CHAPTER THREE

ELEMENTS OF RECEIVING AND TRANSMITTING APPARATUS

The Antenna—Tuning and Coupling—The Detector—Crystal Detector—Electron Tube—The Purpose of the Grid—Amplification—Regeneration—Resonance—Summary of Functions of the Various Parts of Typical Receiving Sets—Generators of Radio Frequency Current—Apparatus for Transmitting Radio Telegraph Signals—Modulation in Radio Telegraphy—Radio Telephone Transmitting Apparatus—Continuous Wave Radio Telegraphy—Spark Radio Telegraphy.

In Chapter Two an explanation was given of the general processes by which radio is carried on. The present chapter explains the action of the various parts used. A few paragraphs are also devoted to transmitting apparatus, for the general information of the user of receiving apparatus. This book does not attempt a complete discussion of transmitting apparatus. A good book for the radio fan who desires to learn how to make or use transmitting apparatus is the "Radio Amateur's Handbook," published by The American Radio Relay League.

The complete assemblage of apparatus for radio reception is called a receiving station. Its principal portion is the receiving set, to which are connected the antenna and ground and phones (headphones or loud speaker).

The Antenna.—The radio waves are produced by alternating current which flows in the circuits of the transmitting station, and these waves are converted back into alternating current in the circuits of the receiving station; that is, electrical vibrations produce electric waves which spread out in all directions and these waves are capable of producing electrical vibrations again in any circuit which they pass. The device which converts the electric vibrations (alternating current) into electric waves, or which converts the waves back into alternating current is the antenna. The antenna really has a large job to do, and for all that, it is nothing but a piece of wire.

The antenna is simply an enlarged portion of the circuit. As previously explained, radio circuits consist of two principal elements, called capacity and inductance. A circuit containing capacity and inductance naturally responds to some particular frequency of alternation of electric current, just as a vibrating bell or tuning-fork has some natural frequency of vibration. The "capacity" is the electrical quality that corresponds to the elasticity or springiness of the tuning-fork, and the "inductance" corresponds to its inertia or mass. Now the antenna can be either one of these two elements, the capacity or the inductance. In most radio stations it is the capacity. It consists essentially of two electrical conductors with air between. One of these conductors is an elevated wire, or set of wires, while the other conductor can be either a similar set of wires or else the ground. A typical circuit in which the antenna thus constitutes the capacity is shown in Fig. 1. The other part of the circuit, the inductance coil, is connected between the elevated wires and the ground.

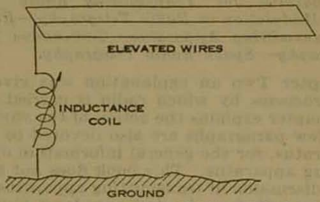

Fig. 1—Simple antenna circuit, with elevated wires and ground constituting a capacity.

Just the opposite arrangement is used with a "coil antenna." The inductance coil is made large and constitutes the antenna, and a device possessing capacity (called a condenser) is connected to the two ends of the inductance coil. The arrangement is shown in Fig. 2. The "condenser" consists of two metal plates or sets of plates, with air or some other non-conductor between.

The simple antenna, consisting of elevated wires together with a ground connection, is much more commonly used than the coil antenna. The reason is that it gives more powerful signals. For special purposes, however, the coil antenna has advantages, especially in a receiving station. It can be very small, so that a complete radio receiving station can be within an ordinary room. Also, the strength of the signal received on it depends on the direction in which the coil is turned. By turning the coil, therefore, one can determine the direction from which the wave is transmitted. A coil antenna is thus a radio direction finder, it is useful in steering ships and airplanes, and also enables one to prevent interference by turning it so as not to receive the signals from a disturbing station.

Tuning and Coupling.—As explained in the last chapter, radio receiving apparatus must be so adjusted as to be in tune with the wave to be received. The alternating current produced in the receiving circuit will be greater the more nearly this circuit responds to the particular frequency of alternation that the wave has. The circuit is adjusted to respond best to the wave by varying either of the two elements, the capacity or the inductance. The process of adjusting the capacity or the inductance is called tuning. When the antenna constitutes the capacity, as in Fig. 1, the tuning is done by means of varying the inductance; and, *vice versa* when the antenna is the inductance coil, as in Fig. 2 the tuning is done by varying the capacity of the condenser.

The diagrams shown in Figs. 1 and 2 are the foundations of all radio circuits and deserve careful study.

