BELL LABORATORIES RECORD

INDEX

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BELL LABORATORIES RECORD

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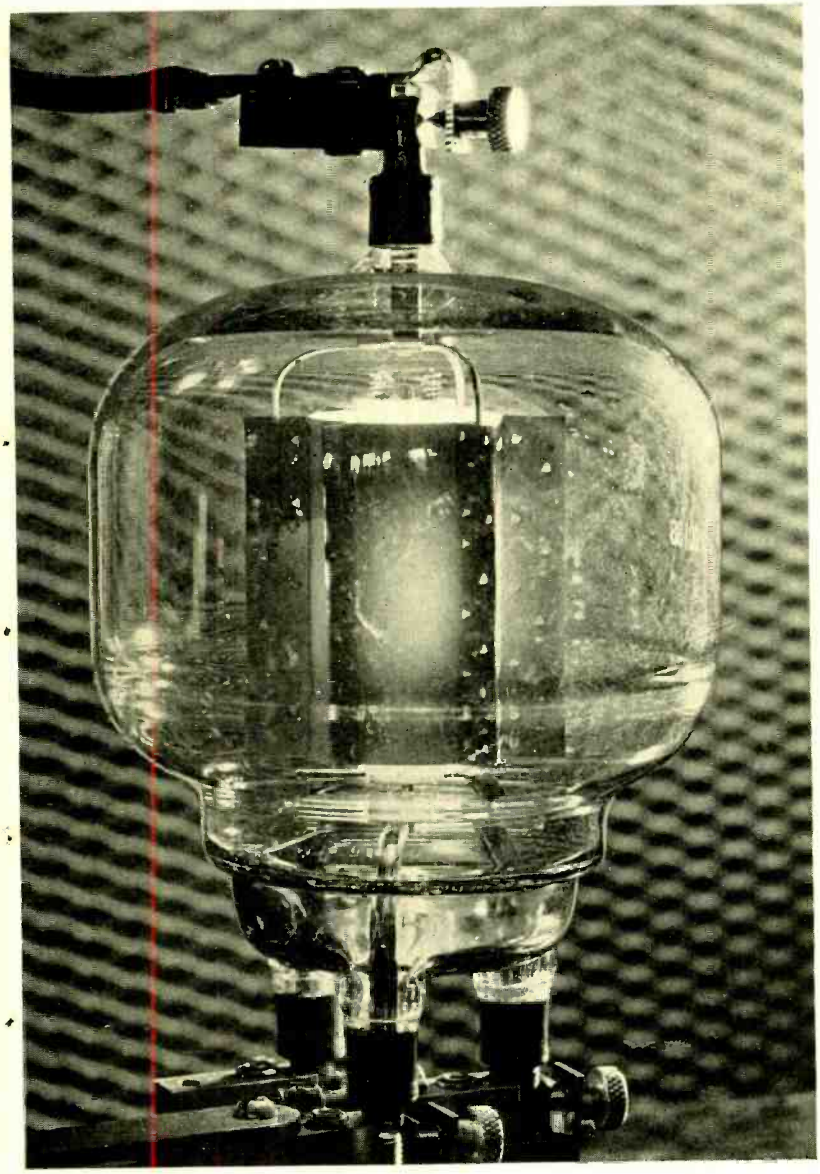

SEPTEMBER
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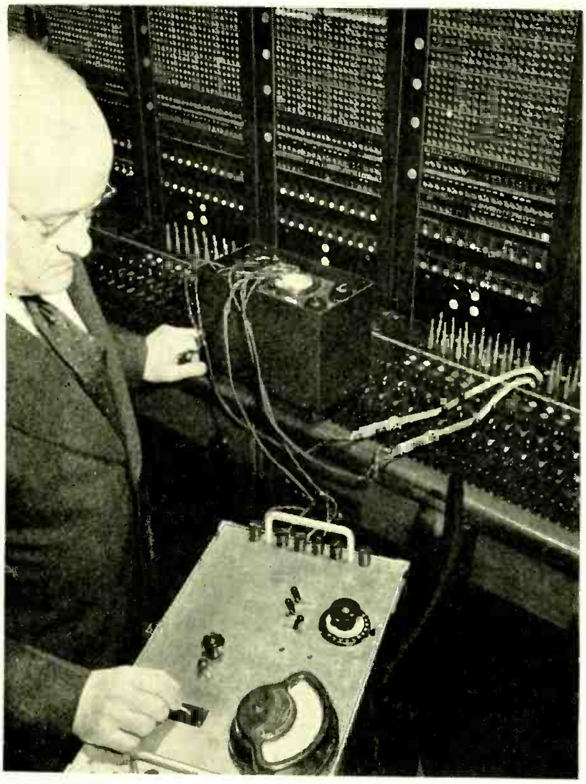
VOLUME XVIII

NUMBER I

The Western Electric 357A Vacuum Tube



The Longitudinal Circuit

By R. A. SHETZLINE
Interference Prevention Engineer

SPEECH is transmitted over telephone lines by current that passes over one conductor of a pair and back over the other. Because both sides of the circuit consist of metal wires, such a current path has come to be called the metallic circuit. The term arose many years ago to distinguish this type of circuit from that formed by a single wire and ground. Even though a telephone circuit does not employ the ground as a return path, the effect of the ground is still present, with the result that the two wires of a telephone circuit, together with the ground, provide a second type of circuit known as the "longitudinal circuit." Over this circuit approximately equal currents flow in the same direction in both conductors of the metallic circuit and return to the source over the ground path.

The importance of the longitudinal circuit arises from the fact that many of the noise disturbances induced into telephone circuits from the outside enter by way of the longitudinal circuit. Since the two wires of a telephone pair, whether run on crossarms or in cable, are close together compared to the distance from the disturbing source, the voltages or currents induced in them are nearly the same. They are made almost exactly equal by transposition schemes for open-wire pairs or by twisting in cable pairs. This is indicated in Figure 1. While there may be slightly more voltage induced in the T wire over one section, there will be proportionately more induced in the R wire over the next section, so that over the length of the exposure, the voltage is very closely the same in amount and direction in both conductors, and as a result the induced current flows over the longitudinal circuit.

So long as the current remains longitudinal, it will not disturb the speech communication, because only current in the metallic circuits can affect the telephone receivers at the ends of the line. Suppose, however, that such a longitudinal current has been induced in a line, and reaches a cord circuit at one end as shown in Figure 2a. In conductor R it encounters an impedance Z due to the supervisory relay. Current I flowing through this impedance causes a voltage drop IZ. If there were a similar Z in the T conductor, the two IZ voltage drops would be equal and opposite as far as the metallic circuit was concerned, and there would be no net effect. Since the Z is in one line only, however, there is the single voltage IZ acting on the metallic circuit, and it results in a metallic-circuit current, which will be transmitted over the circuit just as the voice currents are. This effect is controlled in practice by restricting the magnitude of impedance unbalance Z.

The basic cause of the transfer of current from the longitudinal to the metallic circuit is thus some form of unbalance—a lack of symmetry between the two sides of the line. It might have taken the form of a difference in capacitance between the sheath and the two wires of a cable pair, as indicated in Figure 2b, of a joint with appreciable resistance, of a tree leak, or of a ringer connected between one side of the line and ground, as in Figure 2c. It is always an unbalance of some sort, however, by which induced longitudinal currents enter the metallic circuit. If it were practicable to keep all telephone circuits perfectly balanced, both with respect to ground and outside disturbing sources, there would be no noise induced in them from the outside.

Besides being a link between outside disturbances and the telephone circuit, the longitudinal circuit may also act as a carrier of crosstalk. Voice current in one pair may induce longitudinal current in other pairs, and this, in turn, may become metallic-circuit current in these latter pairs. This situation becomes of particular importance at carrier frequencies because of the greater effect of small unbalanced capacitances. Its effect and

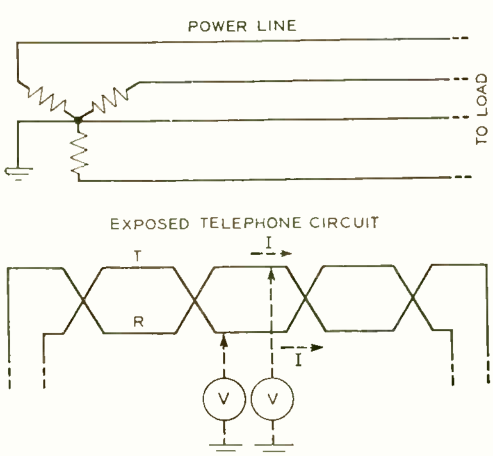


Fig. 1—Induction from an adjacent power circuit is primarily to the longitudinal circuit because of the transpositions

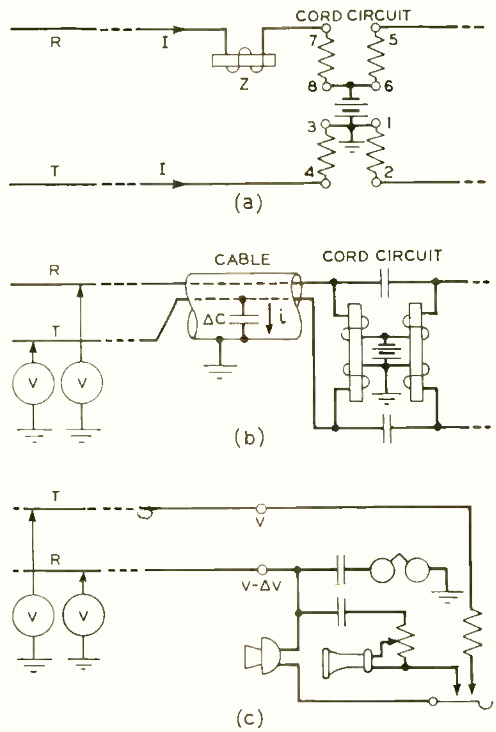


Fig. 2—Various forms of unbalance that may result in metallic-circuit current

reduction in the type-K carrier system have already been described.*

The types of unbalances shown in Figure 2 are of the obvious kind, but unbalances may exist that are not evident in a cursory examination of

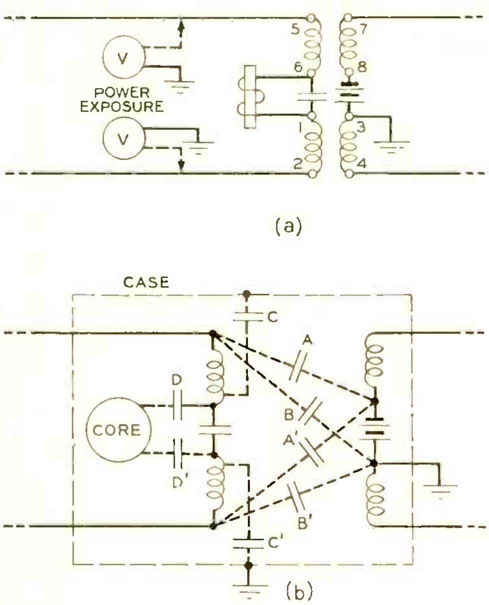


Fig. 3—Where the only path for the longitudinal current is inter-coil capacitance, careful design and construction is required to secure adequate balance

the circuit schematic. The repeating-coil type of battery feed, shown in Figure 2a, might possibly provide an unbalance that would cause disturbances in the metallic circuit even though the supervisory relay were not in the circuit. The longitudinal line current coming in over the T and R leads normally passes to the ground at the midpoint of the coil. If, however, the windings are not perfectly balanced, the effect of the current in the T lead flowing in winding 4-3 will not exactly balance that of the current from the R lead flowing in winding 7-8, and as a result a net differential voltage will be induced in the metallic circuits of windings 2-1 and 6-5.

