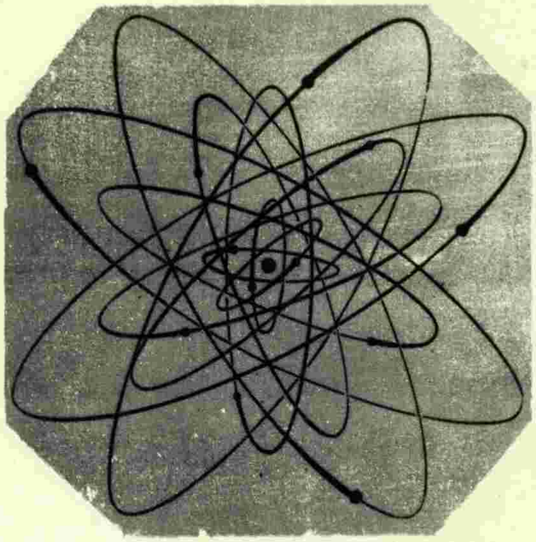

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GENERAL REVIEW

RADIO-TELEVISION TRAINING SCHOOL, INC. LOS ANGELES ESTABLISHED 1922

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GENERAL REVIEW

When Benjamin Franklin discovered electricity through the use of his lightning rod, the two units: positive and negative, were just arbitrary figures to designate the units for electricity in motion. Not until recently was there any definite discoveries made as to how current does flow. Science has since found out through definite experiments that electrons flow from negative to positive. This theory is called the electron theory, because all matter is composed of atoms, and an atom is the smallest particle into which any substance can be broken down and still retain the characteristics of that element. Each atom is composed of a nucleus, which is a positive charge and is stationary. Depending on the matter used, each atom has a definite amount of electrons which are held in their orbit by this plus charge. When an outside force is impressed upon an atom, it tends to allow the electron to break away from its boundary, and it is attracted to the plus charge of the next atom, traveling at such a high rate of speed that it tends to knock other electrons off the preceding atoms. This constant bumping takes place at such a terrific rate, it now constitutes an electron flow. As the electron or negative charge is the only moving part of the atom, science concluded that electrons flow from negative to positive. This is known as the electron theory or electricity in motion.

In the early days of electricity direct current was in constant use, but as electricity was used more commonly, it was found that alternating current, which travels in cycles, could be transmitted a farther distance than direct current without so much line loss. This was a great step forward in the use of electricity and most of the electrical equipment used today, especially in the large cities, is operated on an alternating current line.

It was also through the electron theory that science began to get a more complete understanding of magnetism, whose phenomena has been a controversal subject of the last one hundred years. The only possible way that science arrived at a clearer understanding of magnetism was through the electron theory; they have found that in a magnet there exists another phenomena called the magneton. This magneton is practically the same as an electron and by arranging the molecular construction of a steel bar, magnetism was brought into being. It has been proven that the magneton, like an electron, starts at the south pole in a magnet, travels through the axis of the magnet to the north pole; in other words, it is attracted to a point of higher potential. It is emitted from the north pole, returning to the south pole to complete a magnetic circuit. Magnetic lines of force cannot be seen by the naked eye, but they can be measured as to density with special instruments provided for that purpose. One of the strangest effects of magnetism is that it cannot be insulated; no matter how thick the insulation may be, there will always be a leakage.

Electromagnetism will always be found where electron flow is present. Electromagnets can be built in any size or shape, and its magnetism can be controlled at will. Large electromagnets, like those used in industry, save many man hours and can move tons of metal in a short time where it would take man a greater length of time. The electromagnet has a great attracting force through which it can pick up any object made of iron. Electromagnets are constructed with iron of great permeability, which is used as a core and wound with many turns of wire to be able to produce its magnetic effect. When a current is sent through this winding, there will be a great deal of magnetism present; its magnetism depends upon the number of ampere turns of excitation. Because of the permeability of the iron, a great deal of this magnetism will be lost by the magnet when the current is turned off. The magnetism which remains is known as residual magnetism.

When Simon Ohm gave the world his law for electrical circuits, which are now the fundamental laws that govern the three characteristics of any electrical circuit--namely: voltage, current, and resistance--great strides were made in electricity, as now it was known how these characteristics could be figured out. It was also discovered through his laws that electrical circuits could be connected in different ways to perform certain kinds of work. The three basic connections are the parallel, series, and series parallel. If it were not for his discoveries, electrical phenomena may never have been understood as it is today.

The galvanometer was the first electrical measuring instrument. It was first used merely to detect the presence of electricity, but later on was calibrated to measure the current flow in a wire. As time went on there came many other meters: the solenoid, the iron vane, electrostatic, thermocoupled, hot wire, and D'Arsonval. All these meters had their definite places in the electrical field and were the only means through which the three characteristics of an electrical circuit could be measured. All of these meters were calibrated by scale in order that correct measurements could be made. It was later found that by adding resistors in series with the meter itself, the calibration could be lengthened.

Meters of the long coil type were known as volt meters and the wires on these coils were many turns to create a high sensitivity.