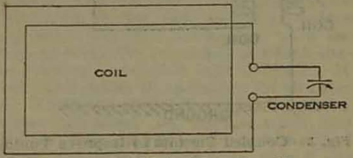

Fig. 2—Coil Antenna Circuit.

Figure 1 in particular should be thoroughly understood, because most radio apparatus is designed for use with the elevated-wire antenna.

Tuning has another object besides getting the strongest possible response from the wave that it is desired to receive, and that is to avoid receiving any other waves of different frequency or wave lengths. It has been found that this is greatly helped by adding another circuit, which is also tuned in the same way as the first circuit. The additional circuit also consists of capacity and inductance, and is called the secondary circuit. The process by which it is connected to the antenna circuit is called "coupling." One method of coupling is shown by the diagram in Fig. 3. The inductance coil of the secondary circuit is simply placed close to the inductance coil of the antenna circuit. The magnetic effect of the latter coil gives rise to a current in the other coil. The condenser in the secondary circuit is varied until maximum current is produced. The amount of this current depends also on the position of the two coils with respect to each other.

The process of coupling may be considered as a sort of straining or filtering scheme to take in the wave desired and exclude others. The antenna circuit filters out the wave desired to a certain extent, by the process of tuning. This is passed on to the secondary circuit which filters once again, thus refining or purifying the received wave still further.

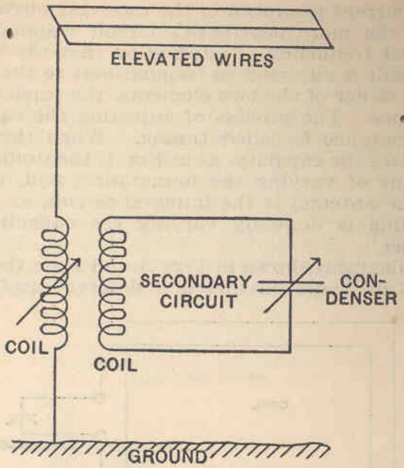

Fig. 3—Coupled Circuits to Improve Tuning.

The Detector.—Besides receiving the radio current in an antenna and adjusting the circuits so that the current is as great as possible, there yet remains something to be done before it becomes possible to translate the received radio current into a sound that can be heard in the telephone receiver. When one of the groups of alternations shown in Fig. 7, chapter 2, acts on the telephone receiver it causes no motion of the diaphragm because each variation of the current in one direction is immediately followed by the current in the opposite direction so that the resulting effect of the group of waves upon the telephone receiver diaphragm is no motion at all. It is therefore necessary, in order to convert the current into a sound, to use something else with the telephone receiver. This something else must be such as to make the current flow through the telephone receiver in only one direction. It must allow the electric current to flow through it in one direction and stop current which tries to flow through it in the opposite direction; that is, it must be some sort of electric valve. The effect of such an electric valve, may, perhaps be understood more clearly by taking a sheet of paper and placing it upon Fig. 7, chapter 2, so as to block out the lower half of the waves shown. This leaves only the upper halves of the little groups of waves and this is exactly what the electric valve does. The thing which acts as an electric valve is called the detector. Using it, successive impulses of current flow through the telephone receiver and all of these tiny impulses in any one group add their effects together and produce a motion of the telephone diaphragm.

Crystal Detector.—The simplest detector is a piece of crystal with a fine copper wire in light contact with it. (There are variations from this; sometimes two crystals in contact are used.) The crystal most commonly used is galena (lead sulphide). At the contact between the crystal and metal, current can flow in one direction but not in the other. When connected to a circuit, therefore, in which alternating current is flowing, it allows only the current impulses in one of the directions to flow through it. It thus has the electric valve action of which we have been speaking.

Electron Tube.—The most satisfactory and sensitive detector is the electron tube. This remarkable device, as will be shown, is not only useful as a detector but also as a high-frequency generator, as a modulator, and also as an amplifier by means of which the currents are more readily controlled and utilized. It is very satisfactory and stable in operation for all these various purposes. The basic principles of action of the electron tube are now discussed. For further study, the student is referred to "The Principles Underlying Radio Communication," Chapter 6. (See note, page 8, chapter 6.)

