ELL LABORATORIES RECORD

JUNE
1938

VOLUME XVI

NUMBER X

Studying the dynamic characteristics of carbon transmitters

The Crossbar Switch in the 755 PBX

By J. N. REYNOLDS
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THE switching problem at a private branch exchange is similar to that at a small central office. There are lines running to the various extensions, and trunks to the central office, corresponding to the subscriber lines and trunks to other offices at a central office. An extension, of course, may either place a call or receive a call, so that the direction of the call between two extensions or between an extension and the central office may proceed in either of two directions. To meet the exigencies of this situation, it is customary in one way or another to wire each extension to two sets of terminals in multiple, one of which will be used for outgoing, and the other for incoming calls. Then, by some linking circuit, provision must be made for connecting the calling terminals of the extension placing the call to the receiving terminals of the extension being called.

A diagram of this general switching scheme is shown in Figure 1. To simplify the illustration, only four extensions are shown and two links. Obviously there would never be needed more than half as many links as there are extensions and trunks combined, because two extensions, or an extension and a trunk, are involved in each call. Usually the number of links will be less than this, because all of the extensions and trunks will not be in use at any one time.

It is not sufficient to connect the two extensions with a simple wire connection. A battery supply is required for talking, and there must be provision for ringing the called extension, for signalling the operator, and for additional supervisory uses; and the proper performance of these and other functions necessitates that a certain amount of equipment be associated with the extensions for each call. Some of this equipment is most conveniently connected into the circuit by way of the link circuit. This is indicated by the boxes marked "equipment" in Figure 1, and the link is divided by the equipment into two sections: an originating section, which connects to the calling extensions, and a completing section, which connects to the called extension.

In the present manual boards these links are usually cords and the terminations of the extensions are jacks. In the step-by-step PBX, the cords and jacks are replaced by a form of switch in which the lines end in fixed terminals, and the links end in brushes, which are moved over the fixed terminals until the desired one is reached. In their many varied forms both of these systems have worked satisfactorily for many years, but a new piece of switching apparatus has been developed in recent years that for many applications seems to offer greater advantages. This new unit is known as the crossbar switch.*

The arrangement for a four-line group using the crossbar switch is shown in Figure 2. The lines, when

*Record, *July*, 1937, *p.* 338.

this switch is employed, are multipled to sets of terminals for each side of each link. Both lines and links terminate in relay-type contact springs, and a set of springs on a line faces a corresponding set on a link. All that is required to establish a connection is to press two of these sets of springs into contact. The closing of one set will connect the calling line to the originating side of the link, and the closing of another set will connect the completing side of the link to the line called.

In the crossbar switch these sets of spring contacts are arranged at the intersection of a rectangular lattice. This resemblance to a lattice is enhanced by the appearance of the switch from the front, shown in Figure 3, where the vertical and horizontal bars that make the lattice are used to close the contacts. It is these bars that give the name "crossbar" to the switch. The ends of the spring contacts may be seen behind the bars. Such a switch has 100 sets

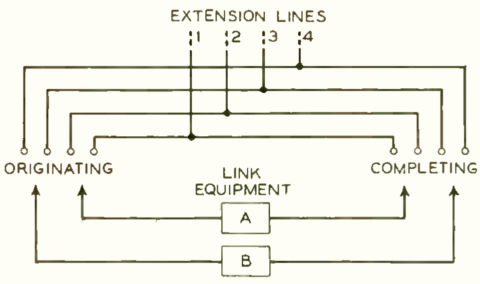


Fig. 1—Schematic representation of method of establishing a connection between two subscribers with previously existing systems

of contacts, corresponding to the intersection points of ten vertical and ten horizontal rows.

The interconnection of these contacts in the actual switch used for the 755A PBX* is as shown in Figure 4, where each line represents a number of wires, and each contact, indicated by a circle, represents an equal number of spring contacts. The vertical lines represent ten possible extension lines—each line having contacts for connection to ten horizontal circuits, which may be links for

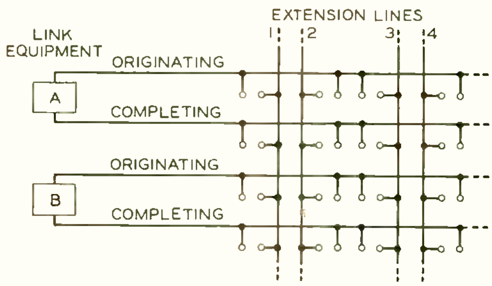


Fig. 2—Schematic representation of method of establishing a connection between two subscribers with the crossbar system

establishing connections between the local extensions or trunks to a central office. The upper six horizontal rows serve as trunks for the originating and completing ends of three link circuits, and the lower four rows are for trunks.

These various sets of contacts are closed by the operation of horizontal and vertical bars in a way that has already been described in the Record. Each vertical bar is operated by an electromagnet, the ten magnets being located in a row along the bottom of the switch as may be seen in Figure 3. Each horizontal bar is controlled by two magnets—one to rotate the bar in each direction. Three of these pairs of magnets are located at one end of the switch and two at the other, as may be seen in the same illustration. Each vertical and horizontal bar also operates a set of off-normal contacts, which are employed for a variety of purposes such

*Page 336, this issue.

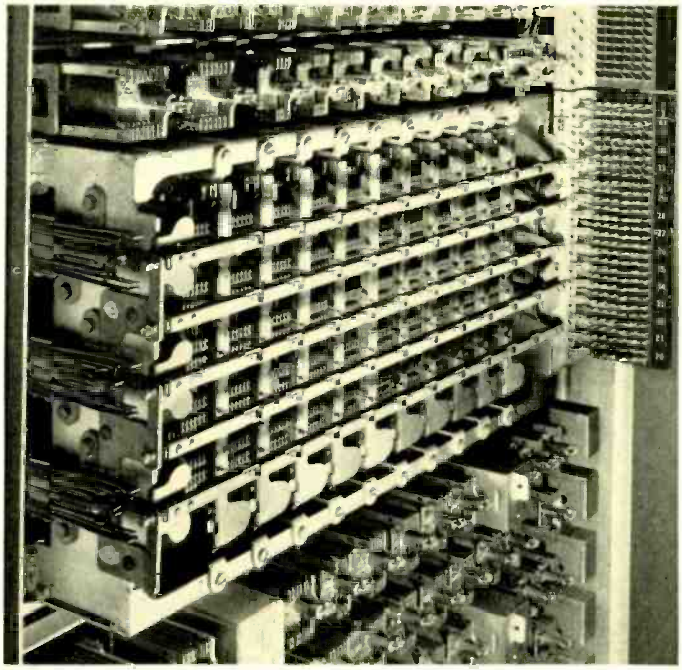


Fig. 3—The crossbar switch as used in the 755A PBX

as indicating whether or not a bar is operated. These off-normal contacts for three of the horizontal bars may be seen at the left of Figure 3. Those for the other two horizontal bars are at the right-hand end of the switch, while those supplied for the vertical bars are placed at the top, and may also be seen in Figure 3.

The general scheme of operation may be followed from Figure 4. When line 3, for example, places a local call, the horizontal bar of an idle link is rotated up and immediately afterward the vertical bar corresponding to line 3 is operated, which connects the calling line to the originating side of the link. The horizontal bar then returns to normal, but the vertical bar will remain operated. When the horizontal bar returns to normal all of its selecting fingers are also returned to normal except the one opposite the calling line, which is held by the pressure of the vertical bar corresponding to that particular line. These fingers have been made very flexible so that they may readily be held in an operated position without retarding the return of the horizontal bar and yet will return to their normal position when released.

After the calling line has dialed the number wanted, the same horizontal bar is again operated, but this time in the downward, or completing, position. The vertical bar corresponding to the line called is now operated, and thus connects the completing side of the link to the line called. Following this the hor-

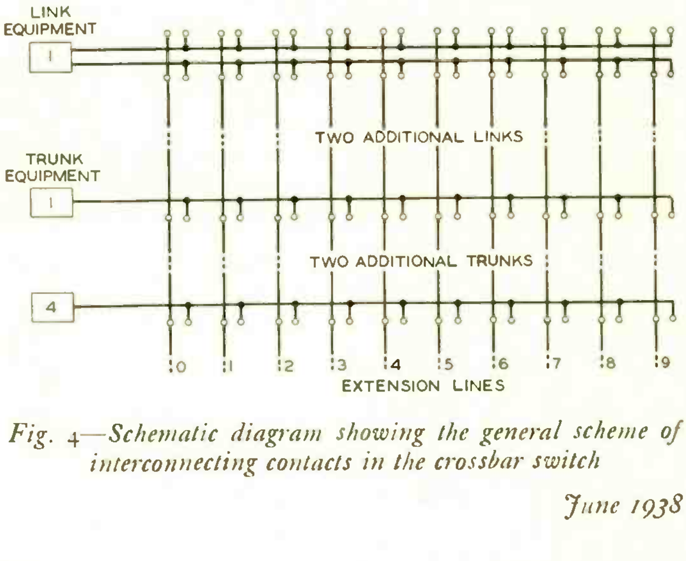
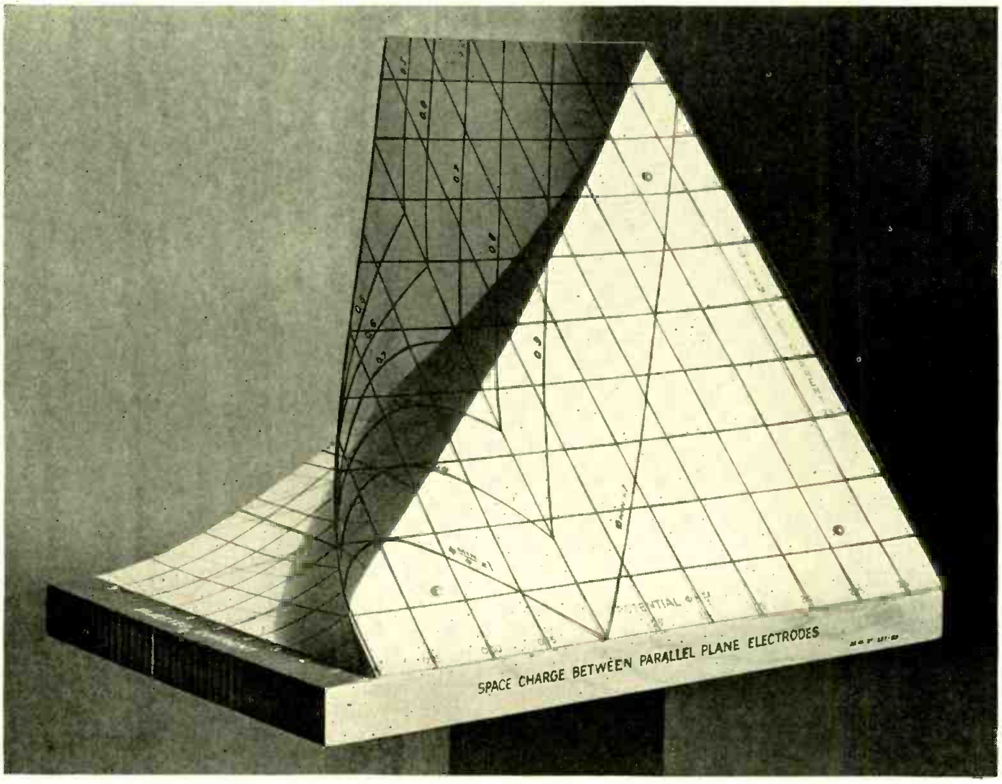


Fig. 4—Schematic diagram showing the general scheme of interconnecting contacts in the crossbar switch

izontal bar will again return to normal, but two of its fingers will remain held: one by the vertical bar of the calling line and one by that of the line called, thus establishing the connection.

