Radio

UP TO THE MINUTE

WITH QUESTIONS AND ANSWERS

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AND
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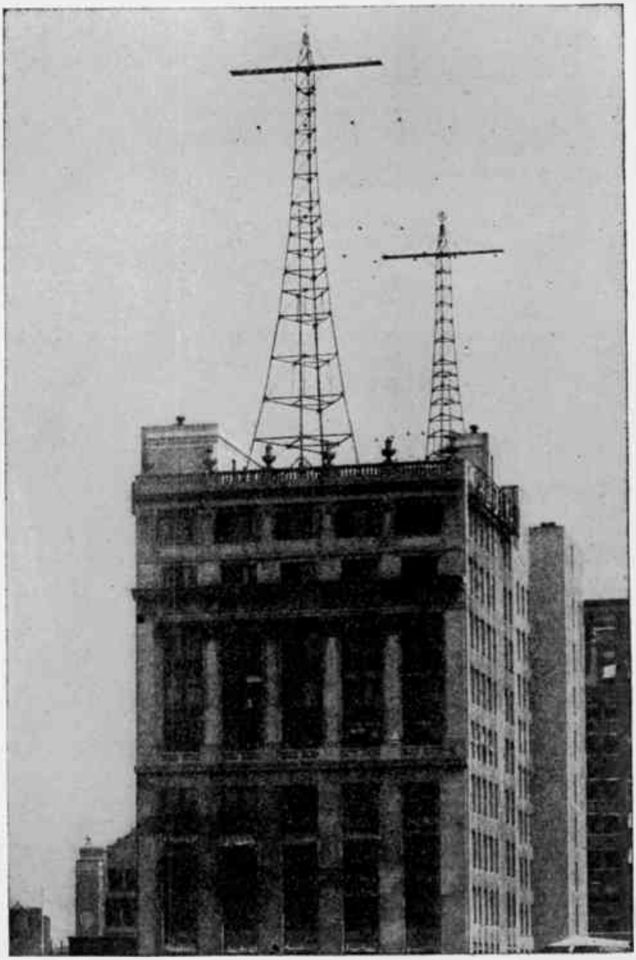

Broadcasting station W J Z and W J Y, one of New York's most powerful broadcasting stations.

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PREFACE

This revised and enlarged edition of RADIO UP TO THE MINUTE incorporates a complete theoretical and practical explanation of radio in non-technical language. Stress has been laid on broadcasting and amateur equipments rather than on commercial apparatus.

It has been the aim of the authors to set forth in common language the Principles Underlying the Operation of Radio and to show how each piece of apparatus functions in the radio circuit.

It is hoped that the experimenter will find the volume useful as a handbook. Radio Clubs will find material for radio talks and discussions. As far as possible, information given ordinarily in radio periodicals has been omitted.

It is intended that this volume shall be true to its name and bring to its readers up-to-the-minute information on Radio as it finds its way day by day into the millions of American homes.

The Authors

New York City

RADIO
UP TO THE MINUTE

CHAPTER I

EARLY DAYS OF RADIO

It is appropriate that any explanation of radio to the uninitiated should include, however brief, something of the origin of the art.

The complete history would require several volumes and would include the efforts of experimenters who have contributed to the final result, but who did not in their day even dream of what they had individually assisted in constructing.

The radio art owes its origin to Professor Heinrich Hertz, a German scientist, who in the eighties conducted a series of experiments which led to the construction of the first apparatus for propagating and detecting ether waves, which he described in 1888 in his book "Electric Waves." Professor Hertz's work, however, was not fully proclaimed until Guglielmo (William) Marconi, then a very youthful Italian student, conceived its commercial advantages and utilizing Hertz's experiments and his own ideas originated the first practical radio stations.

Hertz, the pioneer, had understood and applied the principle of resonance. Marconi took the Hertz oscillator and resonator and adapted them for a transmitter and a receiver, respectively, by making both circuits open instead of closed, and grounding the antenna. Tuning between the transmitting and receiving antennæ in this pioneer work was accomplished by increasing or decreasing the capacity of the plates on top of his aerials.

In his experiments Hertz had used for a detector a microscopic spark gap. Marconi in his work utilized a Branley-Lodge coherer as a detector.

Using the Morse telegraph code, Marconi commenced by signaling a few hundred yards, but with the aid of the Italian and British governments he increased the range of his apparatus until he had demonstrated that radio was a practical commercial possibility with unlimited scope.

It is interesting at this stage to note that Signor Marconi, more fortunate than some famous inventors, surrounded himself with associates who had the foresight and imagination to picture the future possibilities of the new science. It was this that has enabled Marconi to-day, in the prime of his life, to reap the material benefits of his pioneer work.

No historical reference to modern radio would be complete without appreciating the experiments of Sir Oliver Lodge, the famous English scientist who, as early as 1888, experimented along the lines originated by Hertz and contributed valuable aid towards making the art the success of today. Later Professor Lodge was to become associated with the Marconi interests, as also was another eminent Englishman, Professor J. A. Fleming, who has contributed to the radio art several valuable text books. In fact, it might be stated that he was first to write any substantial work on the subject. Later he was to revolutionize radio with his original work on vacuum tubes, which we will deal with in its place or chronological order.

Following Marconi's entrance into the field and the filing of his first patent in 1895, radio telegraphy was taken from the academic to the commercial stage and from that date various improvements by innumerable experimenters have followed with endless repetition.

It may be stated, at this stage, without fear of contradiction, that radio telegraphy and telephony has been productive of more patents and more patent litigation than any other science, art or industry invented by man. Patents issued to date in the United States and foreign countries already number tens of thousands. Litigation upon the subject has littered the courts. Reference to all who have contributed to the art can, therefore, not be made within the scope of this volume, and any neglect to give credit, where credit is due, is not premeditated. We will endeavor to give the reader only the principal events which seem to occur, as it were, as stepping stones in radio engineering.

Following Marconi's commercialization of radio, as we may term it, came rapid developments on both sides of the Atlantic.

Nicolas Tesla, in 1897, introduced the tuned transmitter and receiver, or what was to become known as the two circuit transmitter and receiver, which was eventually to lead to much litigation in the courts. In 1898 Marconi patented his first double circuit receiver, retaining, however, his original plain aerial transmitter. Della Riccia, in the same year, adopted a closed and open oscillatory transmitter, while Braun and Stone, in 1899, both devised inductively coupled apparatus.

Ducretet and Pupin, in 1899-1900, it would seem, were the first engineers to resort to what is known as conductively coupled circuits, which were used most successfully commercially for a number of years prior to the introduction of radio laws and regulations. After the promulgation of these laws, conductively coupled circuits became impractical as the wave emitted did not comply with the requirements of the new regulations.

In 1900 Signor Marconi and Professor Braun shared the Nobel prize for their efforts in the radio field. This was the first public recognition of the new science and an acknowledgement of its importance in the scheme of human events.

High Spark Frequency.—Wireless telegraphy had now reached a stage when its study attracted the brightest minds of the scientifically thinking world.

All the earlier equipments had employed as a primary source of energy induction coils, with various means of breaking the direct current. Owing to mechanical difficulties these "make and break" devices were necessarily slow in action, with the resultant low spark frequency. The manipulation of these early equipments required considerable skill on the part of the pioneer operators to maintain a "spark," indeed, the old time radio telegrapher, in despatching a batch of business, necessarily would conduct a series of experiments during his efforts.

These induction coil sets gradually gave way to "power" sets, in other words, alternating current supplied by motor generators, supplied the power source. The usual commercial frequency of sixty cyles was first employed. While the practical operation of radio apparatus was immeasurably improved, the low spark frequency objection still remained.

Fessenden appears to be the first radio engineer to suggest a remedy to low spark frequencies and apparatus known by his name appeared which gave forth a high musical note and did much to overcome "static" or "atmospherics," which has been and continues to be the bugbear or hoodoo of radio.

A German system known as "Telefunken" also utilized a high frequency alternator to produce the high musical note.

These high spark frequency equipments utilized either rotating gaps to convert sixty cycle alternations or "quenched" gaps. The latter are used almost exclusively in modern equipments, owing to their efficiency in their "dampening" effects.

Perhaps we should here remind the reader that a full or comprehensive study of the above mentioned apparatus will be found in the portion of this work devoted to practical radio, and no effort is made in this chapter to an explanation of their construction or functioning.

While the development of radio was progressing rapidly, during the decade of 1900-1910, the "spark" was practically the only system used in commercial wireless telegraphy. Great progress, however, had been made in what is to-day known as the "continuous wave" or the "arc" systems. As the former term indicates, this system employed a continuous or "undamped" wave as its principle.

Poulsen was the originator of the "arc" method, while Alexandersen produced a high frequency alternator, which, while having a comparatively low rate of R. P. M., delivered an exceedingly high frequency. Both systems are used extensively to-day by operating companies.

An evolution of the vacuum tube, dealt with later, also produced another form of continuous wave radio transmission, which can be said to have put radio telephony where it is to-day.

Undoubtedly, owing to its greater efficiency, continuous wave radiotelegraphy will eventually displace the spark systems, although, especially on shipboard, both systems are often used in one station. This, however, is merely as a convenience and a necessity under existing conditions, as a complete change from one system to the other would be too radical from a commercial or practical point of view. It is one that will come very gradually.

It will now be necessary to go back to the comparative early days of radio to bring the reader to the development in the science, which possibly, has resulted in the astonishing, and we might say, miraculous results that are obtained to-day.

Vacuum Tube Discovered.—Professor J. A. Fleming, after associating himself with Marconi, developed what is known as the "Fleming Valve." This invention was to be the most important development in the radio field.

The Fleming valve was inspired from the effects of the Edison incandescent electric lamp, and takes us into a study of the "electron theory." Thomas Edison, the inventor of the lamp, had experimented in its pioneer days and discovered that by placing a plate within a bulb separate and untouching the filament, a flow of electrons was observed from the filament to the plate.

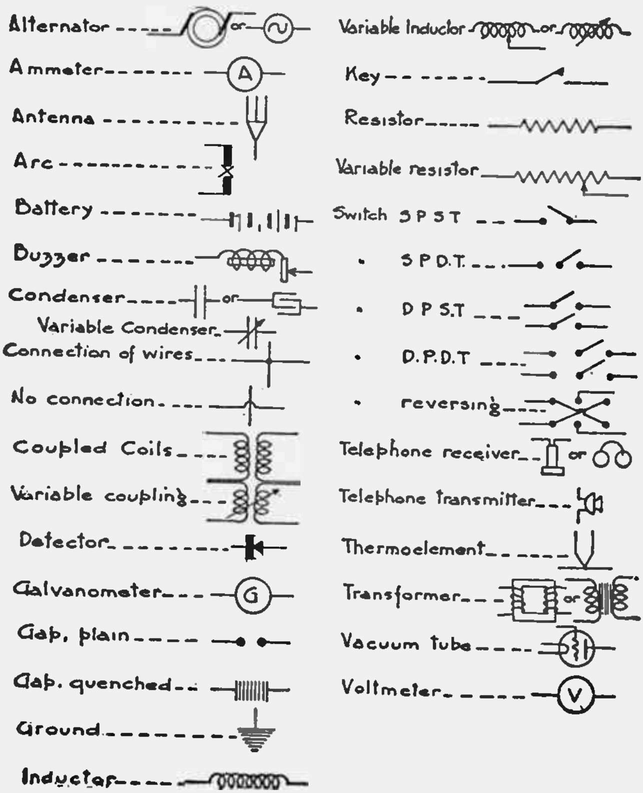
Fleming, casting about for an improved detector, studied this effect and discovered that this flow of electrons was always in the same direction and of a negative nature, flowing from the heated filament to the cold plate. This flow could be controlled by inserting a rheostat in the filament circuit and increasing or decreasing the filament current. These valves when properly constructed made excellent detectors for "spark" radio signals.

After Fleming's valve came the discovery by Dr. Lee DeForest, of the "three element" vacuum tube, which he called an "audion." DeForest inserted what he termed a "grid" between the filament and plate. This was possibly the most important discovery yet made in the new science of radio, and during the years of the World War, was to revolutionize the art. With the coming of the audion, methods of amplifying or increasing the intensity of radio signals were devised.

One method of amplification, discovered by Armstrong, then a Columbia University student, was the "feed-back" or "regenerative" circuit, which is now almost universally used in radio practice.

A full description of vacuum tubes and associated circuits is not intended here, but will be found under that caption in the practical course which follows.

STANDARD GRAPHICAL SYMBOLS



CHAPTER II

ELEMENTARY ELECTRICITY

There is a wonderful phenomena, the exact nature of which we know nothing definite, yet we are able to govern, actually measure and otherwise control its action. This peculiar phenomena is called "electricity." In its action we often compare it with water, as it has analogous characteristics, which are frequently used for comparative purposes in teaching the elementary principles of radio or electricity.

It should, however, be carefully borne in mind whenever electricity and water are likened to each other that expressions of "flow" and "current" and other similar terms are merely analogous. They are methods that originated in the early days of electricity, when electricity was considered some form of invisible fluid which actually flowed. These terms and expressions are utilized to-day in explanatory prefaces only as they are useful in forming mental photographs of the theoretical action of electricity in motion.

Electrical phenomena may be placed in two general classes, one of which is termed "static" electricity, when the electrical charges are at rest, and the other is "dynamic" or "current" electricity, when the charges are in motion along a conductor.

When an insulator, such as sealing wax, is rubbed with fur, or a glass tube with silk, it ac-

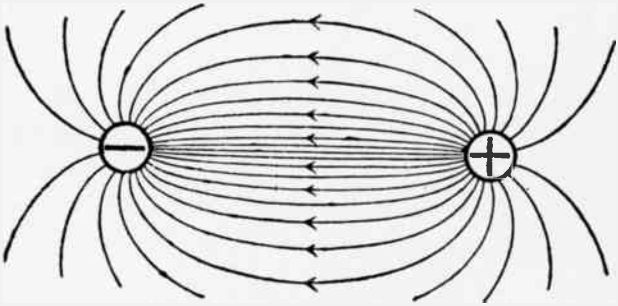


FIG. 1. Unlike bodies attract each other.

quires the property of attracting light bodies near it, and is said to be "charged." This action shows that forces exist in adjacent space, and there is said to be an "electrostatic," or, to use another term, a "static field of force," about the charged body. When two charged bodies are brought near together they may either be attracted or repelled, depending on the nature of the two charges. If the rubbed glass is brought near particles touched and charged by the rubbed sealing wax, they will be attracted to it, and similarly, if the rubbed wax is brought near particles charged by the glass, they will be attracted (Fig. 1); but two bodies both of which have been charged by either the glass or the wax, will repel each other. Hence, like charges

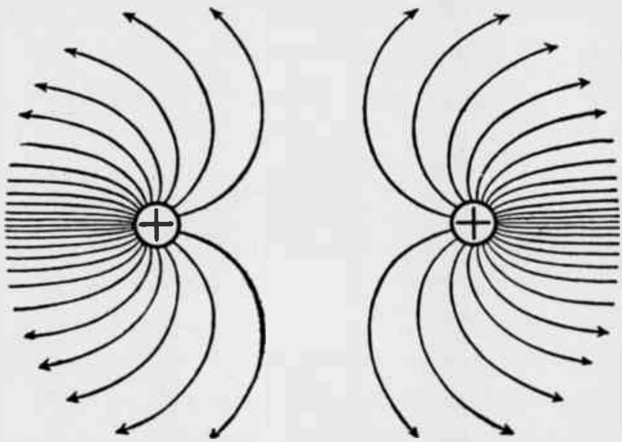


FIG. 2. Like bodies repel each other.

repel each other and unlike charges attract each other (Fig. 2). The names "positive" and "negative" have been given respectively to these charges.

It is common knowledge that a battery or dynamo supplies what is known as a current of electricity. To obtain the current there must be a complete closed or conducting path from the battery or dynamo through the apparatus it is desired to be actuated by the current, and back again to the battery or dynamo. For example, when connecting up an electric bell, a wire is carried from one binding post or terminal of the battery, to one of the bell, and a second wire is brought from the other binding post of the bell back to the remaining terminal of the battery. Any break in the wire immediately causes the current to stop and the bell would cease ringing. This example furnishes an illustration of the easy control of an electric circuit, since it is only necessary to break the circuit at one point to stop the flow of current, or to connect across the gap a piece of metal to start the current going again.

Similar considerations apply when we are using the common house lighting facilities. Wires are brought direct or indirectly, but always in a circuit, from the electric light plant or station to the lamp, a small gap in the socket is provided. When the current is on and the circuit complete this gap is bridged by a metal connection, this is usually controlled by a snap spring. When the light is no longer required, you snap the switch and the metal connection is opened, the gap is formed in the circuit and the current ceases (Fig. 3).

Sometimes the lamps suddenly go out, and it is explained that a fuse has been blown. A short piece of easily fused metal through which current has been passed has suddenly melted. This has caused a gap in the circuit and the current ceases to

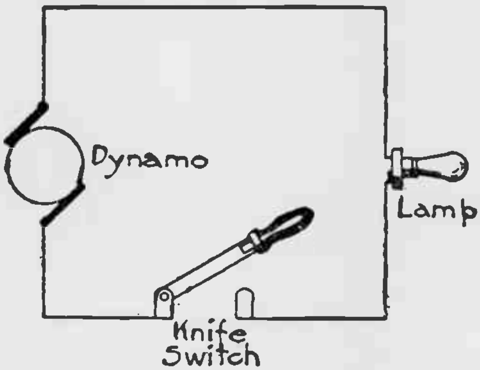


FIG. 3. Simple electrical circuit.

flow and your lights are extinguished. Electricity must therefore flow in very part of the circuit served, so that it is leaving one side of the battery or dynamo and returning to it at the other side. The current flowing in a circuit is no stronger at one point of the circuit than at another. This is proved by connecting a measuring instrument called an "ammeter" into the circuit. Place the ammeter at different points and it will register the same at whatever point the test is made. A useful illustration of the electric current is a closed pipe completely filled with water, provided with a pump or some other device for causing a circulation of the water. The amount of water which leaves a given point in each second is just the same as the amount which arrives in the same length of time.

In the electric circuit we have no material fluid, but we suppose that there exists a substance, which we call electricity. This electricity behaves in the above described circuit in very much the same manner as an incompressible fluid in a pipe line. We are very sure that electricity is not like any material substance that we know, we will, therefore, have to imagine current to be a stream of electricity flowing around the circuit.

One way of measuring the rapidity with which water is flowing, is to let it pass through a meter which registers the total number of gallons which pass through. By dividing the quantity by the time it has taken to pass, we may obtain the rapidity of the flow. There are instruments by which it is possible to measure the total quantity of electricity which passes in the circuit during a certain time. If we divide this quantity by the time, we obtain the amount of electricity which has passed in one second. This is a measure of the current strength.

In practice, however, the strength of the current is measured by instruments known as ammeters, which show at any moment how strong the current is. It also enables us to tell at a glance what changes may take place in the current flow from moment to moment. We may, also, by means of an ampere-hour meter, ascertain the amount of energy that has passed over the circuit. These two recording instruments, the ammeter and the ampere-hour meter, therefore, would correspond to the speedometer on an automobile which points out, on one dial, the number of miles the car is speeding at the moment, and on another dial the number of miles the car has traveled.

Electromotive Force.—Water will not flow in a pipe line unless there is some force pushing it along, as, for example, a pump, and it cannot be kept flowing without continuing the pressure. Electricity, also, will not flow in a circuit unless there is pressure brought to bear. In the case of an electrical circuit a battery or dynamo provides this source of pressure, which is called "electromotive force," or, in other words, a force which puts electricity in motion. In common practice this is always abbreviated to e.m.f. The larger the number of cells in the battery, the greater will be the electric pressure and the larger the current which may flow in the circuit. The size of the battery or the dynamo would correspond to the size of a tank or reservoir of water, and the amount of current which may be allowed to flow in the electric circuit would represent a pipe in which the water from the tank flowed. The amount of water in the tank would be expressed in "gallons." In the case of electricity the amount of pressure would be expressed in "volts" (see definitions), and the amount of current would be shown in "amperes" (See definitions).

Resistance and Conductance.—There is always some resistance or impediment to a flow or current of electricity, just as there is always resistance of some kind which hinders a flow of water. In the case of water, some partially closed valve or faucet would check the flow, also there is always a roughness in the pipe line which causes friction. Similarly in an electric circuit there are certain hindrances which are termed by the name "resistance." The greater the resistance the smaller the amount of current which will pass through the circuit (Fig. 4).

Resistance is determined by the kinds of materials of which the circuit is made up, just as the passage of a stream of water is determined by the character of the path over which it passes, or the pipe through which it flows. Just as the amount of water in a pipe line may be limited by the size of a pipe, so may the amount of electricity in a

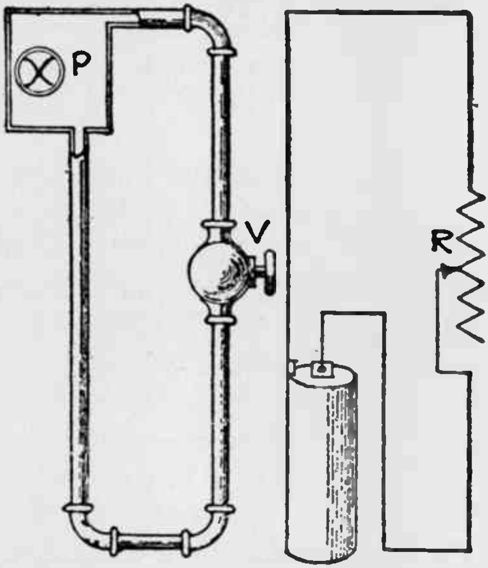


FIG. 4. Illustration of resistance by partially closed valve. P, pump. V, valve. R, resistance in electrical circuit.

certain circuit be limited by the size and material of the wire conducting it.

In governing the flow of water we use valves or faucets to check the flow of water. In handling electricity we use "resistance coils" to govern the flow of current in any given circuit. There is a well defined law which is used in this relation, which is called Ohm's law, being named after its discoverer, Professor Ohm, and in speaking of a given amount of resistance in any given circuit, we always describe the circuit as having so many ohms resistance, an "ohm" being the unit of resistance.

Certain metals or materials offer more or less resistance to a flow of electricity than others. These are well known and divided into well defined groups. A material through which a current will pass readily and with least resistance is called a "conductor," or described as good conducting material, while those possessing qualities which will oppose great resistance and almost prevent any current of electricity to pass are called "insulators" or good insulating material. We also allude to the latter as non-conductors. Among conductors it is well known what amount of resistance a piece of wire of a given metal will offer. It is from this knowledge that we utilize copper for the purpose of conducting electricity without great resistance, and why we generally use "German silver" to manufacture certain resistance coils when we wish to offer resistance in the passage of a current.

It is also known that materials such as glass, porcelain and rubber possess excellent insulating qualities and are therefore used very largely as insulators. However, there is no material that will permit the passage of no electricity whatever, and for that reason we have what is called "leakage current" and "line losses."

While it is a question of material in determining the factor of resistance in a conducting circuit, it is also the size of the conductor which must be considered. In the case of a given piece of wire of a uniform cross section, its resistance is always found to be proportional directly to its length and inversely to its cross sectional area.

Electrical resistance in all substances is found to depend upon temperature and is found to alter more or less with any change of temperature. All metals and mostly all alloys used in electrical engineering increase their resistance with a rising temperature, while carbons and liquid conductors like electrolyte used in batteries, show a decrease in resistance as the temperature rises.

Electrical Control.—Having discussed the question of resistance, we should now pass to the subject of current control. In radio the need is constantly arising for controlling electrical pressure and current to certain required values. This is generally accomplished by varying the resistance in the circuit by means of resistors. Resistors are made in a variety of ways and known by several names, depending upon their current carrying capacity and their range. Some are called "resistance boxes," others, "rheostats," and are generally manufactured in a form which permits of easy variation and are compact for convenience. However, banks of incandescent lamps are very often used as resistance units and are, indeed, most satisfactory in experimental work where fine adjustment is needed. The change in resistance in such a rheostat is made by switching individual lamps on or off as desired.

Conductors.—Conductors of electricity used in leading a current from one point to another are, as pointed out earlier, usually made of metals or metallic alloys. If the conductor is transmitting energy to a distant point, some of that energy will be wasted in heat. These losses should be kept as small as possible and therefore great care is taken in choosing the material and the size of the wire. For economic reasons it is desirable that the cross section be not too great, and a desirable material must be selected that will accomplish two purposes, economy and efficiency. After much experiment, copper is found to be such a material.

Where light weight is important and increased dimensions not undesirable, aluminum is sometimes used. Steel or iron are seldom used in radio work as a conductor. For conductors in antennæ, where strength and atmospheric conditions must be considered, phospher-bronze and silicon-bronze are almost exclusively used. Copper, however, is the best metal conductor, where all considerations must be averaged.

Now, on the other hand, where resistors or resistance coils are essential, the opposite of good conductivity is desired and a material of great resistivity is demanded. A metal is required high and constant in resistivity, yet not bulky. Iron is neither high enough in resistivity nor constant in action. German silver or manganese are generally acceptable as resistors and found to cause less variations in temperature, in fact, their temperature coefficient in the circuit is practically negligible.

Insulators — Non-Conductors. — We have dwelt upon the subject of good conductivity and must next show the importance of good insulation in the scheme of radio.

In order that the electric energy may be confined to the definite and limited path that we desire in radio, it is most essential that the insulation we use be of the best material. Insulators are also known as dielectrics, and the latter expression will often be used later when we deal with the subject of condensers.

We are all familiar with the fact that electric wires are covered with materials composed of layers of cotton, silk, rubber and compounds of various kinds, known to be non-conducting, and that they are generally supported on or strung along glass, hard rubber, porcelain or compound knobs. An excellent compound insulator is one, now standard in the Navy, called "electrose."

Most insulators employed in radio show a decrease in their power of resistance with changes of temperature and atmospheric conditions. Humidity and fog lower their insulating standards, and in the event that such substances as slate, marble, bakelite, hard fiber and similar materials are used as panel boards, unless they are carefully protected from atmospheric conditions will "sweat" and cause a surface leakage.

Sources of Electricity.—In preceding pages we have alluded to electro-motive force, or emf., and having discussed how electrical energy can be conducted along definite lines or paths, we will go into the question of its source.

There are several methods in which electrical energy may be derived from other sources of power. Each one of these power or energy transformations sets up a condition which causes current or emf. to flow, in short, produces electromotive force.

The two most common and practical methods will be discussed in the following pages. These are "static" or "frictional" electricity and "batteries" or electricity produced by "chemical action."

In earlier paragraphs we described how a piece of sealing wax when rubbed with a piece of fur, acquired new properties and could be said to be "electrified." A force would be required to separate the wax and fur and therefore work is done if they are to be moved apart. After rubbing the wax and fur both bodies would now have the power of attracting light substances, such as pieces of tissue paper or light particles of wheat chaff. The wax is said to have a negative charge, and the fur a positive charge of electricity.

These charges exist in equal amounts and taken together neutralize each other. A body that is uncharged is said to be neutral. When these charges are at rest on conducting bodies they are called electrostatic charges.

Electrostatic charges, as a rule are very small.

There are, in radio practice, two methods of deriving the primary source of power. These are from batteries and from "induced" electromotive force. We shall deal with each in its turn.

Batteries.—In general practice, there are two types of batteries used in radio work, one called a "primary" and the other a "secondary" or "storage battery."

With a primary cell new energy can be obtained by putting in new chemicals or parts, in the secondary cell, energy is renewed by sending a current of electricity derived from a mechanical or some other source, through the chemicals already in the cell, and by charging and recharging can be used over and over again. We shall first describe the primary battery.

Wet or Gravity Cell.—If two metal plates, one of pure zinc and one of pure copper, not in contact with each other, are immersed in dilute sulphuric acid, no chemical action will take place. However, when the plates are connected by a wire or some other conductor outside of the liquid, a current will flow in the conductor, as a chemical action takes place in the cell. The sulphuric acid acting on the zinc plate forms zinc sulphate, and the hydrogen liberated from the acid appears at the copper plate. The direction of this flow of current is always from the copper plate, through the conductor or metallic circuit to the zinc plate and back through the diluted acid to the copper plate. The copper plate is termed the "positive" pole and the zinc plate the "negative" pole, and the direction of flow is arbitrarily said to be from positive to negative. For purposes of simplicity

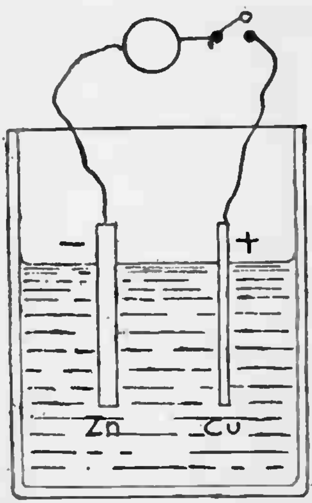


FIG. 5. Simple wet or gravity cell.

in marking terminals or preparing diagrams, the plus (+) sign is always given to the positive and the negative sign (—) to the negative plates (Fig. 5).

The current given by the simple cell described does not remain constant, as it begins to weaken after the connection between the plates is made, or, in other words, the circuit closed. This diminishing current is caused by the hydrogen, liberated from the acid, accumulating in small bubbles on the copper plate. This accumulation of hydrogen bubbles diminishes the area of contact of the liquid on the faces of the copper plate, thus increasing the resistance of the cell. This action is called "polarization." To overcome this, what is known as a "depolarizer" is utilized, in the form of a chemical substance added to the acid, or electrolyte, as the sulphuric solution is also called. The action of the depolarizer is confined to the positive plate and is kept from contact with the negative plate.

There are two principal types of primary cells, the "wet" and "dry" cells. The wet or "gravity" cell, above described, is used largely by telegraph and telephone companies, due to economy and also as it is mainly free from polarization. If a large output is desired, the internal resistance must be low, that is, with a minimum of polarization. In these cells the depolarizer is generally placed in the bottom of the cell and is kept free from the electrolyte by gravity, hence the name. The copper electrode is placed in this solution which consists of copper sulphate. The zinc negative plate is kept separate in the sulphuric electrolyte above.

The voltage given by the average cell is between one and two volts per cell. The voltage of a cell depends upon the substances used for plates or electrodes, and is also effected by the electrolytic solution. Therefore, many varieties of electrolytes are used when the electrodes are copper and zinc, but all give approximately one volt per cell.

When a certain electromotive force is required and no regular source of supply available, it is useful to know that an emergency source of voltage may be obtained by taking two different kinds of metal and placing them in any kind of acid, or even in water. It must be remembered, however, that the solution attacking the plates most violently will produce the best results, bearing in mind the above remarks regarding polarization.

Dry Cells.—The dry or sal ammoniac cell is used largely in radio, not for its superior qualities as compared with the gravity cell, but because of its convenient, compact form. The solution of sal ammoniac used in it is contained in an absorbent material and the cell is thoroughly sealed against spilling or leakage. The outer shell is made of zinc, forming one electrode. The positive electrode is a carbon rod in the center, this is surrounded by a mixture of carbon and manganese dioxide. The latter mixture is saturated with a sal ammoniac solution and takes up most of the interior of the container. This sal ammoniac electrolyte is partly in a depolarizing mixture and partly in a porous separator placed between the zinc and depolarizing mixture.

These dry cells are not as free from polarizing effects as the previously described wet or gravity cells. They are made in several sizes. For heavy or ignition purposes they will deliver a current of thirty amperes when short-circuited, provided they are new or little used. They lose their energy-producing powers very quickly when used constantly, but in intermittent service have a fairly useful term of life, sometimes six months.

Dry batteries for telephones and bells are generally made smaller, delivering about twenty amperes upon short-circuiting, but lasting longer than ignition cells, sometimes they are useful for over a year.

Miniature dry cells for vacuum tube work and for flashlights, are made in varying sizes, but lose their effectiveness quickly, of course, depending upon the period the vacuum tube or flashlight is used.

The emf. developed in an unused dry cell is from 1.5 to 1.65 volts. In purchasing new cells the reader should know that any new dry cell having less e.m.f. than 1.4 volts indicates a defect or deterioration through long "shelf life."

The amount of energy delivered from the dry cell increases with increasing temperatures, but the higher the temperature, the faster does the cell deteriorate when not in use. It is, therefore, best to keep them in a temperature below 25 degrees centigrade.

Owing to various causes, due to compactness in manufacturing and its comparatively rapid polarization, dry cells are not useful for delivering a steady current for a long time in service and should only be used in radio when an intermittent current or a very small current is required, such as plate battery service or buzzer ringing. When heavier duty is required, it is much more preferable and economical to utilize "storage" or secondary batteries, described below.

Storage or Secondary Batteries.—The difference between the gravity primary cell, previously referred to, and the secondary or storage cell, is in the method of renewing the active material. While the primary cell is renewed by supplying new electrolyte and replacing the worn out zinc electrode with a new one, dry cells cannot be renewed. In the storage battery, however, the necessary chemical conditions of the plates is restored by the action of a current of electricity from some outer source, usually from a dynamo.

While the cell is supplying emf., it is said to be "discharging" and when receiving a renewal of energy it is said to be "charging." The direction of the current when charging is always opposite to the current when discharging.

Storage batteries in general have low internal resistances when in good order and will therefore deliver relatively large currents, this is a great advantage. Care must, however, be taken to prevent accidental short-circuiting, as this would cause an excessive current and rapid deterioration, or even ruination, of the battery.

Voltage changes during the period of discharge are small and thus fairly-constant current can be maintained.

There are two types of storage batteries in general use, the "lead" cell and the "Edison" or "alkaline" cell.

The Lead Plate Cell.—In the cell type of battery, the plates are made of lead, in the form of a grid. Each plate contains many tiny cells, like honeycomb, and often called by the name "grid."

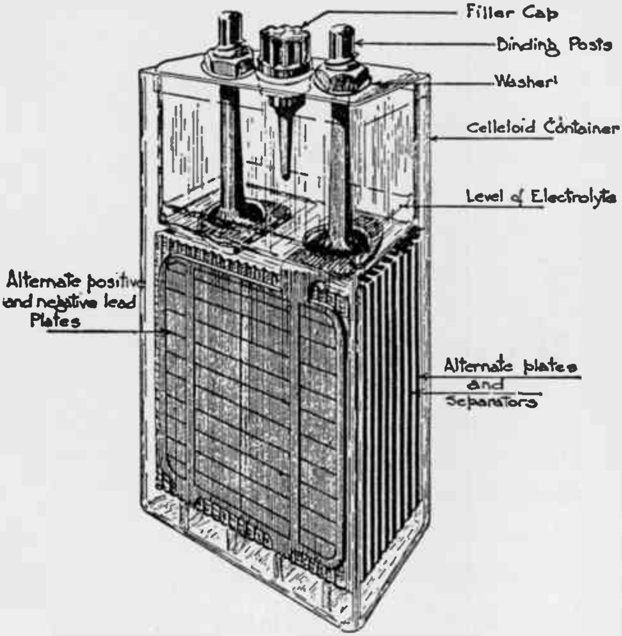


FIG. 6. Lead cell storage battery.

Into these honeycombed cells is heavily pressed, or forced, a mixture of red lead, litharge and sulphuric acid. When two plates thus prepared are immersed in an electrolyte consisting of a twenty per cent sulphuric acid solution, and an electric current passes between them, hydrogen will accumulate on the plate from which the current leaves the cell, thus in one plate the active material is reduced to a spongy lead, and in the other the same material is being changed to lead peroxide, as it takes up oxygen. The cell now contains a lead peroxide plate, called positive (+) and a spongy lead plate, called negative (—) (Fig. 6).

After the charge is cut off, assuming it is fully charged, if the cell is connected in a circuit, current will flow in an opposite direction to that by which it was charged. The cell upon completion of the full charge, should show a voltage, on open circuit, of approximately 2.2 volts, this, however, will quickly drop to about 2 volts. As the battery is discharged the voltage will gradually fall. The discharge should never be carried below 1.75 volts.

The container of a lead cell must be of a material sulphuric acid will not attack and is usually of either glass or hard rubber. The former for large stationary batteries and the latter for the portable types.

The negative plates appear gray and the positive reddish in color.

There are innumerable types and each manufacturer carefully enumerates on the name plate the specific rate, in amperes, of charge and discharge. This is necessary as he is the only one who knows the size, weight and number of plates in the cell, upon which the discharge and charging rate is based, and the life and general efficiency of the battery is greatly decreased if this normal rate is not adhered to.

There is a chemical action between the lead and the electrolyte, which forms lead sulphate during the course of a discharge. This uses up the acid and the density of the electrolyte grows less, this results in the formation of lead sulphate, whitish gray in appearance (when dry) which is dissolved in the solution.

For testing the density of battery electrolytes, an instrument called a "hydrometer" is the best instrument to use, as the density of the solution is the best indication of its condition. In other words, the density of electrolyte rises and falls with the charging and discharging of the cell, and a test of the density or specific gravity of the solution readily indicates its condition.

Great care is required in the handling of storage batteries to prevent "sulphating."

If a cell is repeatedly charged and discharged at its normal rate, as indicated by the manufacturer's name plate, the amount of lead sulphate formed will be small and not harmful. However, if the battery is misused, for instance, charged and discharged at an excessive rate, or perhaps allowed to be idle when in a rundown condition, there will form an excessive deposit of lead sulphate. As the crystals of sulphate increase they crowd out the active materials, stresses are formed and the plates disintegrate or buckle. This renders the cell into such a condition that it is almost impossible to repair, and certainly the battery will never be normal again.

Storage batteries of all types, both lead and alkaline, are graded when manufactured and rated according to the ampere-hour capacity. This capacity is generally expressed by the maker on the same name plate as the rate of charge or discharge. The larger the plate the greater may be the current used from it. For example, a forty ampere hour battery should yield one ampere for forty hours, or, to put it in another way, ten amperes for four hours. If, however, five amperes is the rate mentioned on the normal discharge and charge rate of the cell, it should only be discharged at that rate and also recharged at that rate, which would give the normal usefulness as five amperes for eight hours.

Batteries are seldom used as they were intended and it is thus that so many experimenters have considerable trouble and do not enjoy the full life of the cell.

Edison Cells.—This is a type of storage battery developed by the famous Thomas Edison, as the name indicates, and also known as the "Nickel-Iron and Alkaline Cell" (Fig. 7).

In construction, the positive plate consists of

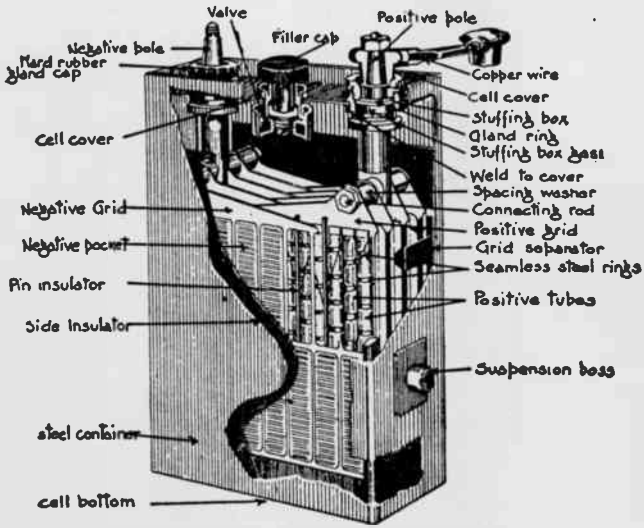


FIG. 7. Edison cell storage battery.

alternate layers of nickel hydrate and pure nickel flake, packed in perforated nickel-plated steel tubes. Several are arranged in a steel frame. The negative plate is of iron oxide packed similarly. These plates are immersed in a twenty per cent solution of caustic potash and water, and the whole is contained in a tightly sealed sheet steel container. This electrolytic solution carries oxygen between the plates, but does not form chemical compounds with the active materials, remaining approximately constant in density during charge and discharge.

The voltage of an Edison cell while charging may rise to 1.8 volts. When discharging this will drop suddenly to about 1.4 volts and as the discharge continues will drop more gradually to 1.1 volts, near the end of the discharge. Discharge should not be allowed to go below 0.9 volt; when that rate is reached the cell should be recharged.

If it is found after much use that the density of the alkaline electrolyte has fallen as low as, about, 1.16, measured by the usual means of ascertaining specific gravity of liquids, the solution must be renewed. This should be done by pouring off the old and refilling with entirely new electrolyte.

The height of the electrolyte above the plates should always be kept at about half an inch. This applies to both lead and Edison cells. As there is always more or less evaporation of the solutions, this may be accomplished by adding distilled or chemically pure water to bring the height half an inch above the plates.

Comparisons of Storage Batteries.—The construction of previously mentioned types of secondary batteries is so radically different, that a brief comparison of the two is not out of place.

The lead cell will suffer serious injury if not well cared for and if not charged and discharged according to the use for which it is rated. Further, it will deteriorate rapidly if allowed to remain idle without care.

An Edison battery, on the other hand, by nature of its sturdier construction and the materials utilized, may be said to be as near "fool-proof" as anything thus far placed upon the market. It will retain its charge over a long period of idleness. It may remain idle for an indefinite time, either charged or discharged, without injury. It may be completely short-circuited and totally discharged without harm, whereas this would ruin a lead cell. An Edison cell can be charged or discharged at rates differing from its normal rate, while it has been previously shown that the lead cell must be handled at near its normal rate.

Charging Storage Batteries.—While the general method of charging both lead and Edison cells is similar, there are features which are

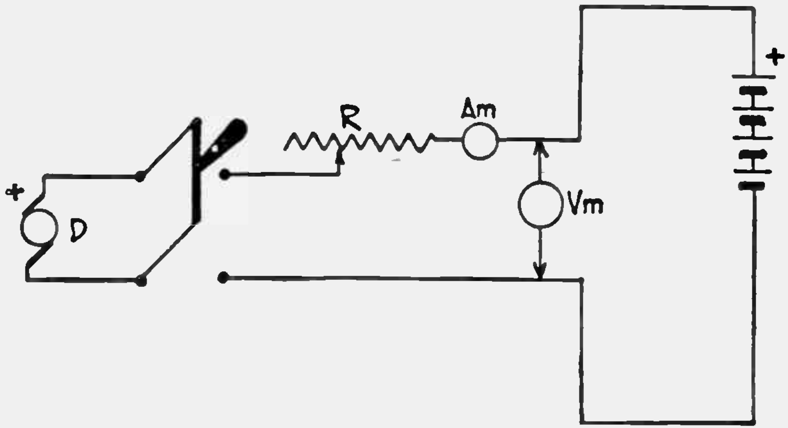


FIG. 8. Storage battery charging circuit.

not alike that would require some differentiation in the description of these charging methods.

Lead Cells.—Previously we have mentioned that there are certain charge and discharge rates prescribed for certain types and sizes of lead cell batteries.

While a battery is receiving a current from some outside source it is said to be "charging."

In Figure No. 8 is given a diagram of a circuit, which is typical for charging batteries. The dynamo, or supply of direct current, is marked D, and is connected through the ammeter and rheostat, marked R, to the battery, so that the positive pole of the supply source or dynamo, is connected to the positive pole of the battery; this will send the charging current against the electromotive force of the battery. To thus connect the positive pole of the dynamo to the positive pole of the battery, is most important, as a reversal of this would cause the storage battery to discharge instead of charge and cause great injury to the cells.

Before charging, an inspection of the electrolyte should be made and if found less than one-half inch above the top, chemically pure or distilled water should be added until that amount of electrolyte shows over the top of the plate. Do not spill the water over the top of the cover of the cell, or a short circuit will result through the water from the positive to the negative poles and a leakage occur, resulting in a total discharge of the cell, if the leakage is allowed to continue.

If suitable measuring instruments, such as a voltmeter and ammeter, are not used, it may not always be known which is the positive and negative line in the source of supply. A very simple experiment may determine this question. Take a glass of water that contains a little salt or acid, place both supply leads in the liquid, being careful to keep them apart, say, by half or one inch. Bubbles will be observed to come from the negative terminal.

For lead cells, in charging, it is necessary to allow two and one-half volts for each cell. If a smaller voltage than that which is to be reached by the cell, you would discharge instead of charge the cell. If the source of supply voltage is not sufficient to charge all your cells in series, they may be divided into groups and these groups may be placed parallel to each other. If this arrangement is necessary, care must be exercised that the negative lead from one bank of cells in series, to the negative pole of the other bank, and from positive to positive terminals of each bank, then the leads from the two banks thus joined will be lead as described previously. From the positive pole to the positive terminal of the dynamo and negative to negative.

Hydrogen is given off from charging batteries, and great care must be taken to keep naked lights from the vicinity of the cells, or an explosion will result. Some very painful accidents have happened to numerous unwary people who have, for instance, lighted a match to peer into a charging battery, in order to ascertain its condition. This precaution applies to both lead and Edison cells.

Edison Battery Charging.—The same circuit utilized for charging lead cells may be employed for charging Edison cells.

The charging source should have a voltage equal to 1.85 times the number of cells in series.

Before starting to charge, open the covers of the compartment, if the battery is in one. See that the solution is at the proper level.

Do not allow the temperature of the solution to exceed 115 degrees Fahrenheit. Excessive temperature on charge will shorten the life of the battery.

As in lead cell charging, be sure to connect the positive side of the line to the positive pole of the battery, and the negative line to the negative pole.

The specific gravity of the solution will not change during the charge or discharge except in cases of extreme low or high temperature and therefore hydrometer readings are of no value in determining the state of charge or discharge of the battery.

The proper length of charge is determined by the extent of the previous discharge. If the battery is totally discharged, recharge it at the normal rate for the proper number of hours. If the battery was only one-half discharged, recharge at the normal rate for one-half the time, etc.

If the extent of the previous discharge is unknown, charge at the normal rate until the voltmeter reading has remained constant for thirty minutes at about 1.80 volts per cell, with normal current flowing.

If necessary, and full capacity is not required, a battery may be taken off charge at any time.

CHAPTER III

MAGNETISM AND ELECTRO-MAGNETISM

THERE is a form of iron found in the earth known as black oxide of iron, also called magnetite or magnetic iron ore. This particular iron ore has remarkable properties. For instance, if a piece of magnetite is dipped into iron or steel filings, the filings will adhere to it and is known as a "natural magnet." If a small piece of this substance is suspended by a very slender thread, such as silk, it will point in northerly and southerly direction.

If a small rod of iron is brought near a piece of magnetite, or is rubbed on it in a certain way, it will show the same properties as the piece of magnetite. If the rod be made of hard steel this effect will persist after the magnetite has been removed from its vicinity, and is known as a "permanent magnet."

We are almost all acquainted with the horseshoe shaped magnet, and probably have played with them when children.

Magnets are also made by winding a coil of wire around a rod of soft iron and passing an electric current through the coil (Fig. 9). As long as the electricity passes through the coil the

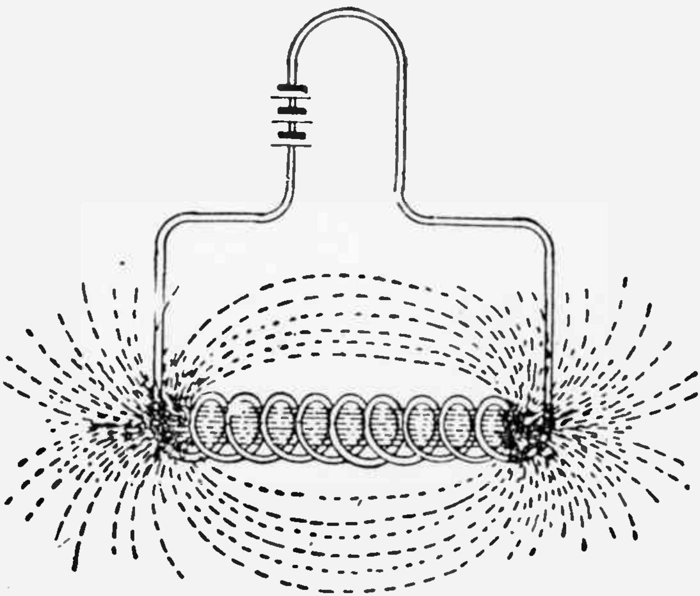


FIG. 9. Magnetic field of a solenoid.

iron is magnetized and is called an "electro-magnet." These are the familiar examples we find in electric bells, buzzers and telegraph sounders, and if you screw the ear cap off a telephone receiver you will find an excellent simple electro-magnet. If the bar around which the coil is wound is made of certain hard steel, that bar would be permanently magnetized.

A small steel rod mounted pivocally will turn in almost a north and south direction and is the familiar compass needle used by mariners to determine the direction they are proceeding. The

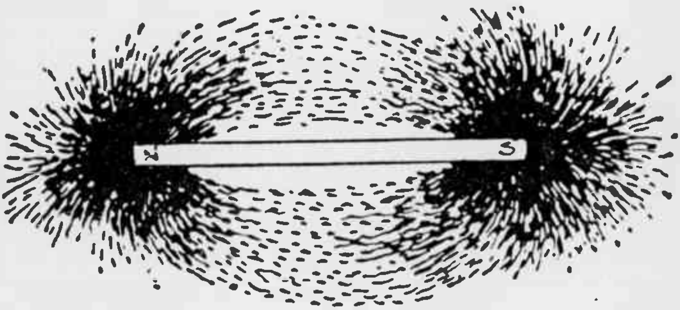


FIG. 10. Magnetic field of bar magnet as shown by iron filings.

end pointing north is called the "North Pole" and that pointing south, the "South Pole."

Two magnetic poles are said to be alike when they both attract or both repel the same pole. If one pole attracts the other they are unlike, if a pole repels another, they are alike, therefore, as previously explained in the discussion of negative and positive connections of a battery, like magnetic poles repel each other and unlike poles attract each other. It is then very easy to determine which is the north or south pole of a magnet by placing a small compass near the magnet and observing which way the needle points.

Place a sheet of paper over a magnet and sprinkle iron filings upon it and you will find they will arrange themselves in two groups, one group over the north and the other over the south pole (Fig. 10). This indicates that there are forces in the space around the magnet that act on its poles. These forces are called "magnetic lines of force" and appear to center in the two poles of the magnet.

The space around the magnet in which these lines of forces may be detected is called the "magnetic field," and the direction of the magnetic field is the direction in which the compass needle will point, if a compass is used as above described. This needle will always point north.