The ammeter is an instrument which has a very low amount of resistance to a flow of current as the result of the good conducting material of which its wire is composed. It was through the effort of John Henry, an American physicist, who developed the electromagnet which was invented by Sturgeon, that it became an instrument of far greater importance than before.

It was previously stated that in any conductor through which a current is flowing, there will be produced a magnetic field; from this theory electromagnetic induction was established. There are two types of induction; one is self-induction and the other is mutual induction. Self-induction is the inductive reactance occurring within a single coil when the current through it changes or varies. This electrical inertia effect, which is caused by inductance, tends to keep current flowing at a steady rate. In other words, it prevents the increase or decrease of current through it. Mutual inductance is the phenomena caused when two coils are placed near each other so that a change of current in one coil can set up a variable magnetic field that cuts the turns of wire on the other coil and induces a voltage in it. These two coils are said to be coupled magnetically and the extent to which one coil can influence the other is called mutual inductance of the coils.

The opposition, which is measured in ohms, that an inductance offers to a flow of current through it is called inductive reactance, and the unit for inductive reactance is designated by the letters XL. The inductive reactance of a coil can be found through the following formula: XL is equal to 6.28 times F times L. Where 6.28 is a numerical constant used in AC circuits, F is equal to the frequency in cycles, and L is the inductance in the coil in henrys.

Another device which is used in conjunction with an inductance is called the condenser. Where the inductance tends to keep the current flow steady, a condenser is used to keep the voltage or pressure at a steady level. A condenser will offer a complete block to a DC flow of current but in effect will pass AC current. The capacity effect exists between any two adjacent objects that are at opposite electrical potential and when these potentials change, the capacity will oppose this change. Thus we can say that a capacitance is a voltage equalizer. The ability of a condenser to store up electricity is called its capacitance, and capacitance is defined as the quantity of electricity that is needed to charge a condenser to a potential of one volt. The unit designating capacitance is the farad. A condenser will also offer a certain amount of opposition in an AC circuit in which it is placed; this opposition is called capacitive reactance. The formula to find how much opposition a condenser will offer in a circuit is as follows: Xc (or capacitive reactance) is equal to 1,000,000 divided by 6.28 times F times C. Where 6.28 is a numerical constant used in AC circuits, F is the frequency in cycles and C is the size of the condenser in microfarads. By the above formula it can be proven that the capacitive reactance varies inversely, both with the capacity and the frequency.

It has been an accepted fact that radio waves are sent out through space and reach us in the form of wave motion. These waves are sent out in the form of electromagnetic waves and electrostatic waves and are carried through a substance that is known as ether. The frequency of a wave is measured in cycles per second. Two complete alternations per second of a sine wave are known as one complete cycle, or the period of time that is required for a fixed wave cycle to pass a given point per second.

The amplitude of a wave is the maximum height or distance that a wave will travel from its position of rest. Sound waves in themselves do not travel instantaneously but require considerable time to pass through space. For example, we have all seen working men using a sledge hammer on a spike, but there is a lapse of time from the instant that this sledge hammer comes to rest until you actually hear the sound of the impact. This is because under ordinary conditions sound travels only at the rate of 1,100 feet in one second's time. Radio waves themselves will travel at the speed of light or 186,000 miles per second. In order to have a successful amplitude modulation broadcast the sound frequency wave which travels at a very low rate of speed, it is superimposed on the radio frequency wave which travels at 186,000 miles a second and given a free ride to a point of interception. In a radio receiver some means had to be provided to separate the audio signal from the carrier, as after the waves once reach the receiver, the radio frequency wave is no longer needed. The action which demodulates the modulated wave is called the detector system. Radio communication is divided into three general fields now: short wave, medium wave, and long wave. The waves that are emanated from a broadcast antenna are likewise divided into two parts; they are the electromagnetic wave and the electrostatic wave. The electrostatic wave and the corresponding electromagnetic waves are always at right angles to each other. For broadcast reception the most important wave is the ground wave. This wave follows the contour of the earth and is very close to the ground. The other wave is called the sky wave, used for long distance communications. The sky wave is reflected or bent back to earth by the fact that there is a layer of ionized air which exists into the upper atmosphere. The ionized air is caused by ultra-violet rays which are emanated from the sun and cause clouds of electrons to be present in the upper strata of the air. As electron is a negative charge, these electrons will cause the wave to be bent back to earth depending upon how many free electrons there are in the upper layer of air; depending upon the frequency of the wave, we get more or less refraction. In the higher frequency range, we will get more refraction than in the lower. The distance that the higher frequency travels along the ground is relatively short. Frequencies above 10,000,000 cycles do not travel as far because the earth's conductivity is good at that high frequency. In other words, as the frequencies go up, the conductivity goes up; as the frequency goes down, the conductivity goes down. Between the point where the ground wave stops and the sky wave is bent down to earth again, there will be a dead spot; that is, weak radio reception will be had. This zone is known as the skip distance.

