CHAPTER 2

STATION APPARATUS

2.1 INTRODUCTION

In considering the various types of communication facilities, we will start with the basic apparatus at each end of the circuit and then, in separate chapters, discuss the equipment available for connecting the two. Normally the equipment at each end of the circuit is considered customer station equipment, or even more briefly, the customers telephone. It has the triple function of permitting talking, listening and signaling. Simply stated, however, the telephone is defined as an instrument for converting the mechanical energy of the speaker's voice into electrical energy having similar characteristics and then in turn converting the electrical energy back into similar sound waves at the listener's end.

2.2 SOUND

Since the primary source of the electrical signals transmitted over a telephone system is a speech sound wave and the end product of the transmission system is the reproduction of the original sound wave, a knowledge of the characteristics of sound will aid in the understanding and operation of our communication facilities.

The word sound has two distinct meanings. A physiologist or psychologist defines sound as a sensation produced by certain types of atmospheric disturbances. The physicist uses sound to define the disturbances rather than the sensations they produce.

These disturbances have been found to be waves in the air much like the waves produced when a stone is tossed in a pond. Sound waves travel in concentric spheres and expand at a definite rate of travel which has been found to be approximately 1075 feet per second varying somewhat with altitude and atmospheric conditions.

Sound waves are produced by the vibration of some source, such as a tuning fork or the human vocal chords. The rate of vibration of the source determines the frequency of the sound. A rapidly vibrating source will produce a tone of high pitch while a tone of low pitch will be produced by a slowly vibrating source. The frequencies of audible waves are in the range of about 20 to 20,000 cycles per second.

Audible sound is thus defined as a disturbance in the atmosphere whereby a form of wave motion is propagated from some source at a velocity of about 1,075 feet per second with a frequency range of 20 to 20,000 cycles per second.

Fortunately, in telephone transmission, which is essentially a problem of conveying "intelligibility" from the speaker to the listener, we are not seriously concerned with sounds having either fundamental or harmonic frequencies that extend throughout the entire scale of audibility. The sound frequencies which play the most important part in rendering the spoken words of ordinary conversation intelligible are the band of frequencies within the audible scale ranging from approximately 200 to 3,500 cycles per second.

2.3 THE SIMPLE TELEPHONE CIRCUIT

The original telephone, as invented by Bell in 1876, consisted of a ruggedly constructed telephone receiver, which at that time served as both transmitter and receiver. The telephone circuit in its simplest form consisted of two wires terminated at each end by such an instrument but without transmitter or battery and without signaling features. Figures 2-1 and 2-2 shows such a circuit.

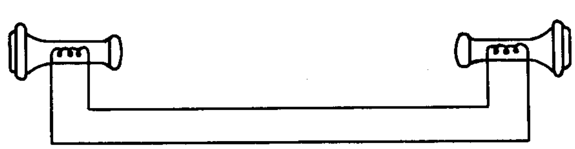


Figure 2-1 Elementary Telephone Circuit

At the speaker's station, the sound waves of the voice strike the metal diaphragm of the telephone receiver, and the alternate condensations and rarefactions of the air on one side of the diaphragm establish in it a sympathetic vibration. Located behind the diaphragm is a permanent bar magnet whose magnetic field is crowded in the vicinity of the metal diaphragm. The vibration of the diaphragm causes a corresponding change in the number of magnetic lines passing through the receiver winding, resulting in the turns of the winding being cut by the building up and collapsing lines. This establishes a varying electric voltage and current in the winding of the telephone receiver, having wave characteristics similar to the characteristics of the sound wave. This varying current passes over the connecting wires and through the receiver winding at the distant end. There it alternately strengthens and weakens the magnetic field of the permanent magnet, lessening and increasing the pull upon the receiving diaphragm, and causing it to vibrate in unison with the diaphragm at the transmitting end, although with less amplitude. This vibrating diaphragm reproduces the original sound, conveying intelligibility to the listener at the receiving end.

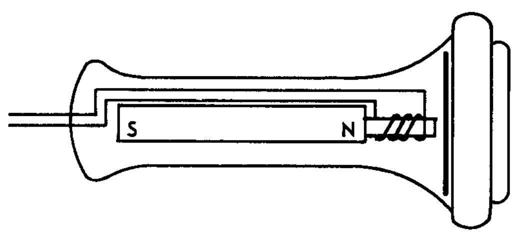


Figure 2-2 Bar-Magnet Transmitter-Receiver

This instrument contains no source of power, but relies entirely on the power generated by the talker's voice, the strength of the field of flux set up by the permanent magnet, and the resistance of the connecting wires. "Voice powered" type sets still exist today (with greatly improved magnetic structures) and are frequently used in the military and in explosive atmosphere environments.

Later developments and improvements in the subsets brought about the splitting of the transmitter and receiver into separate units.

2.4 THE TELEPHONE TRANSMITTER

Although the principle of Bell's original telephone applies to the present day telephone set, it was appreciated in the early stages of telephone development that the electrical energy generated by a diaphragm vibrating in a comparatively weak magnetic field was insufficient for the transmission of speech over any considerable distance. The energy could, of course, be increased by using stronger magnets, louder sounds, and the best possible diaphragms, but even with any ideal telephone receiver that might be perfected, voice transmission would be limited to comparatively short distances. One year after the invention of the original telephone, the Blake transmitter was introduced. It worked on the principle of a diaphragm varying the strength of an already established electric current, instead of generating electric energy by means of electromagnetic induction. It thus became possible to establish an electric current with an energy value much greater than that conveyed to the instrument by a feeble sound wave. The battery in this case was the chief source of energy and the vibration of the diaphragm acted as a means for regulating or modulating this energy supply, rather than as a generating device.

The principle of the transmitter is illustrated by Figure 2-3. The battery establishes a direct current in a local circuit consisting of the primary winding of an induction coil, and a cup of carbon granules. One side of

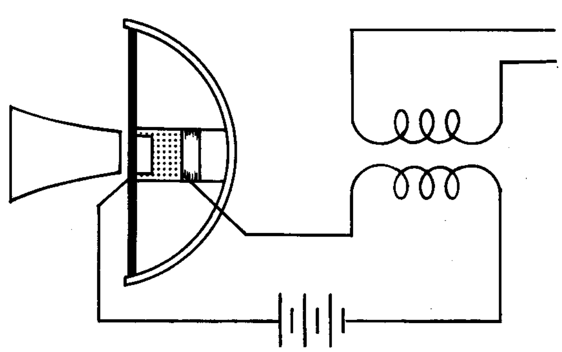


Figure 2-3 Principle of the Telephone Transmitter

this cup rests against a small carbon disc rigidly connected to the transmitter diaphragm. The vibrating transmitter diaphragm varies the pressure on the carbon granules, which causes the resistance of the electric circuit through the carbon granules to vary correspondingly, thereby causing fluctuations in the value of the direct current maintained in the circuit by the battery. These fluctuations, represented by varying direct-current values, establish an alternating emf in the secondary winding of the induction coil. This, in turn, sets up an alternating current through the local receiver, over the line, and through the distant receiver. The operation of the distant receiver is the same as has been explained previously.

The remarkable feature of this unit is the fact that the device is an exceedingly efficient converter from acoustic energy to electric energy. Numerically, the ac power is in the order of one thousand times greater than the acoustic power actuating the unit. The additional energy results from the battery associated with the transmitter.

Figure 2-4 shows a cross section of a standard transmitter unit for subscriber's telephone sets. It is of the "direct action" type; the movable element attached to the diaphram, which activates the granular carbon, is an electrode that serves the dual purpose of contact and pressure surface.