Experiments with a compass, as shown above, determine that there is a magnetic field about a wire in which a current of electricity is flowing, and that this field is in the form of concentric circles about the wire. These circles lie in planes at right angles to the axis of the wire. If the wire is grasped by the right hand with the thumb pointing in the direction of the current, the fingers will show the direction of the magnetic field (Fig. 11). This field extends to an indefinite distance from the wire, but as it becomes more distant the effect becomes correspondingly feeble and there is

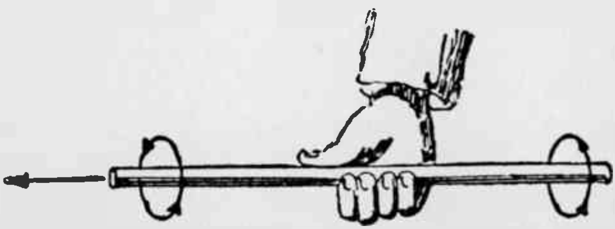


FIG. 11. Right hand rule for determining direction of current and magnetic lines of forces.

greater difficulty in detecting its presence. If the current is cut off, the magnetic field likewise disappears. When a current is flowing in a wire, we must imagine the magnetic field as started and sweeping outward from the conductor, with the axis of the wire as its center.

If the wire in which a current is flowing is bent into many circles or turns and these turns wound close together the intensity of the magnetic field is increased in direct proportion to the number of turns in the wire.

If the space within the coil is filled with iron, the magnetic lines or "flux" is greatly increased. This is due to a peculiar property of iron which is called magnetic "permeability." This is to say that when the space is filled with iron instead of air alone that the magnetism is stronger.

It should be remembered that this magnetic induction in a coil depends upon the number of ampere turns in the coil and the permeability of the iron.

If the current in the windings is reversed the direction of the magnetic field is also reversed.

If two different magnetic fields are brought together in the same space, with their directions parallel, a force is always developed. If the lines of magnetic flux are in the same direction, the two fields mutually repel one another, and if the flux lines are in opposite directions the two fields will be drawn together. When a current flows in a wire which is at right angles to a magnetic field, a force will act on the wire.

When the wire which carries the current is at right angles to the direction of the magnetic field, the pushing force on the wire is equal to the product of the current, the intensity of the magnetic field, and the length of wire which lies in the magnetic field.

If the wire makes some other angle with the direction of the magnetic field, the direction of the force is still the same as for the right angle position, but the value of the force is smaller. In the single instance that the direction of the current coincides with the direction of the magnetic field, the force is zero.

This push on a single wire is in most cases small, but by arranging many wires in a very intense magnetic field, very large forces may be obtained. The powerful turning effect of an electric motor depends upon these principles.

There is always a magnetic field about an electric current. The lines of magnetic flux are closed curves and the electric circuit is also closed. The lines of magnetic flux are then thought of as always interlinked with the wire turns of the circuit. The number of flux lines through a coil will depend upon the current, and any change in the current will change the number of linkings. If there are two turns of wire the circuit will link twice with the same magnetic flux, and so, for any number of turns the number of linkings increases with the number of turns.

Induced Electromotive Force.—Whenever there is any change in the number of linkings between the magnetic flux lines and the wire turns, there is always an emf. induced in the circuit. If the circuit is closed a current will follow. This is called an induced current. As an example we can observe the effects produced by two solenoids fixed in the position

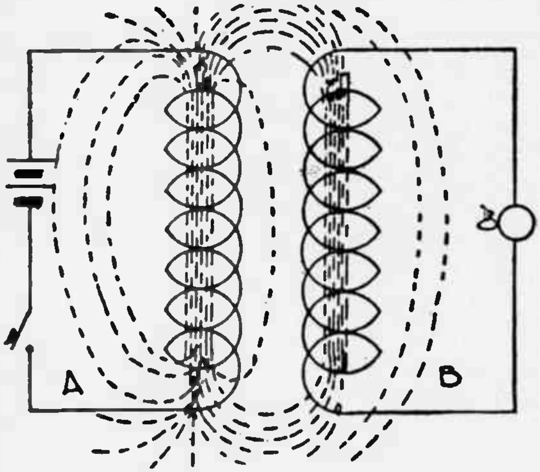


FIG. 12. Illustrating an induced current. Current started in A induces current in B.

shown in Fig. 12. If a current is started in one of them, A, there will be a current induced in the other, which will continue to flow as long as the current in A is increasing. If the current in A becomes steady, there is no current induced in B. If the current in A falls off, the induced current in B is reversed in direction. In all cases it must be remembered that the magnetic field about the induced current tends to oppose the change that is causing the induced current. The magnitude of the induced emf. depends upon the time rate of change of the number of linkings.

Inductance.—The value of inductance depends upon the shape and size and upon the permeability of the medium about the circuit. The inductance does not depend upon the current which is flowing, except when iron is present. By coiling up a piece of wire in many turns and introducing it into the circuit, the inductance of the circuit may be greatly increased. In that case the inductance is said to be concentrated. It must not be overlooked that the entire circuit has inductance. This may be distributed more or less uniformly throughout the circuit.

If a piece of wire is connected to one terminal of a dry cell, and tapped on the other terminal, a very slight spark may be seen in a darkened room. If a coil of many turns of wire is included in series, with this cell, the same process of tapping will show brilliant sparks, particularly if the coil has an iron core. The explanation of this lies in the fact that the cell voltage of 1.5 is too feeble to cause much of a spark. However when the large inductance is included in the current, there is a large number of linkings between wire turns and flux lines. If these flux lines collapse suddenly, as they do when the circuit is broken, there will be a large change in the number of linkings taking place in a very small interval of time. This principle is made use of in ignition apparatus and spark or induction coils.

In mechanics it is well known that a piece of matter cannot set itself in motion and that energy must be supplied from outside. So in the electric circuit, a current cannot set itself in motion, and energy must be supplied by some form of generator or source of electromotive force.

As an illustration of inductance we may use the following example. When a nail is forced into a piece of wood, the mere weight of the hammer as it rests on the head will produce but little effect. However, by raising the hammer and letting it acquire considerable speed, the kinetic energy stored is large and when the motion of dropping the hammer is stopped, this energy is expounded in forcing the nail into the wood. In the electric circuit a cell with its small emf. can only cause a feeble spark. By including a piece of wire of many turns in the circuit, however, a small current will enable a large amount of energy to be stored in the magnetic field, if the inductance is large. Then when the circuit is broken and the field collapses, this large amount of energy is released suddenly, and a hot spark of considerable length is the result.

Alternating Current. — An alternating current is one in which electricity flows around the circuit, first in one direction and then in the opposite direction, the maximum value of the current in one direction being equal to the maximum value in the other. All changes of current occur over and over again at perfectly regular intervals. A graphical representation of this is shown in Fig. 13, the potential commences at A, which represents zero potential, rising to its maximum voltage of, say, 110 volts, then falling to zero at B, the current then reverses itself and flows in the opposite polarity, again rising to 110 volts and drop-

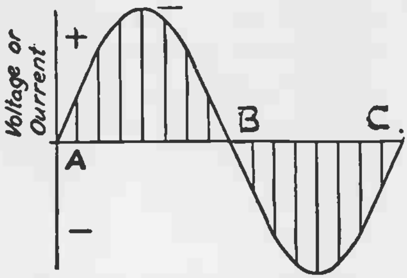


FIG. 13. Showing a cycle of alternating current.

ping to zero at C. From A to B represents an "alternation" and from A to C, a "cycle," thus each cycle consists of two alternations.

The frequency of alternating current is determined by the number of cycles per second. In ordinary commercial use, for lighting and power, 25 to 60 cycles per second is the usual frequency, mostly 60 cycle. In Europe they often use 50 cycle alternators. However, in radio practice higher frequencies are desirable and in modern spark transmitters 500 cycles is considered the standard. This gives the emitted signals a high musical tone, as the spark frequency from such an alternating current would be 1,000 per second, or one spark discharge for every alternation of the current. This matter of spark frequency is only mentioned in passing and will be fully discussed later under the caption of radio transmission.

Alternators.—Alternating current is produced by electrical machinery. Electrical machines are used for conversion of power from mechanical to electrical form, or *vice versa.* If driven by some sort of prime mover like a steam engine, gas engine or water wheel, they convert mechanical power into electrical power and are called "generators." If supplied with current and used to drive machinery, vehicles, or other devices, thus converting electrical power into mechanical power, they are called "motors."

While there are various types of motors and various types of generators, the difference is more in the use than in the appearance or construction. Electric machines may be built for either direct or alternating current. If a generator of alternating current, called an alternator, is driven by a motor, this machine is known as a motor generator.

In general, it is a motor generator that is employed in common radio practice, as a source of power.

CHAPTER IV

EXPLANATION OF RADIO

RADIO signals are produced by propagating waves in that peculiar medium known as the ether. These waves are originated by setting up high frequency oscillations radiating from an "antenna" or, as it is also known, an "aerial."

The antenna oscillations cause waves in the surrounding ether to be radiated into space in all directions at the tremendous speed of 186,000 miles per second, which is the same speed at which light travels.

These ether waves, coming in contact with an antenna at a receiving station, set up in the receiving antenna oscillations which, by means of suitable apparatus (hereafter described in this volume), are rectified by means of a detector so as to be audible to the human ear, generally by the use of telephones.

By this means the signals of the Morse code or telephonic speech can be carried on.

The force or amplitude of ether waves depends on the energy developed in the antenna circuit.

The greater the amplitude of ether waves, the farther do they travel and the farther can they be perceived before their force is spent. But the amplitude of the waves in no way affects their rate of travel, nor their frequency.

The speed at which these waves follow each other is termed "wave frequency." Wave frequency depends upon the characteristics of the sending circuit, and is controlled by varying the capacity, inductance and resistance. In other words, by varying the size of the condenser unit or the inductance coil. Details of various types of apparatus, such as condensers, etc., are discussed elsewhere and will be alluded to in these preliminary pages only as aids to a general understanding of radio.

A given circuit will produce oscillations at only a certain fixed rate depending on the factors of inductance, etc., just as a pendulum can swing at only a fixed rate, depending upon its length and weight. In ordinary commercial practice the wave frequency varies from as much as 2,000,000 per second to as little as 100,000 per second.

Wave Length.—We now come to what is known as "wave length," or in other words the distance from the peak of one wave to the peak of the succeeding wave. As an analogy we can picture the distance from the top of a water wave to the top or peak of the succeeding wave, although ether waves may be of different form to water waves.

Dividing the velocity of the waves, 186,000 miles per second, by the number of waves per second, gives us the wave length. We may put this in another form and say that the product of the wave length by the frequency is always 186,000. It will, therefore, be seen that it is of importance that a student should bear in mind the speed with which ether waves travel.

In discussing wave lengths, it should be carefully noted that it is only by means of variations of wave lengths that it is possible to operate a number of radio stations within the same area or region. Any desired wave length can be obtained by varying the circuit which determines wave frequency.

Wave lengths used in commercial practice vary from a few meters to thousands of meters.

Wave length plays such an important part in radio that a perfect understanding of the subject is essential. For illustrative purposes, we may compare several radio stations working in the same locality, on similar wave lengths, to several persons speaking in the same room at the same time. A listener at a receiving station, or another person listening in the same room to the speakers, would be "jammed," or "interfered with," to use radio terms of expression.

Supposing you could devise something that would eliminate all but one of the stations and all but one of the speakers, you would eliminate interference. In radio, interference is overcome by what is known as "tuning." Stations in the same vicinity, by laws, regulations and mutual agreement, employ different wave lengths. By a receiving instrument known as a "tuner" or "receiver" it is possible to listen to only one station, or if desired, an arrangement of circuits can be made for "broad tuning" and "sharp tuning." As the names imply, broad tuning enables the person receiving to listen to several stations, working on various wave lengths (within a certain scope), but with resultant interference, while the latter permits only the reception of signals from one station.

In commercial practice this arrangement for listening in on broad tuning is very desirable, as an operator is enabled to catch any "call," and by arrangement of switches and dials rapidly throw over to the tuning devices providing for sharp or selective tuning. Details of such receivers will be found under that heading within these covers.

Wave Frequency.—Early in 1923 the Department of Commerce under Secretary Hoover called on a group of radio experts to formulate temporary rules for the regulation of radio broadcasting with the object of reducing interference between stations. This group held what was known as the Second National Radio Conference. One of the important recommendations was that the wavelength at which a station was to operate on be referred to as being composed of so many kilocycles and that kilocycles be the standard term to be used instead of meters. The reason for this as well as its advantages are easily understood.

The waves sent out by a radio transmitter are in fact an alternating current of a very high frequency, the frequency varying inversely with the wavelength. In other words, the longer the wavelength the slower the oscillations, just as if it took longer for the oscillations to make a round trip in a long wavelength than in a shorter wavelength. An oscillation is a complete reversal of an alternating current. The current value at the start of the oscillation is zero and gradually builds up to its maximum value in one direction, which for the sake of explanation may be called positive, it then dies down to zero in value and starts off in the opposite direction which may be called negative. A complete reversal such as this is called an oscillation consisting of one cycle. The longer the wavelength the slower will be these oscillations. There is a definite relationship between the number of oscillations taking place per second and the wavelength which is shown by the following formulæ:

$$\text{kilocycles} = \frac{300{,}000}{\text{meters}} \qquad \text{wavelength} = \frac{300{,}000}{\text{kilocycles}}$$

Velocity of waves in kilometers per second= wavelength×kilocycles.

Using the above method of calculation the following table has been prepared which shows directly the conversion of meters to kilocycles.

meters	kilocycles	meters	kilocycles
100	3000	550	545
150	2000	600	500
200	1500	650	461
250	1200	700	428
300	1000	750	400
350	860	800	375
400	750	850	353
450	666	900	333
500	600	1000	300

It is seen from the above table that there is a difference of 1000 kilocycles in the fifty meters between 100 and 150 meters, while there is only a difference of 33 kilocycles in the 100 meters between 900 and 1000 meters. The difference in kilocycles gradually becomes less as the wavelength increases.

On the above basis, therefore, it is quite evident that it is not logical to expect the same number of stations to work without interfering with one another in the fifty meters between 600 and 650 meters a difference of only 39 kilocycles as between 300 and 350 meters a difference of 140 kilocycles. Yet under the old scheme of allocating by wavelength this was the result.

The conference using the above basis recommended that there be three classes of broadcasting stations called A, B, and C. Class A stations include low power stations and these are allowed to operate on the wave frequency band of from 1,050 to 1,350 kilocycles (222 to 286 meters). Class B stations are stations using 500 or more watts power with strict requirements as to the quality of their program and transmission. To this class was allocated the wave frequencies from 550 to 1,040 kilocycles (228 to 546 meters). Class C to include those stations that desired to retain the 360 meter wave, 800 to 870 kilocycles regardless of whether they operate on high or low power. It is left to the discretion of the radio supervisor of the district as to just what wavelength each station shall operate on and he may issue licenses as he sees fit. The recommendations of the conference will undoubtedly be enacted into the radio laws of the country.

Wave Trains or Groups.—A "wave train" is a group of ether waves, sent out at one condenser discharge and contains numbers of individual waves depending on the circuit conditions previously alluded to.

Wherever these waves strike a receiving antenna in their travel from the transmitting station, they will set up in the receiving antenna oscillations identical to those from the transmitting station. These oscillations, as we have shown, are very frequent, usually so rapid (say over a million per second) that they are beyond the range of the audibility of the human ear which can only detect sounds of a frequency not greater than 4,000 or 5,000 per second.

We must therefore utilize some device to detect ether waves. In common practice this is called a "detector" and using a pair of telephones in conjunction therewith we are enabled, as it were, to take the energy from the antenna, which, passing through the detector produces a click in the telephones. The characteristics of the many detectors together with their associated receiving circuits is fully dealt with in succeeding chapters.

Resonance.—From the foregoing, it will be seen that high frequency oscillations, radiated as ether waves from a transmitting antenna, will set up characteristic oscillations in a receiving antenna, within their path or range.

In practice, however, best results are obtained only when the sending and receiving antennæ are "in tune," or as it is commercially termed, "in resonance."

To properly understand this phenomenon, it would be well to take examples well known to everybody with even a slight knowledge of music, or through acoustics.

Take the example of two bells of similar tone, strike one and the other bell will respond without being struck. Also, the instance of two tuning forks of the same characteristics, strike one until it gives forth a musical note, it will, on the principle of resonance, sound a similar note in the second fork without the latter being struck. However, neither the fork nor the bell will actuate another fork or bell unless they are similar in every characteristic.

A similar condition exists in radio and is a condition that must predominate in the thoughts of the experimenter who would be successful in his efforts.

In order to have radio signals very high frequency currents in the order of a million or more oscillations per second must be produced in both the transmitting and receiving sets. To produce this effect the sending and receiving apparatus must constitute electric circuits within themselves. They must have inductance and capacity and are called oscillating circuits. Every electric circuit whether it be oscillating or otherwise, has an electrical length. In other words, it takes a high frequency current a certain time to pass through it and return. This electrical length is called the "period" of the circuit. The natural period of a circuit, therefore, determines its wavelength and also the number of oscillations that can take place in it in one second of time. As an example, a circuit with a certain value of inductance and capacity may allow 1000 kilocycles to oscillate in it per second. This is the number of oscillations which can pass through it travelling at the rate of 186,000 miles per second. It is easily seen that inasmuch as all electric oscillations travel at this rate of speed the number of oscillations depends entirely upon the length of the circuit electrically. The wavelength in this case is 300 meters according to the formula below:

$$\text{Wavelength} = \frac{300{,}000{,}000 \text{ meters}}{\text{natural period of circuit (frequency)}}$$

Three hundred million meters equals 186,000 miles and is the speed of the waves.

A transmitting circuit having a natural period like the above example would send out waves of 300 meter wavelength and the receiving circuit would have to be placed in resonance to this period of oscillation in order that the signals might be received. If the sending station above were sending out signals on 300 meters or had a period of 1,000 kilocycles (1,000,000 cycles) it has a certain relative electrical length. Now remember the example referred to where two bells of similar tone were struck. Both bells had the same period of oscillation. Likewise, the receiving station to respond to the transmitting station above must have the same electrical length or natural period. When this condition exists the circuits are said to be in resonance.

The energy sent out by the radio transmitter and received by the receiver manifests itself in the form of oscillations which may be likened to waves of unseen energy. It is believed that these waves would appear like the air vibrations seen over a hot radiator if they were visible. Radio waves, however, are electric in nature and travel at the rate of 1860,000 miles per second.

Radio Oscillations.—If a stone is thrown in a pool of still water, waves or ripples are set up on the surface of the pool radiating out in all directions from the point where the stone entered the water. The waves were most violent at the instant when and at the point where, the stone struck the water. As the waves were propagated out in circular form they became weaker in direct proportion to the distance from the point where the stone struck. Likewise, they became weaker in direct proportion to the lapse of time. In other words, they were very strong at the first second, but considerably weaker after the tenth second. To use a scientific term it might be said that the waves were "damped out" shortly after they were started. They could not go on indefinitely because there was no continuous source of disturbing power to "generate" them. Radio waves, too, are "generated" and unless the source of power that makes the waves is continuous, without the slightest interruption, they are also damped waves. If, on the other hand, the source of generating power is continuous the waves are undamped, sustained or continuous, the three adjectives used to designate such waves or oscillations.

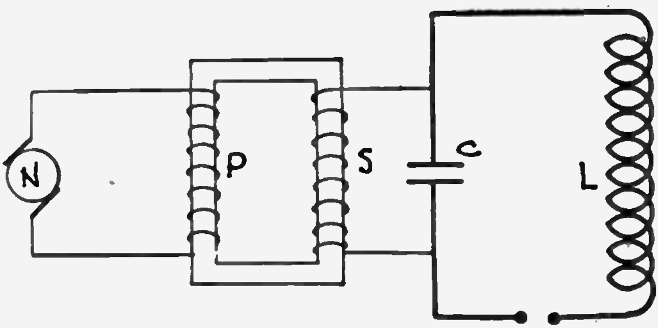


FIG. 14. Simple spark discharge circuit.

Damped Waves.—The circuit in Fig. 14 will produce damped waves, the alternator, N, generates a low voltage current, for example 100 volts. This current flows through the primary of the high potential transformer, P. This sets up a field of force in the primary which induces an electromotive force in the secondary, S. The secondary has many more turns than the primary, therefore the transformer is called a step-up transformer. It will step up the voltage in the same proportion as the winding of secondary is to that of the primary. For example, if the primary has 500 turns and the secondary 5000 turns of wire the ratio of transformation will be as 500 to 5000 or 1 to 10. If the voltage in the primary is 100, as in the above example, then the voltage in the secondary will be 1000; ten times increased or stepped-up.

A condenser, C, is connected across the secondary, S, and is charged by the high voltage current. A condenser may be likened to a tank in that it will hold just so much of an electric charge and no more; when it is full it spills over or discharges, so to speak. The condenser will continue to store electricity which is pumped into it by the secondary as long as there is no conducting path through which it may discharge. It is to be noticed that a coil of wire called an inductance, L, is connected around the condenser, but that the circuit is broken at the point indicated by the two terminating dots. This break is called the spark gap and the distance between the points of this gap determines the break down voltage of the condenser. Let us assume, for example, that the gap is set a fraction of an inch apart; there is a small air space between its points. If it takes

1000 volts to leap this gap the condenser will store up 1000 volts of static electricity and then the potential energy in the condenser which is continually seeking to flow through the inductance circuit will be strong enough to leap the gap and a spark is seen and the condenser has discharged. At the start of the discharge the energy in the discharge is relatively very strong and produces correspondingly strong electromagnetic waves in the same way that the stone caused strong water waves in the pool at the time it struck. Like the pool waves these electric waves, having no continuous source of power, the energy in the condenser being dissipated until it again is charged or pumped up, so to speak, by the secondary, gradually get weaker and weaker until after a few oscillations have taken place they cease or die out. It is said then that they have been damped or smothered and they are called damped waves. A damped wave train may be said to be a train of oscillations in which there is a decrease in the amplitude of each succeeding oscillation, commencing at maximum and decreasing to minimum for each train. The number of oscillations which take place in a given circuit depends on the voltage in the secondary of the step-up transformer, the capacity of the condenser, the value of the inductance, and the length of the spark gap. Damped waves may be received on either a crystal or vacuum tube detector.

Undamped Waves.—If the source of electric power in the Fig. 14, marked N, were a high voltage generator, 500 volts for example, and the condenser connected across the generator, the transformer being left out, and an arc (copper and carbon electrodes) substituted for the spark gap the circuit will generate undamped oscillations. This is due to the fact that the generator, N, keeps the arc burning continuously and the arc in turn discharges continuously through the oscillating circuit. A curve of these oscillations would appear as in Fig. 13, each alternation having the same amplitude, or in other words being undamped. Undamped waves are more efficient than damped waves and are, therefore, used for long distance transmission in such as the transoceanic stations located throughout the world. Undamped waves modulated to conform to sound waves are used in radio broadcasting. Pure undamped waves cannot be received on a crystal detector but require a device called a tikker or some form of beat receiver which is known as the heterodyne or regenerative receiver and which will be described in a later chapter.

An undamped wave may, therefore, be defined as a train of oscillations of constant amplitude; each oscillation being identical with the one preceding it.

Radio in Operation.—Radio or wireless as it was previously called, means to communicate between two distant points without the use of intervening wires. Such a system must do several things and these are listed below:

First, Create radio waves.
Second, Radiate these waves.
Third, Detect the waves.
Fourth, Amplify the waves.
Fifth, Reproduce or make audible the waves.

All radio systems perform the above functions, some do more, such as in the broadcasting transmitter the waves are modulated and sometimes amplified before being radiated.

Radio waves are created or generated in several ways. Damped waves are generated by the discharge of a condenser as described in a previous paragraph. Undamped waves are generated by an arc generator as previously described, by a high frequency alternator connected directly to the aerial and ground or by vacuum tube oscillators. Damped waves are produced by what are called "spark sets" and are used mostly on shipboard or at low power coast stations. They are the source of a great amount of interference due to the broadness of the damped waves which makes it impossible to tune it out. In other words, a damped wave can be heard over a wide range on the receiving set compared to the undamped wave.

Radio waves are radiated by means of the aerial and ground system. An aerial for radiating or transmitting purposes must be much larger than a receiving aerial relatively speaking.

The coherer was the first practical type of detector used in a radio system. It was soon found to be impractical for distance work and was replaced by the crystal detector. Next in order came the two electrode vacuum valve and the most recent inventions for this purpose are the three element vacuum tube and a specially constructed tube using sodium and known as the Sodion tube.

It was not until the invention of the vacuum tube that radio signals could be amplified. It is now possible to amplify the original signal to many hundreds of times its original power. In the amplification circuit small transformers known as amplifying transformers are used in conjunction with the vacuum tubes. There are two methods of amplification employed. One is known as the audio frequency and the other as the radio frequency method of amplification.

Radio signals are reproduced usually by means of headphones or loudspeakers. There are other means of automatic recording used in commercial work but they are beyond the scope of our discussion. Headphones and loudspeakers are made in many types and vary greatly in efficiency.

Fading of Signals.—If you have ever listened to a distant station transmitting it is quite probable that you have noticed that the signals in some cases seem to be strong and weak in an irregular manner. This is called fading and may be due to the fact that as the radio waves leave the transmitting station they take the form of "sky waves" and "ground" waves" which sometimes oppose and sometimes augment each other. A study of Fig. 15 will illustrate the theory of signal fading as accepted by radio engineers.

This fading is not noticeable from all stations, it depends upon the distance the sending station is from the receiving station. A certain station may fade in one section and not fade at all in another

The theory of fading is based on an explanation given by Sir Oliver Heaviside and it is not a proven theory, but simply a logical explanation. Twenty or fifty miles up, the atmosphere surrounding the earth is very rare and is an electrical conductor. Inasmuch as all electrical conductors are also good electrical reflectors we have a mirror, so to speak, which reflects the radio waves in the same way that a common mirror reflects light waves. It is called by scientists the "mirror layer" and theoretically reflects the radio waves as shown in Fig. 15. This mirror layer, however, is not effective during the day; it is, in fact, almost neutralized and instead of being a smooth-surfaced reflector, its surface is very irregular. This is due to sunlight which converts this layer into a sort of fog which readily absorbs the radio waves. We have, therefore, the condition of a reflector by night and an absorber during the day. This no doubt accounts for the fact that radio signals travel at least twice as far by night as by day for a given power.

The Fig. 15 shows that the waves received by the receiving station come through the ground as well as from the sky. It is, furthermore, understood that the sky waves travel twice the distance the ground waves do before they are completely absorbed. It is easily understood, therefore, why night is superior to day transmission. During the day, there are no sky waves due to the absorption effect of the "Heaviside layer" and all of the energy comes through ground waves to all but stations close to the transmitting station. It is also true that ground waves encounter many obstructions not met with by sky waves which accounts for their being of shorter duration.

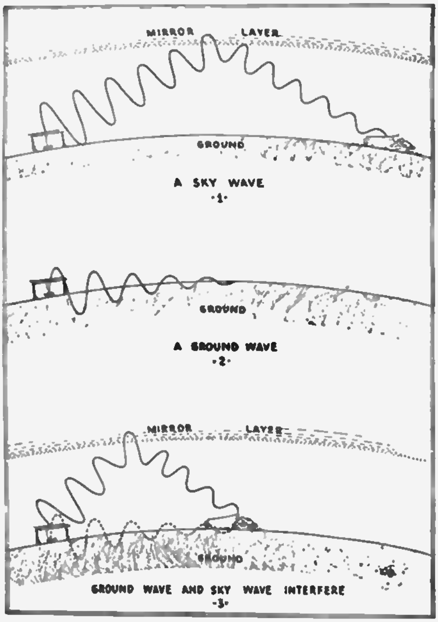


Fig. 15. Why radio signals fade is shown graphically by the curves above.

A study of the Fig. 15 will make clear how the fading effect takes place. Notice the sky waves, how much farther they travel than the ground waves. Also notice the polarity of the ground and sky waves. When they are both positive at the same instant the resultant signal is strong whereas when they differ in polarity the resultant signal is weak. It is a case of positive and negative bucking each other with the resultant or tertiary effect of a weak received signal.

Ether and Ether Waves.—There are two kinds of ether, the most common perhaps is that produced by the action of sulphuric acid on alcohol and used in medical practice as an anesthetic. It is a chemical compound. Then, there is another kind of ether properly known to physicists and scientists as "luminiferous ether" because it has the property of conducting light waves. It is this sort of ether which is of interest to the radio scientist. It is that something which conducts electromagnetic waves through space. It is the substance referred to throughout this book and in any explanation of radio.

Ether is said to be present everywhere, even in solid rock. It has no weight, but is said to have elasticity and density. In other words, it has the properties of restitution and inertia. It is not known whether the light waves or the longer radio waves plow through the ether, that is, displace it, or whether the ether passes through them like wind through a tree. The fundamental theory is that ether is not affected by the passage of matter through it unless the matter is electrically charged.

The subject of the ether is a difficult one to the average reader. Faraday, in his early experiments, assumed that there was ether. The theory of the ether has been discussed from different angles by eminent scientists throughout the history of electricity and astronomy. Einstein proposed a new theory in his papers on relativity and the American astronomer T. J. J. See has deduced a new theory of the ether.

It is sufficient, however, for the average reader to think of ether as the conducting medium for radio waves. Bear in mind it exists in all matter.

CHAPTER V

THE AERIAL EXPLAINED

The antenna is used in radio communication for two purposes: (1) to radiate electric waves, and (2) to absorb or detect the electric waves which come to it. An antenna consists essentially of one or more wires, suspended at some elevation above the earth. When electric waves reach an antenna, they set up an alternating emf. between the wires and the ground. As a result of this electromotive force (emf.), an alternating current will flow in the antenna wires. The energy of the current is absorbed from the passing wave, just as some of the energy of a water wave, is used up in causing vibrations in a slender reed which stands in its way.

A receiving antenna needs to be large, in order to gather in enough energy from the passing waves to effect the receiving apparatus. Likewise a transmitting antenna should be as large as practicable in order to send waves to a greater distance. However, several conditions govern the size of the transmitting aerial, just, for instance, as the size of the heat radiators in an apartment are governed by the amount of heat available to be radiated. The same antenna may be used for both receiving and transmitting, in such cases a change-over or antenna switch is provided in the set to change from reception to transmission, and *vice versa*. An antenna used for receiving only, may, however, be made simpler than one which is also required for sending purposes, as it is obvious, with the absence of the high potential emitted by a transmitter, that the insulation need not be so heavy.

In practice, stranded wire is used for an antenna. High frequency currents with a high potential travel over the surface of a wire, therefore, a stranded wire offers a large surface. It has another advantage, in the event of a strain being placed upon the antenna, one or more of the strands may part, but the remainder will keep the antenna in commission.

As discussed in the chapter dealing with conductors, copper is the best conductor, but for several reasons, it has been discovered that pure copper is not as practicable as some alloys, therefore, in almost universal radio practice, silicon-bronze or phospher-bronze are used. The standard gauges are usually 7-22 or 7-19. In other words seven strands of number 22 or number 19 wire.

All joints in an antenna must be soldered, or a suitable patent joint used, such as that called a "MacIntyre" splice. If joints are soldered, care must be taken that too much heat is not employed, otherwise the wiring at the joint becomes tempered and very brittle and is liable to break when any strain or jar is met with.

The insulation of an antenna is of the utmost importance, especially in damp foggy climates. For damped apparatus using moderate power, an insulator known as "Electrose" is very suitable and is manufactured in a very large variety which meets all demands. For undamped or continuous wave radio, and for high potentials, porcelain is possibly the best insulator; these are also made in a great variety and can be readily obtained for any purpose. Not only should the actual antenna receive great care in its insulation, but the guy wires of masts or towers should also be insulated with strain insulators. If they are lengthy several strain insulators should be employed, inserted in series with the guy at suitable intervals.

Types of Antennae.—Early in the history of radio, Marconi demonstrated that radiation from an antenna was directional in its effect, according to the shape of the aerial employed. It was this discovery which led in later years to the wonderful success of the direction finder or radio compass.

It is well known, that a single vertical wire is, for its size the best radiator, but it has to be made so extremely long in order to obtain sufficient capacity that it is not a practical antenna for long wave or long distance work. Antenna of different numbers of horizontal or inclined wires are therefore used, and are very practicable and radiate very well. It must be remembered that an antenna is merely a large condenser and may have various shapes consistent with this condition, although some forms will radiate much better than others.

Antennæ that radiate more energy in one direction than in the opposite, are termed "directional," while an antenna radiating equally in all directions, is called "uni-directional."

The following types of antennae are the most common in practical use, and are easier to erect under conditions that confront the average experimenter. They are shown in Fig. 16.

What may be considered as the standard form of antenna for ship stations, and also for low powered land stations, is known as the T or inverted L type of aerial. This is an antenna of horizontal wires, usually two or four in number, separated at equal distance on what is termed a spreader, and supported between two masts or towers.

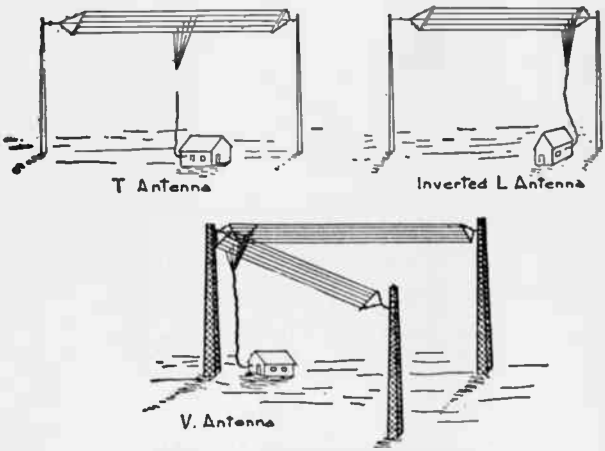


Fig. 16. Typical antennæ construction.

Whether the down leading-in wires are taken from the center or at the end of the horizontal portion determines whether the antenna is of the T or inverted L type.

Another very practicable type for certain work is the V antenna, consisting of two sets of horizontal wires supported by three masts or towers, so that the horizontal portions form an angle or V.

The directional effect of an inverted L or V type is greater than a T. There is a greater amount of energy sent in the direction in which the angle of the L points than in the opposite. With the T type the effect is more undirectional, although more energy is sent in the parallel direction of the horizontal wires, than at right angles. The resultant wave would be oval in shape.

A more recent development in this field is what is known as the loop antenna. This consists of a coil frame constructed by fastening four wooden struts together in the form of a triangle, the apex of which fits into a wide slot in a center fastening, usually in the form of a casting. Four of these are provided and converge into the center casting, where they are held by bolts. This provides a square frame over which many coils of wire are wound. The two ends of the wire are brought in as leads. This loop is mounted on a shaft enabling the loop to be rotated in all directions, and the antenna thus cuts any lines of force desired. This is the type used for radio compasses.

Function of the Aerial.—Fundamentally the radio circuit is made up of inductance and capacity. A circuit of this kind may be made to function in the radiation or reception of radio signals. In some cases both the capacity and inductance is lumped in the form of a condenser and an inductance coil. In other cases, the capacity is formed by an elevated wire called the aerial which forms one plate of the condenser, and the ground which forms the other plate of the condenser. It is this latter method which is in most common use.

The loop aerial or antenna is an example of concentrated inductance and capacity, as a condenser is used in conjunction with the loop.

It may be said that in the case of the ordinary radio aerial system that energy is received because the aerial is exposed to the radio waves. The energy is received through the capacity of the aerial and ground and then transferred to the inductance coil. This is not true, however, in the case of the loop aerial. In this type of radio circuit both the inductance and capacity are concentrated and the energy is received due to the exposure of the loop to the radio waves.

In all cases the amount of energy radiated or received depends upon the physical dimensions of the circuit.

When the aerial or loop is used for transmitting, it is used for radiating purposes. Radiation is the moving disturbance of the ether, the energy associated with which does not return to the radiator. In other words, it differs from induction in that the energy thus radiated is lost to the circuit forever. It has gone out into space like heat from a stove and it is this energy which affects the receiving aerial which acts as a receptor.

Generally speaking, the elevated aerial wire is most convenient as a radiator and receptor. It is true, however, that a loop aerial, if its dimensions approach those of the elevated aerial, will function equally as well as an aerial as a radiator and a receptor. The coil or loop aerial works best on short wavelengths. As a matter of fact, the amount of received current in a loop varies in inverse proportion to the cube of the wavelength. The loop aerial also has directional characteristics which make it valuable as a direction finder and interference eliminator.

Height of the Aerial.—It is assumed that most of the readers of this volume will be interested more in the aerial as used with a receiving set than as used with a transmitter, consequently a detailed discussion of the receiving set aerial will be undertaken.

To most people the aerial is the most conspicuous part of a radio set and it is indeed an important part of the radio equipment. For ordinary purposes a receiving aerial may consist of a single strand of copper wire 100 to 125 feet in length erected between two supports usually fifteen or more feet above the ground. It is important to erect the aerial as high as possible when using a crystal detector but with the adoption of the vacuum tube detector and amplifier a great height for the aerial is unnecessary.

When using a crystal detector set, a general rule is to erect the aerial as high as possible. If the aerial in such a case is so high up that the length of wire from aerial binding post on the receiving set to the farthest end of the aerial is more than 150 feet it is necessary to put a variable condenser in series with the aerial lead to the set in order to be able to cut down the natural wavelength of the aerial circuit and permit tuning-down to wavelengths in the vicinity of two hundred meters and lower.

When a vacuum tube receiver is employed it is advantageous to use a low aerial for two reasons:

first, so called static or atmospheric interference is cut down considerably; second selectivity of tuning is increased to a considerable degree. Both of these advantages are to be had without a loss of signal strength to any marked degree. This is shown by the curves in Fig. 17. Curve A

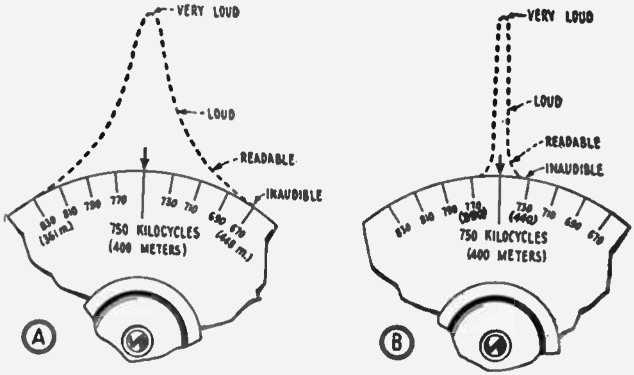


FIG. 17. Curve A shows the "broadness of tuning" resulting from the aerial being erected too high. Curve B shows the "sharpness of tuning" possible with the same aerial erected in a lower position.

shows the effect using an aerial 35 feet, and curve B the same aerial 15 feet above the ground. The same receiving set was used in both cases. The signal strength with the 35 foot aerial is only slightly greater than when using the 15 foot high aerial. On the other hand, notice that the signal in case A is heard between the tuning range 830 to 670 on the receiver tuning dial while in case B the signal is heard only between the range 770 to 730 on the dial. In the first case, the dial may be moved 160 kilocycles. In the second case, the signal is heard only over a range of 40 kilocycles on the dial. The first case shows poor while the second shows very good selectivity.

The importance of aerial height is readily seen from the explanation already given and must be considered in planning the aerial.

Aerial Erection.—Aerials are divided into several classes but only those types generally used by the radiophone listener will be described here.

The most common type of receiving aerial is the one wire type, strung between two convenient points. The next in order is the inverted L type of aerial consisting usually of four wires, as shown in Fig. 16. It is called the inverted L because of the fact that the lead-in wires are taken from one end and the system of wires as a whole resembles an inverted L. The T type of aerial is the same in construction as the inverted L except that the lead-in wires are taken from the center instead of from one end.

The two most important points in connection with the erection of the aerial is that it be properly insulated and that it be not surrounded by obstructions, such as buildings, trees and other aerials. An insulator should be placed at every point where the aerial wire touches a support. There are no exceptions to this rule.

The aerial should be erected as far as possible in a clear space free from trees and tall buildings, especially steel buildings. A good aerial for broadcast receiving may be made by stringing a copper wire about 100 feet long between two points as explained before and in such a position that the lead-in wire shall not be over 25 feet in length. (See Fig. 18.) A good inverted L or

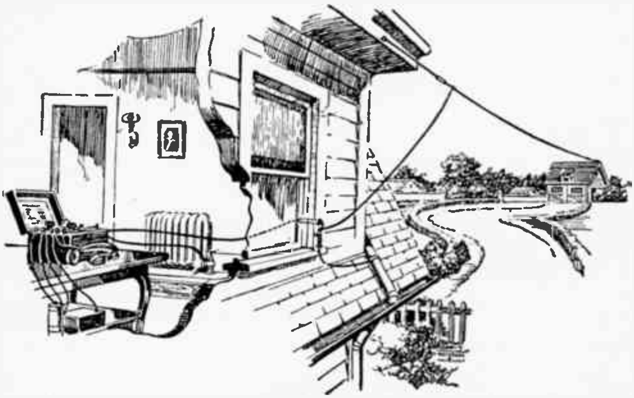


FIG. 18. An aerial should be erected in a space free from surroundings. The above aerial is an ideal one for broadcast receiving.

a T type aerial may consist of four wires fastened three feet apart to a spreader. It may be from 25 to 60 feet high and 100 feet long. The lead-in wires may taper to a point where the lead-in enters the building.

Wire for aerial construction is preferably of copper although a copper coated steel wire is now on the market which serves the purpose well.

Aluminum wire also serves the purpose but becomes extremely brittle after exposure to the elements and, therefore, is not used to a great extent. The aerial wire must offer little resistance to the flow of the high frequency radio currents and it is for this reason that copper rather than steel alone is used for aerial wire.

Care must be taken not to erect the aerial parallel to another nearby aerial or power line as induction from these is likely to be heard in the receiver. When induction causes much interference in the form of a constant buzzing in the receiver the remedy in many cases is to change the position of the aerial. This is especially true if the aerial is located near to and parallel with an aerial to which a regenerative receiver is connected. The radiation of feeble impulses from this receiver may cause interference in your set.

In installations that are intended to be permanent the question of making the aerial strong enough to withstand stormy weather must be considered. Commercial companies use an aerial wire made up of seven small strands of phosphor bronze wire twisted together. By this means a very great tensile strength is secured.

The table below gives the tensile strength of various kinds of wire.

Soft drawn copper	34,000 lbs. per square inch.
Hard drawn copper	50,000 lbs. per square inch.
Hard drawn aluminum	30,000 lbs. per square inch.
Phosphor bronze	90,000 lbs. per square inch.
Galvanized iron	50,000 lbs. per square inch.

It is difficult for the novice to solder aluminum wire but no such difficulty is found with copper wire. If aluminum is used it is important that it be of a good grade otherwise it will soon corrode, become brittle and break down.

All connections of a good aerial are soldered. This reduces any possibility of resistance between joints.

If the aerial is supported by a mast supported by guy wires these guy wires should be broken at least in one place by an insulator. This is to prevent the guy wires from absorbing too much energy which rightfully should go into the aerial.

Glazed insulators are the best and the glazing should be of good quality and able to withstand bad weather.

The length of the aerial is important and for broadcast listening it should not be over 100 feet except in cases where the station to be received transmits on a wavelength about four hundred meters when the aerial may be 150 feet long. If after erection the aerial is found to be too long the remedy is to insert in series with the aerial a variable condenser. In this way the effective length of the aerial can be reduced as much as fifty per cent.

The aerial in a way similar to everything else may get old and dirty, the connections become poor and the insulation bad. To safeguard against poor receiving results because of this inspect the aerial at least every six months and if it doesn't look good it may pay to erect a new one. A new aerial with clean insulation always improves the range of a receiving set. If after using your set for some time it seems to lose its old time efficiency try a new aerial. Many times this is the main trouble with a set.

Great care should be taken in the method employed to insulate the lead-in wire where it comes through the building. It should be brought through a porcelain tube or a small hole drilled in the window pane.

In some respects the transmitting aerial differs from the receiving aerial but principally in insulation and methods of bringing in the lead-in wires. In a great many respects similar rules apply to both.

Indoor Aerial.—In the city it is sometimes inconvenient to erect an outdoor aerial and in such a case an indoor aerial as shown in Fig. 19

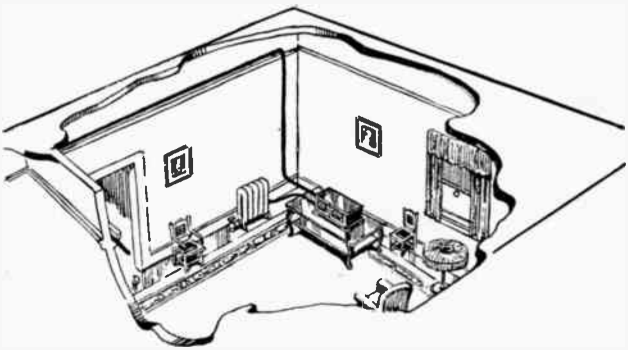


Fig. 19. How an indoor aerial might be installed.

may be employed. Any kind of copper wire may be used, the smaller the wire the less noticeable it will be. It may be tacked along the upper edge of the picture moulding and in this way made very inconspicuous. There should be at least 75 feet of wire used and as much as 125 feet if possible.

An indoor aerial will give good results for local signals provided the building in which it is erected is not all steel. In nearly every case, however, an outdoor aerial will give better results than an indoor aerial. The indoor type may be easily erected and is worth trying out. If it does not work, plans should be made for an outdoor aerial.

Lightning Arrester.—The lightning arrester is a protective device which is connected between the aerial and the ground to provide a path to the ground for high voltage charges gathered on the aerial which otherwise might discharge at the point of weakest insulation and shortest path to the ground causing a spark which may result in fire. A common type of arrester now being sold looks like a large electric cartridge fuse. Inside are two terminals spaced a fraction of an inch apart. A vacuum is pumped into the shell of the container and the gap between the two terminals offers little resistance to a high voltage electric charge. As a matter of fact, after the spark has jumped across the gap, the device is a good conductor of electricity and serves as an automatic switch which connects the aerial to the ground. Lightning arresters are made in two types, namely, indoor type and outdoor type. There is also a universal type which may be used either outdoors or indoors. The type made for indoor use cannot, however, be used outdoors. In most sections of the country the indoor type is not approved of by the Underwriter's Regulations.

In selecting the lightning arrester, ease of installation is an important factor. It is also of consequence that the device comply with the Underwriter's Regulations. In other words, it must be of an approved type. This is usually stated on the label and should be looked for.

When properly erected an aerial is a protection rather than a menace. In a lightning storm it acts, as a matter of fact, like a system of lightning rods. It is not so long ago that this sort of protection was considered essential, at least in suburban sections. In case of a direct stroke, a protective device such as an arrester or even a grounding switch is of little value as the power contained in a stroke of lightning is too great to be controlled without the use of apparatus far beyond the cost of radio set owners. Lightning arresters will, however, drain the aerial of all electric static charge over 500 volts and conduct it safely to the ground.

It is interesting to know that in a period of fifteen years there is only one case in the City of New York in which an aerial was struck by lightning. Another remarkable case is one where the aerial was erected above some telephone wires. The lightning struck the telephone wires, but left the aerial undamaged.

Lead-In.—Bringing the lead-in from outdoors to the set is often a problem to the set owner. There is sold a specially designed lead-in connector which is a piece of copper strip fitted with connectors on both ends and heavily insulated which fits on the window sill and makes the drilling of a hole unnecessary. This type of lead-in is not approved by the Underwriters and is used at the owner's risk. A lead-in to comply with the regulations may come through an insulating tube inserted in a hole which has been drilled in the window sill. This tube should be preferably of porcelain and the wire passing through it must sit loosely and not be tight or binding in any way. This is indicated in the Figure 18.

Spreaders.—A spreader is used when more than one wire goes to make up the aerial. It is not common to employ this type of aerial unless the station is to transmit. Spreaders may be made of iron pipe, bamboo, or strong wood. The length of the spreader depends upon the number of wires and the length of the aerial. A safe rule is to spread the wire at least one-fiftieth of the length of the aerial apart. As an example, suppose the aerial is 150 feet long, then the wires should be spread about three feet apart. In no case, however, should the wires come closer than 18 inches apart. The more spreader the greater the capacity of the aerial as a whole.

Guy Wires.—When guy wires are used to support a mast or to prevent spreaders from swaying they should be broken up into short electrical lengths of not more than 25 feet by means of strain insulators. This prevents the guys from absorbing too much of the radio waves surrounding the aerial. For small equipments it is best to use a strong tarred rope instead of wire for guying purposes Rope, being a non-conductor, absorbs no energy from the aerial. But even when a rope is employed it is well to use strain insulators as carbon will gather on the surface of the rope and in wet weather may provide a leakage path to the ground.

Loops.—A loop or coil aerial is shown in Figure 20 and consists of a number of turns of wire mounted on a frame. Where it is difficult to erect an outdoor aerial or where a portable

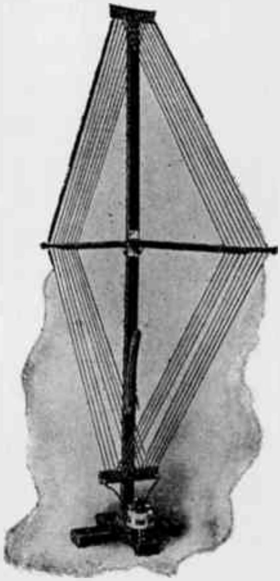


FIG. 20. Loop.

aerial is desirable the loop serves the purpose. It is, however, necessary that several stages of amplification be provided. The loop works best on such a set as the super-heterodyne.

The loop aerial has marked directional characteristics. By this is meant that the intensity of the received signal will depend upon the position of the loop and for this reason the loop is valuable in reducing interference. The loop may be used as a direction finder and the radio compass depends for its ability to indicate the direction from which received signals are coming on the directional characteristics of the loop.

The fundamental wavelength of a loop depends upon the size and number of turns of wire mounted on the frame. The table below gives the characteristics of several sizes of loop aerials as given in the Signal Corps Manual, "Principles Underlying Radio Communication."

Length of a side of the square in feet	No. of turns	Spacing of wire in inches	Fundamental wavelength in meters
8	3	½	160
6	4	¼	170
4	6	¼	174
3	8	⅛	183

Using the above data as a basis it is a simple matter to build a loop suitable for broadcast receiving. The two ends of the loop are connected, with a variable condenser in one lead, to the aerial and ground posts of the receiving set. A variable condenser can also be connected in parallel to the loop to increase its fundamental wavelength.

