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WIRELESS
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BY

P. J. RISDON, F.R.S.A.

LONDON

W. FOULSHAM & CO., LTD.

10 & 11 RED LION COURT, FLEET ST., E.C.4

MADE AND PRINTED IN GREAT BRITAIN AT THE MAYFLOWER PRESS, PLYMOUTH. WILLIAM BRENDON AND SON, LTD.

PREFACE TO THIRD EDITION

FORTUNATELY for mankind, science progresses by leaps and bounds; at the same time, this fact involves the re-consideration, from time to time, of scientific theories which have been firmly implanted in the mind of the amateur—in this case I refer more particularly to the wireless amateur. The theory of relativity has led to considerable doubt in the minds of a good many scientists as to whether there is such a thing as the ether. On the other hand, there are still many who contend that it is impossible to explain such mysteries as wireless phenomena, without the assistance of a hypothetical ether, which has served and still serves (even though it may be on an incorrect assumption) to explain the propagation and reception of wireless waves. Whatever may be the outcome of the new theory, for the present, the wireless amateur need not greatly concern himself as to whether wireless waves are dependent upon such a medium or not, and it would be inappropriate, at the present moment, to do more than mention the fact that there is a well-founded doubt about the whole subject.

One of the most striking recent developments in wireless science is the short wave beam system, by means of which telephony can be carried on between England and Australia. Details of this epoch-marking system will be found in a companion volume of this series.

THE AUTHOR

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WIRELESS REALLY EXPLAINED

CHAPTER I

ELECTRICITY AND MAGNETISM

In order to derive enjoyment and satisfaction from his wireless set, it is not necessary for the amateur to acquire a detailed knowledge of electricity, or to immerse himself in complex mathematical formulæ and calculations involved in the theory of wireless. But if he would take an intelligent interest in this fascinating subject, it is necessary for him to understand a few elementary facts about it, which are capable of being simply expressed and readily understood. For instance, electrical and magnetic phenomena lie at the very root of the science of wireless, and he should therefore understand what the connection is.

When an electric current passes through a conductor—say through a wire—it sets up what is termed a magnetic field round the conductor. The truth of this statement is proved every time we ring an electric bell, but it is quite a simple matter for the reader to verify it by experiment. Roll a piece of stiff paper into the form of a small cylinder a few inches long, and wind a single length of insulated copper wire round it from end to end, with the turns close together, but not overlapping. Attach one end of the wire to one of the terminals of an electric dry cell or of an accumulator, and the other end to the terminal of a switch, and connect by another wire the other terminal of the switch to the other terminal of the battery, first placing the switch in the open position (Fig. 1). Then insert a small iron bar or a bundle of iron wires in the cylinder and switch on, and it will be found that the iron has become magnetized, and will attract another piece of iron, although no current has passed through it. Upon switching off the current it will be demagnetized.

Now construct another coil of such a size that it will fit outside the first cylinder (Fig. 2), using very fine insulated wire and a much larger number of turns, place it outside the first coil (known as the primary coil), hold the two ends in your hands and switch on again. At the moment of switching on, the current in the coil connected to the battery will cause another current of higher voltage to flow in the outer or secondary coil, and if you have made a sufficient number of turns of wire in the secondary coil, you will feel a distinct shock, which will be repeated every time you switch on and off. If by some means such as the vibrator of an electric bell you cause rapid making and breaking of the primary circuit,

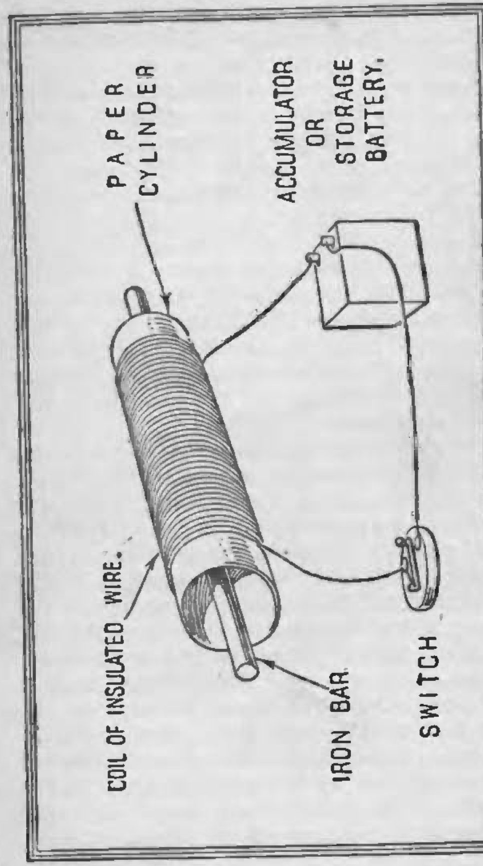


FIG. 1

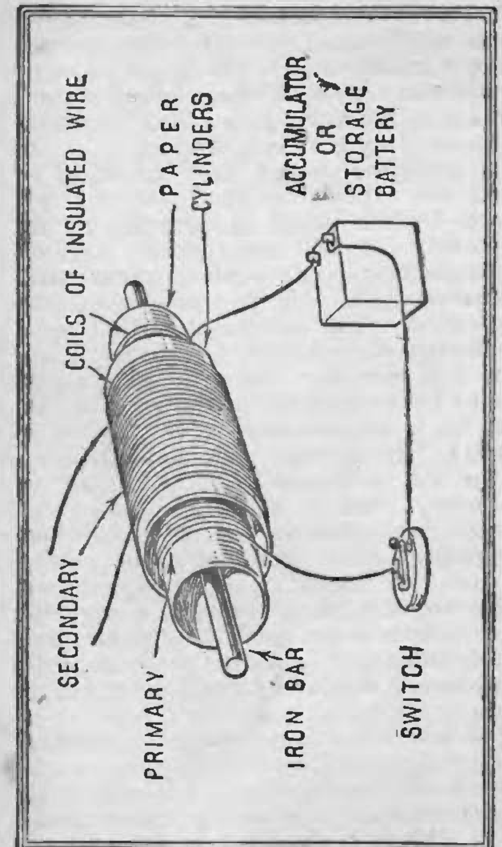


FIG. 2.

you will receive a succession of shocks following so rapidly upon each other that you will think it is continuous. *The current set up in the secondary coil is called an induced current,* the act of producing it is called induction, and such a coil is an induction coil.

I cannot too strongly urge the reader to make this experiment—at a cost of a few pence—because proper appreciation of this important fact will assist greatly towards understanding certain wireless instruments.

Conversely, if a magnet be pushed into and out of a coil of wire, it will set up a momentary electric current in the coil every time it is moved in and out. This can be proved by connecting the ends of the coil wire to a galvanometer instead of to a battery. Exactly the same thing happens if the coil is moved and the magnet is stationary. But if neither is moved no current flows, showing that it is only when the magnetic field is disturbed by the passage through it of the coil that current is produced.

Theoretically, the influence of a magnetic field extends to an indefinite distance, but the useful extent of its influence depends upon several things: notably the strength of the current producing it.

The flow of an electric current is Nature's method of restoring equilibrium when natural forces have been displaced. A dynamo does not create electricity and pump it along wires. What it does is to create what is known as a difference of potential between two points which are called the poles or the positive and negative terminals of the dynamo. On electrical instruments the positive terminal is usually denoted by the sign + and the negative by −.

If we carry a weight up to the top of a house, we expend energy in overcoming the force of gravity attracting the weight to the earth. In other words, we create a difference of potential. If we drop the weight out of the window the force of gravity pulls it down to the ground. We cannot see gravity and we cannot see electricity, but we know what they can do. A dynamo creates between its poles a condition corresponding to that which we create when we lift a weight, but electric current must have a conductor before it can flow. If we connect the two poles or terminals of a dynamo by a wire, electricity flows and restores equilibrium—that is, of course, supposing the dynamo is working.

If in the wire connecting the positive and negative terminals of a dynamo or of a battery we interpose a motor or other electrical appliance, the current can be made to operate it.

THE VOLT is the unit of measurement of the pressure of an electric current. The difference of potential set up by a dynamo or by a battery is not the same in every case,

but may vary enormously, and the pressure of the resulting electric current varies accordingly, much as water pressure in a pipe varies according to the height of the storage tank or reservoir from which the supply of water is derived. But this pressure must not be mistaken for *the amount* of current.

THE AMPERE is the unit of measurement of the *amount* of current passing.

RESISTANCE.—Although an electric current requires a conductor to enable it to flow, even the best conductors, such as copper, offer a certain amount of resistance to the current, just as, although a pipe is necessary to convey water from a reservoir to a house, there is friction between the water and the pipe that tends to restrict its flow. The unit of resistance is the ohm. If we allow too much current to flow through a wire, the wire offers so much resistance that it becomes hot: it may become red or white hot and fall to pieces.

Now the three terms volt, ampere, and resistance, although denoting different qualities, are interdependent. The amount of work that could be done by water flowing through a pipe depends upon the water pressure, the size of the hole in the pipe, and the frictional resistance of the pipe. Similarly, the *power* value of the current that flows along a conductor depends upon the pressure (voltage), the amount (number of amperes), and the size and resistance of the conductor. Knowing these we can calculate the *power* value of the current, which is denoted in watts, 746 watts being equal to 1 horse-power and 746 watts of current for one hour being equal to 1 horse-power for one hour. A kilowatt is equal to 1,000 watts. The following simple equations show how, given any two of the three things—volts, amperes, and ohms—we can find the third.

$$\text{Number of amperes} = \frac{\text{number of volts}}{\text{number of ohms}}$$

$$\text{Number of ohms} = \frac{\text{number of volts}}{\text{number of amperes}}$$

$$\text{Number of volts} = \text{number of amperes} \times \text{number of ohms}$$

Also:

$$\text{Number of watts} = \text{number of amperes} \times \text{number of volts}$$

$$\text{Number of kilowatts} = \frac{\text{number of amperes} \times \text{number of volts}}{1000}$$

To make this quite clear let us apply the equations in the case of a current of 10 amperes and 100 volts.

Then:

$$\text{Number of ohms} = \frac{100}{10} = 10$$

$$\text{Number of watts} = 10 \times 100 = 1000$$

$$\text{Number of kilowatts} = \frac{10 \times 100}{1000} = 1$$

A CONDUCTOR is anything along which an electric current will flow. All metals are conductors, copper being one of the best. Water is a conductor, but not nearly so good as metals. *The earth also is a conductor.*

A NON-CONDUCTOR is any substance which will not conduct electricity. Thus stone, glass, mica, dry wood and most non-metallic substances are non-conductors. Dry air is a non-conductor.

CONDENSERS.—A condenser is an apparatus comprising very thin sheets of metal, separated by an insulating or non-conducting material such as glass, mica, etc., and is used for storing charges of electricity for a short time.