The receiving antenna in its common form consists of a network of wires suspended in space, and in the receiving station, it is used to intercept the radio waves as they move into space and to absorb part of their energy for operating the receiver. Several types of antennas have been devised and are now in use but each has its own special characteristic and is best adapted for a certain class of service. The flat top inverted L, or T type aerials are the most common form of aerials used for low frequency transmission and reception. Extensive experimental work has proven that the best form of antennas for receiving purposes in a single wire from 75 to 100 feet in length and stretched in a straight line between two rigid supports. The loop antenna is a form of indoor antenna suitable only for receiving. Under favorable conditions, the loop antenna is inferior to the outdoor antenna as far as distance and reception and loudness of the signal received is concerned, but a loop antenna is smaller than the outside regular antenna and will not pick up man-made noises or static as much as the outdoor antenna.

As far as the length and height of an antenna itself is concerned, it is entirely dependent upon the location and type of set with which it is to be used. Generally, the longer the aerial, the greater the signal strength received. A shorter aerial may be used for local reception. The characteristics of the receiver must also be taken into consideration. As the newer radios have greater sensitivity and are able to give good volume, they are able to operate efficiently on very short aerials. In a set that does not possess such high sensitivity, a longer aerial is needed to produce equally good results. The height of the antenna above the ground will also affect the quality of reception. The higher antenna will give you better reception, but at the same time, it will also pull in more static. To calculate the natural or fundamental wavelength of a single wire antenna, simply add the length of the horizontal part of the antenna, the lead-in, ground wire, and multiply the result by $1\frac{1}{4}$. This will give you the wave-length in meters.

Radio reception is always best when the signal voltage is strong compared to the stray-noise voltage. The relation between the strength of the signal voltage and the stray-noise voltage is commonly referred to as signal static ratio. Whenever experiencing noisy reception, always erect a good outdoor antenna and run the longest section of the antenna proper at right angles to other wires, such as power lines and telephone lines. Then, too, use a good ground connection.

Resistors of various types and sizes are employed in radio circuits depending on the nature of the circuit in which they are used and the kind of service that they perform. According to the purpose they serve in the radio circuit, resistors are classed as: biasing, volume control, voltage dropping, bleeder, filter, current limiting, and ballast resistors. The carbon resistor is probably the most used because of the low cost at which it is produced. It is available within the range of 100 ohms to 10,000,000 ohms.

Biasing resistors of carbon are most commonly used in series with the cathode return line, so that the combined plate and screen current in flowing through this resistor sets up a voltage drop that makes the cathode at a higher potential than the point at which the grid return is made placing the control grid negative in respect to the cathode.

Voltage dropping resistors are commonly used in series with the plate and screen grid circuits to bring about any voltage drop that may be necessary.

Filter resistors serve to confine certain signal currents to their respective circuits and to prevent them from passing on into other circuit branches where they might cause disturbances. The difficulty often experienced with carbon resistors is that they change their value either to climatic conditions or as the result of being overloaded. Carbon resistors that have been overheated may become noisy, since the carbon is of a granular construction. Whenever these carbon granulars become loose, particles within the structure make poor contact between the body of the resistor and the terminal wires.

Other types of resistors are: insulated carbon, metalized, wire-wound, vitreous enamel, metal clad, and flexible wire-wound resistors. Each of these resistors has a definite value and place in the receiver circuit, but all of them are used to create opposition or to build up difference of potential.

Definite values of resistance are necessary in some circuits to enable them to perform properly. Even very small amounts in other circuits will impair their operation and operating characteristics entirely. To sum up the meaning of resistance: resistance is the opposition or electrical friction that a conductor offers to a flow of current through it. The unit of resistance is called the ohm. Resistors, which have a high ohmic value, are measured in the unit called the megohm, which is equal to 1,000,000 ohms. Resistors are color coded to aid in quickly identifying their ohmic value. This code is known as the R.M.A. color code and is sponsored by the Radio Manufacturers Association.

The circular mil is the area of a circle, which is one-thousandth of an inch in diameter. The use of the unit called the mil greatly simplifies wire calculation. The area of any round section or conductor is explained in circular mils and is equal to the square of its diameter in mils.

To calculate the voltage drop across any resistor, we use Ohm's Law, which states that the voltage is equal to the amperes times the ohms. If we multiply the amount of current through a resistor by its resistance, it will give us the amount of voltage drop across that particular resistor.

To calculate the size of a bias resistor to be placed in the cathode circuit of a particular tube in order to place the control grid at a negative potential in respect to the cathode, we again apply Ohm's Law in that we take the required negative voltage to be placed on the control grid and divide that voltage by the total amount of current that the tube will draw.

The R.M.A. color code was adapted by radio parts and receiver sets manufacturers to designate the value of resistors so that one can tell by observation of the color of the resistor of what value it is without having to resort to some suitable measuring device.

No other single device has played a more important part in furthering the progress of the radio art than the vacuum tube. The high power and high quality radio transmission and reception of today would be impossible if it were not for these highly developed tubes. Although a great number of tubes have been developed, they all operate on the same principle; that is, an emission of electrons from a heated cathode to a point of higher potential, which is the anode or plate of the tube.