In this particular case the unbalance is most likely of the inductive type, and is best reduced by use of a bifilar winding. The wire for coils 4-3 and 7-8 are placed side by side and wound on at the same time so that the windings are as nearly identical as they can be made. With this type of winding, the unbalance is very small. The same construction could be used for windings 1-2 and 5-6.

In an arrangement such as shown in Figure 3a, the longitudinal current does not flow to ground conductively, as in Figure 2a, but through the various inter-coil capacitances as shown in Figure 3b. To avoid an unbalance, capacitance A must equal A[1], B equal B[1], C equal C[1] and D equal D[1] except where certain unbalances can be paired to cancel. Only the most careful design and construction of

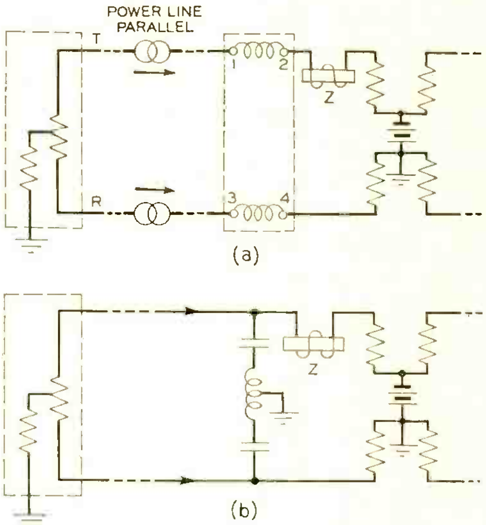


Fig. 4—Choke coils may be used to reduce longitudinal current, as at a, *or drainage coils to drain the current off, as at* b

*Record, *March*, 1939, *p.* 206.

loading coils will keep these unbalances to the desired minimum.

Very often a perfectly balanced circuit either is too costly to be warranted or is not possible, and other methods must be employed to prevent the longitudinal current from seriously affecting the metallic circuit. Perhaps the most obvious and widely used method is that of shielding. In principle this consists in providing a grounded external circuit over which longitudinal current may flow, thus reducing the effect on the telephone circuit. Shielding is particularly effective against electrostatically induced disturbances, because the shield acts as a barrier beyond which the electric field cannot pass. A shield unless of highly magnetic material, however, does not form a complete barrier to a magnetic field, but in spite of this fact it does exert a shielding effect. Perhaps the simplest explanation is that the disturbing flux produces longitudinal current both in the conductors and in the shield, but the current in the shield also induces a current in the conductors, which is in the opposite direction, and thus provides a compensating effect. The lead sheath of a telephone cable is a common example. Here an outside disturbance induces a longitudinal current in the sheath, and since this sheath, as well as the longitudinal current it carries, completely surrounds the conductors inside, the longitudinal current is reduced. Shielding is particularly effective at the higher frequencies, and the coaxial conductor, which is a completely unbalanced circuit, owes its freedom from induced disturbances to effective shielding provided by the outer conductor at very high frequencies.

Another method of reducing longitudinal current is by the use of choke coils inductively coupled so that they offer a high impedance to longitudinal current but very little impedance to the metallic-circuit current. In Figure 4, for example, which is like Figure 2a, choke coils have been inserted and so poled that flux due to metallic-circuit current flowing in the upper coil from 1 to 2 opposes that due to current flowing back through the lower coil from 4 to 3, and thus the only impedance offered is the resistance of the coils, which is small. To longitudinal current, however, flowing from left to right through both windings, thus reversing the effect of the lower coil, a high impedance is offered.

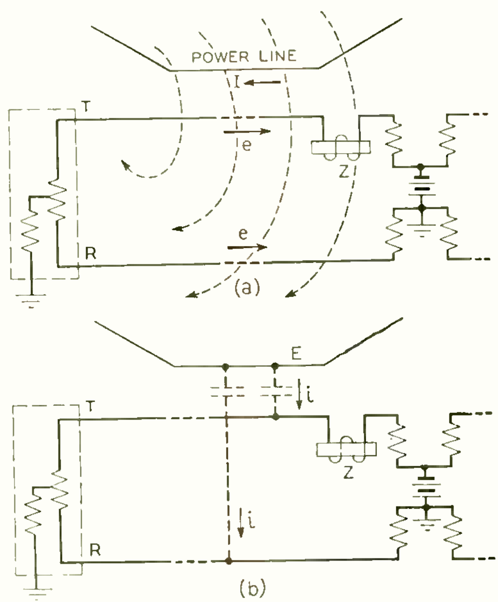


Fig. 5—Disturbances from the outside may be induced by either inductive or capacitive coupling, and the methods used for their control will vary accordingly

The action of these coils depends on whether the longitudinal current is induced inductively or capacitively. The conditions for disturbances due to magnetic induction are indicated in Figure 5a. The induced voltage *e* depends on the current flowing in the power line and the distance of the power line from the telephone line, and not on the characteristics of the telephone line. The disturbing current that flows, however, is equal to this voltage divided by the impedance of the complete longitudinal circuit, which consists for the most part of the resistance and inductance of the wires plus the impedance to ground of the terminal apparatus including the entrance cable. This impedance is not very high, so that by inserting high-impedance choke coils, the total impedance can be greatly increased and the disturbing current in the telephone circuit greatly diminished.

If, on the other hand, the disturbance is induced through the capacity between the power and telephone lines, the situation is as indicated in Figure 5b. Here the voltage-to-ground of the power line, E, induces a disturbing current that is inversely proportional to the impedance, consisting of the capacitance between the power and telephone lines plus the impedance to ground at the two ends of the telephone circuit. The capacitance between power and telephone line, however, is very small and thus its impedance is very high—probably hundreds of times greater than that of the telephone circuit to ground. Because of this, the impedance of the telephone circuit has very little effect on the total disturbing current, and even if a choke coil of high impedance compared to that of the telephone circuit is inserted, the total disturbing current will not be greatly reduced. Although the choke coil used under these conditions will not greatly reduce the disturbing current, it may divert it from the unbalanced termination at the right (see Figure 5) to the balanced termination at the left.

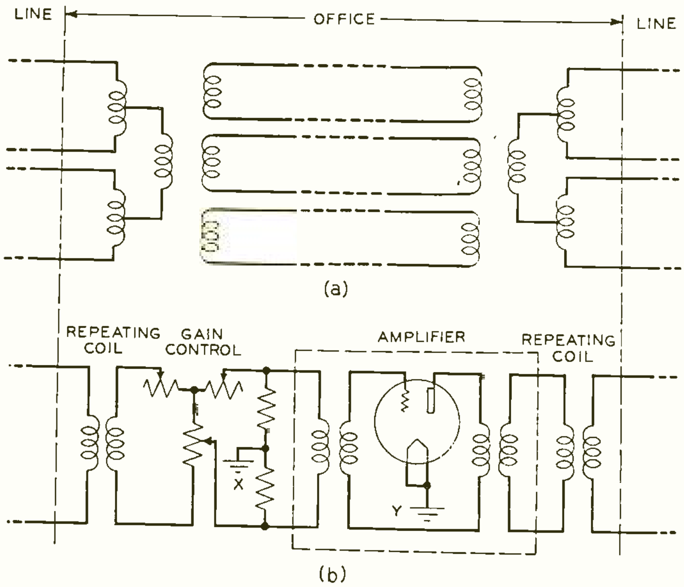


Fig. 6—Sectionalization, as in the phantom termination at a, *is an important method of limiting the effect of longitudinal current. With sectionalized unbalanced circuits, as at* b, *the grounding becomes of great importance*

Another method of reducing the longitudinal current in unbalanced circuit elements is by the use of drainage coils. As indicated in Figure 4b, this consists of a coil (generally with series condensers to block direct current) shunted across the line, and grounded at its midpoint. The two halves of this coil are wound series aiding so that to metallic-circuit current, tending to flow through it from one side to the other, it offers a high impedance. To longitudinal current, however, flowing from both lines to the midpoint, the impedance is very low. Such a coil thus forms a very low impedance path to the disturbing currents, and can be used to drain off by far the greater part of them before they reach unbalanced circuit elements. Neither drainage nor choke coils, however, can be inserted in a telephone line without careful study of their effects on transmission and on all possible circuit operations that are involved.

Another common means employed to break up the longitudinal circuit is to sectionalize the line, so that the longitudinal current is limited to certain sections only. In a phantom group, for example, the office termination, as indicated in Figure 6a, provides no longitudinal path through the office except through the coil capacitances, and since these are small, the longitudinal path is of high impedance except at high frequencies. A form of sectionalization occurs in Figure 2a, since the longitudinal current cannot pass the battery feed, and thus cannot react with any other unbalances to the right of this point, unless the central-office ground is poor.

In many arrangements proper grounding is very important. In Figure 6b, for example, which represents a regulating 44-A-1 repeater circuit, the effect of the unbalanced gain control is partially eliminated by the sectionalization provided by the repeating coil. The arrangement of the grounds X and Y, however, is very important. If there is a difference in potential between them, it will appear in part on the grid-filament circuit of the first tube through the capacitance coupling between the windings of the input transformer.

Another method for reducing the longitudinal current is neutralization. Apparatus used for neutralization and its method of application have already been described in the RECORD.* This method has, to date, been used largely for low-frequency rather than for high-frequency induction.

Before remedial methods can be satisfactorily applied, it is frequently necessary to measure the unbalance of circuits and circuit components. In fact it is part of normal telephone circuit development to insure that the designs are adequate with respect to unbalance. To facilitate such measurements, an unbalance rating circuit has been developed. Its essential features are shown in Figure 7a. An oscillator serves as a source of longitudinal current and is fed into the test circuit at the midpoint of a repeating coil. The apparatus or circuit to be measured is connected to the terminals 1, 2, 3, 4, and 5, as shown in Figure 7b. The ratio of the metallic-circuit voltage *e* to the applied longitudinal voltage E gives a measure of the circuit unbalance. One form of this circuit is shown being used in the photograph at the head of this article.