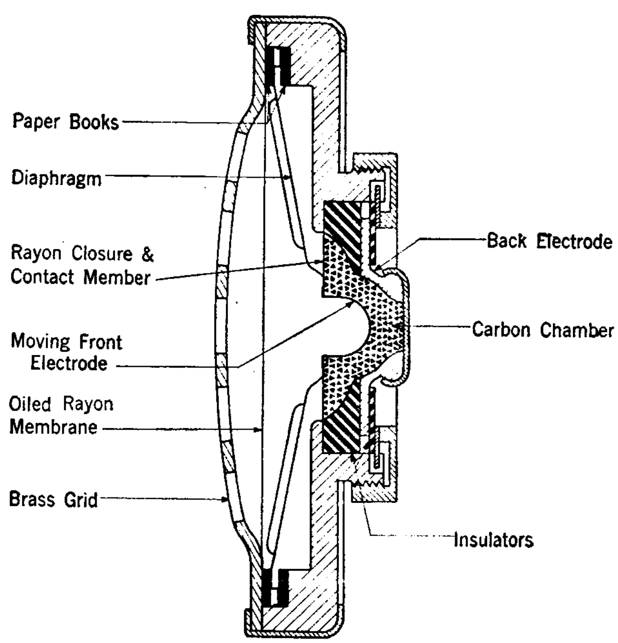


Figure 2-4 Cross-Section of Transmitter Unit

2.5 THE TELEPHONE RECEIVER

The earliest forms of telephone receivers were made with a permanent bar magnet as shown in Figure 2-2. The efficiency of the receiver was later greatly increased by the use of a horseshoe magnet as shown in Figure 2-5. This permitted the lines of magnetic force to pass in a much shorter path from one magnetic pole to the other through the iron diaphragm. The principle of operation of receivers currently in use in the telephone plant does not differ fundamentally from that of the original type although the receivers themselves are generally quite dissimilar in physical appearance.

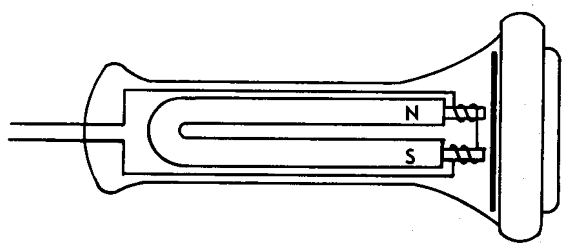


Figure 2-5 Horseshoe-Magnet Receiver

In the receiver the permanent magnet is important not only because it increases the amplitude of vibration of the diaphragm when the voice current is flowing through the windings, but also because it prevents the diaphragm vibrating at twice the voice frequency. This is illustrated in Figure 2-6. When a piece of soft iron is held near an electromagnet, it is attracted by the magnet regardless of the direction of the current in the windings. Thus, an alternating current in a winding on a soft iron core will assert an attraction during each half cycle, which in the case of the receiver diaphragm will establish a vibration with a frequency twice that of the current. If, on the other hand, a permanent magnet is used, the alternating current establishes a vibration of the same frequency as the current by merely increasing or lessening the pull already exerted on the diaphragm.

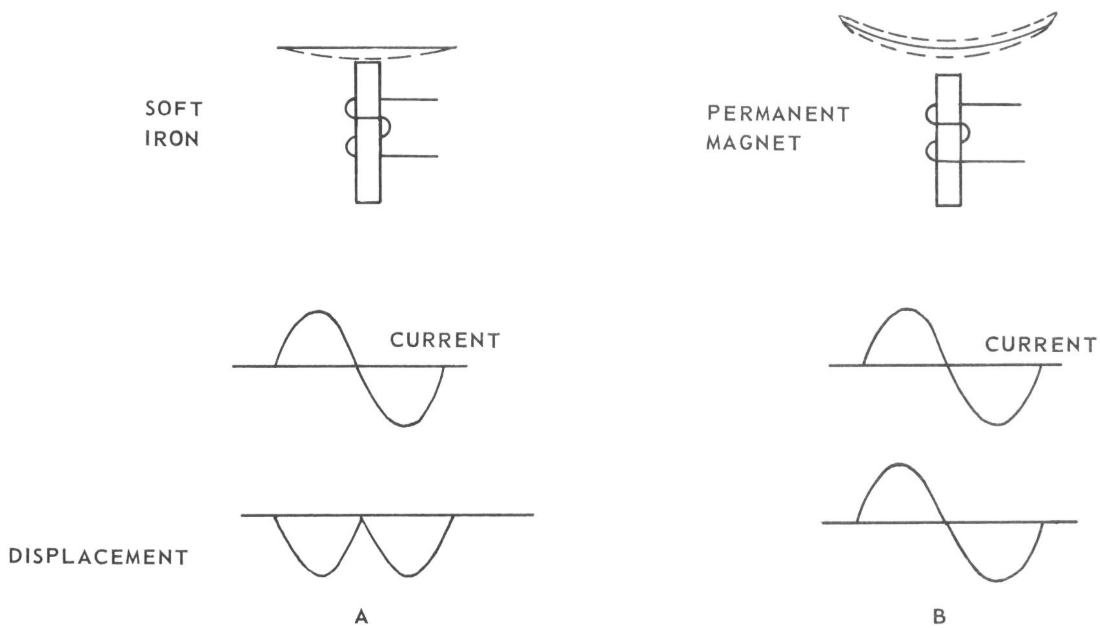


Figure 2-6 Receiver Diaphragm Displacement

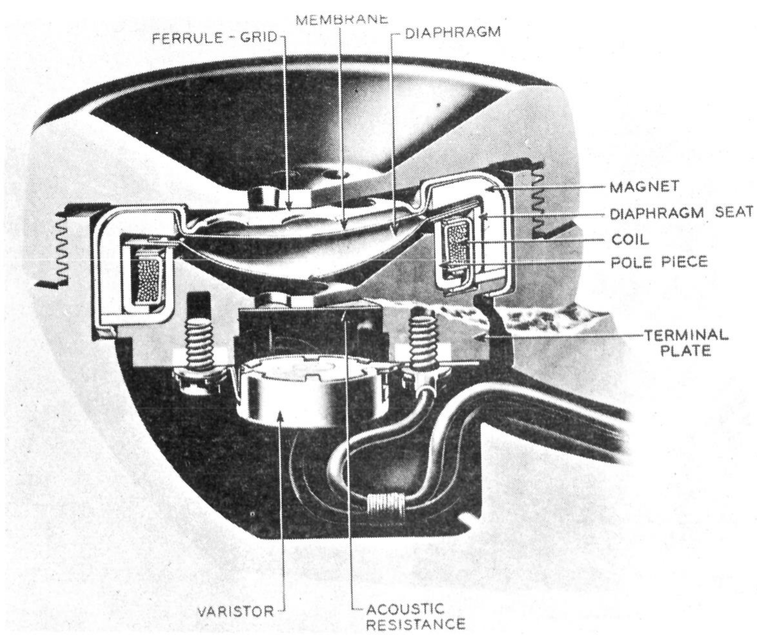


Figure 2-7 Ring-Armature Receiver

The above basic principles also apply to today's receivers, of which a cross section of one of recent design is shown in Figure 2-7. This receiver is known as ring-armature receiver. The diaphram structure is driven like a piston under the influence of the magnetic fields existing in the air-gap across the inner edge of the armature ring.

2.6 THE TELEPHONE SET

A. Local Battery

Figure 2-8 illustrates a local battery telephone circuit. When the magnetic field is established by the fluctuating current through the primary of the induction coil, an alternating current is induced in the secondary of the coil. This current flows through the receiver at the same end of the circuit, giving "sidetone," which will be discussed later in this chapter, to the receiver at the home station. It is also transmitted to the distant station operating the receiver at that point.

