RADIO TELEGRAPHY.

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Ever since the celebrated researches of Hertz in 1887, a new science has been developing which has within recent years proven its value to the practical as well as to the scientific world. The science and development of radio or wireless telegraphy, as it is more commonly known, has been a wonder to most people. However, the principles involved are quite simple and can be easily understood by anyone who has a knowledge of the fundamentals of the electric circuit. Radio telegraphy depends upon the fact that electric waves which are similar to light and heat waves can be produced and will travel through the ether as a medium. It is the purpose of this article first to show how electric waves are produced and second to give in a brief way the application of them to radio telegraphy with some of the later developments.

If a Leyden jar condenser or any other type is connected to some source of high potential the condenser will receive a charge given by the formula Q=CE, where Q is the charge in coulombs per second, C is the capacity in farads, and E is the potential of the charging source in volts. Then if the condenser is connected to a spark gap as shown in Fig. 1, a spark will occur at F_1-F_2 when the voltage of the condenser becomes high enough to break down the dielectric strength of the air gap. The space between F_1-F_2 becomes conductive and a current flows in the circuit as indicated by the arrow. This current does

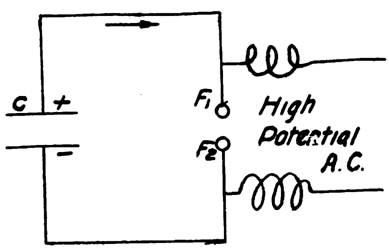

Fig. 1

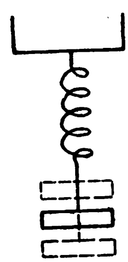

Fig. 2

not flow always in the same direction but is an oscillating current, that is, it flows first in one direction and then in the other, or it changes direction periodically.

Analogous to such a current is the motion of a spring which is stretched and caused to vibrate, as shown in Fig. 2. For a given spring the oscillations set up will occur at definite periods, and the amplitude of each oscillation will be fixed by the stretching force applied to the spring. In this case the rate of vibration depends directly on the stiffness of the spring and the mass of the vibrating material. In a similar way the rate of vibration or number of oscillations per second in the electric circuit depends on the capacity of the condenser and the inductance of the circuit. Hence a condenser similar to the spring acts as a medium for oscillations.

An oscillation set up in such a circuit as the one shown in Fig. 1 follows the law, $T = 2\pi\sqrt{LC}$, where T is the period or time of one complete oscillation in seconds, L is the inductance of the circuit in henrys, and C is the capacity in the circuit in farads. The alternating or oscillating current set up in the circuit produces an alternating magnetic field about each conductor. The entire phenomena, the oscillating current with its alternating magnetic field, is called an electromagnetic oscillation. Electromagnetic oscillations occuring in a conductor which is suspended in space transfer energy into the ether in the form of electromagnetic waves, called hertzian waves after the man who discovered them.

In 1887 Hertz set up an apparatus similar to the one shown in Fig. 3, in order to show that an electric wave existed. He found that when a spark occurred at *a*, with the loop *cbd* of his detector so adjusted that it was in resonance with the radiator AB, a very minute spark also occurred at *a′*. He also showed that electric waves could be refracted through prisms made of

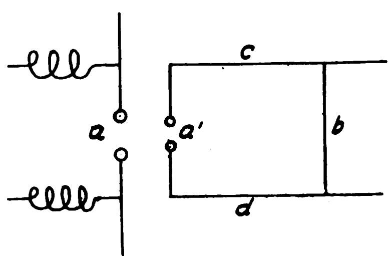

FIG. 3

resin or pitch, and that they could be polarized and reflected. The most important thing which he discovered from his radiator and detector was that if two circuits were tuned to resonance as the one shown in Fig. 3, the oscillations set up in the detector circuit must come from those in the radiator circuit through the ether as a medium and from the electric waves set up by the oscillator or radiator. These waves were found to follow the same law as light waves or,

$$N = V_h/W = \frac{3 \times 10^{10} \text{ cm. per sec.}}{2 \text{ L cm.}},$$

where N is the frequency of the oscillation, V_h is the velocity and W is the length of wave. The only difference between electric waves and light waves was found to be that of wave length.