On establishing a connection to a trunk only a single set of operations is required. The horizontal bar corresponding to the trunk selected operates first, and then the vertical bar corresponding to the calling line. This connects the line to the trunk, completing the central-office circuit.

In the 755A PBX two of these crossbar units may be employed to give a capacity of twenty lines. The connections and operations are so arranged that the switches act as a single switch with twenty vertical bars. The crossbar switch is concerned primarily with completing the actual switching connection, and other devices, largely relays of the U and Y types, are employed for the many other switching functions as described in the article already referred to.



This model was devised by C. E. Fay, A. L. Samuel, and W. Shockley to illustrate the mathematical relationships between current and potential in the space between grid and plate of a vacuum tube

The 755 PBX

By C. R. GRAY
Central Office Switching Development

TO apply the crossbar switch and the U-type relay to private branch exchange service, a new dial PBX has been developed for residences and smaller business houses. This 755A dial PBX will replace the 750A* and by reason of its four trunks and twenty station lines it will have a wider field of use. The power requirement is much less than that of the 750A; and it is expected, because of the improved design of the new switches and relays, that the maintenance effort will be reduced.

The basic function of the new PBX is to establish connections between central office trunks and its local stations, or between two or more of these stations. The actual talking connection is made at the crossbar switch, but for the complete functioning of the PBX six control circuits are employed: the line circuit; the trunk circuit; the link circuit; the common control and cut-off circuit; the common timing, tone, and ringing circuit; and the "link-allotter" circuit. There is one each of the three latter circuits for each PBX regardless of the number of lines or trunks; but there is one line circuit for each line, and one trunk circuit for each trunk. The link is the circuit employed for making a local connection between two lines, and from one to three may be employed as desired. Each of the crossbar switches will accommodate ten lines, and where ten lines or fewer are to be used, only

*RECORD, *February*, 1930, *p.* 278.

one switch will be installed, but for more than ten lines and up to the full capacity of twenty lines, two will be employed.

This PBX is designed to employ a handset on which are mounted the dial and the key buttons used to set up the various trunk and local calls. One of these buttons is used for local calls, one for holding, and the others for making connections to the four trunks. Where desired, however, the usual types of telephone sets may be used in place of the combined handset and when this is done, the buttons will be provided in a separate unit.

Each local station is connected to a set of contacts in a vertical column of the crossbar switch, while the trunks and links are connected to sets of contacts in the horizontal rows. A connection between a trunk or a link and a local station is thus established by operating the selecting magnet corresponding to the trunk or link, and a holding magnet corresponding to the local station. A complete link circuit includes two of the selecting magnets—one to make connection to the calling station, which is called the originating magnet, and one to make connection to the station called; which is called the completing magnet.

A local call illustrated schematically in Figure 1, as originating at station No. 36, is made by pressing the "local" key, and lifting the handset off the mounting. The line circuit then operates to signal the common control and cut-off circuit that a call has started. The common control circuit then determines from the link-allotter circuit that an idle link is available, and operates the start relay in the link circuit. The link originating magnet is then operated, and immediately afterward the common control circuit operates the holding

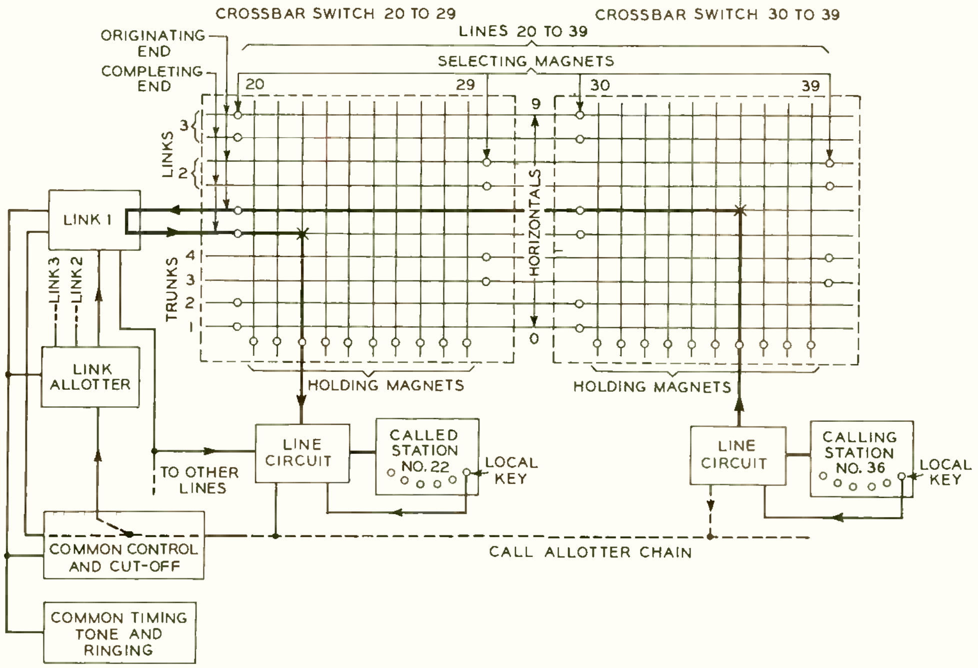


Fig. 1—Block schematic illustrating the setting-up of a local call

magnet associated with the calling line, which closes the crossbar contacts to connect the calling line to the link. The common control circuit then releases the link originating magnet, and restores itself to normal, ready for another call.

Dial tone is received through the link by the calling station, which then dials. Pulsing and register relays in the link circuit record the two digits dialed, and at the completion of dialing the link tests the called line and returns a busy signal if it is busy. If the called line is found to be idle, the link signals the common control circuit which operates the completing magnet of the link and the hold magnet of the called line. The link completing magnet is then released and the common control circuit again returns to normal. The link then rings on the called line, and when the station answers provides a talking path between the two stations. The common control circuit is used only for a very short period at a time, and may thus serve two or more calls during approximately the same interval. If it is in use on one call when needed on another, the delay while waiting for it to become idle is only a fraction of a second and is unnoticeable.

The establishment of a trunk call is illustrated by the block schematic of Figure 2. To make such a call, the subscriber presses the trunk key corresponding to the trunk over which he wishes to make the call, and then lifts the handset. The line circuit immediately operates to signal the common control circuit, which then operates the selecting magnet corresponding to that trunk, and immediately afterward operates the holding magnet of the calling line. The station is then connected directly to the trunk as shown in the diagram. Dial tone will be returned by the central office, and the progress of the call will then proceed in the usual manner. All apparatus is returned to normal when the handset is replaced on the mounting.

Inward trunk calls are indicated to the stations by the lighting of a lamp or the operation of an audible signal, either of which occurs when the central office rings on the trunk. Any of the key stations may an-

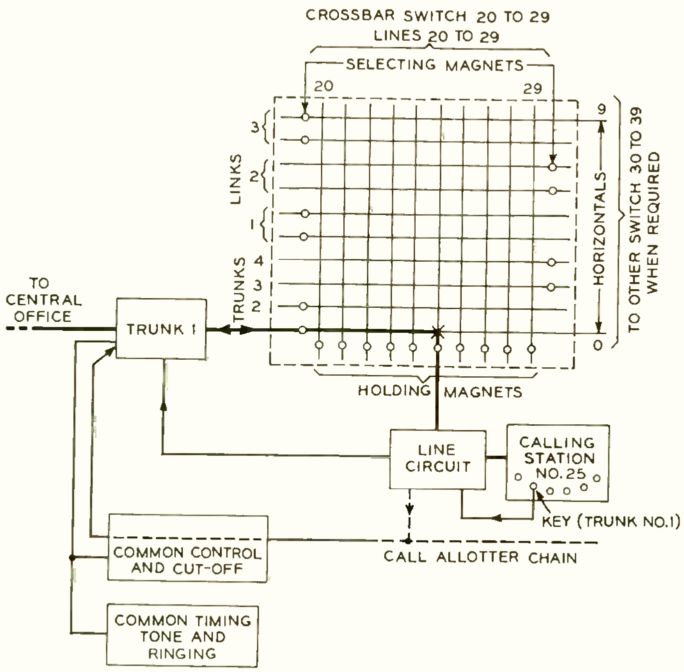


Fig. 2—Block schematic illustrating the setting-up of a trunk call through the 755A PBX

swer by pressing the key button associated with that trunk, and lifting the handset. The line circuit, the common-control circuit, and the cross-bar switch function as on outgoing calls, and the station is connected to the trunk. If the call is for some station other than the one answering, the hold button is pressed, which then connects a holding bridge across the trunk and releases the trunk key. The station wanted is then called as for local calls, and informed that there is a call for it. This station then operates its trunk key, which releases the local connection and the hold on the trunk, and connects its own handset to the trunk—the station that originally answered being then free to originate or receive other calls.