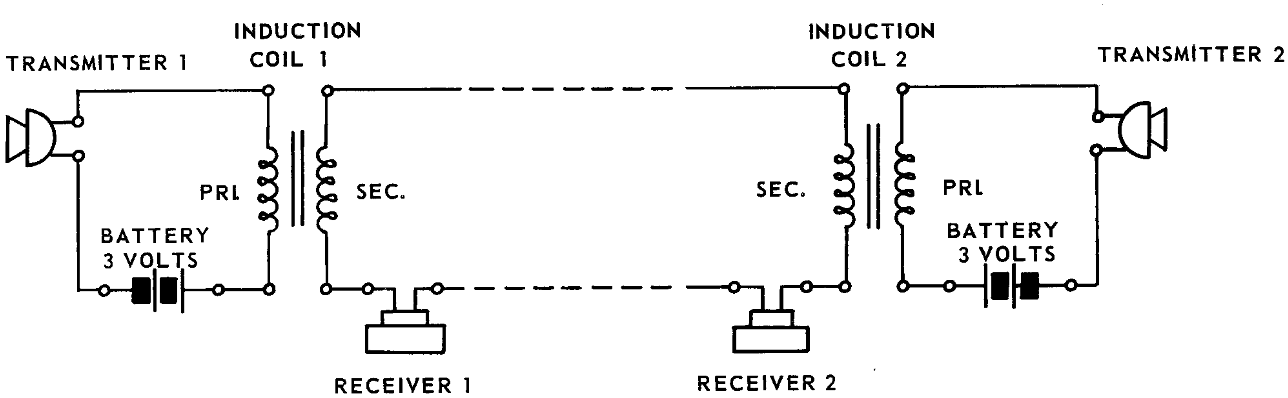


Figure 2-8 Local Battery Telephone Circuit

A local battery system is normally used where the subscribers are reasonably scattered, such as in a rural or farm area or as part of a military communication system.

Like any other communication equipment a local battery telephone system has certain definite advantages and disadvantages. Some of the advantages of the system are:

1. Satisfactory speech transmission is possible over long high resistance lines because there is only alternating current on the line and that of a relatively small value.

2. This means that the wire lines, commonly called the outside plant, can be of a poorer quality and can be constructed more economically and in less time.

3. The switchboard for this system is less complex, less delicate, and less costly.

However, the list of disadvantages for this system far outweighs the advantages. Some of these disadvantages are:

1. The life of the dry cell battery is short. It deteriorates even when standing idle and the voltage varies radically between the time of installation and exhaustion. This means that from the economic viewpoint dry cells are one of the most expensive sources of electrical energy.

2. The batteries must be checked at frequent intervals and exhausted cells replaced. Thus a repairman must visit each subset location no matter how widely scattered or isolated.

3. As the voltage of the battery decreases, the output of the telephone will decrease which will be noticed at the receiving end as a decrease in the volume of the received signal. Consequently, uniform transmission cannot be obtained from all subsets or even from one subset.

4. Some means of signaling the operator or other customers must be incorporated in the subset. This is accomplished by a hand generator or magneto which requires effort on the part of the user and also increases the size of the subset.

5. If the party using the phone does not ring off when through talking, it means more work for the operator since it is then necessary to monitor the circuit to determine when to disconnect. This also tends to reduce the availability and thus the traffic carrying capacity of these circuits.

6. If the switchboard drops are the manual restoring type, this further adds to the operator's work.

7. It can only be used for manual switching systems and not for mechanical switching systems.

B. Common Battery

Figure 2-8 showed a simple telephone connection between two telephone sets, each equipped with a transmitter, receiver, induction coil and its own battery for supplying talking power. In most modern telephone station installations, talking battery is supplied to each subset from a common battery at the telephone central office to which each subscriber line is connected. The simplest subscriber station circuit arrangement under these conditions is shown schematically in Figure 2-9. When the receiver is lifted to close the contacts of the switchhook, and the line is picked up at the central office by an operator or mechanical device, the central office battery is connected in series with the primary winding of the induction coil and the transmitter, and current is sent over the line. Varying currents set up by the transmitter, when it is talked into, add to or modulate the direct current flowing from the central office battery. The varying transmitter currents (which are fundamentally alternating rather than direct) induce a flow of current by transformer action in the secondary of the induction coil through the receiver and causes "sidetone."

The pulsating dc, with its corresponding voltage, variations, are impressed upon transmitter No. 2 and the primary of induction coil No. 2. Transformer action takes place from the primary to the secondary of this induction coil thereby impressing voltage variations upon receiver No. 2 which results in sound in the receiver. The voltage variations across transmitter No. 2 serves no useful purpose.

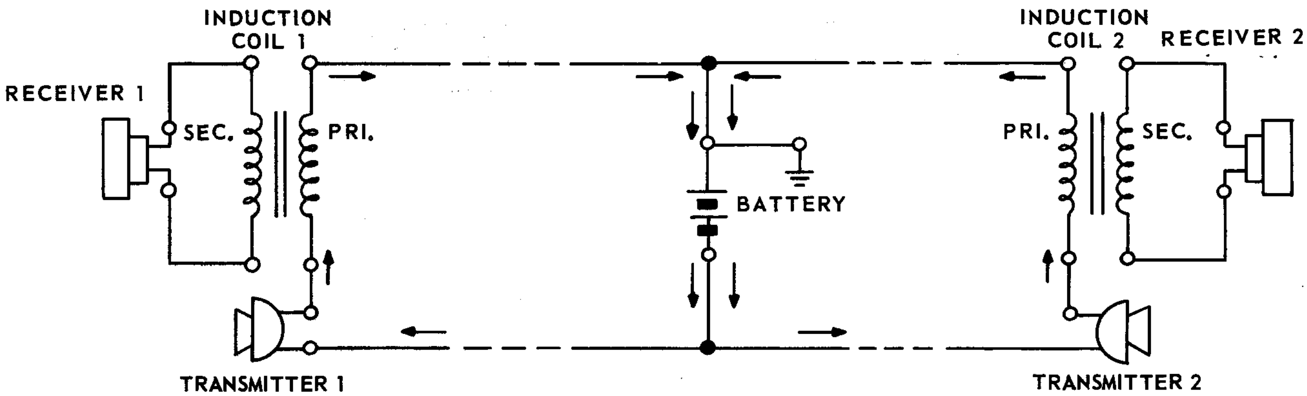


Figure 2-9 Common Battery Telephone System

The common battery system is used where there is a high concentration of customers. Practically all of the telephones in operation today are of the common battery type. This includes all of the telephones associated with the mechanical switching systems.

The use of a centrally located battery overcomes most of the disadvantages listed above for the local-battery system. For example:

1. By furnishing all current from a centrally located battery, the drain on it is such as to warrant the use of storage batteries which are easier and more economical to maintain. Recharging energy for a storage battery costs a great deal less than does the purchase of dry cells - the service requirements being the same.

2. The talking current for the subsets is supplied from the storage batteries which hold their current constant, thus the output of the subset is not affected by battery deterioration.

3. The battery supply being at a central location eliminates the necessity of visiting subsets to test and renew batteries.

4. The switchboard operator, or the mechanical line locating equipment, is signaled by removal of the handset from the switchhook of the subset. This allows direct current to flow in the line which lights a lamp in front of an operator or operates a relay in the mechanical systems. The elimination of the magneto together with the removal of the dry cells means that the subset equipment is smaller and simpler.

5. The operation of the switchhook, when the receiver is removed - or switchhook signaling - not only simplifies the routine for placing calls, but affords a prompt means of indicating completion of the conversation to the operator.

6. A single operator can handle many more lines on a common-battery switchboard than one at a local-battery switchboard and also give better service.

As with any system there are also a few disadvantages connected with the common-battery telephone system.

1. The outside plant must be of higher quality in order to reduce voltage leakage from the lines.

2. Any unbalance in the wire lines of the outside plant will seriously affect quality of transmission and distance over which transmission of speech is possible.

3. The inside plant equipment is far more complex, expensive and delicate; therefore, a longer time is required for installation, and maintenance requirements are increased.

4. The resistance of the loop or line to the subset limits the distance over which transmitter and signaling current may be supplied to a subset.

2.7 SIDETONE

Sidetone is the transmission and reproduction of sounds through a local path from the transmitter to the receiver of the same telephone station. The room noise picked up by the transmitter and reproduced in the receiver through the sidetone path tends to mask the incoming speech. Also the loudness with which the telephone user talks into the transmitter is influenced to a great extent by the loudness of the sidetone. A reduction in sidetone will result in a receiving improvement because of the reduction in the room noise reproduced in the receiver, and a transmitting improvement inasmuch as it influences the telephone user to talk at a normal volume.

Figure 2-10 shows the equivalent circuit of the "antisidetone" feature of a present day 500 type telephone set.