Hertz's method of producing electric waves was not very efficient and could be used for sending signals only a few feet. However, Marconi, having taken up the work of Hertz, happened to ground one side of the Hertz oscillator and found that the range of the radiator was increased wonderfully, the reason being that the earth was a better medium for the electric waves than another layer of ether. He also went a step farther and constructed an antenna, that is a wire from one side of the oscillator to some point several feet higher. This added capacity to the oscillator and greatly increased the range of the waves. Other developments were made until a very efficient sending apparatus as shown in Fig. 4 was developed. In this figure I. C. is an induction coil or a step up transformer which is the source

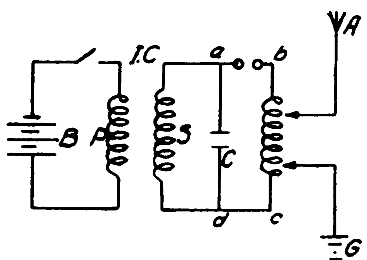

FIG. 4

of high potential, C is a condenser, and S is a spark gap. In such a circuit the oscillating circuit is the path *abcd,* and since the antenna acts as a condenser or capacity to the ground an oscillating current will be set up in the antenna circuit. This oscillating circuit in the antenna will produce an alternating magnetic field about each of the antenna conductors. This alternating magnetic field as stated before will produce electromagnetic waves which will pass off in the ether. Hence if an ordinary Morse key is used to break the current in the low potential side of the coil I.C., a system of dots and dashes can be used to carry on communication with some station at a distance several miles away.

Such an arrangement of apparatus as shown in Fig. 4 produces what is known as damped oscillations. That is, the current in the oscillating circuit if plotted against time forms a curve similar to the one shown in Fig. 5a. This figure shows that the current gradually dies out in time, due to the energy lost in heating the conductor in the circuit. Any method which will give oscillations as shown in Fig. 5b is called the undamped method of producing signals. It has been found in more recent

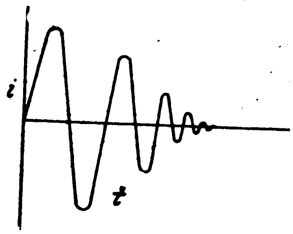

FIG. 5a

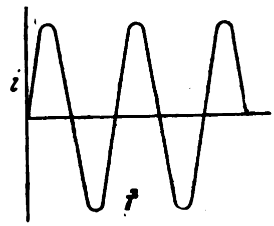

FIG. 5b

years that undamped oscillations produce waves which will radiate farther than the damped waves. The method of producing undamped waves is a little more complicated and will be explained later.

In order to cover any great distance with the radio telegraph it is necessary to have a sensitive means of detecting the electric waves. Hertz's detector can be used only for very short distances, hence the need of a more sensitive detector was soon felt by the earlier experimenters. The coherer which was discovered by Lodge can be used for detecting damped electric waves. The coherer depends upon the principle that when metallic fillings such as nickel and silver are lying loosely between

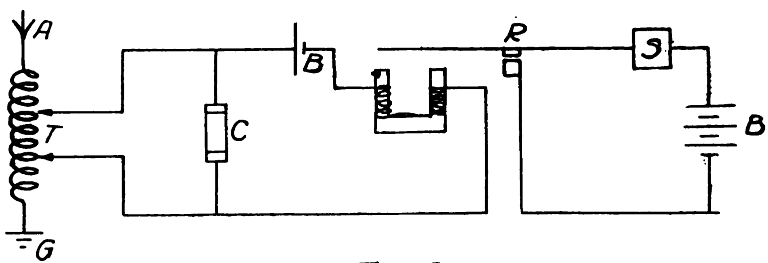

FIG. 6.

two metallic plugs in a glass tube their resistance is greatly reduced when a train of waves from a sending station passes through the filings. If a circuit is arranged as shown in Fig. 6, the reduction in resistance will allow current to flow in the battery circuit. This current in the battery circuit operates a relay R which in turn causes a sounder S to operate. Upon this sounder the signals are read. The coherer needs some means of restoring it to its original condition after each signal has passed. This is done by tapping it, or decoherering it as it is called, at the end of each signal. The tapping is done automatically.

But the coherer is not a very sensitive detector of wireless waves, hence a great deal of research has been done along this line. The two better types of detectors which were discovered are the crystal detector and the audion detector. If some crystal, galena or silicon, is to be used as a detector of electric waves it is placed in the circuit as shown in Fig. 7. D is the detector.