Electrons can be forcibly evicted from an object in several ways, the most common in radio practice being heat or light. When an object is heated, the heat energy is imparted to the electron and is converted into kinetic energy, or energy in motion, causing them to move faster and with greater vigor. As heat application continues, more and more electrons will acquire sufficient energy to set up a steady emission of electrons, which is called an electron flow. Electron emission which is caused by heat is generally termed thermionic emission. Electron emission caused by light is known as photo electric emission. There are two types of electron emitters used in modern radio tubes: one is the directly heated filament and the other is the heater type or indirectly heated cathode. The direct filament consists of a small wire heated by means of an electric current sent through it at a temperature at which the electrons are emitted from the surface. The most commonly used type of tube is the indirectly heated type which can deliver when heated a greater volume of electrons with less current consumption.

The basic tubes, from which all tubes have grown, are called the diode, which is a two-element tube, the triode, which is a three-element tube, tetrode, which is the four-element tube, and the pentode, a five-element tube.

The filament or cathode when heated emits electrons. The control grid is used as a regulator for the emission of electrons, and the plate or anode is the element to which the electrons emitted by the filament or cathode are attracted. In the triode tube, that has just been mentioned, the most positive element of the three elements is the plate and the most negative element is the control grid, which is generally negative inrespect to the cathode. The cathode is the starting point for all electrode voltages.

The electrical resistance of any tube is entirely dependent on the potential of the control grid; if the control grid is placed at a negative potential, it will allow a certain definite amount of electrons to reach the plate (or anode) and as its electrical resistance changes, there will be more or fewer electrons that will reach the positive plate. In other words, a positive or a negative potential on the grid of the tube will either increase or decrease the plate current. If the potential of the grid is made sufficiently negative, its repelling force becomes so great that no electrons at all will reach the plate, and the plate current is reduced to zero. The point at which the grid potential becomes so negative that no more electrons reach the plate is called the cut-off point. When a signal is applied to a tube, it is generally introduced by applying the signal voltage between the grid and the filament or cathode. This is called the input signal.

In a two-element tube, or a diode, electrons will only flow in one direction. It is therefore suited for use as a rectifier of alternating currents, and also is adapted for various alternating control circuits. Although there is no amplification received in the diode tube, it gives excellent rectification.

It should be remembered that although there are many classes of tubes and some tubes are interchangeable, that at one instant when a tube is used to perform a certain type of work, it is classed either as a voltage amplifier or a power amplifier, whether it is in a metal or glass envelope.

Metal tubes employ the same basic operating principles as the glass. In fact, the internal structure is practically the same in both types. In a metal tube an all-metal enclosing shell is made to fit more closely around the inner elements. The metal tubes are much smaller in size than their corresponding glass tubes. All metal tubes are provided with an octal or 8-pin base. At the center of the base is a bakelite lug with a key so that the tube can be inserted in only one posttion in the socket. If the tube structure is such that all 8 pins are not needed, certain pins are omitted but this does not affect the position of the remaining pins. Since the metal tubes are so much smaller than the glass tubes, there is less heat radiating surface and consequently some of the metal tubes become extremely hot while in operation. When octal tubes are being inserted into their sockets, care should always be taken that the locating plug fits properly; with some of the thin wafer sockets, it is very easy to force a tube through and cut a new key-way, the result being that the tube fails to work or that the tube is ruined completely.

The S series or single-ended metal tubes, which have all their electrodes, including the control grid, terminate in pins at the base. These tubes have no top cap connection. The letter S following the first number in the tube symbol indicates that it is of single-end construction.

The G type tube combines a special group of glass-shelled tubes for octal type bases with bakelite locating lug and miniature size metal top cap. There is a G type glass tube corresponding to practically every metal tube. The main advantage of the G tubes is that they permit the use of octal sockets throughout the entire receiver, thus standardizing them.

The GT tubes referred to as bantam tubes are a series of midget tubes designed especially for ac-dc receivers.

Loctal tubes are a series of single-ended glass-shelled tubes that were developed to make available a smaller tube of improved structure design and similar operating characteristics. Loctal tubes are especially adapted for ac-dc sets. Loctal means locking-in. In order to remove such a tube from a chassis, it is necessary first to exert a slight off-side pressure on it. This releases the socket lock allowing it to be easily removed.

Mutual conductance is measured in the unit called the micromho and is represented by the capital letter G and the subscript m. It is generally said that a tube for a high mutual conductance is a better tube. The term mutual conductance is derived from two words: mutual, meaning the passage of the signal through the tubes depending on the relative or combined action of all three elements, and conductance, meaning the ease with which a current can flow through a tube.

The amplification of a tube is merely a numerical measure or the amplification a signal receives in passing through a tube. The symbol for amplification is composed of the letters mu or the letter u.

The structure of the control grid and its location with respect to the cathode and plate will determine, to a greater extent, the amplification factor of a tube. In a high amplification tube, the grid is not always very close to the cathode, but is wound in close turns of fine mesh wire so that it has a retarding effect on the electron flow.

The performance and operating qualities of a tube depend not only on its mechanical construction, such as its internal elements and their arrangements, but also on the electrical potentials operative in the circuits in which the tube is used.