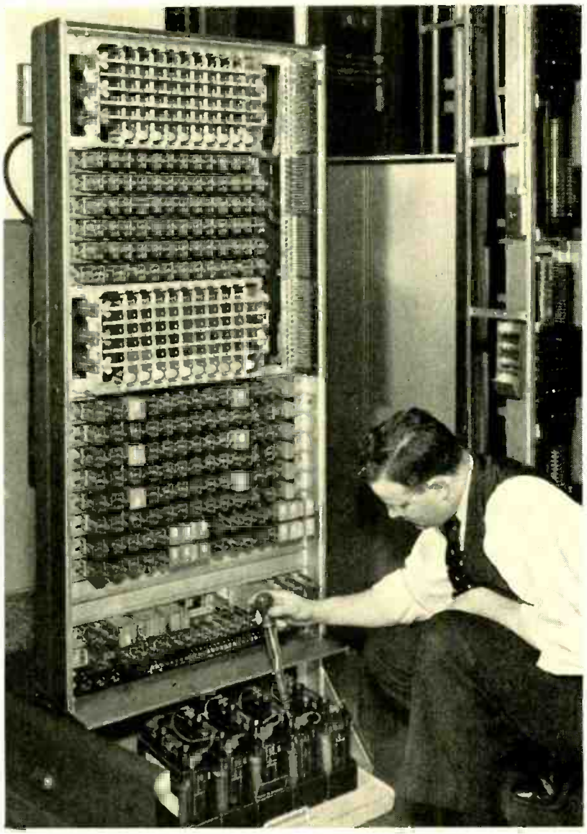


Fig. 3—Installation of the 755A PBX for the 195 Broadway Corporation

The equipment, shown in Figure 3, is arranged on a unit basis to make it possible to equip only the combination of lines, trunks, and links required for a particular installation. The same framework and equipment arrangement is used for all installations so that units may be added as required by traffic growth. Station line circuits are arranged in four-circuit units with either two or four circuits equipped, so that station line growth is in steps of two circuits at a time. Trunk circuits are arranged on two-circuit units with either one or two circuits equipped so that trunks may be added one at a time. Each link is a separate unit, and links may be added one at a time. The PBX is equipped initially with a local cable including all the wiring between units, switches, and terminal strips for a maximum capacity. The apparatus on each unit is wired, adjusted, and tested as the unit is stocked, so that after a unit is installed in a PBX, it is necessary only to connect the inter-unit leads and to perform an operational test.

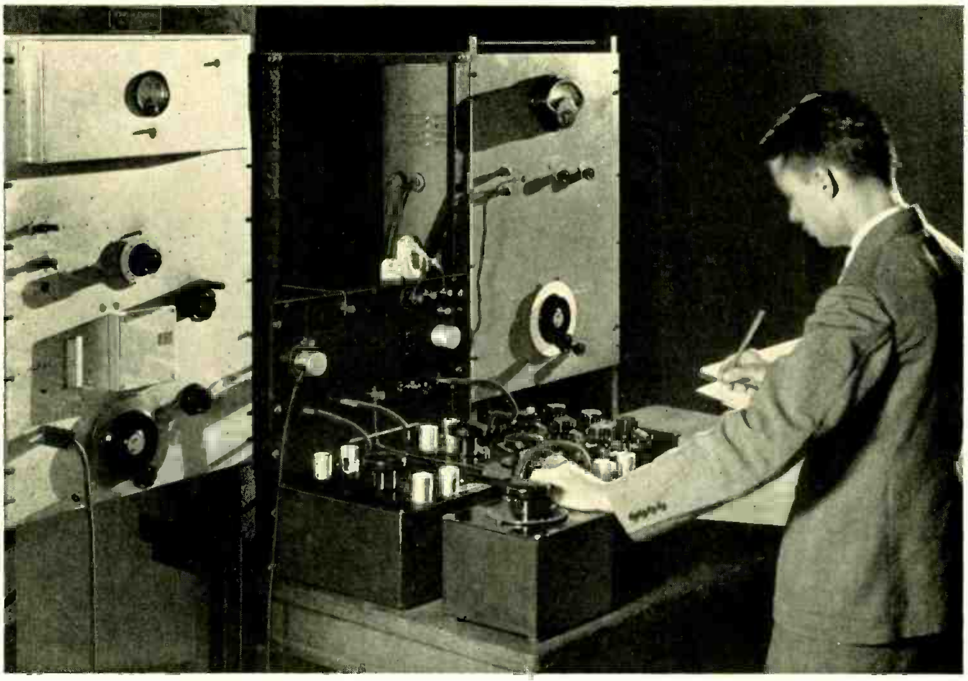
Three classes of trunk service are available for the stations. "Non-lock-out" service allows the station to connect to a trunk whether it is busy or not; "lock-out" service allows the station to connect only to idle trunks; and "restricted" service prevents a station from making outgoing trunk calls, but allows it to answer or transfer incoming calls, or pick up transferred trunk calls. A station may be arranged to have the same class of service on all trunks or a different class on each trunk. This allows several stations to have preferential service on different trunks. The class of service is changed merely by strapping on the terminal strips at the ends of the line units.

Restricted stations may not be provided with the key-button handset, but trunk service may be given these stations through the aid of some key station designated as the control station. This station sets up the incoming or outgoing trunk call for the restricted station with an auxiliary key, and the station is then free to make other calls.

By use of a spare push button, a station may be enabled to pick up calls directed to another, and may thus perform secretarial functions. A lamp may be installed at the secretarial position to indicate calls incoming to the supervised position. On an incoming call the lamp flashes and after it is answered and the line is busy, it lights steadily, or if preferred may be arranged to go out. This provides an indication as to whether the supervised position has answered, and thus whether or not she should come in on the line.

Other features available with this new PBX are line hunting and conference service. The former provides for automatically routing calls to another line if the one called is busy. By this means heavy traffic to one number may be routed to another so that important calls will not be lost or delayed. The conference feature permits three lines to be connected together. To set up such a connection, the originating station calls one of the parties, tells him that a conference is to be held, and asks him to hang up until his line rings again. Without disconnecting, the originating party then calls the third party, and ringing will occur on both lines. When ringing ceases, indicating that the third party has answered, the second party lifts his handset, and the connection is established.

Ringing for the new PBX is usually supplied over feeder wires from the central office, but tones are generated at the PBX by a buzzing relay, as with the 750 PBX. Batteries for the PBX are located in a compartment in the base of the cabinet, and are ordinarily charged over cable pairs from the central office, but the charging is automatically controlled by relays at the PBX. Where conditions make it desirable a local ringing machine may be employed and a rectifier for charging the batteries.



An Inductance and Capacitance Bridge

By S. J. ZAMMATARO
Transmission Apparatus Development

A BRIDGE designed for miscellaneous uses in the laboratory should be capable of measuring both inductive and capacitive impedances. It should be able, moreover, to measure both types of impedances with equal convenience and accuracy whether their Q values are high or low. Such a bridge has recently been developed for the frequency range from 30 to 10,000 cycles to be used in measuring impedances of lines and apparatus for program transmission.

Before the detailed design of the bridge was begun, it was decided to employ capacitance standards for measuring the inductive as well as capacitive impedances, because condenser standards are not only less expensive than inductance standards, but are more stable with frequency, and more compact. It was decided also to use a shunt arrangement of the standard capacitance and resistance because such an arrangement lends itself to simpler shielding.

With the choice of the type and arrangement of the working standards thus settled, it was apparent that the most direct manner of measuring capacitive impedance was by the familiar comparison bridge with equal ratio arms. This arrangement is shown schematically in Figure 1. As is customary in such bridges, a resistance—R_3 in the diagram—is used to shunt any high unknown resistance components of the unknown capacitance so that the resistance of the arm CD can be measured by the resistance standard R_s. Such a bridge determines the unknown impedance in terms of its parallel components, which is preferred for capacitive impedances.

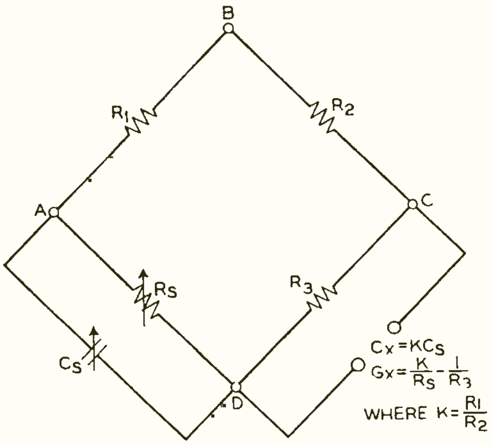


Fig. 1—Schematic of parallel comparison bridge with equal ratio arms

The simplest change required to connect such a bridge so that it could measure inductive impedances would be to provide a switch for transferring the condenser standard from the AD to the CD arm of the bridge. This would give the parallel resonance arrangement shown schematically in Figure 2. Such a method of measuring inductive impedance, however, is not so direct and convenient as is the previous arrangement for measuring capacitive impedance. In the first place, frequency enters into the determination, with the result that it must be more accurately known and controlled than would otherwise be necessary. Also, the readings of the condenser standard must be converted into equivalent inductances by computations. Finally, the determination yields the parallel components of the unknown, while for inductive impedances the series components in general are of major interest.

If in the original arrangement of Figure 1, however, a switch were used to interchange the AB and AD arms, and to change the position of R_3, the comparison circuit would be changed to a Maxwell circuit, as shown in Figure 3. This circuit offers the same convenience and simplicity of operation in measuring inductive impedances that the comparison circuit does for capacitive impedances. When the bridge is balanced, the relations are such that the series components of an inductive impedance in the arm CD are proportional to the parallel components of a capacitive impedance in the AB arm. In other words, a positive impedance is related to a positive admittance. The proportionality factor is the product of R_1 and R_2, for which reason the bridge is classed as the product-arm type in contrast to

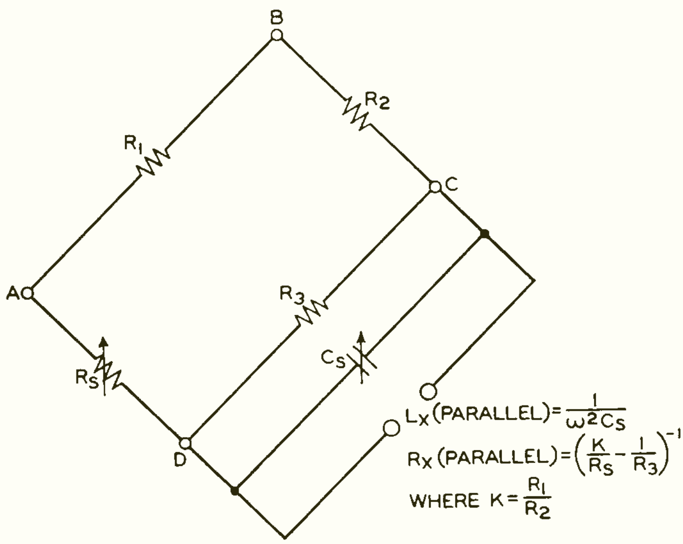


Fig. 2—Schematic of parallel resonance bridge

the ratio-arm type, where the proportionality factor is the ratio of the arms R_1 and R_2.

It is apparent that the product R_1R_2 may be made to give a simple relationship between the inductance and capacitance units, so that the bridge becomes essentially direct reading. Thus by making the product equal to 10^6, one microhenry of the unknown inductance corresponds to one micro-microfarad of the standard capacitance. The resistance component of the unknown, as already stated, is given in terms of the conductance of the AB arm. The resistance R_4 is inserted in series with the unknown to keep the total resistance of the CD arm above a given minimum that can be measured within the range of the standard R_s. This use of resistance R_4 is analogous to that of R_3 in the comparison circuit, where its function is to keep the conductance in the CD arm above a definite minimum. By use of these two arrangements of the bridge arms, therefore, the same testing procedure may be followed whether the unknown impedance is inductive or capacitive, since direct reading is provided for the reactance component, and substitution for the resistance component.