The loop operates in a way quite different from the aerial, depending upon having a current induced in it by passing electromagnetic waves rather than being charged like a condenser by these waves, as is the case with the elevated aerial wire.

One of the fundamental principles of the generation of electromotive force is what *when a conductor is cut by lines of force, a current is generated in it.* This current flows in a certain direction depending upon the direction in which the lines of force are cutting the conductor. If the direction of cutting is reversed the direction of current flow is reversed.

This is the principle of the simple alternator, a machine for generating alternating current. The conductor in the case of the simple alternator is the rotating armature and the lines of force are supplied by the field magnets. In principle the loop may be compared to the armature and the lines of force to the radio waves. In the alternator the armature moved and the field (lines of force) was stationary but in the case of the loop the lines of force, the radio waves (the field) move, and the armature is stationary.

It makes no difference which of these two prime requisites move, the condition being that the conductor shall cut the lines of force, the field, like the prow of a boat cuts the water.

In this last analogy, imagine the boat as the conductor and the water as the field of force. If the body of water is perfectly still and the boat is propelled we have a case of the boat (conductor) cutting the water (field). If, on the other hand, the boat is anchored in a rapid stream where a strong current of water is flowing, we have the case of the water (field) being cut by the boat (conductor).

In both cases the effect at the prow of the boat is the same and if we were to gaze at the prow and not take into view surrounding objects such as land there would be no different optical effect between the case of the boat moving in a still body of water or the water moving past a still boat.

The principle, when a conductor is cut by lines of force a current is generated in the conductor, is one of the most important things to remember in considering anything that has to do with electricity.

The loop has directional characteristics and is used in radio compass work. It is possible by employing a loop and a special receiving circuit to tell quite exactly the direction from which signals are coming. This is due to the fact that the amount of current induced in the loop by the passing radio waves depends upon the position of the loop in relation to the direction in which the radio waves are travelling. If the plane of the loop is turned at right angles to the source of the signals, the signal response is minimum. While, on the other hand, if the plane of the coil lies in the direction from which the signals are coming the current received by the loop will be maximum. This is due to the fact that in the first instance the voltage in both sides of the loop being in phase, tend to cancel each other and in the second case the voltage in the side of the loop nearest the transmitting station is out of phase with the voltage in the opposite side and, therefore, there is no bucking effect and a current flows in the loop.

When using a loop with a radio receiver it is necessary to use a variable condenser to tune the circuit to resonance. A loop to give best results should have just as many turns as the wavelength requirements will permit. The turns should be spaced well apart in order to get maximum inductance. The longer each side of the loop, the greater will be the induced voltage in each side and, therefore, the greater will be the signal strength received by the loop. It must not, of course, have a greater inductance value than that required for tuning.

Ground Connection.—The efficiency of the set as a whole is greatly dependent upon the efficiency of the ground connection. Sometimes it is possible to increase the volume of a received signal fifty percent by improving the ground connection.

There are various ways of making a ground connection and the method employed will depend upon the location of the receiving apparatus. In general it is best to have the ground lead as short as possible. Avoid long bended wires leading from the receiver to the ground connection. If in the city the best ground connection is made by connecting directly to the water pipe. A special ground clamp which can be purchased in any electrical or radio supply store should be used. The water pipe should be carefully cleaned with sandpaper making sure that all rust and other verdigris is removed so that the clamp can make a good connection. The wire leading to the receiver should be soldered to the ground clamp to insure good contact. Unless no water pipe is available the gas or radiator piping system should not be used.

In the country where no water pipe is available a good ground connection may be made by burying about 100 square feet of chicken fence wire about ten feet in the earth and the lead wire soldered to it. In making this sort of a ground moist ground should be chosen. Dry or rocky soil will not serve the purpose. It is sometimes the practice to fill in the hole which has been dug for the ground with charcoal to aid in keeping that particular piece of ground moist and to improve the connection between the fence wire and the earth. If fence wire is not available any kind of sheet metal will serve the purpose.

Counterpoise.—In sections where it is not possible to make a ground as described above a counterpoise may be used instead. A counterpoise takes the place of a ground and consists of a network of wires laid on but insulated from the ground similarly to the aerial. The wires of the counterpoise may stretch out radially from the center where the receiver is located. In area the counterpoise should cover about fifty percent more ground than the aerial system

Theoretically the counterpoise is one plate of the huge condenser of which the aerial is the other plate. This huge condenser constitutes the distributed capacitance of the open oscillating system. In many cases on record the transmitting range of a station has been increased to a very large extent by using a counterpoise instead of the usual ground connection to the earth.

On aeroplanes the counterpoise must be used because of the impossibility of making connection to the earth as in land installations. In these equipments the counterpoise may consist of a special network of wire or the stress guy wires; engine and other metal equipment are electrically connected together and formed into a counterpoise system.

The counterpoise is used to a great extent on portable equipments such as supplied to the Signal Corps of the Army. It is used where the ground itself is rocky in nature and where the earth is especially dry and sandy.

CHAPTER VI

FUNDAMENTALS OF RADIO RECEPTION AND RECEIVING APPARATUS

Introductory.—Receiving sets are divided into two well defined classes, those for damped waves, and those for undamped waves. In modern practice a receiver is so designed that, included in its general construction are methods for rapidly changing from damped to undamped reception and *vice versa.*

Sets for damped wave reception in practice involve the simpler connections and form a good starting point for any explanation of the subject, although it will be found that later, in discussing undamped wave receivers, very slight modifications of the damped wave apparatus will give one method of receiving undamped waves.

How the Detector Functions.—The human ear will respond to vibrations varying from a frequency of below 100 to above 5,000 vibrations per second. Vibrations occurring at a frequency higher than this are inaudible to the human range of hearing. Radio waves, as sent out by a transmitting station, oscillate at a frequency on the order of a million or more per second. It is, therefore, impossible to either record or even hear these radio oscillations as they are sent out. They must be transformed, so to speak, to an audible frequency of wave groups which will fall within the range of audibility.

It is the function of the detector to do this, and in so doing it acts as a rectifier. It is to be remembered that radio oscillations are alternating currents of a very high frequency. If it were possible to construct a telephone receiver which would oscillate at such a high frequency, no sound would be heard because the vibrations of the diaphragm would be above audibility. This is not possible, however, and the headphone does not reproduce radio waves directly as received. Then again, if the high frequency damped wave train were merely chopped up into groups with intervals between each group, each oscillation in a single group arriving so quickly after its predecessor would have a neutralizing effect on the diaphragm.

For example, let us assume that the diaphragm is drawn towards the magnets of the telephone receiver during the positive alternation of the current. Before the diaphragm would have time to come back to normal position and be forced away from the magnet poles by the negative alternation, the negative alternation has taken place, and other alternations have followed, perhaps several hundred times, and the result is that the diaphragm does not vibrate at all.

It is necessary, therefore, to rectify the current which means to allow only a flow of one side (alternations of the alternating current, either positive or negative, causing a series of alternations which in effect are rapid pulsations of current in one direction only. When damped waves or modulated undamped waves, such as telephone speech, is sent out these groups of oscillations, which build up from zero to maximum and down to zero again as many as 5,000 times per second, have the effect of an audible frequency current in the telephone receiver circuit due to the impedance or retarding effect of the circuit itself on the high frequency pulsations. The diaphragm, as a result of this, vibrates accordingly at an audible frequency

The two types of detectors which act as rectifiers are, namely, the crystal detector and the vacuum tube detector.

Test Buzzer.—When a crystal detector is employed it is sometimes necessary to have some way of testing whether or not the detector is in adjustment or is "set." For this purpose a test buzzer is usually fitted to a crystal receiver. Connections are shown in Fig. 31. A common ordinary buzzer or a special high frequency radio buzzer may be employed.

The buzzer circuit is inductively or conductively coupled to the receiver circuit. When the buzzer is set into electrical operation the high frequency oscillations produced by the make and break contact of the buzzer are rectified, and will be heard in the telephone receiver provided the detector is set to a sensitive point on the crystal. A test buzzer is not usually employed with a vacuum tube detector as this type cannot get out of adjustment provided the connecting circuits are correct.

Crystal Detectors.—A very simple and convenient form of detector is obtained by the contact of two dissimilar solid substances, properly chosen. The number of substances which have been found suitable for use in such detectors is large. This type of detector is easily portable, but requires frequent adjustment and is less sensitive than the vacuum tube.

Among the combinations of solid substances which have been used as contact detectors may be mentioned silicon with steel, carbon with steel and tellurium with aluminum. The most important contact detectors, however, are crystals, natural or artificial, in contact with a metallic point. Examples of such minerals are galena, iron pyrites, molybdenite, bornite, chalcopyrite, carborundum, silicon, zincite, and ceruscite. The first three are respectively lead sulphide, iron sulphide and molybdenum sulphide. Bornite and chalcopyrite are combinations of the sulphides of copper and iron. Carborundum is silicon carbide, formed in the electric furnace. The fused metallic silicon commonly used is also an electric furnace product. Zincite is a natural red oxide of zinc.

Probably the three most widely used crystals are galena, silicon and iron pyrites. Sensitive specimens of iron pyrites are more difficult to find than sensitive galena, but they usually retain their sensitiveness for a longer time than galena.

These sensitive pyrites detectors are often sold under the trade name of "Ferron." The detector sold under the name of "Perikon" consists of a bornite point in contact with a mass of zincite.

Fig. 21 shows a typical crystal detector. This particular sample being of silicon with an antimony contact point. Another excellent crystal is ceruscite and is sold under that name.

In order to act as a detector for radio signals a crystal contact should either allow more current to flow when a given voltage is applied in one direction than when it is applied in the opposite direction, or its conductivity should vary as different voltages in the same direction are applied. Practically all detectors formed by contact of two

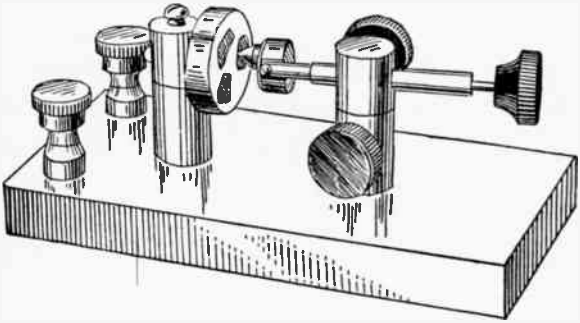


FIG. 21. Typical crystal detector.

dissimilar substances possess both of these properties, at least to a slight extent.

To make use of the latter property, a battery is required in series with the crystal, as explained below. Some crystals, such as galena, silicon, ceruscite and iron pyrites give about as good results as simple rectifiers as when the battery is used, and as a matter of fact, in common practice no battery is employed with them, thus making the apparatus more simplified and effecting economy.

In order to make use of the second property, a local or "booster" battery is inserted in series with the crystal. Generally a small battery of 2 to 4 volts, controlled by a potentiometer is employed.

Telephones.—The distinctive features of telephone receivers for radio work are lightness of the moving parts and the employment of a great many turns of wire around the magnet poles. The lightness of the moving parts enables them to follow and respond to rapid pulsations of current. The large number of turns of wire causes a relatively large magnetic field to be produced by a feeble current. The combined effort is to give a very sensitive receiving device. Inasmuch as the size of the wire used is always about the same (No. 40 copper), the amount of wire and therefore the number of turns is usually specified indirectly by stating the number of ohms of resistance in the coils. Telephone receivers of fair sensitiveness for radio work have about 1000 ohms in each receiver (measured in direct current), while the better ones usually have 1500 to 2000 ohms per receiver.

The most common type, called the magnetic diaphragm type, has a U-shaped, permanent magnet with soft iron poles, and a thin soft iron diaphragm very close to the poles, so that it vibrates when the attraction is rapidly varied, producing sounds to correspond with the frequency of the pulsations of current.

The impedance of a telephone receiver to alternating current increases rapidly with frequency, and at radio frequency is so great as to permit no passage of current. By the use of detectors, however, the current that passes in the telephone consists of a series of pulses of audio frequency, usually from 500 to 1200 pulses or vibrations per second. A typical telephone receiver having a direct current impedance (resistance) of 2000 ohms was found at 400 cycles per second to have an impedance of 2900 ohms, and at 800 cycles per second an impedance of 3900, rising to 4400 ohms at 1000 cycles per second. This is an excellent illustration of the ratio of the frequency to the resistance of telephone receivers.

Watch-Case Type Receiver.—The type of small receiver used in connection with radio is called the watch-case type to contrast it with the long receiver used on an ordinary telephone line. It is possible to make the radio receiver both light as well as small due to the extremely feeble currents handled in the circuit. The watch-case type of receiver permits the wearing of it on the head continuously with comfort. They are usually fitted to a leather or light steel head-band and the cases themselves are made of aluminum or hard rubber.

Two permanent magnets are formed by the ends of a horseshoe magnet, which is bent into a circular form, and fits snugly into the receiver case. On these magnets are wound several thousand turns of very fine insulated copper wire. Silk or enamel covered wire is most commonly used. The magnet coils are wound in opposite directions which makes one pole of the magnet North and the other South in polarity. The receivers are connected to the radio set by a bifurcated silk or cotton covered conducting cord, flexible and five or six feet long.

Sound is produced in the telephone receiver by virtue of vibration of the diaphragm, which is set over the magnets, and is affected by the current flowing in them. The diaphragm is bent in slightly when sitting in its normal position due to the pulling force of the magnets.

Great care must be taken in the manufacture and handling of the diaphragm not to bend it in any way. It is a very difficult matter to make a diaphragm perfectly flat and, therefore, every effort should be made by the persons using the receivers not to bend it out of shape. The efficient operation of the receiver depends in great part on the diaphragm being perfectly flat. It is true, of course, that a diaphragm may become bent as usage goes on, but this cannot be helped, and is usually so slight that it does no harm. If the diaphragm sits loosely over the magnets, or if it hits the pole faces of the magnets, a rattling sound will be heard when the receivers are being used. The remedy is to raise it slightly from the pole faces by inserting a paper washer under the diaphragm seat.

It is important that the diaphragm have equal clamping all around if the receiver is to work well. The reluctance of the magnetic circuit of the receivers depends upon the distance between the pole faces and the diaphragm. This distance should be as small as it is possible to make it without having the diaphragm touch the magnets. Usually it varies between 1/100 and 1/1000 of an inch. The inside of the receiver case should not be affected by temperature as a contraction or an expansion caused in this way would affect the air gap, referred to above, and disturb the efficient working of the receiver.

Sensitivity of Telephone Receivers.—Telephone receivers are rated in ohms. Those most commonly used for radio work being the 2,000 or 3,000 ohms type. It is logical to think that the rating of an instrument having to do with the reproduction of sound, such as the telephone receiver, would be an indication of its sensitiveness expressed in units directly related to this property. Such is not the case, however, since the rating of telephone receivers is according to the resistance of their magnet windings to direct current expressed in ohms.

The sensitivity of a telephone receiver depends upon the magneto-motive force exerted on the diaphragm by its magnets. Magneto-motive force in turn depends upon the number of turns of wire wound on the magnets and the current flowing through these turns. The actual value of these two things is summed up by referring to the number of ampere-turns of wire with which the magnets are wound. Since wire has resistance, it became the practice in the early days of telephone receiver manufacture to designate the number of ampere-turns by the resistance they offered, rather than by the more proper way of giving the amount of magnetomotive force they produced. The more ampere-turns on a magnet winding the more magnetomotive force produced. It is for this reason that extremely small wire is used on the magnet windings. The size used is usually No. 40 B. & S. American gauge.

If resistance alone was desired, telephone receivers would be wound with German silver or other high resistance wire. This is not desirable, of course, and it is not done. The resistance of a radio circuit being already high the insertion of high resistance telephone receivers has little effect on the efficiency of the circuit.

Telephone Receiver Troubles.—The magnets are usually made of the best grade of tungsten or silicon steel and are permanent magnets. If the receivers are dropped very many times they lose their sensitiveness due to the fact that any permanent magnet tends to lose its magnetism if severely jarred. Telephone receivers should, therefore, be handled with care.

If a telephone receiver loses its magnetism it may be remagnetized. This is usually done by a manufacturer who has special apparatus for this purpose. The process calls for the bringing of a larger magnet of opposite polarity in contact with the magnet to be remagnetized. An especially strong magnetic field produced by a solenoid is sometimes used. A magnet which has lost its magnetism has had a disarrangement of its molecules and to remagnetize it means to again arrange these molecules into an order which will properly concentrate their magnetic power at both ends of the magnet.

If the diaphragm of the receiver becomes bent in any way, the sensitiveness of the instrument is reduced. Never, therefore, take a receiver apart unless absolutely necessary and never poke a pencil or other prong into the cap opening so that it touches the diaphragm.

An open magnet coil will make a receiver inoperative, and in case of trouble the windings of the magnets should be inspected for a break, especially at the point where the terminals are soldered to the connecting terminals.

The magnets will also tend to lose their magnetism if the diaphragm is left off the magnet faces, and this obviously should not be done.

Telephone receivers used for radio work may be tested by wetting the tips of the receiver cord on the tongue and bringing them together with a snappy motion. If they are sensitive a slight click will be heard, due to the feeble current generated by the friction of one tip on the other.

Mica Diaphragm Type.—Another very efficient type of telephone receiver used in radio work is called the mica diaphragm or Baldwin receiver. This type differs radically from the ordinary receiver previously described, in that it has a mica diaphragm which is not acted upon directly by the magnets, but is independently balanced and actuated by an armature set between magnetic poles. There is no strain on the diaphragm unless a current is passing through the magnets or, in other words, unless a signal is being received.

The principal advantages of this type of receiver are as follows: responsiveness to extremely feeble signals due to the small current necessary to actuate the armature, a small magnetizing force will cause a relatively large deflection of the diaphragm with a correspondingly intensified signal strength, due to the mechanical construction of the armature and diaphragm on a lever arrangement.

When this receiver is used with a vacuum tube detector or any other detector requiring a battery current in its operation, there is a slight pull on the diaphragm even when no signal is being received. The statement above to the contrary applies only when a no battery detector is used.

Inductance.—Inductance may be defined as the property of a circuit by virtue of which energy is stored up in electromagnetic form. Physically speaking, inductance takes the form of a coil of wire in a radio circuit. Wherever an electric current flows, a field of force is set up surrounding the conductor carrying the current. The conductor, if formed into turns of wire in a coil form, is termed an inductance coil or simply inductance, for short. When a conductor is coiled the fields of force about each turn interlink and strengthen each other. Therefore, if inductance is desired the conductor is coiled to get the concentrated effect of the field surrounding the conductor as a whole.

The following pieces of apparatus are used for their inductance effect in a radio circuit; variometer, vario-coupler, loading coil, grid coils (for transmitters), receiving transformer or loose coupler, honeycomb coils, duo-lateral coils, multistep inductors (load coils), and tuning coils.

Capacity.—Capacity may be defined as the property of a circuit by virtue of which energy is stored up in electrostatic form. Because the term capacity most commonly used to designate this property in a circuit is rather misleading, it has been suggested that the word capacitance be used when referring to radio and electrical circuit properties. This is in order to differentiate between the term "capacity" when used to designate the physical holding capacity of a container such as a box or barrel.

Capacitance, in concentrated form in an electrical or radio circuit, is obtained by the use of a condenser. A condenser may be charged with electrostatic energy and discharged at any desired time after it has been so charged. It will retain a charge until a path has been provided for the charges accumulated on its plates to flow together or neutralize, so to speak. A condenser consists of two conducting surfaces separated electrically by an insulator known as the dielectric. The value of capacitance in a condenser depends upon the area of the conducting surfaces and the kind and thickness of the dielectric used. Capacitance is found in the radio circuit in the form of receiving and transmitting condensers. They are made up as fixed, variable and adjustable condensers. A variable receiving condenser is shown in Fig. 22 and a small fixed condenser is shown in Figure 23. This type of fixed condenser is used mostly to shunt the telephone receivers and causes the signals to come in stronger and clearer. Its capacity is approximately .0165 microfarads. It is called a by-pass condenser when used with any detector which employs a battery in its operation. The main difference between receiving and transmitting condensers is in the dielectric used. In transmitting circuits where the potential of the

FIG. 22. Variable receiving condenser.

FIG. 23. Fixed receiving condenser.

current flowing in the condenser circuit is high a dielectric such as mica or glass is used. On the other hand, where the potential value of the current is low as in receiving circuits, the dielectric not being subjected to a strain may be air or a much thinner form of mica, or even paraffin paper.

Inductance and Capacity.—Every radio circuit is made up of inductance and capacity. In other words, it has an inductance coil and a condenser. Either or both of these pieces of apparatus may be variable. The natural period or wavelength of a circuit depends entirely upon the value of the inductance and capacitance in the circuit. Changing either or both of these values changes the wavelength of the circuit. As was explained in the discussion on resonance the receiving circuit must be tuned to the transmitting circuit, or, in other words, the combined value of inductance and capacitance in both circuits must be the same. Adjusting the inductance and capacitance in this manner and for this purpose is called tuning.

The unit of inductance is the Henry and is the value of inductance through which a current changing at the rate of one ampere per second will produce a pressure of one volt. The Henry is too large for practical use and one-thousandth part of it, the milli-henry, is the practical working unit. For very small values the micro-henry is used, which is equal to one one-millionth of a Henry. Inductance is also measured in centimeters, one milli-henry being equal to one million centimeters.

The unit of capacity is the Farad and is the value of a condenser's capacity when it takes one coulomb of electricity to raise it from zero potential to one volt. The Farad is too large for practical use and one millionth part of it, the microfarad, is the practical working unit.

Receiving Coils and Condensers.—The coils used in receiving apparatus are very simple in construction, being usually wound in a single layer of wire on a bakelite, pasteboard, or other insulating tube. The wire is usually covered with an insulation of silk or cotton, both solid and stranded wire being used. In the older type of apparatus, one or two sliders make contact with any desired turn of wire, the insulation being scraped off on top of the wires along a narrow path lengthwise of the coil. More modern sets use no sliders, but have switches whose points are connected by tap wires to turns of wires in the coil. One switch takes care of single turns, and the other switch makes contact to groups of, say, ten turns each. The construction of a rough example of this type is explained in the chapter explaining how to construct a receiver, found later in this volume.

Loading coils are merely large coils used to increase the inductance of the circuit when the inductance of the receiving oscillation transformer is not great enough to be tuned to the wavelength received.

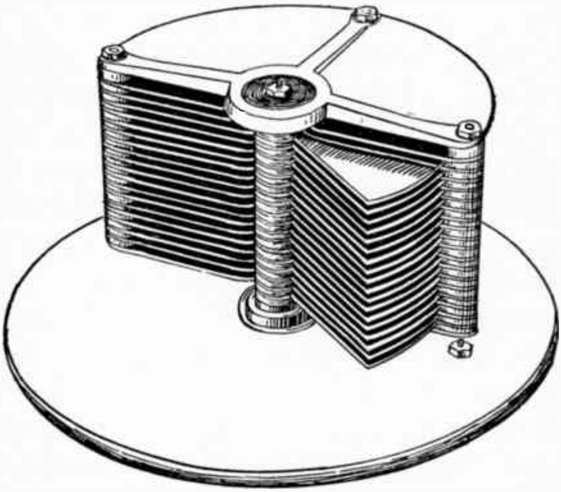


FIG. 24. Inside view of variable condenser.

Fig. 24 shows a typical receiving variable condenser with air dielectric, which is generally used. The maximum capacity of these receiving condensers for short wave receivers, is usually 0.005 microfarads, adjustable to a minimum of nearly zero. A set of semi-circular metal plates is rotated between a corresponding set of fixed plates, forming alternate layers of air dielectric (insulation) with adjacent conductors of opposite polarity. In damped wave reception the finer secondary tuning is done by a variable condenser. In working with vacuum tubes most of the tuning is done with variable condensers. In the primary it sometimes happens that, with undamped or continuous waves, the tuning must be closer than that afforded by single turns of the primary inductance coils, so a variable condenser is placed in parallel with the primary and used for fine tuning.

Tuning Coil.—A tuning coil serves to bring the receiving station in tune with the transmitting station. The usual form of tuning coil consists of a single layer of insulated or spaced bare wire wound upon a cylindrical form. The inductance value of a tuning coil is varied by a sliding contact, which makes contact with individual turns of the coil, or by a multipoint switch which is tapped off to a small number of turns for each contact. A tuning coil may have more than one variable contact and in this case is called a double or triple slide tuner. Figs. 26, 27 and 28 show how the tuning coil is connected in the receiving circuit. Fig. 26 shows L as the single slide tuning coil. Figs. 27 and 28 show a double slide tuning coil.

Open Oscillating Circuit.—The aerial and that portion of the tuning coil from the aerial contact to the ground is the open oscillating circuit. It is called the open circuit because there is no concentrated form of capacity in shunt to the inductance, but rather a large distributed capacity in the form of the aerial and ground. The oscillations in this circuit must flow through the air between the aerial and the ground in order to complete their oscillation. In other words, the circuit is, so to speak, an open one. (See Fig. 28.)

Closed Oscillating Circuit.—The closed oscillating circuit consists of the inductance, L-2, of the tuning coil (Fig. 28) and the condenser, C-2. In this case the circuit is closed due to the inductance and capacity being concentrated in the tuning coil and variable condenser, providing a circuit in which L and C (inductance and capacity) are lumped. When a tuning coil is connected as in this figure the turns from the aerial contact to the ground are part of both the open and closed circuits, and are said to be common to both circuits.

Loose Coupler.—This is the common name of the inductively coupled receiving transformer.

It consists of a primary and a secondary coil, shown at L-1 and L-2 respectively (Fig. 29), which telescope one another. By adjusting the movable coil, whether it be the primary or secondary, the mutual induction between the open and closed circuits is varied and tuning accomplished.

The tuning coil and loose-coupler have been largely replaced in modern receivers by the variocoupler and variometer.

The primary of the loose-coupler is usually larger than the secondary coil and is wound with larger wire. The inductance is varied by either a sliding contact or a multipoint switch.

The secondary of the loose-coupler or receiving transformer, as it is properly called, is wound with a smaller size wire than the primary and has a higher value of inductance. This is necessary because all the inductance of the closed oscillating circuit must be contained in this coil, there being no extra inductance in the form of an aerial or ground wire as in the open oscillating circuit of which the primary is a part.

Variocoupler.—The variocoupler is a form of inductively coupled receiving transformer compactly made into one unit. It has a primary and a secondary, the same as the loose-coupler described above, and in theory its operation is the same as this type of instrument. The coupling between the coils is varied by turning the secondary coil in a circular motion. This coil is mounted on a shaft. The variocoupler is usually employed with the vacuum tube detector. It is not so efficient as the loose-coupler type of receiving transformer when used with a crystal detector, because of the method employed in mounting the secondary. The variocoupler takes its name from the variometer which works on a similar principle, but has instead of two separate inductance coils, a single circuit which is split and mechanically constructed into two coils.

Variometer.—The variometer is shown in Fig. 32 and consists of two coils, one stationary and the other movable, wound with insulated wire. The coils are wound in opposite directions. The principal advantage of the variometer form of tuning inductance is the inductance value of the instrument as a whole may be varied without using contacts of any kind, neither sliding nor multipoint switch as is the case with the variocoupler.

The movable coil is connected in series with the stationary coil, and together they form a straight electrical circuit. Each coil being wound in a direction opposite to the other sets up a correspondingly opposite field of force around it. In other words, one field tends to neutralize the effect of the other. Therefore, when the coils are closest together, one inside of the other, the both fields are bucking each other and the resultant inductance is at a minimum. On the other hand, when the coils are at right angles the effect of one field upon the other is at a minimum value, and the result is a maximum inductance, which is almost the total of the inductance of the stationary coil added to the movable coil.

Inductance Units.—Various types of inductance coils are used in receiving apparatus, all for the purpose of providing inductance for the oscillating circuit. The honeycomb coil is wound many layers deep, and each layer is wound over the other at an angle giving the entire coil the appearance of a honeycomb. By this method of winding, a large amount of inductance can be wound in a small space. These coils are made up in various sizes, small coils for low wavelengths, and larger coils for high wavelengths. A special stand, called a honeycomb coil mounting, is provided on which as many as three coils may be mounted in inductive relation. A means of varying the distance between the coils is provided on the stand. The tuning range is limited by the sizes of coils used. Coils are made to tune in a range from 145 to 21,000 meters.

Another form of inductance unit known as the slab coil is made up in the form of a very short spool of large diameter. On this is wound many layers of wire; the completed unit has the appearance of a slab. Some forms of slab coils are self-supporting.

The spiderweb coil is wound on a form which provides support for the winding in the shape of spokes, like in a wheel without a rim. The winding goes in and out between the spokes and the final form has the appearance of a spiderweb.

Lattice and basket wound coils are multilayer coils in which each winding is at an angle or staggered with reference to the preceding layer.

The inductance value of all of these inductance units are fixed in value, the proper inductance being secured by designing the coil unit to the required size and fitting the proper sized unit in the circuit.

Receiving Tuners.—Having discussed the principal units composing a receiver or tuner, we shall now turn our attention to the various types of tuners and their circuits.

The fundamental principle of the reception of signals is that of resonance, which has been discussed fully in the portion of this work devoted to transmitters. If the receiving circuits are tuned to oscillate at the same natural frequency as the incoming waves, these waves, though extremely feeble, will after a few impulses, build up comparatively big oscillations in the circuits. In reality, then, for the reception of signals, all that is needed is an antenna circuit tuned to the same wavelength as that of the transmitting station, and an instrument capable of registering the current which flows in the antenna connecting wire.

FIG. 25. Simplest form of receiving apparatus.

In Fig. 25 is shown the simplest connection for the reception of signals with a telephone receiver. It is suitable only for damp waves, and also will receive only waves from a transmitting station that correspond to its own, or nearly its own natural period. At D is shown the rectifier, commonly called a "detector," although, really, it detects nothing and merely alters the waves, so that the telephones may receive them. It must be remembered that the waves received are of radio frequency, which are inaudible to the human ear. The upper limit of audio frequency for the human hearing is about 15,000 sound waves per second, so that even if the telephone receiver diaphragm could, without the detector (rectifier), follow the radio frequency, the ear would not hear the signals; the detector rectifies the radio high frequency current, that is, allows but one alternation to pass through it, and lopping off, so to speak, the other alternation of the opposite direction, thus reducing the alternating to direct current and permitting audible signals to be heard in the telephones. In the above circuit it is true that the presence of the detector and telephones offers high resistance in the antenna circuit and renders it not very selective, so that it will respond to a wide range of wavelengths. Tuning to resonance is made possible if a tuning coil is introduced into the circuit, in series with the antenna, such as L in Fig. 26 to vary the inductance of the circuit and hence the wavelengths.

It is well to observe how simple is the apparatus actually needed for reception, contrary to what the uninitiated person supposes. Three pieces of apparatus, telephone receiver, detector (rectifier), and tuning coil will effectively receive damped wave signals. The main disadvantage of the circuit shown above is not being able to tune out stations that one does not wish to hear. Also the amplitude of the oscillations is much diminished by the high resistance of the detector and telephones. The principal resistance is that of the detector.

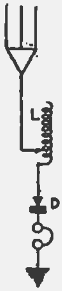


FIG. 26. Simplest form of tuned receiving apparatus. Single circuit receiver.

To avoid the difficulties attendant upon the presence of the detector in the antenna circuit, it is customary to place the detector in a separate circuit coupled to the antenna; or in other words the detecting instruments are placed in shunt to the tuning coil. For instance, Fig. 27 is an improvement and requires no more apparatus than that previously described, except that the tuning coil has two adjustable connections instead of one.

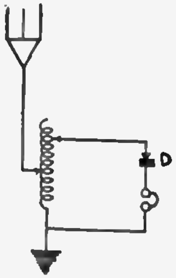


FIG. 27. Simple direct coupled receiving set without variable condenser. Two circuit receiver.

Oscillations now take place freely between antenna and ground. Two telephone receivers are shown, connected in series, one for each ear.

A further improvement, as regards selectivity, that is, elimination of undesirable signals, is shown in Fig. 28, where a variable condenser has been added, C_2. This is called the direct coupled

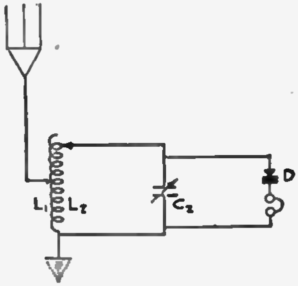


FIG. 28. Direct coupled receiving set with variable condenser. Two circuit receiver.

connection. The antenna circuit is called the primary or open circuit and consists of the inductance and capacitance of that circuit. The secondary in L_2 and C_2, known as the closed circuit. In the same manner in which the transmitting antenna circuit is a good radiator of power, so is the receiving antenna a good absorber. It is tuned to resonance with the incoming wave by adjustment of the inductance L_1. The power is given over magnetically to the secondary, which is tuned to resonance by adjustments to L_2 and C_2. Comparatively large oscillations result in the secondary, producing voltages across the condenser which are detected by the crystal and telephone, and which are not in either oscillating circuit, but shunted across the condenser of the secondary. The oscillations are not damped thereby and sharp tuning is obtained.

Inductively Coupled Tuners.—Hitherto, we have dealt with the simplest circuits possible for receiving damped or spark radio signals, circuits employing the least amount of apparatus and fewest adjustments.

In Fig. 29 is shown an inductively coupled receiving set, which may be said to be the standard set of modern practice, and the one upon which all later changes are based. A fixed condenser (F.C.)

of about 0.005 microfarads is shunted around the telephone and this increases the strength of the signals. Its action is explained as follows: Suppose the principal current flows downward through the detector (D) and telephone (T). While the current flows, the fixed condenser (F.C.) is charged with top plate positive. When

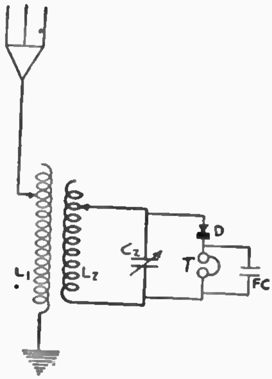


FIG. 29. Inductively coupled receiving circuit. Two circuit receiver.

the reversal of the radio oscillations comes, the current through detector and telephones ceases. Then the condenser discharges through the telephones and tends to maintain the current until the next oscillation flows through the instruments. In this way, the gaps between the successive pulsations of rectified current are filled in, and the cumulative effect of a wave group is strengthened. In practice the telephone cord, containing as it does two conductors separated by rubber, cotton and silk dielectric, forms a condenser which in many cases is sufficient so that an added fixed condenser gives no improvement.

The connection in this set is similar in its action to the direct coupled arrangement above described. In either case, on account of the coupling between primary and secondary coils, there are reactions of each coil upon the other, with consequent double oscillations when the coils are near together. It is found, however, that if the resistance of the circuits is low, by varying the coupling, extremely sharp tuning is possible. The antenna is tuned to incoming waves, by changes of the inductance L_1. If very sharp tuning is desired, a variable condenser is shunted around L_1, and fine adjustments are made therewith. The secondary is tuned to the primary, the operations of tuning being done alternately until the telephone gives the best response. In the secondary the coarser tuning is done by changes of the inductance L_2, and the finer tuning with the variable condenser C_2.

For receiving a longer wave in the primary circuit than is possible by using all of the inductance

L_2, a series inductance L_3 called a loading coil is added. This is shown in Fig. 30. Also, a variable condenser may be connected as shown at C_3 to increase the wavelength and afford fine tuning. The secondary may also be provided with an extra

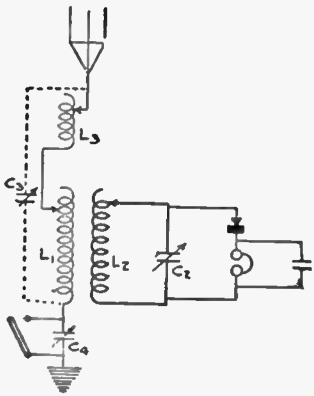


FIG. 30. Receiving circuit for both long and short waves, showing loading inductance and short-wave condenser. Variable condenser as in dotted lines to increase wavelength range of receiver.

inductance in series with L_2 if needed. For receiving short waves on a large antenna, series condenser C_4 is inserted in the ground wire. It is short circuited when not in use.

In the set described above, a crystal detector or rectifier is used as the detector. The principal disadvantage of this type of detector is that it cannot be depended upon to stay in adjustment. Much time would be spent and annoyance caused if the operator had to search for incoming signals. To obviate this trouble, auxiliary apparatus known as a "buzzer" is incorporated into the set. This arrangement is shown in Fig. 31. By setting

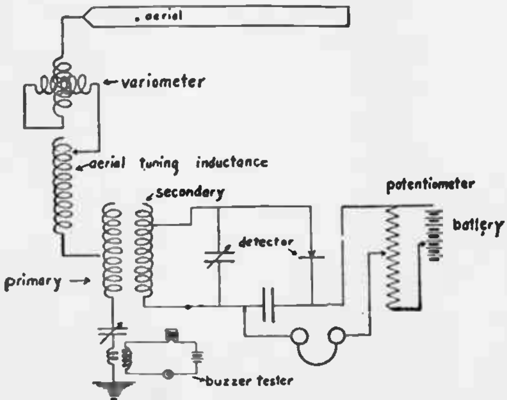


Fig. 31. Inductively coupled set with buzzer-testing circuit.

the buzzer in action, its notes are heard in the telephones, and by careful adjustment of the detector, when the loudest buzzer signals are heard so will the loudest response be heard from incoming radio signals. This buzzer thus enables one at all times to rapidly ascertain whether the detector is functioning.

Having dealt with receivers and circuits employing as a detecting device crystal rectifiers, we can turn to circuits utilizing vacuum tubes. These are rapidly replacing in modern apparatus the types we have just discussed.

Vacuum Tube Receiving Apparatus.—Radio receivers are divided into two general classes: Those using the crystal detector and those using the vacuum tube as a detector and amplifier. The crystal set is the cheapest of the two and the least efficient. For receiving over short distances, however, it is very economical as no batteries are required and the upkeep costs nothing.

The common question of which is the best receiver is a very difficult one to answer. It depends on what distances are to be covered, how much the buyer is willing to spend and whether or not a loudspeaker is to be used. Then the kind of an aerial to be used is important. In all cases an outdoor aerial is preferable to the indoor aerial and a loop aerial should not be considered unless at least three tubes, detector and two stages of amplification, are provided in the receiver.

It is best to be very conservative in arriving at the distances from which a receiver will receive.

In this connection it must also be remembered that the best receiver made will not receive from a place unless the transmitter at that place is powerful enough to reach the receiver. The place in which a receiver is located also affects very materially the distances that might be covered. Certain spots are known as dead spots and regardless of how good the receiver is the results are likely to be poor. The condition may result from surroundings such as tall trees, steel frame buildings or other structures, hills and mountains and other obstacles that would tend to shield the receiver from incoming waves.

The directional effects of the aerial to which the receiver is connected also affects reception and likewise the directional effect of the transmitting station's aerial will have an effect. By directional effect is meant that a transmitting station will carry much farther and a receiver will receive better from the direction opposite to the free end of the aerial if an inverted L type aerial is used. Other types of aerials have other directional characteristics. All of this affects the final results that a receiver will give.

If only reception from short distances is desired and a loudspeaker is not a requirement the crystal set serves the purpose well and may be installed at a cost ranging from ten to thirty-five dollars. The greatest advantage of the crystal receiver is that no batteries are necessary, the upkeep, then, after first cost is nothing. A good outdoor aerial must be used with a crystal set and a loop cannot be used. Under the best conditions a crystal receiver will receive broadcast programs over a distance not exceeding twenty-five miles. There are exceptions to this statement but they are not common.

The quality of the music and speech received through the crystal receiver are excellent but the volume is not great and a loudspeaker cannot be operated on the crystal alone without the use of vacuum tube amplifiers.

An important discovery recently made available to the radio-listener is the Lamp-Socket Aerial Plug. This is an attachment which screws into a lamp socket and permits the use of the electric light wiring of any house in the place of a regular aerial. The efficiency of this device is, however, problematical, as it works well in some instances and not in others. There is, of course, no current consumed even though the lighting system wires are used. As a matter of fact it is only one of the two wires of the electric light circuit that is connected to the receiver through the plug and this acts as an aerial. This attachment should be used with crystal receivers only.

The single tube receiver is recommended to those who desire reliable reception up to several hundred miles using the headphone only and not a loudspeaker. Single tube receivers as well as other receivers using one or more vacuum tubes should be preferably of another type than the single circuit regenerative as this type acts as a

FIG. 32. Variometer.

feeble transmitter and may cause howling in receivers located nearby.

A single tube receiver using the tuned reflex circuit will operate a loudspeaker over a distance of twenty-five miles. The three-circuit regenerative receiver is a very satisfactory type and permits also tuning which is highly desirable in the larger cities where many broadcasting stations are transmitting simultaneously. Fig. 33 shows a modern cabinet type receiver.

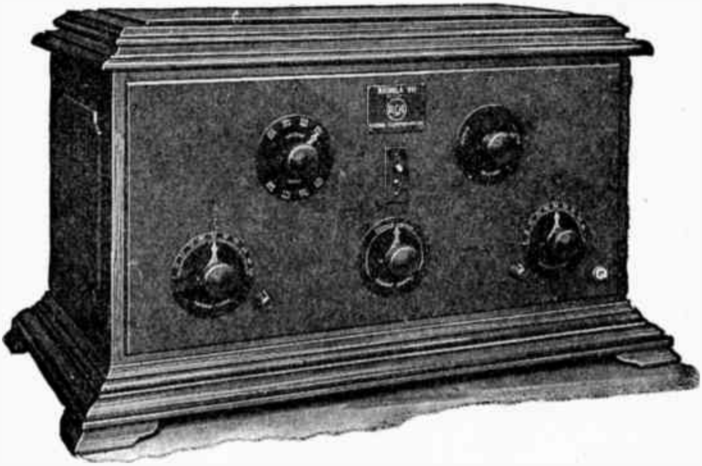


FIG. 33. Modern cabinet receiver.

The two tube receiver permits the use of a loud-speaker provided the transmitting station is not more than twenty-five miles away. The extra tube may be used with either audio or radio frequency amplification. Radio frequency amplification increases the distance over which a set will work but not the volume of the received signal. On the other hand using audio frequency amplification increases the volume of a received signal but does not increase the range of a receiver. The selection of the circuits and amplification to be used will therefore rest with the desires of the listener.

For the average broadcast listener the three tube set is desirable. With this equipment a loud-speaker may be used with much success. The in-door aerial and the loop may also be used with this set. Again the distance over which it is desirable to receive plays an important part in determining just what may be used with this set and as there is no set rule covering this problem it will vary with the location of the set. Wherever a loop is used the substitution of a good outdoor aerial will always increase the range and volume of the set.

The neutrodyne receiver explained elsewhere in this volume makes one of the most popular four tube sets. It will work well with a loop aerial and is ideal for portable work such as when carried in an automobile, small boat or at camp.

Five and six tube sets are particularly desirable where an outdoor aerial is not available and a six tube set will work as good on a loop as a three tube set will on an outdoor aerial.

Any vacuum tube set from the single tube to the six or more tube set can be made to operate on dry cells or on a storage battery. When dry cells are used the tubes will naturally not give as much volume as when storage batteries are used. It is, of course, to be understood that the dry cell tube cannot be used with a storage battery and vice versa for the simple reason that the filaments in each tube are of a different design and require a different current and voltage.

The distances that may be covered with a given set are much greater in the winter than in the summer and about double at night compared with the daytime. The best reception is to be had on cold, clear, moonless nights, the colder the better, it seems. For the most enjoyment a listener must be content with nearby stations; receiving from a distance is uncertain at best and can never be absolutely depended on.

Always ground the aerial during a thunder storm as it is positively dangerous to receive especially with headphones at such times. Operators have been known to be shocked while wearing headphones during an electric storm and equipment has been ruined by heavy current surges gathering on the aerial wires. There is, however, no danger whatsoever so long as the aerial is grounded.

For good loud reception it is necessary that fully charged batteries, a good long aerial at least one hundred feet long, a good sensitive loudspeaker, high plate voltage and careful tuning be used. It is also to be remembered that batteries will last much longer if moderately used than if the set is jammed to its utmost capacity at all times. In the long run moderately loud signals are the best on both the listeners and the equipment.

If a certain station continually interferes and it is impossible to tune him out try putting a variable condenser either in series with the aerial or across the aerial and ground post on the receiver. It might be that you cannot tune properly with the size of aerial that you are using. The condenser in series with the aerial will permit you to tune to a lower wavelength and when placed across the aerial and ground it will increase your wavelength range.

It takes considerable practice and patience before tuning is mastered. It helps to make a note

Wave Length	Primary	Primary Cond.	Secondary	Secondary Cond	Coupling	Tickler
150						
200						
250						
300						
350						
400						
450						
500						
550						
600						

Fig. 34. Tuning chart for recording receiver dial settings for various wavelengths.

of the positions of the various dials on the receiver at which certain stations are received. It is then possible to get ready to receive a given station before he actually starts sending the program. Such a chart is shown in Fig. 34.

The fundamental principle of tuning is that the receiver be placed in resonance with or tuned to the transmitting station. This means that if it is desired to receive from a station sending on 450 meters the receiver must be tuned to this wavelength.

CHAPTER VII

VACUUM TUBES IN RADIO

The introduction of vacuum tubes, also known as audions, audiotrons, vacuum valves and numerous other technical and trade names, resulted in remarkably great advances in radio communication. Such tubes may be used for many purposes, to generate, to modulate radio oscillations, to detect or rectify, as well as to amplify radio signals, and they are now used in all types of modern equipment. The further development of the tube is rapidly progressing and new applications of its use develop so rapidly that one engaged in radio work must be an assiduous reader to keep in touch with these new developments. Therefore, it is of the utmost importance that the principles underlying the use of vacuum tubes and their operation under the widely different conditions met in actual radio practice, be given careful study.

If two wires are connected to a battery, one to each terminal, the other ends may be brought very close together in air, yet so long as they do not touch, no current flows between them. The two ends may be enclosed in a bulb like an ordinary incandescent lamp, and the air pumped out, leaving a vacuum, and still as long as the ends are separated, no current flows. A common experience will illustrate this. When the filament of an electric lamp breaks, the current stops and the light goes out. But if one of the two wire ends mentioned above, is heated to a bright red, or hotter, it is an interesting fact that a current can be made to flow across the apparently empty space between them.

Call the two ends of wire the "electrodes" of the tube. The current between the hot and cold electrode is made possible by the electrons given off by the hot electrode and is a large enough current to be measured by a sensitive instrument and to have highly important uses in radio communication, as will be shown in the succeeding pages.

The Two-Electrode Vacuum Tube.—The question will perhaps arise as to how a single electrode can be heated when it is inside of a glass bulb. That is simply done by shaping it into a loop and both ends brought through the base of the bulb, in exactly the same manner that the filament of an incandescent lamp is used. These ends are connected to a battery of a few cells, generally giving a voltage of about six volts. The current from this battery heats the loop in a similar manner as the filament of the above mentioned electric lamp. Thus the hot filament becomes one of the electrodes. For the other electrode a little plate of metal is used. A bulb containing a hot and a cold electrode as thus described forms a "two electrode vacuum tube" and was originally designed by Professor J. A. Fleming.

The action of these tubes depends upon the fact that when a metal is heated in a vacuum it gives off electrons into surrounding space. A study of these electrons is important, the reason for this is that all matter contains them. Matter of all kinds is made up of atoms, which are extremely small portions of matter (a drop of water contains billions of them). These atoms in turn contain electrons which consist of negative electricity. The electrons are all alike and are much smaller than the atoms. Besides containing electrons, each atom also contains a certain amount of positive electricity. Normally the positive and negative electricity are just about equal. However, some of the electrons are not held so firmly to the atom, but what they can escape if the atom is violently knocked or jarred. Therefore, when an electron, negatively charged, leaves an atom, there is then less negative electricity than positive in the atom; in this condition the atom is said to be positively charged. The atoms in matter are constantly in motion, and when they strike against one another electrons are jarred from an atom. This electron then moves about freely between the atoms. Heat has an effect upon this process. The higher the temperature, the faster the atoms move and the more electrons given off. It is this action of electrons that is made use of in the vacuum tube.

As the electrons have a negative charge, the charge remaining on the metal is positive, therefore few of the electrons go very far, but are attracted back to the metal, so that there is a kind of balance established between the outgoing and the returning electrons. Now, suppose a battery is connected between the two electrodes, that is, between the hot filament and the plate. This battery is so connected as to make the plate positive with respect to the filament. The electrons, being of negative electricity, would be attracted by the plate and retained, returning no more to the filament. Thus the battery causes a continuous flow of negative electrons from the filament to the plate. In other words, a current of negative electricity is flowing in space between the two electrodes of the tube.

The current ceases when the filament is cold, because no electrons are then escaping from the metal. No current will flow if the battery is wrongly connected, since, when the plate is negative with respect to the filament, the negative charge of the plate will repel the electrons back into the filament.

The distinction between direction of current and direction of electron flow must be carefully noted. It happens that for a great many years the direction from the positive toward the negative terminal has been arbitrarily called the direction of the current. It is now found that these little electrons travel from the negative toward the positive electrode. The direction of current and the direction of the motion of the electrons are therefore opposite.

Ionization.—The foregoing explanation of the action of the flow of current between filament and plate, commonly called the "plate current," in a vacuum tube applies to the case where the vacuum of the bulb is very complete. If there is more than the merest trace of gas remaining in the tube, the operation is more complicated, and a larger current will usually flow with the same applied voltage. This is accounted for in the following manner:

In a rarefied gas, some of the electrons are constituent parts of atoms and some are free. These free electrons move about with great velocity, and if one of them strikes an atom it may dislodge another electron from the atom. Under the action of the emf. between plate and filament, the newly freed electron will acquire velocity in one direction, which will be similar to that of the colliding electron and the positively charged remainder of the atom will move in the opposite direction. Thus both of the parts of the disrupted atom become carriers of electricity and contribute to the flow of current through the gas. This action of a colliding electron upon an atom is called "ionization by collision," and on account of it relatively large plate currents are obtained in vacuum tubes having a poor vacuum. The earlier tubes were of this sort, but modern tubes, as a rule, are made with a better vacua than formerly, so that ionization by collision is responsible for but a small part of the current flow. However, tubes such as those above described are often in demand in radio practice for certain uses and are alluded to as "soft tubes."