The screen grid tube or a four-element tube, which has in addition a fourth element known as the screen grid, that is in the form of a protecting screen around the plate, was designed primarily as a radio frequency amplifier. The screen grid tube was developed after the triode, which was a three-element tube, because the triode was subjected to frequency oscillations which manifested themselves as squeals and howls in the loud speaker. These frequency oscillations were the result of feedback actions occurring between the grid and the plate. There were various methods tried to do away with these disturbances and as a result the screen grid tube was developed.

The most important part that the screen grid plays in the tube is that it does away with space charge, which was an accumulation of electrons,making the tube more effective. It gives greater amplification, is more sensitive, and reduces the grid to plate capacity to a minimum. The screen grid itself serves no purpose in the radio circuit as far as the passage through the tube is concerned; it merely does some of the work formerly done by the plate. Since the screen grid is placed between the control grid and the plate, it is kept at a positive potential constantly with the result that it reduces the capacity effect to zero.

The screen grid tube, although possessed of a great many advantages over the triode, nevertheless, had several shortcomings, the most common and disturbing of which was its rapid plate current cut-off. This characteristic caused cross-talk distortion, which became more troublesome as the sensitivity of receivers was increased. This condition was soon remedied by the introduction of the variable mu or super-controlled screen grid tube.

The four-element tube using the screen grid also had disturbing conditions, which were referred to as secondary emission. For the fact that the screen grid was kept at such a highly positive potential, electrons in their migration to the plate were speeded up so that they bombarded the plate, forcing other electrons off the plate, which is known as secondary emission. To overcome this secondary emission another grid, called the suppressor grid, was inserted in the tube. Now instead of having a four-element tube, we have a five-element tube, known as a pentode. The suppressor grid is usually tied to the cathode internally in the tube and is at zero potential or at cathode potential. Having a strong negative charge on it, it prevents secondary emission. The pentode made available a tube with higher amplification and better operating efficiency. The variable mu tube, as stated previously, solved the problem of cross-talk or cross-modulation, and its construction differs in the design and construction of its control grid. The control grid, it will be remembered, is the controlling element or governing element of the tube and its action regulates the behavior of the entire tube. In the ordinary tube the grid is of a uniform construction throughout its entire mass. The variable mu characteristic of this tube is obtained by employing a grid of non-uniform design. When pentodes or five-element tubes, are used for high-power output distortion is introduced at low plate voltages because of the non-uniform action of the suppressor grid due to its consisting of a set of wires. What was needed was a uniform suppressor action in the path of the electron between the screen grid and plate. This is secured in the beam power tube, in which is employed a set of plates instead of the suppressor grid, which tends to cause the electrons to form a beam to the plate or the anode and also to prevent secondary emission. Tubes in general are classified as either voltage amplifiers or power amplifiers. They are also classified as to their operating points on their respective characteristic curves. The operating points are accomplished through the use of biasing resistors.

The three general classes in radio receivers are Class A, Class B, and Class AB. In a Class A amplifier, the grid bias is of such a value that the normal operating point is near the center of a straight portion of the operating curve and the plate current flows for the full 360 degrees of each input cycle. When a tube is operated as an amplifier, use is made of the fact that the grid is close to the cathode, a small grid voltage causes a larger change in plate current than would be produced by a higher voltage. In a Class B amplifier the tube is designed so that the grid bias is of a value that will make its operating point fall near the cut-off region on its characteristic curve. In Class AB the bias is such that this tube operates midway between Class A and Class B as an amplifier. Tubes used in Class B will operate at a greater efficiency than Class A and usually two tubes are used in push-pull in Class B operation. The use of two tubes lowers the percentage of harmonic distortion.

Since radio messages and programs are carried through space in the form of an electrical wave motion, a receiving station, in order to reproduce these waves, must be able to intercept these waves and absorb some of their energy. For the fact that various transmitters send their signals on waves of different frequencies, the receiver must be able to have some selectivity so that it will respond to waves of only one frequency at a time. Such selectivity is obtained through the use of a tuned circuit. The current in such a tuned circuit circulates back and forth at high frequencies, thus the circuit is often referred to as an oscillatory circuit. Every tuned radio circuit involves the two electrical principles: inductance and capacity. Either one or both of these elements can be variable, but it is common practice to employ a definite fixed inductance coil and variable capacity in the form of a condenser. It is also common to employ a number of tuned oscillation circuits and then pass the incoming signal through each one in succession. The advantages of this arrangement are that if the first circuit is not completely effective in filtering out the undesired signal, the second one is sure to block them out and if necessary even a third or fourth tuned filter circuit can be used.

It is through the uses of such a series of tuned circuits that correct selectivity is secured in our modern radio receiver sets. By selectivity is meant the extent or degree in which a receiving circuit can select the waves of a desired frequency and exclude all the rest.