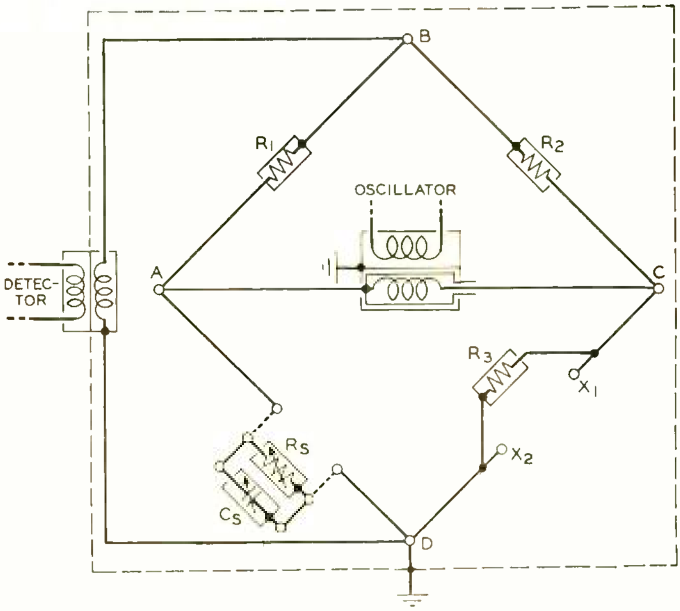


Fig. 4—Complete shielding arrangement for the comparison bridge used to measure inductive impedances

Although the product-arm bridge reduces inductance measurements to a simplicity on a par with capacitance measurements, it results in a more difficult design. The symmetry of the network of a comparison bridge permits simple disposition of shielding; and the compensation of the residual impedance or admittance of corresponding elements can easily be preserved over a wide range of conditions. In addition, the equality of the ratio arms, both in magnitude and phase, is relatively easy to secure and maintain. The product-arm bridge, on

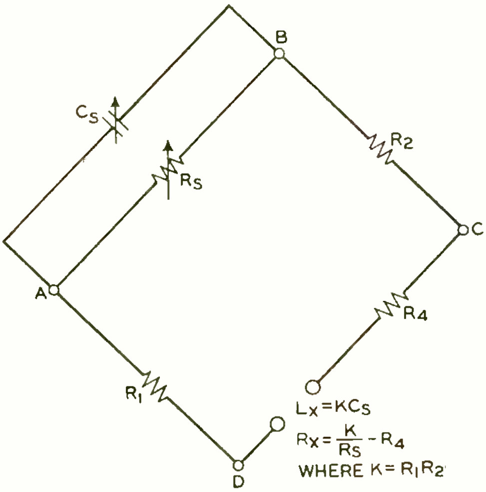


Fig. 3—Schematic arrangement of Maxwell or product-arm type of bridge

the other hand, imposes a more elaborate shielding scheme; and the product adjustment of the fixed arms requires a more painstaking technique.

The complete shielding arrangements for the two types of circuit are shown in Figures 4 and 5. Two double-shielded transformers are used in tandem across the supply corners of the product-arm circuit instead of a single transformer with triple shielding, to secure a more economical construction. In designing a composite bridge that could function as either type, it was necessary to strike a judicious compromise between the theoretically complete shielding shown in Figures 4 and 5 and the less perfect shielding that would permit a ready interchange of connections and still yield the desired accuracy. The modified shielding finally adopted for the composite bridge is shown in Figure 6 which corresponds to the arrangement of the circuit with the key thrown for inductance measurements.

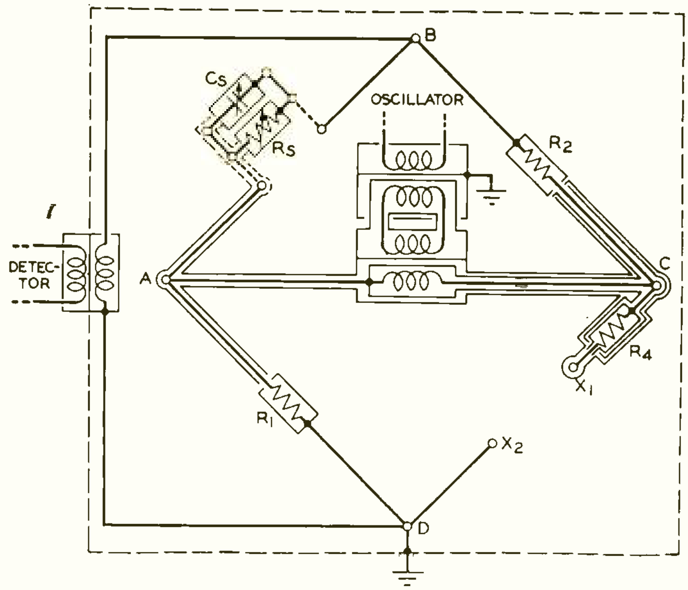


Fig. 5—Complete shielding for the product-arm bridge

The elements designated by lowercase letters are adjustments incorporated after the bridge is assembled, and have required more than the usual share of attention because of the dual function of the bridge. With the comparison bridge, for example, there is no important restriction of the absolute values of the fixed arms R_1 and R_2. The main adjustment requirement is that their difference in magnitude and phase be zero. With the product-arm bridge, on the other hand, the product of these arms must be a specified value, and the sum of their phase angles must be zero. To satisfy both sets of requirements, R_1 and R_2 must be closely adjusted, and the residual capacitance and inductance of each—including the portion contributed by the shielding—must be compensated to give zero phase angle in the separate arms. It is important, moreover, to minimize the residual reactance that needs to be compensated so that the effective resistance of the arms will remain sufficiently constant over the given frequency range.

The phase angle compensation of the arms R_1 and R_2 is indicated in Figure 6 by the inductances l_1 and l_2. Inductance l_S compensates for the residual capacitance across the CD arm of the product-arm circuit, but it is switched out of the circuit for the comparison connection. Instead, the CD arm residual capacitance is padded by c_3 to balance the standard arm AD

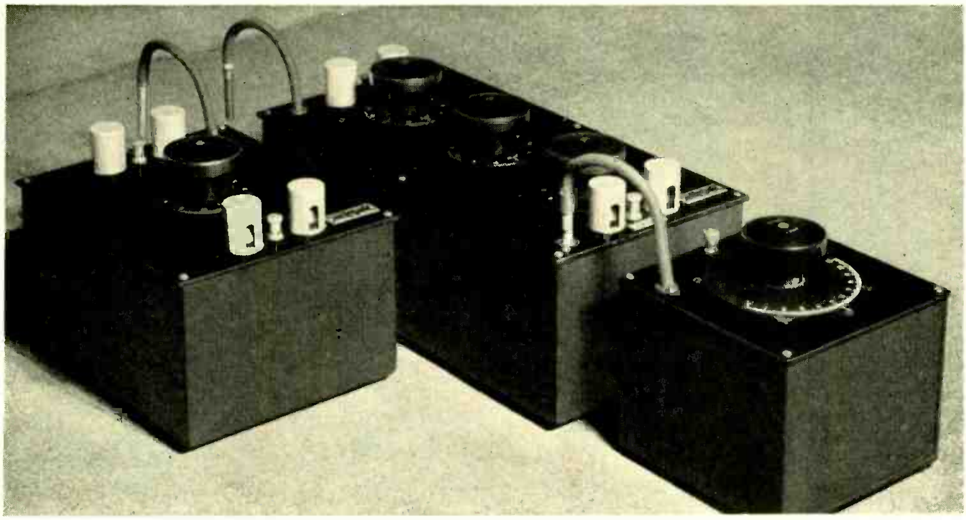


Fig. 7—The capacitance standard comprises three units

when the condenser standard is set on zero. With the product-arm circuit, on the other hand, the zero residual capacitance of the standard C_S is compensated by inductance l_4 so that the range of inductance will extend down to zero. The key K_3 serves to disconnect the D corner of the bridge from ground when the ground-potential condition is to be controlled by the unknown. Keys K_1 and K_2, operated together, effect the interchange of circuits with no other manipulation.

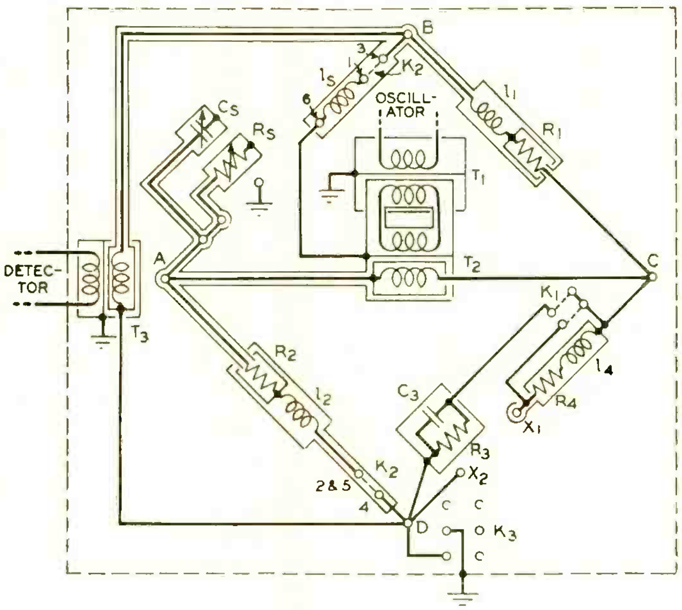


Fig. 6—Shielding adopted for new composite circuit when arranged as a product-arm bridge

The various adjustments have been made with sufficient accuracy to insure satisfactory performance over the frequency range from 30 to 10,000 cycles. The values of the fixed arms R_1 and R_2 are made $10^{7/2}$ ohms each, so that with the product-arm circuit, one micro-microfarad in the capacitance standard C_S measures an inductance of ten microhenries in the arm CD. Since the standard has a total range of ten microfarads, inductances up to one hundred henries can be measured. The range for capacitance measurements, of course, is up to ten microfarads—the range of the capacitance standard. These reactance ranges can be measured for all values of Q normally encountered.

In the model constructed, the adjustable capacitance and resistance standards are made up as separate units which may be readily connected to the rest of the bridge circuit by coaxial plugs and jacks. This arrangement increases the portability of the equipment, and allows the standards to be available for other uses. The condenser standard, shown in Figure 7, consists of three shielded units: an air condenser, a three-decade box of mica condensers, and a single-decade box of paper condensers, which is used for the largest steps. The resistance standard is a six-decade box adjustable up to 10,000 ohms in 0.01-ohm steps. The bridge unit proper is assembled on an aluminum panel and covered with an aluminum box, which serves as an overall ground shield. The appearance of the panel from the rear with cover removed is shown in Figure 8.