In the earlier use of vacuum tubes it would seem an advantage to have ionization by collision, because a larger plate current can be obtained, but there are two difficulties which have proved so great that tubes are now usually made to have only a pure electron flow. One of these difficulties is a rapid deterioration of the filament when a large plate current flows. The positively charged parts of the atoms are driven violently against the negatively charged filament and since they are much more massive than electrons, this bombardment, so to speak, actually seems to wear away the surface of the filament. Another disadvantage of tubes of poor vacuum is that too large a battery voltage may cause a "blue glow" discharge. This action applies more particularly to the efficiency of "three element tube," described below.

The tube described above was the first used in radio practice and after its inventor is called the "Fleming valve." The Fleming valve was originally used as a detector, but has been replaced by the three-element tube discussed below because the latter has proved so much more sensitive, and as previously described, can be utilized for a variety of purposes.

However, before proceeding to the modern vacuum tube, it is well to consider that types of two-electrode tubes are most useful in another field of electrical work. One type, known as the "Kenotron," developed by the General Electric Company, has a higher vacuum than the Fleming valve and is made in larger dimensions. It is used as a rectifier of currents of high voltage, but low frequency. It changes alternating current into a pulsating current all in one direction. Small currents, well below one ampere, are rectified by these tubes, and power up to several kilowatts can be handled even if the applied voltage exceeds 25,000.

Another type, known as a "Tungar rectifier" is utilized for charging storage batteries from a 110 volt alternating current circuit. This type contains rarefied argon gas and relatively large currents are produced mainly through ionization by collision, in the manner before described.

The Three-Electrode Vacuum Tube.—A great improvement upon a two-electrode tube for radio purposes, consists in the addition of a third electrode or element, inside the tube in the form of a metallic gauze, or, as it is known, "grid." This grid consists of an electrode of fine wires between the filament and the plate of the vacuum tube. This makes it possible to increase or decrease the current between plate and filament through wide limits. In order to understand how this result is obtained, it will be necessary to first consider what happens in a two-electrode tube having a good vacuum, when either the voltage of the "B" battery or the temperature of the filament is varied.

Suppose that the filament temperature is kept constant, then a definite number of electrons will be sent out per second. The number of electrons that travel across the tube and reach the plate per second determines the magnitude of the current through the plate circuit. The number of electrons that reach the plate increases as the voltage of the "B" battery increases. If this voltage is continuously increased, a value will be reached at which all the electrons sent out from the filament will arrive at the plate, therefore we arrive at what is termed the "saturation" current, as no further increase of the electron flow can be obtained by increasing the voltage.

Suppose now that the voltage of the "B" battery is kept a constant value, and the filament temperature gradually raised by increasing the current from the heating battery, known also as the "A" battery. The number of electrons sent out will continue to increase as the temperature rises. The electric field intensity, due to the presence of negative electrons in the space between the filament and plate, may at last equal and neutralize that due to the positive potential of the plate so that there is no force acting on the electrons near the filament. This effect of the electrons in the space is called the "space charge effect." It must not be supposed that the space charge effect is caused by the same electrons all the time. Electrons near the plate are constantly entering it, but new electrons emitted by the filament are entering the space, so that the total number between filament and plate remains constant at a given temperature. After the temperature of the filament has reached the point where the effect of the electrons present in the space between filament and plate neutralizes the effect of the plate voltage, any further increase of the filament temperature is unable to cause an increase in the current. The tendency of the filament to emit more electrons per second because of the increased temperature, is offset by the increase in space charge effect, which would result if electrons were emitted more rapidly; or, to put it more exactly, for any extra electrons emitted, an equal number of those in the space are repelled back into the filament.

Thus, whether the "A" battery is kept at a constant value and the "B" battery varied, or *vice versa,* in either case we find that the electron flow or plate current can only rise to certain value.

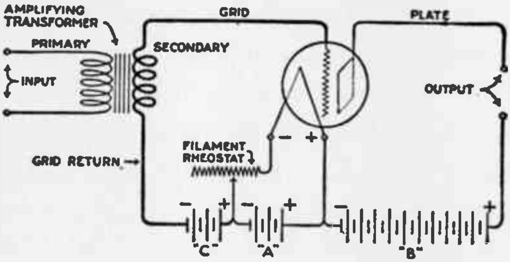


FIG. 35. Method of connecting A B, and C batteries in circuit.

In the three-electrode-tube, by inserting a grid between the filament and the plate, as stated before, in the form of several small wires, the grid is placed in the path of the stream of electrons which constitute the plate current. When this grid is charged positively, the space charge will be neutralized, as it is of a negative character and thus a greater plate current will result. Also, if the grid be charged negatively, the space charge will be increased, and a greater number of electrons driven back to the filament, with a lessening of the plate current. Thus it will be seen that the value of the plate current can be controlled by means of the third element or grid in the vacuum tube. This control is accomplished in a variety of ways, depending upon the use for which a given set is designed, also, upon the characteristics of the particular vacuum tube used. Various tubes have a variance of characteristics.

Circuits that may be utilized in the employment of the vacuum tube, showing various methods of vacuum tube control are to be found in the following pages.

As a Damped Detector.—We shall first take a simple detector circuit and an explanation of its action. In order to understand how a vacuum tube acts when used as a detector, consider the circuit shown in Fig. 36. Suppose the receiving antenna picks up a signal. Oscillations in the tuned circuit LC, are set up, because L is inductively coupled to the antenna circuit. The radio frequency alternating voltage between the terminals of L is impressed between the filament and grid, and brings about changes in the plate circuit. On the average the plate current is increased while the signal is passing. The frequency of the wave trains should be within the range of audible sound, preferably between 300 and 2,000, because the telephone inductance smooths out each train of high frequency oscillations into a single pulse and the pulse frequency must, therefore, be within the audible range in order that signals may be heard.

In some cases it may be necessary to use a "C" battery between points F and G in Fig. 36 in order to bring the plate current to a correct value. This,

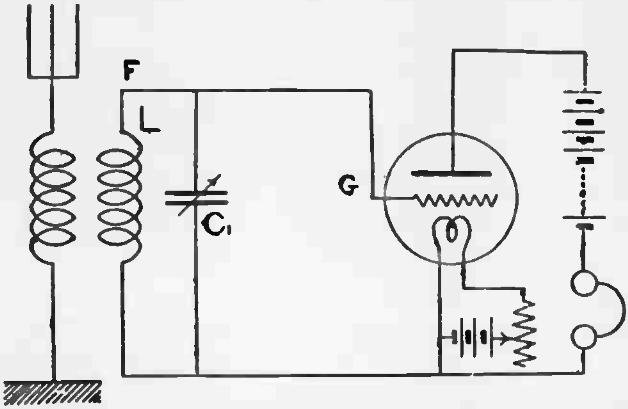


FIG. 36. Connections for using vacuum tube as a simple detector.

however, does not change the action; the variations of the plate current are brought about by the alternating emf. between the terminals of coil L just the same as when the "C" battery is absent.

If the grid battery voltage is adjusted so that the plate current has a value near the upper bend of the plate current-grid voltage curve instead of the lower bend, the action will be essentially the same, but the effect of the arrival of a wave train will be to decrease momentarily the plate current instead of to increase it. As before, there will be fluctuations of the plate current keeping time with the arrival of train waves, and a sound in the telephone of a pitch corresponding to the number of wave trains per second.

Care must be taken in the use of receiving tubes that the "B" battery voltage is never high enough to cause a visible "blue glow." The tube becomes very erratic in behavior when in this condition, and is very uncertain and not sensitive as a receiver. This is because the plate current becomes so large that it is unaffected by variations of the grid voltage. Furthermore, the tube gets hot and its safety is endangered by the blue glow discharge.

If the circuit shown in Fig. 37 is used, having a condenser in series with the grid, the action of the tube as a detector is different. When the grid voltage is the same as that of the filament and there are no oscillations, the grid current is zero; that is, no electrons are passing from the filament to the grid. Now suppose that a series of wave trains falls upon the antenna of Fig. 37, as shown in (1) of Fig. 38. If the circuit LC. is tuned to the same wavelength as the antenna circuit, oscillations will be set up in it, and similar voltage oscillations will be communicated to the grid by means of the stopping condenser C_2. (A suitable capacity value for this condenser would be 0.0001 mfd). Each time the grid becomes positive, electrons will flow to it, but during the negative half

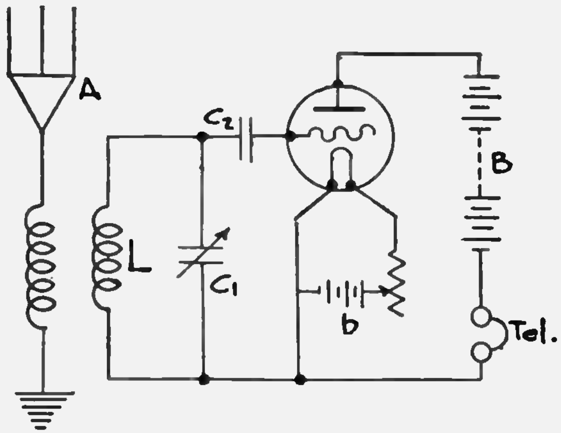


FIG. 37. Vacuum tube as detector of undamped waves. Condenser in grid circuit.

of each oscillation no appreciable grid current will flow. This is shown in curve (2) of Fig. 38. Thus during each wave train the grid will continue gaining negative charge and its average potential will fall as shown in (3) of the same figure. This nega-

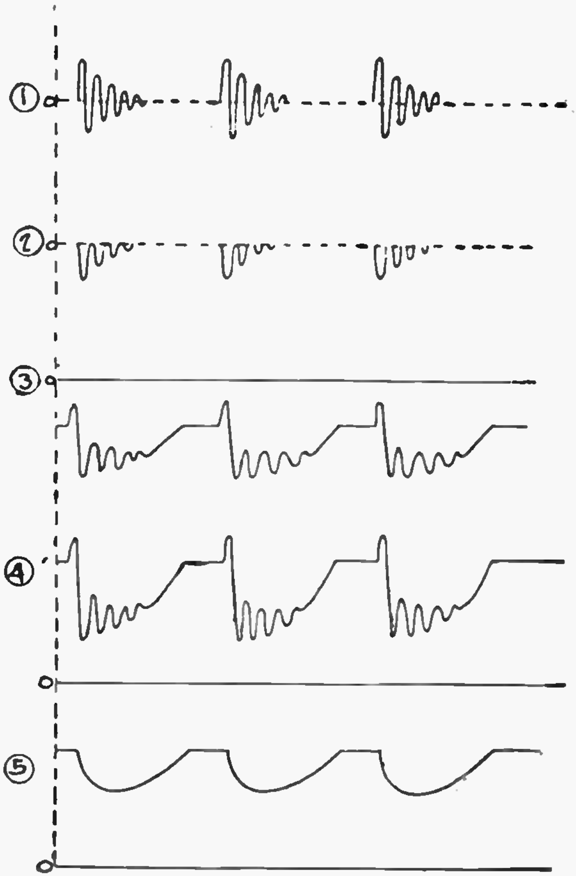


FIG. 38. Reception with grid condenser in circuit. (1) Incoming oscillations, (2) grid current, (3) grid potential, (4) plate current, (5) current in phones.

tive charge on the grid opposes the flow of electrons from filament to plate, causing, on the whole, a decrease in the plate current. At the end of each wave train this charge leaks off through either, the condenser or the walls of the tube (or both) and the plate current rises again to its normal value as shown in (4) of the same figure. This should happen before the next wave train comes along, but sometimes the leak is not fast enough for the discharge to take place. In this case a better result is secured if a resistance of a megohm or so is shunted across the condenser. Such a resistance is called a grid leak.

The telephone diaphragm cannot vibrate at radio frequency, but the high inductance of its coils smooths out the plate current variations into some such form as shown in (5) in Fig. 38. Thus as in the case of the circuit in Fig. 37, the note heard in the telephone corresponds in pitch with the frequency of the wave trains. To receive undamped waves which are not divided up into groups of audible frequency, vacuum tubes may be used in special ways called the heterodyne and autodyne methods, which are explained later in this chapter.

The Vacuum Tube As An Amplifier.—If, as in Fig. 39, a source of alternating e.m.f.

were interposed between the filament and grid of an audion the potential of grid with respect to the filament would alternate in accordance with the

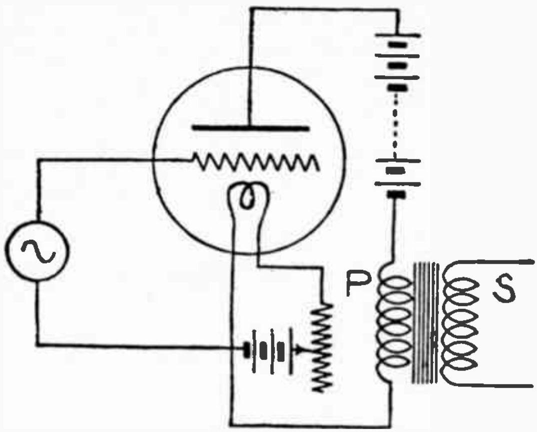


Fig. 39. Vacuum tube as an amplifier.

alternations of the generator. These variations of the grid potential produce changes in the plate current corresponding to the plate characteristic. If the mean potential of the grid and the amplitude of its alternations are such that the plate current is always in that portion of its characteristic where it is a straight line, then the alternations of the grid potential will be exactly duplicated in the variations of the plate current and the latter will be in phase with the former, at least in a high vacuum tube. Thus, if (a) of Fig. 40 represents the alternating potential of the grid, then (b) would represent the fluctuations of the plate current. For a given amplitude in (a) the amplitude of the alternating component in (b) will

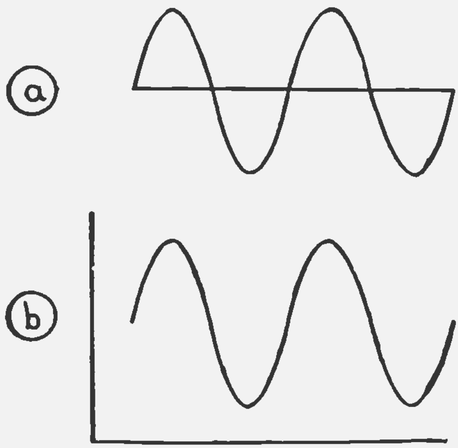


FIG. 40. Variations of plate current with grid voltage.

depend upon the steepness of the plate characteristic, increasing with increasing slope. The alternator in the grid lead supplies only the very small grid filament current, thus the power drawn from it is extremely small. The power represented by the alternating component of the plate current is, however, considerable; thus there is very large power amplification. This larger source of power might be utilized by inserting the primary P of a transformer in the plate circuit, as in Fig. 39, in which case the alternating component above would be present in the secondary S. This illustrates the principle of a vacuum tube as a relay. The voltage in S might again be inserted in the grid lead of a second vacuum tube and with proper design a further amplification obtained in the second tube. This may be carried through further stages and illustrates the principle of multiple amplification.

Regenerative Amplification.—It has been shown by Mr. E. H. Armstrong, that amplification similar to that obtained with several stages may be secured with a single tube. Instead of feeding the voltage of the secondary coil S into the grid circuit of a second tube it is fed back into the grid circuit of the same tube so as to increase the voltage operating upon the grid. This results in an increased amplitude of the plate current alternations, which likewise being fed back into the grid circuit increases the voltage operating upon the grid, etc.

One form of the so-called feed-back circuit for rectifying and amplifying damped oscillations is shown in Fig. 41. The operation of the circuit, used as a receiving device, is the same as that described above for the case of a condenser in the grid leak. The condenser C_2 is merely to provide a path of low impedance across the phones for

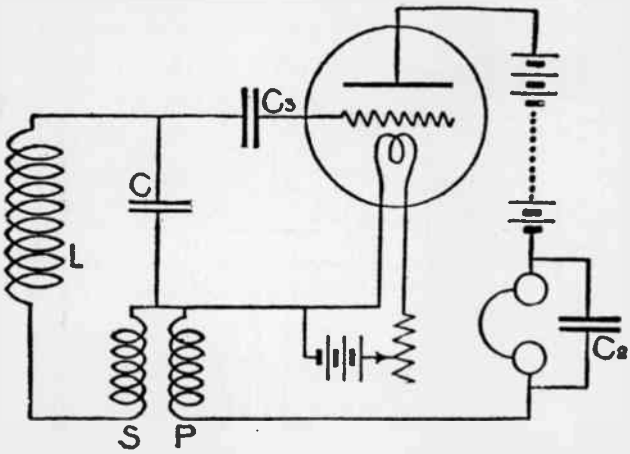


FIG. 41. Use of vacuum tube as a regenerative amplifier (feed-back circuit).

high frequency oscillations. The coils P and S constitute the feed-back by means of which the oscillations in the tuned circuit are reinforced. The mutual inductance between S and P must be of the proper sign, so that the e.m.f. feed-back aids the oscillations instead of opposing them.

Reception of Undamped Waves.—In Fig. 42 is shown the connections for the reception of undamped waves. This circuit was used by Dr. Lee DeForest, the inventor of the three electrode

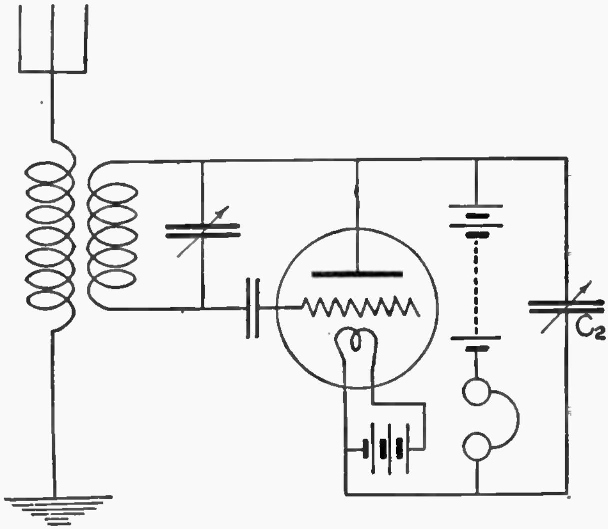


FIG. 42. Circuit for use of vacuum tube for reception of undamped waves.

vacuum tube, which he called an audion. He termed this circuit the "ultraudion." The oscillatory circuit is connected between the grid and the plate with a condenser in the grid lead. The variable condenser C_2 shunted across the plate battery and phones is important in the production of oscillations; in general, its value cannot be increased beyond a certain point without stopping the oscillations.

By this beat method high sensitiveness and selectivity are attained in receiving. Interference is minimized because even slight differences in frequency of the waves from other sources result in notes either of different pitch or completely inaudible.

Heterodyne and Autodyne Reception. —If two tuning forks mounted on resonance boxes, one vibrating 256 and the other 260 times per second are sounding together, a listener a short distance away will hear a sound alternately swelling out and dying away four times per second. These tone variations are called "beats." Similarly if two sources of undamped electrical oscillations act simultaneously upon the same circuit, one of a frequency of 500,000 and the other of 501,000, the amplitude of the combined oscillation will successively rise to a maximum and fall to a minimum 1,000 times per second. If rectified by a vacuum tube (or a crystal) their variations will produce an audible note of frequency 1,000 per second in a suitable telephone receiver. If one of the two oscillations is the received signal in the antenna and the other is generated by a circuit in the receiving station, we have "heterodyne" or "beat reception." In the receiving telephone a musical note is heard, the pitch of which is readily varied by slight variation of tuning of the local generating circuit.

If a regenerative circuit similar to that of Fig. 41 is used (L being coupled to the antenna), the same tube may be used as a detector and as a generator of local oscillations. This is called the "autodyne" reception. The procedure is to tune the antenna circuit to the incoming signals and adjust the local oscillating circuit so that it is slightly out of tune with these incoming signals. Thus beats of audible frequency are produced.

By these methods of reception very faint signals can be received. Also interference from other stations is reduced to a minimum, because a slight difference in frequency of the interfering signal would give a note of an entirely different pitch, or even inaudible. For instance, if the local oscillation had a frequency of 500,000 the received oscillation 501,000 and the interfering oscillation 502,000, the interfering note would have a frequency of 2,000, or be a whole octave higher in pitch than the received note. If the interfering source had a frequency of 530,000, its beat tone would be so high as to be entirely inaudible.

Oscillating and Non-Oscillating Circuits.—The oscillating vacuum tube circuit is one in which the plate circuit is coupled to the grid circuit as in Figs. 41 and 42. In this method of connection three important actions take place; first, the grid controls the plate current; second, the plate reacts upon the grid circuit due to the fact that it is coupled to it; third, the grid again affects the plate circuit in a more pronounced way, due to the added impetus of action two. These actions are called regeneration, and result in the original impulse, referred to as action one, being amplified many times its original value.

The non-oscillating vacuum tube is shown in Figs. 36 and 39. In both cases there is no coupling of the plate and grid circuits, and the tube acts merely as a valve, which automatically releases a large plate current every time an impulse is impressed on the grid. The grid in this case shuts on and off the plate current. In Fig. 36, therefore, no plate current flows until a signal is received by the aerial circuit and impressed on the grid.

"A" Battery.—The "A" battery is employed to heat the filament. The voltage of the

"A" battery depends upon the type of vacuum tube or tubes employed. It is important that the polarity of the "A" battery be in such direction that it will not oppose the plate battery to which a connection is made from one side of the "A" battery as shown in the diagrams. (See Fig. 35).

Usually the highest voltage employed for the "A" battery is six volts, and the smaller sizes of vacuum tubes will operate on as low as 1.1 volts. The current flowing into the filament is controlled by a rheostat, or some sort of special variable resistance device.

The brilliancy of the filament which is in direct proportion to its heating is controlled by the rheostat or other control device referred to above. This in turn affects the stream of electrons leaving the filament for the plate when the tube is in operation. A fine control of filament current is necessary when receiving weak signals. In some cases the wire rheostat does not give this fine control and a carbon variable resistance instrument is desirable.

"B" Battery.—The "B" battery is connected in the plate circuit with the positive terminal always connected to the plate of the vacuum tube. (See Fig. 35). Compared with the "A" battery, the "B" battery gives a high voltage.

This is required due to the operating characteristics of the vacuum tube. The "B" battery voltage varies from 22½ to 150 volts depending upon the particular tube and use of the tube in the circuit. A detector tube usually requires 22½ volts while a power amplifier may require 150 volts.

Because of the extremely small current consumed by the plate circuit the "B" battery will last for a relatively long time. Its actual life depending entirely upon the number of hours the tube is in operation.

Storage batteries made up in small sizes are now available as "B" batteries. These are made especially for vacuum tube operation and are desirable when the set is used a great deal. The first cost of the storage battery type is much greater than that for the dry cell type, but in some equipments it is cheaper in the long run to use the storage battery type. These are made up in both the lead acid type and the Edison cell type.

"C" Battery.—The "C" battery is connected in the grid circuit, and acts to keep the grid at a negative potential in respect to the filament. (See Fig. 35). It is especially effective when gas filled or so-called "soft" tubes are used. When the tube is used as an amplifier it acts as a valve to release the high powered plate battery current. Small changes in the grid potential in respect to the filament potential cause a large change in the plate current.

If distortion is to be prevented it is important to have the plate follow exactly the variations of the grid potential, otherwise the signals received will be blurred. Distortion usually occurs when the grid is positive in respect to the filament. Therefore, it is desirable to make the grid permanently negative. For instance, suppose that the maximum grid signal strength is eight volts, then if a "C" battery potential of four volts is applied to the grid negatively, the grid potential cannot become positive, and distortion, because of this characteristic, will not take place.

The method of connecting the "A", "B", and "C" batteries in the circuit are shown in Fig. 35. Particular notice should be taken of the polarity connections. If any of these batteries are connected in the wrong direction, the operation of the vacuum tube will be seriously interfered with.

Developments in Vacuum Tubes.—Research engineers are bending every effort towards the reduction of current necessary to light the vacuum tube filament, and to improve at the same time the operating characteristics of the tubes.

Great strides have been made in the refinement of tubes used for receiving purposes along these lines.

The most popular line of vacuum tubes is made by the General Electric Company, and sold in the Eastern section of the United States by the Radio Corporation of America as "Radiotrons," and in the Western sections of the country through the Cunningham organization as "Cunningham" tubes.

The UV-199 and the C-299 is designed for use as a detector and amplifier and operates on dry cells. The filament voltage is three volts and the current consumption is 0.06 amperes. A 30 ohm rheostat should be used as the filament current regulator. The plate voltage when the tube is used as a detector varies from 20 to 45 volts. The best voltage may be found by trial. When the tube is used as an amplifier the plate voltage may be from 40 to 80 volts, best found by trial. The "C" battery may vary from 1 to 4.5 volts, best found by trial. A grid condenser of .00025 microfarads shunted by a grid leak of from 2 to 6 megohms has been found to give satisfactory operation. The plate current varies from ¼ to 4 milliamperes.

This tube due to its small size acts only as a fair detector and audio frequency amplifier, but for radio frequency amplification it is very efficient. It is classed as a hard tube, which means that the vacuum is very high and little gas has been left in the tube. It is especially popular for portable sets, and sets having several stages of radio frequency amplification. Size of tube, 3½ inches high and 1 inch in diameter.

The UV-201-A and the C-301-A may be used as a detector or an amplifier, and was designed to replace the UV-200 and C-300. It draws only one quarter the filament current of these latter tubes, and is, therefore, more economical to operate. The filament voltage is 5 volts, and the current consumption is ¼ ampere. While this tube may be operated on dry cells, if the set is not used more than one or two hours daily, the storage battery as a source of filament current is desirable. It works best as an audio frequency amplifier, and only fairly well as a detector and radio frequency amplifier. In some cases, however, it has worked very well in these last two functions and is considered by some users to be good.

For filament current control a 16 to 30 ohm rheostat is necessary. When used as a detector the plate voltage may be from 18 to 45 volts, but when used as an amplifier from 40 to 120 volts should be provided. The "C" battery may be from 1 to 9 volts. The grid condenser and grid leak may be the same as for the UV-199 or C-299. It is a hard tube and gives good volume when used as an audio frequency amplifier. Although the filament requires only five volts a six volt "A" battery is usually used. Size of tube 4 3/16 inches high and 1¾ inches in diameter.

The WD-11 and the C-11 has a prong base and an adapter is required to make it fit in the standard base. The WD-12 and the C-12 is the same tube with a standard base. This type operates on a filament voltage of 1.1 and dry cells are used. For filament current regulation a 6 ohm rheostat is necessary. The plate voltage may be from 20 to 45 volts when used as a detector and from 40 to 90 volts when used as an amplifier. The "C" battery may be 1.5 to 3 volts. The grid condenser may be .00025 microfarads shunted by a grid leak of 2 to 3 megohms. The plate current is from ¼ to 4 milliamperes.

The outstanding advantage of this tube is that it may be operated on one dry cell. It was the first of the dry cell tubes and is very popular with thousands of broadcast listeners. It works best as a detector or audio frequency amplifier, but not so good as a radio frequency amplifier. It is classed as a hard tube.

The UV-200 and the C-300 is a soft tube, and considered by many to be the best detector tube available. Its filament voltage is 5 volts and the current consumption is 1 ampere. These characteristics make it somewhat expensive to operate and for this reason it has been largely replaced by the UV-201-A type.

This tube is very sensitive to filament adjustment and a 6 ohm vernier rheostat is necessary for "A" battery current regulation. The grid condenser may be .00025 to .0005 microfarads shunted by a grid leak of ½ to 2.5 megohms. The plate current is ¼ to 1 milliampere. Due to its high current consumption a storage battery is required for economical operation.

Thoriated Filaments.—The UV-201-A and the UV-199 type tubes have what is known as the thoriated filament. This filament is known to the research engineer as the X-L filament, and is perhaps the most important improvement in vacuum tubes since their perfection into their present form.

The old type of filament was made of pure tungsten and had many disadvantages; short operating life, weak electrical robustness, noise in operation and non-uniformity of electronic emission. All of these disadvantages have been eliminated by the thoriated filament. The old pure tungsten filament was burned at a fair brilliancy, while the thoriated filament is lighted with a very faint glow, sometimes hard to see during the daytime.

The important features of the thoriated filament are: during the life of the filament the electronic emission is several times that of the old type filament and only a fraction of the current necessary to light the old filament is necessary for the thoriated type. The table below shows how the UV-201, which has the old type filament, compares with the UV-201-A, which has the thoriated filament:

	Filament voltage	Filament current	Electronic emission
UV-201	5	1 amp.	7.5 milamps.
UV-201-A	5	¼ amp.	45 milamps.

It is seen that the electronic emission is six times as great when the thoriated filament is used, and the current consumption is only one quarter as great.

Due to the low operating temperature of the thoriated filament internal tube noises are practically eliminated.

The thoriated filament has a very long life due to its low operating temperature. As a matter of fact the life of this filament is terminated by the loss of electronic emission rather than by the burning out of the filament.

The X-L or thoriated filament is a tungsten filament in which a small percentage of thorium is mixed early in the process of manufacture. When the filament is heated in a vacuum there is a change from the chemical compound to pure thorium. By certain heating processes the thorium atoms are brought to the filament surface one layer deep. This layer has a high radio activity and accounts for the great increase in electronic emission from this type of filament as compared with the old type.

In order to keep the radio active surface of the filament clean certain substances are placed inside the bulb which prevent contamination of the filament by combining with the contaminating agents. In combining with the contaminating agencies the special substance placed inside the tube for this purpose forms a silverlike opaque coating on the inside of the glass bulb making the electrodes invisible. The X-L filament is also used in larger size vacuum tubes designed for transmitting purposes.

Noises in Tubes.—Certain noises heard in the radio receiver are due to the tubes themselves and are not static as a great many people believe.

Internal tube noises may be due to loose elements inside the tube which cause a variation in the internal resistance of the tube producing a microphonic noise. This kind of noise may also be caused by vibration of the cabinet or table on which the set is placed.

Soft rattles and hisses may be caused by erratic electron emission from the filament. In a soft tube a certain point will be reached where hissing starts, this point and above it is a poor operating point and operation should be carried on below this adjustment.

Sodion Tube.—The Sodion tube manufactured by the Connecticut Telephone and Electric Company is a radical departure from the ordinary type of three electrode vacuum tube. Its make up is shown graphically in Fig. 43. This type of tube

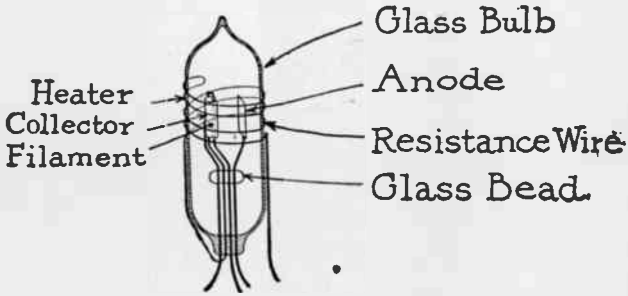


FIG. 43. Showing the parts of a Sodion detector.

consists of three elements; namely, the filament, the collector and the anode. All but the filament are of nickel. The wires holding the collector and the anode are sealed through the glass bead as shown. In series with the filament is connected a few turns of resistance wire which is called the heater, and serves to maintain the proper vapor pressure within the tube and provides the necessary potential for the collector. A small quantity of sodium is introduced within the tube during the process of evacuation which provides the proper operating characteristics.

FIG. 44. Sodion detector tube.

The finished Sodion tube is shown in Fig. 44. In size it measures 2¾ inches long and 1 inch in diameter. The bulb is frosted and the elements cannot be seen.

The theory of operation of the Sodion tube may be understood by referring to the Fig. 45A. When the filament is heated electrons are emitted in a relatively large stream. These flow to the collector without much loss, due to the large area of the collector and its close proximity to the filament. Because of this large electronic emission from the filament, and the magnitude of the stream reaching the collector, the tube functions very well as a detector.

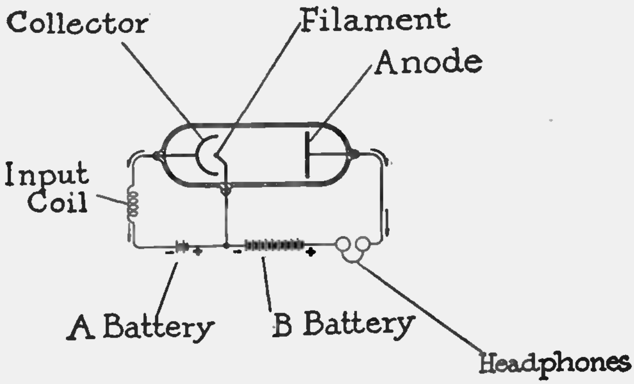


FIG. 45A. Schematic wiring diagram of Sodion showing position of A and B batteries.

The Sodion tube acts as a detector only and will not function as an amplifier. There can be no regeneration with the Sodion tube, therefore it does not interfere with nearby receivers. As a detector the Sodion tube works a trifle better than the ordinary three element vacuum tube, in a regenerative circuit, just below the point of regeneration.

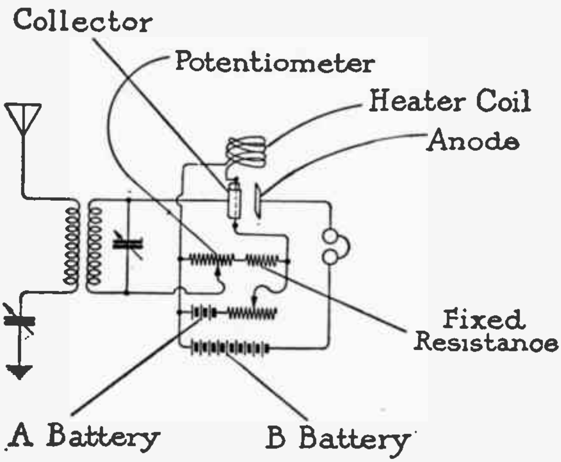


FIG. 45B. Sodion detector with inductively coupled receiver.

A method of connecting up the Sodion tube to a two circuit inductively coupled tuner is shown in Fig. 45B. One terminal of the secondary connects directly to the collector, the other connects to the movable contact on the potentiometer which is connected across the "A" battery. The remainder is a simple detector circuit.

The adjustment of the Sodion is very simple, it only being necessary to adjust the collector potential ("B" battery) to the point of loudest signal. This adjustment is not critical and in some cases the "B" battery may be varied as much as from ten to thirty volts without much effect. The tube is, nevertheless, very stable in operation. There is no distortion as with the regenerative vacuum tube circuit. The circuit is not affected by small capacity changes such as the operator's hand as is the case with many circuits when using the ordinary three electrode vacuum tube.

The secondary of the receiving transformer requires very careful adjustment and best results are obtained using very loose coupling between the circuits.

Since the collector potential variation need never be more than a few tenths of a volt there is connected a fixed resistance, as shown in the diagram, in series with the end of the potentiometer controlling the "B" battery current.

The "B" battery is 22½ volts. The tube should be burned at a bright yellow color. The filament current should never exceed .26 amperes. As the filament is lighted and the filament current increased a hissing noise will be heard which becomes louder as the filament current is increased. The best point of operation is when the hissing noise is just faintly audible. If hiss is heard at all potentiometer adjustments it is an indication that the filament current is too great and it should be reduced. The point of adjustment of the "B" battery which is best for strong signal is not necessarily best for weak signal. The best adjustment varies with the wavelength of the received signal.

CHAPTER VIII

VACUUM TUBE RECEIVING CIRCUITS

To the uninitiated the great number of circuits spoken and written of today makes it difficult to choose between them. If, however, certain fundamental circuits are analyzed and understood it is found that the principles of all are closely related. Some function entirely on a single principle while others are a combination of two but given a special name. In this explanation only some of the more important circuits are to be discussed. Since the advent of broadcasting, numerous connections have been used each striving to make for greater distance, elimination of interference, simplicity of tuning, etc. The radio magazines of today are full of descriptions of such circuits as the Autoplex, Reflex, Reinartz, Flewelling, Super Heterodyne, Tuned Radio Frequency Amplifiers, Neutrodyne, Grimes Inverse Duplex, the simple Regenerative circuit and others. Some circuits work better than others but there is no consistency about all of the circuits. Where one person might find one circuit best another person will find another. The truth of the matter is that a circuit in order to give good results must be understood and properly operated. Some circuits are simple, others may seem extremely complicated and it is perhaps best for the beginner to take the simple circuits first and use the more refined circuits later on. This would, of course, apply only to the builders of sets and not so much to the listener who buys his equipment completely assembled. Do not condemn a circuit merely because you cannot get it to operate as expected. Perhaps you are not tuning properly. Above all remember that a radio circuit is a highly scientific piece of machinery and must have intelligent operation if maximum and even desirable results are to be obtained.

Reflex Amplifier Circuit.—This is one of the most ingenious circuits devised for getting maximum efficiency from two or more tubes. The Fig. 46 shows the reflex circuit using two tubes. By studying the diagram carefully it is seen that the two tubes serve the purpose of three in the following way: the first tube first amplifies the incoming radio waves by radio frequency, then this amplified energy is detected or rectified by the second tube and lead back again to the first tube which now again amplifies the energy by audio frequency which may be heard in the headphone

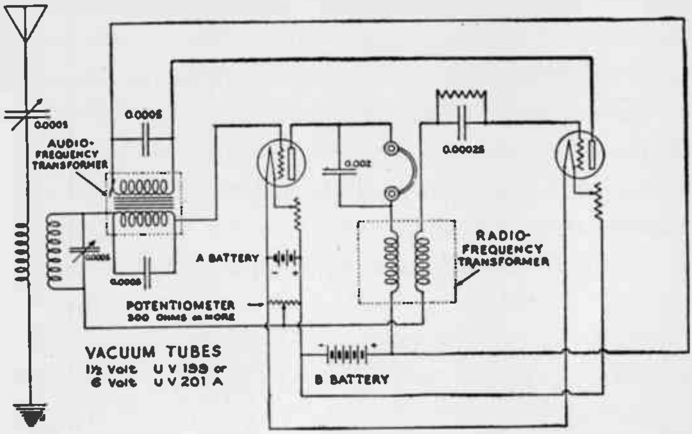


FIG. 46. Reflex circuit.

connected as they are in the plate circuit of the first tube.

The first stage of amplification is not audible in the headphone as it is of radio frequency, up into the millions of cycles per second while the second stage of amplification is of radio frequency and within the audio range of the human ear and low enough so that the diaphragm of the headphone can vibrate with the current. The first tube, therefore, acts as both a radio and audio frequency amplifier and the second tube acts as a detector. There is a throwing back or reflexing of the energy so that it goes through the first tube twice and the circuit thereby receives its name as the reflex circuit.

It is possible to use a crystal detector instead of the second tube but the results are not as good. When this is done a reflex circuit can be made using only one tube. This scheme of using the crystal detector where the vacuum tube detector is generally used is also applied to other circuits.

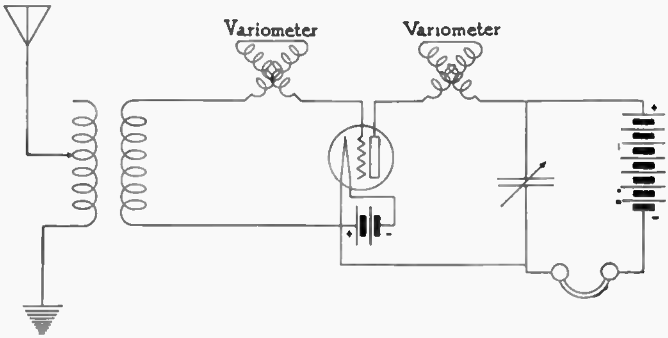


FIG. 47A. Regenerative circuit with tuned plate and grid circuits.

Simple Regenerative Circuit.—In the regenerative circuit shown in Fig. 47A the plate circuit is tuned to the grid circuit by a variometer connected as shown. The action is as follows: oscillations in the grid circuit produce corresponding oscillations in the plate circuit which is tuned to it. This plate current in turn affects the grid circuit, both circuits being in tune with one another, and causes an increased impression of energy on the grid circuit; in other words it regenerates the original grid current. This produces a larger current in the grid circuit and still greater variations in the plate circuit, the result being a reinforcement of the currents in the circuit as a whole. Much louder signals in the headphones are heard because of this regenerative action. The principle to remember is that the circuit regenerates because the grid and plate circuits can be tuned alike. The tuning may be accomplished by connecting in the grid and plate circuits variable inductances in the form of variometers as shown in the diagram.

The disadvantage of this type of circuit is that it may act as a radiator of feeble waves; in other words it may oscillate and become a low power transmitter. When this takes place interference in the form of squealing is caused in nearby receivers. In congested districts where many sets of this type are in operation it is sometimes impossible to enjoy a complete broadcast program due to this re-radiation and the resultant squeals. It is estimated that in some instances a regenerative receiver so adjusted as to make it oscillate may transmit feeble oscillations for several miles and any receiving set within its radius will be interfered with.

The regenerative receiver operates on the feed-back principle; that is the energy in the plate circuit is fed back to the grid and reamplified, so to

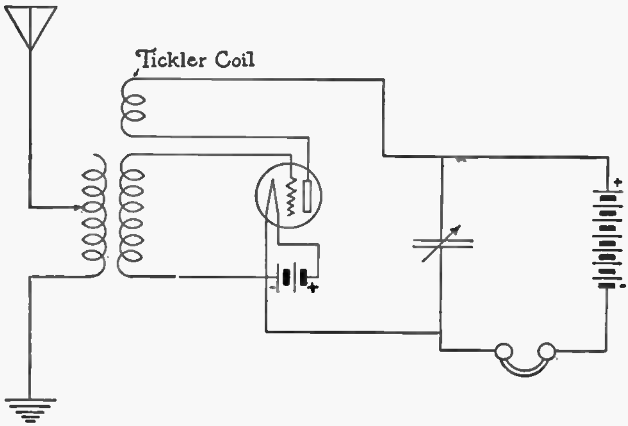


Fig. 47B. Regenerative circuit with tickler coil.

speak. The coupling of the plate to the grid circuit is usually accomplished by a tickler coil arrangement as shown in Fig. 47B.

When the tickler coil is set at minimum coupling little regeneration takes place but as the coupling is made closer the regeneration increases and a point will be reached where hissing can be heard in the telephones. As the hissing increases distortion of signals takes place, and as the coils are brought closer together a point will be reached where a "blub-blub" sound will be heard in the telephones. The hissing and "blub-blub" points are the adjustments where the circuit starts oscillating and if this adjustment is allowed to stand, a great deal of howling and squealing will be caused in nearby receivers as explained above. As soon as the hissing noise is heard the tickler should be turned back so that instead of increasing in intensity the hissing sound is decreased. The point of adjustment just below the hissing sound is the best point of operation on a regenerative set.

If when the coupling of the tickler coil is decreased the set does not regenerate the connections of the tickler coil should be reversed. This is necessary because the flow of current through the tickler coil should be in the same direction as through the secondary coil of the receiving transformer to which it is coupled.

When the tuned plate and grid circuit shown in Fig. 47A is used the same hissing and "blub-blub" points will be found and the same operating rules apply regardless of the method used to obtain regeneration. In the tuned plate and grid circuits ordinary variometers are used as shown in the diagram. The receiving transformer may be a variocoupler or two honeycomb coils.

Because of its simplicity of operation and its great sensitivity the regenerative receiver has found extensive use in commercial practice. A standard receiver of this type is shown in Figs. 48 and 49. On the front of the panel is seen tuning adjustment knobs as follows:

Open oscillating circuit (aerial circuit):
- Primary inductance
- Primary condenser

Closed oscillating circuit (detector circuit):
- Secondary inductance
- Secondary condenser
- Stopping condenser

Coupling adjustments:
- Coupling between primary and secondary
- Tickler coupling (coupled plate and grid).

In the rear view of this set are seen the two tuning condensers in the primary and secondary circuits located near the top of the panel. Below the condensers are seen the primary and secondary inductance coils. The tickler coil is mounted inside the coil to the left and is not visible in the photograph.

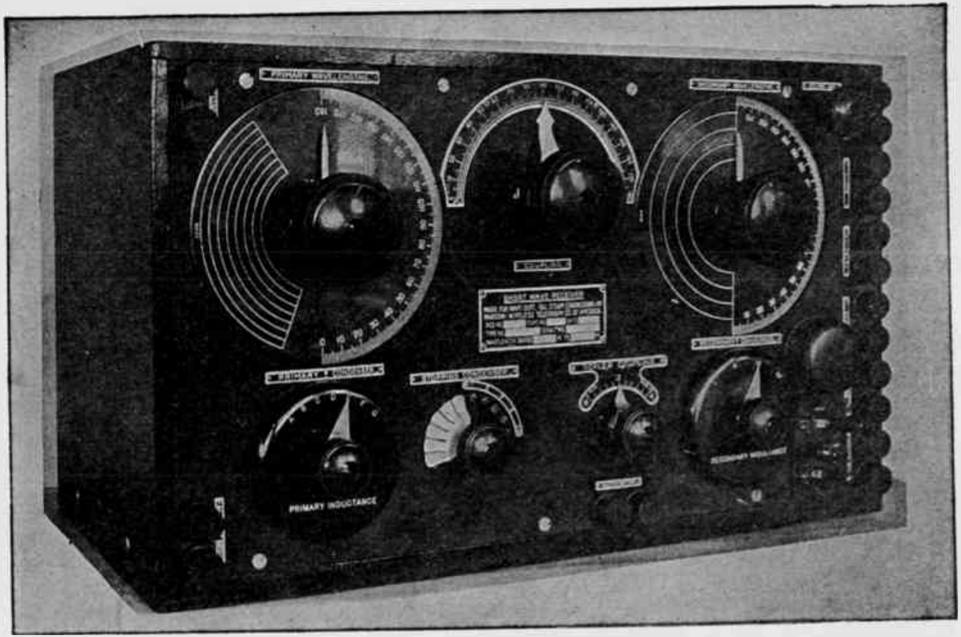


FIG. 48. Front view, standard commercial receiver, commonly used on ship equipments.

The Super-Heterodyne Receiver and the Principle Underlying Its Operation. —Anything not clearly understood in principle seems complicated and of questionable value to the ordinary radio listener. If we adopt for our use something which we do not understand, we do so either because it is recommended by some authority in whom we have faith or we take a chance, so to speak, on it being able to fulfill requirements.

Because no less a firm than the General Electric Company through its sales organization, the Radio Corporation of America, has concentrated its entire resources on the development of the Super-Heterodyne circuit into a practical receiver for household use it can be taken for granted that the receiver will meet the most exacting requirements.

The Super-Heterodyne circuit is a result of the war. It was first constructed in the form of a practical receiver by the well-known radio engineer, Armstrong, then a Major in the American Expeditionary Forces in France. The receivers constructed were very few in number and far from being as compact as the models now found on the market. The results obtained, however, were of such extraordinary character that

Armstrong continued his research work upon returning to the United States and after three years' labor presented his ideas to the radio commercial organizations for further refinement.

Heterodyne.—The word heterodyne is a combination of two words; hetero meaning "another" or "unequal" and dyne meaning power. So we have the combination "another-power" or "unequal power." Now, the circuit used in this type of receiver is based on a principle which produces "another" or an "unequal" power in the circuit. And the way it is done is very simple when it is understood.

A good practical analogy may be had by using the following illustration: assume you are riding in a train and the train is passing two ordinary picket fences about a mile in length. Both fences are on the side of the train from which you are looking out the window, one fence is built running along say fifty feet from the track and the other is built one hundred feet from the track, both running parallel to the rails. As we look through the pickets of the nearest fence at the pickets of the fence farthest away we see not the pickets of the first nor the second fence as single rows of pickets but a periodic blurr occurring at regular intervals about half a second apart. If we stop to reason this out it is obvious that we do not see the nearest pickets because we are not looking at them but through them and we do not see the pickets of the second fence in a normal way as a single fence because the pickets of the first fence obstruct our view at regular intervals. What we do see is the third optical effect described above, a periodic blur or third set of reflections, which is the result of the reflection of the first or nearest fence and the second or farthest fence upon the eye.

If the pickets in the nearest fence are spaced six inches apart and the second fence is similarly made the spacings between pickets of the farther fence will seem closer together because they are farther away from the eye. In other words, if the speed of the train is such that fifty pickets of the nearest fence pass the eye every second a less number will be seen of the farthest fence, say perhaps thirty. We can then say that the pickets in the first fence pass the eye at a frequency of fifty and the second at a frequency of thirty. In this case the periodic blurs will be seen at a heterodyne frequency which is the difference between the frequency of the two fences taken separately, or twenty. The heterodyne frequency of these two optical effects, is therefore, twenty.

The same effect may be seen by placing two ordinary window screens one in front of the other about a foot apart and moving one screen from right to left and *vice versa* in its own plane. The blur seen is caused by the heterodyne principle and is the result of two slightly different optical effects on the eye.

Heterodyne Receiver.—The definition of a heterodyne receiver as given by the Standardization Committee of the Institute of Radio Engineers is as follows: "A radio receiver for continuous waves employing the principle of reaction between locally generated oscillations and incoming oscillations." Note that it is the "reaction" or resultant effect of two sets of oscillations. In the same way the periodic blur seen by looking at the two fences is analogous to this definition. We might use the definition as applying to the fences if it is worded like this: "The blur was caused by the reaction between nearest fence (locally generated oscillations) and the farthest fence (incoming oscillations)."