The fundamental wave length of such an oscillatory sircuit can be found by the following formula: wave length is equal to $1884\sqrt{L \times C}$ or it is only necessary to multiply 1884 by the square root of the product of the inductance and capacity in which W is the wave length in meters, L is equal to the inductance measured in microhenrys, and C the capacity in microfarads, the wave-length range of a coil tuned by means of a variable condenser. The maximum capacity of the condenser determines the highest wave length that can be reached while the minimum determines the lowest wave length. When a condenser is selected for such a circuit, the following points should be carefully observed. The bearing should be rugged, but smooth-running. The plates should not be too thin but evenly spaced and rigidly clamped. The coil used in a tuned circuit functions the most efficiently when it has the greatest inductance for the amount of wire used. Although the function of the coil is to provide a definite amount of inductance, it is impossible to wind a coil without introducing some capacity. This capacity effect exists between the adjacent turns of wire in the coil; the successive turns of wire lying next to each other with a small space between them act as though a small condenser were connected across each turn and since this capacity exists throughout the entire length of the coil, it is known as distributed capacity. The total combined effect of the resistance and inductance, inductive and capacitive feactance, is known as the impedance of a circuit. Impedance represents the total opposition offered to an alternating current in an oscillatory circuit and is measured in ohms. When the capacitive reactance and inductive reactance of the coil and condenser are equal and opposite, they cancel each other out and the circuit is said to be at resonance.

The power supply is a device for transforming the currents from an electrical circuit so that it can be used to effectively operate the component parts of a set. The transformer itself is used either to step up or step down the voltage. This is accomplished through two separate windings: the primary winding consisting of a certain number of turns of wire and a secondary (in a step-up transformer), consisting of many more turns of wire than the primary. Usually a ratio of one to three is maintained; in other words, if there are 110 volts coming in on the primary, there will be 330 volts coming out of the secondary. The power transformer is used in place of batteries and will always maintain a constant supply of voltage and current so that all the tubes will operate at their best efficiency. The power supply itself consists of four component parts: namely, the transformer, the rectifier, filter, and bleeder unit. The rectifier tube is the item that converts the alternating current (from a transformer) into a pulsating direct current. The filter circuit consists of an arrangement of choke coil and condensers. The choke coil permits free passage of direct current but retards the flow of alternating current or pulsating current. The condensers on the other hand, permit the passage of alternating current but completely block the flow of direct current. In other words, the filter system changes the pulsating current into a direct current. The voltage divider or bleeder supply is that part of the power supply unit by means of which the total voltage from the power supply is divided up into the various values that are needed to operate the radio receivers or amplifier. It consists of a series of resistors connected across the output of the power supply and the current through these resistors is tapped off at different points. Also, the desired pressures are obtained for efficient operation.

Radio frequency amplification is the process of amplifying or strengthening an incoming signal before it passes through the detector of a receiver, that is while it is still at the high frequency at which it was sent out by the transmitting station. The important features of good radio frequency amplification are as follows. It makes possible the reception of weak signals from distant stations; that is, it generally increases the sensitivity of a receiver. A well-designed radio amplification circuit uses tuned transformers as coupling units between these successive tubes. These transformers also serve as wave filters and permit signals of only desired frequencies to pass through. Radio frequency amplifier systems are classified according to the coupling methods employed; namely, resistance coupled, impedance coupled, and tuned-transformer coupled, but of these only the tuned transformer system is used in radio receivers for broadcast reception. Although resistance coupling is inexpensive and yields a good quality amplification, it has several disadvantages. One is that the maximum amplification available is that gained from its tube. Also, resistance coupling is well-adapted for only long wave reception and is not readily applicable below 600 meters. Tuned impedance coupled R-F amplifiers will give increased selectivity and although it is a little more expensive than resistance coupled, we do get some amplification. Oscillations in a radio frequency amplifier are also caused by a regenerative or feed-back action that results from some coupling between the grid and the plate circuit of one tube or between the grid circuit of one tube and the plate circuit of an adjacent amplifier tube. Coupling between the grid and plate circuit of a tube may be internal or external. Internal coupling results in the capacity effect that exists between the elements within the tube. External coupling between the grid and plate circuits of a tube will interact and cause violent oscillation. If the grid and plate wires lie close together, the magnetic fields surrounding these wires will react with each other and cause magnetic coupling so that an interchange of energy takes place and oscillation sets in.

Shielding is the practice of inclosing various component parts of a radio receiver in metal cans. Such shielding protects the coils, tubes, etc., from undue electrostatic coupling between one another. It also prevents the inclosed units from picking up noise due to any stray magnetic fields that may be hovering around the receiver. All shielding elements must be well-grounded to the chassis or the effectiveness of the shielding is lost. The function of the detector and its circuit is to demodulate the modulated wave and often its ability and efficiency of demodulation without distortion of the audio signal will govern the quality of the audio reproduced at the loud speaker. There are various types of detectors used in a receiver. Two of the most commonly used are the diode detector, which gives no gain or amplification to the signal, although it reproduces excellently. The plate detector which is also known as the power detector biased at cut-off gives a great deal of power amplification but is not very sensitive to weak signals. The grid-leak detector is a very sensitive detector, but it tends to overload very easily.