The simplest form of condenser is known as a Leyden jar (Fig. 3). This consists of a glass jar with a metallic coating inside and outside, the inner and outer coverings being separated by the glass which is called the " dielectric " —which means a non-conducting or insulating substance separating two oppositely charged portions of a condenser. If one of the coverings be connected up by a wire to an electrical machine and charged with positive electricity, this charge will induce a negative charge in the other covering through the glass. If the first covering be alternately charged and discharged, every time the change occurs a strain will be set up through the glass—not a strain that will break it, but a kind of impulse or wave of energy.

If we have two metal plates separated only by air, and charge them in the manner just described, and if, when one plate is fully charged with positive electricity, a wire attached to it were brought near enough to

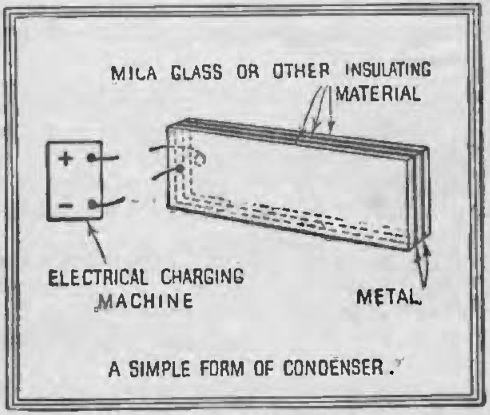


Fig. 3.

the other sheet, electricity would leap through the air across the gap. But air, being a non-conductor, offers so much resistance that it becomes hot, and so the charge of electricity appears as a spark or streak of light. The greater the difference of potential or pressure the greater the

distance will the charge leap through the air.

The capacity of a condenser means the extent to which it can be charged with electricity. The larger the area of the metal sheets used the greater the capacity, but the wider apart the sheets are placed the less the capacity.

Direct or Continuous Current.—When a dynamo is at work it does not produce a perfectly continuous difference of potential. It creates differences that follow each other very rapidly. Consequently the flow of current is not absolutely continuous, but consists of a series of impulses, so close that for practical purposes we may regard them as continuous. These impulses all travel in the same direction, and the current is known as "continuous" or "direct." By inserting a vibrator in the circuit (similar to the vibrator of an electric bell) interruptions can be effected so that the current travels in jerks. The current from primary cells and from accumulators is also continuous.

Alternating Current.—This is a type of electric current in which the impulses do not all travel in the same direction, but alternately in opposite directions due to the differences of potential being produced so that they act first in one direction and then in the opposite direction, with the consequence that the direction of each current impulse is opposite to that of the one before and after it. It is generated by a machine called an alternator to distinguish it from a dynamo, which generates direct current.

Both alternating and direct current can be generated at different pressures. In the case of alternating current, it can also be generated at different speeds of alternation called the periodicity or frequency. For instance, when used for lighting or power purposes the average frequency is 60 changes of direction per second. When used for wireless transmission the frequency may be as rapid as 20,000 a second when generated by an alternator.

SPEED OF ELECTRICITY. — Electricity travels with the same speed as that of light and of electro-magnetic waves—namely, about 186,000 miles a second—11 million times faster than that of an express train.

CHAPTER II

ETHER WAVES

ONCE upon a time it was supposed that, beyond the film of air surrounding the world, space consisted of a boundless vacuum through which the sun's light and heat poured down to the earth in a kind of shower.

But at last scientists began to examine more carefully into the reason of things, and came to the conclusion that in order for the sun's light and heat to reach the world some kind of medium is necessary. A medium simply means something by means of which something else can take place. Thus water is the medium by means of which sea-waves travel. A medium was therefore assumed and called "æther" or "ether." The ether is supposed to possess some very extraordinary properties which are a little difficult to grasp. Although invisible and transparent, it is supposed to be more than a million times denser than steel, and to penetrate and permeate all matter, and yet not to hinder the passage of suns and worlds through it.

All matter, whether metals, rocks, liquids or gases, consists of minute particles called molecules, far too small to be seen by the most powerful microscope. These molecules in turn consist of atoms, and atoms of electrons. Electricity is also believed to consist of electrons, so that when we get down to the electron we are near the basis of everything of the existence of which we are conscious.

We know quite well that sound is a sensation produced by air waves travelling at 1,100 feet a second impinging upon the ear drum and producing vibrations which are conveyed to the brain by auditory nerves.

It is now believed that light and heat proceed from the sun through the ether as waves travelling at a speed of 186,000 miles a second, which is the proved speed of light. Light waves are reflected by objects to our eyes, on the retina of which images are produced and conveyed to the brain by the optic nerves, where they produce the sensation of light, colour, and form. Heat waves, which are invisible, produce a different sensation—namely, that of heat. It is not that the waves themselves are hot, for they can pass through many feet of ice-cold water, and even then, if focussed by a magnifying glass, will set fire to an inflammable substance.

But light and heat waves are not the only kinds of ether waves—there are many others. One of these is electro-magnetic waves which

all travel at the same speed, but vary greatly in length.

Let us consider now the nature of these waves, beginning with the usual illustration.

If we drop a pebble into a pool of still water we set up ripples which are waves of energy, and which travel in ever-widening concentric circles away from the point of disturbance. As they extend they become weaker and weaker. Whilst they are still there, drop another, much larger stone, which will make a greater disturbance than the first. On the surface of the pond you will then have two different sizes of waves overlapping each other, one kind being longer than the other, from crest to crest. You might keep on dropping stones in this manner, and you would see that the waves cross each other.

It is very important to remember that the water does not travel along; it only moves up and down. It is only the waves that travel.

Of course these are only surface waves. But supposing that at half the depth of the ocean we were to explode a charge of dynamite: the disturbance would set up waves that would travel outwards from the point of the explosion, like expanding globes instead of circles. And they would not be quite the same kind of wave. It is more or less in this manner that light waves proceed from the sun in every direction, and you may compare, if you choose, waves from the sun with the skins of soap bubbles one within another, almost touching each other and joined together, and always expanding to an indefinite size. As these vast globular waves spread outward they strike against anything in their way. Our little world catches only the very minutest fraction of each wave. If the skins were some distance apart but still joined together, they would correspond to electro-magnetic waves.

Now the electro-magnetic waves which we produce in the ether for wireless purposes possess the same essential properties as those that reach us from the sun, but there are certain important differences.

Aerials consist of wires leading up masts and stretching across to other masts. Into these wires electric current is allowed to flow intermittently. The wires and the earth correspond to the two plates of a condenser (described in the last chapter), and the intervening air or ether constitutes the dielectric. Every time the current speeds into the aerial and out again, it produces a strain or pulsation in the ether between the wires and the earth; in other words, it sets up in it an electro-magnetic wave. All the waves set off at a speed of 186,000 miles a second, their strength depending upon the strength of the electric current producing them. Their length from crest to crest varies according

to other considerations—it would be possible to set up about 1,000,000 different wave lengths which could be distinguished from each other. But, unlike light waves, these electro-magnetic waves do not travel in straight lines. They spread out, it is true, but they follow the curvature of the earth.

The reason for this was a puzzle for a time, until at last a theory was evolved, which apparently offers a satisfactory explanation, and which such eminent scientists as Dr. J. A. Fleming (the inventor of the thermionic valve) uphold.

It is well known that tremendous upheavals take place in the sun's glowing mass. Tongues and jets of flame hundreds of thousands of miles in length shoot out, when eruptions occur, and far beyond these flames immense quantities of dark gases are projected into space. Probably the bulk of these fall back again to the sun, but it is thought that much finds its way beyond the orbit of the earth, and that large quantities of this "dust" become entangled in the earth's atmosphere. Of course we must not think of this as ordinary dust; it may be of an atomic character, and too fine to penetrate the lower and heavier part of the air. It is supposed that this "dust" is ionised or electrified, and that it acts as a screen round the world, and prevents our electro-magnetic waves from escaping, and that when they encounter this screen, they are reflected or deflected by it, and compelled to travel round the world.

That, briefly, is the principle underlying the production of electro-magnetic waves for wireless.

CHAPTER III

HOW A WIRELESS MESSAGE IS DESPATCHED

LET us suppose we want to send a wireless message from London overseas.

The form containing the written words is handed to an operator before whom is an instrument that looks like a typewriter, running through which is a long narrow paper tape instead of an ordinary sheet of paper. The operator taps the keys, but instead of typing letters the levers punch small holes in the paper tape. These holes represent the Morse code equivalent of ordinary letters and figures. You know that words and figures can be expressed in shorthand characters. Well, the Morse code is simply a method of expressing letters and figures, in a manner that enables them to be telegraphed. One way is by different arrangements of dots and dashes, and another by means of different spacing and arrangements of holes in a paper tape.

The tape passes on through another instrument known as a Wheatstone transmitter (see Fig. 4 at end of book), through which an electric current is flowing to a distant wireless transmitting station, such as Carnarvon or Chelmsford. On this instrument are tiny little projecting rods called peckers, over which the tape passes. When a punched hole comes opposite a rod the rod slips through it. The rods are so connected by levers with electrical contacts, that their movement causes interruptions in the flow of the electric current, and in this way the holes in the tape, which are variously spaced, pass on the message to the current in the form of interruptions corresponding to the Morse code.

Now, the current flowing along the land wires is so feeble that it would be quite useless to send it up into the transmitting aerial, and therefore, when it reaches the transmitting station, it has to hand over the message to a very much more powerful current. This is done by means of big transmitting valves.

As the thermionic receiving valve will be described in a later chapter, and as the principle is practically the same, it will suffice for the present to state that, by means of the transmitting valve, the message is delivered to the current which speeds into the aerial and produces those electro-magnetic waves already described, which in turn have impressed upon them variations corresponding to the message.

At some transmitting stations, especially in Amercia, high-frequency current of 20,000 alternations, produced by alternators, is employed instead of transmitting valves.

It will be convenient at this point to give the very simple formulæ showing the relation between wave-length, frequency, and velocity.

The velocity being constant (186,000 miles per second), if we know the frequency we can ascertain the wave-length, or if we know the wave-length we can ascertain the frequency.

$$\text{Frequency} = \frac{\text{Velocity in feet per second}}{\text{Wave-length in feet}}$$

$$\text{Wave-length} = \frac{\text{Velocity in feet per second}}{\text{Frequency}}$$

$$\text{Velocity in feet per second} = \text{Frequency} \times \text{Wave-length.}$$

The principal methods of generating electro-magnetic waves are the spark, the arc, the valve, and the high-frequency alternator. Of these, the valve and high-frequency alternator are chiefly employed in big transmitting stations. The spark, which was the original method, is still used on board ship. In cases where the despatch of messages is almost uninterrupted, the continuous wave system, a long, unbroken train of waves without interruption, with the power always on, is generally employed; in wireless telephony and for the broadcasting of speech and music it is essential.

