considered in the first part of the book. We shall now tell about the instruments used. While wireless apparatus is changing from day to day, all the instruments described here are the most general type used by amateur operators. A clear knowledge of the apparatus is a great help toward becoming a proficient operator. If you will read the next part with care, it will make operating come more easily.

SENDING APPARATUS

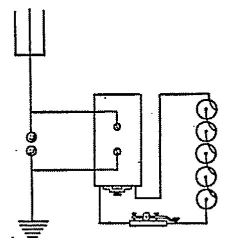


Fig. 9

In the sending set of amateur type, we start first with some source of power. Six or eight dry cells will make a battery which does very well. These are connected up with a key, gap and spark coil, and then to the antenna and ground as shown in Fig. 9. This will send out a wireless wave, but it has one fault—the wave is not of definite length. It is rather broad and is called **untuned.** A wave which does not have a definite length is not desirable. To overcome this difficulty, we connect a condenser and what is known as an oscillation transformer, as shown in Fig. 10.

THE OSCILLATION TRANSFORMER

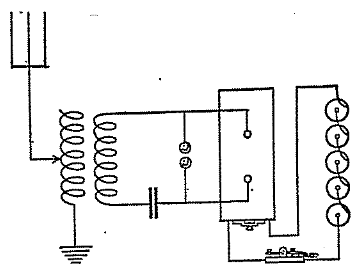


Fig. 10

When we connect an oscillation transformer, condenser and spark gap, as shown in Fig. 10, it is found that a wave of definite length is sent out. The size of the waves sent out by the apparatus depends on the size of the condenser and oscillation transformer. If we have a large condenser and a large amount of wire in the transformer, we find the sending wave is also large. By having different sizes of condenser and different amounts of wire in the oscillation transformer, we can send out waves of varying lengths.

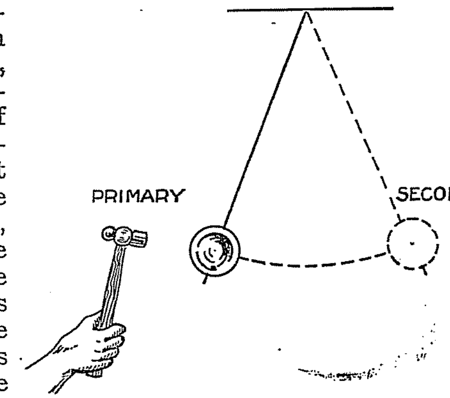


Fig. 11

Fig 12 shows the connection which is known as the **primary circuit**, consisting of gap, condenser, and one part of the oscillation transformer. The other part is connected with the aerial and the ground, and is known as the secondary circuit. The secondary circuit has an adjustable wave length which depends on the length of the antenna and the number of turns of wire of the secondary in use. In actual practice, the wave lengths of the primary and secondary are made the same, and a wave is sent out which can be measured.

The question of tuning the sending set is a rather complicated one, and we can best picture it by a simple comparison with a pendulum. Consider Fig. 11. This picture shows a pendulum in motion with a hammer ready to tap it at the proper moment, so that it will be kept swinging. This is just what the primary circuit does to the secondary. The primary circuit supplies the

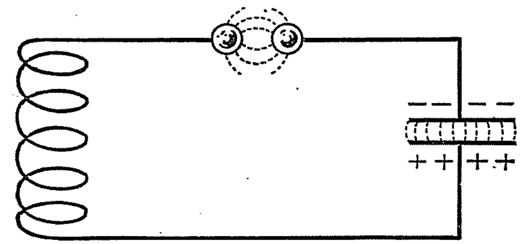


Fig. 12

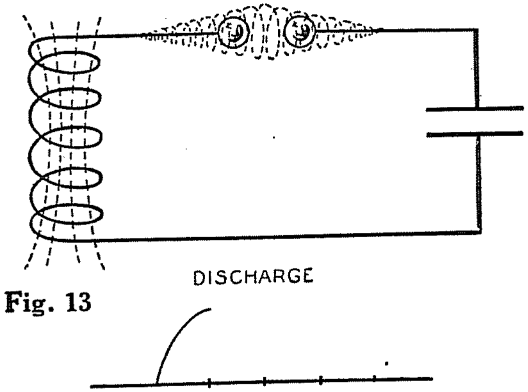


Fig. 13

energy to the secondary circuit at the proper intervals so that wireless waves of the right length are being sent out and are reinforced at the proper time.