In the heterodyne circuit there is provided a set of oscillations which are generated by an oscillator. In modern sets this oscillator is a vacuum tube, although in early models the electric arc was used. This is shown as curve A in the

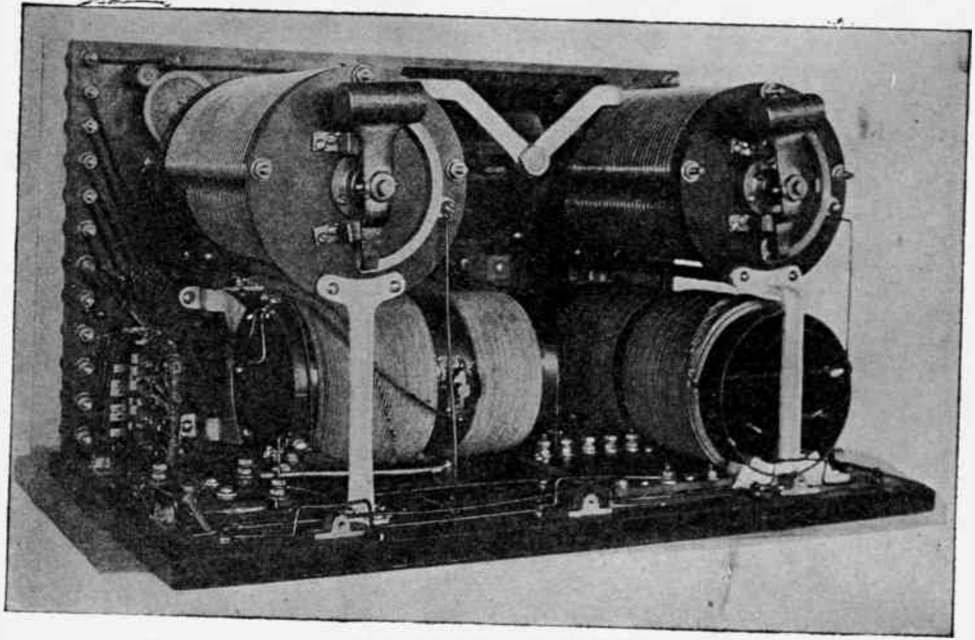


FIG. 49. Rear view, standard commercial receiver used for commercial work. Note strong construction of parts.

Fig. 50. Let us assume that these oscillations occur 600,000 times per second, in other words this is their frequency.

The signals coming in from the station being received are called the incoming oscillations. These are represented as curve B in Fig. 50. Let us assume these are of a frequency of 650,000 cycles. The difference then between the oscillations in curve A which are locally generated and

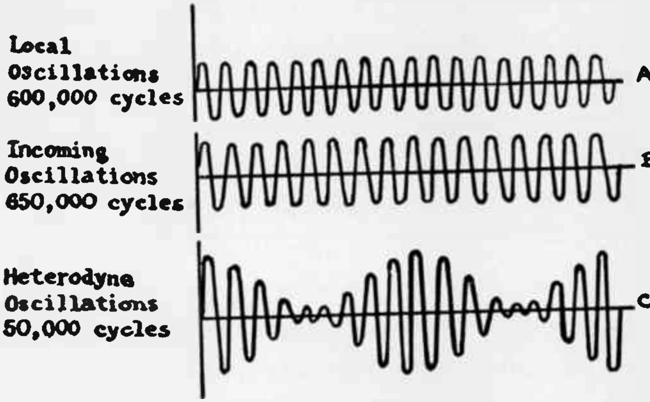


FIG. 50. Oscillations.

the oscillations in curve B which are incoming from the received station is 50,000 cycles. The heterodyne result is, therefore, a set of oscillations of a frequency of 50,000, curve C.

Super-Heterodyne Receiver.—High frequency oscillations of the order of several hundred thousand cannot be satisfactorily amplified by vacuum tubes and for this reason it is desirable to lower the frequency before amplifying it. This is readily done by the heterodyne method. The vacuum tube heterodyne receiver incorporates other principles which make it extremely sensitive and therefore in order to differentiate from the old type heterodyne receiver invented long before the war by Fessenden, an American radio engineer, the word "super" was prefixed and the modern set called the "Super-Heterodyne."

The ordinary, older super-heterodyne receiver, as built experimentally by a few advanced radio enthusiasts in the past, used from eight to ten tubes, was difficult to operate, and did not have many of the other characteristics of a satisfactory set for use in the broadcast reception field.

All super-heterodyne receivers are members of the well-known heterodyne receiver group, and these have long been used to receive so-called continuous wave radio telegraph and radio telephone signals. It is a complicated class of receivers which require expert radio knowledge in their construction, but they may be used by anyone when properly built.

The term "super-heterodyne" means that this set does not depend alone on radio frequency amplification, nor yet on audio frequency amplification alone, nor on regeneration, nor even on a combination of these powerful methods of increasing the signal strength. More was required in the way of stable and selected amplification than these two previously used methods of amplification could alone yield. It became necessary to have a third and new frequency at which to amplify, namely: an "intermediate frequency," which is considerably higher than the audio frequency and much lower than the radio frequency. The combined use of these three frequencies gives an over-all amplification of an amazing magnitude which makes the set so sensitive that it reaches further on a small loop than other type sets do on a large antenna.

The super-heterodyne is so sensitive that it can hear across the continent on its own self-contained loop under good conditions, needs no antenna or ground, and installing in the home means placing it where you think it looks best and leaving it there.

The adjustment of the set is simple since there is no variable antenna to take account of, but only a permanent and constant self-contained loop. It is possible to mark on dials provided for this purpose the setting corresponding to the stations desired, no matter where the set is located. After this is done, getting a station means merely setting the pointers to the desired station and listening. If desired, the music can be made louder or softer by an additional control which influences in no way the tuning adjustments of the set.

The loop circuit of the receiver is a tuned circuit at radio frequency. It is adjusted by the listener. At three different points in the receiver are circuits sharply tuned to the intermediate frequency but not adjusted by the listener. They are set once and for all by the maker of the set and to make full use of them all that the listener needs to do is to tune the oscillating detector so that it will produce the proper intermediate frequency from the incoming waves. This means, in plain language, that he simply turns a second knob until the signals are loudest. The listener therefore has only two tuning adjustments, and these are stable and definite. So that the intermediate frequency employed by this receiver enables the receiver to have no less than four sharply tuned selecting circuits in it, one after the other, and yet only two of which are ever adjusted. And the nature of these selective circuits is such that the selectivity must be carefully controlled and limited in order to avoid making the set unusable because of excessive selectivity. This may sound like a joke to the broadcast listener who has been accustomed to present-day interference on existing receivers, but it is meant in sober earnestness.

The super-heterodyne receiver admits a band of frequency or wavelengths just wide enough to enable radio telephone music to be perfectly reproduced and no more. With the existing type of broadcasting transmitters more selectivity would simply ruin the musical quality and not improve station selection in the least. This means an increased enjoyment to the broadcast listener for it is possible to listen without interference to concerts from distant stations while nearby stations on neighboring wavelengths are going full power.

A modern type of super-heterodyne now on the market has six tubes, which actually do the work of eight or nine tubes in the older experimental super-heterodyne sets. Those who have been accustomed to what a high-grade four-tube or five-tube receiver can do should have some idea of what a perfectly designed set equivalent to eight or nine tubes will do in the way of distant reception. Loudspeaker operation in winter time on a loop from stations more than a thousand miles away, even in unfavorable city locations, is commonplace with such a receiver.

By the use of a special muffler tube circuit re-radiation may be eliminated from the set.

This is a great advantage since the ordinary super-heterodyne receiving set is often a real menace to the neighborhood in the way of producing outrageously loud squeals in other people's receivers.

It is obvious that a receiver that carries its own loop within it is a portable article and that its adjustments and settings are the same everywhere, thus making it entirely portable.

In a model now on the market a real novelty in receiver construction has been adopted. The entire circuit parts, with the exception of two or three husky and larger elements, are enclosed in a heavy metal box where they are carefully wired and definitely adjusted. The entire box is then closed by a firmly fastened metal cover, admitting only the tubes, and the box filled with a special wax. Thus the entire receiver unit is a block or solid mass, which is mounted on shock-absorbing springs, thereby making transportation safe, and making sure of a quiet operation, free from "ringing." This receiver unit, or "catacomb," as it is called, is permanent and readily replaced in the most unlikely event that it is damaged.

Everyone knows that, in an attempt to get more signal strength, or higher selectivity, or both, the broadcast listener with the ordinary set often ruins the quality of the incoming music or speech. This cannot be done with the super-heterodyne. The quality on the one hand, and the signal strength and selectivity on the other hand, have no relation to each other so far as the receiver is concerned; and indeed the selectivity is constant and always at its highest value regardless of the way in which the receiver is used.

Dry battery tubes may be used throughout. By placing proper circuit arrangements in the set, a large output at excellent quality is obtained from tubes which require only simple dry cells for operation.

Years of experimenting were required for the development of a receiver which met the extremely difficult requirements of present-day congested districts. But, once built, such a receiver amply repaid the effort spent on it by furnishing the broadcast listener with an instrument definitely in a class by itself. A modern portable type super-heterodyne receiver is shown in Fig. 51.

FIG. 51. Modern Super-Heterodyne receiver showing two control handles.

Super-Heterodyne Circuit.—This type of receiver is perhaps the most sensitive yet devised. It is, however, rather complicated in construction and operation and requires considerable study before it is completely understood or before it can be worked at its highest efficiency Generally, the super-heterodyne receiver employs eight vacuum tubes as follows: independent oscillator, first detector, three tube frequency changer, second detector, two tube audio frequency amplifier, making eight tubes necessary. The last stage of audio frequency amplification may be left out and in such a case only seven tubes are necessary. Fig. 52 shows the connections employed with this circuit.

This circuit was originally invented by E. H.

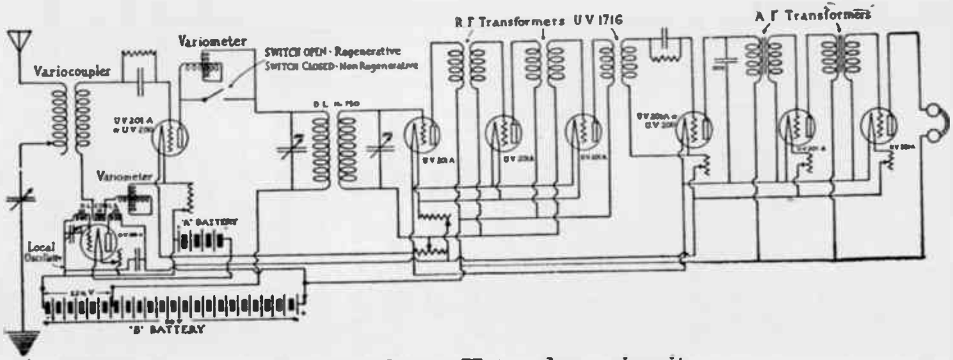


FIG. 52. Super-Heterodyne circuit.

Armstrong of New York and given to the public early in 1921. Since that time it has been improved and is now the most sensitive receiving circuit available. It gives excellent results on either a loop or an outdoor aerial. It is used chiefly for receiving short wave signals. Fundamentally it transforms the extremely high frequency current received by the aerial into a current of a lower frequency which can be more easily amplified.

The action of the super-heterodyne is based on what is known as the "beat" phenomenon. This phenomenon is the result of the difference of two high frequency alternating currents; one being received from the transmitting station and one being generated in the heterodyne receiver. Suppose, for example, that the incoming oscillations are of 3,000,000 cycles per second (100 meters) and there is generated by a separate oscillating vacuum tube included in the super-heterodyne receiver cabinet oscillations of a frequency of 2,950,000 cycles or $3,500,000 cycles per second, the difference then between the incoming oscillations and those generated locally is 500,000 cycles and this is the "beat" current. The beat current is the resultant of two differing oscillation frequencies and its frequency is the difference between the two frequencies of the currents from which the beats result.

The first detector tube picks up the beat current and passes it on to the radio frequency amplifier which consists of the next three tubes. The radio frequency amplifier amplifies the beat current in a very great ratio and, therefore, the oscillations after having first passed through the first detector tube and then through the radio frequency amplifier are still of a radio frequency and similar to the original oscillations coming into the aerial circuit. At this point the second detector functions and passes on a rectified audio frequency current to the two tube amplifier to which the headphones or loudspeaker are connected.

The super-heterodyne is rather hard to adjust at first but after practice becomes very simple. It is very selective and permits the tuning out of unwanted stations without much difficulty.

Wave Traps.—In certain localities it is impossible to tune sharply between two stations especially if the two stations are transmitting on wavelengths not far apart. For instance in certain parts of New York City it is almost impossible to tune in WJZ (located in Aeolian Hall, 42nd Street) which sends on 455 meters (about 660 kilocycles) when WEAF (located at 195

Broadway) is transmitting on 495 meters (about 606 kilocycles) and *vice versa*. This is due to the nearness of the wave frequencies used by these two stations. It is in such a case as this that the wave trap or wave filter as it is sometimes called is valuable. The wave trap consists of an inductance coil and a variable condenser connected as shown in Fig. 53. The wave trap is tuned to

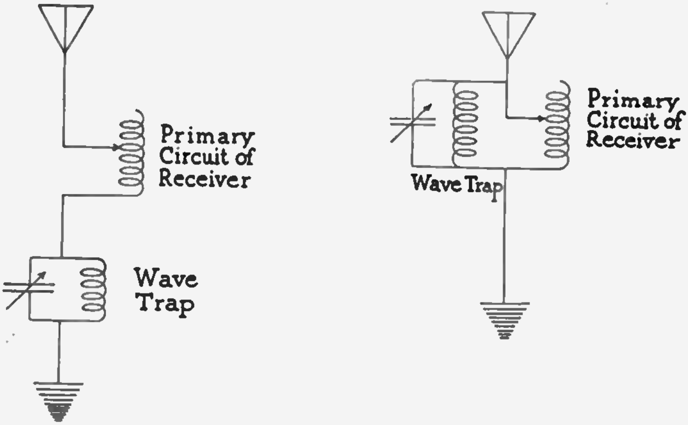


FIG. 53. Wave trap or interference eliminator.

the station which it is desired to eliminate and it is effective in absorbing the energy of this station as it is received and thereby keeping it out of the receiving set proper. The inductance of the wave filter is fixed in value and tuning is done by varying the condenser.

A wave trap suitable for cutting out stations in the broadcasting range may be made by winding about 80 turns of No. 22 wire on a tube 3½ inches in diameter. The variable condenser may be of .0005 microfarads capacity.

In practical operation the wave trap is connected as shown in Fig. 53 and the condenser of the wave trap adjusted until the interfering station is tuned out. At this point only the desired station is heard in the receiver headphones.

Amplifiers.—Radio signals as heard through the detector only are relatively weak, especially distant stations. To increase the loudness of the signal, and to make it possible to operate a loudspeaker, it is necessary that the signal be amplified. This is done by the vacuum tube amplifier.

Amplification is accomplished in two ways, by audio frequency amplification and by radio frequency amplification. Audio frequency amplification deals with oscillations up to 10,000 cycles per second. These frequencies are within the audible range of the human ear. Radio frequency amplification affects frequencies between 20,000 and several million, perhaps as much as three million, cycles per second.

In radio circuits, the radio frequency amplification is connected in before the detector, and audio frequency amplification takes place after the signal has been detected and, therefore, is connected in the circuit after the detector.

An amplifier consists of two or more vacuum tubes so connected in the circuit that the signal to be amplified is impressed upon the grid of the first tube causing variations of the larger current in its plate circuit. This plate current of the first tube is then impressed on the grid of the second tube which causes a like effect on its plate current. The signal may then be made audible through the telephone receivers or loudspeaker. An amplifier repeats the signal from tube to tube making it stronger each time, until the last tube is reached when the signal is made audible. There may be many stages of amplification; audio frequency amplification, however, is usually limited to two stages, because after that amount of amplification the signal becomes distorted due to internal tube noises. Radio frequency amplification may be carried as many as three or even four stages with good results.

A six tube set may be connected up as shown in Fig. 54. In which there are provided three stages of radio frequency amplification, the detector and two stages of audio frequency amplification.

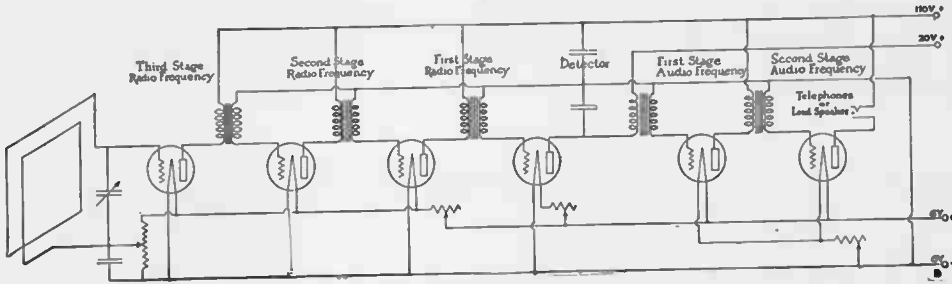


Fig. 54. Utilizing radio and audio frequency amplification.

In order to pass on the energy from the first stage of amplification to the second, to the third and so on, the plate circuit of the first stage is coupled to the grid circuit of the second stage and the second to the third until the last tube is reached. The coupling between the stages is the heart of the amplifier system.

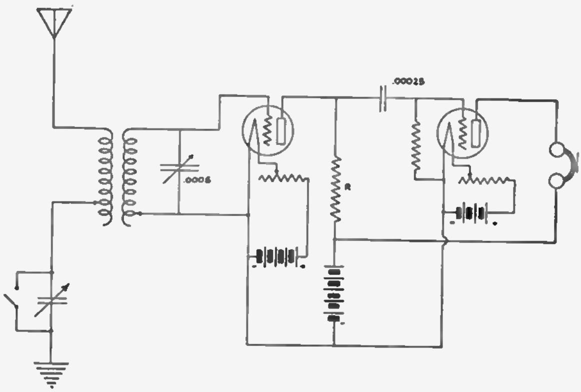


FIG. 55A. Resistance coupled radio frequency amplifier circuit.

There are various methods of coupling the successive stages and these may be classified as follows; resistance coupling, choke-coil coupling, and transformer coupling. These methods are shown by Fig. 55A.

Resistance coupling is especially recommended when amplification without distortion is necessary. In Fig. 55A the coupling of the first tube plate circuit to the second tube takes place through the resistance R which may be approximately from 10,000 to 100,000 ohms. A resistance coupled amplifier, while it gives practically constant amplification over a wide range of frequencies, does not give as much amplitude of signals or loudness as the transformer coupled amplifier, and, therefore, an extra step of amplification, one additional stage, is usually provided. This means that a three tube amplifier resistance coupled will not give much louder signals than a two stage amplifier, but the quality of the received signal will vary very little with frequency. One of the characteristics of the transformer coupled amplifiers is that they suppress the lower, and favor the higher frequencies of the voice waves. This does not hold true with the resistance coupled amplifier, and this point makes this later type highly desirable in some cases where quality rather than volume is desired. It is now possible to purchase resistance units built especially for amplifiers.

For very long wavelengths, in the order of several thousand meters, the inductance method of coupling is preferable to the resistance coupling due to the fact that equal results can be obtained with a lower plate battery voltage. The circuit is the same as the resistance coupled circuit, the only difference being that instead of a resistance R an inductance or choke-coil is substituted. For short wavelengths of the higher frequencies, however, the choke-coil method is less desirable than the resistance or transformer methods of coupling. A choke-coil built for coupling purposes may have a value of from 50 to 75 Henrys inductance.

The transformer method of coupling the successive stages of both radio and audio frequency transformers is the most practical way of repeating the energy from tube to tube for wavelengths around 300 meters, and those used by broadcasting stations. The transformers in addition to coupling the successive stages serve to step up the voltage, and thus increase the amplification results. Fig. 55B shows how transformers are connected in the circuit. The transformer primary is connected in place of the telephone receivers, and the secondary is connected to the grid and filament of the next stage, and so on until the last tube is reached. Note how short and straight are the wires interconnecting the vacuum tubes and transformers on the board. This is important if the set is to operate properly. It is a good

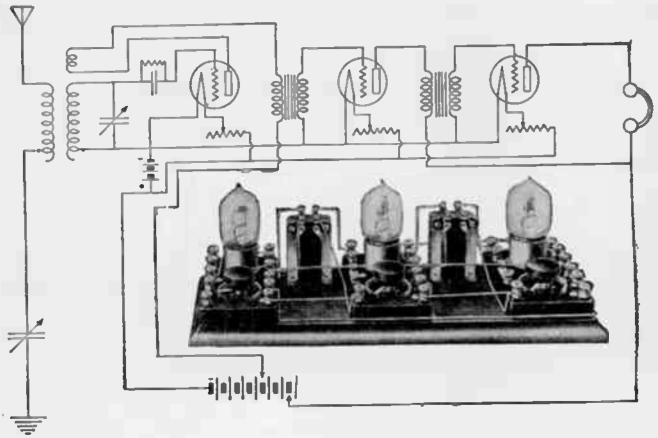


FIG. 55B. Transformer method of amplifier coupling.

rule to make all connections as short as possible.

Just what methods of amplification to use on a given set must be determined by the builder. If the set is to receive from great distances, it is preferable to first increase the strength of the received signals by one or more stages of radio frequency, after which the amplified signal may be detected and again amplified by audio frequency.

The radio frequency amplifier does not amplify atmospheric disturbances, static, as much as the audio frequency amplifier, but has the disadvantage of being very difficult to construct and adjust.

On the other hand the audio frequency amplifier amplifies equally well both the static and the radio signal being received.

Operation of Amplifiers.—Assuming that the amplifier has been properly constructed, the operation of the amplifier depends upon proper "A" and "B" battery voltage, and voltage adjustment, and on the proper tuning-in of the received signal. One of the greatest difficulties with amplifiers is commonly referred to as squealing. This whistling noise is in fact the oscillation of the vacuum tubes in the amplifier circuit, or in the circuit from which current is sent into the amplifier. Because an amplifier does not squeal is no sign that it is properly designed; as a matter of fact it may be that the overall amplification of such an amplifier is lower than it should be.

Certain precautions may be taken in the design of the amplifier which will eliminate squealing to some extent, but in some cases, the amplifier will squeal in spite of such precautions. To prevent or cut down squealing, see that the output and input circuits are not coupled in any way. Keep all wires and connections as far apart and as short and straight as possible. The transformers may be mounted at right angles to one another. Each tube should be placed in a copper or brass chamber which completely shields it from the next tube. This shield may be connected to the ground. This prevents any induction effects between tubes.

In some cases noises in an amplifier are due to the tubes themselves, and the only way to test for this sort of trouble is to try different tubes. Low "B" battery voltage will causes noises in the amplifier. The batteries should be carefully checked up with a voltmeter from time to time.

Mechanical movements of the apparatus or looseness of construction may cause noises in the amplifier. All parts should be securely fastened. Great care should be taken in the way the tubes are supported as they are the most common cause of noises due to vibration. It is easily understood that if the tube vibrates, and the elements in the tube are in any way insecure, the distance between the grid and the filament and the plate will vary and change the resistance of the tube thereby causing noises.

Push-Pull Amplifier.—The push-pull amplifier circuit was invented by Colpitts of the Western Electric Company in New York, and provides for intense amplification without distortion. When using the ordinary audio frequency amplifier circuits, there is a tendency to overload the tubes in order to increase the volume of the signal. This interferes with the proper operating characteristics of the tubes, and poor quality signals are heard, the distortion is bad.

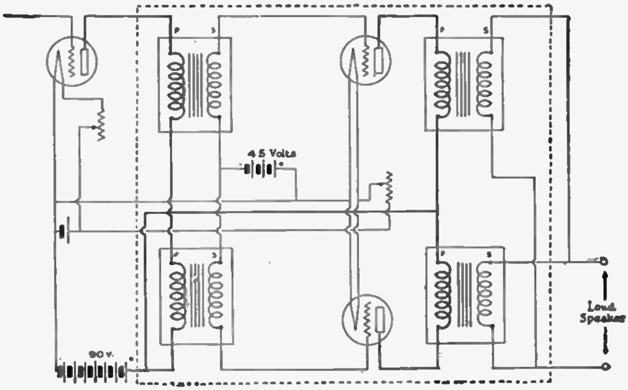


FIG. 56. Push-pull amplifier circuit using standard audio-frequency transformers.

The push-pull amplifier circuit shown in Fig. 56 consists of two tubes and four ordinary audio frequency transformers. The connections are so arranged that two primaries are used for input and two secondaries for output. The two intermediary primaries and secondaries are connected as shown.

The amplification load is divided evenly between the two tubes, in other words each tube takes only one-half of the input load. For example, suppose that the input load is 6 volts, then each tube will have impressed upon its grid 3 volts. Every tube has what is called operating characteristics. These characteristics are plotted in the form of a characteristic curve, and each tube operates best on certain portions of this curve. Distortion is not present on what is called the straight portion of the curve, and it is, therefore, desirable to operate on this portion of the curve. A study of the characteristic curve shown in Fig. 57 shows that the straight portion of the curve extends from X to Y. In other words, distortion does not take place from the points where the grid is charged with a positive voltage of 2 to a negative voltage of slightly more than 6. It is to be noticed, however, that the plate current also rises as the grid becomes less negative and more positive. Now suppose that only one tube was used and the voltage impressed upon the grid was six volts, the plate current in milliamperes would then be relatively low. In the push-pull amplifier the voltage is divided equally between the tubes, which allows operation on the desirable portion of the curve, and at the same time gives sufficient plate current for the proper operation of the loudspeaker. This increased plate voltage is due to

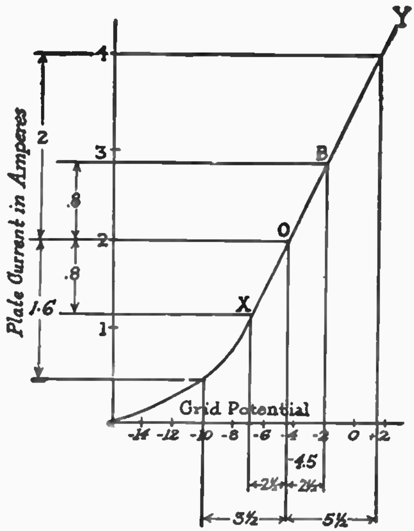


FIG. 57. Vacuum tube characteristic curve.

the fact that the plate of each tube is connected to the primary of an output transformer, which in turn induces current into the secondaries, which are connected in parallel, or are in common, so to speak.

The push-pull amplifier is usually constructed as a unit including a detector, one stage of ordinary audio frequency amplification, and one stage of push-pull amplification. In Fig. 56 the push-pull amplifier, within the dotted lines, is shown connected to a stage of audio frequency amplification. The connections back of the audio frequency amplifier tube are not shown, as they are those commonly employed in an audio amplification circuit.

Muffler Tube.—The muffler tube is the name given to the first stage of radio frequency amplification of a regenerative receiver. It is so called because it prevents the set from re-radiating oscillations at an audio frequency and causing interference in near-by receivers. It has been suggested that all regenerative receivers be required to use this first stage of radio frequency in order to eliminate the very undesirable whistling caused by these sets when worked by an inexperienced operator.

In congested districts the interference caused by these receivers has been a big handicap to the full enjoyment of radio broadcasting by the radio public as a whole.

The majority of regenerative receivers on the market today consist of a detector and two stages of audio frequency. Such sets are the kind that produce the most interference. A muffler tube as explained above would eliminate all possibility of such interference and be a great benefit to every owner of a radio receiving set.

Muffler tube units are now being manufactured as separate units and go by various names. One of the most popular makes is called a "Clarifier" but, regardless of the name applied, a muffler tube is nothing more than a stage of radio frequency introduced as the first stage of amplification after the aerial.

Portable Sets.—The set in Fig. 57A is a six-tube radio frequency receiver employing a loop antenna as the energy collector. It employs three stages of transformer coupled radio frequency amplification, a detector and two stages of audio frequency amplification, together with a loudspeaker unit and horn complete with batteries, in a leatherette covered case. The loop antenna is contained in the lid of the case and is mounted on four slotted bakelite strips. These are wound with special loop antenna wire, the ends of the loop terminating on a connection block on the right hand side of the rear of the case when lying down. There is only one major control for tuning and two minor controls for adjusting filament current and biasing potential. The tuning control or variable condenser is mounted on the left hand end of the case toward the front and is operated by a bar which has a small white line inscribed as an index. This travels over an arc of 180 degrees inscribed on an etched metal plate.

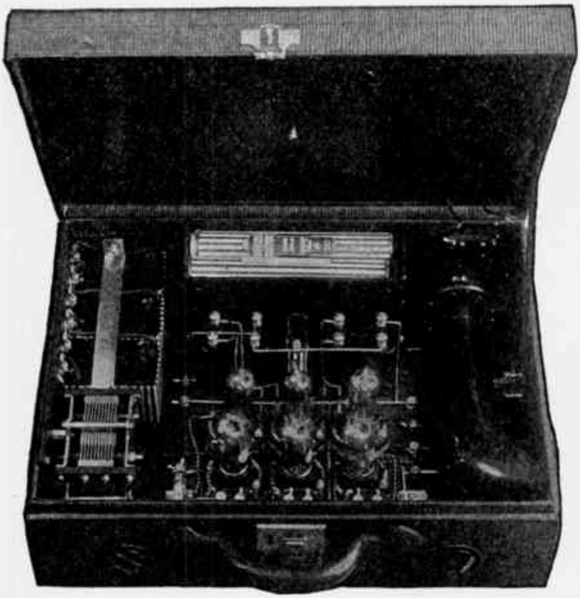


FIG. 57A. A compact suitcase set which requires no aerial or ground.

Once stations are tuned in and the settings noted, the same stations will always appear on the same figures on this dial. The small dial on the left hand side of the front of the case controls the filament current. When in the extreme anti-clockwise position, the filament circuit is off and the tubes do not consume any battery power. Turning this rheostat clockwise, turns on the tubes and increases the filament current as it is rotated. Care should be taken that this filament rheostat is completely off at all times when the set is not in use. The small control on the right of the front of the case controls the positive or negative bias on the grid of the radio frequency amplifier tubes and is called a "stabilizer." As this control is rotated clockwise, signals are increased in volume until a high-pitched squeal is heard. The greatest signal strength will be received just under this point.

When the broadcast stations are within a radius of twenty-five miles, tuning is comparatively easy and it is very rarely necessary to use a fine adjustment of the stabilizer. Ninety degrees on the condenser scale is approximately 400 meters, and using this as a guide, stations above and below 400 meters can be received by using a proportionate amount of the condenser above and below ninety degrees. After the station is heard, the signals can be intensified by rotating the stabilizer in a clockwise direction. In tuning in distant stations, it is often helpful to bring the stabilizer up to a point where the tubes begin to hiss, at the same time rotating the tuning control. When a high-pitched whistle is heard, the stabilizer is brought back slightly and the final tuning accomplished by means of the tuning control.

CHAPTER IX

LOUDSPEAKERS AND BATTERY CHARGERS

Loudspeakers.—Loudspeakers differ as to mechanical type of construction but they all consist essentially of three parts; the electromagnetic structure, the diaphragm, and the horn. The simplest loudspeaker is nothing more than an ordinary telephone receiver attached to a horn. In some types the magnets have been enlarged to handle a greater current and the diaphragm enlarged to produce a louder sound. Such a type is shown in Fig. 58. The construction is similar to the ordinary watchcase type of telephone receiver with the customary pole pieces, magnet coils and diaphragm. The volume of sound that can be obtained with clarity from a speaker of this type is limited due to the closeness of the diaphragm to the pole faces. Certain tones are accentuated due to the resonance characteristics of the diaphragm but this has been overcome to a large extent by carefully designed horns and sounding chambers. The magnets are also made adjustable which eliminates this distortion to some extent.

This type of loudspeaker is not the best as it does not respond properly to very high or very low frequencies of sound vibration. Ordinary speech is reproduced well while the deep bàss notes of the organ may sound blare-like.

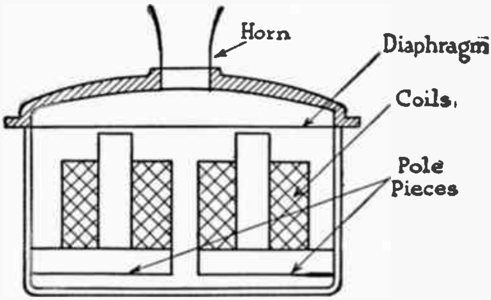


FIG. 58. Ordinary telephone receiver type of loudspeaker.

In this type it is very important that the diaphragm be seated properly and does not touch the tops of the pole pieces. The pressure which holds the diaphragm to its position should be even all around its circumference.

A very good loudspeaker of this type is now made with two diaphragms, one smaller than the other, the centers being directly one over the other. The small diaphragm is set over adjustable magnets and connected to the larger one, from which it is separated by only a fraction of an inch, by a riveted pin. The vibrations pass from

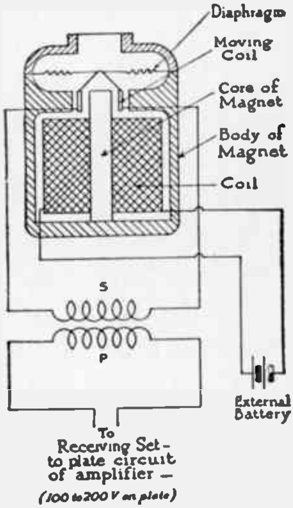


FIG. 59. Moving coil type loudspeaker.

the small diaphragm to the larger diaphragm through this pin. The results are very satisfactory.

The moving coil type shown in Fig. 59 is very extensively used and gives very good results. It consists of a circular magnet coil located in a round air gap. The air gap is traversed by a strong magnetic field, excited by an inner coil which carries direct current, while the circular coil mentioned above carries sound producing alternating current. The circular coil is attached to the center of the diaphragm. This type is also called the floating coil type.

The advantage of this type of construction is that there is no magnetic pull on the diaphragm when no signals are being received. Neither can this type rattle when strong signals are received due to the mechanics of its construction. From the engineering standpoint its main disadvantage is that it is difficult to keep the magnetic pull on the moving coil at zero when the potential of the stationary coil is zero.

The loudspeaker shown in Fig. 59 is referred to as a power loudspeaker because it requires an external source of power for its operation.

The impedance (due to alternating current resistance) of the loudspeaker magnetic circuit must be the same as that of the receiving circuit. The average impedance of a receiving circuit is 22,000 ohms to alternating current. The impedance of the moving coil of the type of loudspeaker described above, however, is not so high, therefore, a transformer is necessary. Such a transformer is shown in the figure where P is the primary and S the secondary. The combined impedance of the moving coil winding and the secondary is made to equal the impedance of the average receiving set to which the primary of the transformer is connected. The loss in the transformer is very low, in the vicinity of ten percent.

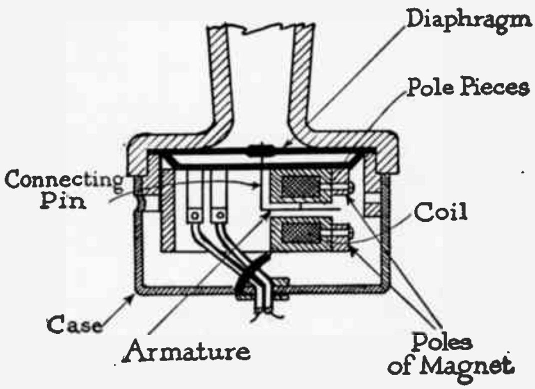


FIG. 60. Enclosed armature type.

Another type of loudspeaker is the enclosed-armature type shown in Fig. 60. An armature is shown suspended between two U-shaped pole pieces in the center of a magnet coil by two thin piano wires. A magnetic flux is produced in the air gap by a permanent magnet. The armature is caused to vibrate to and fro by the current flowing through the magnet coils which simultaneously magnetizes them diametrically opposite. The vibrations are communicated to the diaphragm through a connecting pin which extends to the armature This loudspeaker is also called the balanced armature type.

In this type it is very important that the connecting pin be securely fastened, otherwise the speaker will rattle. This type of speaker gives a fairly uniform range of loudness over a band of frequencies from 100 to 10,000 cycles per second. This covers the ordinary broadcast range of frequencies.

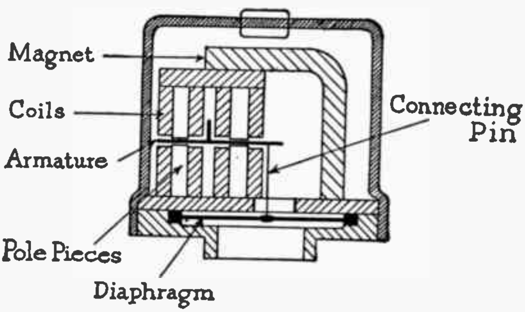


Fig. 61. Vibrating reed type.

The vibrating reed type of loudspeaker is shown in Fig. 61, it is also called the relay type because it is developed along the lines of a polarized relay. A thin iron armature is set between four pole pieces each carrying a coil. These pole pieces are magnetized by an L-shaped magnet and the coils are connected in such a way that the pole pieces diametrically opposite exert simultaneous attraction. The diaphragm is connected to the armature by a connecting pin.

A type of loudspeaker which eliminates the horn and reproduces directly from the diaphragm is shown in Fig. 62. It consists of the ordinary telephone receiver type of speaker unit, the magnets of which act on a movable magnet. This magnet is directly connected to the large conical diaphragm by a thin rod. This type gives good quality reproduction, but the sound is not so loud as with the horn type. The range of sound frequencies to which it will respond well are limited, however, it not reproducing well the very high or very low frequencies. Adjustment is made by moving the magnet away from or towards the diaphragm by a special adjusting screw.

The horn is a very important part of the loudspeaker and unless properly designed the speaker will not give good results. The exact shapes and lengths of the horn for best results are beyond the scope of this book and rather the problem of the acoustic technicians designing the loudspeaker. In general, however, horns are made of wood,

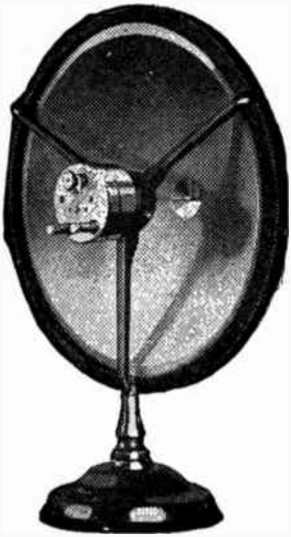


FIG. 62. Loudspeaker, large conical diaphragm, no horn type.

sheet iron, fiber and papier mâché. If the horn is too short it will give a shrillness to the sound reproduced, and if the horn is too long the sound will be muffled.

Diaphragms are made in various shapes as shown in the Fig. 62A. It will be noticed that all diaphragms are not perfectly flat but that some have corrugations of various sizes; some small and close together, others larger and farther apart.

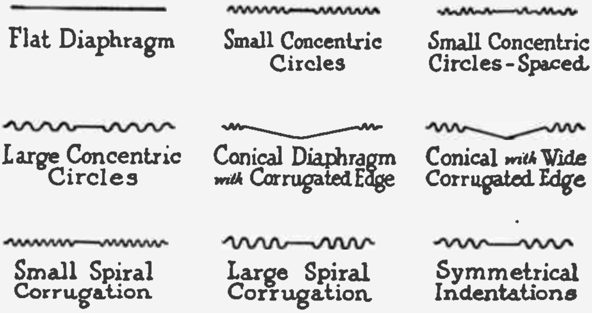


Fig. 62A. Various types of loudspeaker diaphragms.

There are certain things a good loudspeaker should do and these are listed below:

(a) It should respond to high as well as low pitched notes.

(b) It should reproduce different musical instruments in a natural way with their natural harmonics.

(c) It should not have a resonance point, a point in its frequency range which is affected in an extraordinary way, causing the speaker to "blare" when notes of this frequency are received.

(d) It should respond to weak signals and give a good reproduction to reasonably loud signals.

The type of loudspeaker which requires no external battery is called a no-power loudspeaker. It operates on the plate current from the vacuum tube amplifier in the same way as the ordinary telephone receiver. Some types of loudspeakers require an external battery (Fig. 59) and these types give a louder signal than the no-power type. Loudspeakers used in large halls and in the open are of a heavy current type, and are used in conjunction with a power amplifier. A power amplifier consists of several large size vacuum tubes in cascade and built in a separate cabinet with transformers and current controls.

Battery Chargers.—A discharged storage battery of the lead type is in a condition where the acid of the electrolyte has gone into and combined with the active materials of the plates. The plates have soaked the acid up, so to speak, and the specific gravity of the electrolyte (consisting of acid and water) is lower than before this action took place.

In order to again charge the battery it is necessary to draw this acid out of the plates and back into the electrolyte. During this process the specific gravity of the electrolyte is continually rising until it is about 1.250 when the battery is fully charged.

It is seen from the above that the change from charge to discharge is purely a chemical one in the electrolyte and plates. This is likewise true for the Edison type of battery, although no acid is used and the chemical action affects the elements (which are nickel and iron) in a different way. The basic principle of charging a battery is that a chemical action must take place in a direction the reverse of that which took place during discharge. This chemical action is, in the case of discharge, the cause of an electric current in the battery and in the case of charge the electric current is the result of the chemical action. During discharge the current flows from the negative to the positive plate inside the battery while during charge the flow is from positive to negative. In both cases the current flows through the electrolyte which is thereby decomposed if the current is too strong, as is many times the case during charge. The battery is then said to be gassing.

If during charge all of the acid is not driven out of the plates and into the electrolyte the remaining acid will clog up the pores in the active material of the plates and the battery is said to be sulphated. Badly sulphated batteries require an extra heavy charging current to dislodge the hardened acid which is clogging the pores of the active material. As the sulphation is removed less current is necessary and, therefore, the charging current is tapered, in other words it is gradually reduced from maximum rate at the commencement of the charge to minimum rate at the finish of the charge.

Because the action in a battery during charge or discharge is either from negative to positive (discharging) or *vice versa,* the resultant current is a direct current flowing in one direction only during discharge, and reversing during charge. A direct current, therefore, is necessary to charge a storage battery.

An alternating current cannot be used because it changes its direction of flow periodically. The usual alternating current used for lighting purposes is of a frequency of 60 cycles. It is made up as shown in Fig. 13 of alternate positive and negative alternations; two alternations making a complete cycle. If this current is to be used to charge a storage battery, one polarity of alternations must be removed or prevented from flowing. This is called rectification and if the negative polarity is the one removed the resultant rectified current would be a series of positive alternations. In the case of a 60 cycle current there would be 30 positive pulsations in a second of time. While the current is not steady in value it is all in the same direction and, therefore, suitable for charging purposes.

A battery charger is a device for rectifying alternating current, so that it will flow in one direction only, through the battery which is on charge. This definition does not hold true for direct current chargers. There are four types of battery chargers commonly used. These are as follows:

(a) Bulb type.
(b) Electrolytic type.
(c) Vibrator type.
(d) Motor generator type.

The heart of the bulb type charger is a vacuum tube, containing two elements, called the Kenotron or Coolidge tube. In construction, these tubes are similar to the ordinary three electrode receiving tubes except that they have no grid and are larger in size. The plate is called the cold electrode and the filament the hot electrode. The tubes have a very high vacuum. In the bulb there is an inert gas, at a low pressure, which is ionized by the electrons emitted by the filament. This ionized gas acts as the principal current carrier.

The filament is known as the cathode and consists of a small tungsten wire in the form of a closely wound spiral. The anode or plate is a piece of graphite relatively large in cross section.

The bulb acts as a rectifier because on the negative alternation of the cycle the filament electronic emission is pulled directly towards the anode. These electrons collide with the gas molecules, ionizing them and making them conductive in the direction of anode to cathode. On the positive alternation of the cycle, the filament is positive and its electrons instead of being attracted towards the plate are repelled back to the filament, so that no current passes between the elements during this half of the cycle. This bulb is conductive, therefore, on only one half of the cycle, which accounts for its rectifying properties.

The bulb after being exhausted to the highest possible vacuum is filled with argon. To keep the gasses within the bulb pure a purifying agent in the form of a wire ring on the anode is introduced which reacts chemically with any impurities. In so doing the purifier is volatilized and somewhat discolors the interior of the bulb.

There are two types of bulb rectifiers; namely, the half-wave and full-wave types. The full-wave type employs two tubes and the half-wave type employs one. The full-wave type is more expensive to purchase and operate and is, therefore, not commonly used by radio listeners. All the popular types of bulb type chargers now on the market are of the half-wave type and for this reason this

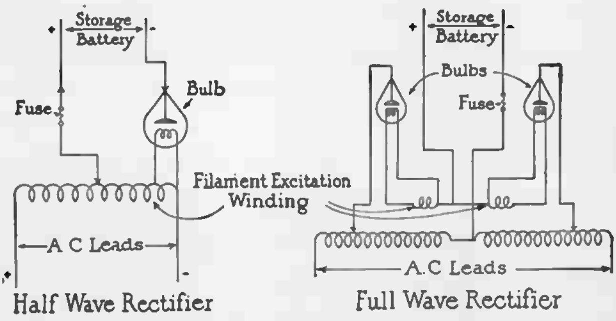


Fig. 63. Two types of battery chargers—bulb type.

is the only type discussed fully in this book. Both types are shown in Fig. 63

In the bulb type rectifier a relatively high voltage is required to make the bulb "pick up" or start operating and for this reason an arrangement is provided which lowers the voltage automatically after the bulb picks-up. It takes but a few seconds for the bulb to get into operation or start rectification. This inherent reactance, as it is called, also tends to keep the voltage constant during the entire charging period of the battery.

Bulb type chargers now on the market are made in two sizes, the 2-ampere and the 5-ampere types. Which one is best suited to a given need is determined best after the needs are known. In general if the storage battery employed is of the 40-ampere hour size or smaller the 2-ampere charger will serve the purpose. If, on the other hand, the battery is larger than this in size, the 5-ampere size should be used. The smaller size will charge the larger sizes of battery but the time required is relatively much longer than when the larger size charger is employed.

Another point which has a bearing on the choice of the size of charger to be used is the extent to which the receiving set is operated. If a set having four or more tubes is used for several hours each night it is advisable to have a 5-ampere charger even though the storage battery employed is of the 40-ampere hour or smaller type.

The auto-transformer in both types of chargers must be very carefully designed in order that the bulb or bulbs pick up properly. In the 5-ampere outfit the auto-transformer has two secondary windings. One of these windings consists of a relatively few turns of heavy wire which is connected in a series with the filament. This winding serves to excite the filament and enables it to pick up in a few seconds. The other winding consists of a greater number of turns and these function to supply current for charging the battery. Three taps are usually brought out near one end of the primary winding (the heavy wire turns) which serves to adjust the charger for various line voltages.

When the line current is shut off the circuit to the battery is automatically opened due to the fact that the bulb is in series with the battery. The bulb is connected to the negative terminal of the battery and when the filament goes out, electronic emission being thus stopped, current cannot flow between the two elements of the bulb. The battery, therefore, cannot discharge back through the charger.

The 5-ampere type will charge 3 cells at 5 amperes or 6 cells at 3 amperes. The 2-ampere type will charge 3 cells at 2 amperes or 6 cells at 3 amperes.

The electrolytic type of rectifier is perhaps the type used least of all due to the fact that a liquid electrolyte is necessary. This rectifier consists of two electrodes immersed in a solution called electrolyte. The electrodes may be carbon and lead, tantalum and lead or aluminum and lead. Other combinations will also function as rectifiers. The principle accepted as the rectification theory of the electrolytic type of rectifier is that a gas film forms on one electrode (called the valve metal) when the current is flowing towards this electrode and permits the flow of electrons in one direction only. It does not permit the passage of electrons from the electrolyte to the valve metal but does permit a flow from the valve metal into the electrolyte.

Among those metals which show this valve action are aluminum, tantalum, magnesium, zinc, cadmium, and tungsten. Aluminum and tantalum are the only two which are used commercially. The valve action in the others is not pronounced enough to permit dependable operation.

The rectifying action in an electrolytic type charger consisting of aluminum and lead plates in a dilute solution of sulphuric acid would be as follows. As a result of exposure to the air the aluminum plate has deposited on its surface a very thin coating of aluminum oxide. The acid of the electrolyte leaks through the pores of this oxide coating and attacks the metal of the plate. This forms more oxide which results in a thicker coating which is also porous. When the current is turned on the acid in the solution is ionized and oxygen molecules are liberated which are negatively charged. These oxygen molecules are drawn towards the positive aluminum plate where they are neutralized and form oxygen gas. This gas forms an effective resistance to the passage of current towards the positive electrode during one half cycle and permits a passage during the other half. The action of the valve plate towards the flow of current is, therefore, valve-like with the resultant rectification. The alternating current is changed to a series of direct current pulsations. The number of pulsations depending upon the frequency of the charging A.C. line. If the frequency is 60 cycle, which is ordinarily the case, the number of pulsations will be 30 per second.

Unless the electrolyte is pure sulphuric acid and water considerable leakage is likely to occur, destroying the valve action. Among the impurities which will have this effect are chlorine, bromine or iodine. Carbonate or borate solutions are preferable to the sulphuric acid solution and the efficiency of the rectifier is higher when these are used.

Although the aluminum type of electrolytic charger has been used to a great extent the tantalum is better for quick charging at higher rates. The tantalum type is constant in operation over a wide range of temperature and is independent of changes in frequency and line voltage.

The electrolytic type of chargers causes no disturbances in the line since there are no circuits to be opened or closed mechanically, nor are there any magnetic fields built up to collapse and cause surging. The efficiency of electrolytic rectifiers is approximately the same as for other types.

The method of connection for the electrolytic type of rectifier is shown in Fig. 64. The electrolyte may consist of a dilute solution of sulphuric acid or ordinary washing borax (three heaping teaspoonsful of borax to two pints of water) and water.

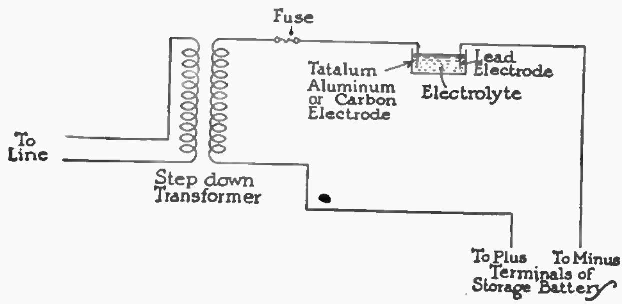


Fig. 64. Electrolytic type of battery charger.

When operating the electrolytic type of charger "boils," and in order to keep it from getting too hot it is sometimes made up of two or three jars in parallel.