The details of the various systems and their relative advantages and disadvantages could only be properly explained at considerable length and in a much bigger volume than the present one, but we may now consider another important feature about wireless waves—namely, their continuity or otherwise.

Supposing that we push a pole into a pool of still water and draw it out again a limited number of times, so as to keep time with the waves we produce, but that, each time, we push the stick in a less distance. By so doing we should produce a train of waves, of which the biggest would be the first, gradually dwindling down to nothing. Then, starting again and again, we should produce one short train of waves after another. In much the same way, the Hertz oscillator (described in the next chapter) produced a train of electro-magnetic waves which quickly died down as the oscillations dwindled away, and the same thing happened in the case of the earlier types of spark generators used in wireless. The consequence was that there was a pause after each train of waves, until the condenser was charged again sufficiently to cause another spark and a fresh train of waves.

Now such separate trains of dwindling waves are not so useful for conveying messages as one long continuous chain of waves would be. Clearly, if the condenser could be so charged and discharged as to prevent the oscillations of the current from dying down, such a continuous chain could be generated. That meant charging and discharging the condenser in such a manner as to keep the oscillations of constant strength.

It was this problem that led to the invention of the transmitting valve, which sends electric current oscillating into and out of the aerial without variation of the oscillations. The high-frequency alternator was also invented and serves the same purpose, but the alternator is such an expensive machine that for big transmitting stations it is believed nothing but valves will be used in future.

CHAPTER IV

A BRIEF HISTORY OF WIRELESS

It is almost impossible to think of wireless without thinking of Senatore Marconi, for it was he who first applied electro-magnetic waves to telegraphy on a practical and commercial scale. But the history of wireless begins much further back than that.

In the year 1864, a physicist named James Clerk Maxwell, as the result of many experiments with light and with electricity and magnetism, predicted that there are such things as electro-magnetic waves. He did not succeed in discovering them, but in 1888 another physicist, Professor Hertz, succeeded in doing so. The apparatus he employed was very simple, consisting of two metal plates, each with a wire and small knob on the end of it (Fig. 5). These he placed so that the knobs were a short distance apart. Then he connected one plate to the positive terminal of a sparking coil, and the other plate to the negative terminal, and charged the two plates, one positively and the other negatively, thus causing a difference of potential between them. When the difference became sufficiently great, electricity leaped across from one knob to the other with such energy that the difference of potential was reversed; the charge over-reached itself, so to speak,

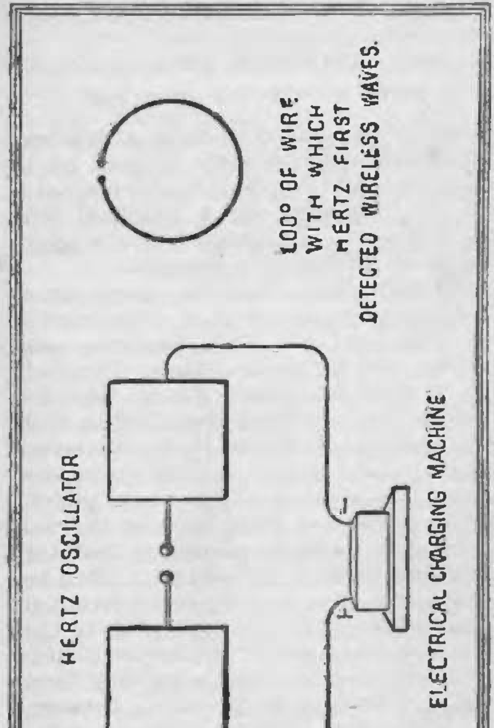


Fig. 5.

and surged backwards and forwards until equilibrium was restored.

Supposing that we have a long trough with an inch or two of water in it, lift it at one end, and then suddenly lower it to a horizontal position. The water, in trying to distribute itself equally, will surge to the other end of the trough first, then back and forth again and again, until at last it comes to rest. That is what happens when electricity is allowed to discharge suddenly—but electricity oscillates to and fro hundreds of thousands of times a second.

At a little distance from the apparatus, which we will call the oscillator, Hertz held a loop of wire (Fig. 5) with the two ends just separated. Every oscillation of the current set up an electro-magnetic wave causing a current to flow in the loop, so that as the current passed the gap there were electric sparks. It must be borne in mind that the loop was in no way connected with the oscillator. But the size of the loop had to be proportioned to the waves generated by the oscillator, and the loop had to be held in a certain position.

This simple apparatus was the foundation of the art of wireless as practised to-day. You may think of the oscillator as the transmitting station, one of the plates as the aerial and the other as the earth, the wire loop corresponding to the receiving aerial. And, just as the wire loop had to be

proportioned or "tuned" to the waves it received, so our receiving aerials have to be proportioned or "tuned" to the waves of wireless.

But it was a long, long way from that first apparatus used by Hertz to the wireless systems now in use.

Hertz then made further experiments proving that these invisible electro-magnetic waves could be reflected and focussed by metal reflectors just as easily as light waves can be reflected and focussed. He also found that they would pass through wood and stone.

Righi, Branley, Sir Oliver Lodge, and others effected improvements both in apparatus for generating and for detecting electro-magnetic waves, until at last it became possible to generate waves in one room and to ring a bell in another.

Strange to say, it does not seem to have occurred to these scientists that such waves could be applied to wireless telegraphy, until about twenty-eight years ago Marconi appeared on the scene. It was not long before this brilliant inventor conceived the idea of wireless telegraphy, and with that end in view he effected refinement after refinement. Finding that the bigger the oscillator the further the waves would travel, in order to make room for still larger models he elevated one plate and buried the other in the ground. Then he found that the higher he raised the elevated plate, the better the results obtained.

In his first experiment in England he succeeded in transmitting and receiving messages at a distance of 100 yards. Rapidly the distance was extended, until a year later it had become 10 miles. Two months after that it was 34 miles, and in December, 1897, a ship was fitted with a wireless set and kept up communications with the shore at a distance of 18 miles. In 1899 messages were received at a distance of 100 miles, early in 1901 at 200 miles, and in December, 1901, the first Transatlantic wireless signals were despatched and faintly received.

In due course it was found that a length of wire carried up a mast and stretched across to another mast served the same purpose as the upper plate of the oscillator, and that is how the present-day wire aerial came into use.

Space does not permit of a description of all the detailed improvements effected, but the spark system of generating oscillating current may again be mentioned.

The spark system which was the first, and which is still used on shipboard for wireless telegraphy, corresponds most nearly to the original Hertz oscillator, in which it will be remembered, the oscillations of the currents of electricity, were effected across an air gap. Of course, there are many more complications and refinements, and instead

of the two plates there is an aerial wire and the earth, but the principle of generating the waves is the same.

In the case of high-frequency alternators, one terminal is connected to the aerial and the other to a plate buried in the earth. There is no need of a spark gap to cause the current to oscillate: the oscillations in this case are the alternations of the current generated.

CHAPTER V

HOW A WIRELESS MESSAGE IS RECEIVED

UP to the present, we have been considering how electro-magnetic waves are generated, and how a message is virtually impressed upon them. Now let us turn to the other side of the problem—reception.

In the last chapter was described how Hertz first detected electro-magnetic waves with a loop of wire, in which the waves caused a feeble electric current to flow and to spark across the gap, and that the loop had to be a certain size, and the wire of a certain thickness, before it would respond to the waves at all—in other words, "tuned" to receive the waves.

The reader may try the following simple experiment for himself: Stretch a piece of piano wire, which we will call A, between two fixed points. Then, at a little distance from it, stretch several other piano wires of varying length—some slightly longer, and some slightly shorter than A. Now twang one of these other wires smartly. If A does not respond, tune it by tightening or loosening it by degrees, and when you have it stretched to exactly the right extent you will find that, when you twang the other wire, A will begin to vibrate in sympathy. Within reasonable

limits, A can be tuned to respond to any of the other wires.

Similarly, before we can detect electro-magnetic waves in the ether, our receiving wire or aerial has to be tuned according to the kind, or rather length of wave sent from a transmitting station. Obviously, it would be of no use to tune it for only one length of wave, because we should then only be able to receive messages from one transmitting station. For every transmitting station uses a different wave-length, so as to avoid confusion by keeping the signals from each station distinct from all the others. The consequence is that means have to be provided for tuning a receiving aerial, so that, by turning switches, we may quickly adjust it to suit any of a big range of wave-lengths, and thus "pick up" from any broadcasting station within range. Such tuning, however, is not done by tightening or loosening the wire: it is done in a very different manner, which will be described in a later chapter.

It must be remembered that at a transmitting telegraph station, what is done is to impress a message on a train of ether waves. At the receiving end, two things may be done. One is, by means of telegraph receivers (see Fig. 6 at end of book), to punch a tape with the Morse code, and to run the tape through an electrically-operated high-speed printer (Fig. 6), which types the message in English letters and figures at a speed of from 120 to 150 words a minute. This is all done automatically, so that only one man is needed to read the tape as it comes out of the printer, and to tear it off as each message coming through is completed. It is a very wonderful procedure, but lies outside the immediate interest of the amateur.

The alternative is to translate the message from ether wave language into that of sound waves, and to listen to them with a telephone receiver. In the case of telegraphy, this requires a knowledge of the Morse code, which will be found at the end of this book.

The wireless transmission of music and speech comes under wireless telephony, which is more complicated than telegraphy. In this case, at the transmitting or broadcasting station, the sound waves of speech or music cause variations in currents of electricity, which in turn set up electro-magnetic waves as already described. At the receiving end the procedure is exactly reversed: the ether waves deliver over their message to an electric current, which in turn reproduces the original sound waves in a telephone receiver.

The receiving aerial corresponds to the transmitting aerial, but whereas the use of the transmitting aerial is for generating ether waves, the function of the receiving aerial is to assist the waves to generate electric current again. At some stations, the

same aerial is used both for transmission and reception.

There are two important points to bear in mind. One is that when the waves encounter a receiving aerial they do not travel along it, as is sometimes supposed. What they do is to set up a difference of potential between the aerial and the earth, thus causing currents of electricity to oscillate in the wire.

The other is that, whereas powerful currents of electricity are necessary to generate the waves, not only do those waves become weaker the further they spread out, but an aerial only intercepts each wave at a point, so that it only receives a minute fraction of the original energy. If you think of each wave as the skin of an imaginary soap bubble, expanded to many miles in diameter, and of a pin placed on the surface, you will gain some idea of what a very tiny proportion of the energy of a wave is intercepted by one aerial.