THE TRANSFER OF ELECTRICAL ENERGY BY INDUCTION

Electro-magnetic induction is a term which you are already familiar with, having found it in the GILBERT Elementary Electricity. Induction plays a very important part in connection

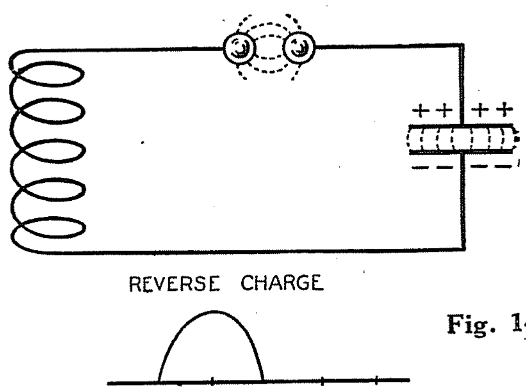


Fig. 14

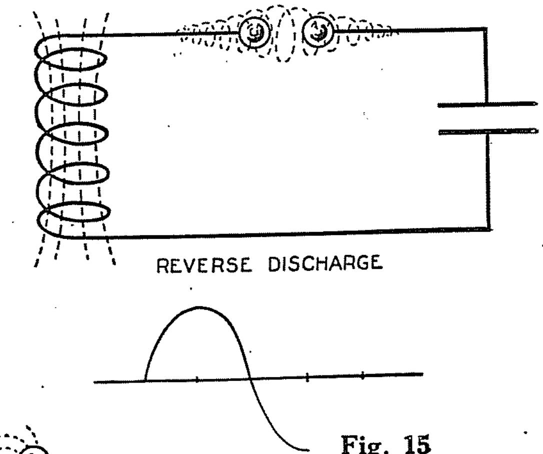


Fig. 15

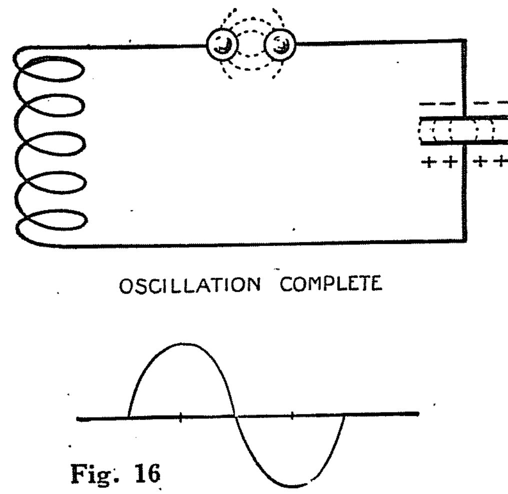


Fig. 16

with the oscillation transformer. The energy is transferred from the primary circuit to the secondary circuit by means of electromagnetic induction.

When an electric current flows through a wire, it is accompanied by a series of magnetic lines of force which surround the wire. On the other hand, we can surround a wire by a series of magnetic lines of force and have it set up a current when the lines of force move. That is, if instead of the current moving, we have the magnetic lines cut the conductor, they will set up an electrical current. In the case of our primary and secondary, a similar thing takes place. The current flowing in the primary circuit creates magnetic lines of force, and these, in turn, set up an electrical current in the secondary circuit.

Figs 12, 13, 14, 15 and 16 tell the whole story. They show the four stages which accompany a complete oscillation at the spark gap. Fig. 12 shows the condenser charge and the current going across the gap. As the current passes, it goes into Fig. 13, which shows the magnetic lines of force around the gap and oscillation transformer. Fig. 14 shows the change reversed, and Fig. 15 shows the reversed electro-magnetic field. Fig. 16 brings the circuit back to the original case.

As the magnetic lines of force which we have shown in the primary circuit break down, they cut the wires in the secondary of the oscillation transformer and a current is induced. This current oscillates just as the condenser current, and the energy from it flows up into the antenna and down to the ground, sending out the wireless waves.

SENDING WAVE LENGTHS

Since we have found out that various wave lengths may be used, we can increase our knowledge if we have some idea as to the actual length of these waves. If, in the primary circuit, we have for a condenser ten glass plates, 8 x 10 inches, coated on each side with tinfoil, 6 x 8 inches, connected together and used with one turn in the primary of the oscillation transformer, which is $8\frac{1}{2}$ inches in diameter, we send out a wave which is approximately 200 meters, or 657 feet.* The wave length of an antenna without the secondary coil may be found approximately by taking the total length of the antenna and ground wires in meters and multiplying by 4.7. For example, if we take an antenna with a length of 65 feet, a lead of 25 feet, and a ground connection of 30 feet, the total length in feet is 120; this changed to meters is approximately $36\frac{1}{2}$, and multiplying by 4.7 we get about 175 meters for

*1 meter = 39.37 inches or approximately $3\frac{1}{4}$ feet.

the wave length of the antenna without the secondary coil in the circuit. By adding the secondary coil, we increase the wave length.