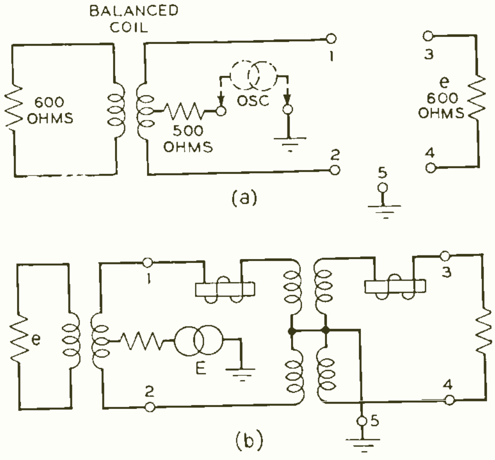
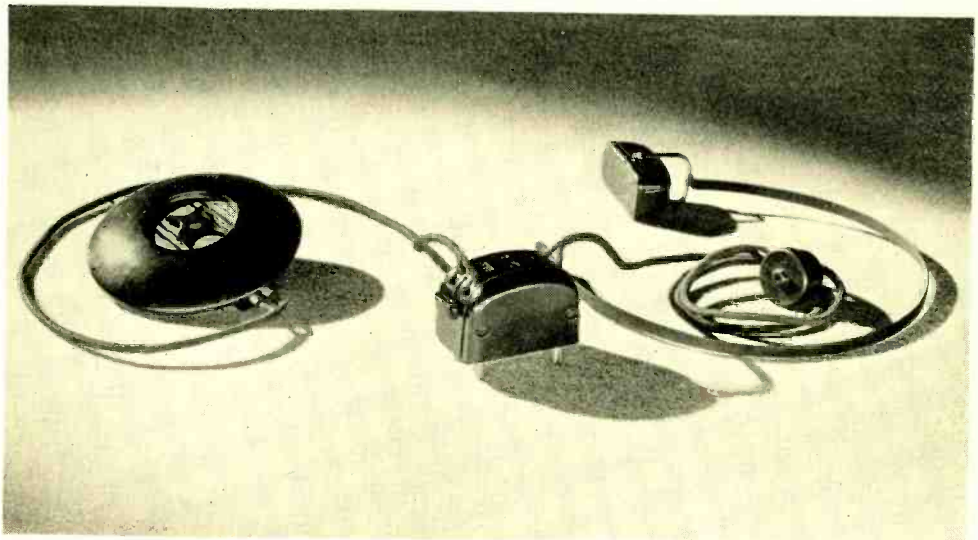


Fig. 7—Circuit for unbalance rating, at a, *is shown with a circuit connected for measurement at* b

*June, 1934, p. 311.



The Ortho-Technic Audiphone

By W. L. TUFFNELL
Transmission Instrument Development

A HEARING aid is really a miniature telephone system, and in developing the new Western Electric audiphone, advantage has been taken of much of the recent research on telephone instruments. The new set marks a distinct advance. The complete equipment consists of a microphone, a mechanical amplifier, and either an air- or bone-conduction receiver. The photograph at the head of this article shows all four of these units. Where the hearing loss is slight, the mechanical amplifier may be omitted. All of the instruments have phenol plastic housings, an obvious improvement over the previously used metal casings.

An important improvement in the new audiphone is the use of a split battery. Previously the same set of dry cells was used to supply current to both the transmitter and the amplifier. This meant, as can be seen from Figure 1, that the internal resistance of the dry cells was a common element in both the input and output circuits of the amplifier. With advancing life, the resistance of dry cells increases, and eventually the coupling becomes high enough to cause sustained feedback oscillations. These oscillations, which are in the audio-frequency range, can be so disturbing that the value of an audiphone is greatly reduced. To eliminate the oscillations, replacement of the battery may be necessary before its otherwise useful life is exhausted.

Such effects are now avoided by the use of two separate batteries housed in a single container and connected as shown in Figure 2. With this arrangement, there is no common resistance in the receiver and transmitter circuits and thus no means for transferring disturbances from one to the other. The double battery of the present set is of approximately the same size and weight as the single battery of the former set. This is possible because the instruments of the audiphone are of high sensitivity and operate on less current.

The microphone, shown in Figure 3, comprises a molded plastic case enclosing a transmitter unit similar to that recently developed for the new telephone handset. The housing has been made thin and smooth, so that it will be as inconspicuous as possible under clothing. The transmitter unit is resiliently mounted in the housing, so that the effects of vibrations will be minimized. Volume control is obtained with a slide-wire rheostat which is adjusted by a flat knob at the center of the transmitter.

The audiphone transmitter unit differs from that built for the new station handset in that the mechanical impedance of its vibratory system and car-

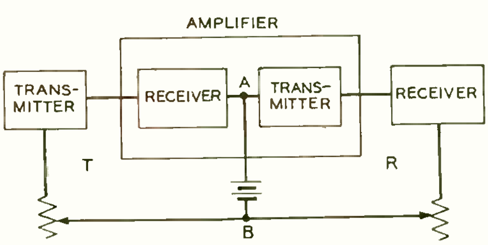


Fig. 1—Previous audiphones have had a single battery, which forms a common element of transmitter and receiver circuit

bon chamber has been made considerably lower to obtain greater sensitivity. This is, of course, an obvious requirement for a transmitter to be used with a hearing aid, inasmuch as its conditions of use are frequently such that the acoustic input may be anywhere from one-tenth to one-hundredth of that reaching the ordinary telephone transmitter. The new audiphone has been designed to operate in all positions, which adds greatly to the ease with which it may be worn.

To aid in meeting various hearing-loss characteristics, microphones with two types of frequency-response characteristics have been provided. One, the 637B, discriminates against the lower frequencies, being more efficient at the higher frequencies. In addition

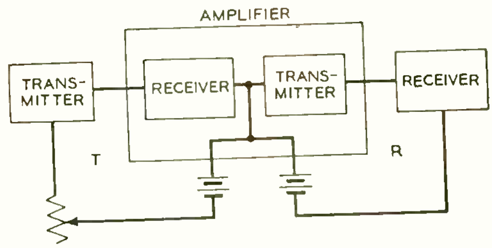


Fig. 2—In the Ortho-Technic Audiphone a double battery is employed, and there is no common element to the two circuits

both air-conduction and bone-conduction receivers have been made available to satisfy the requirements of the two general types of deafness: conductive deafness, where the hearing loss is in the auditory transmission system between the ear canal and the auditory nerve, and nerve deafness, where there is a loss in sensitivity of the auditory nerves. People with conductive deafness usually obtain more benefit from a bone-conduction type of receiver, whereas those with nerve deafness usually require an air-conduction type of receiver.

An air-conduction receiver is worn with an individually molded receiver attachment that fits the contour of the outer ear; and hence its size and weight are important. Advantage has been taken of recent advances in magnetic materials and in receiver designs to produce a receiver that combines a high performance with small size. Figure 4 illustrates how completely the objective of a small receiver has been met. The magnetic element is housed in a phenol plastic case; and a disc of relatively thick permalloy is fastened to the center of the diaphragm to improve the efficiency of the magnetic circuit. Three air-conduction receivers, differing in low-frequency characteristics, have been designed to aid in meeting the requirements of people having different hearing-loss characteristics.

Fig. 4—Receiver unit for the new audiphone showing permalloy disc on diaphragm

The amplifier unit consists, essentially, of the magnetic unit and diaphragm of the air-conduction receiver and a carbon chamber element similar to that used in the microphone. The moving electrode of the carbon element is directly fastened to the permalloy diaphragm, thus giving maximum coupling between the receiver and the carbon element. This results in a remarkably efficient amplifier. Its gain is approximately 25 db over a range in frequency from 200 to 2500 cycles per second, and it will give outputs up to zero level without serious distortion. One of the disadvantages of previous audiphone amplifiers has been that when the direct current decreased as a result of either a falling battery voltage or a rising resistance of the transmitter carbon, caused by aging, the amplifier gain would decrease appreciably. This variation is practically eliminated in the new amplifier by the use of a permanent magnet rather than the electromagnetic element formerly used. The unit is mounted in a phenol plastic housing that plugs into the double battery; and included in the housing is a switch for turning the set on and off. A diagrammatic sketch showing the amplifier unit mounted in the housing is shown in Figure 5.

Concentric cords are used exclusively for connecting the various units into a complete set. These cords are equipped with small plugs at the ends which fit into sockets in the units, thus eliminating the soldered or screw connections that have been employed previously. With this arrangement, the user may readily replace cords that are worn out, and thus avoid the inconvenience of

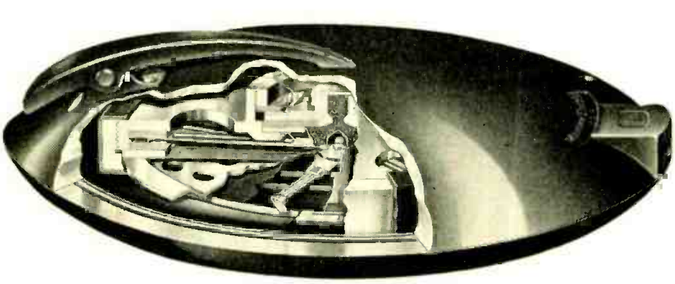


Fig. 3—The transmitter element of the new audiphone is less than two inches in diameter and well under a half an inch in thickness

sending the set to a dealer for repairs.

The speech amplification on a loudness basis, with the most efficient combination of instruments, is from 15 to 20 db for the non-amplifier, air-conduction audiphone; and from 40 to 45 db with the amplifier. The response of the bone-conduction audiphone is fairly uniform for the important speech frequencies, and the output level is such that the loudness of reproduced speech by bone conduction is almost as loud as the original speech would appear to be to a person who had normal hearing but who was listening to the speech with one ear.

Throughout the development of this Ortho-Technic Audiphone, stress has been laid not alone on an increase in volume, which gives an audiphone a superficial appearance of efficiency, but on an increase in intelligibility—a faithfulness in reproduction that enables the user to understand readily. Increased volume may be obtained merely by making the resonance peaks of the component instruments occur at the same frequency, but increased intelligibility requires the more difficult achievement of eliminating disturbing noises and increasing faithfulness of reproduction.

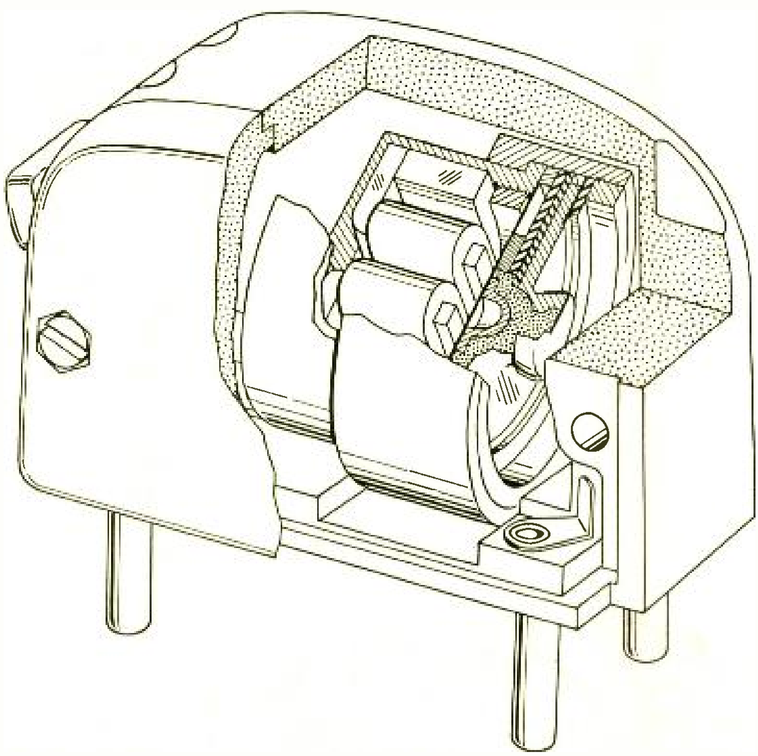


Fig. 5—The amplifier consists of a microphone and receiver unit closely coupled

The 710A Bone-Conduction Receiver

By M. S. HAWLEY
Transmission Instrument Development

HEARING loss may result either from some defect in the inner ear of such a nature that vibrations reaching it do not produce the normal intensities of sensation, or from some defect in the chain of small bones or ossicles connecting the drum to the inner ear, with the result that much of the sound incident on the drum is lost before reaching the inner ear. Combinations of these defects may exist, of course, but usually one is sufficiently dominant to characterize the type of hearing loss as the inner-ear or outer-ear type. With an outer-ear loss, the auditory nerves may be intact, and the problem is to get the normal intensity of vibration to them. With inner-ear loss the auditory nerves themselves have lost their sensitivity, and, as a result, the intensity of vibration delivered to them must be greater than normal.