The electron tube is a very simple device which looks more like an ordinary incandescent lamp bulb than anything else. While experimenting in the development of the incandescent lamp, Edison made the discovery that an electric current could be made to flow in the empty space inside the bulb near the hot filament. If a metal plate is placed inside of an incandescent lamp bulb near the filament (Fig. 4) and if by means of a wire through the glass this metal plate is connected by wire through a battery and an indicating instrument to the filament, a current will flow as indicated by the instrument. A current is flowing in the wire and also flowing across the empty space between the filament and the plate. By much patient scientific research, scientists have found that this current taking place in the lamp consists of the flow of a stream of very small electric particles, called electrons. These electrons are shot out into the surrounding space in all directions by the hot filament. The electrons may be said to fill the bulb like a vapor. They move at random in all directions unless there is an electric force to make them move in some particular direction. The battery connected in the circuit outside the bulb supplies an electric force which acts between the filament and plate and makes the electrons move from the filament to the plate. If the battery is disconnected, there is no current, and as many electrons as strike the plate fall off again into the bulb. The current depends on the number and speed of the electrons. The battery is what gives them their speed in the direction from filament to plate. The battery performs much the same action as a pump would if the bulb were a tank into and out of which water pipes were connected. If the pump were disconnected, there would be no flow of water, and when the pump is connected, water is made to flow into and out of the tank and through the pipe.

The point of all this is that the electron flow in the bulb has a sort of valve action. The electrons are shot out from the very hot filament and can be made to

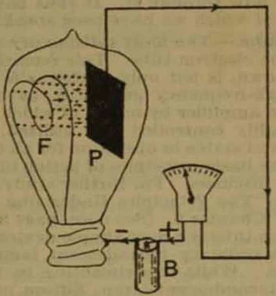

Fig. 4—Use of electron flow from hot filament (arrows show direction of electron flow, the reverse of the conventional direction of current).

flow toward the plate by connecting a battery in the proper direction. If the connections of the battery are reversed, however, no current will flow because there is no such emission of electrons from the plate, which is cold; the electric force produced by the battery in this case has nothing to work on and can do nothing except prevent the flow of electrons out of the filament to the plate. It should be clearly understood before going further that the action of the electron tube thus depends upon the fact that an electric force can be applied in one direction which causes an electric current from the filament to the plate, but that if this electric force is reversed, no current flows. The device gives exactly the rectifying action needed in order to make the received signals in radio produce sound in a telephone receiver. Suppose that the bulb shown in Fig. 4 is connected to a radio receiving circuit in place of the battery. Suppose also that the indicating instrument is replaced by a telephone receiver. This is shown in Fig. 5. The pulses of current in the receiving circuit similar to those of Fig. 7, chapter 2, produce electric force inside the bulb between the filament and plate which alternates in direction just as the pulses of current do. On account of the rectifying action, current can flow through the bulb only in one direction, and consequently the pulses of electric force in one direction only are effective. As a result, pulses of current flow through the telephone receiver in groups, the

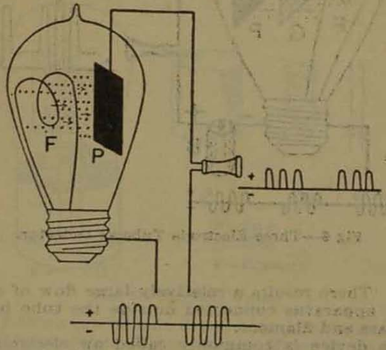

Fig. 5—Showing Principle of Detector Action

pulses being all in one direction. This causes a note in the telephone receiver, as already explained.

The Purpose of the Grid.—An improvement in the original electron device was made by L. DeForest, which very greatly extended its power and usefulness. As shown in Fig. 6, a grid of very fine wire is placed in the tube between the filament and the plate. The grid is placed closer to the filament than to the plate. The electrons which are emitted by the filament can move freely between the grid wires. If by means of a battery or something else an electric force is established between the filament and the grid, this electric force causes electrons to move away from the filament toward the plate, and since the grid is placed much closer to the filament, the electric force makes the electrons move much faster than would the same electric force between the filament and plate. Very few of the electrons are taken by the grid, and a very small current thus goes through the wire connected to the grid. Thus a very small current to the grid controls the flow of a much larger current to the plate. Hence a larger current can be taken out of the tube than is put into it. A small electric force acts between grid and filament, causing a large electron flow from filament to

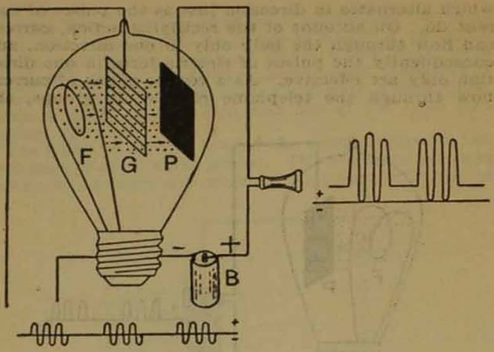

Fig 6—Three-Electrode Tube as Detector.

plate. There results a relatively large flow of current in the apparatus connected outside the tube between the plate and filament.