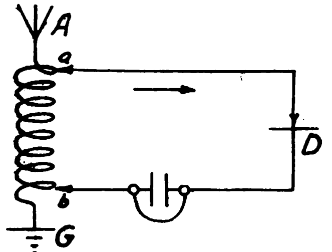

FIG. 7

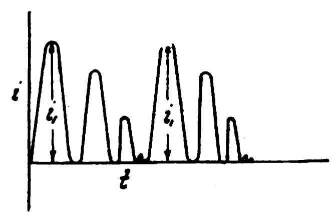

FIG. 8

The arrow represents fine wire contact if galena is used or a pointed brass contact if silicon is used. Such a detector acts as a rectifier to high frequency alternating currents,—that is, the oscillating current brought into the circuit from the terminals *ab* will flow through the detector in one direction only as indicated by the arrow. When the oscillation is of the kind shown in Fig. 5a, a damped oscillation, only the rectified portion of the current in Fig. 8 will pass through the telephone receivers R in Fig. 7 and only *i* of the rectified oscillation will produce any effect upon the diaphragm of the receiver. This means that a pulsating direct current passes through the receivers which causes the diaphragm of the receivers to vibrate at the same frequency as that of the transformer or induction coil of the sending station, and not the frequency of the oscillation.

In order to be able to receive messages from one station and not from another, some method of putting the receiving station in tune with the sending station is necessary. This is accomplished with a coil of wire T in Fig. 7, called a tuning coil. The two terminals *a* and *b* are made to slide over a cylinder of insulated copper wire in order to vary the number of turns of wire between the two terminals. This particular method of tuning is known as the close coupled tuning method. A better tuner, which is now used almost exclusively, and is known as the loose coupled tuner, consists of two coils of wire one of which slides inside the other. These two coils may be wound with the same size or with different sizes of wire, depending largely upon the nature of the station in which it is used. When such a loose coupled tuner is used, the connections are made according to the diagram of Fig. 9. Closer tuning can be done with a loose

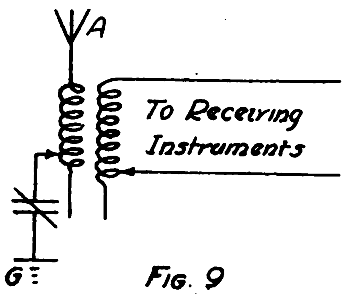

FIG. 9

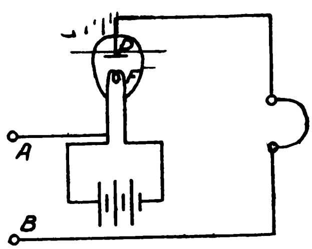

FIG. 10

coupled tuner and also atmospheric disturbances can be eliminated to a great extent. The variable condenser in the ground circuit may be used and will give better results in tuning. Since tuning is the sole means of being able to hear just one station when dozens of others are operating at the same time, much research has been made along this line and there is still room for more development, the ideal tuner being one that will pick up one station when thousands of others are operating. Therefore tuning is accomplished by changing the wave lengths of both receiving and sending station until they are the same. This means that there must be some means of tuning at the sending station which in principle is similar to that of the receiving station.

Perhaps the greatest discovery that has been made in the wireless field is the valve detector by Prof. Fleming. This consists of two elements, a filament F and a plate P placed in a vacuum bulb as shown in Fig. 10. When the filament is made to glow from the battery B, a current in the telephone receiver circuit T will flow in such a direction that a negative charge flows from the filament to the plate P. Then when a train of waves is brought in from the terminals A and B the detector will act as a valve permitting current to pass through the receiver circuit in the direction of the negative charge. Hence this form of detector acts much like the crystal detector but is much more sensitive and efficient.

Prof. Fleming's type of vacuum valve has been modified by De Forest, who placed three elements in the bulb instead of two. The third element consists of a grid shaped wire placed opposite the plate or wing. The principles of this detector are essentially the same as of the Fleming type. The connections for such a detector are as shown in Fig. 11. With this modified form of

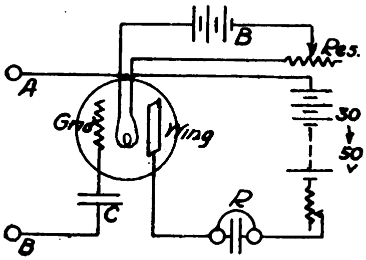

FIG. 11

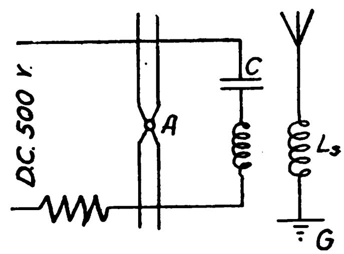

FIG. 12

detector a second battery of from 30 to 50 volts is needed in the telephone receiver circuit. One of the advantages of such a detector over the old crystal detector is that it can be connected in the circuit in such a manner that undamped as well as damped oscillations can be received.