There are two ways by which vibrations may be transmitted to the inner ear. One is by passing the vibrations along the highly efficient linkage of ossicles extending from the drum to the inner ear. The other is by transmitting the vibrations through the bones of the skull—usually through the mastoid bone. This method is much less efficient, and normally requires considerably greater intensity to produce the same vibration in the inner-ear. The most effective way of overcoming a hearing loss due to inner-ear defects, therefore, is to transmit the sound vibrations from a small air-conduction receiver fitted closely in the ear. An effective receiver of this type, designed for the new Western Electric audiphone, is described in the preceding article.

In some cases, however, where the hearing loss is principally due to an inability of the ossicle chain to transmit vibrations satisfactorily, a bone-conduction receiver may prove more effective. Such a receiver is worn just behind the ear against the mastoid bone, through which it transmits the

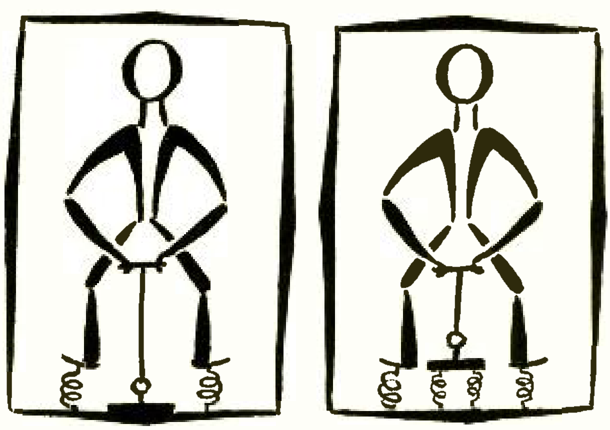


Fig. 1 (left)—This jack-in-the-box can't get out but he can vibrate the box by pulling up and down on the rope. The operation of the earlier bone-conduction receiver was of this type

Fig. 2 (right)—By providing a spring-supported plate on which the jack-in-the-box pulls, the box can be made to vibrate at higher rates vibrations to the inner ear. Such a receiver was developed by the Western Electric Company in 1912, and was used for measuring hearing loss with an audiometer.

A receiver of this type for use with

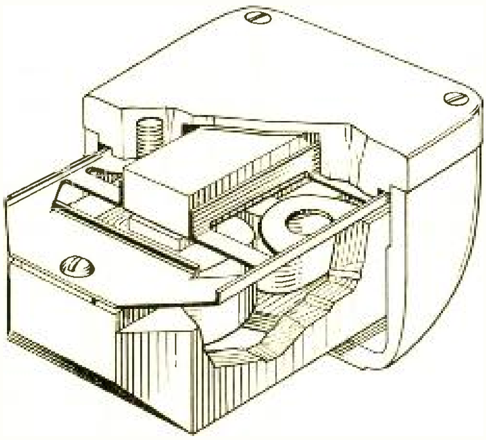


Fig. 3—An approximate, perspective view of the 710A receiver looking from the armature side

an audiphone has already been described in the RECORD.* The principle on which this receiver works is suggested by Figure 1, which shows a man inside of a light packing case standing on two springs. In his hands he holds a rope fastened to a plate attached to the bottom of the box. If he suddenly jerks up on the rope, the box will jump off the ground, and if he alternately jerks up and relaxes his pull on the rope in rapid succession, the box will naturally jump up and down.

In the bone-conduction receiver, the case of the receiver plays the part of the box, and the magnet structure of the receiver, which is fastened to the case by a spring, plays the part of the man. The periodic attraction of the magnet for its armature, which is rigidly fastened to the case, exerts the force that the man does on the rope. The man can control the rate, or frequency, of vibration of the box by merely changing the rate at which he pulls and releases the rope, but he is limited in both directions. If he pulls very slowly, the pull will be completely absorbed by the spring, and the box will not move, while if he pulls with very short rapid motions, the box will not be able to move rapidly enough to follow. This is equally true of the receiver, which vibrates most effectively from about 300 to 1500 cycles per second.

Since the previous receiver was developed, new materials have come into existence, and more experience has been gained in the development of hearing aids. As a result it has been possible to design a new bone-conduction receiver known as the 710A which gives better quality of sound reproduction over the hearing range and is higher in efficiency.

The response of the new receiver extends to a higher frequency before cutting off; however, when the cut-off is reached, the response drops very rapidly. The extension in the frequency range of response and the sharp decrease in response after the cut-off both contribute to the quality of sound reproduction. The extension in frequency range allows the transmission of the higher frequencies which add to the clearness of sounds. The sharp cut-off filters out high-frequency components of modulation from the carbon element of the mechanical amplifier. These components normally are a source of objectionable noise and produce a distortion in the quality of sound reproduction.

This modification in the characteristic has been secured by incorporating an additional spring in the vibrating structure. The action of the new receiver could be represented as

*August, 1935, p. 364.

shown in Figure 2. The difference is that the plate on which the man pulls is fastened to the case by a relatively stiff spring. The man, as before, represents the magnet structure, and the plate is the armature, which in the new receiver is attached to the case by springs, instead of being rigidly fastened. The effect of this additional spring is difficult to isolate because the overall result depends on the stiffness of the springs on which the man stands as well as on that of the springs supporting the plate. It can be shown both mathematically and experimentally, however, that the overall effect is to extend the response-frequency range and to steepen the cut-off of the receiver.

The construction of the new receiver is indicated in Figures 3 and 4. The springs that fasten the magnet and the armature to the case are formed from a single piece of beryllium copper—one of the new materials that have contributed to the success of the receiver. It is formed into shape in the annealed condition and hardened afterward by heat treating. This permits sharper bends to be made in it, and thus allows a more simple and compact construction. The armature is soldered into place in the central portion of this spring lattice, and moves with respect to the main body of the spring by flexing two narrow strips on each side. A screw in each side of the spring lattice fastens it to the case, and one in each end fastens it to the magnet. Between each of its fastenings, the spring can flex, so that its action is similar to that of the springs in Figure 2.

The magnet structure consists of two permanent magnets connecting two U-shaped pole pieces. On the two inner arms of these two U's are placed the coils of wire through which the speech currents flow; the two outer arms are merely supporting members for fastening to the springs. The magnets are made of remalloy—the other new material that has contributed to the success of the receiver. Because of the efficiency of this new material as a permanent magnet, it has been possible to increase the size of the pole pieces—and thus to increase the efficiency of the receiver—without increasing the size of the magnets themselves.

By employing these new materials, and profiting by experience over the past few years, it has been possible to secure a gain in efficiency of the new receiver, besides getting the wider frequency band and a reduction in the disturbing noises of higher frequency. These are very appreciable improvements, and together with those secured by designing the receiver as part of a complete system including transmitter and power supply, result in a very superior hearing aid.

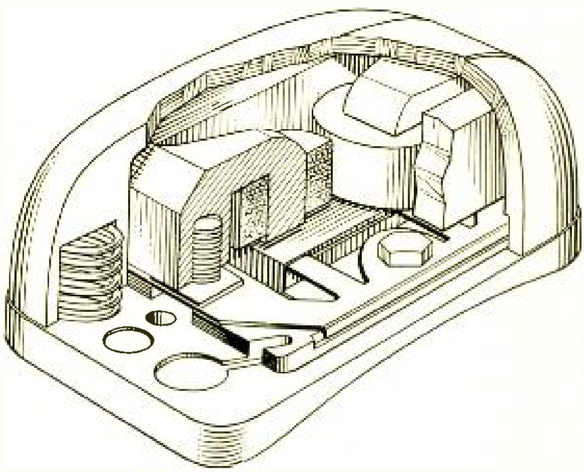


Fig. 4—A cut-away view of the 710A receiver looking from the bottom

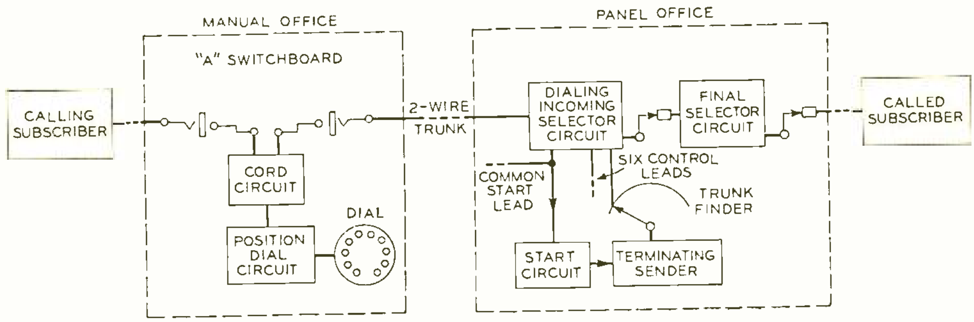
Dialing Incomings

C. E. GERMANTON
Central Office Switching Development

WHEN there are both manual and panel offices in the same area, switchboards have been required in the panel offices to complete calls from the manual offices. These boards, known as cordless "B" boards*, are used for calls from toll or tandem switchboards as well as from local manual boards, and are equipped with a key set with which the operator sends the key pulses that set up the connection. As the ratio of panel to manual offices in an area increases, the load on these "B" boards becomes less; and if the toll and tandem traffic in the area is handled by means of key-pulsing equipment, the "B" boards would then care only for the traffic from the manual offices, and would be very small in size and consequently inefficient. In such areas the elimination of "B" boards may be very desirable, and one way to accomplish this would be to provide dialing incomings in the panel office and dials on the "A" boards in the manual offices. The only operator involved under these conditions would be the "A" operator in the manual office, who would dial the desired number in the panel office. The arrangement is indicated below. These dials in some cases may already have been installed for completing calls to nearby step-by-step offices. In other cases the expense of installing dials may be justified by the greater saving in eliminating the "B" board.

When the calling subscriber in the figure originates a call, the manual "A" operator answers by plugging a cord into the jack associated with the calling subscriber, and receives the number in the usual manner. If the number is for a subscriber in the panel office, the operator will plug into an idle trunk to that office just as for a call to another manual office. Now, however, there is a difference. Instead of receiving the manual order tone (zip-zip) which is a signal to give the called number audibly, the operator will hear, after a short delay, dial tone as a signal to dial the number. Having dialed the number, the operator then disconnects her position circuit and may give her attention to other duties.

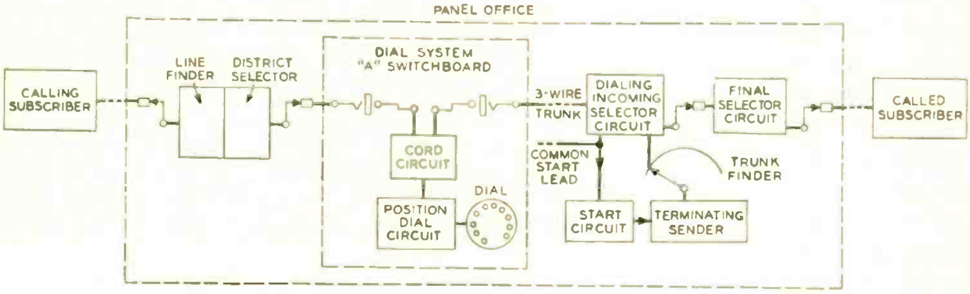
*RECORD, *December*, 1930, *p*. 162.