This device is commonly called an electron tube. (It is also known by many other names, as vacuum tube, audion, triode, and radiotron.) It magnifies or amplifies electric currents. It accomplishes the control of a large amount of power by a small power. This is just the same thing that a gun does—pressing the trigger several times in a repeating pistol is like the action of the tube with successive pulses of electric force. The grid corresponds to the trigger, and the plate to the gun barrel.

Electron tubes which are used as detector tubes ordinarily have a slight amount of gas remaining inside. These are more sensitive than the highly evacuated tubes used as amplifier tubes, but they require more careful adjustment of the current which lights the filament and of the voltage of the battery connected to the plate circuit. On account of the fact that the adjustments are not so critical when amplifier tubes are used, many operators prefer to use them as detector tubes.

The electron tube detector has the advantage that it does not require special adjustment of a delicate contact to make it sensitive. Its sensitivity can be kept invariable, and it may also be much more sensitive than the ordinary crystal detector. The filament lighting battery or "A" battery, is usually a storage battery of about 6 volts or consists of one or more dry cells; though this depends upon the type of electron tube used. The other battery employed in connection with the electron tube, or "B" battery, usually consists of a number of small dry cells sealed in a block as a unit.

The frontispiece shows a number of electron tubes of various types designed for use as detectors, amplifiers and transmitters. The more recently developed tubes which operate on dry batteries are smaller than the others and are on this account often more convenient.

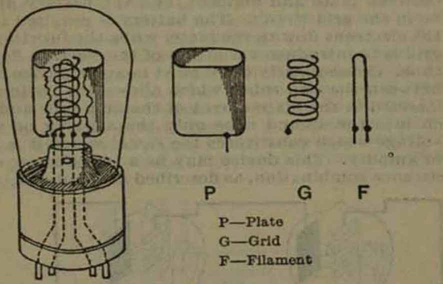

Fig. 7—Electron Tube.

In Fig. 7 there can be seen the several parts or elements of an electron tube. These are the filament, grid, and plate, mounted inside of the glass tube from which the air has been pumped. Each of these elements is separated from the other by a small space. There are two connections made to the filament, one at each of its ends. There is only one connection made to the grid and one connection to the plate. These four connections come to the four prongs on the base of the tube. The filament is surrounded by the grid, which is usually a spiral coil or lattice work. The plate is located outside of the grid and is usually cylindrical but is sometimes flat.

The construction features of tubes used as amplifiers are identical to those of the detector tubes. They differ in the degree of vacuum produced within the bulb. The amplifier tubes have a more nearly perfect vacuum than tubes suitable for detection only.

Amplification.—On account of the control of the plate current by a smaller grid current, the electron tube makes possible some very wonderful things.

It is perfectly possible and quite easy to take the magnified output from an electron tube and pass it into a second electron tube, using that to make a still further amplification of the current. Using one tube after another in this way, we obtain what is called an amplifier. Two tubes joined together in this way are shown in Fig. 8 and the process can be repeated several times, using a number of tubes. The current is increased by each tube and handed on to the next without any change or distortion of the current, even though it passes through several stages.

Fig. 8 is only schematic. It is not possible, in actual practice, to run the connection directly from the plate of one tube to the grid of the next tube. The reason is that there must be a battery connected between plate and filament, and the battery must not be in the grid circuit. The battery is required to make the electrons flow to the plate, while the function of the grid is to introduce variations of the electron flow in its tube. Consequently there must be some device inserted between the two tubes which allows the battery to be inserted in the plate circuit of the first tube and passes on into the second tube only the altering or varying voltage which constitutes the signal which it is desired to amplify. This device may be a transformer or a resistance combination, as described in chapter 4, page 9.

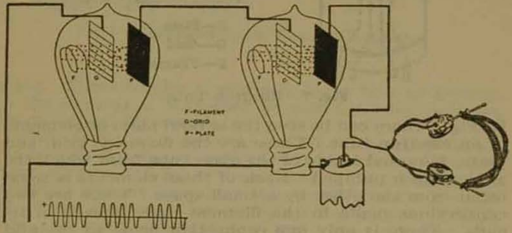

Fig. 8—Principle of the Amplifier.