The mechanical or vibrator type of charger is used to a large extent. A schematic diagram of this type is shown in Fig. 65. This is the half-

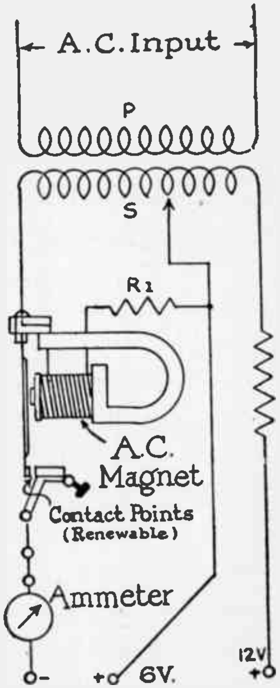


FIG. 65. Battery charger, vibrator type.

wave type and the only one commonly used for radio battery charging. The theory of operation is that the vibrator shall make and break contact in direct step with the alternating line current. It shall, in other words, cut off one half of the alternating cycle and produce a pulsating direct current suitable for charging a storage battery. In this type of charger it is highly important that the vibrator be correctly adjusted otherwise the battery will not be charged because the alternating current will not be completely rectified.

The secondary of the step-down transformer may be tapped for voltage regulation. This is shown in the diagram. High efficiency is obtained only when the charging circuit is closed at the instant the A.C. voltage rises to the value of the battery voltage and opened instantly as soon as it drops below this value and reverses polarity. This condition is brought about by careful adjustment of the resistance in series with the A.C. magnet of the charger. If, as is the case in some types, the vibrator is actuated by a direct current magnet in shunt with the battery the same means of resistance adjustment is provided.

The principal disadvantage of the vibrator type of charger is that after a time the contacts burn up and either new contacts or an entire new armature must be provided. The proper adjustment point is found at the point of least sparking. Ordinarily, contacts need not be renewed oftener than once a year, although this depends altogether on the use to which the charger is put. The efficiency compares favorably with the bulb type charger, both varying between 30 and 35 percent in efficiency.

The motor-generator type of charger consists of a motor and a generator mounted as one unit. The motor is made adaptable to the charging line and the generator is designed to give a low voltage direct current. The connections are shown in Fig. 66. Rotary converters are in the same class

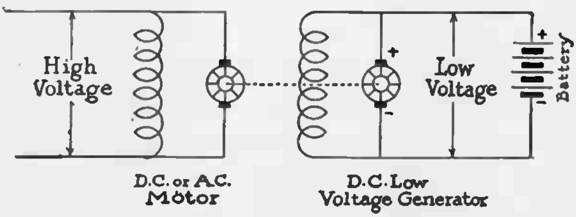


FIG. 66. Motor generator connections for battery charging.

as motor-generators when considered as chargers. This likewise applies to the machine called the dynamotor. These two latter type machines have separate motor and generator field coils but have the armature wound as one unit. The rotary converter armature winding serves both as a motor and generator. The dynamotor has two separate armature windings usually wound one over the other on one form.

The motor-generator types of chargers (Fig. 69) are seldom used except in commercial equipments. These chargers are used to convert high voltage A.C. or D.C. to low voltages suitable for battery charging without the use of transformers of any sort. The principal advantage of the motor-generator type of charger is high operating efficiency. This is especially true of the machines having a separate motor turning a generator. These machines have as high as 45 percent efficiency.

With all types of chargers it is best to disconnect the battery from the radio set while charging. If an ammeter is provided with the charger it is easy to tell when the battery is charging.

CHAPTER X

SENDING STATIONS, BOTH TELEPHONE AND TELEGRAPH

Broadcasting.—Broadcasting is something new in the radio field but it has developed in a way which is nothing short of marvelous. Radio telephony had been carried on successfully for a number of years before the world war but it was not until several years after the war that broadcasting on its present scale was established. At the beginning the programs offered were more or less crude due in part to the lack of experience on the part of the program arrangers and to the inefficiency of the radiophone transmitters employed. The qualities of the programs offered today speak for themselves.

Broadcasting transmitters are especially built for this sort of work, they are different from the commercial transmitter in many respects. The requirements to be met as to service and costs of operation make this type of transmitter different. These requirements are totally unlike those met in the commercial field. Although the requirements are different the broadcast transmitter is in a class with the highest type of commercial equipment.

Perhaps one of the outstanding differences between the commercial and broadcast transmitters is that the former is only required to handle ordinary speech while the latter must respond to and send out into the air all ranges of tones from the deep tones of the basso horn to the high note of the piccolo.

The service of a broadcasting station must be continuous, every provision must be made to carry on an uninterrupted program. To this end duplicate apparatus is installed where there is a possibility of a breakdown which would cause a suspension of service. This additional apparatus is arranged so that the change can be made by simply throwing a switch.

A broadcasting station may consist of three parts, power plant, control equipment and studio. In some cases all of these three parts are contained in one room while in others they are separated by several floors in the same building. In certain cases the studio apparatus may be separated by miles as is the case when church services are broadcast directly from the church or a speech broadcast directly from a meeting held at some remote point.

The power plant is the mainspring of the broadcasting station and includes all the apparatus necessary to generate, modulate, and radiate the radio frequency power which leaves the aerial at the rate of 186,000 miles per second and reaches thousands and thousands of broadcast listeners.

It is necessary to provide several thousand volts for the plate current of the vacuum tubes used in the transmitter and this is usually done by transforming an alternating current from a low to a high voltage and then rectifying it through what are called Kenotrons, a special type of vacuum tube. This is really the "power" behind the radiophone transmitter.

This high voltage power operates the vacuum tube oscillators which generate the high frequency radio currents sent out through the aerial wires. There may be one or more of these oscillator tubes working together. When the oscillator is generating the high frequency undamped alternating current as it is called there is set up in the air an unexplained electric strain called oscillations.

This strain is in the form of electric waves which could we but see them would perhaps look much like the heat waves visible over a hot radiator. The number of waves per second, however, is constant and they occur with such a rapidity that they are inaudible to the human ear unless modulated.

By modulating the wave sent out by the oscillator is meant to make the amplitude of this wave correspond to the amplitude of the sound waves to be transmitted. A current corresponding to the modulated wave is then set up in the circuit of any receiving apparatus tuned to the transmitter. A better idea of these various wave transformations may be had by looking at Fig. 68. The top curve (a) shows the high frequency "carrier wave" generated by the oscillator tubes, the middle curve (b) shows this same wave modulated to correspond to the sound waves which are impinged on the microphone and the bottom curve shows the resultant effect on the radio receiving apparatus.

It is easy to realize that any speech or other matter transmitted from a broadcasting station must be carefully censured and the operator of the station must be ever on the alert to disconnect the studio from the transmitter if anything undesirable is about to be sent out. The manager of a broadcast station owes a distinct responsibility to his radio audience in this respect. To effect this control the operator is provided with a control cabinet which regulates the quality of the broadcasting and enables the operator to disconnect the studio from the transmitter at will. Then it is also necessary that the operator listen in constantly and be ready to shut down in case a distress signal from a ship is sent. It is an unforgivable sin for any radio station to interfere with the reception or transmission of distress signals.

The studio of the broadcasting station may be separated by a considerable distance from the room in which the transmitter itself is located. In some cases the studio is on the ground floor of a building and the power and control rooms are located on the roof directly under the aerial wires.

In most cases at least two studios are provided, one for large assemblies and a smaller one for individual speakers. The studio must be very carefully planned, for on it depends the success of a broadcasting station. No matter how well the transmitter operates if the acoustic properties of the studio are bad the broadcasting will sound bad in the radio receivers.

The placing of the singer, speaker or musical instruments in the studio are very important. Experience tells the studio director just how this should be done. The control operator can usually tell whether or not the modulation is good.

The antenna of the broadcast station must be very carefully designed. One of the most important broadcasting stations in the United States is located at Schenectady, N. Y. At this station the antenna is erected on towers 185 feet high and placed 352 feet apart. The flat top portion of the antenna is 200 feet long.

The vacuum tube has made radio broadcasting possible. It functions in four important ways in that it is used as a generator of high frequency undamped waves, as a modulator, amplifier and detector of these waves. A modern broadcasting transmitting station is shown in Fig. 79. It contains the necessary oscillator, modulator and amplifier tubes, current meters, wave change switches and regulating rheostats.

In the Schenectady installation the oscillator consists of one tube and the modulator consists of five tubes which includes an amplifier tube. The plate current used on these tubes is 2000 volts.

The instrument upon which the sound waves to be transmitted are impinged is called the pick-up device. This is a most important instrument for upon it depends the transformation of the efforts of the artist to the form of radio waves. There are various types of pick-up devices in use, carbon transmitters, magnetic transmitters, condenser transmitters and special types one of which is the pallophotophone. This last named type has a sensitized film passing at a uniform rate behind a narrow opening across which a beam of light is made to vibrate. The film then goes through another machine which transforms the light beams into vibrations corresponding to the original sound.

The operation of a broadcasting station calls for great care on the part of the entire personnel from the operator down to the studio manager and announcer. The equipment is thoroughly tested at regular intervals and always before the starting of a program. During the time that a program is being sent out the operator must continuously check up to see that the power and modulation sent out is satisfactory. In the studio the announcer and program director must see that the singers, speaker and other performers are properly arranged before the microphone pick-up device.

When everything is ready in the studio the control operator is notified through a signal light system, he flashes back and the program starts. If the operator notices anything wrong he can talk to the studio by telephone.

Radio Telephony.—The principles of radio telephony are the same as those of radio telegraphy by undamped waves except that the sending key is replaced by apparatus which varies the sending current in accordance with the sound waves produced by the voice. A wave of radio

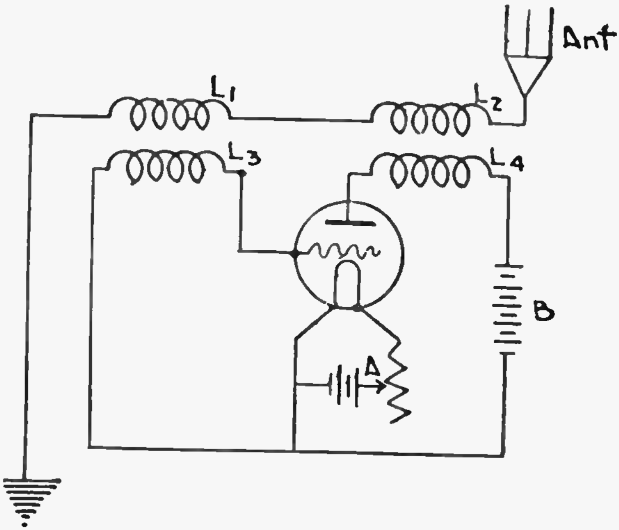


FIG. 67. Circuit for vacuum tube as a generator of undamped waves.

frequency is sent out by the antenna, the intensity of which varies with the frequency of the voice sound waves. The sound waves have a frequency much lower than the radio frequency, so that each sound wave lasts over a considerable number of radio alternations, as in the lower curve of Fig. 80. The radio wave is thus transmitted in pulses, and is received on any ordinary apparatus used for receiving damped wave radio telegraph signals, such as previously described.

The power involved in the sound waves generated in ordinary speech is relatively very small, yet this must be made to control a kilowatt or more of radio frequency power in long distance radio telephony. The effect of the sound waves must therefore be amplified. The way in which the audio frequency is made to control the amplitude of the radio oscillation will now be explained.

Suppose a generator of radio oscillations is placed in series with the antenna, as in Fig. 67. Various types of arc, quenched spark, timed spark, high frequency alternators, and vacuum tube oscillators have all been used as sources with more or less success. The controlling device is usually the combination of a telephone transmitter with an arrangement of vacuum tube circuits, as shown in Fig. 74. The plate circuit of the vacuum tube is conductively coupled to the antenna by the coil L. The grid of the tube is kept at a negative voltage by battery C. The current through the antenna coil induces potential differences between filament and plate, but this produces only very slight changes in plate current on account of the large negative voltage of the grid. Now suppose voltage variations of audio frequency are impressed on the grid by means of the telephone transmitter T and the transformer Tr. As the grid becomes less negative, or even somewhat positive, the rectified plate current increases, absorbing power from the antenna and diminishing the amplitude of the antenna oscillations. The high frequency oscillations in the antenna therefore show variations in amplitude which keep time with the audio frequency variations of voltage in the grid circuit, diminution of antenna current corresponding with increasing positive potential of grid. These variations are illustrated in Fig. 80. In the upper part of the figure the fluctuations of grid voltage due to the telephone transmitter appear; in the lower part of the figure are shown the resulting variations in the amplitude of the high frequency oscillations in the radiating antenna.

The audio frequency variations of amplitude in the radio frequency wave will be reproduced in the antenna of the receiving station, and these will be rectified in the receiving circuit, giving in the telephone receivers audio frequency variations of current, corresponding in frequency and wave form to the boundary of the curve in the lower part of Fig. 80 (as shown on dotted line).

Radio Telephone Transmitter.—The radio telephone transmitter is made up of four principal parts; oscillation generator, transmitter pick-up, modulator, and aerial and ground system. All of the equipment is mounted on a panel of insulating material such as marble, hard rubber, or some insulating composition which looks like hard rubber. This is called the transmitter panel.

Oscillator.—The oscillation generator consists of one or more vacuum tubes connected up so that they oscillate and produce undamped oscillations in the aerial circuit. The power of the oscillations depends, of course, upon the rated wattage of the oscillator tubes. It is to be remembered, that the ordinary small tubes connected up as a regenerative circuit in a receiver send out feeble oscillations into the surrounding ether. Much larger tubes are used for transmitting purposes. It is the general practice to obtain high power by connecting several 50 or 250-watt tubes in parallel.

If a vacuum tube is connected up as shown in Fig. 67 it will act as an oscillator and send out radio waves through the aerial and ground. The

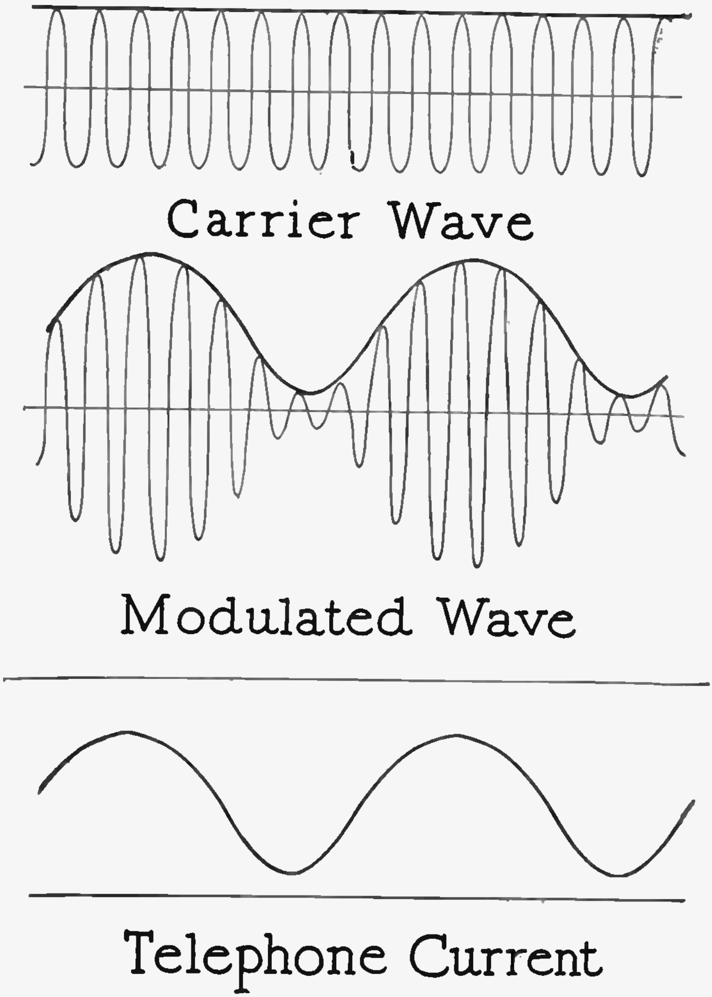


FIG. 68. Changes in wave form in a radio telephone transmitter.

waves sent out by the tube in the figure shown will be undamped in character, that is, constant in amplitude and of a very high frequency on the order of 50,000 to 300,000 cycles depending upon the wavelength. (See table showing relationship of wavelength to frequency, page 63.) In the radio telephone transmitter this is known as the carrier wave and is shown in Fig. 68, top. It is of such a high frequency that it is inaudible and not heard in the telephone receiver at the receiving station.

In order that sound be transmitted from the transmitting station it is necessary to modulate the carrier wave so that it conforms to the im-

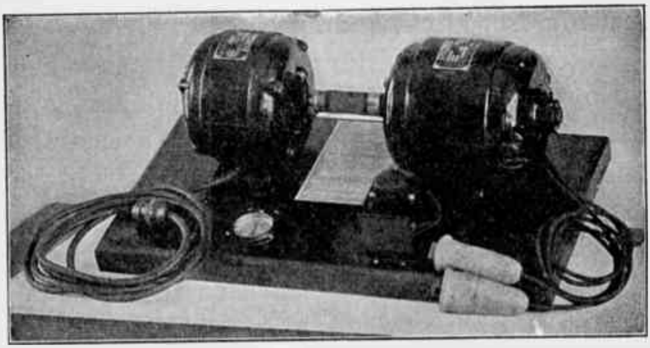


FIG. 69. Motor generator, used to charge storage batteries and as a source of high voltage supply for low power (plate circuit) tube transmitters.

pulses of the voice or instruments from the broadcasting studio. This is called modulating the wave. As the voice waves leave the mouth of the singer they are impinged on the diaphragm or its equivalent in what is known as a pick-up device. The power in the voice or other sound waves is very feeble and must be amplified before it is able to exert a modulating force on the carrier. A schematic wiring diagram of a speech amplifier tube is shown in Fig. 76.

Pick-up Device.—The pick-up device is commonly referred to as a microphone, although there are other types in use. Pick-up devices are divided into four classes: carbon transmitter (single and double button), magnetic transmitter, condenser transmitters, and special types.

The carbon transmitter for very low power sets, as shown in Fig. 70, may be the customary telephone carbon grain transmitter of the size used on telephones but built to stand slightly higher currents. The carbon transmitter for high power transmitters, such as is shown in Fig. 71, is much larger in size and more sensitive to the sound waves within the broadcasting studio. Such a transmitter is affectionately known as "Mike" (microphone) and is shown in Fig. 72. Notice the decorative harp with super-imposed spark; the harp symbolizing music and the spark, the high frequency radio waves which carry the artist's voice or music to the thousands of listeners.

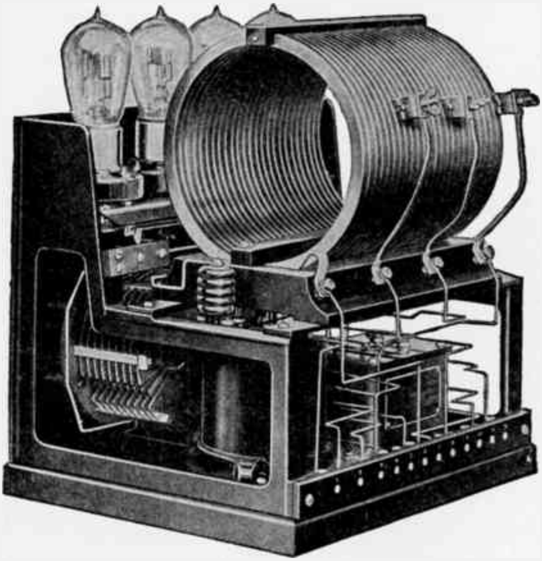


FIG. 70. Radio telephone transmitter unit, low power.

The carbon type transmitter consists of two conducting surfaces between which are placed carbon granuals. Either one or both of these surfaces may be diaphragms. If only one is a diaphragm the transmitter is of the single button type, while if both conducting surfaces are diaphragms it is a two button type. The carbon type gives very good results and is used to a great extent in broadcasting work.

The magnetic transmitter consists of a coil so arranged that it is affected directly by the vibrations of the sound waves. It is surrounded by a strong magnetic field, and as the sound waves cause it to vibrate there is induced in it potentials corresponding to the frequency of the sound waves; these are amplified by a special first stage amplifier, and control directly the amplitude of the oscillating waves. This makes the modulator tube unnecessary.

This type of transmitter is very satisfactory when large orchestral ensembles are being broadcast, as individual control of the volume from any selected instrument may be effected.

Another type of transmitter pick-up device is the condenser transmitter. It is used to some extent in broadcast studio work and consists of a variable capacity mounted directly on or very near to the first stage amplifier of the modulator system. One or two additional stages of amplification are introduced to step up the energy of the sound waves when this type of transmitter is used. There is an electromotive force of 500 volts im-

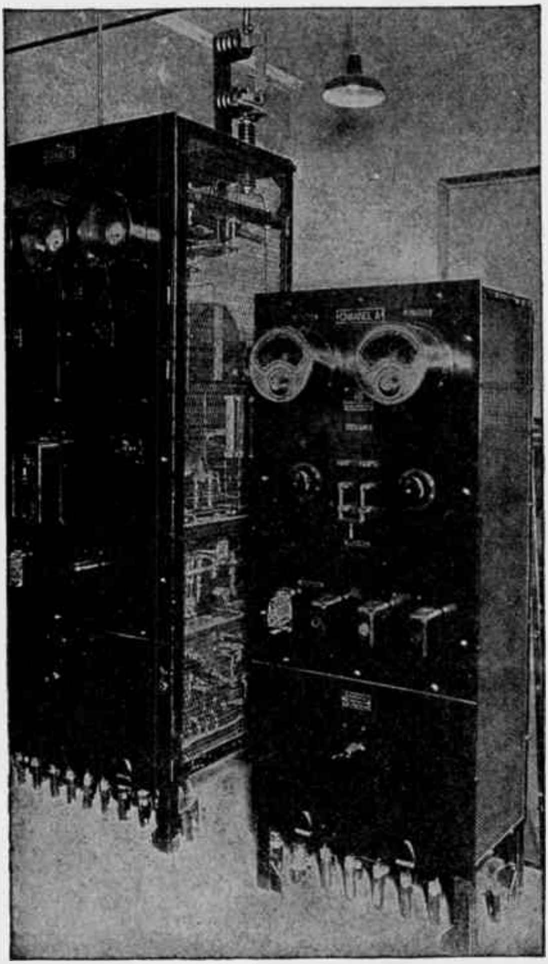


FIG. 71. Radio telephone transmitter unit, high power.
Vacuum tube panel (left). Control panel (right).

pressed on the plates of the condenser when the transmitter is in operation. This type of transmitter is not used when remote control is desired as it must be placed on or near the transmitting apparatus itself.

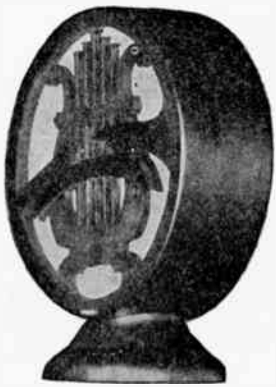


Fig. 72. Microphone, pick-up device. Type used for broadcasting.

Under special types of transmitter pick-up devices comes the Pallophotophone, shown in Fig. 73. This device depends for its operation on a beam of light which fluctuates on and off a sensitized light-sensitive cell and regulates the current in the amplifier tube. This type reproduces the sounds of the artist with very little distortion due to the fact that the voice affects the light-sensitive

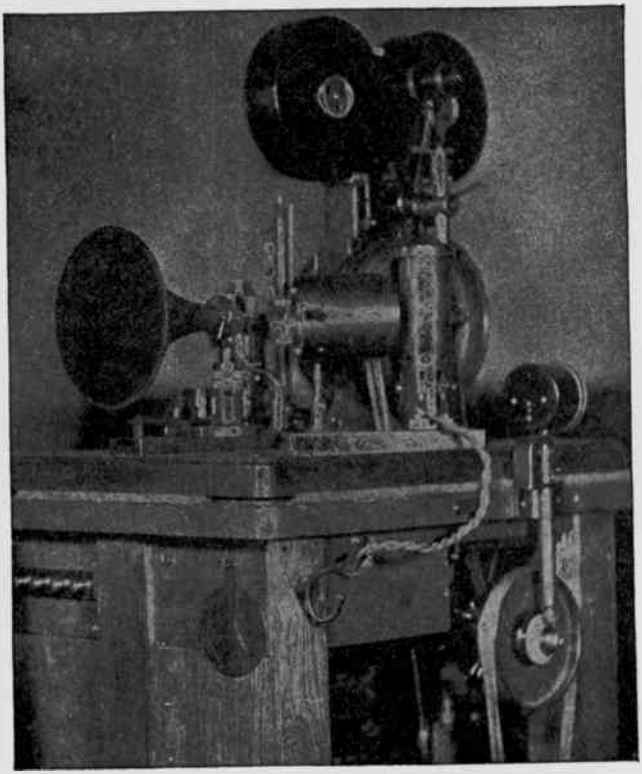


FIG. 73. The pallophotophone, a type of pick-up device used in broadcasting stations.

cell direct, which in turn immediately affects the current in the amplifier tubes.

Modulator.—The oscillation generator sends out the carrier wave which is of a steady frequency, and too high to be heard. The sound spoken into the transmitter pick-up device consists, as does all speech and music, of sound waves of various frequencies. These frequencies are caused to regulate the current in the modulator tube, which in turn modulates the carrier wave to conform to the frequencies impressed on the pick-up device. The effect of the modulator tube on the carrier wave is shown as the second curve of Fig. 68. During the course of ordinary talk, however, the modulation is not as evenly effective as shown in the figure. It is, as a matter of fact, made up of a very complex series of varying frequencies which go to make up the sounds that are to be broadcast.

There are various methods of obtaining modulation, one of the simplest is to insert an ordinary telephone transmitter directly in the aerial circuit. (See Fig. 75 I). The resistance of the aerial to the radiation of the carrier wave was effected in such a way as to make the carrier wave conform to the shape of the sound wave. It was only possible to connect in a transmitter in the aerial circuit on very low power sets and from an engineering standpoint the power lost did not make it a desirable method to use for modulation. It is not used except by amateurs for low power work.

Using this method any regenerative receiver could be used as a radio telephone with a very limited range. This range might be three miles.

Another method of modulation is called the absorption method. It consists of placing a few turns of wire around the oscillation transformer of the transmitting outfit and connecting a carbon grain transmitter in a circuit with these turns of wire. (See Fig. 75 II). The resistance of this absorption circuit is changed as the transmitter is spoken into, and it in turn "absorbs" energy from the carrier wave and molds it to conform to the sound waves.

Another method of modulation is called the magnetic modulating system. It consists of a special transformer with an iron core, the primary winding being in series with a low voltage electromotive force and a carbon transmitter, and the secondary (low resistance) is placed in the ground lead of the aerial circuit. (See Fig. 75 III). When the microphone is spoken into it sets up a fluctuating field in the primary corresponding to the frequency of the sound waves. This field is induced into the secondary, which is in series with the ground lead, and causes an identical modulation of the carrier wave. This method is very similar to the first method described except that there is very little energy lost by direct resistance in the aerial circuit. Magnetic amplifiers have the further advantage in that they can be made to handle any power, regardless of the size of the transmitter.

Grid modulation is now commonly used among amateurs. This is an efficient method of modulation and consists of a transformer of special design, the primary of which is connected in series with a low voltage electromotive force and carbon transmitter and the secondary connected between the grid and the filament of the oscillator tube. The transformer has an iron core. (See Fig. 75 IV).

The theory of operation is as follows: a high alternating current corresponding to the original sound waves is induced in the secondary of the modulation transformer referred to above; this changes the grid current which in turn changes the plate current, which is being radiated out into space through the aerial.

This method is very efficient, for a small change in the grid current will produce a large change of plate current. All of the methods of modulation thus far described are for low power sets. The more powerful transmitters such as are used for broadcasting use a system similar to the Heising, or constant current system now to be described.

For simple sets using one oscillator tube, one modulator is used. If two oscillators are used, two modulators are used, etc. Fig. 74 shows the Heising method of modulation. It is to be noted that for simplicity's sake only one oscillator and

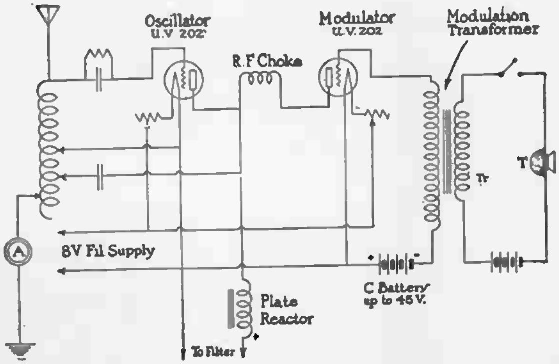


FIG. 74. Heising modulating system for radio telephony.

its modulator are shown in the diagram. The same general scheme is followed out when more tubes are used, both as oscillators and modulators. In this circuit the secondary of the modulation transformer controls the grid current. In addition a "C" battery is used which controls the modulator grid potential and, therefore, the plate current. This prevents overheating and controls the quality of the modulation. The plate reactor shown in the plate lead consists of several hundred turns of wire on an iron core. In cases where

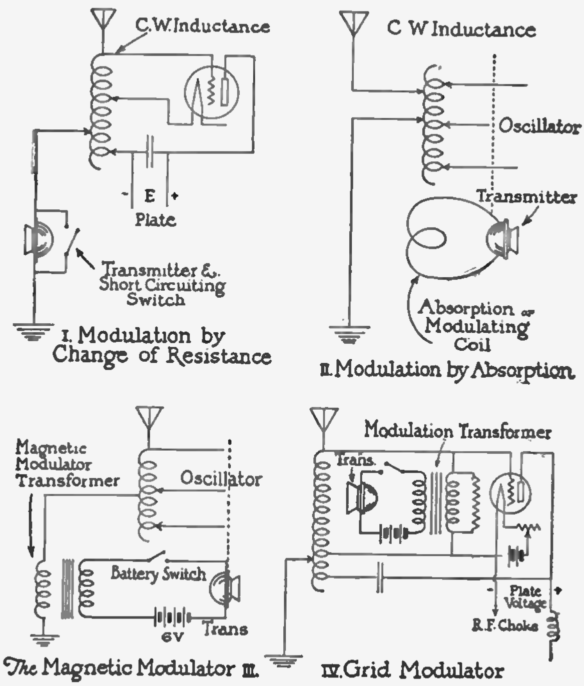


FIG. 75. Methods of modulation.

a filter bank is used this plate reactor is omitted. The radio frequency choke-coil which connects the plates of the oscillator and modulator tube together consists of about a hundred turns of wire on a 3-inch tube. This coil prevents radio frequency currents from entering the modulator tube and becoming dissipated in that circuit.

Modulation is accomplished by this circuit as follows: if the plate current of the modulator increases, due to the action of the plate reactor, the plate current of the oscillator decreases. The reverse is also true. Consequently, the oscillator plate current swings between the limits of the modulator plate current. If the plate of the modulator heats too much, more "C" battery must be added. The negative side of the "C" battery is always connected to the grid.

Speech Amplifier.—In order that the modulator may be affected by even the feeble parts of the sound waves a system of amplifying the sound wave before it gets to the modulator is employed. This is shown in Fig. 76. There is connected between the carbon transmitter and the modulating tube a modulation transformer which serves to amplify the sound wave currents flowing in the transmitter and produces a larger effect than if the transmitter were connected in the modulator circuit direct. A very careful balancing of circuits is necessary when a speech amplifier is used in order to prevent distortion.

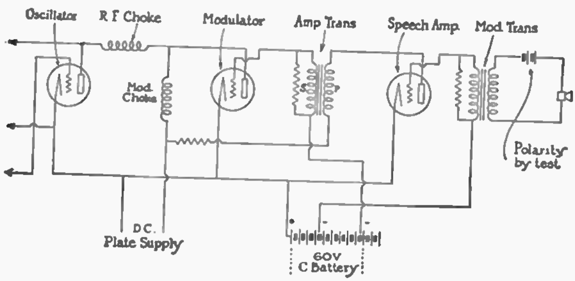


FIG. 76. Speech amplifier.

Plate Voltage on Transmitters.—The plate voltage of a transmitter may be anywhere from 100 to 2,000 volts depending upon the size of the tubes employed. In broadcasting transmitters the plate voltage is usually in the vicinity of 2,000 volts.

Care and Operation of a Transmitter.—A radio telephone transmitter like any other mechanical instrument or piece of apparatus must be carefully handled and kept in repair if it is to work at a high efficiency at all times. The tubes especially should be handled with a great deal of care. The life of a tube depends on how long the filament will burn and any methods to lengthen the life of the filament should be eagerly employed. It has been found that a filament lighted by alternating rather than direct current has the longest life. To use alternating current a step down transformer may be employed or the plate transformer may be especially designed to take care of this. Burning the filament too brightly unnecessarily shortens the life of a tube without increasing its efficiency to any marked degree. Therefore, a volt meter in the filament circuit to show exactly the amount of filament current being used is a tube saver. Burning the tube at 95 percent rated capacity lengthens its life considerably.

It has been found that with tubes of 50-watts or larger that turning the filament current on and off gradually lengthens the life of the filament. It is common practice to turn the filament current on immediately with full power using a switch instead of a rheostat. This is not good practice

Meters are to a radio set what gauges are to an automobile, and a good radio set is amply protected in this respect. In addition to the filament voltmeter referred to above there is the aerial ammeter. This meter does not read directly the radiation of the aerial in definite units but gives a relative reading from which may be deducted whether or not the set is working properly. By reading this meter it is possible to tell which adjustments of the set give the best results. A milliammeter in the plate circuit gives the power at which the set is operating and is very useful. This plate meter is very useful in adjusting the set, to see that the highest plate current flows for the lowest filament current possible. It thereby is an indication of the efficiency of the set.

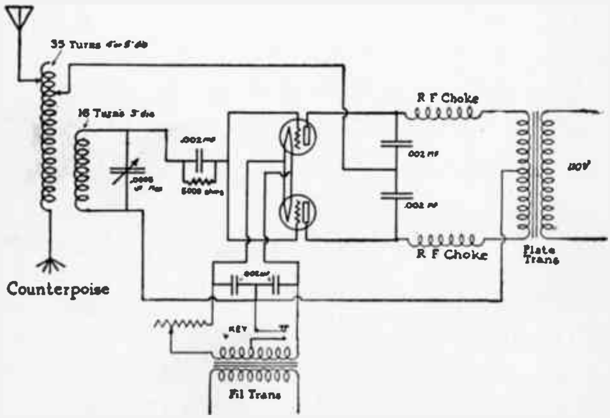


Fig. 77. Wiring of a full wave self-rectified tube transmitter with reversed feed back.

In general the set should be kept clean, free from dust and tarnish.

The Telegraph Key.—If a telegraph key is placed in the oscillator circuit so that it stops and starts oscillations in the aerial circuit at the will of the operator the radio telephone set may be used as a radio telegraph set. It is necessary, of

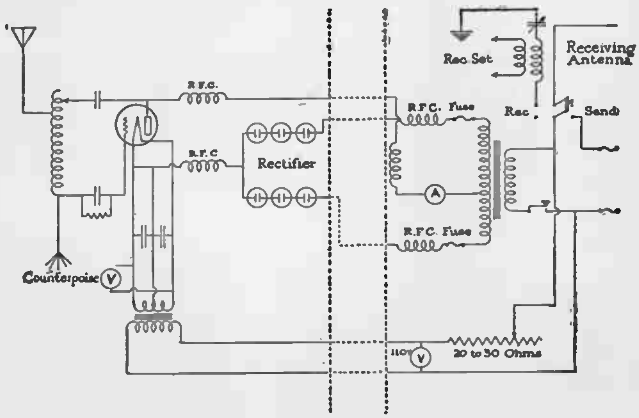


FIG. 78. Showing connections for remote control.

course, that the operator understand the telegraph code (Continental) in order that telegraphing may be done. A telephone set designed to carry over a distance of 25 miles may serve very well as a telegraph transmitter over a distance of 50 or more miles. The telegraphing is done by means of the carrier wave and this being unmodulated carries over a much longer distance than the modulated wave of the telephone set. A complete circuit showing the location of the telegraph key is shown in Fig. 77.

Remote Control.—If the transmitter panel must be located in some other place than the operating room it is necessary to provide for remote

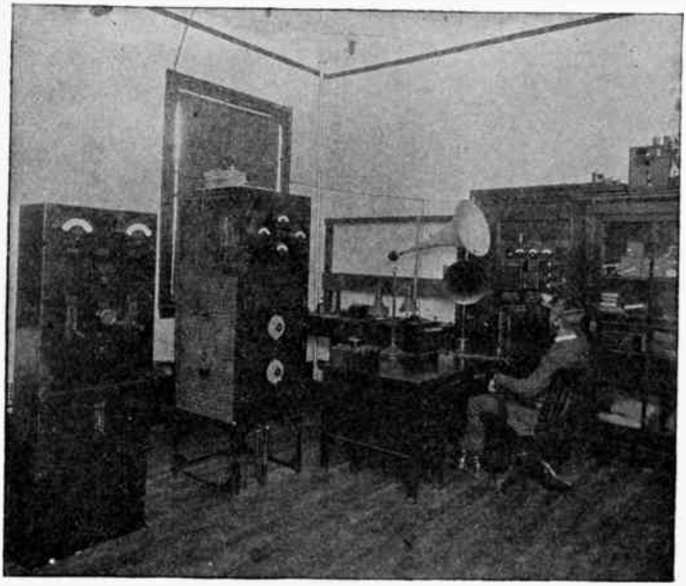


Fig. 79. Interior of broadcasting station showing transmitting apparatus.

control. This consists in running several control wires from the transmitter panel to the operating room as shown in Fig. 78. The advantage of this system is that the transmitter panel may be placed in the best possible location, a location suitable for a good aerial free from trees and other obstructions.

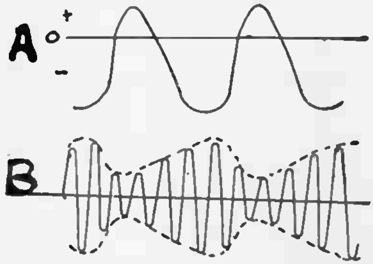


Fig. 80. Voice modulations of antenna oscillations. A, grid fluctuations. B, modulation of carrier wave.

Telegraph Transmitters, Damped Waves, Spark Type.—Every inductively coupled spark transmitter is divided into four circuits which are designated as follows:

1. The low frequency, low potential circuit which includes all apparatus from the supply of alternating current to the low voltage supplied to the primary winding of the power transformer. Included is a telegraph key to make or break the circuit.

2. The low frequency, high potential circuit, which includes the secondary or high voltage windings of the power transformer and the condensers.

3. The high frequency, high potential, closed oscillating circuit including the condensers, the primary winding of the oscillation transformer and the spark gap.

4. The high frequency, high voltage oscillatory circuit, which includes the secondary winding of the oscillation transformer, also antenna inductance.

Sometimes in commercial equipment a series condenser is inserted in this circuit to reduce the fundamental wavelength, enabling the apparatus to transmit on 300 meters, thus complying with a governmental requirement.

The action of this transmitter is as follows:—

Having a source of alternating current, when we depress the telegraph key mentioned in circuit numbered one, this alternating current flows in a circuit from the alternator windings through the primary windings as the power transformer and back to the generator. When the lever of the key is raised the circuit is broken. By means of this key, this primary circuit is made and broken, generally in the shape of the familiar dots and dashes of the Morse Code. Bearing in mind the preceding chapter devoted to electro-magnetism, the following action takes place in the circuit.

As the key is depressed and releases, the alternating current flowing through the primary winding of the power transformer sets up magnetic lines of force which rise and fall, and also reverses in unison with the alternating current which has previously been described as one which alternates in its direction of flow.

These lines of force in turn cutting the winding of the secondary or high potential windings of the power transformer build up a high voltage in that circuit, which we have described as number two. The increase in this voltage is proportional to the ratio of turns. For example, if there were ten turns in the primary, and one hundred turns in the secondary, the secondary voltage would be ten times as great as the primary voltage. The alternating current voltages usually employed are from 100 to 250 volts, thus giving a secondary voltage of from 10,000 to 25,000 volts. The primary winding generally consists of comparatively few turns of heavy wire, while the secondary is built up of a great many turns of fine wire. The number of turns employed depending upon the voltage desired and the type of spark gap utilized. With a 500 cycle, quenched gap set, the secondary voltage is relatively small.

The high voltage from the secondary circuit of the transformer is then delivered to a condenser, the construction of which we have previously discussed. This energy is then stored in the condenser until a point is reached when the condenser can hold no more, and the electro-static charge thus accumulated is discharged across the spark gap, creating an oscillating circuit in the circuit we have described as number three. This circuit is generally alluded to as the closed oscillatory circuit. These oscillations are of radio frequency. Radio frequencies are those above the range of audibility and are generally considered frequencies above 10,000 cycles per second.

We have explained in the previous explanatory chapter on radio that this radio or wave frequency depends upon the characteristics of the sending circuit, in this case the frequency of the oscillations in the closed oscillatory circuit would depend upon the amount of capacity and inductance; in other words, it would depend upon the size of the inductance coil and the condenser and may be anywhere from 1,000,000 to 2,000,000 per second. It is customary to construct apparatus wherein it is possible to vary the inductance and capacity. This can be done by varying either or

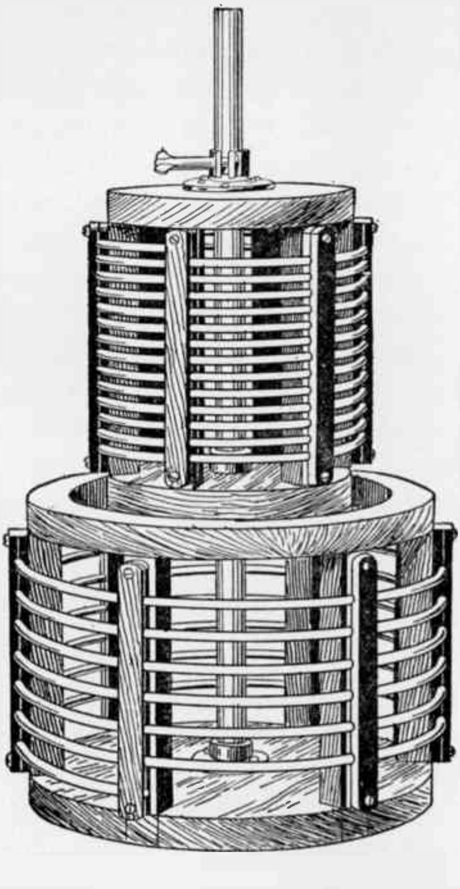


FIG. 81. Oscillation transformer. The secondary moves up and down the rod, inside the primary.

both; but in modern practice it is usual to use a certain fixed condenser and make the inductance variable, thus permitting a convenient method of changing wavelengths. This inductance will depend upon the number of turns in the wire and the diameter of the turns.

Having developed, by the foregoing means, oscillations in the closed oscillatory circuit, these are now transferred from the primary windings of the oscillation transformer, in circuit number three, to the secondary windings of the oscillation transformer in the open oscillatory or as it is also known, the antenna circuit, which has been previously alluded to as circuit number 4. This oscillation transformer (Fig. 81) is just what its name implies, and is a device for transferring energy (in this case radio frequency current) from one circuit to another, this being done by means of magnetic coupling, just as the low potential alternating current was transferred by means of the power transformer from circuit 1 to circuit 2. While these radio frequency oscillations are flowing in the oscillation transformer primary they set up magnetic lines of force about it, in the manner described in the chapters dealing with magnetism and electromagnetism. These magnetic lines of force cut the secondary windings of the oscillation transformer in circuit 4, inducing therein a current of the same frequency. As these oscillations travel the windings of the secondary and the remainder of the open oscillatory circuit, or, in other words, circuit number 4, electrostatic and electromagnetic strains are set up in

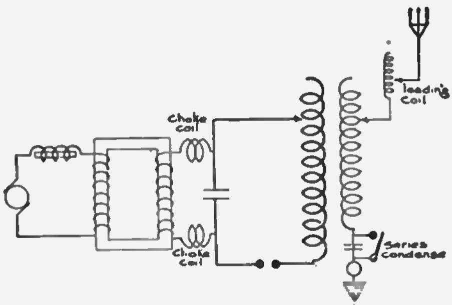


FIG. 82. Inductively coupled transmitter circuit.

the surrounding ether and thus these disturbances give rise to the radio waves, which are propagated into space at the speed of light, 186,000 miles per second.

A complete diagram of the above described transmitter will be found in Fig. 82.

Damping and Decrement.—If the energy in the antenna circuit is dissipated at too rapid a rate, owing either to radiated waves or heat losses, the oscillations die out rapidly and not enough waves exist in a received train to set up oscillations of a well defined period in a receiving antenna. Such waves are strongly damped and have a large decrement. They produce received currents of about the same value for a considerable range of wavelengths. Thus selective tuning is not possible. To increase the number of waves sent out in each wave train from the open circuit, that is, to make the oscillations last longer, the resistance of the circuits must be kept low. When using a plain gap the coupling between closed and open circuits must be small enough not to take energy too fast from the second oscillating circuit. At each condenser discharge the primary has a train of oscillations which at best die out long before another train starts, these oscillations are stopped more quickly, however, if the energy is drawn rapidly out of the circuit by the antenna. Close coupling is permissible only when a quenched gap is used, as previously explained. With any other kind of gap, the secondary is kept oscillating by energy continually received from the primary.

A great many factors contribute to the resistance of the antenna circuit, and this must be kept as low as possible. The antenna must have a good, low resistance ground, must use wires of fairly low resistance, must not be over trees or other poor dielectrics. The resistance of the closed oscillatory circuit must be very low. Heavier currents flow there than in antenna wires. For this reason the closed circuit wires must be short and of large surface, preferably stranded copper wires or copper tubing should be used. The condenser should be a good one, free from power loss.

Undamped Wave Transmitters.—Undamped oscillations are not broken up into groups like damped oscillations. Exactly similar current cycles follow one another continuously, except as they are interrupted by the sending key, or subjected to gradual fluctuations of intensity as when used in radio telephony. Undamped oscillations are produced by a high frequency alternator, an arc or by vacuum tubes.

The main advantages of undamped, or as they are also known (especially in Europe) continuous waves, are the following: 1. Extremely sharp tuning is obtained and consequent reduction of interference between stations working close together. A slight change of adjustment throws a receiving set out of tune, and the operator may pass over the current tuning point by too rapid a movement of the receiving adjusting dials.

2. Radio Telephony is made possible. 3. Since the oscillations go on continuously instead of only a small fraction of the time, as in the case of damped waves, their amplitudes need not be so great, hence the voltages applied to the transmitting condenser and antenna are much lower. 4. With damped waves the pitch or tone of received signals depends entirely upon the number of sparks per second of the transmitter. With undamped waves the receiving operator controls the tone of the received signals, and this can be varied and made as high as desired, within certain audible limits, to distinguish it from "atmospheric" or "static," and to suit the sensitiveness of the receiving operator's ear and the telephones used in reception.

These advantages, freedom from interference from other stations through selective tuning, the high tones and low voltages, and the greater freedom from strays combine to permit of a higher speed of telegraphy than could otherwise be obtained with other classes of transmission.

High Frequency Alternators.—The scope of this work, primarily intended for the use of readers unacquainted with or with slight knowledge of the radio art will not permit of a lengthy discussion of this type of transmission.

However, in conjunction with the other contents, a brief outline of this, the latest form of radio-telegraphy, may prove of interest.

For the production of continuous oscillations an alternating current generator of very high frequency can be used. Alexanderson and Goldschmidt both developed alternators which generate alternating current of *radio* frequency. This alternator is connected directly or inductively to the antenna and ground, and constitutes the simplest possible connection for producing continuous or undamped waves. However, to obtain a wavelength of say 1500 meters, the frequency of the A.C. must be as high as 200,000 cycles per second. The generator speed required to produce this frequency is so high that a special time of construction is necessary for such a machine. It is also necessary to secure apparatus for keeping the speed of the machine constant, so that the wavelength will not change. This system is impossible for very short waves and therefore arc and vacuum tube apparatus is utilized for the shorter wavelengths and less powerful stations.

Goldschmidt employed a radio frequency alternator, with a "frequency changer." An initial A.C. of about 10,000, which, by means of what is known as a "reflection" process, is changed to 40,000 cycles, giving a wavelength of 7,500 meters.

The Alexanderson machine is one of great speed and many field poles, and frequencies as high as 200,000 cycles are obtained. This radio frequency, which is impressed on the antenna circuit, is actually taken from the terminals of the machine.

Undoubtedly for long distance work employing very long wavelengths, these high frequency alternators will be used to a very large extent, in fact, the large radio corporations competing with the submarine cables are using them to-day with most successful results.

Arc Transmitters.—The arc system of radio-telegraphy was invented by a Danish scientist, Valdemar Poulsen. Much of the success of the system, however, can be claimed by American engineers employed by the Federal Telegraph Company of San Francisco, who acquired the American rights to Poulsen's invention. Possibly the chief of these being Mr. C. F. Elwell.

The method used for producing undamped waves of rather great wavelength (generally over 2,000 meters), is by means of a direct current arc operated on about 500 volts. It has been dis-

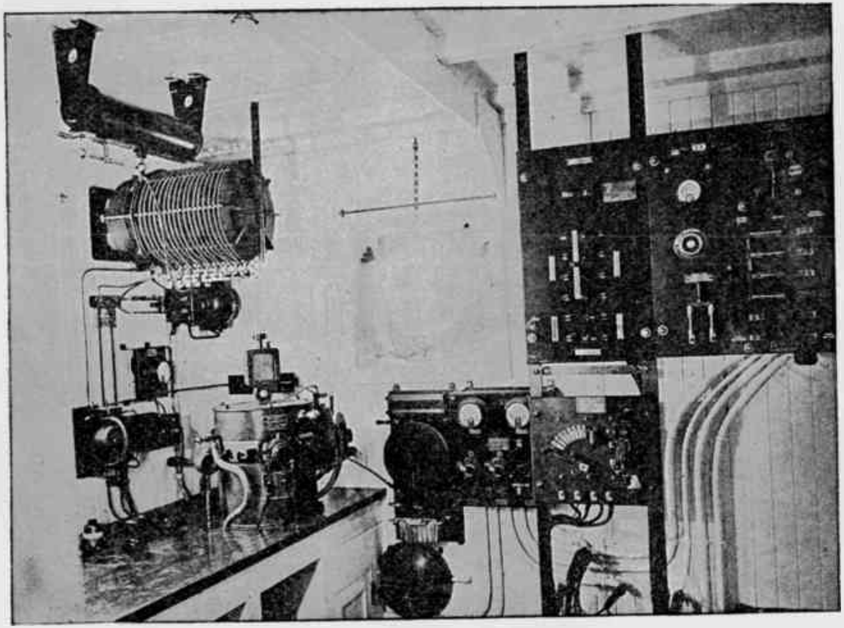


FIG. 83. Complete arc installation aboard ship.

covered that an electric arc between proper electrodes, shunted by an inductance coil and a condenser, will produce undamped oscillations through the shunt circuit. The operation is as follows: The current through the arc is always in the same direction but may vary in magnitude. It is found that when the current in the arc increases, the voltage at its terminal falls off. Suppose the arc to be burning steadily with the capacitance and inductance circuit disconnected. If now that circuit is connected, the condenser begins charging with the left plate positive, and draws current away from the arc. The potential differences of the arc increases and helps the charging. The charging continues until the counter electromotive force of the condenser equals that of the applied. As the charging nears its end, the charging current becomes gradually less, and the arc current as a whole increases to its normal value, with a corresponding drop in voltage. The condenser then begins to discharge downward through the arc, increasing the arc current and lowering its voltage. Lowering the voltage across the terminals of the arc aids the condenser to discharge, and the effect of the inductance in the circuit tends to keep the current flowing and a charge is accumulated on the condenser plates of the opposite sign from the first one. As the charge now nears its end, the charging current downward through the arc becomes gradually less, and the arc current decreases, causing the voltage to rise. It is seen that the rise of the direct current voltage is such as to attempt to charge the left plate of the condenser positive, and the positive charges on the right hand plate begin at once to come back, going up through the arc and decreasing the current. There is a consequent further rise of voltage, and in a direction to assist first the condenser discharge, and then the recharge in the opposite direction (on the left hand plate). The action now begins all over again, and thus continuous oscillations take place through the circuit.