When the operator inserted her plug into the jack associated with the dialing trunk leading to the panel office, relays in the dialing incoming selector circuit responded to this closure of the trunk and signaled over the common start lead to the start circuit, which immediately relayed this signal to a preselected—or rather a preferred—idle terminating sender. This sender then actuates one of its trunk finders to hunt for the dialing incoming, which can be identified by a condition on one of the leads terminating on the bank of the trunk finder. When the connection is made, the start signal is removed and dial tone is sent from the sender through the trunk finder into the dialing incoming and over the interoffice trunk to the operator in the manual office as mentioned above. The dialed number is then recorded on relays in the sender, which now has a dialing range of more than thirty miles, and the selector apparatus in both the incoming and final selectors is then controlled by the sender in the usual manner for panel office equipment. When the called line has been found the sender disconnects itself and ringing is begun. If the called line is not reached, or if the line is busy, the incoming will recall the operator with a re-order lamp signal, and will send a busy tone to the calling subscriber.

For this arrangement very little new equipment is required in the panel office. The terminating senders, trunk finders, and the start circuit were already designed and are provided in many cases for use with the No. 14 test desk for testing subscribers' lines. It was necessary only to increase the capacity of this circuit group, which resulted in additional economy since its group efficiency was thereby increased. The dialing incoming selector circuits themselves cost somewhat more than the standard full-mechanical incomings, but can readily be converted at slight additional cost when the manual office with which they are used is converted into a dial office of the panel or crossbar type.

When the "B" switchboard is omitted in a panel office, provision must be made for handling traffic from the "DSA" board, such as assistance, delayed ringing, and verification calls, to subscribers within the office. To complete calls of this nature without the use of the more costly key-pulsing equipment, a different type of dialing incoming selector circuit was developed. This differs chiefly in that certain economies were possible because of the availability of the third conductor in the trunk, and the elimination of certain transmission and supervisory equipment since such equipment is always available in the switchboard circuit. The illustration below shows how the "DSA" operator may use this circuit in assisting one subscriber to reach another in the same office.



A One-Kilowatt Broadcast Transmitter

By H. A. REISE
Commercial Products Development

BESIDES the basic invention and discoveries that are continually improving modern apparatus, there has been a steady progress in design. Perhaps its most outstanding feature is simplicity. The gingerbread and pseudo-ornamentation of the late century is gone, and in its place are plain surfaces, sweeping lines, and sparseness of unnecessary detail. The change is more than superficial. Simplification is carried to all the component structures and to the manufacturing processes. This trend is evident in the design of all Bell System apparatus, such as the subscriber's telephone set with its graceful exterior simplicity.

This same trend in design extends to the considerable amount of radio apparatus designed by the Laboratories for the American Telephone and Telegraph Company, to be used in its many transoceanic services, and for the Western Electric Company, to be used in broadcasting and in the rapidly expanding field of airplane communication and safety. Many of the distinguishing features of this modern design are exemplified in the new 1000-watt broadcasting transmitter recently made available. Besides incorporating all the recent technical advances, such as stabilized feedback* to reduce noise and harmonics, and the Doherty high-efficiency circuit†

*Record, *February*, 1937, *p*. 182.
†Record, *June*, 1936, *p*. 333.

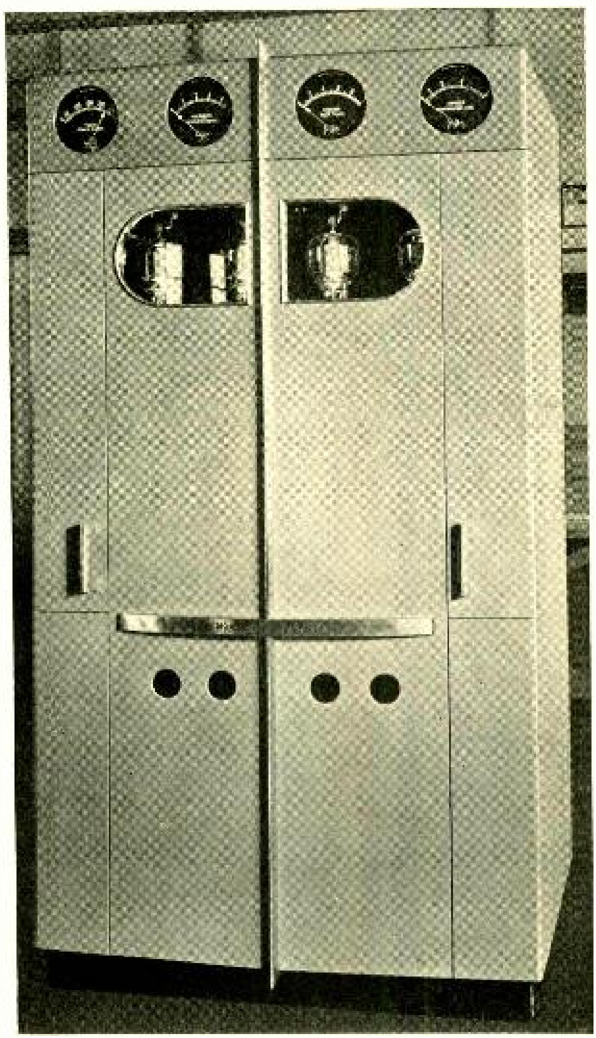


Fig. 1—The 443-A-1 radio broadcast transmitter

that permits full output of the transmitter with only 4.4 kw input—a reduction of 28 and of 56 per cent compared to the two previous models of this rating—it attains a new simplicity of assembly and structure in a distinctly modern exterior.

Many broadcast stations are licensed for lower power during the night than during the day. To accommodate such users, this transmitter is designed for operation at either 500 or 250 watts as well as at 1000. The higher rating may be either 500 or 1000 watts, but by operating a toggle switch, the output is cut to either 500 or 250 watts when the maximum is 1000 watts, or to 250 when it is 500. For full 1000-watt operation, four output tubes are employed, but when the maximum output is to be 500 watts, only two are installed. The transmitter is crystal controlled, using the 702A oscillator which is capable of maintaining its frequency within a few cycles for any temperature and voltage variations ordinarily encountered in broadcasting service. A spare oscillator unit is included, and control of the set may be transferred to it by the simple operation of a switch.

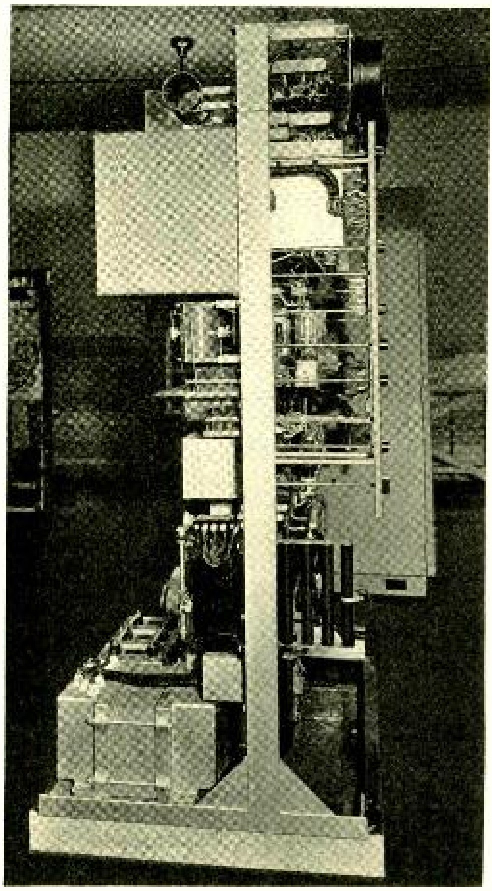


Fig. 2—All the electrical components, except the three door switches, are mounted on the central structure

The output of the oscillator is amplified in three successive stages by direct-coupled and tuned amplifiers, and then by the final power-output stage, which employs the new 357A radiation-cooled tubes. Modulation is achieved by applying the output from a two-stage voice-frequency amplifier to the grids of this stage. The output of this final stage is fed through a radio-frequency filter and coupling circuit to the antenna, either directly or through a transmission line. A small portion of the radio-frequency output of the transmitter is rectified by a vacuum tube, and the rectified wave is fed in series with the program input to the first audio stage to furnish stabilized feedback. Another rectifier tube, coupled to the radio-frequency circuit, is used for audio monitoring. Four tubes are used in parallel in the second audio stage, which is resistance coupled to the grids of the modulating final amplifier.

All power is obtained from a nominal 230-volt single-phase circuit at either 50 or 60 cycles. A manual regulator permits adjustment for line voltages from 187 to 250. A single-phase four-tube bridge-type rectifier

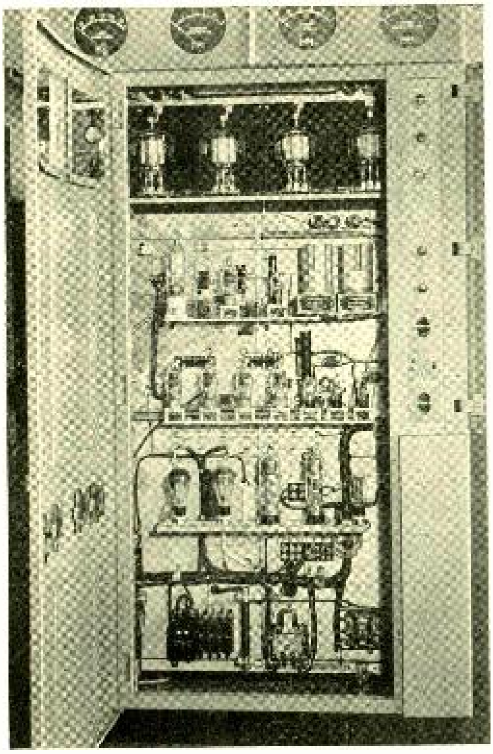


Fig. 3—Front view of 443-*A*-1 *radio transmitter with door open*

with its associated potentiometer supplies all plate and screen potentials. All audio and radio stages are self-biased except the final radio-frequency stage, which obtains its bias from a single-phase full-wave rectifier.

A feature of considerable interest to the operator of the transmitter is the absence of fuses. Overload protection is obtained by circuit breakers of a new type, which also serve as switches to make possible a very simple and effective control circuit. Door switches at the front and back trip the magnetic contactor feeding the plate- and grid-supply rectifiers when either door is opened. On the front door is another switch, closing slightly after the first one opens, which grounds the high-voltage d-c lead through a low resistance. If the contactor, for any reason, should fail to open when the first switch operates, the circuit breaker will be tripped by the overload placed on it by the second switch.

A blower in the back of the unit furnishes forced-air cooling for the entire transmitter. The system provides a slight air pressure within the unit, and thus prevents the entrance of dirt. A spun-glass filter in the intake to the blower filters the air drawn in, and a very thin spun-glass filter in the top of the transmitter serves as outlet for the air and prevents dust from entering when the blower is stopped. A thermostat and buzzer are provided to give warning of excess temperature should the

Fig. 4—On the rear of the transmitter are the coils, condensers, and the voltage regulator, evident at the right

blower stop or the intake filter to the transmitter become clogged.

Considerable thought has been given to the arrangement of the apparatus, and has resulted in a high degree of accessibility. All the apparatus is mounted on a central vertical structure as shown in Figure 2. The cabinet is only a cover for the transmitter assembly, and nothing is mounted on it but the three door switches. The vertical mounting area is divided into three sections, with all power-supply equipment on the lower section, voice-frequency and low-power radio-frequency stages on the middle section, and output circuits on the upper. This brings all the major heat generating units in the upper part of the unit where the heat is carried off without affecting the lower sections. On all units such components as coils, condensers, and the regulator are mounted on the back, while the tubes, oscillators, and practically all the wiring—including the circuit breakers—are on the front (Figure 3).