The consequence is that the current generated in an aerial is so feeble that it needs a delicate apparatus to detect it. Again, it is an oscillating or alternating current, and has to be transformed into a direct current by cutting out all the pulsations in one direction and only using those in the other direction. And it is so weak that it is only capable of producing a strong enough effect to actuate telephone receivers within about fifteen miles of a powerful broadcasting station. (It is true that better results may occasionally be obtained, but they cannot be relied upon.) At great distances the current is so weak that it has to be magnified, or made to impress its variations corresponding to the original sound waves, on a stronger current capable of reproducing those sound waves so as to be perceptible in a telephone receiver; this is done by means of thermionic valves, which will be described in another chapter.

Every receiving station, then, must comprise the following equipment:

(1) An aerial, which may consist of a wire stretching up a mast, post, or other suitable support, or alternatively may be placed inside a house or building, or may consist of a few turns of wire round a wooden frame (known as a frame aerial).

2. A means of detecting the current produced by the waves in the aerial and converting this oscillating or alternating current into a direct current: this is called "rectifying" the current.

3. A means of tuning the aerial, so that it can be made to respond to any wave-length employed by broadcasting stations within range.

4. A telephone receiver for listening-in.

5. The earth (which is always there).

More ambitious amateurs possess valve receivers, which not only rectify but magnify the incoming current from the aerial, and

enable messages to be picked up from much greater distances, and to employ a loud speaker, so that any number of persons sitting in a room may enjoy broadcast music without the use of telephone receivers. Some amateur stations can pick up signals from America. And in big commercial stations there are many complications which do not come within the scope of this book.

CHAPTER VI

HOW TO OBTAIN AND ERECT THE AERIAL

STRICTLY speaking, this chapter ought to be devoted to further explanations of how reception is effected, but if the reader has carefully followed what has already been stated, it is possible now to begin a practical description of how to instal his receiving station at the lowest cost, explaining, as we go along, the reasons for the various requirements.

First of all, however, it is necessary to secure a Post Office licence, for which application must be made at the General Post Office. This licence, which costs 10s. and has to be renewed yearly, only permits you to indulge in a receiving set. If and when ambition prompts you to try your hand at wireless transmission, you will have to apply for a special licence, which you may have a difficulty in obtaining, but which fortunately does not concern us now.

Let us start with the aerial: first, the outdoor, and then the indoor type.

The longer and higher the aerial, the better the results we shall secure. Unfortunately, the Post Office regulations limit the total length of wire used by an amateur to 100 feet for a single wire, although greater lengths are

permissible if more than one wire is used and the wires are placed parallel with each other.

A single length of 100 feet is cheaper and gives better results than wires side by side, although, when space is limited, shorter lengths have to be employed. We will, therefore, take the case of a single wire.

The wire should be of copper, and consists of 7 wires of 22 gauge, stranded or twisted. The cost of 100 feet is about three shillings. It is well to obtain a few spare yards in case of emergency. Do not cut the wire unless and until it is absolutely necessary; the fewer joints made in it, the less the chance of trouble. A single wire may be used, but a stranded one is less liable to break.

Now comes the problem of erection. As everything depends upon the size of the garden, and the facilities for supporting the aerial, I cannot do better than give a few illustrations (Figs. 7 to 12) of how an aerial may be fixed, and describe one of them. It may be mentioned, however, that when one's garden is too small, it is sometimes possible to obtain a neighbour's permission to support one end of the aerial on his house, the other end being supported on your own; indeed, sometimes neighbours share an aerial in that way. In such a case, two chimney-stacks are the best positions, providing you can reach them to fix the attachments. Again, you may sling one end from a tree or a fence—I have even seen a wooden

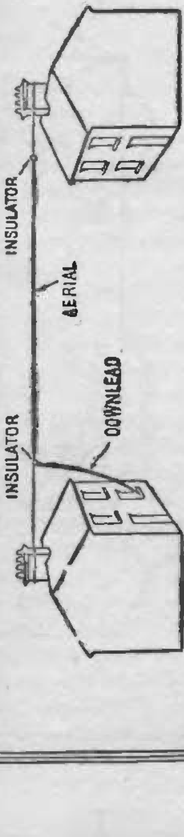


FIG. 7.—AERIAL WHEN NEIGHBOUR'S HOUSE IS USED AS A SUPPORT.

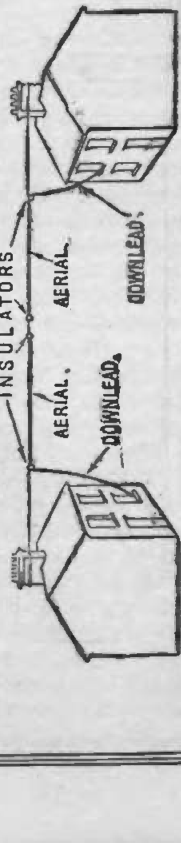


FIG. 8.—AERIAL WHEN NEIGHBOUR'S HOUSE IS USED AS A SUPPORT AND BOTH HOUSES HAVE A RECEIVING SET INSTALLED.

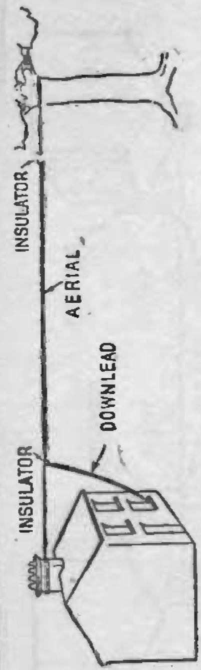


FIG. 9.—AERIAL USING HOUSE AND A TREE AS SUPPORTS.

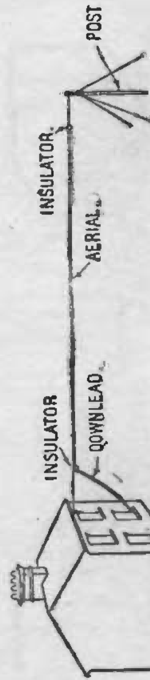


FIG. 10.—AERIAL USING HOUSE AND POST AS SUPPORTS.

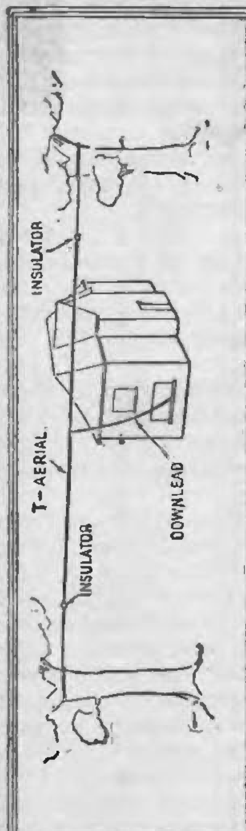


Fig. 11.—T-Aerial using Two Trees as Supports with Central Downlead.

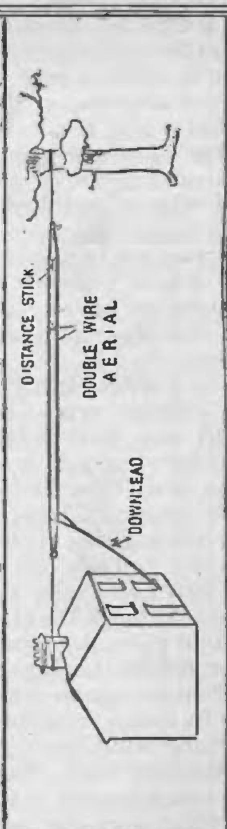


Fig. 12.—Double Wire Aerial using House and Tree as Supports.

clothes-prop used! If you choose a tree, be careful to make sure that none of the twigs or leaves can possibly touch the aerial wire, even in a high wind. The disadvantage of a tree, or any support that sways in the wind, is that it may break the aerial.

One of the supporting wires should be tightened up, so as to keep the aerial just taut without unduly straining it.

Supposing that you are going to use your receiving set in a room on the ground-floor, and that it takes 30 feet of wire from the receiver to where the aerial is supported: that will leave a horizontal length of 70 feet of wire.

You will need two insulators of which there are different types, varying in price from threepence to a shilling or two. The cheaper ones are of porcelain, which do not insulate quite so well.

The best insulators have two holes in them (Fig. 13), or a ring at each end. The aerial wire is passed through one of these holes or rings, and twisted securely so that it cannot work loose. Through the other hole thread a piece of stout galvanized iron wire, and fasten the other end of this wire to the support in any convenient manner—there is no magic about it. But make sure that it is secure, because a strong wind causes an aerial to exert a considerable pull. Pass the other end of the horizontal portion of the aerial wire through the other insulator, and secure the insulator to its support, so that the end of the aerial hangs down near the window of your room. This portion of the aerial is called the downlead. Be careful that the wires on which the insulators are slung do not touch the aerial anywhere. The very object of the insulators is to prevent the aerial wire from touching anything else.

Remember that there should be the greatest

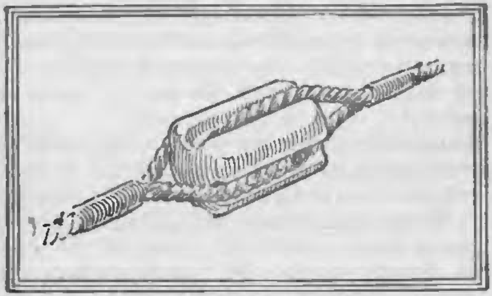


FIG. 13.

possible clear height from the ground to the aerial. If possible, avoid passing it over a house or building, because any wire, metal, or water in a house acts as the "earth," and so reduces the effective height of the aerial.

To bring the downlead into the house, bore a hole in the window or door-frame, and insert in this hole a tube made of some insulating

material, such as ebonite, porcelain, or glass, slightly longer than the thickness of the frame. The lower end of the downlead may then be passed through this tube into the room: this is called the lead-in. Care should be taken so that wet cannot get through the hole. A better but more expensive arrangement is a special lead-in insulator, with a screw terminal at each end for attaching the wires to. The price is about 1s. 6d.

The best form of aerial is one in which the downlead is continuous with the horizontal portion thus ⌐: this obviates the necessity for making a joint in the wire. Sometimes, however, it is more convenient to join the downlead to another part of the horizontal wire: in that case the joint must be in the centre, so as to form a T *with two equal arms*.

When there is not room for a single wire aerial, two parallel wires may be employed, as already mentioned. In that case, if the downlead is, say, 30 feet long, each of the horizontal wires may be of any convenient length—say, 55 feet each. Near each end, they must be distanced by means of a stick, if possible, about 6 feet long, so as to keep them well apart. The downlead must be joined to each of them at the centre of the span or at one end. The two-wire aerial is, of course, more troublesome and expensive to fit up than a single wire.

A house in a valley surrounded by hills is unfavourably situated for wireless reception, because high ground surrounding an aerial in a hollow space tends to screen it from the waves. In some places it is impossible to detect them at all.

A single wire aerial, erected as above described, should not cost more than about six shillings all told, whereas a mast alone might cost several times as much.