The arc burns in a closed chamber having hydrogen passing through. The positive electrode is of copper and the negative solid carbon, both being of large size and cooled by a water jacket. The key is arranged to short circuit some of the turns of inductance in the antenna circuit, the correct number of turns being adjusted for resonance with the key closed. Then with the key open, the antenna circuit is out of tune with the arc oscillations and the current is negligible, thus forming the intervals between dots and dashes.

Tuning Continuous Wave Sets.—With high frequency alternator apparatus the frequency and hence the wavelength are determined by the speed of the generator and the number of poles. The inductance and capacitance of the antenna should be of such values as to give the circuit the same natural frequency as the generated current. This is brought about by adjusting the antenna loading coil to give maximum current in the hot wire ammeter.

Much of the same method is used with arc sets. The desired wavelength is obtained by adjustment of the condenser and inductance, the antenna circuit being opened, and the wavelength being set on a wavemeter which is brought near. The antenna circuit is then adjusted to the same wavelength by varying the loading coil until the hot wire ammeter gives a maximum reading. A pilot lamp can be substituted instead of the hot wire ammeter, since it can be adjusted by a shunt to light only when the circuits are in resonance. Sometimes this lamp is connected inductively by a loop of wire instead of being directly in the ground wire.

CHAPTER XI

DEFINITIONS

THE following are brief definitions of electrical terms, and explanations of various instruments used in radio telegraphy and telephony.

Many of these definitions are the work of the standardization committee of the Institute of Radio Engineers.

Absorption—That portion of the total loss of radiated energy due to atmospheric conductivity.

Aerial—See Antenna.

Alternation—An alternation of current is one-half cycle or the rise and fall of an alternating current in one direction.

Alternating Current (abbreviated A.C.)—An alternating current is electromotive force that gradually flows from a zero to a maximum value in one direction, then decreases again to zero, rises in maximum value in the opposite direction and again decreases to zero. This is repeated over and over again. The number of repetitions per second determining the frequency of the alternating current.

Alternator—Is a device for converting mechanical energy into alternating current.

Alternator, High Frequency—Is an alternating current generator for radio frequency having a rotor of solid steel shaped as a disc for maximum strength, and provided with inductor poles, and having stationary armatures with radial faces on both sides of the rotating disc.

Ammeter—An instrument for measuring the current of electricity flowing in a circuit. See Ampere.

Ammeter, Hot Wire—An ammeter dependent for its indications upon the change in dimensions of an element which is heated by a current passing through it.

Ammeter, Thermo—An instrument for measuring current, depending for its indications on the voltage generated at the terminals of a thermo-junction heated either directly or indirectly by the current to be measured.

Ampere—The unit of current. Coulombs per second flowing in a circuit.

Ampere-Hour—The unit expressing the quantity of current passing through a circuit when one ampere flows therein for one hour of time.

Amplification, Coefficient of—The ratio of the useful effect obtained by the employment of the amplifier to the useful effect obtained without that instrument.

Amplifier or *Amplifying Relay*—An instrument which modifies the effect of a local source of energy in accordance with variations of received energy; and, in general, produces a larger indication than could be had from the incoming energy alone.

Amplifier Tube—A vacuum tube designed for the amplifier circuit. This tube has a higher vacuum than the detector tube. Sometimes called a "hard" tube.

Antenna—A system of conductors designed for radiating or absorbing the energy of electro-magnetic waves.

Antenna, Directive—An antenna having the property of radiating a maximum of energy in one (or more) directions.

Antenna, Flat Top—An antenna having horizontal wires at the top covering a large area.

Antenna, Harp—An antenna having approximately vertical sections of large area and considerable width. (This description may also be applied to a fan antenna.)

Antenna, Inverted L—A flat top antenna in which the leading down wires are taken from one end of the long narrow horizontal section.

Antenna, Loop—An antenna in which the wires form a closed circuit, part of which may be the ground.

Antenna, Plain—An approximately vertical single wire.

Antenna, T—A flat top antenna in which the horizontal section is long and narrow, the leading down wires being taken from the center.

Antenna, Umbrella—One whose conductors form the elements of a cone from the elevated apex of which the leading down wires are brought.

Antenna Resistance—An effective resistance which is numerically equal to the ratio of the power in the entire antenna circuit to the square of the R. M. S. current at a potential node (generally the ground).

NOTE—Antenna resistance includes:

Radiation resistance.

Ground resistance.

Radiation frequency ohmic resistance of antenna and loading coil and shortening con-condensers.

Equivalent resistance due to corona, eddy currents, and insulator leakage.

Antenna Tuning Inductance—A wire coil used to increase the inductance in the antenna circuit and regulating the radiated energy.

Aperiodic—This term is applied to a circuit which has no definite time period, due either to its resistance being large enough to prevent natural oscillations occurring, or to its having no capacity or inductance by which it can be tuned.

Aperiodic Receiver—Aperiodic receiver usually refers to an inductively coupled receiver, the secondary circuit of which is made aperiodic by placing the detector directly in series with the secondary coupling inductance and without any secondary tuning condenser. This makes a receiver responsive to a broad range of wavelengths at once, in other words, it makes it tune broadly.

Arc—The passage of an electric current of relatively high density through a gas or vapor, the conductivity of which is mainly due to the electron emission from the self-heated cathode. Under present practical conditions the phenomenon takes place near atmospheric pressure.

Arc Oscillator—An arc used with an oscillating circuit for the conversion of direct to alternating or pulsating current. The oscillations generated are classified as follows:

Class 1. Those in which the amplitude of the oscillation circuit current produced is less than the direct current through the arc.

Class 2. Those in which the amplitude of the oscillation circuit current is at least equal to the direct current, but in which the direction of the current through the arc is never reversed.

Class 3. Those in which the amplitude of the initial portion of the oscillation circuit current is greater than the direct current passing through the arc, and in which the direction of the current through the arc is periodically reversed.

Arrester—The term usually applied to the safety device connected between the aerial and ground. Properly known as a lightning arrester. This automatically grounds the aerial in case it is struck by lightning or accumulates a heavy static charge and prevents possible damage.

Atmospherics—See Static.

Attenuation (*Radio*)—This is the decrease, with distance from the radiating source, of the amplitude of the electric and magnetic forces accompanying (and constituting) an electromagnetic wave.

Attenuation, Coefficient of (*Radio*)—The coefficient which, when multiplied by the distance of transmission through a uniform medium, gives the natural logarithm of the ratio of the amplitude of the electric or magnetic forces at that distance to the initial value of the corresponding quantities.

Audibility—The ratio of the telephone current variation producing the received signal, to that producing an audible signal. (An audible signal is one which permits the mere differentiation of dots and dashes.)

The measurement of audibility is an arbitrary method for determining the relative loudness of telephone response in radio receivers, in which it is stated that a signal has an audibility of given value. The determination of the above ratio may be made by the non-inductive shunt-to-telephone method, except that a series resistance should be inserted to keep the main current constant, and that the shunt resistance should therefore be connected as a potentiometer.

Audibility Meter—An instrument for comparing a given signal with a standard which is just audible. (See definition for Audibility.)

Audion—The name formerly applied to the vacuum tube by De Forest.

Auto Jigger—An English term which means loose coupler or an inductively coupled oscillation transformer.

Automatic Transmitter—An instrument which is substituted for the hand-worked signaling key. Makes possible very high speed transmission and insures regularity.

Battery—Consists of one or more storage or dry cells used for producing electric current. This term is also applied to a number of condenser units connected together. The condenser as a whole is then known as a battery of condensers.

"B" Batteries—Used in the plate circuit of a vacuum tube set.

Binding Post—The terminal point to which electrical connection is made. Usually takes the form of a special machine screw or spring clip.

Blower—A motor driven fan which throws a pressure blast. Used for blowing burnt-out gas out of an arc, cooling quenched spark gaps, or high-powered vacuum tubes.

Brush or Corona Losses—Those due to leakage connection electric currents through a gaseous medium.

Bus Bar—A heavy metal strip designed to carry a high current or used to conduct high frequency currents because of its great surface area.

Buzzer—A small instrument (electromagnetic) used for rapidly making and breaking an electric circuit. When connected in series with part of a circuit in which oscillations are possible it continually impulses the circuit, thereby producing oscillations which are convenient for testing purposes.

Buzzer Practice—Practicing the code by means of a buzzer and ordinary telegraph key.

C. W. Transmitter—The term applied to any transmitter producing continuous waves. May be either arc, high frequency alternator or vacuum tube.

Cage Aerial—An aerial which uses hoops for spreaders. The wires are spaced symmetrically around the hoops.

Capacity—The property by which a condenser stores up electrical energy, measured in microfarads.

Cascade—The term applied to a number of pieces of apparatus connected up in series.

Change-Over Switch—A device for the convenient and rapid shifting of the antenna from the receiving to the transmitting apparatus. This is also called an Antenna or Transfer Switch.

Changer, Frequency—A device delivering alternating current at a frequency which is some multiple of the frequency of the supply current.

Changer, Wave—A transmitting device for rapidly and positively changing the wavelength.

Characteristic Curve—A curve showing the variation of a property of a material or a piece of apparatus when submitted to a changing influence which produces that variation. The characteristic curve of a vacuum tube shows the action of a tube with a given value of plate and filament current.

Choke-Coil—A coil for checking the amount of current flowing in the circuit. These coils are usually wound over an iron core and have a great selectivity.

Chopper—An instrument for breaking undamped high frequency radio oscillations into groups of audio frequency oscillations.

Circuit—A continuous path through which a current of electricity may flow.

Circuit Breaker—A safety device which automatically opens the circuit when the current reaches the danger point. Takes the place of fuses.

Closed Oscillating Circuit—A circuit which provides a complete electrical path for oscillations. As an example, the primary circuit of a loose coupler set is an open oscillating circuit because there is no direct electrical connection between the aerial and ground. On the other hand, the secondary circuit is closed.

This may be readily understood by referring to any inductively coupled transmitting or receiving circuit.

Coefficient of Coupling, Inductive—The ratio of the effective mutual inductance of two circuits to the square root of the product of the effective self-inductances of each of these circuits.

Coherer—A device sensitive to radio frequency energy, and characterized by (1) a normally high resistance to currents at low voltages, (2) a reduction in resistance on the application of an increasing electromotive force, and (3) the substantial absence of thermo-electric or rectifying action.

Communication, Radio—The transmission of signals by means of electro-magnetic waves originating in a constructed circuit.

Commutator—A device fitted to a direct current generator or motor which in the case of the generator automatically makes the alternating current direct and in the case of the motor automatically maintains a North and South polarity between armature coils and the field coils causing rotation.

Compass, Radio—A radio receiving device for determining the direction (or the direction and its opposite) of maximum radiation.

Condenser—Two or more sheet conductors insulated one from the other by a dielectric which forms an instrument capable of storing electricity in electrostatic form.

Condenser, Air—One in which air is the dielectric.

Condenser, Adjustable—A condenser, the capacity of which is varied in steps and not gradually as is the case with the variable condenser. Usually a number of fixed units connected to a multipoint switch.

Condenser, Compressed Gas—A condenser having compressed gas as its dielectric.

Condenser, Fixed—A condenser of fixed value.

Condenser, Glass Plate—One in which the dielectric is glass.

Condenser, Oil—One in which the dielectric is oil.

Condenser, Stopping—Used in receiving apparatus to prevent the flow of battery current through the tuning coil of the closed oscillatory circuit instead of through the crystal detector, as intended. It is also used in shunt to the receiving headphones to assist in the intensification of signals.

Condenser, Variable—A condenser the capacity of which is variable.

Continuous Waves—See Undamped Waves.

Corona—See Brush and Corona Losses.

Coulomb—The amount of electricity passed by one ampere in one second.

Counterpoise—A system of electrical conductors forming one portion of a radiating oscillator, the other portion of which is the antenna. In land stations, a counterpoise forms a capacitive connection to ground.

Coupler—An apparatus which is used to transfer radio frequency energy from one circuit to another by associating portions of these circuits.

Coupler, Capacitative—An apparatus which, by electric fields, joins portions of two radio frequency circuits; and which is used to transfer electrical energy between these circuits through the action of electrical forces.

Coupler, Direct—A coupler which magnetically joins two circuits having a common conductive portion.

Coupler, Inductive—An apparatus which by magnetic forces joins portions of two radio frequency circuits and is used to transfer electrical energy between these circuits through the action of these magnetic forces.

Coupling—See Coefficient of Coupling, Inductive.

Critical Point—The point where best results are obtained. Usually refers to the position of the adjustment switches or dials on a transmitting or receiving set.

Crystal—A mineral which has the properties of rectifying radio waves so that they are audible in the headphones. Some of the best crystals are: galena, silicon, iron pyrites and the combination referred to as the Perikon detector, which consists of iron pyrites with a bornite contact.

Crystal Amplifier—A vacuum tube circuit so connected that it amplifies signals rectified by the crystal detector.

Current—The amount of electricity flow in a circuit measured in amperes.

Current, Damped Alternating—An alternating current whose amplitude progressively diminishes (also called oscillating current).

Current, Forced Alternating—A current, the frequency and damping of which are equal to the frequency and damping of the exciting electromotive force. See further Current, Free Alternating.

Note—during the initial stages of excitation, both free and forced current co-exist.

Current, Free Alternating—The current following any transient electromagnetic disturbance in a circuit having capacity, inductance and less than the critical resistance. See further, Resistance, Critical.

Curve, Distribution, of a Radio Transmitting Station for a Given Distance—This is a polar curve the radii vectors of which are proportional to the field intensity of the radiation at that distance in corresponding directions. See also, Compass, Radio.

Note 1—The distribution curve depends, in general, not only on the form of the antenna, but also on the nature of the ground surrounding the station.

Note 2—The distribution curve generally varies with the distance from the station.

Curve, Resonance, Standard—A curve the ordinates of which are the ratios of the square of the current at any frequency to the square of the resonant current, and the abscissas and ordinates having the same scale.

Cycle—Refers to alternating current. It is the complete rise and fall from zero to maximum back to zero in the positive direction and from zero to maximum back to zero in the negative direction.

Cyclogram—See Characteristic, Dynamic.

Cyclograph—An instrument for the production of cyclograms.

D. C.—The abbreviation for Direct Current.

D. C. C.—The abbreviation for Double Cotton Covered.

D. S. C.—The abbreviation for Double Silk Covered.

Damped Waves—Waves composed of trains of oscillations in which the oscillations decrease in amplitude from maximum to minimum for each train.

Damping—The lessening of the total amount of energy in an electrical circuit resulting from loss of energy.

Dead Beat—Circuits so designed that the desired period of oscillation is very quickly obtained.

Dead Short—Means a complete short-circuit.

Decrement—A measure of the rate of decay of an electric oscillation under the influence of damping. When referred to as logarithmic decrement, it is the logarithm of the ratio of successive current amplitudes in the same direction. (See explanation of damped and undamped waves in this course.)

Decremeter—An instrument for measuring the logarithmic decrement of a circuit or a train of electromagnetic waves.

Demagnetize—To cause to lose magnetism.

Detector—That portion of the receiving apparatus which, connected to a circuit carrying currents of radio frequency and in conjunction with a self-contained or separate indicator, translates the radio frequency energy into a form suitable for the operation of the indicator, such for instance, as a pair of telephone receivers. This translation may be effected either by the conversion of the radio frequency energy, or by means of the control of local energy by the energy received.

Device, Acoustic Resonance—A device which utilizes in its operation resonance to the radio frequency of the received signals.

Diaphragm—A thin circular disc of metal used in a telephone receiver which vibrates causing the sound heard in the receiver.

Dielectric—Any medium which will only allow electric conduction to a small or negligible extent.

Direct Coupling—When one circuit is linked to another in such a way that a portion of one forms part of the other, they are said to be directly coupled. The two slide tuning coil is an example of direct coupling.

Direct Current—Current flowing in one direction only.

Discharger—Another name for a spark gap.

Double Pole Switch—A switch having two blades or poles.

Double Slide Tuning Coil—A tuning coil having two sliders. This type allows a separate tuning of the open and closed oscillating circuits and is therefore more selective than the single slide type.

Down Lead—Connection to the ground.

Dubilier Mica Condenser—A type of condenser perfected by William Dubilier. Specially made with mica dielectric and very compact. This type is made for various uses but usually used in the transmitting circuit.

Duplex Reception—The simultaneous reception of two signals by a single operating station.

Duplex Signaling—The simultaneous reception and transmission of signals.

Duplex Transmission—The simultaneous transmission of two signals by a single operating station.

E. M. F.—The abbreviation for Electromotive Force

Earth—The connection to the ground or earth. For receiving systems, this is usually made to the water pipe or to a number of metal plates or wires buried in the ground. (See Ground.)

Electrode—The end of the conductor leading current into a liquid or gas.

Electrolytic Interrupter—Usually consists of a jar filled with a 10% solution of sulphuric acid into which are placed two electrodes and used for breaking up a continuous current into a succession of pulses more or less rapid.

Electron—The smallest electrical unit. Electrons congregate to make an atom.

Ether—The medium assumed to exist everywhere and by which an explanation of the transmission of energy by electromagnetic waves is made possible.

Electromagnetic Lines of Force—Lines of strain about the poles of a permanent or electromagnet, or in a wire in which an electric current is flowing.

Electrostatic Lines of Force—Lines of strain about a body containing an electrostatic charge.

Excitation, Impulse—A method of producing free alternating currents in an excited circuit in which the duration of the exciting current is short compared with the duration of the excited current.

Note—the condition of short duration implies that there can be no appreciable reaction between the circuits.

Factor, Damping—The product of the logarithmic decrement and the frequency of an expotentially damped alternating current.

Factor, Form—The form factor of a symmetrical antenna for a given wavelength is the ratio of the algebraic average value of the R. M. S. Currents measured at all heights to the greatest of these R. M. S. currents.

Note 1—For a given R. M. S. current at the base of the antenna, the field intensity at distant points is proportional to the form factor times the height of the antenna.

Note 2—The effective height (height of center of capacity) is equal to the form factor times the actual height of the antenna.

Note 3—The form factor varies in a given antenna at various wavelengths, due to variation of the current distribution.

Fading—This word is used in referring to signals which vary in intensity and is self-explanatory. The fading of signals is noticed only when receiving from far distance stations.

Farad—Is the unit which expresses capacity of a condenser. It is the capacity of a condenser charged to one volt by one coulomb of electricity. The farad is too large a measurement for practical purposes and, therefore, the microfarad (one-millionth of a farad) is used.

Flat Top Aerial—An aerial having horizontal wires at the top covering a large area.

Frequencies, Audio (abbreviated A.F.)—The frequencies corresponding to the normally audible vibrations. These are assumed to lie below 10,000 cycles per second.

Frequency, High—Is an alternating current which oscillates several thousand or more times per second.

Frequency, Low—Is an alternating current which oscillates below one thousand cycles per second.

Frequencies, Radio (abbreviated R.F.)—The frequencies higher than those corresponding to the normally audible vibrations, which are generally taken as 10,000 cycles per second. See Frequencies, Audio.

Note—It is not implied that radiation cannot be secured at lower frequencies, and the distinction from audio frequencies is merely one of definition based on convenience.

Frequency, Changer—See Changer, Frequency.

Frequency, Group—The number per second of periodic changes of amplitude or frequency of an alternating current.

Note 1—Where there is more than one periodically recurrent change of amplitude, or frequency, there is more than one group frequency present.

Note 2—The term "group frequency" is often called by the term "spark" frequency.

Frequency, Spark—The number of spark discharges per second across a spark gap.

Frequency, Tone—See Frequency, Spark and Frequency, Group.

Frequency Transformer—See Changer, Frequency.

Fundamental of an Antenna—This is the lowest frequency of free oscillations of the unloaded antenna (no series inductance or capacity).

Fundamental Wavelength—The wavelength corresponding to the lowest free period of any oscillator.

Galena—A lead sulphide used as a detector crystal. Has rectifying qualities. See Crystals.

Galvanometer—A sensitive instrument for measuring feeble electrical currents.

Grid—The element in the vacuum tube situated between the filament and the plate. Is made in the form of a wire frame or perforated metal plate. Also refers to the lead framework which holds the active material of storage battery plates.

Grid Condenser—A small fixed condenser connected in the grid circuit of a vacuum tube set.

Grid Leak—A very high resistance, one to five million ohms, connected across the grid condenser.

Ground—A conductive connection to the earth.

Ground Circuit—One in which the earth is employed as one conductor. The ground side is usually the negative or return side of the circuit.

Ground Clamp—A clamp which fits around the water pipe and to which the ground lead from the radio set is connected.

Ground Wires—Wires connecting to the ground.

H. F.—The abbreviation for High Frequency.

H. F. Choke—A choke-coil inserted in any circuit where there is liable to be a back kick of high frequency current. Prevents the high frequency current from flowing back and burning out apparatus.

Henry—Is the inductance of a circuit or coil. It is the inductance in the circuit when the applied voltage is one, and the current changes at the rate of one ampere per second.

Heterodyne—A receiver for radio frequency signals which operates by the production of interference beats between two radio frequency currents or voltages, a series of one of these radio frequencies being located at the receiving station.

Honeycomb Coil—A special type of receiving inductance coil wound one layer over the other, adjoining layers being wound slightly off the parallel plane. This type of coil takes up very little space for a given inductance.

Hot Band Ammeter—See Hot Wire Ammeter.

Hot Wire Ammeter—An Ammeter which works on the principle of the expansion and contraction of a metal strip (band) or wire.

Hysteresis—When used as an electrical term, hysteresis is the lagging effect in an alternating current behind the voltage due to the resistance and impedance of the circuit.

Impedance—This is the combined opposition of reactance and resistance to a current in any circuit.

Inductance—The characteristic of a circuit that tends to oppose any change in strength or direction of electromotive force in an alternating current circuit. The inductance of a wire circuit is greatly increased by winding the wire in a spiral.

Induction, Mutual—This is induction due to two independent circuits reacting on each other. In other words, the electromotive force induced in one of the circuits when the current in the other is changing at its unit rate per second.

Induction, Self—Phenomena arising from the rise and fall of a magnetic field about a coil of wire, through which an electrical current is passing. It is the property of an electrical circuit which tends to prevent a change of the electric current established in it.

Insulator—Any material through which electricity will not pass excepting when the voltage is comparatively very high.

Interference—The term applied when two or more stations interfere with one another while transmitting or when correct reception of signals is difficult because of atmospheric or other outside disturbances.

Interference, Wave (*in radio communication*)—The reinforcement or neutralization waves, arriving at a receiving point along different paths from a given sending station (to be distinguished from ordinary or station interference, which is simultaneous reception of signals from two or more stations).

Interrupter—A device which automatically makes and breaks an electrical circuit.

Ionization—When an electron is taken from or added to a previously neutral atom or molecule the charged particle which is thus formed is called an ion. This taking and adding of electrons from and to atoms is called ionization.

Jacks—Automatic slips into which a plug is inserted, making electrical contact.

Jamming—Interference caused by two or more stations transmitting at once.

Jigger—This is the English term for an inductively coupled receiving or transmitting oscillation transformer.

Joule—Is the quantity of electrical energy expended by one ampere through one ohm.

Kenotron—A special type of vacuum tube used for power rectifying apparatus.

Key—A device for making and breaking the electrical circuit of a radio transmitter and in that way forming the characters of the telegraph code.

Key, Relay—See Relay Key.

Kilowatt—One thousand watts.

Laminated—Usually refers to the core of a transformer. A laminated core is one made up of thin strips of iron.

Lead-in—A wire which connects the receiving set to the aerial.

Lead-in Insulator—Any insulator used to insulate the lead-in.

Leyden Jar—A glass jar coated with tinfoil on the inside and the outside to within several inches of the top. This apparatus will store electrical energy in electrostatic form and is a condenser.

Lightning Switch—A switch having a high current capacity which is used to ground the aerial during electrical storms.

Litzen-Draht Wire—This wire is composed of a number of copper magnetic wires separately insulated from each other, and braided, the whole covered by a single braided silk wrapping.

Loading Coil—Any inductance coil connected in the circuit to increase the wavelength range beyond that which it was before the coil was so connected.

Loop Aerial—A large coil (several feet in diameter) used in place of the aerial radio receiving sets.

Loose Coupler—The name applied to an inductively coupled radio receiving transformer.

Losses, Brush or Corona—See Brush and Corona Losses.

Macaroni Tubing—Tubing resembling macaroni. Used in the construction of high grade receiving apparatus to insulate internal connecting wires.

Magnetic Flux—Magnetic lines of force surrounding a magnet or a conductor carrying electrical current.

Magnetism—That property possessed by various bodies, as iron or steel, of attracting or repelling each other according to certain physical laws; the science that treats of such magnetic phenomena and laws.

Meter—An automatically registering measuring instrument. Also a unit of measurement in the decimal system, 39.37 inches.

Meter, Wave—See Wave Meter.

Mica—A mineral used greatly as an insulator, divides itself into thin transparent sheets.

Microfarad—One-Millionth of a farad. Refers to the capacity of a condenser.

Microphone—An instrument for changing the current value and in this way producing electrical currents which vary at an audio frequency.

Modulation—The varying of the amplitude of the radio waves to correspond to voice or sound waves sent out from a continuous wave sending station.

Mutual Induction—In order that mutual induction may take place, two circuits, A and B, are necessary. A affects B and B in turn affects A. The induction is, therefore, mutual. The final current set up in A because of its action on B is the result of mutual induction.

Natural Wavelength—The wavelength of any electrical circuit taken by itself.

Ohm—Is the resistance offered by a circuit to an electrical current. It is the resistance offered to an unvarying current at the temperature of melting ice by a column of mercury 14.4521 grams in mass and 106.3 ohms long. The resistance of a circuit that will pass one ampere at a pressure of one volt.

Ohm's Law—A scientifically correct law used only for computing values in direct current circuits. The law is as follows:

$$E = I \times R \qquad R = \frac{E}{I} \qquad I = \frac{E}{R}$$

E = Volts I = Amperes R = Resistance

Open Circuit—If the path of current flow in a circuit is not complete there is what is called an open circuit.

Oscillations, Electric—Oscillations produced electrically, and alternating electromotive force which reverses its direction periodically with time.

Oscillations, Free—Those produced by an isolated electrical displacement in a circuit having capacity, inductance and less than a critical resistance.

Oscillations, Forced—Those produced in any circuit by the application of an alternating electromotive force.

Oscillation Transformer—A device to transfer oscillations of radio frequency from the closed oscillatory circuit to the open or antenna circuit of a radio transmitter.

Oscillator, Arc—See Arc Oscillator.

Oscillatory Circuit.—A circuit permitting a free flow of oscillations, generally consisting of a wire coil in series with a condenser.

Parallel—Is the method of connecting electrical apparatus in which two or more paths of nearly equal resistance are provided for the current to flow.

Period—The time necessary for any varying quantity to regularly repeat itself, referred to as periodic time.

Permeability—The ratio of the magnetic flux density produced in a medium by a given magnetomotive force to the magnetic flux density produced by the same magnetomotive force in air.

Plain Aerial—An approximately vertical single wire.

Plate—An element in a vacuum tube made in the form of a metal sheet or tube.

Plate Circuit—That circuit in a vacuum tube receiver consisting of all apparatus connected in series with the plate and through which the plate current flows.

Pliotron—A pliotron is a kenetron provided with a member for electrostatically controlling the electron discharge.

Polarity Indicator—A device for automatically indicating the positive or negative side of an electrical battery or machine.

Potential, Electrical—The state of charge of an electrical condenser or conductor. The work done in carrying a unit charge of electricity from infinity to the point considered.

Potentiometer—As commonly used for radio receiving apparatus, a device for securing a variable potential by utilizing the voltage drop across the variable portion of a current carry-resistance.

Quenched Spark—A spark which produces oscillations that quench out very rapidly, permitting the secondary circuit to oscillate in its own natural period without being affected by primary oscillations.

R. M. S. (*root-mean-square*)—The root-mean-square current is proportional to the first maximum value of the oscillations of a wave train, and to the factor which depends upon the number of trains of oscillations per second and the damping factor of each train.

Radiation—The energy radiated by a radio transmitter.

Radio Frequency—Above ten thousand cycles per second. Above audio frequency.

Radiogram—A telegram sent by radio.

Radio Telephone—An apparatus for the transmission of speech by radio.

Radiotron—A trade name for the vacuum tube manufactured by the Radio Corporation of America.

Reactance—Opposing currents set up by an alternating current which tends to have the effect of resistance and is expressed in ohms.

Rectifier, Electron—A device for rectifying an alternating current by utilizing the approximately unilateral conductivity of a hot cathode and a relatively cold anode in so high a vacuum that a pure electron current flows between the electrodes.

Rectifier, Gas—An electron rectifier containing gas which modifies the internal action by the retardation of the electrons or the ionization of the gas atoms.

Regenerative Circuit—A method of connecting a vacuum tube so that original oscillations in the grid circuit are returned again to the grid circuit and regenerated. One in which the plate circuit is coupled to the grid circuit.

Relay, Electron—A device provided with means for modifying the pure electron current flowing between a hot cathode and a relatively cold anode placed in as nearly as possible a perfect vacuum. These means may be, for example, an electric control of the pure electron current by variation of the potential of a grid interposed between the cathode and the anode.

Relay, Gas—An electron relay containing gas which modifies the internal action by the retardation of the electrons or the ionization of the gas atoms.

Relay Key—An electrically operated key. See further, Key.

Resistance—The opposition a conductor offers to a flow of electric current. The unit of resistance is the ohm. See Ohm.

Resistance, Antenna—See Antenna Resistance.

Resistance, Critical, of a Circuit—That resistance which determines the limiting condition at which the oscillatory discharge of a circuit passes into an aperiodic discharge.

Resistance, Effective, of a Spark—The ratio of power dissipated by the spark to the mean square current.

Resistance, Radiation—This is the ratio of the total energy radiated (per second) by the antenna to the square of the R. M. S. current at a potential node (generally the ground connection). See further, Antenna resistance.

Resistance, Radio Frequency—This is the ratio of the heat produced per second in watts to the square of the R. M. S. current (r. f.) in amperes in a conductor.

Resonance—When two circuits are in tune, *i. e.*, have the same natural period of oscillation, they are said to be in resonance.

Resonance, Acoustic Device—See Device Acoustic Resonance.

Resonance, Sharpness of—See Tuning, Sharpness of.

Rheostat—A device for regulating current flow. Usually placed in series in the circuit in which the amount of current is to be regulated.

Rotary Gap—A spark gap on which one electrode rotates. The rotating electrode is usually a wheel with a number of studs. This wheel is sometimes fastened to a separate motor or on the end of the radio motor generator shaft.

S. C. C.—Is the abbreviation for Single Cotton Covered (Wire).

S. S. C.—Is the abbreviation for Single Silk Covered (Wire).

Selectivity—That property of a circuit which makes it easy to adjust it to any given wavelength and which makes the circuit respond to only a small band of wavelengths after it is so tuned.

Self Induction—Induction set up in a conductor carrying alternating current, due to the cutting of the conductor by the rise and fall of the current which it is carrying.

Series—A method of connecting instruments or batteries so that the current must pass through all of them in regular order.

Sharpness of Tuning—The measure of the rate of diminution of current in transmitters and receivers with detuning of the circuit which is varied.

Sharp Tuning—When applied to a receiving set means that the set is so adjusted that it responds to only a very small band of wavelengths. When applied to a transmitting set means that energy radiated is nearly all in one definite wavelength.

Short-circuit—If an instrument, battery or line is in any way crossed by a metallic conductor or low resistance, which provides a short path for the current to flow through, the instrument, battery or line is said to be short-circuited.

Shorted—Means short-circuited.

Shunted—To connect in parallel. See Parallel.

Silicon—A mineral used in a crystal detector. See Crystals.

Silicon Bronze Wire—A wire made of a silicon-bronze alloy. Is used for aerials where great tensile strength is desired.

Slider—A movable contact used on inductance coils, potentiometers, and variable resistances. Provides a means for varying the value of the instrument.

Spark—An arc of short duration.

Spark Gap—The points through which the condenser of a spark transmitter discharges. There are several types, namely, straight (fixed), quenched and rotating.

Static—Interference caused by atmospheric conditions. Is heard in the radio receiver as clicks, grinders or hums.

Strays—Electromagnetic disturbances set up by distant discharges. See Static.

Syntonic Circuits—Are several circuits having the same natural period of oscillation.

Syntony—See Resonance.

T Aerial—A flat top aerial with a lead-in taken from the center.

Telephone Condenser—A small fixed condenser connected across (parallel) the head telephones.

Telephone Receiver—A device consisting of fixed magnets and a diaphragm so arranged that the diaphragm produces a sound when a current flows through the magnets. Sometimes referred to as headphones, phones or receivers.

Terminals—Points to which electrical connection is made, usually binding posts.

Tikker—A receiving device for changing circuit connections in such a manner as to render the sustained radio frequency electrical energy stored in an oscillating circuit, available for operating a telephone receiver.

Time Period—See Period.

Train, Wave—The waves emitted which correspond to a group of oscillations in the transmitter. See also Frequency Group.

Transformer—A device used for stepping up or stepping down an alternating current. Has two windings called the primary and secondary.

Transformer, Amplifying—Used in a vacuum tube amplifier and connects the plate circuit of one tube to the grid circuit of the next. Steps up the voltage in the plate circuit of the first tube as it passes it on to the next tube.

Transformer, Filament Heating—Makes it possible to heat the filament of a transmitting vacuum tube directly from the lighting circuit by reducing the voltage to its proper value. This eliminates batteries.

Transformer, Power—In a vacuum tube transmitting set the power transformer eliminates the motor generator set by stepping up the power in the ordinary house lighting circuit to 325 or 550 volts. In a spark transmitter, the power transformer steps up the low frequency alternating current to a high potential high voltage current which charges the condenser.

Tube—A short name for the vacuum tube.

Tuner—See Tuning Coil.

Tuning—The process of securing the maximum indication by adjusting the same time period of a given element. See Resonance.

Tuning Coil—An inductance coil provided with a multipoint switch or slider by which the circuit is tuned by either increasing or decreasing inductance.

Tuning, Sharpness of—See Sharpness of Tuning.

Two Stage Amplifier—An amplifier using two vacuum tubes. See Amplifiers.

Umbrella Aerial—A form of aerial having one mast for a support, the wires radiating out from the top to the base in the form of an umbrella. Used mostly on portable sets.

Undamped Wave—Waves radiated from an aerial in which a regular alternating current flows. Waves, the alternations of which are all equal in amplitude.

V. T.—The abbreviation for Vacuum Tube.

Vacuum Tube—A device in the form of an exhausted bulb similar to an ordinary electric lamp but having three elements, namely, filament, grid and plate.

Variocoupler—A receiving instrument having a primary and secondary similar to a loose coupler. The coupling of the vario-coupler is varied by turning the secondary at right angles to the primary instead of sliding it in and out as in the case of the loose coupler.

Variometer—Two coils wound in the opposite direction, one located within the other and connected in series. The inductance value of the instrument is varied by turning one coil in a parallel or right angle position, or any position in between these two positions, to the other coil.

Vernier—A device for use with vacuum tube oscillating circuits to obtain the exact capacity value necessary in order that the circuit may be properly tuned.

Volt—Is the pressure required for one ampere to pass through a resistance of one ohm. It is the electromotive force induced in a circuit when the number of lines of force link with but change at the rate of 108 per second.

Watt—Is the work done by one joule per second.

Wave Changer—A device for quickly changing the wavelength of a radio circuit. Usually fitted to a transmitting set.

Wave, Continuous—See Wave, Undamped.

Wave, Sustained—See Wave, Undamped.

Wave, Undamped—Is a continuous wave which has a constant amplitude.

Wavelength (of an Electromagnetic Wave)—The distance in meters between two consecutive maxima, of the same sign, of electric and magnetic forces. In other words, the distance from crest to crest of two waves.

Wavelength, Fundamental—See Fundamental Wavelength.

Wavelength, Natural—In a loaded antenna (that is, with series inductance or capacity) the natural wavelength corresponds to the lowest free oscillation.

Wave Meter—A radio frequency measuring instrument, calibrated to read wavelengths.

Wave Train—The waves produced by one discharge of the primary condenser in a spark circuit.

Waves, Damped—See Damped Waves.

Waves, Electromagnetic—A periodic electromagnetic disturbance through space.

Woods Metal—An alloy which melts at about 140° Fahrenheit. Consists of two parts lead, one part tin, four parts bismuth and one part cadmium. Is used for fastening crystals in the holding cup.

X—The abbreviation for Static or Interference.

X-stopper—A device for bringing down to a minimum interference caused by static.

CHAPTER XII

QUESTIONS AND ANSWERS

The following are some of the more common questions occurring to the mind of the radio experimenter. They by no means cover thoroughly all of the phases of radio telegraphy and telephony, but give in a general way a résumé of the theory and operation of radio apparatus and accessories. If any answer given in this section is not complete enough to meet requirements it is suggested that the subject be further studied as it appears in other sections of the book.

Q. 1. Describe the construction of some form of standard wavemeter.

A. The following briefly describes a simple wavemeter. It consists of a variable condenser to which is connected an inductance coil of a fixed given value. The inductance is attached to the condenser by means of a flexible cord so it can be placed in any position desired, while the variable condenser is placed at some distance from the circuit to be measured. A carborundum crystal is connected in series with the head telephones, both are then connected in shunt to the variable condenser. A small glow lamp is included in series with the coil, and may be cut out of the circuit by means of the switch indicated.

A scale is placed directly on the variable condenser, which in turn moves under a stationary pointer. The scale reading of the condenser may be graduated directly in wavelengths or the data may be plotted in the form of a curve in the terms of an empirical scale on the condenser. These calibrations are obtained by comparing the wavemeter to a standard oscillatory circuit or by calculation of the constants in the wavemeter itself.

The point of resonance on the wavemeter may be located either by a lamp in series with the circuit, by a crystal detector and head telephones in shunt to the condenser, a hot wire milliammeter in series with the wavemeter, a Neon gas tube in shunt to the variable condenser, or a crystal detector and headphones connected unilaterally to a binding post of the variable condenser.

Certain types of wavemeters have a variable inductance and a fixed capacity, while others may have a variable inductance and a variable capacity.

In using a wavemeter care must be taken that the coil of the wavemeter bears a certain relation to the circuit under measurement, otherwise it will not be cut by the lines of force.

Q. 2. If the head telephone circuit is found open, where is the trouble most likely to be and how would you remedy it?

A. Probably the fault may be found in the cords, a disconnection at the metal tips, or at the binding posts on the ear pieces of the phones. If the cord is worn out, ordinary wire may be substituted, preferably flexible lamp cord, untwisted. If the fault is in the magnets, the job will be more difficult and will necessitate sending it to the manufacturer, or some other expert, for repair.

Q. 3. Where are variable condensers used to advantage in a receiving circuit?

A. A variable condenser may be placed in series with the aerial in order that low wavelengths may be tuned in. A variable condenser also serves to sharply tune the secondary circuit of the receiving set. If the aerial is very short, a variable condenser may be connected across the aerial and ground binding posts of the receiving set and the effective wavelength of the receiver as a whole increased.

Q. 4. What is a loading coil?

A. A loading coil is any inductance placed in series with another inductance in order that longer wavelengths may be tuned in.

Q. 5. What is the difference between a voltmeter and a variocoupler?

A. A voltmeter consists of two coils each wound in opposite directions and connected in series. A variocoupler consists of two coils not electrically connected; one coil being the primary and the other the secondary of the receiving transformer.

Q. 6. What is the advantage of a regenerative receiver?

A. By using the regenerative method the amount of amplification is increased many-fold. The regenerative action causes the vacuum tube to amplify and detect the radio waves simultaneously.

Q. 7. What conditions should be obtained within the receiver in order that sharp tuning may be accomplished?

A. The coupling should be loose; in other words, the primary and secondary should be at minimum coupling.

Q. 8. May a loudspeaker be used with a crystal detector?

A. Not unless a vacuum tube amplifier is employed. The current flowing in the crystal detector circuit run is not strong enough to operate a loudspeaker.

Q. 9. How is storage battery placed on charge?

A. A source of charging current must be available. If this is alternating current a storage battery charger may be used. If the charging source of current supply is direct current a bank of lamps may be used to cut the current down to the proper value. Never charge the battery above the reading given on its nameplate. Always connect the positive side of the battery to the positive side of the charging line or the red colored terminal of the battery charger. Unscrew caps from the top of each cell so that gassing can go on freely.

Q. 10. What is meant by the specific gravity of a storage cell?

A. The specific gravity of a storage cell refers to the density of its electrolyte as compared with pure water. If the specific gravity of the electrolyte is 1.300 (that of a full charged cell) it shows that the acid in the electrolyte has caused the mixture to weigh 1.300 times as much as the same quantity of pure water. The specific gravity of a lead-acid cell rises and falls with charge and discharge. When the battery is discharged considerable acid has left the electrolyte and entered the active material of the plates and therefore the specific gravity is low. When the battery is charged this acid is driven out of the plates and back into the electrolyte, making the specific gravity high. Specific gravity is measured by a hydrometer.

Q. 11. What is the best indication of a fully charged cell?

A. A fully charged storage battery gives a high specific gravity reading. This reading is usually noted on the nameplate of the battery. In most cases it is approximately 1.300. The specific gravity reading is the best indication of the state of charge of a storage battery. If a battery has been on charge for a reasonable length of time it will "gas." After gassing has gone on for at least two hours it is quite certain that the battery is nearing full charge.

Q. 12. How may the polarity of the charging line be determined?

A. If the charging line is direct current the polarity may be determined by a voltmeter. If the voltmeter is not properly connected in the circuit it will not give a reading. If the two line terminals are submerged in a glass of salt water bubbles will appear at the negative terminal. In determining polarity by this method great care must be taken not to bring the terminals of the lines together as a short circuit will occur.

Q. 13. What are the elements in the Edison storage battery?

A. The positive plate consists of rows of perforated nickeled steel tubes into which is packed alternate layers of nickel hydroxide and exceedingly thin plates of pure nickel. The negative plate consists of a number of rectangular pockets, perforated, and filled with powdered iron oxide. The electrolyte consist of a 21% solution of potassium hydrate in distilled water with a small percentage of lithium hydrate having a specific gravity of 1.200. The electrolyte does not fall in specific gravity during charging and discharging, therefore, hydrometer readings are unnecessary.

Q. 14. If the natural period of an aerial is 250 meters, how may signals coming in on a 200-meter wavelength be tuned in?

A. By inserting a variable condenser in series with the aerial lead. This serves to cut down the fundamental wavelength of the aerial. The general rule regarding capacities in series is as follows:

> Two capacities in series give a total capacity less than that of any one of the two capacities taken singly. Therefore, the capacity of the aerial in series with the capacity of the condenser is less than that of the aerial alone. Decreasing the capacity decreases the natural period and therefore it is possible to tune to the lower wavelengths.

Q. 15. How would you adjust a regenerative receiver?

A. The principal adjustment of the regenerative receiver is the tickler coil coupling. If the tickler coil coupling is set as loose as possible and then carefully brought up closer a blub-blub noise will be heard in the headphones. This is the point of oscillation. As the coupling is brought closer a hissing noise which finally turns into a whistle is heard. This is the point of regeneration. When the set is hissing or whistling it is sending out feeble radio waves and any receivers in the vicinity will be affected. It is a good practice, therefore, to operate the regenerative receiver just below the point of regeneration.

Q. 16. What is meant by disturbed capacity?

A. Disturbed capacity is that which occurs between the turns of wire of all inductance coils of the receiving set. If two or more leads are placed close together in the wiring of the set there will be a distributed capacity between them. Distributed capacity lowers the efficiency of the set and should be avoided wherever possible.

Q. 17. What is the difference between damped and undamped waves?

A. An undamped wave consists of a train of oscillations all of equal amplitude. A damped wave consists of a series of oscillations of progressively decaying amplitudes. The undamped wave is of zero decrement. The damped wave has a decrement depending upon the rate at which the amplitude of the successive oscillations are decreasing.

Q. 18. How fast do radio waves travel?

A. 386,000 miles or 300,000,000 meters per second.

Q. 19. What is meant by a pure wave in radio telegraphy?

A. If there are two waves emitted by a transmitter a wave is considered "pure" when the energy of the lesser wave is less than two-tenths of that of the greater wave.

Q. 20. What is the difference between radio frequency and audio frequency amplification?

A. Audio frequency deals with frequencies below 10,000 cycles per second. Radio frequency deals with frequencies between 10,000 and 300,000 or more cycles per second.

Q. 21. Explain the function of the "B" battery.

A. The "B" battery is the principal source of electromotive force which is controlled by the vacuum tube. It is always connected in the plate circuit with its positive terminal to the plate. It is the "B" battery current which operates the loudspeaker and headphones. The incoming radio waves merely serve to control the flow of "B" battery current through these reproducers.

Q. 22. How bright should a vacuum tube be burned?

A. This depends upon the type of tube used. If the filament is made of pure tungsten it should burn a bright yellow. If the filament is of the new thoriated tungsten type it should be burned very dimly.

Q. 23. May a vacuum tube amplifier be used in connection with a crystal detector?

A. Yes, crystal detector signals may be amplified by means of a vacuum tube amplifier.

Q. 24. What is the difference between a soft and a hard tube?

A. A soft tube is one in which the vacuum has not been pumped to a high degree. Gasses are still present in the soft tube. The hard tube is one in which there is a very high degree of vacuum and a very small amount of foreign gasses remaining in the tube.

Q. 25. What causes a "frying" noise to be heard when a soft tube is used?

A. This is caused by burning the filament too brightly. To eliminate the noise, reduce the filament current.

Q. 26. What is the usual plate voltage of a detector tube?

A. 22½ volts.

Q. 27. What is the plate voltage used on amplifiers?

A. From 60 to 80 volts.

Q. 28. What tests may be made to ascertain whether a vacuum tube is oscillating?

A. A clicking sound will be heard in the telephones when the system is oscillating under the following conditions:

1. When the tickler is short circuited.
2. When the grid binding post is touched.
3. When secondary inductance switch on receiver is moved from one contact to another.

If the buzzer is started when audion is oscillating, a soft hissing noise will be heard in the telephones instead of the true note of the buzzer.

Periodic clicks will be heard in the telephones if the tickler coupling is too tight and the grid leak not great enough.

Q. 29. To what cause may failure to obtain oscillations in a vacuum tube be due?

A. Failure to obtain oscillations may be due to the *following causes:*

1. Reversed filament battery.
2. Reversed plate battery.
3. Reversed tickler leads.
4. Reversed leads from the "audion" binding posts on the receiver to the RA and RE terminals on the vacuum tube control apparatus.
5. Value of bridging condenser too small.
6. Improper value of stopping condenser.
7. Tickler too loosely coupled to the secondary.
8. Value of plate current not sufficient.

9. Bad cells in plate battery.
10. Defective vacuum tube.

Q. 30. What is the best wire to use for an aerial?

A. Pure copper wire about No. 14 B. & S. gauge has been found the best for practical usage. In commercial service where great tensile strength is required a stranded wire made up of seven strands of No. 21 B. & S. gauge phospher bronze wire is used.

Q. 31. Is aluminum wire suitable for an aerial?

A. Aluminum wire is satisfactory as far as its electrical qualities are concerned but unsatisfactory from a mechanical standpoint. The weather soon corrodes the aluminum and it becomes brittle and easily breaks. Furthermore, aluminum is very difficult to solder.

Q. 32. How far apart should the wires of a multiwire aerial be stretched?

A. If more than one wire is used in the aerial the strands should be at least one-fiftieth of the length of the aerial apart. Therefore, a four-wire aerial one hundred feet long would have its strands two feet apart.

Q. 33. Should all the connections in the aerial be soldered?

A. Yes. It is good practice to solder aerial connections as the radio waves are very feeble and all unnecessary resistance should be removed from their path. It is more important to have the wires of the receiving than of the sending aerial soldered.

Q. 34. Can insulated wire be used for aerial purposes?

A. Yes. All insulation is opaque to radio waves.

Q. 35. Are cheap porcelain insulators as efficient *as the more expensive molded composition type insulators?*

A. Yes, for receiving purposes the porcelain insulator is as efficient as any that can be obtained.

Q. 36. Is it necessary to insulate an indoor aerial?

A. No. The supports in the inside of a house are in themselves non-conducting enough so as to function as insulators.

Q. 37. What is the best location for a receiving aerial?

A. The receiving aerial should be erected at least 20 feet above the ground if a vacuum tube receiver is used or much higher if a crystal detector is used. It should be in a position so that radio waves from all directions can approach it without striking surrounding objects for a distance of at least a quarter-mile. This is the ideal location and the nearest approach to this possible should be made.