On the lower section, above the circuit breakers, are the four rectifiers for plate and screen supply at the left, and the rectifier for the final stage biasing is the small tube at the right. In the middle section, along the lower row from left to right, are the four parallel tubes for the second stage audio amplifier, the first audio stage, and the rectifiers for feedback and monitoring. In the upper row are the two oscillators at the right, and the three low-power radio-frequency amplifier tubes at the left. In the top section are the four output tubes. A row of four meters is mounted across the top of the front, and down the upper half of the unit on each side of the front door are the controls. A narrow door on each side covers these controls when not in use to prevent accidental displacement of any of them. Figure 4 shows the arrangement of apparatus in the rear of the transmitter.

Like other Western Electric Transmitters, the 443-A-1 is capable of complete modulation with very high quality, and transmits a frequency range from 30 to 10,000 cycles. Its arrangement into a single compact unit, with maximum accessibility for all component parts, gives it a distinguished place in its field, and its moderate cost and low power input should make it very attractive for commercial and police broadcasting applications.

Lockout Circuits

By F. A. KORN
Central Office Switching Development

IN ANY automatic telephone switching system, the time required to set up a connection is only a very small part of the total time from the beginning to the end of the call. In the crossbar system, for example, the selection of the paths through the switches and the operation of the cross points requires but a fraction of a second, while the following conversation may last several minutes. If the equipment used for establishing the connection is made part of the main switching units, its efficiency of use will be very low, since it will be used for only a fraction of a second on each completed connection. By dissociating the controlling equipment from the switching units used in the talking path, however, the control circuits may be employed very efficiently, since they may be used almost continuously in establishing one call after another.

This is the principle employed in the crossbar system. Separate controller or marker circuits are used, for example, at the various stages of the switching chain, each being associated with a call only long enough to perform its switching function. In this way these expensive controller or marker circuits are employed very efficiently, and thus become inexpensive per call.

Each such circuit must be able to connect itself to each switching unit it controls; and paths must be provided as indicated in the upper diagram of Figure 1. If the arrangement were as simple as there indicated, however, several of the controller circuits might connect themselves to the switching unit at the same time, and thus interfere with each other. To avoid this, an additional circuit is interposed between the controller and the switching circuit as indicated in the lower diagram. This circuit is known as a lockout or "gate" circuit. It is arranged to permit only one controller circuit to be con-

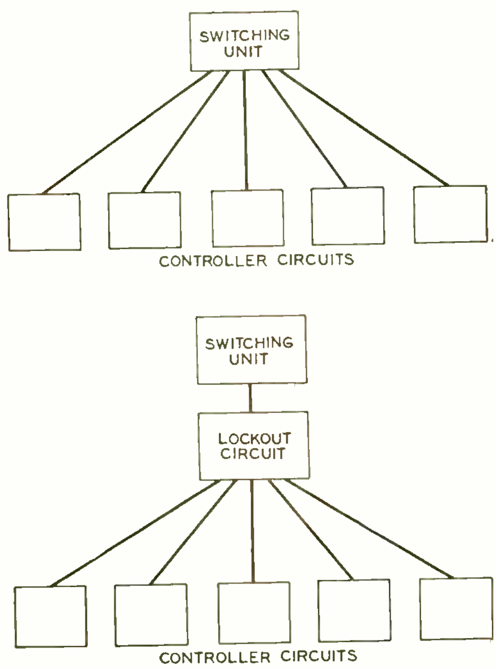


Fig. 1—Each common controller circuit must have access to the switching units it controls (upper diagram); and to prevent several controller circuits seizing the same switching unit at the same time, a lockout circuit is interposed (lower diagram)

nected to the switching unit at a time, and where a number of controller circuits are awaiting connection, to select them successively as nearly as possible in the order of their request for connection. Such lockout circuits are employed at many points in the system, and although they differ somewhat in type, depending on their location, their functions are essentially the same.

One place where such lockouts are used is between the terminating markers and the number groups.* There may be as many as twenty-five number groups in an office and from three to ten markers. Each marker must be able to reach any number group but not more than one marker must be allowed to connect to the same number group at the same time. Each number group has a lockout circuit through which all the marker connections must pass, and the circuit provides that only one connection be made at a time and that the markers will be served as nearly as possible in the same order in which they ask for connection.

*Record, *July*, 1939, *p.* 356.

The essential features of the lockout circuit provided for this situation are shown in simplified form in Figure 2. The relays in the top row, marked MC, are the ones that close the connection between the number group and one of the markers, while those in the bottom row are in the marker, and are operated when the marker wants a connection to that particular number group. The lockout relays themselves comprise the middle row, and are marked MP. All the relays have following numbers to indicate the marker served. It will be noticed that two circuits run through the back contacts of the MP relays. Each chain is grounded at one end. The ground G1

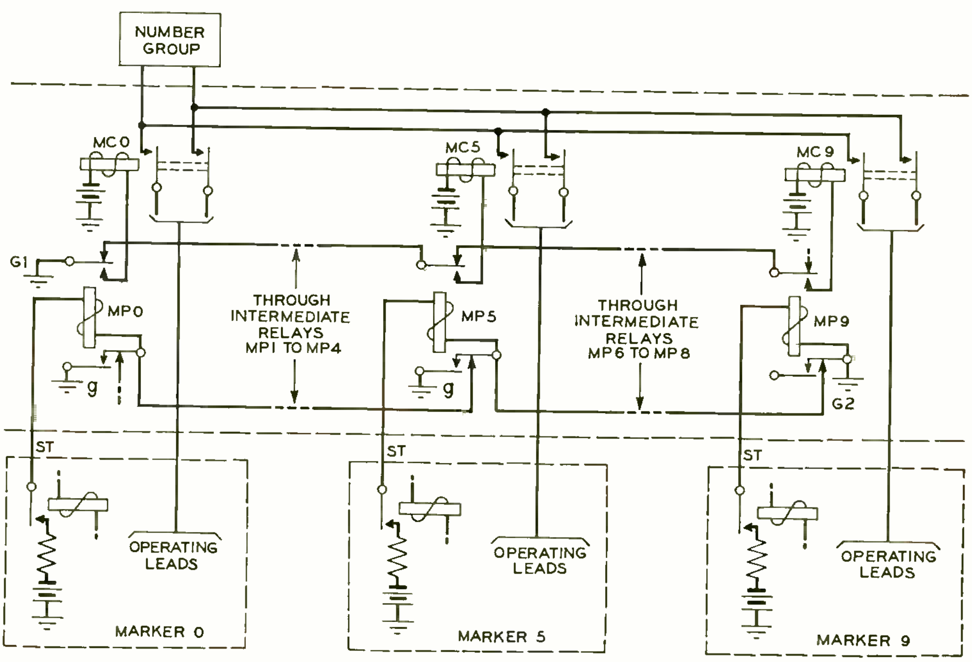


Fig. 2—Simplified lockout circuit of the type used between the terminating marker and the number group

for the upper chain is at the left and that for the lower chain at the right. In addition each relay but the last has a ground *g* on a front contact by which it holds itself operated.

When marker No. 5, for example, desires a connection to the number group, it closes its ST lead, which operates the associated MP relay through the chain circuit to G2. This relay holds itself operated through *g*, and connects ground G1 through the chain circuit to the winding of MC5. This relay operates and connects marker No. 5 to the number group. By the operation of MP5, the G1 chain is opened to MP relays 6 to 9 inclusive, so that even if these relays should operate, they would not operate their associated MC relays. The G2 chain, on the other hand, is opened to MP relays from 0 to 4 inclusive, so that these MP relays cannot operate even though the markers closed their ST leads. As a result of this situation, markers 6 to 9 inclusive may operate their MP relays but no further action will result, while if markers 0 to 4 close their ST leads, nothing happens.

When marker 5 finishes with the number group, which will be in less than a second, it will release MP5, and the reëstablishment of the G1 chain will bring in the MC relay of the next operated MP relay. When this next marker finishes with the number group, the next MC relay of higher number will be operated, and so on until all markers up to No. 9 have been served. With the release of MP9—or the highest MP relay that was operated—the G2 chain will be reëstablished, and any waiting markers will operate their MP relays. The lowest numbered one will operate its MC relay and in doing so will open the G1

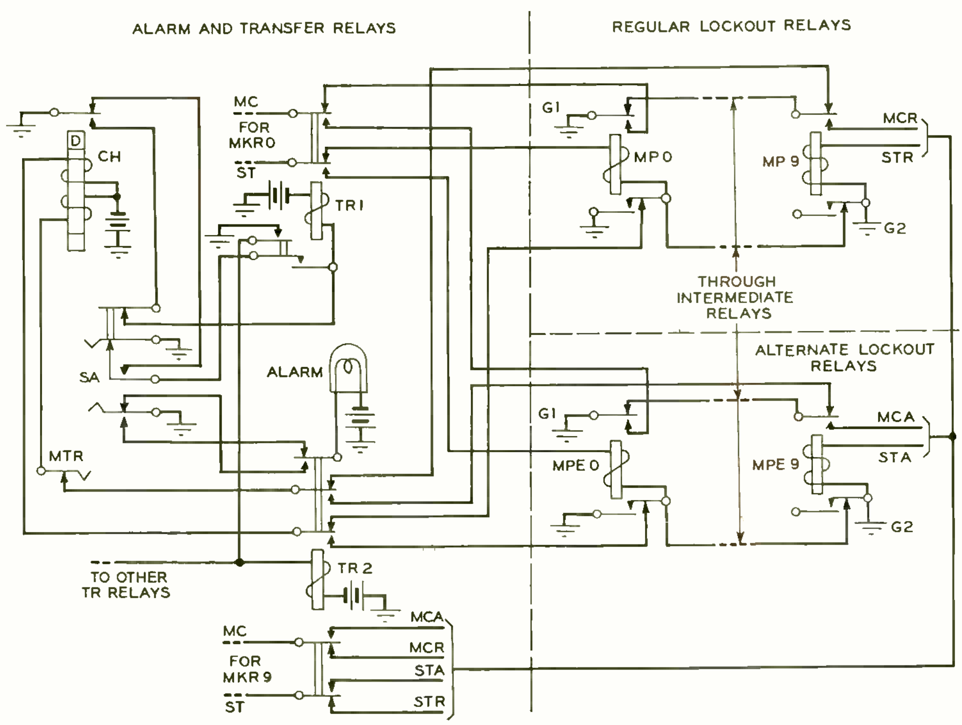


Fig. 3—Alarm and transfer circuits used with important lockout circuits

chain to the higher numbered relays, and the G2 chain to the lower numbered ones. The cycle will then proceed as before. It begins with the lowest numbered marker, travels successively through those of higher number, and then starts over again.

The two chain circuits may be looked upon as doors to a physician's reception room, with the number group acting as the doctor. The G1 chain is the door leading to the consultation office, and the G2 chain is the door from the street. When MP9 is released, the outer door is opened, and all the marker patients waiting step inside the reception room. The door to the doctor's office is then opened wide enough to admit the patient at the extreme left. After he has been served, the door is again opened to receive the next patient, and so on until all have been served. While this serving of patients has been going on, the outer door has been closing from left to right, so that new patients can enter the reception room if they are to the right of the one being served. After the reception room has been emptied, however, the outer door is opened wide, and all waiting patients step in.