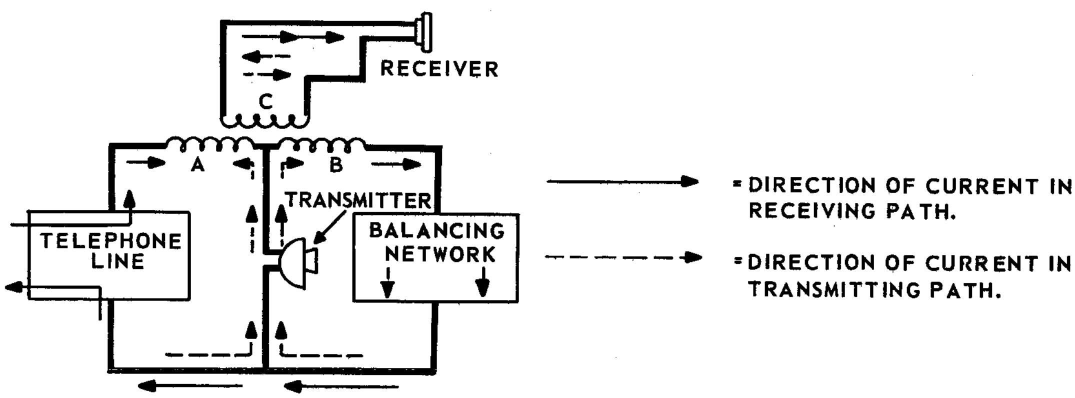


Figure 2-10 Antisidetone Station Circuit

This circuit makes use of a different induction coil having a third winding. The varying currents set up by the transmitter flow through the coil designated "A" and out over the line. This varying current induces a current in the coil designated "C". Another path for the transmitter current is through the coil designated "B" and through the balancing network. This varying current will also induce a current in the "C" coil but in the opposite direction. If the impedance of the balancing network is adjusted to equal that of the line, then the flux in the "C" coil set up by the "A" and "B" coils will be equal but opposite and therefore cancel each other out. Sidetone would not be present in the receiver.

When receiving, current coming in from the distant transmitter passes through the "A" and "B" coils in the same direction and is induced into the receiver circuit through coil "C". This circuit is no more efficient than the sidetone circuit although it may seem so, principally because in receiving, the listener is not distracted by extraneous noises coming from his own transmitter.

2.8 DIAL

In a manual telephone system the subscriber tells the number he desires to an operator who either selects the number for him and connects his line to the line of that number, or, in larger systems, connects the line to a trunk to a distant office and repeats the number to another operator who selects the line for him. In automatic systems, the sequence of operations is somewhat similar but the operations are performed by electromechanical switches.

Since an electromechanical switch cannot respond to the voice of the subscriber as an operator can, it is necessary to provide a means by which the subscriber can convey to the switches what number he wants.

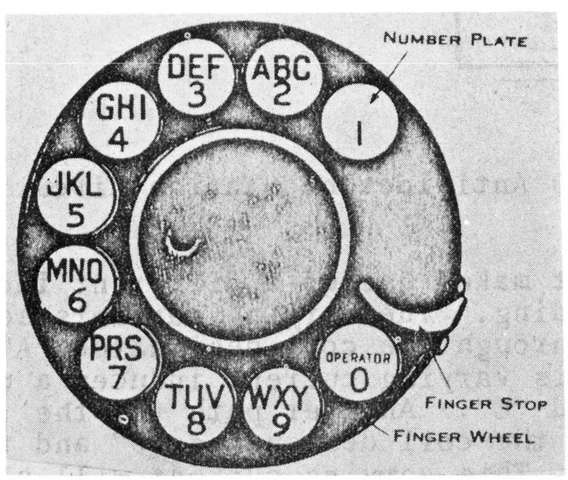


Figure 2-11 Telephone Dial (Front)

This mechanism is the "dial" (Figures 2-11 and 2-12). Most people are now familiar with the operation of the dial. The customer puts his finger in the hole of the dial in which appears the letter or figure which he wishes, pulls the rotating disc around until his finger strikes the stop and lets go.

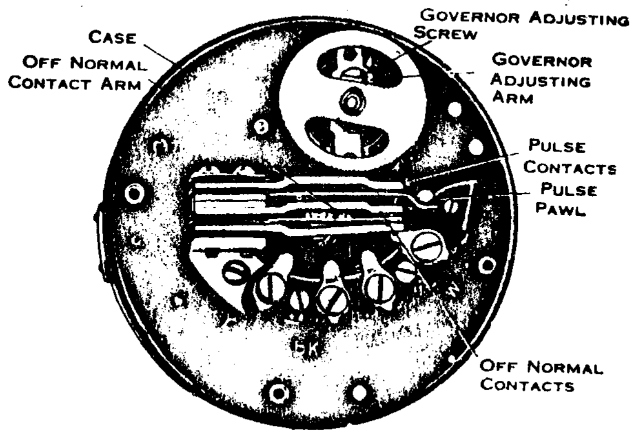


Figure 2-12 Telephone Dial (Rear)

A spring rotates the disc back to its normal position and in doing so simply opens and closes the circuit of the customer's line the number of times indicated by the number under the hole into which the customer puts his finger. It must be remembered that that is all the dial does -- it opens and closes the circuit of the customer's line a certain number of times. A little governor in the back of the dial controls the speed of the rotating disc and assures that the opening and closing of the circuit is uniform and regular. By performing this operation the proper number of times, the customer relates to the relays or switches the central office in which the desired line is located and the number of that line. It should be noted that rotating the disc with the finger in the hole marked "zero" opens and closes the circuit ten times.

If the customer wishes to reach the operator, the dial in restoring to normal will cause the pulse contacts to open and close ten times. The opening and clsoing of the dial pulse contacts will cause the "line pulsing relay" in the central office to release and operate ten times. In releasing and operating ten times the "line pulsing relay" conveys this information to the "pulse counting circuit" or "switch mechanism" and the automatic equipment functions to establish a connection to the zero operator. In a similar manner other call combinations can be established.

In order to eleiminate the dial clicks in the receiver when the dial is restoring to normal a pair of off-normal contacts in the dial <u>break</u> and the receiver is out of the circuit. After dialing is completed the off-normal contacts restore the circuit to normal.

The average customers dial is designed to operate at about 10 pulses per second. The circuit of the 500D type dial telephone set is shown in Figure 2-13. The 500-type set includes a mechanical dial with a precision pulsing mechanism,