Undamped waves are produced from oscillations in which the current is not damped out in the series of oscillations but the current reaches the same maximum value with each oscillation. Such an oscillation may occur in a circuit which contains no resistance. Fig. 5b represents such a current plotted against time. Since it is impossible to have a circuit without resistance, there must be some other means of producing an oscillation of this character. There are two general methods of producing oscillations of this type, the high frequency alternator method and the electric arc method.

When a bow is drawn across the string of a violin the string is set in motion but as soon as the bow is removed the motion of the string quickly dies out. Now if a continuous bow were drawn over the string, the string would continue to vibrate. The same holds true of an electric circuit such as shown in Fig. 12. The arc is started and maintained, and the current in the parallel circuit which contains capacity and inductance oscillates with constant amplitude. The antenna which is coupled loosely to the oscillating circuit will radiate waves of an undamped character. In order to signal with such an apparatus it is necessary to short circuit some of the turns in the coil L-s, which changes the wave length of the waves emitted.

The type of arc shown in Fig. 12 is known as the Duddell singing arc, from the fact that the arc produces a very high pitch tone. The type of arc that is used in actual practice is the Poulsen arc. It is essentially the same as the Duddell arc except that one of the electrodes is carbon and the other copper, and both are placed in a hydrogen chamber which greatly increases the arc capacity. A magnetic blow-out and a means of cooling the arc are also used. These last two improvements are essential to prevent the energy from being dissapated in the arc itself.

Damped oscillations can be produced which approach the character of undamped oscillations. There are two general methods by which these oscillations can be produced, the rotary spark gap method and the quenched spark method. If a rotary spark gap is substituted for the ordinary stationary gap, less energy will be lost in the gap itself. Such a gap is illustrated in Fig. 13. This type of gap gives a musical tone to the spark

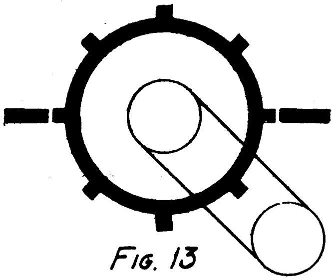

FIG. 13

which is not so high pitched as the tone obtained by the arc, but it is much more pleasing to the ear than the tone emitted by the stationary gap. Since there is less loss of energy in the oscillating circuit, there will be less damping and therefore the wave emitted will be more distinct. Such a gap is placed in the circuit as shown in Fig. 14. In ordinary practice the gap is run at such speed as will give a frequency of about 500 sparks per second.

The quenched spark has advantages similar to the rotary gap except that the wave is still purer and the tone a little higher. It consists of a number of brass or copper plates separated by mica rings. These plates are built up according to the number desired, depending upon the size of the station. Hence instead of having just one gap for the spark there are several gaps in series and of much shorter length. The gap is usually cooled by some method of passing cooling water around it. This type of gap likewise permits of less loss of energy in the gap itself.

As has been mentioned the ordinary detector cannot render undamped oscillations audible in the telephone receiver. When such oscillations are passed through the detector circuit they produce only a click in the receiver when the first oscillation passes and another click when the last oscillation passes. Unless they are chopped by means of an instrument called a ticker, which periodically makes and breaks the receiver circuit, they cannot be used for signalling. Tickers are rather troublesome to operate because they involve some means of driving them which usually makes quite a lot of noise in the operating room. Mr. Armstrong of Columbia University has shown that an audion detector can be used to produce local oscillations. Hence the audion was resorted to for detecting undamped waves. If two oscillations of different frequencies are occuring in the same circuit, interference between the two will take place and at times the resulting oscillation will be of a greater amplitude than either of the two, while at other times they will completely annul one another. Then when an audion detector is used for this purpose as in the circuit of Fig. 14, beat tones will be produced in the receivers. The analogy of beat tones is the effect produced by two violin strings of slightly different frequencies vibrating at the same instant. If we could hear the beat tones alone without hearing the natural tones of the strings, we would have some idea of the vibrations of the telephone receiver.