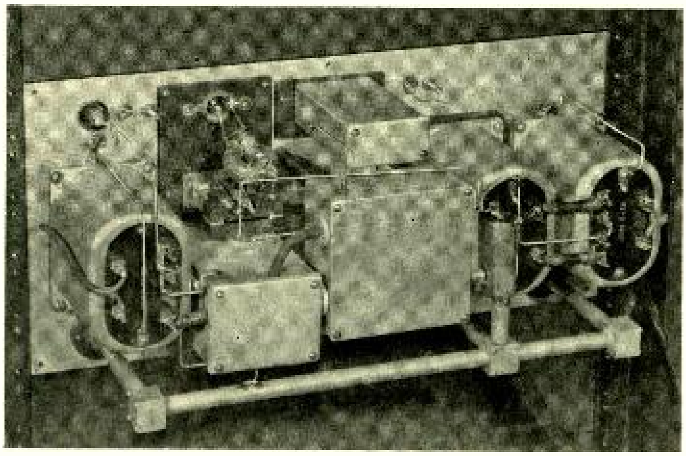


Fig. 8—Rear view of bridge with cover removed

This new bridge will find wide application in the laboratory for miscellaneous impedance testing. It will prove especially useful in making frequency measurements of the impedance of networks in which the sign of the impedance may change many times over the test band.

The Morris Liebmann Memorial Prize

has been awarded by the Institute of Radio Engineers to Dr. G. C. Southworth of the Radio Research Department "for his theoretical and experimental investigations of the propagation of ultra-high-frequency waves through confined dielectric channels and the development of a technique for the generation and measurement of such waves."

Making Broadcast Synchronization Easy

By J. C. BAYLES
Broadcast Development Department

In recent years there has been some interest in operating a number of radio transmitters in "synchronism" when they are all broadcasting the same program. The usual objective of such operation is to make it practicable to permit the full-time operation of stations otherwise restricted to part time, or to permit the operation of additional transmitters on frequencies already assigned, so as to increase program coverage. The technical difficulty of frequency control is only one of a number of factors which must be adequately taken into account, but this element in the overall problem is met by the synchronizing apparatus developed by the Laboratories. This apparatus can readily be applied to almost any type or size of radio transmitter.

"Synchronization" as applied to broadcast stations does not mean that the transmitters involved are operating at exactly the same carrier frequency, but that the variation from exact synchronization is very small. For satisfactory operation it has been found desirable to maintain the frequency difference between two stations of a system to within less than 0.1 cycle per sec. In developing the Western Electric 280A synchronizing panel, the Laboratories have met this requirement, and have produced a compact bay of equipment, completely a-c operated and self-contained. The method of synchronization used in this equipment is that of continuously correcting the frequency of all transmitters so as to maintain a selected relation to a basic reference frequency transmitted to all stations from a very stable common source. Among the advantages of this system is that in case of an interruption of this reference frequency there is no interruption of the program, since the oscillators of Western Electric transmitters will maintain adequate synchronism for short periods without correction being necessary.

The method of synchronization may be followed in outline from the block schematic of Figure 1. In brief, the scheme is to derive from the reference frequency, usually 4 kc, a harmonic that is 50 kc higher or lower than the station carrier frequency. This frequency and a portion of the station carrier are passed through a modulator, at the output of which will appear a frequency of 50 kc plus or minus the deviation of the carrier from its assigned value. If this deviation of the carrier is called Δ, the output of the modulator is thus (50 ±Δ) kc. A 50-kc current, also derived from the reference frequency, is passed through a phase-shifting network providing two outputs—one in phase with the reference frequency and one shifted 90 degrees from it. These three frequencies—the 50 kc "in phase," the 50 kc at an angle of 90 degrees, and the (50±Δ) kc—are then fed to a second modulator, which provides a two-phase current at frequency Δ. This current supplies power to a polyphase control unit which operates a shunting condenser for the transmitter oscillator. The direction

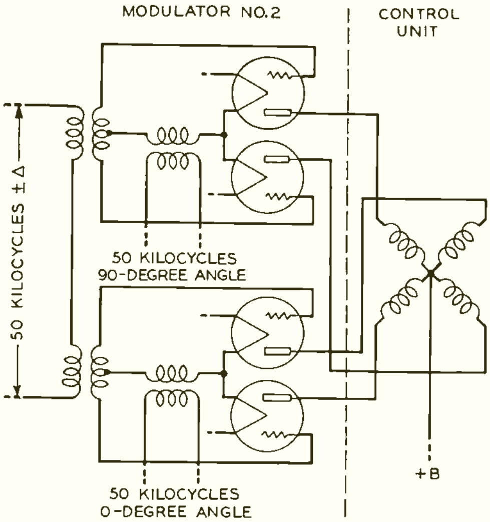


Fig. 2—Simplified schematic of modulator No. 2, which produces a two-phase current of frequency Δ

of rotation of the control unit is such as to decrease the frequency of the oscillator when it is too high, and to increase it when it is too low.

In greater detail, it will be noted from the diagram that the 4-kc reference frequency is first passed through a selective amplifier, and then through a ferro-magnetic frequency

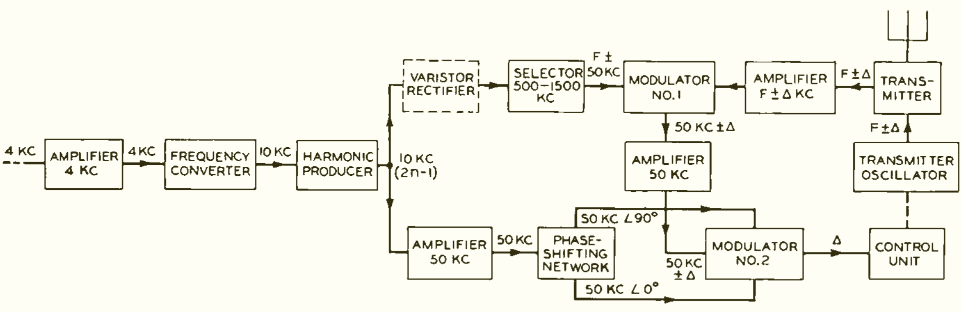
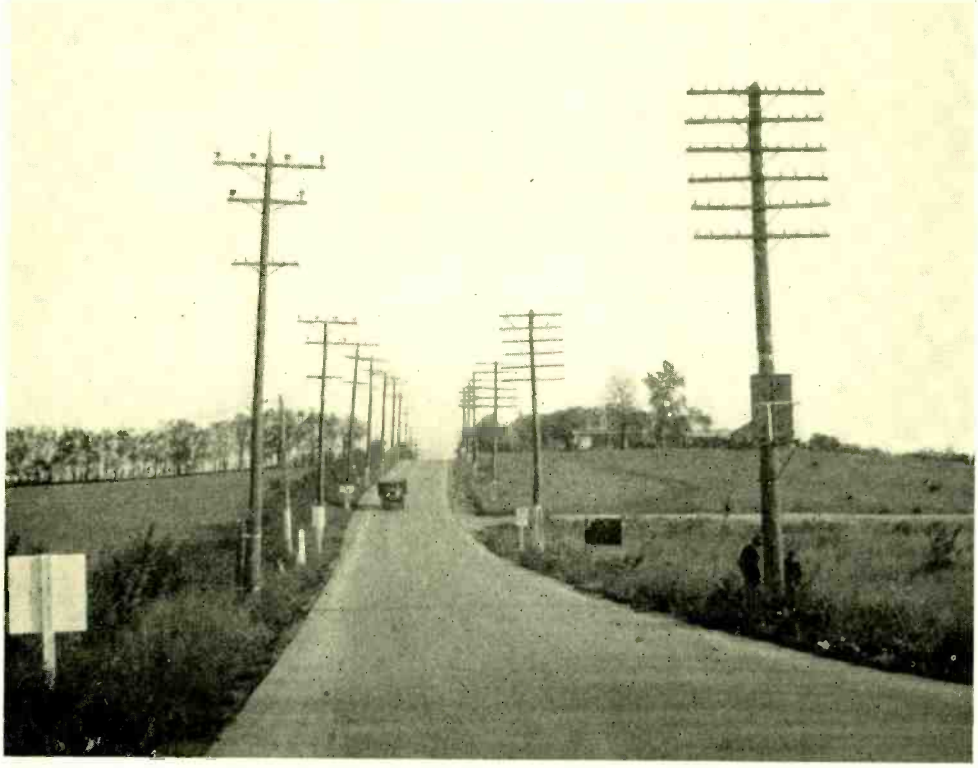


Fig. 1—Block schematic of the 280A synchronizing system

converter that provides a 10-kc frequency. This is then amplified and passed through a ferro-magnetic harmonic producer that gives all odd harmonics of 10 kc. Two branches lead off from the harmonic producer: one going to a 50-kc amplifier, which selects and amplifies a 50-kc voltage for supplying the phase-shifting network, and the other passing through the selector that picks the harmonic 50 kc above or below the assigned carrier frequency. When the carrier is an odd harmonic of 10 kc, a varistor—used as a rectifier, and shown dotted on the diagram—is inserted ahead of the selector to provide the even harmonics by a process involving frequency-doubling.

The output of the selector is thus always 50 kc above or below the assigned carrier, and it is supplied to modulator No. 1 together with an amplified portion of the actual carrier. The output of this modulator is—as already noted—at a frequency of 50 kc $\pm\Delta$, and after amplification is supplied to modulator No. 2 along with the two 50-kc components from the phase-shifting network. A simplified schematic of this modulator, which produces the two-phase current of frequency Δ, is shown in Figure 2. This circuit balances out the 50 kc, and only the component at frequency Δ remains, which because of the two circuits that are supplied by the quadrature components, appears as a two-phase current.

Equipment for the 280A synchronizing panel is divided into three units: the harmonic producer unit, which includes the reference-frequency amplifier, the frequency converter, and the harmonic producer; the selector-modulator unit, which includes the selector, the phase-shifting network, and both of the modulators; and a power-supply unit. The two-phase control unit for adjusting the oscillator of the transmitter is located in the transmitter. Power—about 200 watts—is drawn entirely from the a-c mains at 115 volts and 60 cycles.



Short-Circuiting Relay Protectors

By D. T. OSGOOD
Protection Development Department

BELL System circuits are frequently of open-wire construction, and extraneous voltages are occasionally impressed upon them by lightning, by contact with power wires, or by induction from paralleling power lines during times of ground faults on the power system. To limit these voltages to safe values, so as to protect telephone equipment and to guard against other hazards, carbon block protectors are connected between the telephone conductors and ground. These protectors ground the conductors with extreme rapidity whenever excessive voltages appear.

Such carbon blocks provide very effective protection, but if they are called upon to carry heavy current for more than a very short time, they may permanently ground the conductors with which they are associated. Permanent grounds are much more likely to occur from high-voltage power surges than from the very short-lived surges of lightning. In either case, however, a service interruption will result, even in central offices where personnel are available to replace the grounded protectors. Where protectors are installed either on a line remote from a central office, or in small offices where plant forces are not in continuous attendance, the loss in circuit time from permanent grounding may become excessive.