In actual operation, amateur stations have been limited by the Government to wave lengths up to 200 meters. Commercial stations operate on 300 and 600, while the Government stations from 600 up. A few stations operate on wave lengths of 1,000 and 1,500 meters. The big Government station at Arlington, Virginia, sends out the weather reports and time signals on a wave length of 2,500 meters.

THE SPARK GAP

We have already explained how a condenser works, and it will not be necessary to consider this question any further from the standpoint of sending. In the primary circuit, another important piece of apparatus is the spark gap. Its work, as we have seen, is to allow the condenser to discharge and thereby set up the oscillation with which we transmit signals. When connected with a spark coil, a plain fixed gap is used. When used with a transformer, a rotary gap is usually made to take the place of the fixed one. The rotary gap consists of a rotating wheel with a number of sparking points on it, as shown in Fig. 17. When the wheel rotates, large numbers of sparks are had per second, due to the speed with which it travels. This gives a musical note, and we are able to transmit very effectively with it.

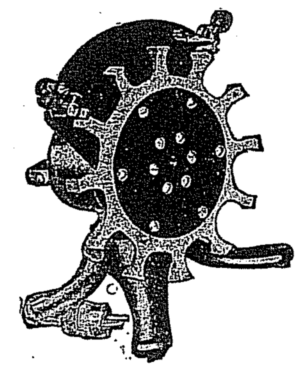


Fig. 17

We have left last for description some of the things which come first as they are connected in the circuit. We supply the condenser with high-voltage current from either a spark coil or a step-up transformer. The current, which is supplied to this step-up device, is broken into dots and dashes by means of a telegraph key.

SENDING APPARATUS

Now that we have considered the different units of the sending set, we can connect them all together and consider its operation as a whole. Fig. 18 gives a complete hook-up of a sending set comprised of batteries, spark coil, key, condenser, gap, oscillation transformer, aerial, and ground. Let us trace the course of the current and find out just how it acts. The key is closed; this completes the spark coil. The current which flows through the

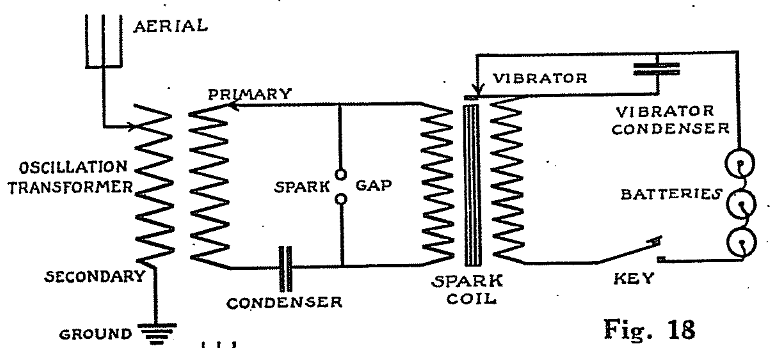


Fig. 18

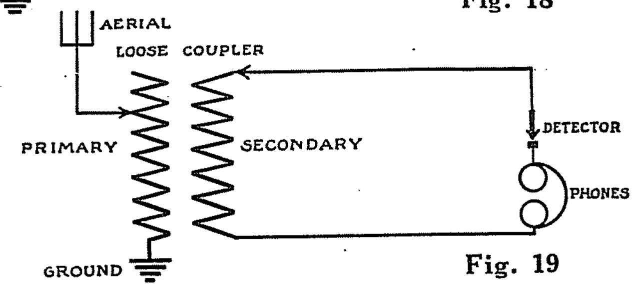


Fig. 19

coil is interrupted by means of a vibrator and it is stepped up in voltage from about ten volts to 20,000. It then passes into the condenser, and the electrical energy is stored up until it reaches a point where it can jump the gap. In crossing the gap, the current passes through the primary of the oscillation transformer, setting up magnetic lines of force, which cut the turns of the secondary of the oscillation transformer. The lines of force disappear and a current is induced in the aerial circuit. This current turn creates the wireless waves which travel out from the aerial and through the ground in all directions.