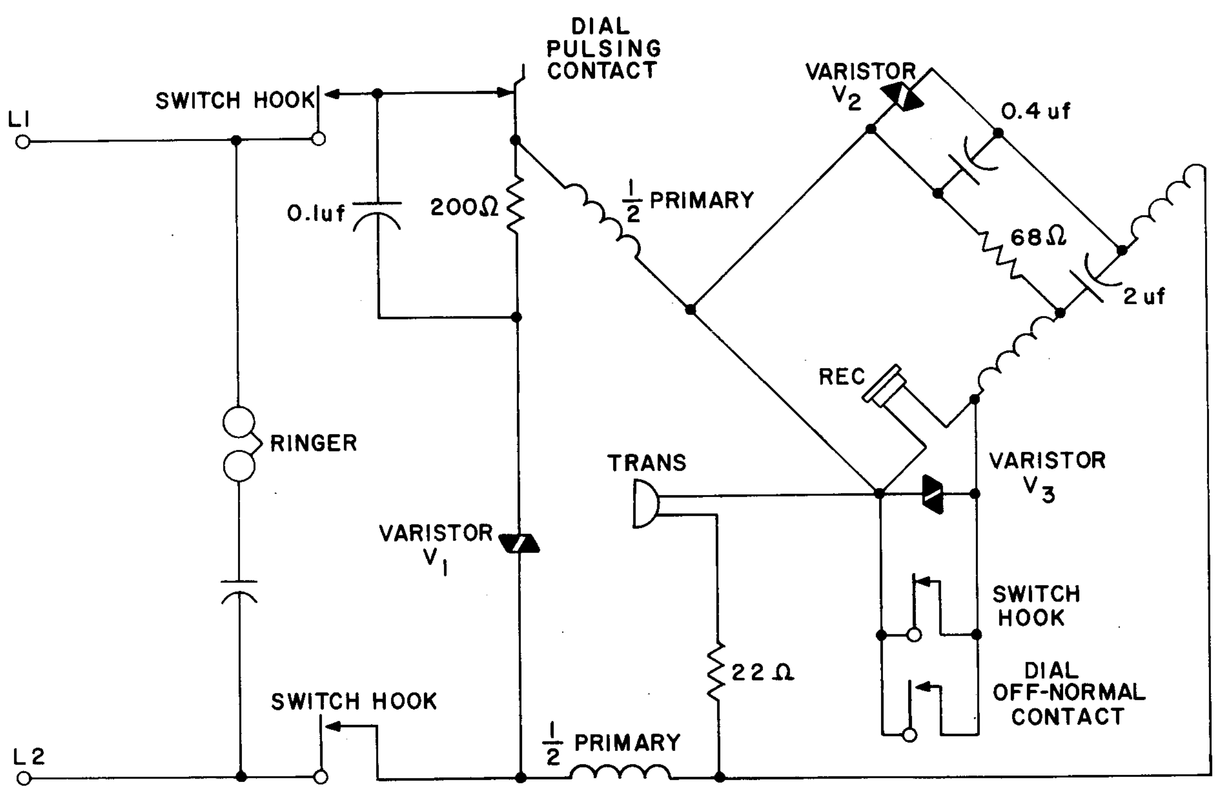
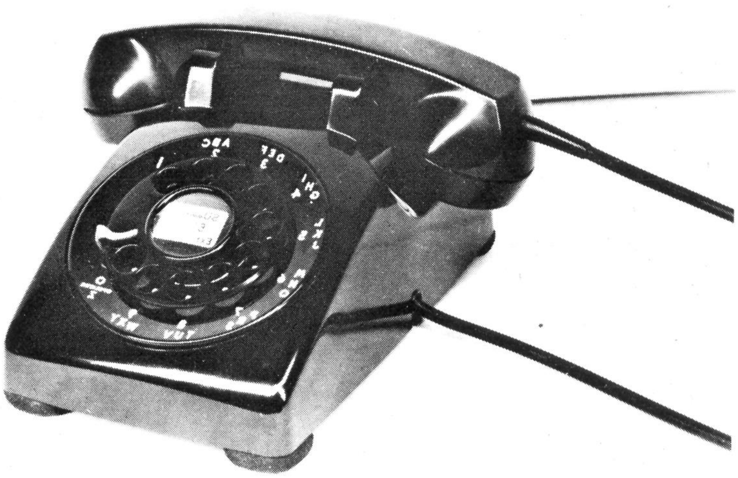


FIGURE 2-13 - Complete Circuit of Type 500D Telephone Set and it is self adjusting in its speech transmission and sidetone characteristics to match the length of subscriber line on which it is used. Automatic control of transmission features is accomplished through the variable characteristics of varistors V1 and V2 shown in Figure 2-13. Both the ac and dc resistance of these varistors depends on the direct current passing through them and the magnitude of this current is determined by the resistance (length) of the subscriber loop. These circuit elements adjust the speech transmission and sidetone characteristics of the subscriber set as required for any type of telephone connection. The 500-type set also has improved ringing features, compared with earlier sets. A 500-type telephone set with the letters and numbers appearing outside the dial is shown in Figure 2-14.



2.9 TOUCH-TONE

TOUCH-TONE dialing offers to the customer speed and convenience through the use of a "pushbutton" rather than the rotary type dial. Consequently, the telephone set contains a set of "pushbuttons" rather than the dial of Figure 2-11. Multifrequency tones are generated by depressing the pushbuttons of the subset instead of direct current pulses being generated by the pulse contacts of the dial.

The subset contains a double frequency transistorized oscillator which is powered by the central office battery. Depressing any pushbutton will generate two frequencies; one from a high group and one from a low group. Each group consists of four frequencies as follows; low group - 697, 770, 852 and 941 cps, high group - 1209, 1336, 1477 and 1633 cps.

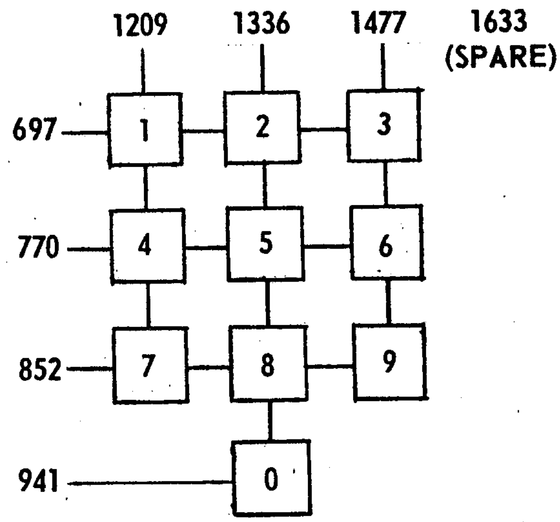


Figure 2-15 TOUCH-TONE Dialing Freq Combinations

The two frequencies generated will indicate a digit from 0 to 9 and two special service tones as shown in Figure 2-15. The combination of one low group frequency and one high group frequency gives 16 possible signal combinations. The extra four signals are for use with the special 16 push-button phones.

Depressing any pushbutton also operates the "Common Switch" which reduces sidetone to the receiver, opens the transmitter path and applies bias voltage to the transistorized oscillator.

2.10 RINGERS

The telephone ringer or "bell" is used to indicate the presence of an incoming call. Three types of ringers are in use today; the unbiased ringer, the biased ringer, and the harmonic ringer.

Unbiased ringers are intended for use on alternating current only. When alternating current passes thru the electromagnets, the magnetism set up by the permanent magnet is strengthened in one coil and diminished or overcome in the other on the first half cycle. The armature now tilts toward the core having the strongest magnetism and the clapper ball strikes one gong. As the current is reversed on the half cycle, the other coil has the greater attraction and the clapper ball strikes the other gong.

The biased ringer is used in all cases where superimposed current (direct current superimposed on alternating current) is used for ringing. The biased ringer is constructed like the unbiased ringer except that it is equipped with a biasing spring to hold one end of the armature against the respective magnet core. See Figure 2-16. A pulse of the proper polarity will overcome the pull of the spring and pull the armature against the other core, ringing first one gong and then the other as the armature is released and returned to the biased side by the biasing spring. Pulses of the opposite polarity would, of course, have no effect on the ringer. This makes it possible to ring either of two ringers on one wire by choosing the polarity of pulses to be sent out over the line.

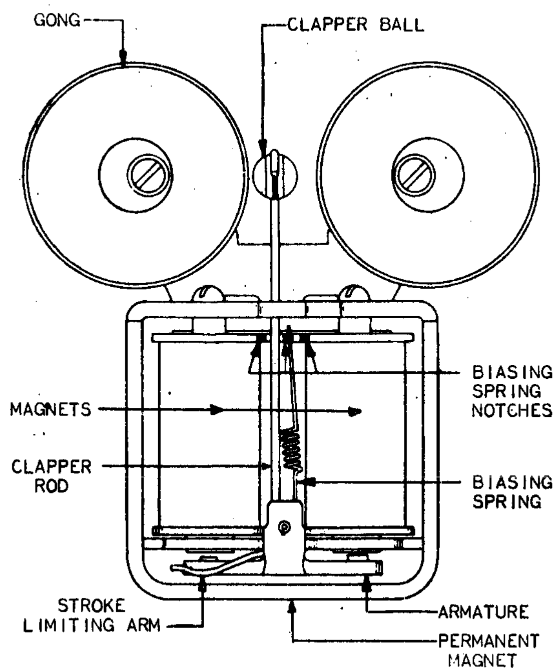


Figure 2-16 Biased Ringer

The harmonic ringer resembles the unbiased ringer in general construction. However, the armature of the harmonic ringer is secured to a stiff steel spring rigidly mounted between the two halves of the core yoke, instead of being pivoted by trunion screws. Thus, the armature and tapper are held normally in a median position. Each ringer is mechanically tuned so that it responds only to ac ringing of one frequency. The natural period of vibration is determined by the strength of the spring and the weight of the gong tapper. The four ringing current frequencies are: 16-2/3, 33-1/3, 50 and 66-2/3 cycles per second.