In cases where it is impossible to erect an outdoor aerial—for instance, if you happen to live in a flat—indoor aerials may be used instead, but it may be stated at once that if you possess a crystal set reception will only be obtained with an indoor aerial from a broadcasting station within from 2 to possibly 4 or 5 miles. But with valve sets indoor aerials will give satisfactory results up to hundreds of miles.

Questions that every beginner naturally asks are: "What is the range of a crystal set?" and "What is the range of a valve set?"

Unfortunately it is quite impossible to answer those questions without explanation. The answer depends upon the size of your aerial: whether it is of the outdoor, indoor, or frame type; the power of the waves from the broadcasting station (which vary considerably); the sensitiveness and efficiency of the receiving set; atmospheric conditions; and the degree of skill and ingenuity you exercise to obtain the best results.

For instance, with a crystal set a powerful

broadcasting station might be heard at twice the distance at which a less powerful broadcasting station cannot be heard at all. A valve set might pick them both up and others at much greater distances. With a sufficiently powerful valve set, an American station might be picked up, whereas a weak station at half the distance might be inaudible. Again, the owner of a receiving set might pick up signals which another person with a similar set could not detect at all. It is clear, then, that the maximum range can only be determined by experiment and experience. Fortunately, once you have your set installed, it is a very inexpensive matter to try a large number of experiments with various arrangements of aerials both out of doors and in the house.

When, therefore, you see a crystal set at £3 10s. advertised to receive at 25 miles, don't imagine that means you will hear everything broadcasted at that distance. That claim is pretty sure to mean the limit of the instrument under the most favourable conditions.

It has already been mentioned that the electro-magnetic waves of wireless pass quite easily through bricks and mortar and wood, and it is that fact which makes indoor aerials possible. The wire, however, should be insulated.

There are many ways in which an indoor aerial may be erected. It may be stretched across the ceiling of an upper room, or even carried round the picture rail of the room in which your receiver is placed. To make it longer it may be carried round the ceiling of a loft or attic, brought down through the floor into a lower room, and carried round that room also. Ordinary staples should not be used for fastening the wire, but eye screws with insulator rings. Walls subject to much moisture from condensation and very damp rooms should be avoided.

A frame aerial consists of a few turns of insulated wire round the outer edge of two pieces of wood fixed together on a stand, so that the wire forms a square measuring about 3 feet or more on the side.

The advantage of a frame aerial is that it is portable and can be used either indoors or out, or carried about from place to place. But it is not of much use with a crystal receiver.

In a later chapter the relation between wave-length and length of aerial will be explained.

CHAPTER VII

CRYSTAL RECEIVERS

Crystal receiving sets are not only by far the cheapest type to make or to purchase, but, once installed, there is no further outlay as in the case of valve sets, which require batteries and accumulators that need frequent charging, and expensive valves which do not last indefinitely but have to be replaced periodically by new ones.

A crystal receiver is so-called because a piece of crystal is used to rectify the currents set up in an aerial by wireless waves.

Certain metallic crystals, of which there is quite a variety, possess the curious property of only allowing currents of electricity to flow through them in one direction, so that if such a crystal be placed in an electric circuit in which an alternating current flows, only the current impulses in one direction can flow through the crystal; by this means we obtain a direct current—which is necessary for use with a telephone receiver.

The lead-in wire from the aerial is therefore connected to a terminal on the receiver stand or baseboard, and this terminal is wired up to the detector, at one end of which is a pointed piece of metal or wire which can be moved about. Opposite the end of this wire, a little lump of crystal is mounted in a holder, which in turn is connected up with other parts of the apparatus to be presently described.

Supposing that the length of our aerial were proportioned to receive only one wave-length, then all we should need would be a wire connected to a plate buried in the earth or to a water-pipe (known as the "earth"), and another pair of wires connected through a crystal detector to a telephone receiver; this would enable us to listen-in to concerts, etc., from one broadcasting station within range. But as that would limit the enjoyment of wireless to what we could receive from only one broadcasting station, certain other apparatus becomes necessary to enable us to tune our aerial so that we may adjust it to suit different wave-lengths from other broadcasting stations.

To effect this there are introduced a condenser and an inductance.

Let us make the reason for this perfectly clear.

An aerial wire 100 feet long will only respond to one particular wave-length. If we increase its length it will respond to a greater wave-length, and *the more we increase it the greater the wave-length it will respond to.*

An inductance consists of a coil of wire connected to the aerial wire in such a manner as virtually to increase the length of the aerial.

Again, it has already been explained that

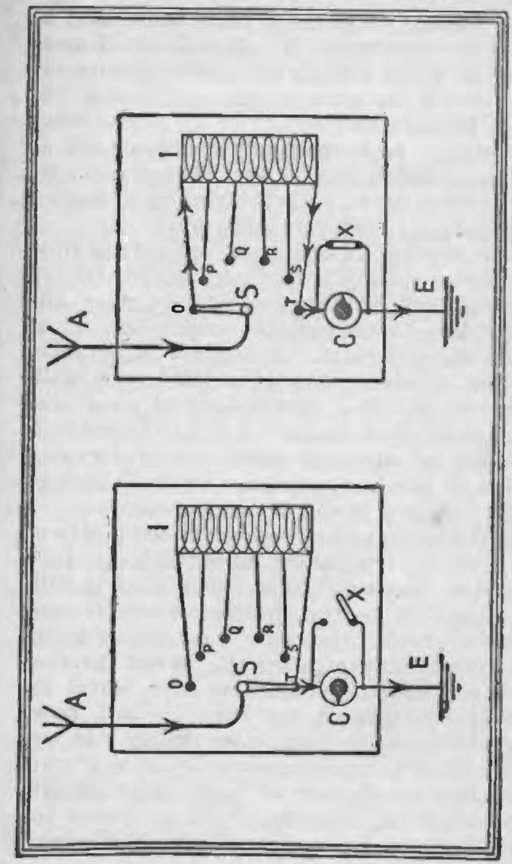
the aerial wire and the earth constitute the two plates of a condenser. Owing, however, to their fixed distance apart, the capacity is a fixed one, and that fact also fixes the wave-length to which the aerial will respond, but if we can reduce its capacity it will respond to shorter wave-lengths: *the more we reduce its capacity the shorter the wave-length to which it will respond.* To fulfil this condition a condenser may be introduced into the circuit in series with the inductance. It might be thought that an additional condenser would increase the total capacity, but, strange to say, that is not so. The effect of the condenser actually is to decrease the capacity of the aerial.

It is clear, then, that by introducing these two things, a condenser and an inductance, and providing means for adjustment, by merely turning switches we are enabled to vary or tune the aerial to receive any of a large number of different wave-lengths, and thus to respond to waves from different broadcasting stations. It corresponds to tuning the piano wire (referred to in Chapter V.), by tightening or loosening it; if we only possessed a means of loosening it or only of tightening it, we could not tune it to respond to the other wires.

Now the tuning of an aerial could be effected within certain limits, either by providing a fixed condenser with an unvarying capacity and a variable inductance, or by means of a fixed inductance and a variable condenser. (A variable condenser is one of which we can vary the capacity at will, and a variable inductance is one by which the effective length of the aerial may be varied.) But, clearly, if we have both a variable condenser and a variable inductance, the two will give us a greater range of wave-lengths than if only one is variable.

As it is very important to understand this method of tuning a receiving aerial, let us illustrate it. In Figs. 14 and 15 A is an aerial wire, C a variable condenser, E a wire leading to earth, I a variable inductance (a coil of wire connecting the aerial and earth wires), S a switch, and O to T are contact studs of the switch. To the wire of I leading off wires are connected at intervals, each wire being attached to one of the switch studs. X is a short-circuiting switch.

With the inductance switch in the position S-T and the condenser adjusted to its full capacity, the aerial is so tuned that it will only respond to the shortest waves it can receive—shorter than if the condenser were not there. If we move the switch to the position SO, the length of the aerial is virtually increased, so that it will now respond to waves of greater length. If we now adjust the condenser so that it is cut right out of the circuit, and short circuit the switch X, the aerial will be tuned to the maximum wave-length it can receive,



Figs. 14 and 15.

but, of course, to no other wave-length. It will be seen, then, that according to where we place the switch and how we adjust the condenser, so we tune the aerial to a particular wave-length.

That is the function of the inductance and of a variable condenser. When we move the inductance switch from one stud to another, we alter the tuning of the aerial, not gradually but in steps, so that, although we may tune the aerial nearly enough to catch the waves, it may not be perfectly in tune, and by a movement of a variable condenser in series with the inductance tuning will be effected.

The popular type of variable condenser consists of a set of thin metal sheets, arranged parallel with each other, forming a half-circle or disc in plan, and slightly separated from each other. Arranged on a central rod, with a handle to it, is another similar set of plates. By turning the handle, these plates can be rotated, so that those of one set are quite clear of those of the other set, or so that they overlap or partly overlap each other, but without touching. The two sets are insulated from each other. When they are moved, so as to overlap completely, the condenser acts at its full capacity; when they are entirely clear, it practically does not act at all. Intermediate positions give intermediate degrees of capacity, and that is how adjustment can be effected.

But there is another function of a condenser: it serves to store up electrical energy and to part with it again at the right moment, and it is in this sense that we are largely concerned with it. To serve this purpose, a fixed condenser is inserted in a wire across the telephone.

Instead of tapping the inductance coil (*i.e.*, attaching wires to it at intervals), sometimes a metal rod is provided with a little block of metal on it, making contact with the coil, which can be slid along the coil so as to make contact at any point (Fig. 16). This gives a fine adjustment, but the wire is apt to become defective as the result of wear and tear.

Since the aerial and the earth constitute the two plates of a condenser for generating electro-magnetic waves in the intervening ether, it follows that the current must flow to and fro between the aerial and the earth. Consequently there must be a connection to the earth. This may be made by connecting one of the wires to a water-pipe. Or it may be soldered to a metal plate buried in the earth, but in such case it should be buried at a good depth—not just below the surface where the soil may become dry, as dry earth is a bad conductor.

We have now described the essential parts of a receiving station, and it remains but to couple up the telephone receiver to be ready for receiving any concert or speech from any broadcasting station within range.

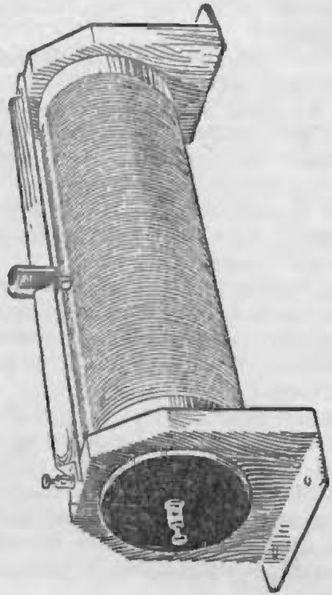


FIG. 16.

For the benefit of those who desire an explanation of how a telephone receiver works, a later chapter will be devoted to a description of it, and of certain essential features of wireless telephony waves.