Since two systems of wireless telegraphy, the spark or damped wave system and the arc or the undamped wave system, are used at present, it might be well to compare the two. Undamped waves permit of sharper tuning, radiate farther at the same expense of energy and are less affected by atmospheric disturbances known as static, than are damped waves. Damped waves require a less expensive generator, a less complicated receiver and can be operated at much shorter wave lengths than the undamped waves. The tendancy at present is toward undamped wave systems.

In order that a wireless station may operate well there must be a good aerial and a good ground connection. There are several types of aerials used. The general classes are:

1. The vertical type
2. The horizontal type
3. the slanting type.

The umbrella type of aerial has several merits, one being that it is not directive. The fan shaped type is used mostly for short wave lengths and was very popular with the wireless amateur. There are still other modified forms of these general types. Some of these are more directive than others; i. e., they cause the radiation to go better in one direction than in another.

Atmospheric disturbances are troublesome to wireless telegraphy. They affect the range of the radiation and the ease of reading the signals in the telephone receiver. They are much more noticeable in summer than in winter and more noticeable in the daytime than at night. As yet no means has been devised whereby they can be eliminated entirely. Atmospheric disturbances may be eliminated to some extent in the telephone receiver at the expense of affecting the strength of the signal being read. Undamped waves which seem to be less affected than the damped waves by these kind of disturbances are perhaps the best solution that has as yet been discovered. The ultimate solution will perhaps be some sort of a receiver that will vibrate at its natural period and can be adjusted for different natural periods corresponding to the frequency of the oscillation being received.

The diagram shown in Fig. 14 will give the reader of this brief article on radio telegraphy some idea as to how the complete connection for a station is made. The connection illustrated in this figure is for a station which will send out damped

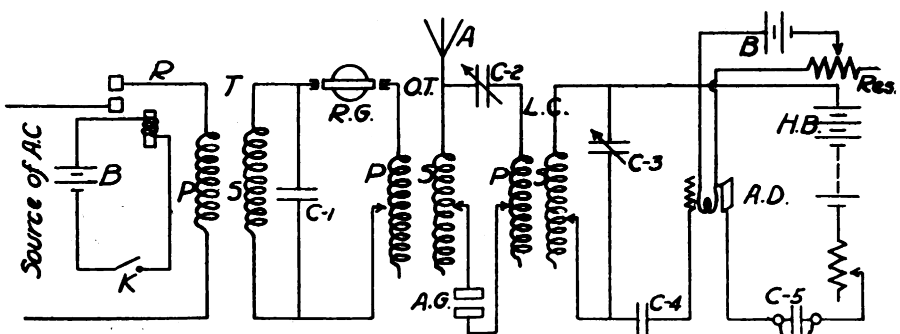

FIG. 14

waves and receive either damped or undamped waves. A key to the different apparatus used is given below.

K = telegraph key
R = relay key
T = step-up transformer
R.G. = rotary spark gap
C_1 = high voltage condenser
O.T. = oscillation transformer or tuner
A = antenna G = ground
A.G. = anchor gap
C_2 = variable condenser
L.C. = loose coupled tuner
C_3 = variable condenser
C_4 = small fixed condenser
A.D. = audion detector
B = low voltage battery
H.B. = high voltage battery
Res. = resistance
Tel. = telephone receivers
C_5 = fixed condenser

CONCLUSIONS

Wireless telegraphy probably has been most useful to mankind as a means of communication between ships at sea or a ship at sea and the shore. For transoceanic communication it has also proven its worth. A wireless station that is capable of carrying on communication across the Atlantic is very much less expensive to install than the cost of a submarine cable. However, before it will replace the wire telegraph many improvements in the way of tuning will have to be made. It is the writer's belief that the wireless telephone will be as useful and satisfactory for carrying on communication between stations on the land in the future as the present telephone. There is also a belief among all radio engineers that wireless waves can be made to carry energy as well as signals and that the day is not far distant when we will have wireless transmission of energy.

THE SALT OF LIFE

Fate doesn't take our order, but serves a table d'hôte,
And each of us must eat it like a man.
The salt of life is humor; without it all is flat—
The wise chap puts a pinch in where he can.

—*The Times of Cuba.*

AN ENGINEER'S OCCUPATION

is largely to deal with trouble, either directly, to overcome it, or by due preparation, to avoid it, as this country should have done regarding war.

Noah was six hundred years old before he learned to build an ark. Don't lose your grip.