On very important circuits, where the failure of the chain circuit would seriously affect the service given, two such lockout circuits are provided, one to be switched in automatically on failure of the other. Alarms are provided to indicate when a transfer occurs, and controls to permit the transfer to be made manually to insure that both circuits are always in working order.

The essential features of this circuit are indicated in Figure 3. Under normal conditions, the operation of an MP relay opens and closes both of the chain circuits together so that current is always flowing in both or neither of them. Under the most

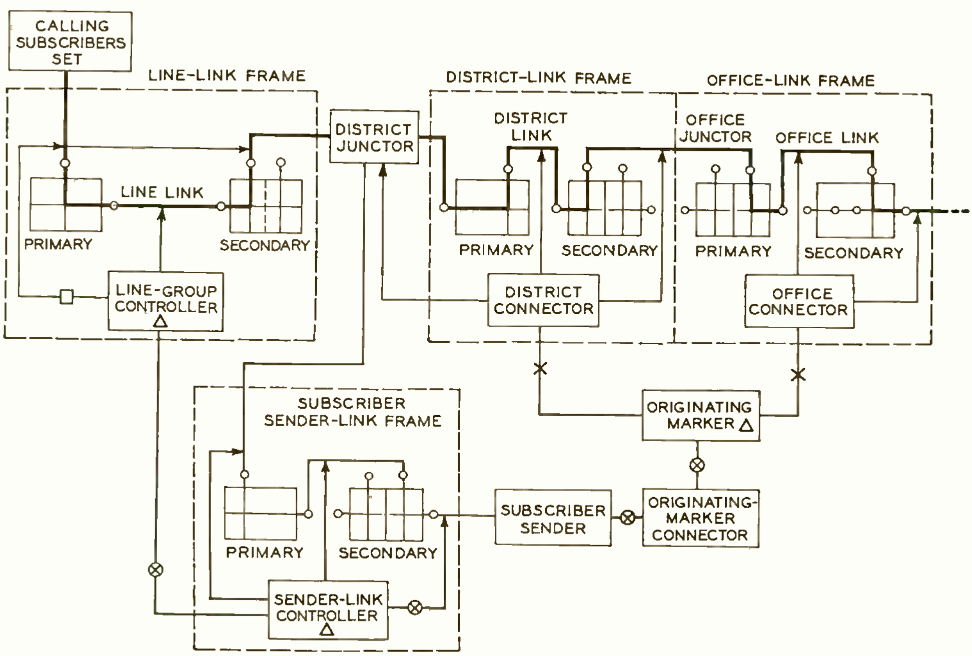
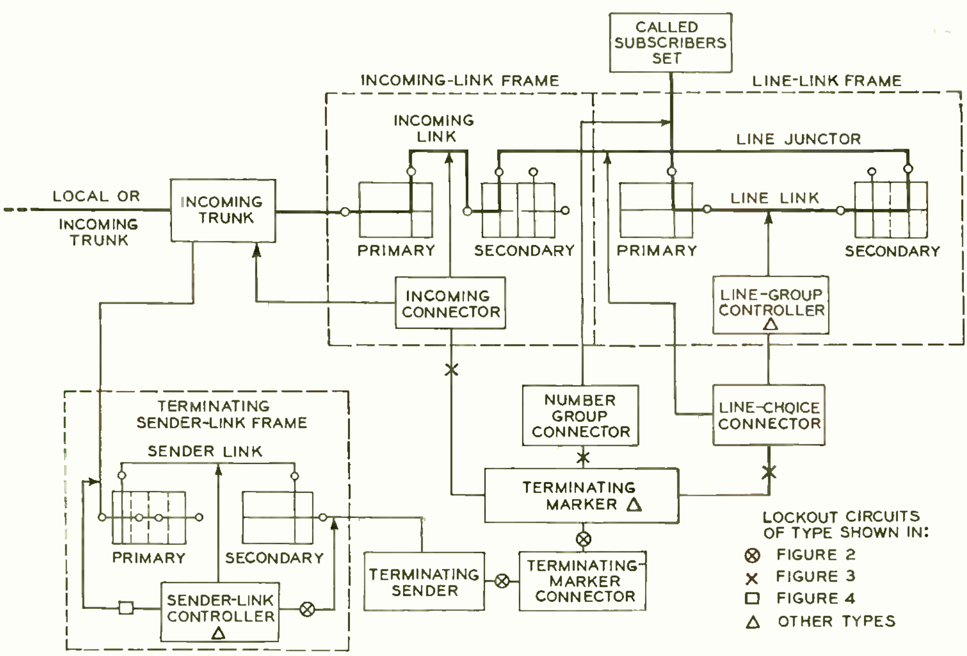


Fig. 4—Block schematic of crossbar system showing

likely trouble conditions, however, such as faulty contact, false grounds, or crossed contacts, there will be occasions when current will flow in one chain only. Under these conditions all the MC and ST leads are transferred to the other chain through two or more TR relays under control of the double-wound CH relay. One end of each winding on this latter relay is connected to battery and the other ends run, through the transfer relay TR2, to the ends of the G1 and G2 chains. The two windings on the CH relay are differentially connected so that with current in both of them, the relay remains unoperated. With current flowing in only one of the ground chains, however, as would occur under trouble conditions, mentioned above, CH operates and in turn operates TR1. This relay holds itself operated through a ground on the key SA, and also operates the other TR relays. Only TR2 is shown, but if there are not enough contacts on TR1 and TR2 to transfer the leads from all the markers, one or more similar relays will be added. In addition to transferring the MC and ST leads for MP9 and the chain leads to CH, TR2 lights a lamp and sounds an audible alarm. The maintenance man stops the alarm by operating the key SA, and then proceeds to correct the trouble on the first lockout circuit.

In the meantime the alternate lockout circuit is in use, and its chain circuits have been transferred to the CH relay, taking the place of those from the regular lockout circuit. Should the alternate lockout circuit fail, therefore, CH would again operate, and by releasing the TR relays, would bring the regular lockout circuit into use again. This transfer may also be made manually at any time by operating the MTR key, which will make the transfer regardless of which lockout circuit is in use.

A somewhat different type of lock-



the locations of various types of lockout circuits out circuit is employed in the line-link controller circuit* to determine the order of serving the lines when a number of calls come in at the same time. This arrangement is shown in simplified form in Figure 5. The lines of each frame are divided into ten horizontal groups, and a common ST lead for each group is grounded when any line relay of that group operates. Only one group can be served at a time, however, and the lockout circuit shown in the illustration provides the necessary control.

If, for example, a ground should appear on ST5—because of the operation of a line relay in horizontal group five—relay H5 would be operated, and would connect ground to the operating circuit for that group by ground from the lower contact of the GT relay and a chain circuit through back contacts on the H relays. The GT relay is also operated through a front contact of H5, and in operating, opens the ST leads from the other groups of line relays so that no other call can gain access to the controller circuit until this call is handled, which is only a matter of a fraction of a second.

A ground on any of the other ST leads would have resulted in a similar operation through one of the other H relays. Had calls come in from several of the horizontal groups at the same time, all the corresponding H relays would have operated and at once have operated GT to prevent further calls from coming in. Although a number of the H relays operate, only the lowest numbered one will connect ground through to its operating circuit because of the chain circuit from ground on the GT relay. The lowest numbered H relay that operates opens this circuit so that ground is not accessible to the others. After this circuit has been served, however, its H relay releases and reestablishes the chain circuit to the next relay. This procedure continues until all the operated H relays have been served. The last H relay to release opens the circuit to the GT relay, which releases to allow any waiting calls to operate their H relays.

It will be noted that the action of this "gate" or "lockout" circuit is slightly different from that of Figure 2 in that the gate opens or closes completely like a portcullis rather than with the action of a sliding door. When the gate opens, on the release of GT,

*RECORD, *May*, 1939, *p.* 266.

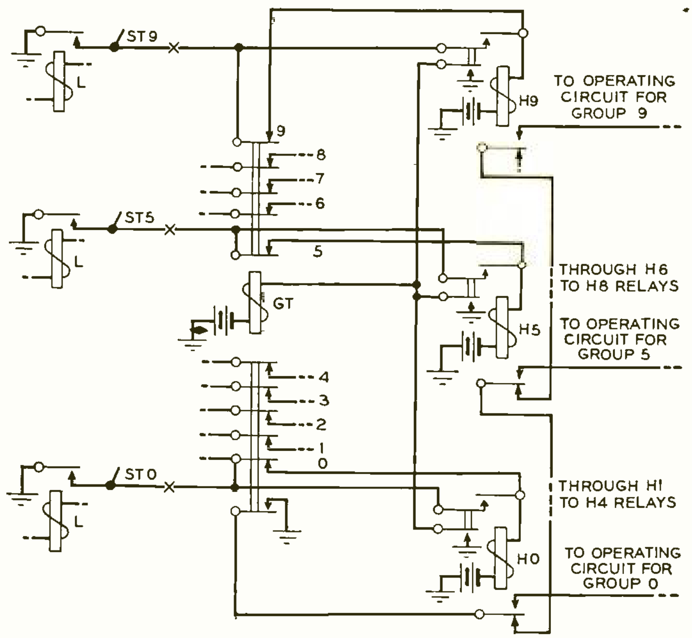
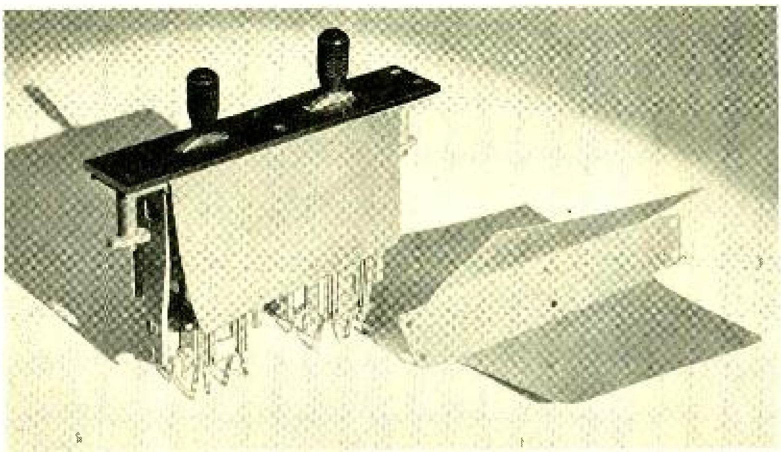


Fig. 5—A form of "gate" or "lockout" circuit employed in the line-link controller circuit

all waiting calls may enter, and when it closes—on the operation of GT—no more calls may enter until all those within have been attended to. With the circuit of Figure 2, however, the gate—when a call comes in—slides from the left up to that call, but remains open for calls to the right of that call to enter; it closes completely only when battery appears on the ST lead for marker 9. This difference is employed because of slight variations in the circuits with which they are associated.

Although the use of lockout circuits in telephone systems is not new, the common control features of the crossbar system have required their application to a much greater extent and with more elaborate circuit refinements. Applications of similar principles, however, may be found in the start circuit of the panel line finder, and in manual systems in connection with automatic listening, where it is necessary to permit the connection of only a single trunk to an operator's telephone circuit at a time. Later, such circuits were used with the panel decoders. A duplicate set of relays with a transfer relay and alarm were added to this latter circuit to make it suitable for some of the crossbar circuits.

The two types of lockout circuits described above are used in a number of places in the system as indicated in Figure 4. Other types of lockout circuit are also used at the locations marked. In general they function in a similar manner to the circuits described, but usually are less elaborate.