To minimize this difficulty, relays were designed which would operate promptly to short-circuit the protector for the duration of the disturbance. With such an arrangement, the protectors would discharge the moment the voltage rose above the critical value, and the immediate action of the short-circuiting relays would prevent the protector blocks from fusing together and, as a result, creating a permanent ground.

One form of this arrangement, which is known as the multi-grounding relay protector, is described in an accompanying article. This was developed for installation in central offices or in the outside plant on lines where excessive voltages to ground from induction might occur frequently. A telephone line equipped with these protectors is shown in the photograph at the head of this article.

Another form is called the unit-type relay protector. It is designed for two wires; and is applicable where only a few circuits are to be protected, or where it is not desired to ground all wires at a given point upon the operation of one or more carbon protectors.

Fig. 2—Test set for adjusting short-circuiting relay protectors

This device consists of a relay, shown in Figure 1, which carries the protector blocks at one end. After one of the blocks breaks down, the discharge current passes to ground through the winding of the relay. The armature operates; and the contacts directly short-circuit the blocks. This relay is rugged in construction and its contacts are designed to withstand at least 150 amperes without fusing. The magnetic circuit of the relay saturates at a relatively small value of current, so that the voltage across the relay will remain low even for high discharge currents. To prevent the relay from being held up by direct current from a grounded telegraph system after having been operated by lightning or induction, a

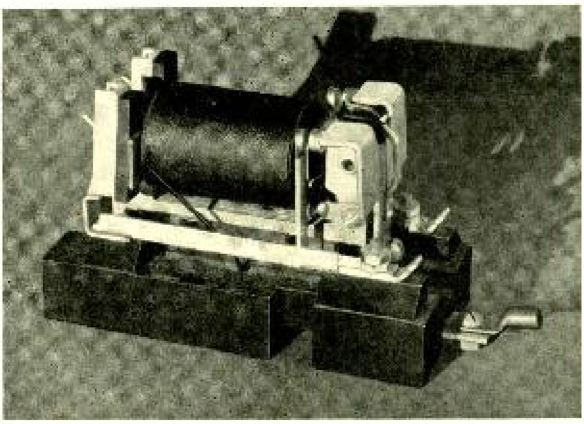


Fig. 1—The unit-type relay protector

non-magnetic stop is placed between the armature and the core of the relay.

In general, short-circuiting relay protectors have required very little maintenance. In areas where the multi-grounding type are now installed, regular routine inspections at approximately six-month intervals have been instituted for the purpose of observing their operation and making adjustments if necessary. For these inspections a special test set was developed, shown in Figure 2, which contains a low-voltage d-c to a-c dynamotor, together with the necessary ammeters, rheostats, and other apparatus. The instrument is compact and can be carried up the pole to the protector. Long leads connect the dynamotor to a storage battery, which may be placed at the base of the pole or left in the car or truck. In making these tests, the a-c end of the dynamotor is connected to the input terminals of the protector; the current is adjusted to a specified value; and adjustments are then made on the relays to assure their proper functioning. The resistance of each of the short-circuiting relay contacts is indicated by another circuit in the test set. If the resistance is above the required maximum, it can be reduced by burnishing or cleaning the contacts.

Several installations of both the multi-grounding and the unit-type short-circuiting relay protectors have been made. In most cases their operation has been carefully observed over a period of several years, and it has been found that they have been effective both in limiting the voltage to ground along the line due to induction, and in reducing lost circuit time. In some instances, over a thousand operations have been recorded without the necessity for changing a single carbon protector block.

Dr. Williams's Medal

"*The Willard Gibbs Medal, perhaps the highest honor of American organized chemistry, has had many distinguished recipients, but none more worthy than our fellow townsman, Dr. Robert R. Williams, of the Bell Telephone Laboratories, who got it last week for separation and artificial production of Vitamin* B_1. *First known as a vitamin, the lack of which can cause the not common disease called beriberi, this substance now has wider importance. . . .*

"*Nearly thirty years ago Dr. Williams was a young chemist in Manila. Among other improvements introduced by the Americans was better food for prisoners in the jails, including polished rice instead of cheaper brown rice. Many prisoners promptly got sick, an illness finally traced by Colonel E. B. Vedder and other American medical officers to something present in the rice hulls, but absent from the rice after polishing. At that time nobody knew much about vitamins, but the unknown material in the rice hulls roused Dr. Williams's imagination. For two decades his spare time went into trying to extract it, a quest finally successful in* 1933 *and followed soon by making the compound synthetically. This perseverance now receives a first installment of its just reward.*"

—*From an editorial in the "Herald Tribune" (New York), May 8, 1938.*

Design Features of Short-Circuiting Relay Protectors

By J. D. TEBO
Electromechanical Apparatus Development

SHORT-circuiting relay protectors* have been designed for use on open-wire telephone lines to provide protection against excessive voltages and at the same time to minimize the amount of service interruption of the affected circuits. A study of this general problem led to the investigation of several types of protective devices, but the simplest and most satisfactory from the standpoint of speed of operation and impedance following breakdown is the standard carbon block protector of the 26 and 27 types which are well known in the telephone plant. Design work was therefore concentrated on a short-circuiting device which would shunt the protectors during discharges, and consequently reduce the tendency of these protectors to permanently ground the telephone circuits following heavy discharges.

The original circuit for such a short-circuiting device passed the discharge current through a low-impedance resistor to ground, rectified a portion of the current by means of a copper-oxide rectifier, and passed the rectified current through a relay that short-circuited the protector block. One of the main problems of this development work was to find contact materials capable of withstanding the severe operating conditions. The contacts may be required to carry peak currents reaching 150 amperes before the power circuit breakers operate; they must not stick or weld if a momentary interruption in the discharge current permits the relay to start to release and the current returns, causing a momentary arc at the contacts; and their resistance must not become excessive even though the protector remains idle for extended periods. The contact materials finally selected were platinum-iridium operating against silver-impregnated carbon, materials which have proved very satisfactory in use with the KS-6254 electrolysis switch.*

The potentials at which the carbon blocks break down vary, and where a large number of circuits on the same pole line are to be protected, some of the protectors might operate and others not. As a result, undesirable differences of potential between wires may occur. To avoid the possibility of this condition, the circuit was modified to include a second relay. The contacts of this second relay connect a common battery to all the other short-circuiting relays for the group of lines, so that the operation of any one protector of the group will result in all the protectors of the group being short-circuited.

In addition to this "multi-grounding" feature, a second modification was introduced. Since the potential to ground varies directly with the amount of discharge current passing through

*Page 350, this issue.

*RECORD, *April*, 1930, *p.* 364.

the resistor, for large values of discharge current, there may be high potentials applied to the copper-oxide rectifier that provides the operating current for the relays. The rectifier must therefore be designed to resist comparatively large potentials, without decreasing the sensitivity of the protector to small discharge currents. An impedance which decreases with increase in current was therefore designed, so that the potentials across it would increase at a much slower rate than the discharge current. This impedance unit consists of two sets of copper-oxide discs connected in parallel but oppositely poled so that the unit will pass current both ways.

A schematic for this form of protector, called the 1A protector group, is shown in Figure 1, where S is the short-circuiting relay, and M the multi-grounding relay. When the protector of one such unit discharges, both relays S and M of this unit are operated by the rectified current, and the operation of relay M connects positive battery to the upper of the two busses shown at the bottom of the diagram. With battery on this bus, any of the groups not operating will have battery applied to their S relay through a back contact of the M relay—the current flowing to ground through one side of the bridge rectifier. Protectors for five circuits, or ten wires, are mounted on a common base to form a protector group as shown in Figure 2, and from one to five of such groups may be installed together. These are mounted on the central panel in the illustration. Above them are the non-inductive resistances, and below are the relays. The copper-oxide discs for both rectifier and impedance group are mounted on a common spindle for each unit.

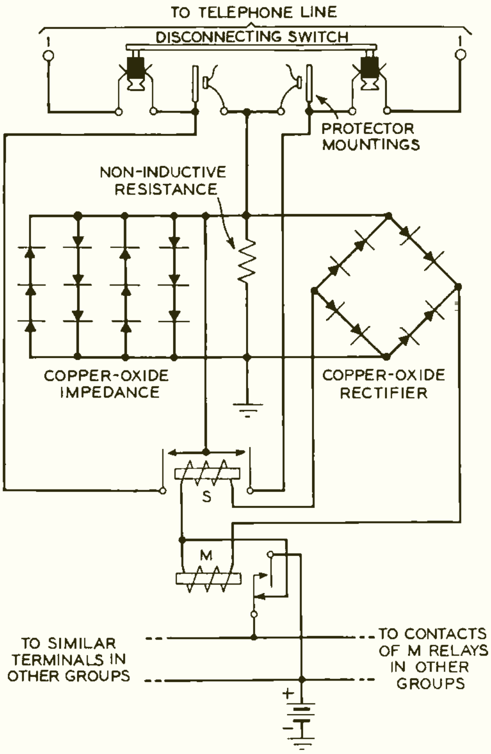


Fig. 1—Schematic circuit representation of the 1A protector group

To facilitate routine inspection and testing, the switch shown in the upper part of Figure 1 and at the left of Figure 2 has been provided. It also contains the mountings for the carbon block protectors and was especially designed for the 1A protector group. When pulled forward, the switch disconnects the entire 1A protector group from the line so that the unit is available for testing without disturbing the line. To insure that the protector will never be left in the disconnected position, the design is such that closing the door of the box in which the group is mounted closes the switch.

Although the 1A protector group proved satisfactory, further study was made in an effort to increase the discharge-current range, increase the speed of operation, reduce the cost, and eliminate the rectifiers which

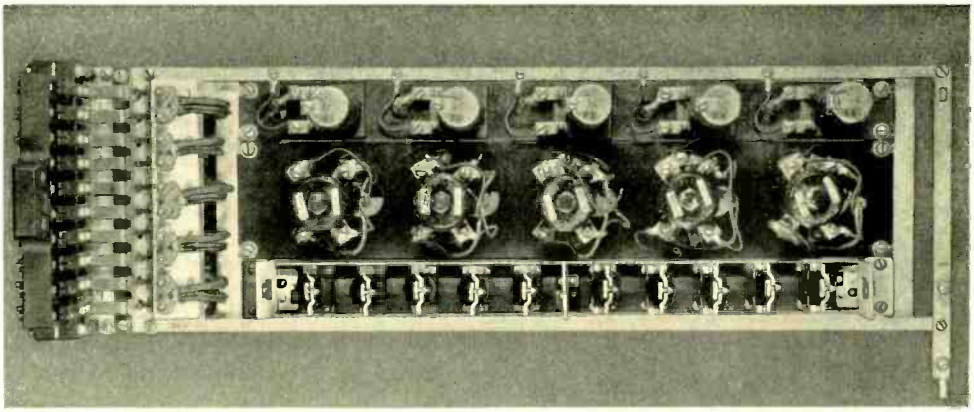


Fig. 2—The 1A protector unit showing the can cover removed from the short-circuiting relays along the bottom

sometimes failed under heavy lightning conditions. A development program was begun, resulting in the design of a protector which has for its distinctive features the use of an alternating-current master control relay, and a transformer for the ground impedance. The circuit arrangement is shown in Figure 3, and the equipment arrangement in Figure 4.