A large number of well-performing tuned radio frequency receivers were developed for electrical operation, and many of them are still in active use and are giving satisfactory service. The alignment procedure of a TRF set is as follows: Disconnect the aerial from the receiver and connect the high side of a service oscillator to the aerial post. Also, connect the low side of the oscillator to the ground post on the receiver with the regular ground connection remaining undisturbed. Connect an output meter into the circuit and then turn on the receiver and the oscillator. If the sections of the tuning condenser are equipped with trimmers, set the oscillator at 1000 kilocycles and also bring the receiver dial to this frequency so that the signal can be heard in the speaker. Turn the volume control of the receiver full on and the output adjustment on the oscillator down low enough so that the dial on the output meter stands at about the middle of the scale for the lowest output range. Don't forget the 1-microfarad condenser. If it is not built into the meter, it is to be added in series. Start with the trimmers on the condenser section, tuning the last RF stage nearest to the detector; with an insulated screw drivef or by aligning tool, work towards the antenna. Turn the trimmer adjustment up or down so that the output meter indicates increases. Continue until tuning the trimmer in either direction causes the output to decrease. Proceed in like manner with the trimmers across the next section of the tuning condenser and continue toward the antenna tuning section. As the sensitivity of the receiver increases, the output will also increase and the meter pointer will swing to the right. To keep the meter pointer near the middle of the scale, reduce the service oscillator output from time to time and always leave the receiver volume control full on. During this aligning procedure the tuning adjustment on the receiver must not be touched or altered in any way for this would throw off the entire results obtained and necessitate a repetition of the whole job. When the work is completed and you feel satisfied that all adjustments are as close as they can be made, disconnect the service oscillator and output meter and put the antenna back on the receiver.

During the process of balancing and aligning a radio receiver, either of the tuned radio frequency or superheterodyne type, some form of output indicating device is necessary, for the ear is not sufficiently sensitive to detect small differences in volume, such as must be recognized when an accurate aligning job is to be done. Such an output meter need not be calculated in volts or other absolute values as long as it indicates in some form of graduated scale the relative signal output strength at all times.

The method of connecting an output meter into a circuit system depends entirely on the kind of output circuit employed. Whether a single output tube is used, or two tubes in push pull, and if a magnetic or dynamic speaker is used, the single power output tube is used to operate a dynamic speaker. The output meter can be connected either directly across the voice coil terminals in the speaker, or the secondary terminals of the output transformer. Or, the output meter can be connected directly from the plate of the output tube to chassis with a one-microfarad condenser in series. If two tubes are used in push pull, the output meter can also be connected across the voice coil or transformer secondary, or from the plate of one output tube to the plate of the other. If a single power output tube is used that connects directly to the loud-speaker with no coupling unit, the output meter can be connected directly across the speaker with a condenser in series. If an output transformer or output filter is used, the output meter is connected from the plate of the tube to ground with a condenser in series. If there are two power tubes in push pull driving a loud-speaker, the same arrangement can be used.

The loop aerial is a convenient form of aerial to use for receiving radio messages when it is difficult or impossible to erect a suitable outdoor antenna or when an antenna is desired that can be readily carried from place to place without involving extensive construction work. The loop is also the best antenna to use when it is desired to reduce to a minimum the interference from other stations operating at nearly the same wave length. The loop antenna has greater directional qualities and is entirely immune from danger due to lightning but requires a receiver with high sensitivity or over-all amplification. There are two types of loop aerial used: the spiral and the solenoid loop. A receiver which employes a loop aerial must in itself be very sensitive and selective, as a loop aerial is not as efficient as a regular outdoor antenna.

There have been many feflex circuits developed but all use the same reflex principles with slight deviations. In order for a reflex circuit to work properly, it is very important that the transformers used be properly balanced. Reflex circuits have the undesirable characteristics of other dual purpose circuits. In a reflex circuit the radio signals are first amplified at radio frequencies, then they are reduced to an audio frequency by means of a detector and are finally sent through the same tube again. The advantage of a reflex circuit is its low cost, greater tube economy and better tone quality, if a crystal detector is used.

In an inverse duplex system, the audio signals are reflexed in a reverse order thus equalizing the load on all tubes. In a reflex cifcuit using a crystal, signal distortion may be caused by a poor crystal or by the feflex and incoming signals being out of phase due to faulty transformer design.

After a signal has gone through the demodulating process in the detector and is reduced to an audio frequency, it is further amplified to operate a loud speaker and this process is now called audio or voice frequency amplification. Audio amplifiers were also used for other purposes that are not concerned with radio problems. For example, they are used in electric phonographs in connection with the pick-up for the reproduction of phonograph records; they are also employed in public address systems to make a speaker's voice or music audible over a large area. In sound picture reproduction high grade audio amplifiers are employed. Even photo-electric cell devices involve the use of audio amplifiefs for reliable operation. It is the function of the audio amplifier to amplify the signal from the detector output and apply it to the loud-speaker. It must be able to accomplish this without producing any noticeable change in the speech or music initially transmitted. Consequently, a good audio amplifier must meet the following two requirements: it must transmit and amplify all tones (at all frequencies) alike without showing preference to anyone. It must also amplify all frequencies alike at high and low volume. There must be no frequency distortion or volume distortion. Distortion can be defined as a deformation or change in the wave form of a signal as it passes through the successive stages of a radio receiver. The frequency range of an audio amplifier depends entirely upon the nature of the system in design and quality of the parts employed.