2.11 RINGING MULTIPLE-PARTY LINES

A. 2-Party Selective Ringing

In 2-party selective ringing, the ringers of the two parties are connected one from each side of the line to ground, instead of across the line as in individual lines. This is shown schematically in Figure 2-17, in which the subscriber stations, other than just the ringer portions, do not appear. Likewise, the tripping circuit is not shown, and the ringing circuit is shown only symbolically. Actually, the ringer is essentially the same as already indicated, but with a means for applying the ringing

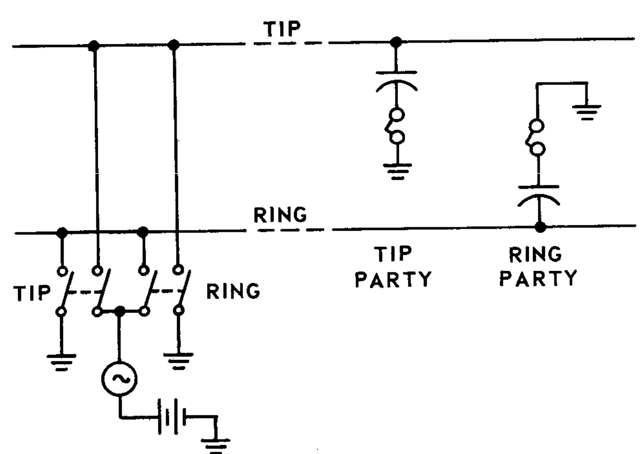


Figure 2-17 2-Party Selective Ringing

voltage to either side of the line at will, ground being applied to the opposite side in either case. If ringing voltage is applied to the tip side of the line, only the tip-party ringer will operate, as the ring-party ringer is then grounded on both sides. When ringing voltage is applied to the ring side of the line, the opposite occurs.

B. 4-Party Full Selective Relay System

The first successful 4-party full-selective ringing was accomplished by having a relay in series with a capacitor bridged across the line at each party's station. Operation of the relay applied ground to the ringer, as shown in Figure 2-18. In this diagram, two degrees of selection in the ringing are obtained, first by applying the ringing voltage to either tip or ring wire, as in the case of 2-party ringing, and further by changing the polarity of the battery current which is superimposed on the alternating current from the ringing machine. Thus four selective combinations are obtained, positive or negative direct current with alternating current on the tip wire, and positive or negative direct current with alternating current on the ring wire.

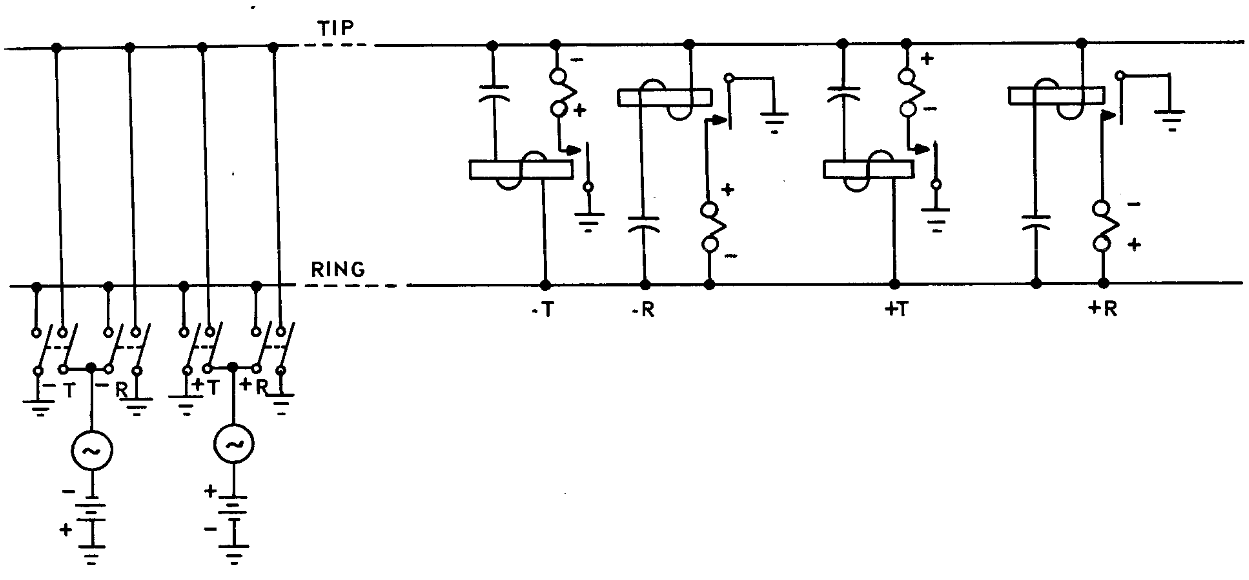


Figure 2-18 4-Party Full Selective Ringing Using Relays

When any one of the four combinations is applied (by throwing any one of the four switches in the diagram) all four of the relays operate, as there is no directional or polarity sense in the operation of the relays. Ground is thus applied to all four ringers, but only two of these are connected to the side of the line corresponding to the one switch thrown, thus eliminating the other two ringers. Which one of the two possible ringers operates, is determined by the polarity of the direct current and the bias of the ringer. The bias is obtained mechanically by means of a spring which pulls one end of the armature of the ringer to a stop position where it is nearly in contact with one of the cores of the ringer winding. Of the two ringers connected to the tip wire, one is biased to the side which requires positive direct current to overcome the pull of the spring (negative direct current only holds the armature more firmly against the core), and the other to the side which requires negative direct current. The two ringers connected to the ring wire are similarly biased for positive and negative operation. Thus only one ringer can operate when one of the switches shown in the diagram of Figure 2-18 is closed.

C. 8-Party Semiselective Coded Ringing

8-party semiselective ringing is obtained by doubling up on a 4-party full-selective arrangement. Two ringers operate for each of the four combinations of ringing. The final step in selection is achieved by code, for instance, one ring for one of the two selected ringers and two rings for the other.

D. Inverted Relay Biased Bell System

In order to overcome the difficulties experienced with ground potentials which seriously interfered with the operation of Relays in the Central Office, as well as causing substation "Cross-Ringing" or failure to ring, the position of the ringer and the relay was reversed to obtain the Inverted Relay Biased Bell System as shown in Figure 2-19.

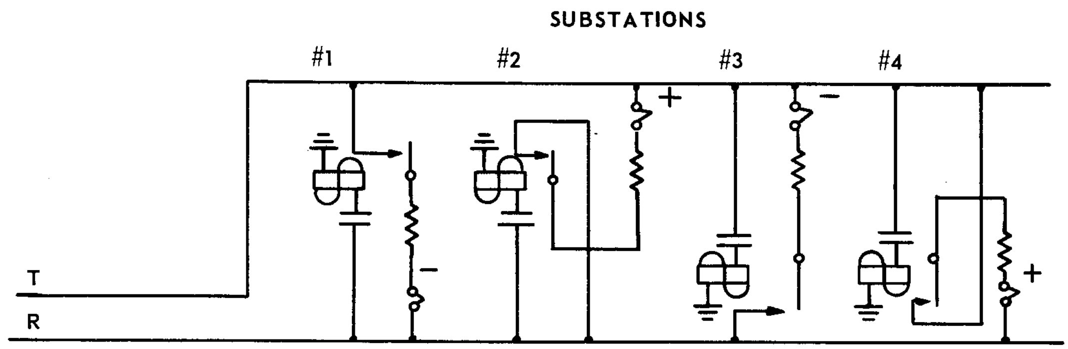


Figure 2-19 Inverted Relay Biased Bell System

Two (2) substation relay windings are connected from each side of the customer line to ground, each relay in series with a capacitor. When pulsating ringing current is applied to the called customer line, one side of the line is grounded. As a result, only two(2) substation relays operate - those two having their windings connected to the ungrounded side of the line. One of the two substation ringers, bridged across the customer line by operation of the two substation relays, is selected by applying pulsating ringing current of the proper polarity to the line.