The amplifier is of the greatest importance in radio and in long-distance wire telephony. It reduces the amount of power that must be used in a radio transmitting station, because when an amplifier is used in a receiving station, signals can be received which are far too feeble to be received without an amplifier. By means of amplifiers to which are connected loud-speaking telephones, speeches are made fully audible to all persons in a very large crowd. The large announcers used in railway stations now make use of amplifiers. By means of amplifiers, submarine vessels can receive radio messages when entirely submerged.

Regeneration.—An electron tube may act as a detector and an amplifier simultaneously; that is, the output from the detector tube, instead of being connected to a second tube, may be connected back to the input of the detector tube itself. The current is then amplified in the tube and the process repeats itself. This results in enormous increase in the sensitiveness of the detector. The process of feeding back the output to the input circuit is called "feed-back" or "regeneration," and the principle is shown in Fig. 9. The radio-frequency input circuit consisting of the (coil of wire) inductance L_1 and the (condenser) capacity C is connected to the grid and filament of the electron tube. Between the plate and filament there is connected, besides the telephone receivers and battery the inductance L_2. This is placed close to inductance L_1, and the magnetic field caused by the current in it reacts on L_1, increasing the current in it. This current in L_1 then flows to the grid and is amplified in the tube. The amplified current flowing in the inductance L_2 again reacts on L_1, and so the process is repeated over and over. These repetitions are simultaneous, and the net result is very greatly increased output current in the plate circuit and hence in the telephone receivers. There are other methods of connection, but the prinple is the same.

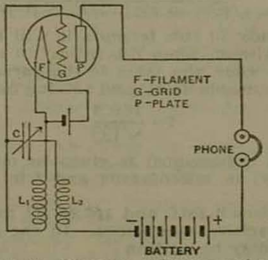

Fig 9—Schematic Diagram of Regenerative Amplifier.

If a regenerative receiving set is adjusted to the condition where it is receiving signals from a distant station and is generating current in the antenna, signals are retransmitted from the antenna in the form of radio waves and may be received by comparatively insensitive receiving sets nearby. Thus, a person having a crystal detector set, located near to another receiving station which uses a regenerative set adjusted as described above, may receive broadcast service from distant stations to which the operator of the regenerative set may tune, but does not receive from other distant stations to which that set is not tuned.

While this is temporarily convenient for the operator of the simple set it does not make for satisfactory broadcast service, since the distant reception ceases for both as soon as the operator of the regenerative set readjusts or turns off his set, while the interference caused by the regenerative set may make it impossible for many persons to receive local broadcast service which they may desire to hear.

Resonance.—In any electric circuit, the value of the current flowing through the circuit depends upon the voltage impressed and the **resistance** of this circuit to the flow of current. In other words, the value of the current may be expressed as the voltage divided by the resistance. This relation holds true whether the current be direct or alternating, high frequency or low frequency. The difference in the several cases lies in the value of this resistance. For alternating currents it is known as the **impedance,** which includes the direct current resistance as well as the resistance offered by inductances and capacities. These latter are known as **inductive reactances** and **capacitive reactances.**

The formula for direct current is $I = E/R$; for alternating currents it is $I = E/Z$, in which I is the current in amperes, E the voltage in volts, R the resistance in ohms and Z the impedance in ohms. For resistance R, inductance L, and capacity C, in series,

$$Z = \sqrt{R^2 + (6.28fL - 1/6.28\,fC)^2}.$$

From a study of this formula it will be seen that I will be a maximum when Z is least. In other words, Z will be least when the term in the parentheses equals zero. Using suitable units, and solving for f, we obtain:

$$f = \frac{159.3}{\sqrt{LC}}$$

when L (the inductance) is given in microhenries, C (the capacity) in microfarads and f in kilocycles per second.

The quantites 6.28fL and 1/6.28 fC are the **inductive** and **capacitive reactances.** In the same units as above these may be written

$$X_c = -\frac{159.3}{fC} \qquad X_L = .00628\,fL,$$

where X_c = capacitive reactance and X_L = inductive reactance.

The condition for maximum current is that the impedance is least, or $X_c = X_L$, and is known as **resonance.**

The values of inductance and capacity, which, together, will give resonance with a given frequency or wave length are shown in Chapter seven. These curves have been constructed for the condensers available, viz., 0.001 and 0.0005 *uf.*

Summary of Functions of the Various Parts of Typical Receiving Sets.—The functions of the several parts of the simple **crystal detector set** shown in Fig. 9, chapter 4 are summarized below:

Antenna: Converts radio wave into an alternating current of high frequency.