The new protector has the features of "multi-grounding" and of the variable impedance in the discharge current path, but performs its function somewhat more simply and efficiently than does the 1A protector group. The transformer is designed so that the iron core becomes saturated magnetically at comparatively small discharge currents, and as the discharge current increases, the impedance of the primary winding becomes smaller, resulting in the potential across the primary remaining nearly constant for a wide range of discharge currents. The voltage across the secondary, and hence that applied to the control relay, remains very nearly the same for all values of discharge current. This, of course, made it possible to design the relay for its maximum sensitivity at low values of discharge current without having to be concerned with overheating of the relay at high currents, which would be the case if the saturating transformer were not used.

As may be seen from Figure 3, "multi-grounding" is obtained by having the ground lead from all pro-

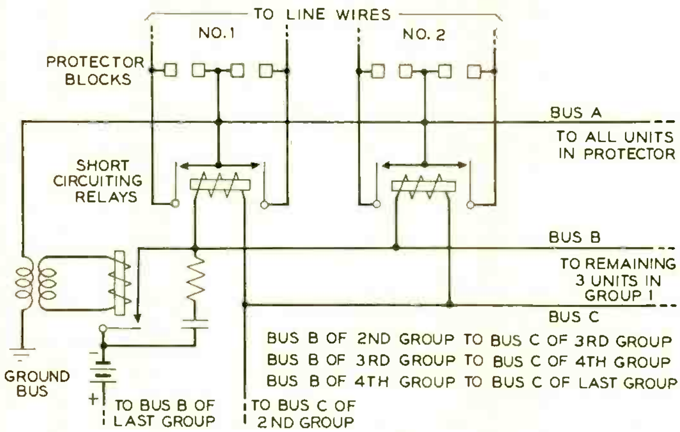


Fig. 3—The newer relay protector has a control relay operated directly by the discharge current through a transformer

tector blocks connected to a common bus running to the primary of the transformer and by having the operation of the control relay operate all the short-circuiting relays from a

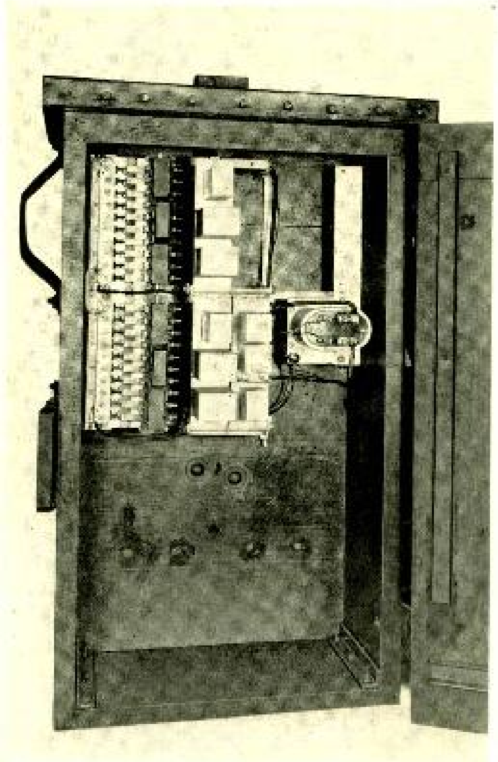


Fig. 4—Pole-mounted a-c type short-circuiting relay protector

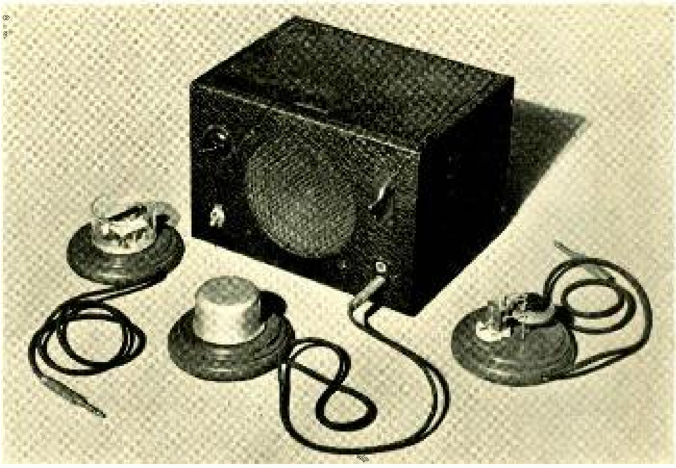
common battery. Such an arrangement is simpler than the earlier form because a single ground impedance (the transformer) and a single control relay take the place of the discharge impedance, rectifier, and M relay required for each pair of wires with the 1A protector. The disconnecting switch arrangement designed for use in the 1A protector group is also used in the new protector.

Speed of operation is increased by using a very sensitive and very fast relay as the control relay, which is the only load across the transformer. In addition, the short-circuiting relays are operated from a battery which can be made large enough to insure maximum speed of operation.

As with the 1A protector this new unit is arranged in groups of five, and as many as five groups may be mounted together, and employ a single transformer and control relay shown in Figure 4. The five short-circuiting relays of each group are operated in parallel, but successive groups are connected in series as indicated on the diagram, thus giving a series-parallel operation from the battery—additional cells being added for each additional group. This arrangement has the advantage of keeping the current drain on the battery small, and reducing the effect of voltage drop in the connecting leads.

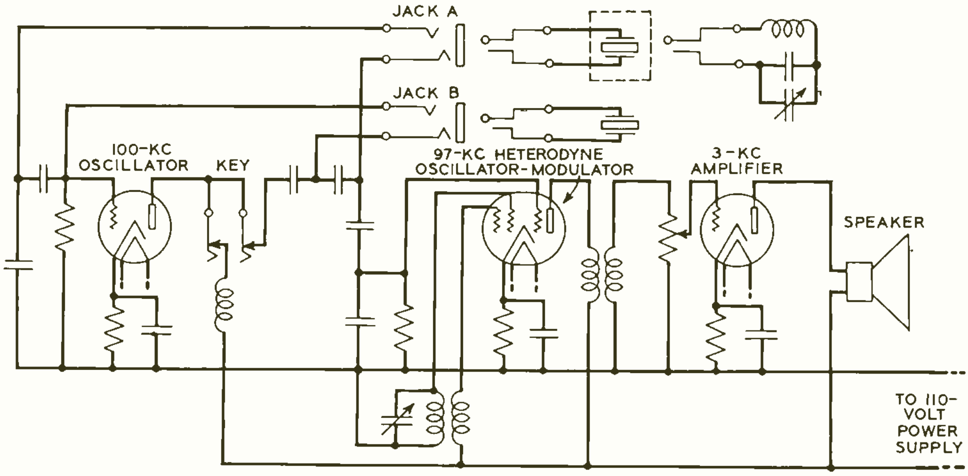
On circuits carrying direct-current grounded telegraph, it was found that with the earlier forms of relay protectors, the current to ground through the protector circuit from the telegraph batteries was sufficient under some conditions to hold the short-circuiting relays operated after they had been operated by induction or lightning. In some cases, therefore, the sensitivity of the protector had to be decreased to avoid this possibility. The use of the transformer in the new design eliminated this condition since a direct-current discharge in the primary of the transformer has no effect upon the relay connected to the secondary.

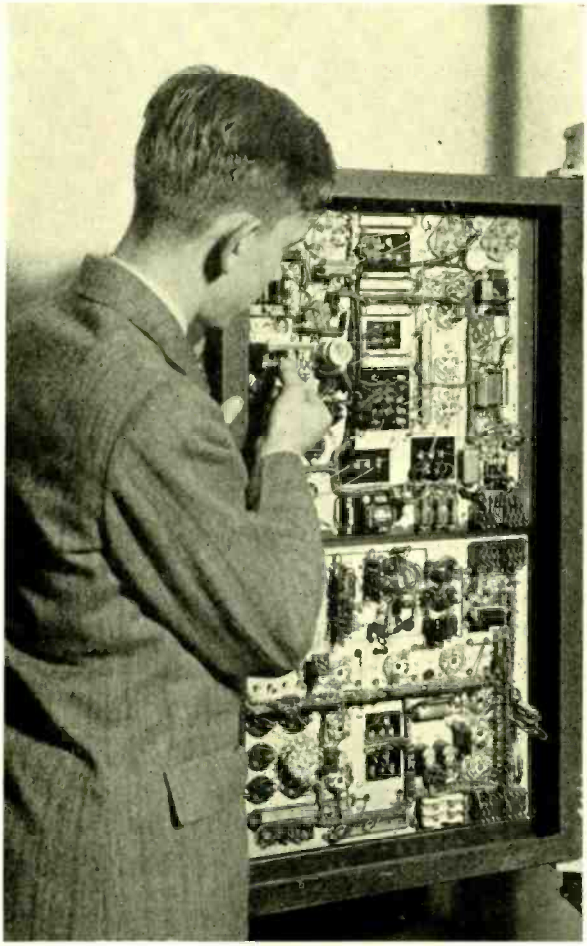
The new protector has been made available both for pole mounting and central-office mounting. Each unit is mounted on a separate framework arranged for convenient installation on a wall or relay rack. They may therefore be used in central offices or in the outside plant as desired.



Oscillating Crystal

THIS apparatus was used by Dr. O. E. Buckley in a talk before the A.I.E.E. in New York City to show the small damping effect in a crystal-controlled oscillator compared with that in a coil and condenser circuit which oscillates at the same frequency. Two crystals and a coil-condenser unit are provided. One of the crystals is exposed to the air to demonstrate the damping effect of atmospheric pressure and the other is enclosed in an evacuated container. The output of the oscillator is heterodyned with another current to produce an audible frequency and applied to a loudspeaker after the power is cut off. The crystal in vacuum vibrates about ten times longer than the unprotected one and about 1000 times longer than the coil-condenser oscillator. Breathing moist air on the open crystal damps it so heavily that it ceases to vibrate. A crystal in a vacuum oscillates about 80,000 times before its amplitude is reduced one-half. This is equivalent to a second's pendulum beating for two days.





A New Coastal Marine Radio Telephone Set

By F. B. WOODWORTH
Radio Development Department

ONE of the first steps toward giving a coastal and harbor telephone service was the opening of a station at Green Harbor, Massachusetts, which had previously been used for experimental studies. This station provided telephone communication not only for Boston harbor but for coastwise shipping from Maine to Montauk Point, as already described in the RECORD.* Subsequently stations were opened at New York, Miami, Los Angeles, San Francisco and Seattle. These stations are available for service twenty-four hours a day, and each has a range of several hundred miles to sea. A construction permit for an additional station to be installed at Norfolk has also been obtained. The stations on the Atlantic coast are equipped to dial the vessels called, so that the telephone service provided to ships is substantially the same as that now familiar on shore.