When positive ringing pulses are applied to the tip conductor of the called customer line and ringing ground to the ring conductor, Substation #3 and #4 relays operate, bridging their respective ringers across the subscriber line. Only Substation #4 ringer operates as it is biased for positive ringing pulses.

E. 4-Party Full Selective Ringing Using Harmonic Ringers

In 4-party full selective harmonic ringing, each substation ringer is bridged across the customer's line, in series with a capacitor. A particular substation is signaled by the selection of one out of four ac ringing current frequencies: 16-2/3, 33-1/3, 50 or 66-2/3 cycles per second applied to the called customer's line. Only the ringer tuned to the frequency selected will operate.

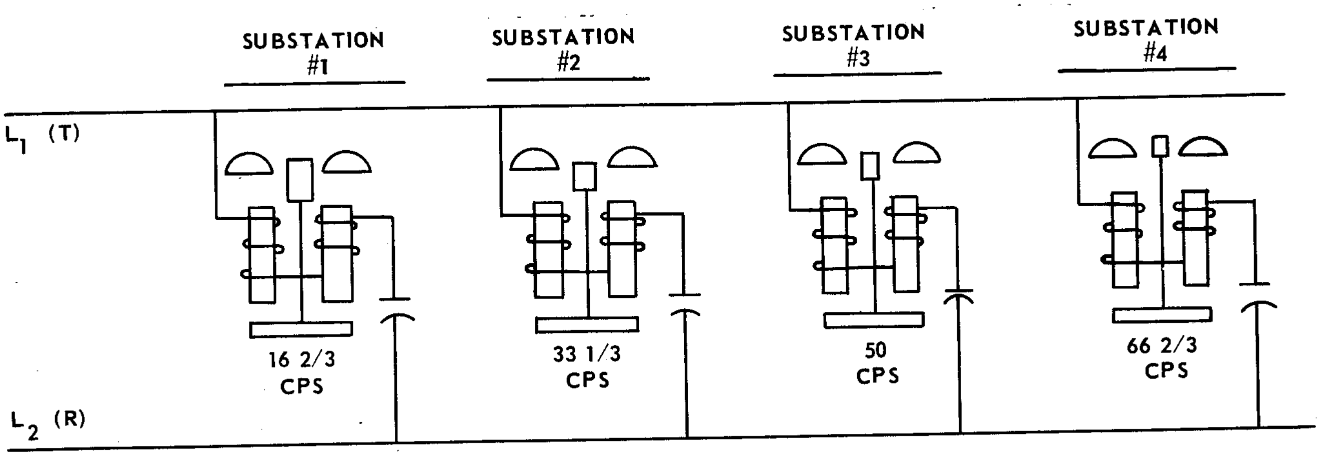


Figure 2-20 4-Party Full Selective Ringing Using Harmonic Ringers

8-Party full selective ringing is then possible with the use of harmonic ringers. Four substation ringers are connected from one side of the line, and the remaining four ringers from the other side of the line, each to ground and each through a capacitor. Any one of the eight substations may be signaled, with the exclustion of all others, by applying ac ringing current of the correct frequency to the side of the customers line, tip or ring, to which that substation ringer is connected, utilizing ground return.

The harmonic ringer is not used too frequently in the Bell System. It is inconvenient to manufacture four different types of the harmonic ringers. It is simpler to manufacture a ringer with the biasing spring that can be positioned to operate on positive superimposed ringing, negative superimposed ringing or ac ringing current alone, by neutralizing the biasing spring.

F. 4-Party Full Selective Ringing Using 3-Element Cold-Cathode Tubes

The present standard method of 4-party full selective ringing is one which employs 3-element cold-cathode tubes instead of the relay and capacitor. These are arranged as indicated in Figure 2-22. The tubes have a control anode and cathode which form a "control gap." This breaks down, or ionizes, when a potential of

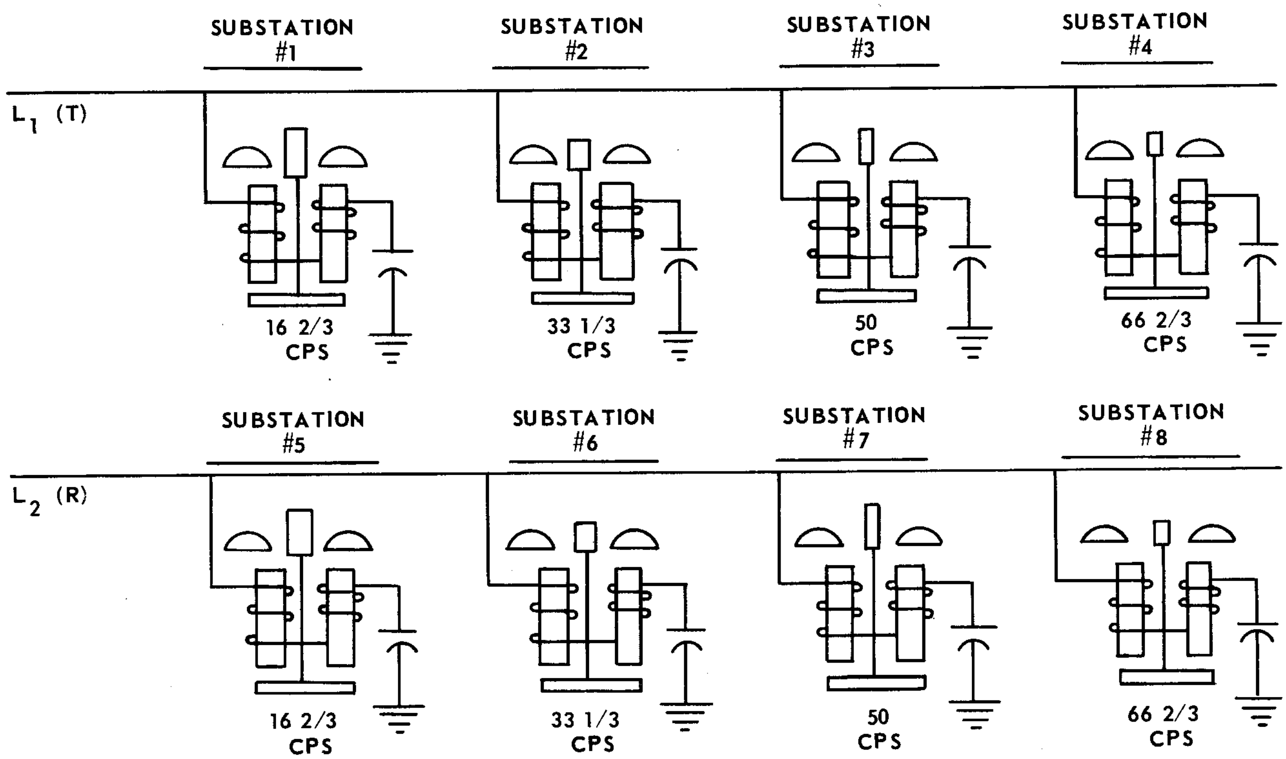


Figure 2-21 8-Party Full Selective Ringing Using Harmonic Ringers

about 70 volts (of either polarity) is applied across it. Ionization of the gas in the tube permits current conduction to occur in the main gap, provided the third element, the main anode, is positive with respect to the cathode. Current in the control gap is limited by a series resistor to about one microampere, but the main gap can handle currents as high as 30 milliamperes. Referring to Figure 2-22, it will be noted that when any one of the four switches is thrown, the control gaps of two of the tubes will breakdown. The other two control gaps cannot breakdown because both sides of the gaps are at ground potential. For instance, if the -T switch is thrown, the control gaps of the tubes for the -T and +T parties will breakdown. The superimposed direct current has the correct