RECEIVING APPARATUS

What takes place in the receiving apparatus is not unlike that which takes place at the sending station. Instead of an oscillation transformer, we have a receiving transformer or loose coupler. Its work is similar to that of the oscillation transformer at the sending end. The receiving transformer has a primary which consists of a number of turns of wire connected to the aerial and the ground. The secondary of the receiving transformer is connected to the telephone receivers and detector. (See Fig. No. 19.).

Let us follow the wave as it comes in from the antenna. When the electrical oscillations are received, they are similar to the currents set up by the condenser. If we represent them with a line, it would look not unlike Fig. 20. The sound we hear is made up of a series of the rapid condenser discharge groups. This is received by the primary of the loose coupler, which can be made to receive a large number of wave lengths by using either a few or a great many turns of wire. That is, we can add wire to the aerial by means of the primary and increase the wave length so that the apparatus can be tuned to receive any number of stations sending on different wave lengths.

The current which is received in the primary sets up a similar current in the secondary, and here again the amount of wire can be varied so that the secondary circuit can be made to have a wave length the same as that of the primary. If the primary is receiving a wave 300 feet long, the secondary is adjusted so that

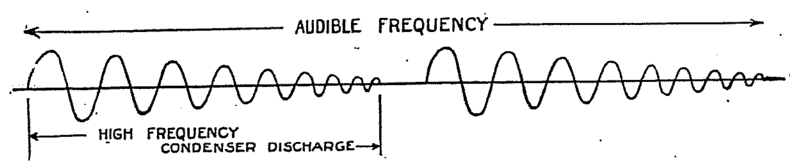


Fig. 20

it will receive a wave of similar length. When the two circuits are tuned alike they are said to be "in tune," or "in resonance." When two circuits are in tune, the greatest amount of energy can be exchanged between them. In other words, we can get the full strength of signals from the primary to the secondary.

TELEPHONE RECEIVERS

We have succeeded in tracing the wireless waves to the secondary of the loose coupler. If a pair of 'phones is connected, we would **not** be able to hear any signals. The reason is clearly shown when we think of the nature of the current. The current is oscillating at a very rapid rate; in the neighborhood of 1,000,000 times per second. If we should attempt to move the diaphragm of the

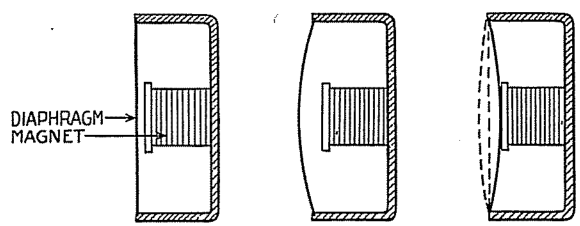


Fig. 21

telephone receivers, Fig. 21, at the rate of 1,000,000 times per second, it would be moving so fast that it would not "move at all." Even if it could move, it would be making a noise so very high in note we should be unable to hear it. To make the signals audible, we put in the circuit a detector. See Fig. 23.

DETECTORS

We have said the work of the detector is to make the signals audible. The manner in which it does this is interesting, and one cannot understand how a set works without considering it. The current which comes in is similar to the illustration in Fig. 22. The detector has a peculiar property of allowing this current to flow through it more easily in one direction than in the other. It takes the current and cuts out one-half of it, similar to the illustration already mentioned. This decreases the frequency and the sounds are allowed to act in groups which become audible.

Fig. 23 shows a detector which is known as a Crystal. The crystal consists of some mineral such as silicon, carborundum, galena, or even common coal. One connection is firmly fixed, while the other is a fine wire with which we "feel" over the surface

of the crystal. The fine wire strikes a spot which is more sensitive to the wireless waves than other parts of the mineral which are less sensitive. We may find a great many sensitive points on one mineral, while another will not be nearly as good a detector. Galena is one of the most sensitive detectors, but very delicate and usually hard to adjust. Once in adjustment, it can easily be

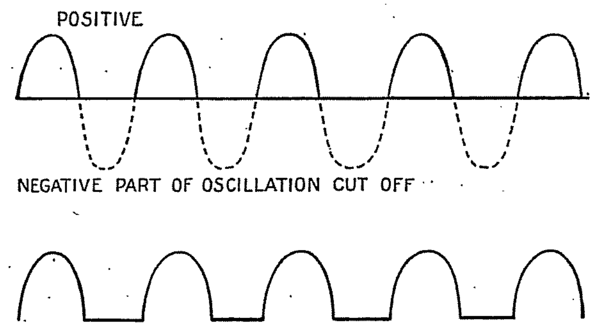


Fig. 22

knocked out by jarring the detector base. Silicon is rather easy to adjust and fairly sensitive. There are no end of minerals, and every experimenter has plenty of room to try his skill in this direction. The writer remembers occasions when he has been able to receive signals over distances of 75 to 300 miles on a piece of coal.