Inductance Coil: Forms, together with the antenna, a circuit which can be tuned to respond to the incoming radio wave.

Crystal Detector: Converts the alternating current in the antenna into a pulsating unidirectional current.

Telephone Receivers: Convert the pulsating unidirectional current into sound.

The functions of the parts of a **two-circuit electron tube set** may be summarized as follows:

Antenna: Converts radio wave into an alternating current of high frequency.

Primary Inductance Coil: Forms, together with the antenna, a circuit which can be tuned approximately to respond to the incoming radio wave. In this set it is the primary coil of the "coupler."

Series Condenser: Shortens the wave length to which the antenna responds. It also gives fine adjustment of the tuning of the antenna circuit.

Secondary Circuit: Provides means of tuning more sharply to the desired wave than can be done by tuning in the antenna alone. It consists of the secondary inductance coil and the secondary condenser.

Secondary Inductance Coil: Couples the secondary circuit to the antenna circuit. It provides rough adjustment of tuning of secondary circuit.

Secondary Condenser: Provides fine adjustment of tuning of secondary circuit.

Electron Tube: Converts the alternating current in the secondary circuit into a pulsating unidirectional current and amplifies it.

Filament Battery (A): Supplies current to heat the filament of the electron tube.

Filament Battery Rheostat: Regulates current through the filament of the electron tube.

Plate Battery (B): Supplies current through the tube between plate and filament.

Telephone Receivers: Converts the pulsating unidirectional current from the electron tube into sound.

The functions of the several parts of the **regenerative set** shown in Fig. 11, chapter 4, may be summarized as follows: All parts are the same as in the two-circuit electron-tube set above except the following:

Tickler Coil: Feeds the effect of the current in the plate circuit back into the grid circuit so that the current is re-amplified.

Grid Condenser and Leak: Adjust voltage on the grid to a value giving sensitive action of electron tube as a detector.

Telephone Condenser: Provides path for radio-frequency current that is easier than through the telephone receivers.

The functions of the parts of the amplifier shown in Fig. 16, chapter 4, as far as not already covered above, are as follows:

Electron Tubes: Convert the small voltage and power applied to the grid into larger voltage and power in the plate circuit.

Amplifier Transformers: Convert the small voltage applied to the input side into a larger voltage on the output side.

Generators of Radio-Frequency Current.—Turning now to radio transmitting apparatus, the principal apparatus which is required is a generator of alternating current of radio frequency. There are numerous kinds of generators, but the kind used in radio-telephony makes use of powerful electron tubes similar to those used in receiving sets, but larger.

The way in which electron tubes are used to generate current is a mere extension of their use in amplifiers. If, in Fig. 9, the coils L_1 and L_2 are placed close together, the effect of L_2 on L_1 can become so great that the current continues to flow even if no signals are coming into the antenna to which the input circuit CL_1 is connected. The alternating current thus produced will have the frequency to which the circuit CL_1 is tuned. What happens might be expressed by saying that an amplifier can be made so powerful that no input current at all is required. This does not mean that it is a perpetual motion machine, because the power to operate it must be supplied by the battery that is connected in the plate circuit of the tubes. It does mean, however, that the electron tube can be used to generate alternating currents as well as to receive and to amplify them.

Apparatus for Transmitting Radio-Telegraph Signals.—The apparatus for transmitting radio-telegraphy and telephony differ mainly in the arrangement by which the continuous current produced by the generating circuits is modulated or changed in strength to follow the dots and dashes of the telegraph code or the variations of the voice. Radio-telegraph transmitting sets are the simpler. Means are provided to modulate the radio-frequency current at an unvarying audible frequency. To signal it is only necessary to stop and start the current suddenly by means of an ordinary telegraph key which opens and closes the circuit. The inductance coils and condensers are of somewhat different design than the coils and condensers used in receiving sets. In transmitting sets the various parts of the circuit must carry considerably larger currents. The filaments of the electron tubes are lighted from storage batteries, as in receiving sets, but the "B" battery (battery in plate circuit) is replaced by a dynamo which will supply more power than is economically obtained from batteries. The voltage of this dynamo may be between 300 and 2000 volts. The power which it delivers depends upon the type and number of electron tubes used in the transmitting set. The power of the