The foregoing must only be regarded as an outline of a very simple receiving apparatus. As the amateur progresses in the art of wireless, he will find that even in crystal sets there is a wide variation in design and in the arrangement of circuits, which in some cases are a great deal more complicated than that just described. Not very long ago it was thought that the maximum range of crystal sets would never exceed about 20 miles, but even now it is said that there are sets capable of receiving signals at ranges of from 50 to 200 miles or more, and it is probable that still further improvements will be effected.

It is worse than useless, however, for the beginner to overburden his mind with many diagrams. An ounce of practice is worth a pound of theory. When he has fitted up his first modest set and has used and understands it, then is the time to look round with a view to development and improvement.

CHAPTER VIII

HOW TO CONSTRUCT A CHEAP CRYSTAL RECEIVER

BEFORE reading the following description, it should be clearly understood that it relates to the construction of a very simple form of crystal receiver, which will not possess a great range of reception—possibly not more than about 15 miles.

The cost of purchasing the parts is so small that I do not advise the beginner to try to make them himself. When he has fitted together this set and really understands it, if his appetite be whetted for something on a more ambitious scale, he will have learnt a lot that will help him to make the parts of another set himself. Moreover, in any case, the telephone receiver must be purchased, and that is the most expensive item in such a receiving set. In pricing the items, the cheapest prices are quoted, but in some cases alternative prices are given, because by giving a little more you will obtain a quality which will enable you to use parts of the apparatus again in a more advanced receiving set, whereas the cheapest ones might have to be discarded. The choice must depend upon your purse. There is one consolation: any aerial that gives satisfaction with this simple crystal receiver ought

certainly to be good enough for a more ambitious set, either of the crystal or valve type.

The first thing is to provide a stand or baseboard. This may consist of any piece of wood you choose; mahogany or oak looks well. It may be of any convenient size—say about 12 inches square. It should be planed on one surface—preferably on both surfaces—and have the edges smoothed and bevelled. To the underside of two of the edges screw two strips of wood. Then varnish, or stain and varnish, the stand, and let it thoroughly dry.

You will now require the following:

1. A CRYSTAL DETECTOR, complete with stand, terminals, and crystal (see Fig. 17 at end of book). This may be purchased for about 3s. 6d., but a much better quality, with the crystal enclosed in a glass tube, can be obtained for from 5s. upwards.

2. AN INDUCTANCE TUNING COIL.—The cheapest type consists of a coil of insulated wire wound on a short length of cardboard tube, with leads (short separate lengths of wire) taken from it at intervals. This may be purchased for a few shillings—the price depends upon the range of wave-length required. For a reason given in Chapter XI. it is better to obtain a cheap unlacquered coil first, which should not cost more than 4s. 6d.

3. A CONDENSER.—A fixed condenser may be obtained for about 1s. 9d.

4. Two Switch Arms for Inductance, and Two Sets of Stud Terminals.—Supposing that there are 18 wire leads from the induction coil, then you will need 18 stud terminals (at 9d. a dozen), 4 stops at 1½d. each, and 2 switch arms at 1s. 6d. each.

5. Four Screw Terminals.—These may be of the type illustrated at a cost of about 10d.

6. A few feet of No. 22 insulated copper wire, for wiring up your set (or electric bell wire would do).

7. A Pair of Head 'Phones.—These should be of not less than 4,000 ohms resistance. They vary in price from about 22s. 6d. up to several pounds a pair.

Adding up the foregoing items and including 6s. for the aerial, it will be seen that for about £2 it is possible to purchase the parts (allowing for the lowest prices), and to instal a receiving set and aerial that should enable broadcast to be received from a distance of 15 miles, with a wave variation of from 200 to 600 metres. And for about £3 the set would include a better quality of telephone receivers and crystal detector, and a variable condenser, so that practically everything would come in usefully in building up a more elaborate set later on.

The probability is that sooner or later you will want to cover a greater range of wave-length; in that case you would need to obtain or to make another induction coil, or even

two more so arranged that you could switch any of the three into or out of service.

The manner in which the various parts are fitted together is shown in Fig. 18 (at end of book) and Figs. 19 and 20 on pp. 68 and 69, and the order of procedure may be as follows:

1. If the induction coil has open ends, cut circular holes in two pieces of wood, so that the ends of the cardboard cylinder will just fit into them, and glue the cylinder in position. When dry, screw the pieces of wood to the baseboard from underneath. Before screwing down to the baseboard, bore a number of fine holes, and pass the leads from the coil through them in their correct order.

2. Near each end of the baseboard drill a pair of holes, insert the four terminals, and screw them up tight.

3. Fix the crystal detector in the position shown by means of wood screws. (There should be holes in the base of the crystal detector for that purpose).

4. Fix the condenser to the baseboard in the position shown.

5. Mark a point where each of the switch arm pin-holes will be bored, and describe a circular curve from this point with a pair of pencil compasses, so that the curved line is centrally under the contact point of the switch arm. Mark off, on this curved line, at equal distances apart, a number of points corresponding to the number of leads from the coil, and at each point bore a hole just

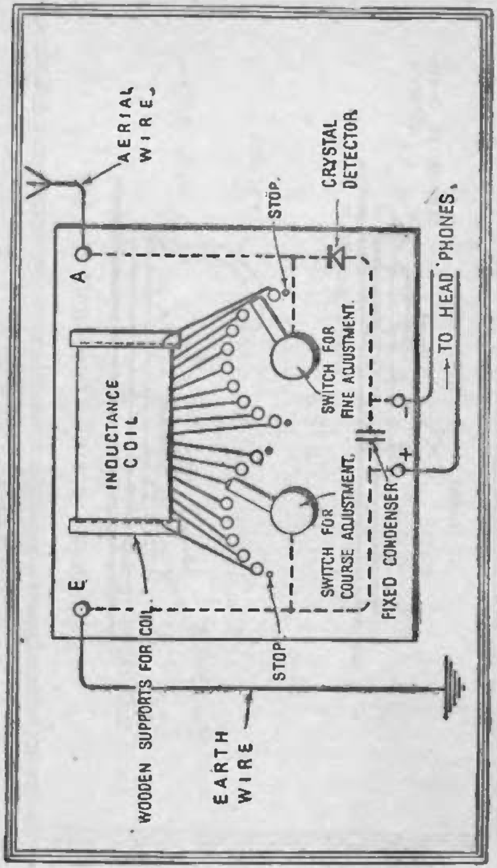


FIG. 19.—DIAGRAM OF RECEIVING SET.

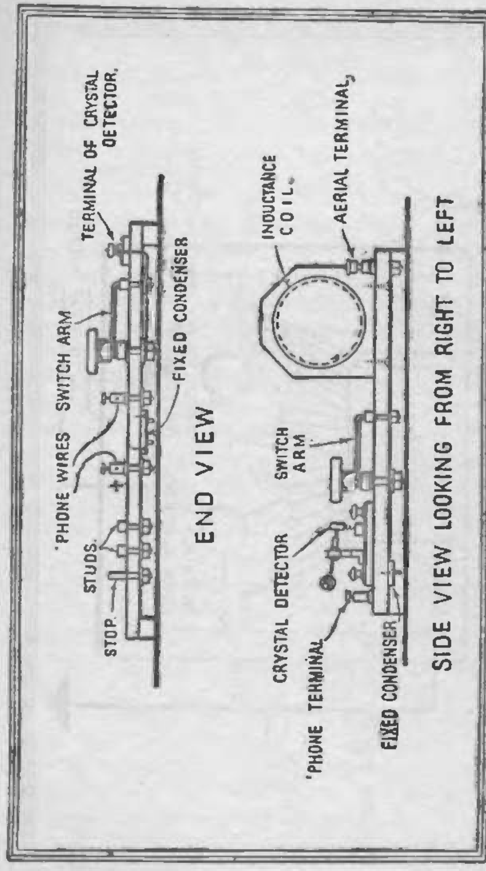


FIG. 20.—DIAGRAM OF RECEIVING SET.

large enough for the screwed end of the contact stud to pass through. Then push the screwed ends of the contact studs through these holes. Try with the compasses whether they are on a truly circular line and equidistant from the centre point. If so, bore a hole, and fix the switch arm in position.

6. Tilt the baseboard, and connect each of the wire leads from the inductance coil to the terminal end of a stud, taking care that they are connected up in the right order, and that they do not overlap. It is advisable to solder each connection.

7. Connect a length of insulated wire to each terminal of the crystal, and to each terminal of the condenser, and pass it through a small hole in the baseboard.

8. Below the baseboard make the wire connections between the various terminals as shown.

9. Mark with letters two of the terminals on the baseboard " A " and " E " indicating aerial and earth. Also the other two terminals " +T " and " −T " indicating the telephone connections. Attach a small linen label to each of the two ends of the telephone wires with similar marks.

10. With an insulated length of wire connect the inlead from the aerial to the terminal A.

11. To the terminal E attach a length of insulated wire of such length as will permit

of " earthing " it. Earthing may consist of attaching the other end of this wire to a water-pipe, or it may be necessary to take it out of a window and solder it to a pail or some large metallic object buried deep in the ground.

We will now suppose that all this (which is really very simple, and requires no scientific knowledge—for any boy can do it), has been done, and that the great event—our first listening-in—is about to take place.

It is 7.55 p.m. Glancing at the daily newspaper we see that at 8 p.m. Madame Prettiscreem's latest thrill is to be communicated from Macaroni Buildings, on a wave-length of 400 metres.

Alas and alack! How are we to tune-in to 400 metres?

Well, that is the first penalty of building up your own set. If you buy an expensive set, probably you will find that your switches indicate how to tune-in to different wavelengths merely by turning them until the hand points to a certain figure. That would be very nice and easy, but—it won't teach you much. It is what the rich radio-enthusiast likes.

With your first little home-made set you may have to try and try, again and again. But if you have patience you will learn more by so trying than the author could teach you in many volumes of theory.

And if you have faithfully followed instructions simply by tuning your aerial, you will catch Madame Prettiscreem's wave-length.

It should be clearly understood that although this set is not the best or even the cheapest to make, it is the most instructive type to indulge in for the first time.

CHAPTER IX

VALVE RECEIVERS

WHATEVER kind of wireless receiver is employed, it is essential to rectify the current from the aerial before it can be used in the telephone. As already explained, in the case of crystal receivers, rectification is performed by the crystal itself, and the current is then employed directly to actuate the telephones.

In the case of valve receivers, not only can the current be rectified by the valve, but it can also be magnified in strength—hundreds or even thousands of times if required. But let us first describe the valve itself—the "thermionic" or "three-electrode" valve, as it is called, for the invention of which the world is indebted, in the first place, to Dr. J. A. Fleming.