CONDENSERS

In the receiving set we can have condensers as well as in the sending. It is possible to connect a condenser across the primary or secondary of the receiving transformer and increase the wave length for receiving signals. In actual practice, a variable condenser is used. One is illustrated in Fig. 24. In a variable condenser, air acts as the insulating material, and the capacity is made large or small depending on the amount of area between the fixed and rotating plates.

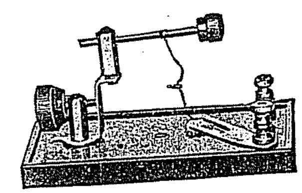
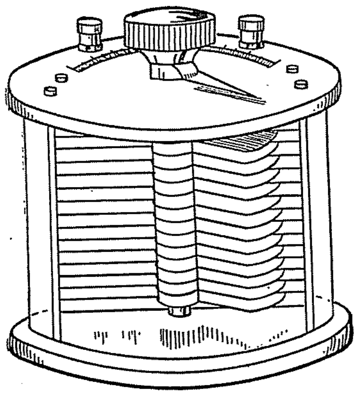


Fig. 23



ROTARY VARIABLE CONDENSER

Fig. 24

It is more customary to connect the variable condenser in the secondary circuit since it enables sharp tuning.

Small condensers are often used in connection with the telephones when a crystal detector is employed. The effect here is often to increase the loudness of signals and at the same time the tone is changed slightly.

AERIALS

In a wireless set, the aerial or antenna is a device on which the electro-magnetic waves are received. When the waves flow past the antenna they create an electrical charge in it which flows through the antenna to the ground to complete the circuit. In erecting an antenna, you must take into account the length of waves which you expect to receive. Under "Sending Wave Lengths" we have told how the natural wave length of an antenna may be calculated.

The big Government station at Arlington has towers to support its antenna which are 450 and 600 feet high. The majority of amateur stations have antennas which are under 100 feet in height. For ordinary work, an aerial 50 feet high will be very effective for amateur use. Its length usually depends on the conditions where it is to be erected. In some cases amateurs stretch their aerials from house to house, or from house to tree, and when no suitable support can be found, a pole is erected. The length of an antenna, to work with the GILBERT Wireless Sets, may vary from 30 to 200 feet long.

As to the number of wires, from one to six may be used. Very little difference is noticed in receiving for one wire antenna or six. In the case of sending, the difference is more marked. The more wires in the antenna, the greater help is given to the sending set. In aerials which have more than one wire, they should be spaced

approximately one-twenty-fifth of their length; that is, if we have an antenna fifty feet long, we should space the wires two feet apart. The usual construction brings all the aerial wires to the switch which connects the antenna to the sending or receiving apparatus. The part of the antenna which connects from the main wires to the apparatus is called the lead-in. An antenna construction of suitable size is shown in Fig. 25.

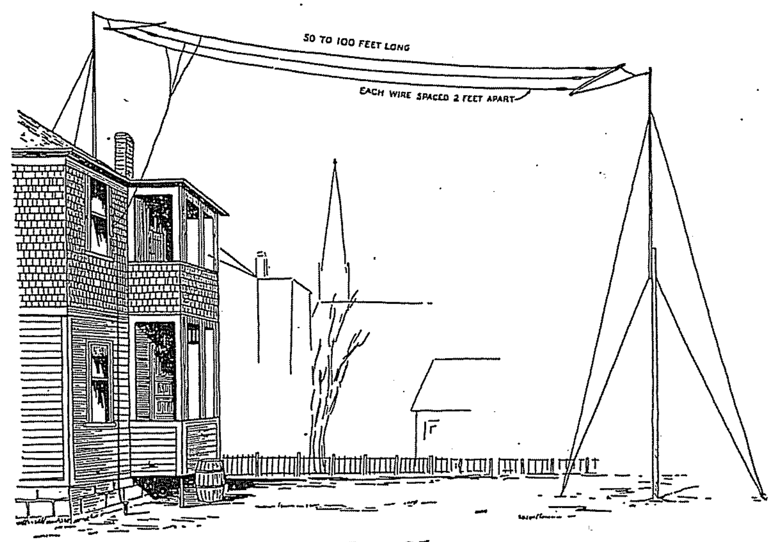


Fig. 25