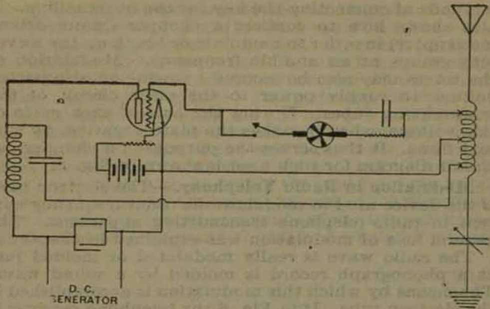

Fig. 10—Circuits of radio-telegraph transmitting set using chopper for securing modulated waves.

set may be increased by using a larger electron tube or by connecting additional tubes to the circuit. In the latter case, the grids of all of the tubes are connected

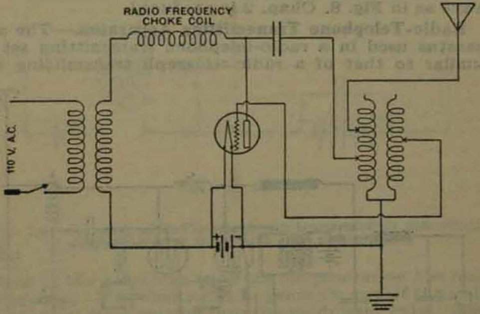

Fig. 11—Circuits of radio-telegraph transmitting set using alternating current for plate supply and modulation.

together and the plates of all of the tubes are likewise connected together. The filaments are all heated by current from the same storage battery.

One type of radio-telegraph transmitting circuit is that shown in Fig. 10. This shows one of various methods of connecting the key for use in signalling. It also shows how to connect a chopper (motor-driven interrupter) in order to modulate or break up the waves into groups at an audible frequency. Modulation of the waves may also be secured by using an alternating voltage to supply power to the plate circuit of the transmitting tubes. During the half of each cycle of this voltage, when it makes the plate negative, no current flows. It thus serves the purpose of a chopper. A circuit diagram for such a set is shown in Fig. 11.

Modulation in Radio Telephony.—The electron tube is the device used to modulate the radio-frequency current in radio-telephone transmitting apparatus. The general idea of modulation was explained in chapter 2.

The radio wave is really modulated or molded just as a phonograph record is molded by a sound wave. The means by which this modulation is accomplished is the electron tube. If in Fig. 6 the telephone receiver is replaced by any kind of generator of radio-frequency current, then if a person speaks into a telephone transmitter connected between the grid and filament of the tube, the variations caused by the sound of the person's voice cause the intensity of the radio-frequency current in the plate circuit to vary correspondingly with the voice sound wave. The radio-frequency current is thus not of constant amplitude but varies in amplitude in accordance with the voice. Thus a modulated radio wave as in Fig. 8, Chap. 2 is produced.

Radio-Telephone Transmitting Apparatus.—The apparatus used in a radio-telephone transmitting set is similar to that of a radio-telegraph transmitting set

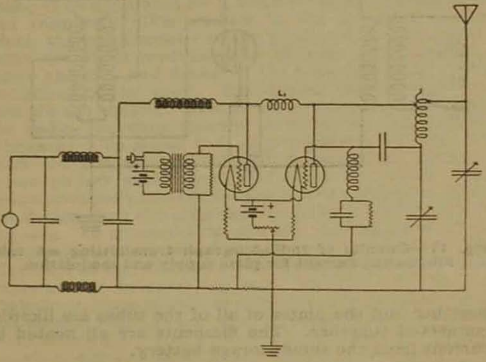

Fig. 12—Circuits of radio-telephone transmitting set using one generator tube and one modulator tube.

except for the modulating device. A diagram of a complete set is shown in Fig. 12. Here the microphone, into which the speaker talks, is connected through a suitable transformer to the grid and filament terminals of an electron tube. This tube, on account of this use, is called the modulator tube. The plate current from this tube varies according to the sound-wave variations of the voice. The plate current of the generator tube, which is to the right of the modulator tube, has variations corresponding to those of the modulator tube because there is a choke coil in the lead from the generator (at the left) which keeps the sum of the direct current supplied to the plate circuits of the two tubes constant. The arrangements of coils and condensers to the