Whilst experimenting with ordinary incandescent electric lamps, Dr. Fleming came to the conclusion that when the filament is glowing an invisible something is shot off from it. That something we call electrons—"the stuff electricity is made of." Dr. Fleming then had some lamps made, in each of which there was a small metal plate with a separate terminal, and discovered that by connecting up the terminal of the metal plate and one of the filament wires in such a manner as to allow an alternating current to flow through it, only the impulses in one direction could pass, those in the other direction being for the most part stopped, much as the valve of an inner tube of a bicycle or motor car will only allow air to pass through it in one direction. His invention, therefore, came to be known as the "Fleming valve," and one of the first uses it was put to was to rectify alternating current from wireless aerials, and render it suitable for use in the telephone. In this respect the valve serves the same purpose as a crystal.

Later on, Mr. Lee de Forest made an improvement, which consisted of introducing a piece of metal gauze or a coil of fine wire between the ordinary filament and the plate. This was attached to a separate terminal, and from this the modern three-electrode valve was developed. The valve, as now made, consists of a glass bulb—exhausted of air—with a straight tungsten filament entering and leaving the bulb, much as in the case of an ordinary electric lamp. Around the filament is a little cylinder of metal gauze, or a coil of fine wire called the "grid," and round the grid is a thin circular cylinder of metal known as the "plate." The filament, grid, and plate do not touch each other, the grid being connected to a separate terminal, and the plate to another terminal, so that there are four

terminals, two for the filament, one for the grid, and one for the plate.

Each of the terminals is in the form of a spigot or little round rod of brass, and each of the four spigots fits into a corresponding hole or socket on a wireless receiver stand. The sockets are connected to wires leading to batteries and other parts of the apparatus. When pushed into these holes, current from an accumulator lights up the filament, and as it does so the filament projects a stream of negative electrons towards the grid and the plate. (There are several types of valve, but this is one of the popular amateur types.)

Now, electricity can only flow as between positive and negative poles. That is to say, that positive and negative mutually attract; but positive repels positive, and negative repels negative.

If we connect one end of a wire to the plate terminal of a valve and the other to one of the filament terminals with a suitable battery interposed, and connect the filament terminals to another battery so that the filament glows, a rush of negative electrons takes place from the filament towards the grid and the plate, the stream of electrons constituting a path or conductor, and allowing the current to flow in the plate circuit through the valve. And if we then interpose a source of alternating current in the grid circuit, owing to the electrons projected from the filament being "negative," they are repelled by the negative impulses of the alternating current, which only allow impulses to pass in one direction, and in this way rectify the current.

But the valve can also be made to act as a magnifier or amplifier, and to impart the variations of the feeble oncoming aerial current to a stronger current in the plate circuit.

If we connect one end of a wire to the negative terminal of a third battery and the other to the grid terminal, and the positive battery terminal to the filament terminal by another wire, we shall have a third circuit in which a negative charge flows into the grid, and if we can vary this negative charge we may increase it to such an extent that it will repel the stream of electrons from the filament and prevent them from passing the grid and reaching the plate. By increasing the grid charge sufficiently it will overcome the stream of electrons entirely. On the other hand, if we connect the positive terminal of the battery to the grid, the positive charge will attract and assist the flow of electrons. By a suitable arrangement of circuits a strong current in the plate circuit can be made to oscillate in sympathy with the aerial currents. This more powerful current varying just as the aerial current varies, it follows that all the interruptions in the aerial current

(which interruptions correspond to the original sound waves) are impressed upon the current in the plate circuit, and are ultimately reproduced in the telephone as air vibrations or sound waves again. This magnification of the feeble aerial currents is called "amplification."

That is the simplest application of the valve as a detector, rectifier, and magnifier or amplifier of the aerial currents, but there are other applications involving too many diagrams and too much explanation for us to deal with here. Suffice it, therefore, to mention that the valve may be used solely as a rectifier or as an amplifier, or as both, and that many valves can be used in a receiving set, each one amplifying still further the current magnified and passed on to it by the preceding valve, until the feeble aerial current has been magnified hundreds or thousands of times. Again, by a certain arrangement of circuits, valves can be made to remagnify what they have already amplified. In some cases, a crystal is used as the rectifier and the valve as an amplifier.

Unfortunately, valve receivers entail the use of an accumulator for supplying current for the filament, and batteries (which may comprise a large number of small dry-cells) for supplying current to the plate circuit. This means a great deal more expense and trouble than is involved in crystal sets, but the results are of course far more satisfactory. For instance, using only an indoor or frame aerial, an amateur valve set, comprising several valves in series, will enable signals to be received in England from America.

CHAPTER X

WIRELESS WAVES AND TELEPHONY

In Chapter IV. it was explained how Hertz first discovered that electro-magnetic waves could be generated and detected, and how, many years later, Marconi invented the means of applying this great discovery to wireless telegraphy.

Curious as it may at first appear, wireless telegraphy—the transmission of signals—was a fairly easy matter even over long distances compared with telephony—the transmission of speech or music.

In Chapter III. it was explained how a written message is translated into the Morse code by perforating a paper tape with certain combinations of holes, and that by passing the tape through an instrument called a transmitter these holes cause interruptions in an electric current. Thus every interruption in the current causes corresponding interruptions in the wireless waves generated at the aerial, and at the receiving end the current generated by the waves in the aerial is impressed with the same series of interruptions which can readily be reconverted into the Morse code and so into a written message again.

But when we come to transmitting speech, the Morse code is of no use to us. We cannot say that a dot or dash shall represent a particular sound. Again, there is an infinite variety of sounds.

Instead, therefore, of punching a paper tape as in the case of telegraphy, in wireless telephony—the transmission of sound—a means had to be found of impressing upon the ether waves vibrations corresponding to the sound waves.

To do this necessitates a continuous and unbroken train of ether waves which can be modulated by means of sound waves, so that the slightest modulation or merging of the sound waves produces a corresponding effect upon the train of ether waves. These continuous ether waves are called "carrier waves."

We will first follow out the process of ordinary telephony from end to end.

A telephone transmitter comprises a little case in which there is loosely packed a small quantity of carbon granules, and through these granules an electric current from a battery flows. At one end the carbon granules bear against an extremely thin metallic plate or diaphragm fitted in the mouthpiece of the telephone. By lifting the receiver off the hook, we close an electric circuit and a current begins to flow steadily through the granules. But the moment we begin to speak, the sound waves of our voice impinging upon the diaphragm (which is

exceedingly delicate and sensitive) cause it to vibrate and to press against the granules behind it with a force that varies exactly according to the modulations of the sound waves of our voice. Now, the flow of the current of electricity varies according to how tightly the granules of carbon are packed; consequently the varying pressure of the diaphragm upon the granules causes the flow of the current to vary accordingly.

The electric current passes along land wires to a receiver, which the person we are talking to holds to his ear. In this receiver there is a little electro-magnet energized by the current, and close to it a diaphragm which is attracted by the magnet. As the strength of the current varies, the impact also varies in strength, with the consequence that the diaphragm moves to and fro with varying force. With every such movement the diaphragm hits the air and reproduces exactly the original sound waves of our voice.

In the case of wireless telephony, we begin and end in the same way. But instead of the mouth-piece and ear-piece being connected by wire, the electric current, upon which the modulations of our voice have been impressed, is led to a transmitting valve, which causes it to impart its modulations to another current, thousands of times stronger, which speeds into the aerial. This current sets up an unbroken train of ether (carrier) waves, but every modulation in it causes a corresponding variation in the regularity of the ether waves. The current produced by these waves in an aerial also bears the same modulations, and eventually the current flowing through the 'phones of our wireless receiver reproduces the original sound waves again.

The principle on which music is transmitted is just the same.

A loud speaker is merely a means of magnifying and distributing the sound waves at the receiving end, and is not an essential feature of wireless, although a good loud speaker may be a useful one, in that it enables any number of persons in a room to hear, instead of only one or two who have to don head 'phones in order to listen-in.

CHAPTER XI

GENERAL HINTS AND NOTES

SEE that your aerial is insulated properly, and does not come into contact with anything else; also that all joints and wire connections are properly made.

Treat your set as you would treat a box of eggs—it is the safest plan. Remember that valves are expensive things to replace. Dropping or knocking a variable condenser may alter the spacing of the plates and render it practically useless.

Never use accumulators to the end of the charge. Keep them regularly charged; even if you do not use them for a fortnight, give them a small charge now and then. Accumulators last years if they are taken care of, but deteriorate rapidly if allowed to run down. Keep the terminals always clean and the screws hard up against the ends of the wires.

When you have fixed up your set and have recovered from the first shock of delight, study the subject of wireless more deeply, carry out experiments for yourself, always aiming at improvements, learn all you can about wireless developments, and what others are doing; then perhaps some day you may make a wonderful discovery, for wireless is still in its cradle.

Do not handle a crystal unless absolutely necessary, and never do so with greasy hands. Grease and dirt greatly impair its sensitiveness.

If you are not getting satisfactory results when listening-in with a crystal set, re-adjust the wire or metal point against the crystal. Most crystals are more sensitive in some spots than in others, and you will need to find one of these sensitive spots to get the best results. Occasionally it is well to dip a clean stiff brush into alcohol and scrub the crystal gently all over.

Remember that the current coming from the aerial is exceedingly feeble. Although it oscillates at a speed of, perhaps, a million times a second, it may possess only a millionth of the strength of an electric torch battery. Consequently you cannot afford the least chance of leakage. That is why insulators are employed for the aerial, and insulated wire is used indoors. Use large copper wire for "earthing," and make sure that all contacts are good, and that the wire is well secured to "earth."

If intermittent, sizzling noises occur, they are probably due to atmospherics (*i.e.*, electrical disturbances in the air), and you cannot do anything but possess your soul in patience until they stop. But if they are persistent and continuous, they are probably

due to something else. It may be due to a loose connection somewhere, or even to an accumulator that has been overcharged, and has not quite stopped gassing.

It is important for the telephone wires to be attached, so that the current flows in the right direction, otherwise the telephone receivers will be demagnetized and ruined in time.

When tuning-in, continue the adjustment until you hear a clear steady note. If you possess a valve set, and are receiving a concert quite well, but to the accompaniment of hissing sounds, it probably means that your set is oscillating—*i.e.*, sending out waves from your aerial to the annoyance of other listeners. Correct this until you get the steady note, remembering that you have no right to interfere with the enjoyment of other people.

Do not expect too much of a crystal set. If you are within ten to twenty miles of a sufficiently powerful broadcasting station, you may derive great enjoyment from it, but if you are more ambitious you will need a valve set.

If you invest in a valve set, buy one on the unit system, so that you can add an extra amplifying unit at any time in case you want to increase the range or to tune-in to less powerful stations.

Never use a gas pipe as an "earth"—there is risk of fire or explosion in so doing.

There are many other precautions and don'ts that might be added, most of which you will learn by experience.