In switching apparatus contact troubles are occasionally caused by dirt, principally lint. Engineers of the Cincinnati Suburban Bell Telephone Company suggested a preventative in the form of a shield of vulcanized paper, which has recently been standardized. The shield is placed over the key frame and its sides folded down to form an apron along each side of the key. It fits snugly around the lever cam and thus effectively retards the entrance of dirt from the keyshelf surface. The aprons minimize circulation of air-borne dust around the key springs

Optical Curve Analysis

By H. C. MONTGOMERY
Physical Research

ANALYSES of the complex sounds of speech and music into the simple tones of which they are composed are often desired in fundamental studies in telephony. Machines* have been made to perform this operation mechanically but they are complicated and require considerable time for an analysis. A much simpler method, which makes analyses rapidly by optical means, has recently been devised by the Laboratories. A variable-area recording on film of the complex sound to be analyzed is projected onto a variable-density record of a pure tone whose frequency is the fundamental or a harmonic of the complex sound, and the intensity of the transmitted light is measured. By repeating this process with variable-density records of other frequencies, as many harmonics as desired may be measured.

*Record, *May*, 1935, *p.* 259.

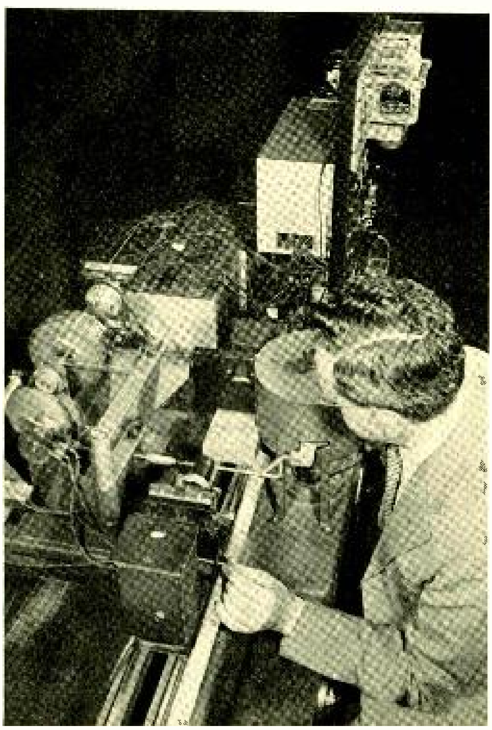
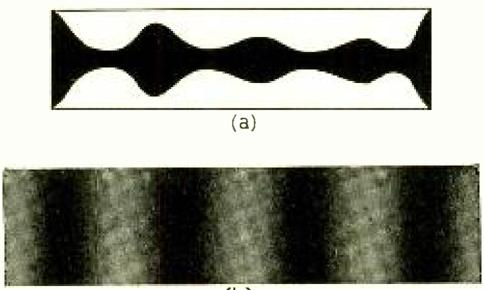


Fig. 1—Optical curve analyzer which can measure the first thirty harmonics of a complex sound in a minute and a half

The principle underlying this method is the theorem of Fourier, which states that a given periodic function, such as that representing a sound wave, can be expressed by a series of sinusoidal terms of proper amplitude and phase. For a sound, these terms are the fundamental tone and its harmonics. The amplitude of each term is the integral of a continuous function formed by multiplying instantaneous values of the given wave form by the corresponding values of a sinusoidal function whose frequency is that of the harmonic in question.

These operations may be performed optically. Assume that the given function be represented by a variable-area record (Figure 2a), the sinusoidal function by a variable-density record (Figure 2b), and that these two records be superposed in the path of a beam of light. Consider now a narrow vertical element of the two records. An instantaneous value of the given function is represented by the length of the element left uncovered by the variable-area record, while the sinusoidal function is represented by the transmissivity of the corresponding element in the variable-density record. Obviously the amount of light transmitted through the element is proportional to the product of the area by the transmissivity. Measuring the total amount of light transmitted within the limits of one cycle corresponds to the mathematical process of integration.



(a)

(b)

Fig. 2—The analyzer projects a variable-area record, a, *of the sound analyzed onto a variable-density record*, b, *of a harmonic of that sound, and measures the light transmitted*

In the practical form of instrument developed in the Laboratories, the variable-area record of the sound analyzed is placed in a holder, A, Figure 3, and illuminated strongly by an incandescent lamp. A lens system projects an enlarged image of this sound track on the "cosine plate," B, which is a variable-density record of a pure tone. Different wave lengths on the sound record at A can be accommodated by adjusting the enlargement so that they are projected to the same size at B. The transmitted light falls on a photoelectric cell, C, whose output is a measure of the amplitude of the harmonic component of the complex sound whose frequency is that of the cosine plate. A different cosine plate is used for each harmonic.

With the Laboratories' instrument, which has thirty plates, thirty harmonics can be found. The plates are stored in slots in the drum-shaped magazine shown in the photograph and are drawn out, one at a time, into the optical path by a system of cams and levers at the back of the instrument. Each harmonic is measured by displacing the corresponding cosine plate along its axis in the plane of the projected image of the sound wave. If the sound wave contains a harmonic of the same frequency as that of the cosine plate, a cyclic variation in intensity of the transmitted light occurs as the cosine plate moves. The difference between the maximum and minimum intensity is proportional to the amplitude of the harmonic; and the displacement of the cosine plate for maximum intensity is directly proportional to the phase angle of the harmonic. An automatic voltage recorder is connected in the photoelectric cell circuit to give a continuous record of the light intensity on a chart as the cosine plate moves across the field.

The instrument operates entirely automatically after initial adjustments have been made and an analysis to thirty harmonics requires only about a minute and a half. Since the record on the chart is in graphical form, its general characteristics can be seen at once. The amplitudes of the harmonics are read in linear or logarithmic units with an appropriate scale.

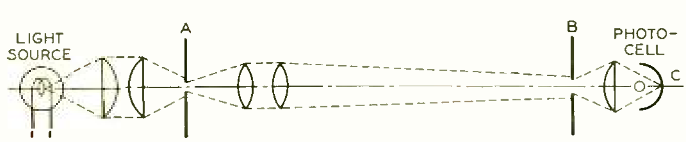


Fig. 3—Diagram of the optical curve analyzer

This method of analysis is applicable to many different functions but the machine described here was designed particularly to study speech and music. It has an advantage over many other types of analysis for this purpose because it uses a record as obtained, without tracing, blacking in, or other preparation, and the record can be played before and after analysis. The optical analyzer offers the most rapid means available; other suitable methods require several hours to complete an analysis to thirty harmonics. The various resonance methods of analysis* are not suitable for speech studies because the duration of many of the speech sounds is too short for the resonant elements to attain a steady state response.

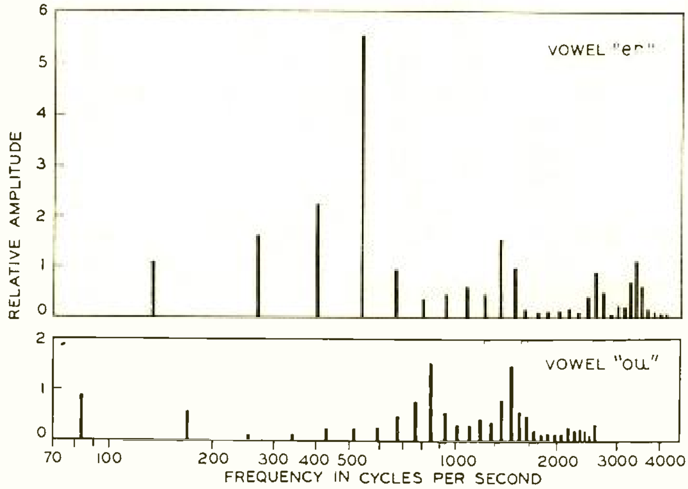


Fig. 4—*Analyses with the optical analyzer of the vowel sounds* er *as in* father *and* ou *as in* out. *The prominent peaks are believed to correspond to resonant cavities in the vocal passages*

From records taken at the standard film speed of eighteen inches per second, complete analyses can be made if the fundamentals are between 65 and 310 cycles. Fifteen harmonics can be measured for fundamentals up to 620 cycles. The amplitude range is about 50 to 1, and the measurements are correct within one db except for very small components.

Examples of the work of the analyzer are given in Figure 4, which shows analyses of single cycles from two vowel sounds, the *er* in *father* and the *ou* in *out*. The envelope of the analysis shows three or four rather prominent peaks which are thought to correspond to resonant cavities in the vocal passages. A single analysis represents an interval of approximately ten milliseconds; a complete vowel may last from one hundred to four hundred milliseconds. Thus it may require from ten to forty analyses to completely describe a vowel. The features of these analyses change rather slowly during the mid-portion of the vowel, but quite rapidly at the beginning and end. It seems probable that the changes in the analyses during the course of the vowel are closely related to corresponding changes in the vocal cavities. The optical analyzer is rapid enough so that extensive studies of such phenomena are entirely practical.

*Record, *October*, 1934, *p.* 60.

Contributors to this Issue

H. C. Montgomery received an A.B. at the University of Southern California in 1929 and an M.A. at Columbia in 1933. Since joining the Research Department of the Laboratories in 1929 he has been engaged largely in studies of hearing acuity and related problems in physiological acoustics. More recently his attention has been given to investigations in speech analysis.

M. S. Hawley received the B.S. degree in electrical engineering from Union College in 1929 and in the fall of that year joined the Laboratories. As a member of the Transmission Instrument Development Department he has been chiefly concerned with the development of telephone receivers of various types, such as the handset receiver, the operator's headset receiver, and those used in aircraft work and with the audiphone. He has also contributed to the development of moving-coil microphones. At the present time he is engaged in fundamental receiver studies.

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F. A. Korn joined the Laboratories in 1920 and took the course for technical assistants, spending six months in the field with the Western Electric Installation Department. Subsequently he was in the circuit laboratory, and since 1924 has been engaged in the design of switching systems for manual and dial central offices. In 1933 he became a member of the group responsible for the fundamental planning of the crossbar system. Since early 1937 he has been supervising a group engaged in the development of crossbar switch and trunk circuits for local, toll, and tandem offices.

W. L. Tuffnell joined the Laboratories in 1922 and took the three-year student assistant course. For two years of this period he took part in the design

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C. E. Germanton joined the Technical Staff of these Laboratories in 1926, after receiving a B.S. degree in electrical engineering from Lafayette College. As a member of the local central office development department he has since been engaged chiefly with the analysis and test of dial switching circuits.

After receiving a B.S. degree in electrical engineering from the University of Washington in 1928, H. A. Reise worked for the Seattle Broadcasting Company for one year. In 1929, while in Seattle, he obtained a position with Bell Telephone Laboratories and came East to join the Radio Development group. Since then he has engaged in the development of radio broadcast transmitting equipment at both the Whippany Laboratory and in New York.

R. A. Shetzline received a B.S. degree from the University of Pennsylvania in 1915 and a B.S. in E.E. from the same University in 1917. He joined the Engineering Department of A. T. & T. in 1917, and began making coördination studies between electrified railways, power transmission lines and telephone systems. From 1924 to 1929 he was in charge, for the Bell System, of a coöperative field study, with the National Electric Light Association, of power and telephone circuit coördination. Since 1929, he has been in charge, in the Transmission Development Department, of studies of telephone apparatus from a noise and crosstalk standpoint, including the evaluation of noise and crosstalk effects and the establishment of suitable standards.