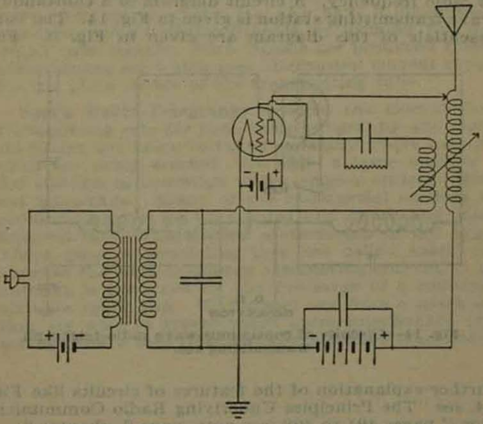

Fig. 13—Circuits of radio-telephone transmitting set using a single electron tube with grid modulation.

right of the generator tube are for generating the radio frequency. The choke coil L_1 prevents any of the radio frequency from getting into the modulator tube. Thus the radio-frequency current is produced in the generator tube and has the voice variations impressed on it by the modulator tube. For further details, see "The Principles Underlying Radio Communication," pages 521 and 527 (see note, page 8, chapter 6). The adjustments of the circuits associated with a modulator tube are usually very critical, and it is quite difficult to secure accurate production of current which varies in exactly the same way as the sound waves of the voice.

A somewhat simpler circuit arrangement, in which a single tube serves as both generator and as modulator, is that shown in Fig. 13. It is even more critical in adjustment but is sometimes used where a low-power transmitting set with a simple circuit arrangement is desired.

Continuous-Wave Radio-Telegraphy.—While considerable stress has been laid in all these explanations on the process known as modulation, the reader should know that there is a system of radio-telegraphy in which there is no modulation. This should be kept apart, however, in thinking on radio, as it is done by distinctly different processes. There being no modulation, the wave is simply an unvaried continuous wave of radio frequency. A circuit diagram of a continuous-wave transmitting station is given in Fig. 14. The bare essentials of this diagram are given in Fig. 9. For

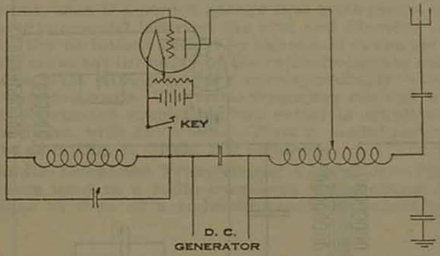

Fig. 14—Circuits of continuous-wave radio-telegraph transmitting set.

further explanation of the features of circuits like Fig. 14, see "The Principles Underlying Radio Communication," pages 491 to 498 (see note, page 8, chapter 6).

A "continuous wave" would not be heard in the ordinary receiving set because, as already explained, the frequency of radio waves is so high that the human ear does not react to a sound of such high frequency. These continuous waves are received by an ingenious scheme. In the ordinary regenerative receiving set, the coupling of the "feed-back" from the plate to grid is increased until the circuit begins to generate ("oscillate"), as explained on page 14 under "Generators of Radio-Frequency Current." The condenser is adjusted until the circuit is tuned to a frequency just a little different from that of the received continuous-wave current. There are thus present two high-frequency currents of slightly different frequency, the received current and the generated current. Beats are produced between the two, and these beats are heard in the telephone receivers. Thus if the continuous-wave frequency is 200,000 and the generated current frequency is 201,000, a beat note of a frequency of 1000 is produced, and this is readily heard.

The signals from a nearby continuous-wave radio-telegraph transmitting station are heard in the ordinary receiving set (which is not oscillating) as a series of clicks, a click occurring at the beginning and end of each dot and each dash of the code signals. If the receiving set is, however, so adjusted as to be generating ("oscillating"), the signals from a continuous-wave radio-telegraph station are heard as long and short whistling sounds forming the dashes and dots. Sometimes signals are heard which cause the series of clicks referred to above, but also have a low-pitched, humming sound distinguishable as forming the telegraph code signals. Such signals are produced from a transmitting set which uses alternating current supply for the plate circuit of the transmitting tube.

Spark Radio-Telegraphy.—While the electron-tube transmitting sets for both radio-telegraphy and radio-telephony are being installed generally where new stations are being erected, there are a large number of old stations in operation which employ entirely different apparatus. Many of the commercial stations for radio-telegraphy between ships and shore and many amateur radio transmitting stations are of old types. These older transmitting sets are called spark sets because the high-frequency alternating current in the antenna is produced by the discharge of a condenser across a spark gap. Waves sent out from a spark station are able to create much more interference than waves from a well designed electron-tube transmitter.