There is still a good deal of mystery about aerials, and we have yet a great deal to learn about them. Although we know that certain results can be obtained with certain types of aerial, experimenters are continually discovering new arrangements, which give satisfactory results, and—especially if you possess a two or three valve receiving set—you will find a great deal of fascination in experimenting with indoor aerials.

You cannot do better than begin by constructing the crystal set described in Chapter VIII. It is the type which is most readily understood, and when you understand it, you will easily be able to construct other inductance coils for yourself, to cover other ranges of wave-length. Later on you will study the mysteries of vario-couplers, and so gradually work up to a higher class instrument. Freak sets, although for the most part not very useful, offer an interesting field for experiment. Freak sets have been made smaller than matchboxes.

If at any time you contemplate purchasing a ready-made set, do not believe everything makers tell you. Remember that, like other things, wireless receiving sets are made to sell, and although there are leading firms whose reputation depends upon the quality of what they sell, there is always plenty of

cheap and out-of-date stock on the market—especially of foreign manufacture. Your best course is to ask the advice of a friend who has had experience, as to what to buy, where to go, what to pay, and what you may expect in the way of reception.

The principal morning newspapers publish daily the broadcasting programmes and the wave-lengths of the various stations, so that you have merely to tune-in to the right wave-length at the right time, in order to enjoy the concert, lecture, or children's bedtime stories.

CHAPTER XII

THE MARVELS OF WIRELESS

THE real wonders of wireless lie, not in the mere fact that we can listen-in to music and speech at a distance without the use of wires, as in other aspects of this branch of science. For there is really nothing to the physicist more wonderful in wireless telegraphy and telephony than in telegraphy and telephony carried on by wire. Nor is it particularly wonderful to construct freak sets in rings and matchboxes.

Let us consider, then, a few of the real wonders of wireless.

Into an overhead wire an electric current speeds with the velocity of light—186,000 miles a second. To and fro the current surges, changing its direction hundreds of thousands of times a second, and with every alternation sets up an invisible electromagnetic wave which sets off and in one-sixteenth of a second has struck every aerial in the world, setting up a ripple of electricity in each one tuned to receive it.

In a room in London a woman stands, singing a song. Every note is impressed as

a modulation in that vast torrent of waves, and in about one five-hundredth of a second it is heard by thousands of listeners all over England. Following one upon another at hundreds of thousands to the second, each wave expands like a vast unseen globe, striking an electrically charged, invisible screen thirty or forty miles overhead, which sends it hurtling downward again and again, until at last it dies out in the ocean of ether.

It is comforting to reflect that wireless is not merely an amusement for the rich. It is an amazing reflection that for two or three pounds a wireless set may be constructed or purchased and that broadcast concerts may be enjoyed in hundreds of thousands of humble homes. And it is an almost ludicrous fact that essential parts of receiving apparatus are exposed for sale in the street on costermongers' barrows!

Yet what a terrible waste of energy is there!—more than enough to convey messages to every spot on earth.

Yes, and that loss of energy brings us to the next wonder—directional wireless.

Long before wireless telegraphy and telephony were invented it was known that electro-magnetic waves could be reflected and focussed like those of light. And so men set themselves to generate wireless waves and direct them in beams, instead of allowing them to expand in all directions.

And now they carry on telegraphy between London and the Continent with wireless beams, missing out all other stations with which they have no wish to communicate. They have even made a "wireless lighthouse" that revolves and sends out beams of wireless waves at regular intervals, that can be picked up by ships at sea, though they be fogbound and out of sight of land.

During the war, they found out how to locate transmitting stations—known as "direction finding," so that guns and aeroplanes could be turned against them, and it often happened that transmitting stations had to be abandoned or moved to other positions in consequence.

The pilot of an aeroplane, lost in darkness or in a dense fog, speaks into his wireless telephone. He doesn't waste words, but just enquires where he is—apparently a curious thing to ask—and listens. In a matter of seconds the reply comes—more clearly than if the speaker were seated beside him. It is the voice of a man in the office of a distant aerodrome, far below in the fog or darkness, whose business it is to listen-in for lost airmen and direct them. In a few words he tells the pilot just where he was when he spoke.

Wireless control of airships and of vessels at sea is a *fait accompli*, and before long it may be no uncommon thing to see a crewless

aeroplane or airship rise from the ground and, responding in every movement to the touch of switches in a control room on the ground, set off and deliver mails in Paris or wherever else desired.

The same may be done with ships—a steamer might easily leave an English port without a soul on board and cross to France, guided in the same manner.

In the next Great War such applications of wireless will inevitably be utilized for purposes of dealing death and destruction.

Wireless is already in one sense a transmission of power without wires, but there are those who believe that it will ultimately be employed to transmit sufficient power to operate motors directly. Here the small-engined glider offers opportunity. Not merely should we then see aeroplanes in flight controlled from the ground, but aeroplanes without fuel deriving their driving power by wireless from transmitting stations below.

If you tune-in to Eiffel Tower wave-length at the right time morning or evening, at 10.45 you will receive the time signal. Not too interesting perhaps? Or possibly you think that signal is sent out for you to set your watch by? Well, there are more important watches than yours and mine that will be set by it. Far out at sea, fog-bound or storm-tossed and at the mercy of the waves, a ship is in distress. She has lost her bearings and cannot wireless her whereabouts to would-be rescuers. Suddenly her wireless operator picks up the time signal, and in a few seconds the navigating officer has found his longitude and knows exactly his position east or west.

In the same way the longitude of any place in the world can be found with the aid of time signals: a receiving operator or another man with him could place his hand on the ground and say, " Through this spot meridian so-and-so passes," or "This spot is 170 degrees 45 minutes 30 seconds east of Greenwich," and from that the exact distance would be known. Before the advent of wireless that could only be done by laying a telegraph wire to every separate spot to be located.

And now, what of the future? Who can tell what wonders there are ahead?

Wireless is still in its infancy. We live in an age of waves and vibrations—life itself may be but a spell of vibrations that rise to a maximum amplitude and then die away.

The field for research is a big one and full of mystery and promise.

The day may come when telepathy—thought transference—will be practised as readily as wireless telephony; when television—the sight of distant objects beyond the

range of our eyes now—will enable us to see people in far-off countries and to witness events there as they occur; and when we shall discover that greatest secret of all—the secret of life.

THE MORSE CODE

ALPHABET.

a	· —	n	— ·
b	— · · ·	o	— — —
c	— · — ·	p	· — — ·
ch	— — — —	q	— — · —
d	— · ·	r	· — ·
e	·	s	· · ·
f	· · — ·	t	—
g	— — ·	u	· · —
h	· · · ·	v	· · · —
i	· ·	w	· — —
j	· — — —	x	— · · —
k	— · —	y	— · — —
l	· — · ·	z	— — · ·
m	— —	é	· · — · ·

FIGURES.

1	· — — — —	6	— · · · ·
2	· · — — —	7	— — · · ·
3	· · · — —	8	— — — · ·
4	· · · · —	9	— — — — ·
5	· · · · ·	0	— — — — —

PUNCTUATION AND OTHER SIGNS.

Full Stop (.) · · · · · ·
Note of Interrogation, or request for repetition (?) · · — — · ·
Note of Exclamation (!) — — · · — —
Hyphen or dash (-) — · · · · —
Bar indicating fraction (/) — · · — ·
Call (*Preliminary*) — · — · —
Double dash (*separating preamble from address, address from text, and text from signature*) — · · · —
Error · · · · · · · ·
End of transmission · — · — ·
Invitation to transmit — · —
Wait · — · · ·
Received Signal · — ·
End of Work · · · — · —
All Stations — · — · — — · —
"TR" (*prefix for preliminary correspondence*) — · — ·

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FIG. 4.—THE CREED TRANSMITTER, SHOWING THE PERFORATED TAPE PASSING THROUGH IT.

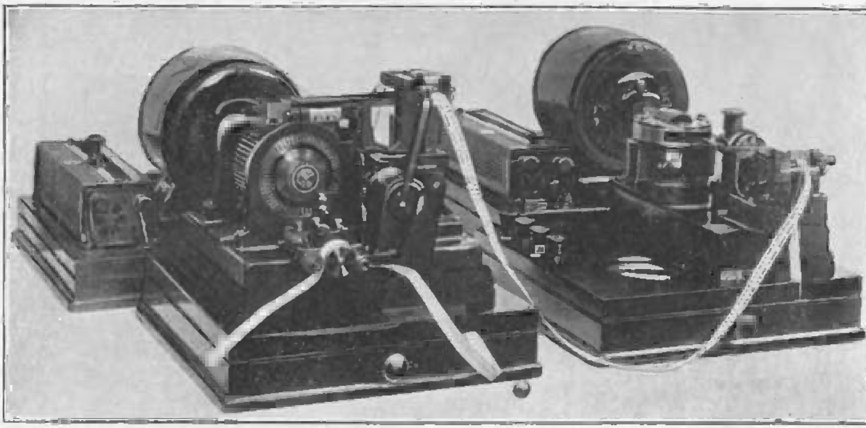

FIG. 6.—THE CREED RECEIVER (RIGHT) AND RAPID AUTOMATIC PRINTER (LEFT) WITH PRINTING HEAD HINGED DOWN TO SHOW TYPE HEAD.

FIG 17.—CRYSTAL DETECTOR.

By moving the round knob the wire may be moved about until a sensitive spot on the crystal is found.

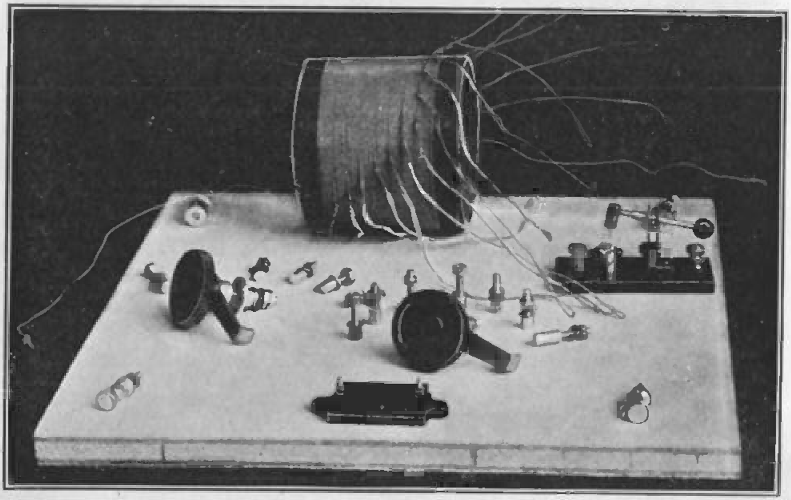

FIG. 18.—PARTS OF RECEIVING SET ROUGHLY ASSEMBLED READY FOR FIXING