The building up of the signal strength in an audio amplifier depends on the ability of a radio vacuum tube to receive a weak signal voltage on the grid and to relay it or cause it to reappear in the plate circuit with greater intensity. Since the grid is placed much closer to the cathode or filament than the plate is, a very small potential on the grid will bring about the same change in plate current as a very much greater change in plate potential would. Amplification factor is merely a measure of the amount of amplification and signal strength actually taking place and numerically is equal to the ratio of the change in plate potential to the change in grid potential required to bring about the same change in plate current. The number of amplifier tubes used will be determined by the signal strength available from the detector and the amount of power required to operate the loud speaker or reproducing system. Audio amplifiers are also classified according to the method of coupling used between successive stages. Resistance coupling, impedance coupling, and transformer coupling all have their different places in the audio amplification system. When using transformer coupling, for best results an audio transformer should have a transformer ratio of about 2½ or 3 to one. In resistance coupling in which are used resistors in conjunction with condensers, the value of the first plate resistor would depend very much on the characteristics of the tube. A practical rule to follow in using a plate resistor for an audio amplifier is to use a resistor equal from two to three times the plate impedance of that tube. The plate impedance of that tube can be obtained from any tube manual. Higher values are sometimes used; values from 200,000 to 250,000 ohms are often found in these systems. The blocking condenser must be of such size or capacity as to freely transmit the lowest frequency desired. Higher frequencies will pass through with less impedance because the reactance of the condenser decreases as the frequency increases. The condenser must have a sufficiently high voltage rating to withstand the high potential of the plate circuit to which it is connected. If the condenser is too small, the lower frequency response will suffer. A common value fof a condenser in an audio system is a .01 microfarad. The grid resistor must be large enough to permit a high voltage to build up across it and yet not too large to prevent the condenser from discharging rapidly enough not to allow the tube to clog or block. Resistors range from 15 megohms to 5 megohms; these are usually found in radio receivers, the most common value being .5 megohm. A big factor about resistance coupled amplification is the fact that nearly uniform amplification is obtained over the greater part of the audio frequency range but the amplification gained in this type of coupling is only from the tube itself. It is almost impossible to point out definitely any one system of coupling and say that it is the best, because various persons differ in their likes to fesponse depending upon the acuteness of their sense of hearing. Every amplifying system usually has a tone control enabling the individual to select the most pleasing balance; that is, the best tone quality as far as he is concerned.

The use of power tubes in the last stage of an audio frequency amplifier makes it necessary to provide special protection for the loud-speaker. This is done by using a transformer.

For most efficient operation, such last stage power tubes require plate potentials ranging from 135 to 450 volts. By this statement,it is evident that loud-speaker windings are consequently subjected to large increases in plate voltages and current, and are subjected to heavy overloads and severe electrical strains. An output transformer is a transformer that is especially designed to provide the necessary coupling between the two circuits. The primary winding is wound so that it can safely carry the heavy currents that flow in the plate circuit of the power tube. A situation that is occasionally experienced while operating a receiver system is that the audio amplifier refuses to function, even though everything was in perfect working order befofe the set was turned off. Examination will reveal that one of the audio transfofmers is burned out. That is, at some point the winding of the transformer was overheated and melted. This causes an open circuit and no current will flow. This condition invariably occurs in the primary winding of the transformer. The coils of an audio transformer are wound with vefy fine wire just large enough to accommodate ten or twelve milliamperes of plate current that flows through them. The current, in flowing through the transformer winding, stores up a great deal of energy in the form of magnetism in the iron core. When the current to the radio is turned off, this magnetism collapses or tends to cut the wire in the opposite direction to which it formerly was and in doing so, induces the voltage in the winding which tends to keep the current flowing. This is known as self-induction and is merely a form of electric inertia. If the current is turned off very abruptly, as with the snap of a switch, this voltage of self inductance is great; the result is that a larger current surge takes place and the fine wife is overheated and melted at some weak point. This will occur only if the transformer is defective and cannot handle the power.

The operation of a loud speaker differs from that of a grid circuit of an amplifier tube in that the grid is purely a voltage operating device with no current drain while actual power is requifed to operate a loud speaker.

The power amplifier tube will always be found at the last output stage preceding the loud speaker. The pushpull system is a system of audio frequency amplification designed to supply energy to a loud speaker. It will render a great volume of power output and is practically distortionless, therefore, it is a very faithful amplifier. This means that smaller power tubes can be used to provide the given output and smaller power tubes require lower B voltage and this gives greater economies in the B power supply unit. Basically the action of the push pull amplifier is such that the incoming signal swings the grid of one tube positive and that of the other negative. In this manner, it sets up a plate current flow in each tube, the magnetic effect of which is to produce the signal output as though the two tubes were acting in series. One tube acts on the positive half of the cycle, and the other tube acts on the negative half of the cycle.

Care must be taken that the tubes used are similar in their characteristics. This will make the two plate currents equal and, since these currents flow in opposite directions through the primary winding, they will produce equal and opposite effects in the transformer coil. In other words, the magnetizing effects neutralize each other and no magnetization or magnetic flux is set up in the transformer coil. Since no magnetic flux is set up, the iron core of the output transformer can be made much smaller without any danger of magnetic saturation. Tubes placed in push-pull can handle twice as great a signal input voltage as any one tube alone.

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