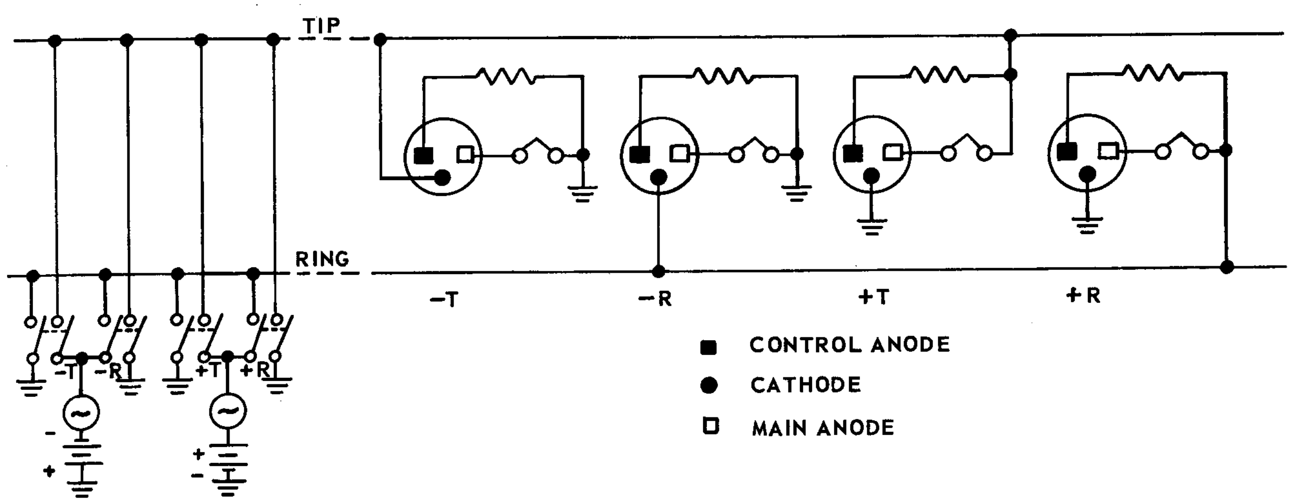


Figure 2-22 4-Party Selective Ringing Using 3-Element Cold-Cathode Tubes

polarity to cause conduction of ringing current in the main gap of the -T party, but the wrong polarity for that of the +T party. Hence the ringer of the -T party is the only one of the four which operates. In the same way, throwing any one of the other three switches operates only the one corresponding ringer.

The tube subset has several advantages over the relay type. With the relay type subset, ringing current flows through 2 ringers and 4 relays. In the case of the inverted relay biased system, ringing current flows through 2 relays and 1 ringer. However, ringing current flows through only 1 ringer in the tube-type subset since the electron tube will pass current in only one direction. This arrangement reduced the voltage drop due to line resistance, and permits an extended ringing range for 4-Party Service.

The electron tube also eliminates bell tapping and false ringing sometimes caused by dialing or switching operations.

In addition, the tube may be mounted in any position, while the relay must be mounted vertically to insure proper operation. Adjustment of the relay is also required to insure proper functioning of the relay type subset.

2.12 RINGING AND TRIPPING CIRCUITS

A simplified schematic of a ringing machine appears in Figure 2-23, which shows ringing and tripping circuits applied to an individual line, that is, to a subscriber line to which only one station is connected. It will be noticed that the commutator which supplies ringing current to the line is divided into two segments which correspond, respectively, to a ringing interval of about two seconds, followed by a silent interval of four seconds. During both ringing and silent intervals, direct current from a 45-volt battery is supplied. Alternating current is supplied only during the ringing interval.

Ringing is accomplished by closure of switch contacts, or, in dial offices, relay contacts as shown at the point marked C in the diagram. This causes the relay marked A to operate and relay B remaining unoperated since its winding is short-circuited. Operation of relay A applies ground to one side of the customer loop and the ringing commutator to the other side. Alternating current flows through the ringer at the customer station set during the ringing interval, and to ground back at the central office, thereby ringing the bell. As long as the customer does not lift the handset from its mounting, there is no dc path in the customer circuit.

The purpose of the tripping relay is to insure that the called subscriber cannot be "rung in the ear," whether he answers the call during the ringing interval or the silent interval. In other words, operation of the tripping relay is an indication that the customer has removed the handset from its mounting, and is presumably ready for conversation. The tripping relay is so designed that it cannot operate on alternating current alone, that is, as long as the direct current path is open. Removal of the handset closes the direct current path through the switch-hook, transmitter, and one induction coil winding at the subscriber station. The relay will operate firmly on direct current alone if the call is answered during the silent interval. If the call is answered during the

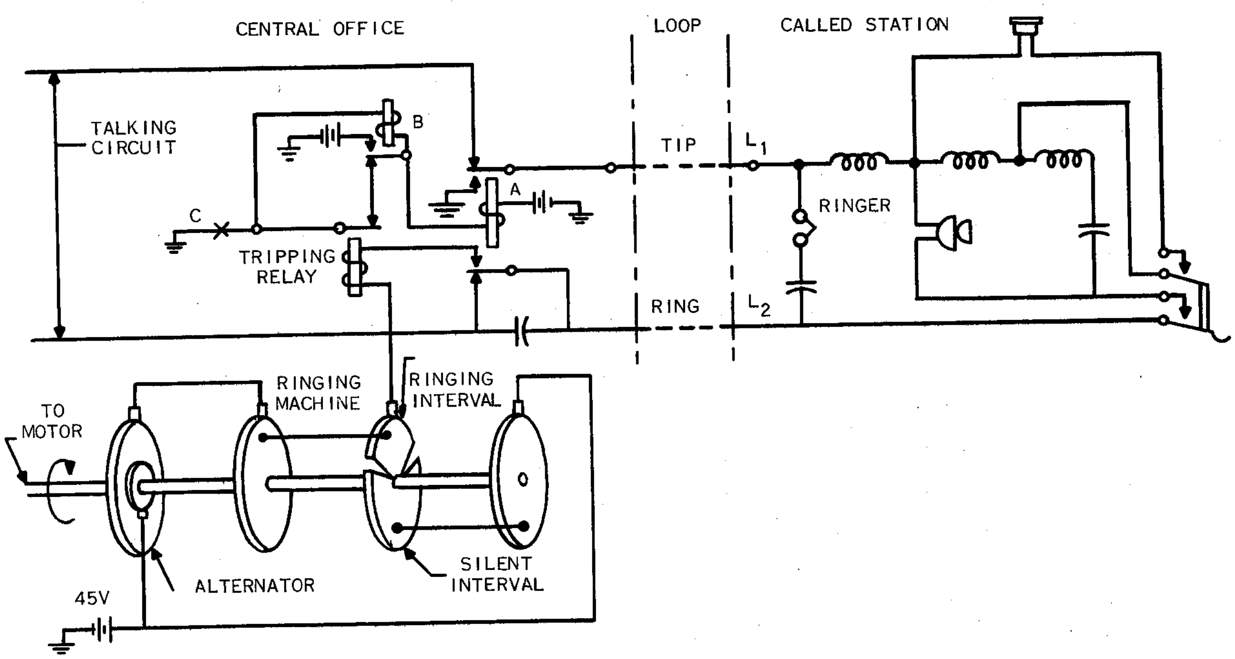


Figure 2-23 Superimposed Ringing and Tripping Circuits

ringing interval when both alternating and direct currents flow through the winding of the tripping relay, the latter will tend to operate intermittently. However, at the first operation of the tripping relay, the short-circuit is removed from the winding of relay B, which operates and locks up to battery through its contacts, thereby shunting down relay A. This, in turn, restores the line to the talking condition before the called customer can raise the handset to his ear.

A condenser is shown in Figure 2-23 near the contacts of relay A. When the circuit is in the talking condition, with relay A nonoperated, the capacitor is short-circuited. In the ringing condition, relay A removes the short-circuit from the capacitor, which allows a small amount of ringing current to flow back to the calling customer, thus permitting him to hear the so-called "audible ring."