Q. 38. What should be the length of the receiving aerial?

A. The receiving aerial may be anywhere from 75 feet to 150 feet long. If a stretch 75 feet long cannot be obtained, two shorter wires side by side at least 3 feet apart should be used. If the aerial is longer than 150 feet the lead-in should be taken from the center. In cases where the aerial is shorter than 150 feet the lead-in may be taken from one end.

Q. 39. What is the principal advantage of the loop aerial?

A. The loop aerial not being exposed to as large an atmospheric surface as the ordinary wire aerial is not affected to any marked degree by static. The loop aerial also has directional characteristics which are very definite. It is sometimes possible to choose between two stations operating on the same wavelength but located in different positions by simply rotating the loop.

Q. 40. What is the best ground?

A. In the city the best ground is made by connecting to the city cold water pipe system. The gas pipe system. The gas pipe should never be used. In the country a good ground may be made by burying twenty or more square feet of wire netting in moist earth.

Q. 41. What is a counterpoise?

A. A counterpoise is a network of wires used in place of the usual ground connection. It is located if possible directly beneath the aerial and covers considerable more area than the aerial.

Q. 42. What is the purpose of a lightning arrester?

A. A lightning arrester provides a direct path to the earth for all high-powered electric surges such as lightning discharges.

CHAPTER XIII

HOW TO BUILD A NEUTRODYNE RECEIVER

Possibly the most important development in radio engineering in recent years is the introduction of the "Neutrodyne" receiving and amplifying circuit. For the first time really efficient radio frequency amplification is possible.

Technically the "Neutrodyne" circuit neutralizes the inherent coupling capacities of both the vacuum tubes and their associated circuits. This eliminates distorting regeneration, local reradiation and other radio receiver circuit disadvantages.

The "Neutrodyne" circuit is the result of several years' research work by Professor L. A. Hazeltine, Professor of Electrical Engineering at Stevens Institute of Technology, Hoboken, N. J.

Professor Hazeltine is one of the world's noted consulting radio engineers. His work in radio has been of great value to the art, and a fitting addition to his achievements is the development of the "Neutrodyne" circuit. The American Institute of Electrical Engineers have honored Professor Hazeltine by making him a Fellow member. Professor Hazeltine is also a member of the American Society of Mechanical Engineers and a Fellow member of the Institute of Radio Engineers.

On March 2nd, 1923, Professor Louis A. Hazeltine delivered a lecture before the Radio Club of America at Columbia University, New York City, entitled "Tuned Radio Frequency Amplification with Neutralization of Capacity Coupling."

Intensive development work for several months previous to the date of the lecture experimentally verified the importance of the "Neutrodyne" principle.

In fact, there appeared on the radio market at about the time of the lecture two types of radio receivers utilizing the "Neutrodyne" circuit. During the past several months these complete "Neutrodyne" receivers have demonstrated in every part of the United States their superiority for both local and long distance radio broadcast reception.

Literally thousands and thousands of people who like to "construct their own" radio equipment, after knowing the success of the "Neutrodyne" circuit receivers have been waiting for accurate and complete details which would enable them to build their own receivers of this type.

This is published to supply that information and tells in simple and understandable language how to construct, adjust and operate both four and five tube "Neutrodyne" circuit radio receivers

There is no greater thrill than the moment when after the constructional work one is ready to listen-in on the new set of signals. An added joy of the owner of a radio set is to hear the broadcasted concerts from stations hundreds or even thousands of miles away.

Basically the "Neutrodyne" circuit accomplishes a feat which has long baffled the best of all radio engineers. Efficient radio frequency amplification has been a laboratory achievement up until the advent of this circuit. The inherent disadvantages of attempting to combine pure radio frequency amplification with the almost impossible problem of eliminating undesirable regeneration and oscillation has been the bugaboo of both engineer and home experimenter.

Publication of constructional information on the "Neutrodyne" circuit has accordingly been withheld until actual how-to-build-it models could be built and it was felt that the layman could, with pictures and complete data, get satisfactory results from home-made "Neutrodyne" receivers.

The "Neutrodyne" radio receiver requires several special pieces of apparatus. The tuned radio frequency transformers or "Neutroformers" and the special very low capacity variable condensers or "Neutrodons" are the most important units in the circuit.

"The "Neutroformer" (Fig. 84) is a special tuned radio frequency transformer. The design is especially important. The several characteristics

FIG. 84. The neutroformer with variable condenser.

of the unit, such as the distributed capacity and inductance of the windings, mechanical arrangement of the coils, mutual inductance, position of taps and the co-efficient of coupling have been determined very accurately in the laboratory.

The "Neutrodon" (Fig. 85) is a very special variable condenser of extremely low capacity of the order of one to ten micro-micro farads. The

FIG. 85. The Neutrodon, a low capacity condenser.

neutralizing adjustment of the circuit is focused in these "Neutrodon" condensers and they must have practically no losses at radio frequencies.

Three "Neutroformers" and two "Neutrodons" are necessary in constructing either a four or five tube receiver. These parts are packed in a combination package as pictured and can be obtained from most radio merchants or direct from the manufacturer (Fig. 86).

Templates greatly aid the constructional work as they can be made very accurately and can be trimmed to size and pasted directly on the panel and all holes drilled to sizes mentioned.

Bakelite, Formica or Radion hard rubber panels can be purchased, either 24 or 26 inches long, and 7 inches wide by 3-16 inch thick, at most every radio store. The 24 inch panel is for the four tube set and the 26 inch panel for the five tube set.

Carefully trim the paper template to exact size of the panel and paste the corners down onto the panel securely with library paste. A small prick punch can then be used to locate the centers of the holes. After this a hand drill should be used to drill the holes in the panel. Care should be taken in locating the centers of the holes through the

FIG. 86. Combination package, Neutrodyne receiver.

template accurately, and particularly in the case of the "Neutroformer" mounting holes.

The holes on the template marked "countersunk" can be countersunk by using a larger drill and hand brace if necessary, or, where one has it, a regular countersink.

A combination square and dividers may be of assistance if one desires to lay out the panel drilling by scaling the dimensions from the panel template and scribing these dimensions directly on the panel.

The home experimenter can have the engraving placed on the panel by giving the work out to a shop which has regular engraving machines, or can roughly engrave his own panel by carefully making the lines and letters with a sharp scriber and afterward filling in these lines with white enamel. Of course, the most desirable way is to purchase the panel from any good radio instrument shop completely drilled and engraved.

Assembly of Parts on the Panel.—The assembly details of either the four or five tube sets are practically the same, so this data will be taken up in the order of assembling each individual unit on the receiver panels or baseboards.

The only tools required for assembly work are screwdrivers (thin and coarse blades) hand drill and drills, small hammer, prick punch, combination squares, dividers, and a small wrench for fastening the telephone jacks.

Neutroformers.—(Fig. 84.)—The three "Neutroformers" are mounted in the center of the panel height. The panel drilling is such that all three of these "Neutroformers" are mounted approximately at a 60 degree angle from the horizontal. Accurately this angle is 54.7 degrees. This angle is very important and one should not attempt to construct a "Neutrodyne" set without carefully following the paper template layout.

The photograph shows the general relation of the "Neutroformers" to the rest of the set. Each of the "Neutroformers" have a tap in the winding on the outside.

After the "Neutroformers" are screwed onto the panel with the condenser shaft protruding from the panel, the adjusting dials should be fastened onto the shafts nicely so that they do not rub against the panel when rotated.

Rheostats and Filament Switch.—(Fig. 87.)—On both four and five tube "Neutrodyne" sets a regular vernier rheostat is recommended to control the detector tube filament current. This is the rheostat at the extreme right hand end of the front of the four tube set and the second rheostat from the right hand end of the five tube panel. Detailed instruction for mounting the vernier rheostat follows:

1. Remove the entire vernier attachment which will be found attached to the rheostat shaft with a set screw.

2. This releases and allows the removal of the rheostat shaft, the knob and pointer. The rheostat base with resistance strips can then be fastened on the rear of the panel with the machine screws and nuts furnished. The knob and shaft should be inserted through the panel from the front.

3. Rotate the knob and shaft until the pointer is at the desired off position at the left side.

FIG. 87. Rheostat and filament switch.

4. Now press the vernier attachment on the end of the shaft and press it down on the shaft until it rests firmly against the contact strip and until the outer end of the contact lever makes good contact to the resistance strip.

5. Adjust the contact lever pressure so that the lever makes just strong enough contact to permit rotating the vernier disc without causing the main lever to jump from one turn to the next on the

resistance strip. Then secure firmly to the shaft with a set screw.

The same general procedure should be followed in mounting the power tube rheostat, except that the vernier attachment, of course, is replaced by the ordinary contact lever. The power tube rheostat controls the filament current of the three amplifier tubes used. As will be noted from the accompanying drawings, the sockets used should be of a type that allows room for mounting the rheostats between the sockets and the panel.

The filament circuit, "A" battery switch is fastened to the panel by removing the knurled nut and after inserting the threaded stem of the switch through the panel, replacing the knurled nut and turning it up tight.

Binding Posts.—Seven binding posts are used on either the four or five tube "Neutrodyne" set. After inserting the binding posts through the panel, terminal clips should be placed over the screws and then the binding post nuts tightened down securely.

Tube Sockets.—In the four tube "Neutrodyne" set only single tube sockets are used, while in the five tube set two single and a triple socket are required. The sockets may be securely fastened to the panel with the flat head machine screws furnished. One should use care in tightening upon the machine screws so that the heads of the screws will not be injured and that the screws exposed on the front of the panel will not appear unsightly. Before assembly of the sockets on the

FIG. 88. Tube socket.

FIG. 89. Tube sockets.

panel it may be well to see that all contact springs are firmly attached to the socket base and bent up into the socket shell so that good contact will be assured when the vacuum tubes are inserted.

Telephone Jacks.—Two telephone jacks are used on these receiving sets. One of these is of the "single open circuit" automatic filament control type and the other a "single closed circuit" type (Fig. 85).

On the four tube set the "automatic" type, or the one with the three contact springs, should be fastened onto the left hand end of the panel. The jack with two contact springs, of course, must then be fastened on the four tube panel under the number 3 "Neutroformer" tuning dial.

On the five tube set the reverse arrangement is followed. The three spring jack is at the right hand of the panel, and the two spring or "closed

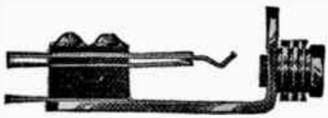


FIG. 90. Telephone-jack

circuit" jack is mounted directly under the vernier tube rheostat knob.

Before assembling the jacks on the panel the contact springs should be examined to see that proper contact is made when the telephone plug is inserted.

Baseboards.—The wooden baseboard is fastened to the panel by three wood screws. It should be carefully located, even with the bottom of the front panel and the screw holes started with a small drill. Using a small starting hole and rubbing soap on the wood screws will allow screwing the baseboard and panel together very firmly.

The baseboard should be shellaced or varnished to prevent the absorption of moisture and the consequent warping and splitting.

Neutrodon Condensers.—These two "Neutrodons" are mounted on the baseboard between the first and second and the second and third "Neutroformers." Use a combination square and line the bakelite "Neutrodon" bases up square and true with the edges of the baseboard if you desire a neat looking finished instrument. Then fasten this bakelite base down to the baseboard using two wood screws.

The adjustable brass tubes of the "Neutrodons" should be placed about in the center of the glass tubes and under the fastening down clamp.

Audio Frequency Transformers.—Two audio frequency amplifying transformers are

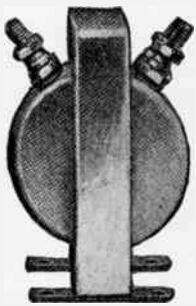


FIG. 91. Audio frequency transformer.

used on either the four or five tube sets (Fig. 91).

Care should be taken in mounting the audio transformers to arrange the terminals so that all wiring to the transformers is as short and direct as possible.

WIRING UP THE ASSEMBLED NEUTRODYNE RECEIVER

The Four Tube Set.—It is best to fasten the baseboard to the panel when assembling in order to properly locate the holes for fastening, etc. After the entire receiver is assembled, however the baseboard should be removed from the panel in order to facilitate the wiring. This will mean that the receiver is wired up complete without the baseboard, with the exception of the audio transformers and "Neutrodons" which are actually fastened to the baseboard.

A complete wiring diagram for the four tube "Neutrodyne" receiver is shown (Fig. 92). One should study this diagram carefully before proceeding with the wiring to get in mind the general plan of the connections. The tuner, first radio frequency unit, and second radio frequency unit on the diagram are respectively the left hand, center and right hand "Neutroformers."

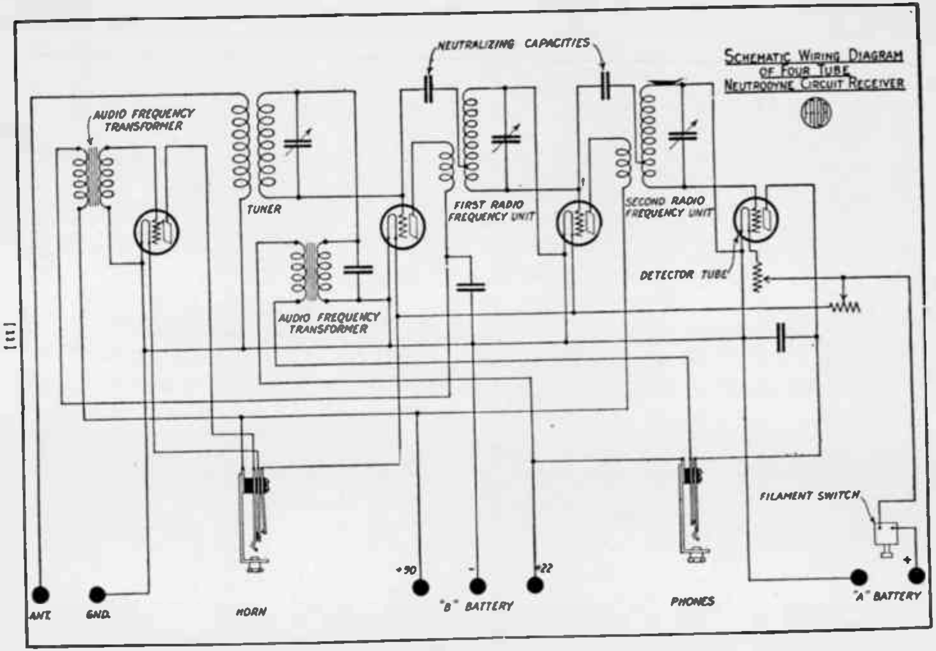


FIG. 92. Four-tube neutrodyne circuit.

The fixed condenser on the diagram shown connected in parallel with the audio frequency transformer secondary between the first two vacuum tubes should have a capacity of .0002 microfarads. The other two fixed condensers shown should have a capacity of .006 microfarads. The neutralizing capacities on the diagram are the "Neutrodon" condensers.

It is usually best to begin wiring by connecting up all of the negative vacuum tube socket terminals and then extending this same wire to the ground binding post.

In like manner the positive filament connections can be made, the positive terminals of two of the amplifying tubes being connected together. The wiring of the detector tube, power rheostat, vernier rheostat and filament current switch, to the 6 volt or "A" battery bind posts can then be completed.

The next units to wire up are the fixed condensers and the telephone jacks. The fixed condensers can be wired in the circuit and by using No. 14 solid copper wire, the wires soldered to each terminal of the fixed condensers will support them solidly and eliminate the necessity of fastening the fixed condensers down to the baseboard with wood screws.

Now the "Neutroformer" connections can be made. It will be noted that all three "Neutroformer" secondary windings have a small loop or tap. It is very important that no connection be made to the tap of No. 1 or the left hand "Neutroformer" looking from the panel front. The lead from the No. 2 and 3 "Neutroformer" tap should go direct to one terminal respectively of the second and third "Neutrodons" as shown in the wiring diagram.

Final connections can be made to the audio frequency transformers, "Neutrodons," binding posts, etc., after the baseboard has been replaced on the panel.

Five Tube Set.—The five tube "Neutrodyne" set wiring is practically the same as the four tube set except, of course, the socket layout and the position of the audio frequency transformers. It will also be noted from the five tube wiring diagram in Fig. 93 that only two fixed condensers are used in addition to the grid condenser. These two fixed condensers should each have a capacity of .006 microfarads.

No grid leak and grid condenser is shown in the wiring diagram for the four tube set. This, however, is optional with the user. It may be found that the four tube set will function more efficiently

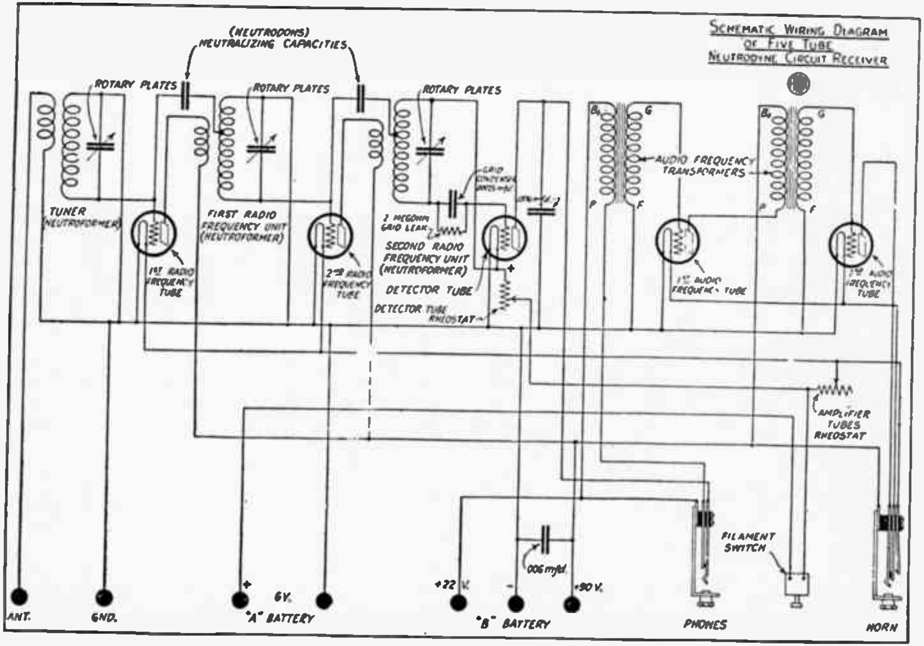


FIG. 93. Five-tube neutrodyne circuit.

with the grid lead and condenser, although it is not a necessity on either the four or five tube receiving set.

General Wiring Hints.—The general procedure in wiring is to cover each wire with insulating tubing after it has been cut to exact length. The bending of the wires can be done after the insulating tubing is placed on the wires. The bending of the wires should be done carefully, all corners being slightly rounded, but with the leads at right angles and square to each other.

All soldering should be very carefully done and under no consideration should acid be used as a soldering flux. The most desirable flux to use is a mixture of alcohol and resin. The no-corrode soldering pastes on the market are permissible if the joints are carefully cleaned, immediately after soldering, with alcohol or gasoline. Another point of importance in soldering is to use a soldering copper that is hot enough. Cold soldering means high frequency resistance and poor mechanical strength in connections.

Another wiring hint of value is the plan of checking off with ink very carefully each wire on the wiring diagrams after it has been connected in place. This gives one a ready check on the wiring and helps in being sure that all connections are properly made.

On both four and five tube wiring diagrams no wire is shown jumping another wire with a semi-circle. The plan shows each wire passing across the others and only connecting to cross wires

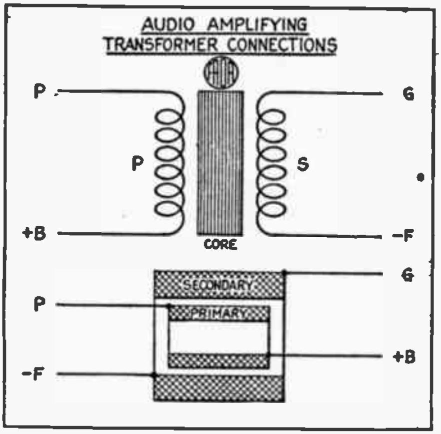


FIG. 94. Audio frequency transformer, showing method of connection.

when represented by a solid black dot. Check this carefully with your wiring.

Fig. 94 will be of assistance in connecting up the audio amplifying transformers as it shows the correct polarity of the windings and should in every case be followed out.

Adjusting the Neutrodyne Circuit.—After the "Neutrodyne" circuit receiver is completely wired up it must be adjusted to neutralize the vacuum tube and stray circuit capacities before it can function properly.

The adjusting process consists of exciting the coupled receiver circuits with a strong signal and then neutralizing the tube and circuit capacities, preventing that signal from being heard through the circuits. This adjustment is one for a minimum signal or inaudible signal, and can accordingly be made very exact, proving the neutralization of the capacity coupling of the circuit. In that this process is carried on with the vacuum tube filament circuits inoperative or cold, it can be readily seen that the process is one of actual circuit capacity neutralization, and not a method of .preventing or reducing regeneration.

The balancing-out procedure as it is called, requires an external circuit made up as in the drawing on p. 370. It consists of an inductance and a variable condenser excited by a buzzer and coupler to the input or antenna terminal of the completed receiver. It is usually desirable to place this adjusting circuit 10 or 15 feet away from the actual receiver and lead a single wire over to the antenna binding post. To complete the circuit arrangement a wire is run from the ground to the ground binding post of the receiver (Fig. 95).

With the adjusting or balancing-out circuit connected as above and with the "A" and "B" bat-

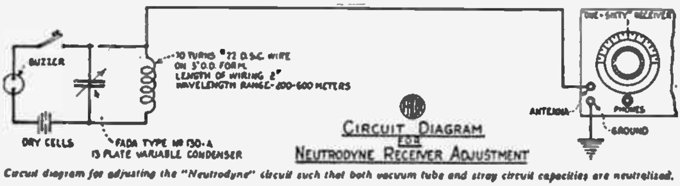


FIG. 95. How to neutralize the neutrodyne.

tery connections made as shown in the drawing Fig. 96, we are ready to balance out our receiver. The method is as follows:

1. Insert three UV-201-A vacuum tubes in the amplifying tube sockets and one UV-200 tube in the detector tube socket. The detector tube socket is the one, in both receivers, directly behind the vernier rheostat. Start the buzzer of the adjusting circuit going and then light the vacuum tube filaments by pulling out the filament switch button. See that the power rheostat is turned as far to the left as possible. Adjust the vernier detector tube rheostat to a point just before a decided "sizzling" and "frying" sound is heard in the

telephones which have been plugged into the "phones" telephone jack.

2. Now rotate all three "Neutroformer" dials on the front of the panel about in step with each

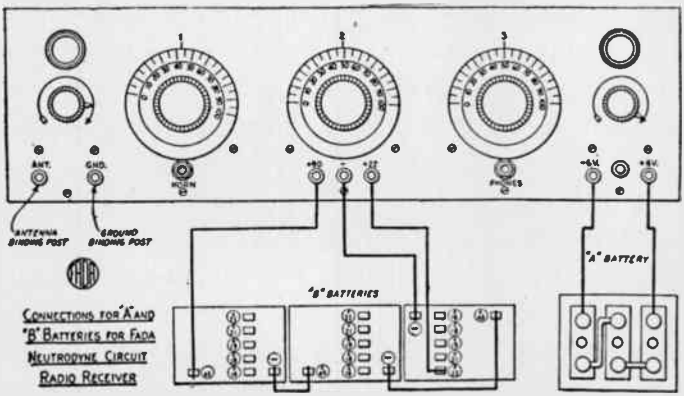


FIG. 96. How to connect A and B batteries to the neutrodyne.

other, and pick up the buzzer signals. The variable condensers of the adjusting circuit should be placed approximately at 15 to 20 degrees, or at an approximate wavelength setting on the scale of 250 meters. All of the receiver dials should then be carefully turned until the buzzer signals come in loudest. All three dials will then be found to have about the same setting.

3. Completely remove the first amplifier or first left hand tube from its socket.

4. Now readjust all three "Neutroformer" dials carefully until the signals again come in at their loudest.

5. Now take the tube you removed from the first socket and place a small piece of paper over one of its filament contact pins so that it will remain in position when the tube is inserted in its socket shell.

6. Placing the tube back in its socket will connect the plate and grid of the tube in circuit but will not allow its filament to light as the small piece of paper over the pin prevents contact. With the tube back again in the socket without the filament lit, signals will undoubtedly still be heard in the phones. The strength of these signals can, however, be varied from loud to weak by moving the brass tube of the first "Neutrodon" or the one placed at the left on the baseboard. This adjustment should be made to a point where the signals are very weak or disappear entirely, and no sound is heard. Now by entirely removing the tube from its socket signals will come in loud. Immediately replacing the tube in its socket (with the paper still in place) the signals will disappear or be very weak. This is the desired condition

and the "Neutrodon" condenser, after being very carefully adjusted to this minimum signal point, may be permanently fastened by soldering the brass tube to the brass clamp in the center.

This covers the neutralizing adjustment for the first radio frequency amplifier tube. Identically the same procedure is followed out with the second tube, having all other tubes, including the first tube, in their sockets and lighted, but putting the paper over the contact pin of the second tube and adjusting the second "Neutrodon" while the tube is in its socket and with its filament unlit. In balancing out the second tube the above numerical instructions can be followed as before, beginning with number 2. It is important when adjusting either Neutrodon that all three "Neutroformer" dials should be adjusted for maximum signals before final neutralization adjustments are made.

The picture in Fig. 97 shows the layout of the adjusting circuit in general and the second "Neutrodon" condenser being adjusted.

The "Neutrodon" condenser, as will be noted from the picture has three terminals. Ordinarily the connections are made to the two terminals at each end. Sometimes, however, one cannot seem to obtain a good minimum signal balance in this way. Then it is recommended that one of the connections of the "Neutroformer" be made to the center terminal. This gives a greater capacity range to the "Neutrodon" and by proceeding with

FIG. 97. Showing the five-tube "neutrodyne" receiver being adjusted for complete neutralization.

the adjusting as above a good minimum or inaudible signal adjustment can be obtained.

A further test to see that the circuit is properly adjusted is to try to pick up broadcasted signals from local stations with the complete receiver hooked up and with all tubes operating as covered on the pages entitled "How to Tune a Neutrodyne Receiver." By rotating the dials over the range of the receiver one should be able to receive the broadcasted signals without hearing beat notes, whistling, etc., which are the usual indications of regeneration and oscillation. If under any circumstances these conditions prevail the entire receiver should be carefully readjusted, wiring separated as much as possible which should eliminate the trouble. If beat notes, etc., are heard it is proof that the circuit is not functioning according to the "Neutrodyne" principle and most satisfactory results cannot be obtained. The experimenter is cautioned in particular to make sure that his receiver is adjusted properly and that no parasitic disturbance is caused by improper neutralization of the circuit.

A very accurate method of adjusting or neutralizing these circuits is the one used in the testing laboratories of one of the commercial companies who are manufacturing "Neutrodyne" receivers.

This method is to use an oscillating circuit whose wavelength is adjustable by variable condensers, which circuit when oscillating is modulating by an electrically maintained tuning fork system.

The home experimenter can readily construct such an oscillating circuit and can use an ordinary buzzer to modulate the circuit and get quite satisfactory results.

The reason for using the tuning fork system is to obtain a constant tone in the ear phones and care should be used to see that the buzzer contacts are clean and that the buzzer is operating smoothly.

When using such a system as this to adjust the "Neutrodyne" circuit, an added advantage is also gained in that an oscillating circuit is used as a test circuit, the receiver can be checked for prevention of oscillations very accurately and quickly because if it is oscillating, beat notes will be picked up from the test oscillating circuits.

This same check is, however, obtained as described above by actually listening to broadcasted signals from nearby stations, and it is recommended that the experimenter always check his receiver in this manner.

Connecting Up the Neutrodyne Circuit Receiver.—Connecting the "A" and "B" batteries to the "Neutrodyne" receiver is a simple task. An enlarged drawing in Fig. 96 shows the battery connections of the four tube home-made receiver. This will make the connections practically self-explanatory and the five tube battery connections are arranged identically the same way.

Both the "A" and "B" batteries have a certain polarity, that is, there is a positive terminal (marked +) and a negative terminal (marked —) to each battery. On both the "A" and "B" batteries the positive terminal is usually painted red or has a red connection wire attached to it.

From the positive terminal on the "A" battery a wire should be connected directly to the positive (+) "A" battery binding post on the front of the panel. From the other or negative (—) terminal of the "B" battery, a wire should connect directly to the negative "A" battery binding post on the panel.

The "B" batteries are made in blocks of 45 volts each. Three of these batteries are connected as shown in Fig. 96. The negative (—) and positive (+) terminals of the "B" batteries will be found marked in the insulated wax on the top of the batteries. To make the series battery connections the wires should connect from the positive (+) terminal of one battery to the negative (—) terminal of the second battery, and from the positive (+) terminal of the second battery to the negative (—) terminal of the third battery. This will leave a positive and a negative "B" battery terminal, and wires should connect from the negative (—) terminal to the center binding post on the receiver between the two binding posts marked +90 and +22, and from the remaining positive "B" battery terminal to the binding post on the panel front marked +90.

Now only one "B" battery binding post on the receiver remains unconnected. A connection wire should go from this binding post to the clip terminal (marked 22 1-2 volts) of the first "B" battery. The first "B" battery is the one to which the wire from the center or negative binding post is connected.

Best results are often obtained by a detector voltage as low as 15 or as high as 35. Likewise, the amplifier voltage may be as low as 90 and as high as 130 volts. Trial alone will determine which is best.

How to Tune Neutrodyne Radio Receivers.—The "Neutrodyne" radio receivers have many advantages over the ordinary receiver in tuning or in selecting one station from another. This method of tuning "Neutrodyne" receivers is much different from that used for the ordinary receiver. Accordingly these tuning instructions should be studied very carefully and the manner of adjusting thoroughly understood, otherwise the receiver may seemingly be inefficient, the fault, however, being with the operator.

The procedure of tuning a "Neutrodyne" receiver, providing antenna, ground and all battery connections have been properly made, is as follows:

1. Insert the recommended vacuum tubes in their respective sockets and with the power rheostat at its correct position for the type of tubes you are using, and with the vernier rheostat knob turned to the left as far as possible, and with the plug of the loudspeaker inserted in the "horn" jack, pull out the knob of the filament switch on the panel front, causing the three amplifier tube filaments to light.

2. Turn the vernier rheostat knob to the right slowly. When the filament current is turned on the first indication that the receiver is functioning properly will be indicated by hearing a slight noise in the phones. As the rheostat knob is turned further to the right this slight sensitivity indication does not increase in volume until a point near the end of the rheostat adjustment is reached. At this point will begin a comparatively loud "hissing" and "frying" noise which is objectionable. For the best signal reception the rheostat should be turned back slightly to a point just be-

fore this "hissing" and "frying" starts. The coarse adjustment of the rheostat enables you to quickly adjust the rheostat and then very accurately adjust it by using the smooth running vernier.

3. With detector tube at approximately its right operating point, set "Neutroformer" dials 2 and 3 at the same dial setting. Select any particular dial setting, but as shown by the curve in Fig. 98, take for instance the wavelength of station WEAF on 492 meters. Dial settings for this particular station are approximately 66 or 67. Setting dials 2 and 3 at this point, now rotate dial 1 very, very slowly over its entire range from 0 to 100. If any broadcasting station is operating at the particular time on a wavelength of 492 meters, it should be heard at a maximum when the setting of dial 1 is approximately in the range of 10 to 15 above or below these settings of dials 2 and 3.

4. When signals from any particular broadcasting station are coming in, it is advisable to slightly readjust dials 1, 2 and 3 and possibly also the vernier rheostat in order to increase the intensity of the signals.

In tuning, the dials should not be moved faster than a few degrees per second. With either the headtelephones or loudspeaker plugged in the

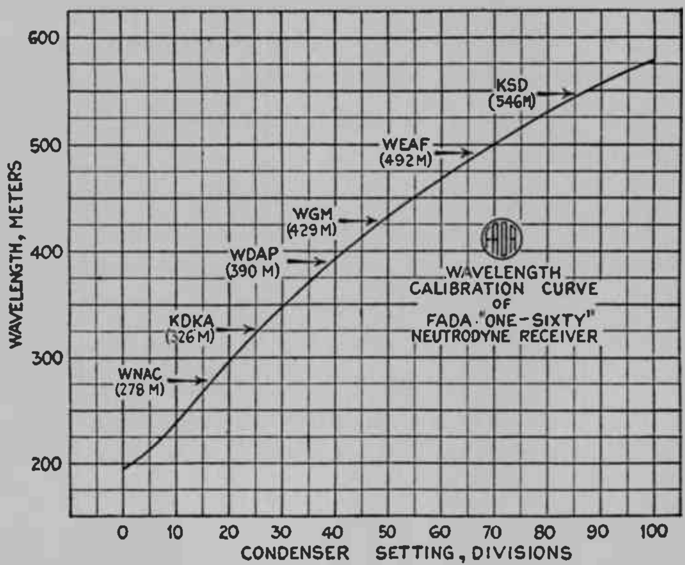


Fig. 98. Tuning curve using the neutrodyne receiver. Note how each wave is received on a different setting.

"phone" or "horn" jack, it may be found that the tuning adjustment will need to be changed slightly when shifting from one jack to another.

Dials 2 and 3 should be rotated slowly at the same time, and about in step with each other. Then with dials 2 and 3 on the setting for a particular station, dial 1 is rotated until signals come in with maximum strength and clarity.

Sharpness of tuning of "Neutrodyne" circuit receivers when using short indoor antennas is much greater than when using an outdoor antenna and care should be taken in adjusting the receiver, particularly dial 1, when an indoor antenna or loop is used.

In tuning "Neutrodyne" circuit receivers, the broadcasting stations will not be picked up by hearing "beat notes" and the usual regenerative whistling. As the dials are rotated from division to division the program of different stations will be heard, first gradually, then with greater intensity and clarify as all adjustments are properly made for that particular station.

As the user succeeds in picking up programs from various stations, notations should be made in the log book of the call letters and dial settings and if at a later date one desires to listen to the same station, it is merely necessary to reset the dials to these same positions. If the particular station is operating at the given time the signals will be heard. This is a feature possessed by practically no other radio receiver developed up to the present minute.

The wavelength calibration curve of the Fada "One-Sixty" neutrodyne receiver, which uses "Neutroformers" practically identical with the ones furnished for home construction, will greatly aid in tuning the four or five tube "Neutrodyne" receivers.

Using Dry Cell Tubes With the Neutrodyne Circuit.—There are several kinds of vacuum tubes on the market which can be used with dry cells. Among these are the UV-199's, WD-11's, WD-12's and the DV-6's. Such tubes operate with a very low filament current consumption. The four and five tube "Neutrodyne" circuit receivers described in this booklet were not designed particularly to operate with such tubes. It is recommended that wherever possible either UV-201 and UV-201-A amplifier tubes be used together with a UV-200 detector tube.

These "Neutrodyne" receivers will, however, function fairly well using the dry cell tubes mentioned above. Adapters may be used to allow placing tubes in the regular standard sockets.

The radio experimenter may find with these dry cell tubes that by varying the various constants of the circuit, or by using a negative grid bias or "C" battery, good reception can be had on both local and long distance stations. One should not, however, expect the volume of signals from UV-199 tubes, for instance, as when using UV-201 or UV-201-A tubes, as the current that the tube is capable of handling is very much smaller.

CHAPTER XIV

IMPROVEMENTS IN RADIO APPARATUS

Like the automobile, radio apparatus is being constantly improved. Although no radically new circuits have been developed recently there has been a re-designing and improving process applied to vacuum tubes, inductance coils, condensers, and receivers in general. These improvements have made the quality of the signal received better. New cabinets have made sets more pleasing to the eye. However, the most modern receivers operate on the same underlying principles of radio heretofore described in this book.

Alternating Current Vacuum Tubes. —The first practical alternating current vacuum tubes to appear on the market, known as the McCullough A.C. tubes are a marked improvement in tubes which operate directly from the A.C. house lighting circuit. The use of these tubes eliminates batteries entirely, as the power supply is taken directly from the light-socket. This method also, of course, eliminates the need of a battery charger or B-battery eliminator and current controlling rheostats. These tubes are designed to have a longer operating life than the battery type tubes.

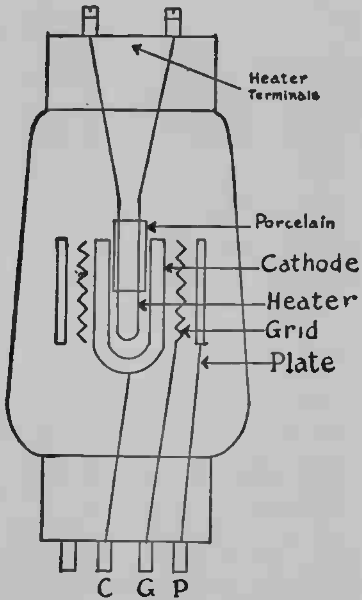


FIG. 99. Schematic diagram of A.C. tube construction.

The quality of the received signal in a radio set depends in part upon the density of the electron stream emitted from the tube filament. Due to the fact that the electron emission in the new tube is from an extra heavy element called the cathode and not from the filament, a much heavier stream is emitted with the resultant increase in the amplifying power of the tube. Microphonic sound so common to the battery type tubes is eliminated in the new A.C. tubes. The operating cost of these tubes is practically negligible, amounting to only a few cents an hour.

The diagrammatic illustration in Fig. 99 shows how the A.C. tube is constructed.

This tube has no filament, but in its place is a heater coil which heats the cathode. It is to be noted that the tube has five terminals: plate, grid, and cathode on the bottom, and the heater terminals on top. One prong in the base is left disconnected.

As the tube has no filament its life is long. The heater coil, being of rugged construction, does not burn out quickly.

A stepdown transformer reduces the alternating current to the proper voltage for the tube. It consumes about as much current as a 30-watt lamp and cost approximately two cents an hour to operate. The exact cost will, of course, vary with the number of tubes operated.

The theory of the A.C. tube is the same as for the original three element vacuum tube. As a

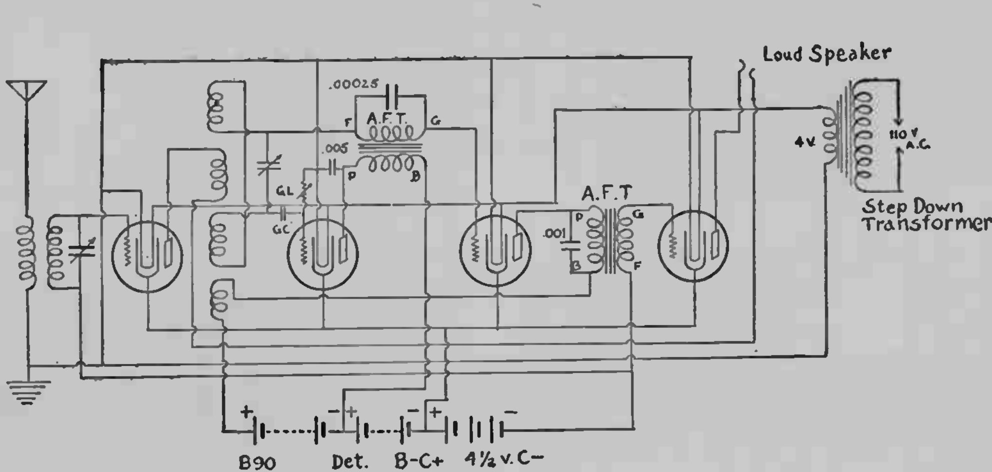


FIG. 100 A method of connecting the A.C. tube.

matter of fact, the A.C. tube is a three element tube from a radio standpoint, the plate and grid being identical in both types of tubes. It is in the construction of the electron emitter (filament) that the new tube is a departure from ordinary battery tubes.

As shown in the illustration of the tube construction, the old style filament gives place to the "cathode" as the electron emitter. Inasmuch as the "cathode" will not emit electrons unless it is heated, provision is made to bring it to a dull glow by the "heater." This "heater" does not function in the radio circuit, but serves only to heat the cathode.

A study of the diagram of connections, Fig. 100, shows the heater grounded at the end farthest from the transformer. This connection is made to eliminate the hum of the A.C. current and is, at least theoretically, of no use to the actual functioning of the tube.

A point of argument has arisen as to the actual performance of the heater. Some engineers claim that the heater also emits electrons, thus aiding the operation of the tube. The engineers originally conceiving this tube left this function entirely to the cathode. Eventually, perhaps, actual measurements will settle this mooted point.

All of the negative (—) terminals of the sockets are connected together. The cathode of each tube makes contact to these terminals as indicated in the diagram.

The tubes operate on four volts supplied by the stepdown transformer, as shown. This transformer may have three taps, viz.: 4, 4½, 5 volts. Connection is made to the 4 volts tap when using from one to three tubes, to the 4½ volts tap when using four or five tubes and to the 5 volts tap when using five or more tubes. The transformer should be placed at least three feet from the set to avoid any A.C. hum.

All of the tubes in the circuit as shown, except the detector tube, have a grid return made to the cathode or filament circuit through a 4½ volt "C" battery whose positive terminal is connected to the cathode lead as shown.

Radiotron UX Type Vacuum Tubes.—Vacuum tubes are being constantly improved. The original vacuum tubes were made with tungsten filaments, which consumed a relatively large amount of current. As an improvement, the thoriated filament was invented. This meant a lower filament current and a consequent saving in batteries. The latest developments have to do with tubes capable of handling greater power, which means the elimination of distortion. The first of these tubes were placed on the market by The Radio Corporation of America and designated by the numbers UX-120, UX-112, UX-210, UX-216-B and UX-213.

The Radiotrons UX-120, 112 and 210 are designed for audio frequency amplification. The Radiotrons, UX-216-B and UX-213, are rectifier tubes for use in "B" battery eliminators and other similar devices.

The Radiotron UX-120 is a dry battery power amplifier tube designed especially for use in the last stage of an audio frequency amplifier. It will give a large volume of undistorted signals to the loudspeaker.

The plate potential is 135 volts, a lower plate voltage will reduce the volume in the loudspeaker. When this tube is used in the last stage of audio frequency amplification, large size "B" batteries will give most economical operation.

All high plate potential audio frequency amplifiers need a "C" battery. In this case, the grid return lead should go to the negative terminals of a 22½ volt "C" battery. The positive terminal of this battery is connected to the negative filament lead between the rheostat and the tube.

A special base (small "UX" base) is used with this tube. An adapter provides for its use in the regular UV-199 socket.

The Radiotron UX-120 is a power amplifier tube to be used usually as the last audio stage of sets employing UV-199 tubes.

The UX-112 tube is designed to be used on storage battery sets as the last audio stage amplifying tube. Due to its heavier current carrying capacity, a greater volume with less distortion than when using the UV-201-A type of tube is to be had.

As an audio frequency amplifier, the UX-112 tube occupies a position half way between the UX-120, which is a dry cell tube, and the power amplifier tube UX-210.

Care should be taken not to operate this tube above a dull red heat as excessive filament current shortens the life of the tube.

The UX-210 Radiotron handles a relatively heavy power, as shown in the table of tube characteristics. It is designed primarily for use as a power amplifier with loudspeaker where great volume without distortion is required. It may also be used in any ordinary amplifier circuit where long life is necessary or where the plate voltage is high.

As the plate voltage of this tube may be as high as 425 volts, great care must be taken to avoid shock when handling exposed circuits. However, if the high voltage circuit wires are not exposed there is no more danger in handling this than any other Radiotron. All current should be turned off at the source before any adjustments are made in the circuit. The user is cautioned not to use excessive filament or plate voltage with this tube. The plate temperature should never exceed a dull red heat.

A large standard (UX) base is used with this tube.

Because this tube has a rated output as an oscillator of 7.5 watts, it should prove popular in amateur transmitting sets. With plate voltage under 160, the filament may be operated direct from a 6 volt storage battery without a rheostat. The proper "C" battery voltages are given in the table of characteristics and vary with the plate voltages.

The Radiotrons UX-216-B and UX-213 are half and full-wave rectifiers, respectively. They are used to supply D.C. power from an A.C. source.

Two model UX-216-B tubes connected in parallel will function as a full wave rectifier.

In the model UX-216-B, only three of the prong contacts are used, one being left disconnected. This tube has only two elements, a filament and a plate. The model UX-213 has a filament and two separate plates and, therefore, uses all four of the prong terminals in the base. The operating characteristics of these tubes are given in the table.

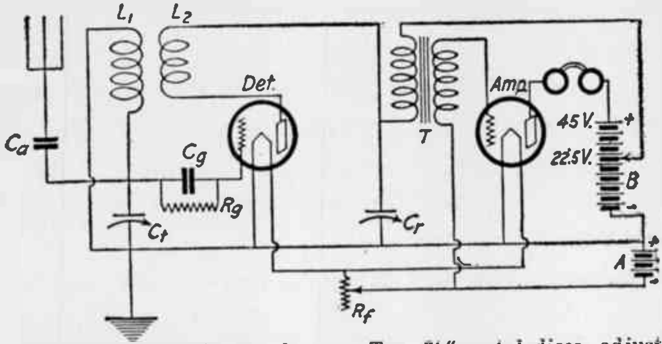
Short Wave Radio.—Perhaps the most important recent development work in Radio has been with short waves in the range between 5 and 100 meters. Considerable experimental work has been done in both America and Europe in utilizing these wavelengths for radio broadcasting. American radio amateurs of the American Radio Relay League have been particularly successful with this type of apparatus.

Amateurs in America have regularly communicated with fellow amateurs in France, England, and even in far-away New Zealand. The General Electric Broadcasting Station at Schenectady have transmitted regular programs on short waves. The Westinghouse Station, KDKA, at Pittsburgh has likewise utilized short waves for transmitting broadcast programs.

CHARACTERISTICS OF UX TUBES

Type	Base	Use	"A" Battery Source Volts	Fil. Term Volts	Filament Amperes	"B" Battery Volts	Plate Current Milliamperes	"C" Battery Volts
UX-120	Small RCA "UX"	Last Stage Audio Amp.	4.5	3.0	.125	135	6.5	22.5
Radiotron UX-112	Large RCA Standard "UX"	Detector or Amplifier	6.0	5.0	0.5	157.5 Max.	7.9	10.5
			6.0	5.0	0.5	135.0	5.8	9.0
			6.0	5.0	0.5	112.5	2.5	7.5
			6.0	5.0	0.5	90.0	2.4	6.0
Radiotron UX-210	Large RCA Standard "UX"	Amplifier Oscillator	6.0 to 8.0	7.5	1.25 Max.	425.0 Max.	22.0	35.0
				7.5	1.25	350.0	18.0	27.0
				7.5	1.25	250.0	12.0	18.0
				6.0	1.1	157.5	6.0	10.5
				6.0	1.1	135.0	4.5	9.0
				6.0	1.1	112.5	3.0	7.5
				6.0	1.1	90.0	3.0	4.5

Type	Base	Use	Filament Terminal Voltage	Filament Current Amperes	Maximum A.C. Input Voltage Per Anode	Maximum D.C. Load Current Milliamperes
Rectron UX-213	Large RCA Standard "UX"	Full-Wave Rectifier	5.0	2.0	220 (R.M.S.) from Plate to Filament or 440 (R.M.S.) total A.C. Input Voltage	65
Rectron UX-216-B	Large Standard RCA "UX"	Half-Wave Rectifier	7.5	1.25	550 (R.M.S.) Maximum A.C. Input Voltage	65



Ca = Antenna coupling condenser. Two ¾″ metal discs, adjustable ln binding posts.
Ct = Tuning condenser. Three rotary plates, any low-loss condenser.
Cr = Regeneration control condenser. 0.00025; any good make.
Cg = Grid condenser. 0.00025 MFD fixed mica.
L1 = Grid coil, diameter 3 in. No. 16 D. C. C. copper wire, Lorenze type. 17½ turns for 80 meter band, 7½ turns for 40 meter band, 2½ turns for 20 meter band.
L2 = Tickler coil, diameter 3 in. No. 16 D. C. C. copper wire, Lorenze type. 9½ turns for 80 band. 4½ turns for 40 meter band, 3½ turns for 20 meter band.
Rf = Filament rheostat. 30 ohms for 199 tubes, 6 ohms for 201A tubes.
T = Audio transformer. Any good make.
Rg = Grid leak. Fixed, 9 megohms. (Different tubes may require from 5 to 9 megs.)
Coils for each wave band fixed in position relative to one another by 3 glass rods and few drops of collodin.

FIG. 101. A short wave receiver.

Short waves have the advantage of travelling over exceedingly long distances on low power with little absorption. Another advantage is that short waves being of very high wave oscillation frequencies allow more stations to operate simultaneously over a given wavelength band without interference. For example, where only 14 stations can operate between 300 and 350 meters, 300 stations can operate between 50 and 100 meters. This is due to the fact that the low wave stations are separated by the same wave frequencies as the high wave stations.

Referring to the table on page 63 we can see that there is a difference of 1,000 kilocycles between the wavelengths 100 and 150, while as the wavelength is increased, the difference in cycles between 300 and 600 meters remains almost the same, while the difference in wavelength is much more.

The Burgess Battery Company have designed a short wave receiver for amateur use which is described in detail in their Engineering Circular No. 7. The schematic diagram with nomenclature included here, Fig. 101, is from this booklet.

An interesting use of short waves is in what is called re-broadcasting. This means that signals are sent out from a transmitting station on short waves, received at some distant point, perhaps thousands of miles away, and again transmitted through a transmitter located at this point. Signals have been sent from England and received in New York to be again sent out from a New

York broadcasting station on regular broadcasting wavelengths.

Low-Loss Coils.—The name low-loss has come to be a big selling point with many radio set manufacturers. This name was, perhaps, first coined by the American Radio Relay League laboratories at Hartford, Connecticut, and grew out of the attempt to build inductance coils and condensers for low wavelength use where it was of prime importance to eliminate high frequency current losses.

While all radio designers strive to make losses low in the radio circuit, it was not until low waves came into general use that this feature of design was greatly stressed.

Low-loss coils and condensers are built with a minimum number of insulating supports. The electrical circuits are as far as possible physically self-supporting. An example is found in the well-known basket weave coil, where supports for the wire turns are completely eliminated. A high grade of insulating material and careful circuit design will tend to cut down current leakage and make a set low-loss. Radio signals are so extremely weak when received by the receiving set that low-loss design is a big advantage to the otherwise well-built set.

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SUPPLEMENTARY INDEX