The Western Electric ship equipment previously available for this type of service consisted primarily of apparatus originally designed in the Laboratories for aircraft, and later adapted for marine service. Experience with this equipment pointed the way to many improvements and they have been embodied in the new 224A radio telephone equipment designed by the Laboratories specifically for coastwise commercial vessels and yachts.

Figure 1 shows an overall view of this new apparatus, known as the 224A Radio Telephone Equipment, and Figure 2 shows the main units with covers removed. It consists of a 50-watt radio transmitter and a superheterodyne radio receiver mounted together on a channel-iron framework, and a control unit incorporated in a standard telephone desk set. The

*RECORD, *Nov.*, 1932, *p.* 77.

framework may be hinged on any one of four sides to facilitate installation in a vessel, and at the same time to provide access to the rear for maintenance purposes as shown in the headpiece to this article. The equipment operates entirely from 110-volt, 60-cycle, alternating current, which on shipboard will be obtained from a small motor alternator.

The radio transmitter and receiver may be adjusted manually to any one of nine predetermined frequencies in the range from 2.0 to 2.8 megacycles. For coastwise communication these frequencies are from 2.1 to 2.2 megacycles for the transmitter, and from 2.5 to 2.6 megacycles for the receiver.

The carrier frequencies of the radio transmitter and the beating-oscillator frequencies of the superheterodyne receiver are controlled by quartz plates, which assure tuning stability of the equipment. The quartz plates are of the plug-in type, and only as many as required need be purchased. Switching to any of nine shore-station channels is accomplished by two dial switches marked with station identification and mounted on the front of the radio transmitter and radio receiver. Besides these nine frequencies to which the transmitter and receiver may be set, a tenth frequency is provided which may be selected remotely as required from the telephone control unit. This frequency will usually be the ship-to-ship frequency of 2738 kilocycles, although the emergency Coast Guard frequency of 2670 kilocycles may be used instead.

This new marine equipment incorporates several outstanding features previously not available in apparatus for mobile applications. Transfer from the condition for receiving to that for sending is now accomplished by voice-controlled switching instead of by the "press-to-talk" switch previously used for this service. The transmitter is put "on the air" within a few thousandths of a second after talking begins, a time short enough to avoid objectionable clipping of the initial speech sounds. The carrier is maintained for a short period after talking ceases to prevent the transmitter from going off the air between syllables or words. The radio transmitter also incorporates an automatically controlled audio amplifier which assures substantially complete modulation of the carrier over a speech range of 30 db. This feature insures considerably better telephone circuits with different types of talkers than could otherwise be obtained, particularly when transmission condi-

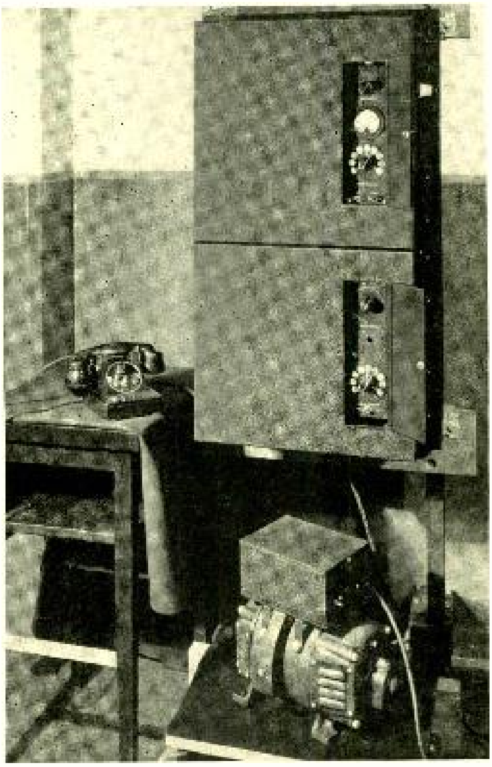


Fig. 1—Overall view of the 224A radio telephone equipment

tions are poor. Another feature of this transmitter is the use of a new Western Electric pentode, the No. 339A, which requires only 500 volts for its plate supply. This relatively low plate voltage permits the use of a plate-voltage rectifier of the type usually employed in radio receivers, which saves both space and cost.

The receiver is a very selective and sensitive superheterodyne set which has built into it a selective ringing unit,* thereby enabling a ship to receive calls without the use of a loudspeaker. An improved automatic volume-control circuit in the receiver provides a constant audio output over a wide range of radio signal inputs. This is a very desirable feature where automatic operation by the general public is required.

*Record, *April*, 1936, *p.* 255.

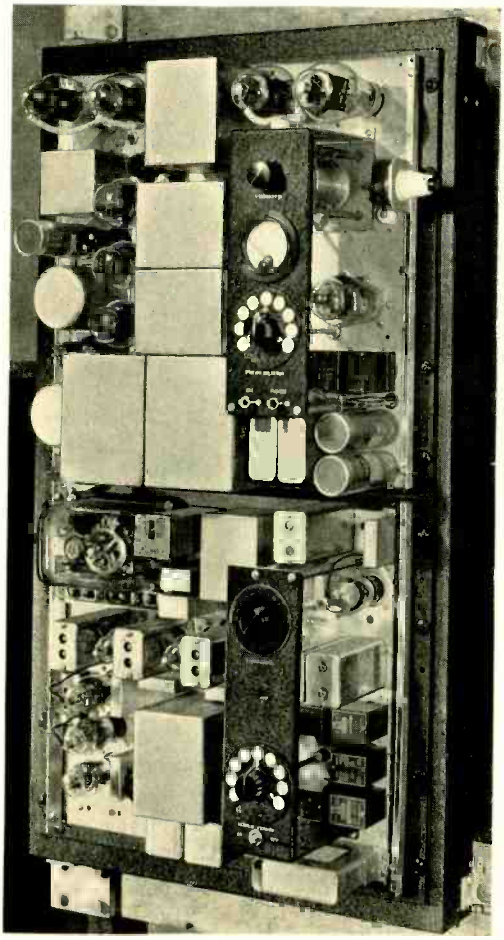


Fig. 2—Front view with cover removed. Transmitter above and receiver below

The remote-control unit incorporates the bell operated by the selective ringing circuit and all the controls necessary to operate the system as a two-way telephone circuit. In place of the dial in the front of the handset cradle is a small panel incorporating a master control switch, volume control, indicator light, and a momentary contact switch for quickly changing to the ship-to-ship or Coast Guard frequency. This change may be accomplished only when the handset is removed from the switchhook, and when the handset is replaced on the switchhook, the equipment automatically returns to monitoring on shore channel to which it was last set.

The radio equipment, which weighs about 180 pounds, requires a space 36 by 21 by 10½ inches, and may be mounted either on a bulkhead or on the deck. The rotary converter for supplying the alternating current may be installed in any convenient place, since it is very quiet in operation and occupies a space only 15 inches long, 12 inches wide and 12 inches high. The remote-control unit may be installed in the chart room, pilot house, or other convenient part of the ship. Additional extension telephones may also be installed.

This new equipment makes possible an inexpensive and adequate telephone system that will make telephone service for coastwise commercial ships and yachts as simple as the conventional land telephone.

Contributors to this Issue

For slightly more than a year in 1923-1924 F. B. Woodworth was a member of the Research Department. He left for Schenectady in September, 1924, to study Electrical Engineering at Union College. For three summers while at college he worked with the New York Telephone Company. Following his graduation in 1928, he became a member of the Radio Development group and worked on radio-beacon and aircraft radio-telephone development at Hadley Field. During the summer of 1930, Mr. Woodworth was in Alaska conducting ship-shore radio-telephone tests with the salmon canning industry. Subsequently, he has been directly associated with other harbor-craft and ship-shore development projects, notably the radio service to the fishing fleet off the New England coast, the emergency short-wave radio link along the Florida Keys, and more recently, the Philadelphia harbor-craft system.

F. B. Woodworth

After obtaining the degree of B.E. from the Johns Hopkins University in 1924, J. D. Tebo spent a year with the Westinghouse Company on relay design. He then returned to Johns Hopkins for graduate work, and in 1928 received the degree of D.Eng. Immediately joining the Laboratories' Technical Staff, he spent several years in relay design, particularly as applied to the reduction of interference between power and telephone lines. During the past five years he has been engaged in crossbar switch development, designing the magnets and establishing requirements for crossbar switches and multi-contact relays. In addition to the magnetic design, Dr. Tebo supervises the dial apparatus laboratory.

Before graduating from Cornell, S. J. Zam-

J. D. Tebo

S. J. Zammataro

C. R. Gray

D. T. Osgood

J. N. Reynolds

J. C. Bayles

mataro spent three summers on coil design with the Engineering Department of the Western Electric Company. After getting his E.E. degree in 1921, he returned to these Laboratories and for four years was engaged in testing work in the Special Products Laboratory. He then became interested in alternating-current bridge measurements and worked on the development of precision bridges for use at high frequencies. In 1928 he became supervisor of the group on this work and at present is in charge of transmission as well as impedance measurements.

C. R. Gray joined the Laboratories in 1923, and at once became associated with the dial-systems laboratory. While here he took the technical assistants' engineering course, and subsequently took part in tests of most of the step-by-step, PBX, and community dial-office circuits. He also engaged in the development of various community dial offices, and during the past winter taught the step-by-step out-of-hour course. Recently he has developed crossbar PBX's.

D. T. Osgood was graduated from M.I.T. in 1930 with the degrees of S.B. and S.M. in Electrical Engineering. While at Tech, he had taken the coöperative course with the Bell System, and on graduation at once joined the D & R Department of the American Telephone and Telegraph Company. Since that time his work has been concerned with the development and application of methods for protecting communication circuits against disturbances from power systems.

J. N. Reynolds graduated from Purdue University in 1904 with the degree of B.S. in E.E. In 1907 he received an E.E. degree. After his graduation he came to the Bell System to engage in the development of dial apparatus with which, in both creative and supervisory capacities, he has been associated ever since. As Special Studies Engineer he heads a group concerned with the development of automatic switching equipment, and particularly with devising new and improved switch mechanisms and associated electromagnetic devices.

J. C. Bayles joined the Radio Development Department early in 1930, having received an engineering degree from the University of Illinois, where he also was a member of the staff of the university radio station WILL. His work with the Laboratories has given him a diversified experience in the development and the field application of broadcasting apparatus. It has included the development and study of quartz-crystal-controlled oscillators and the development of the 280A synchronizing panel. He has also developed radio transmitters and speech-input equipment. As a member of the Broadcast Development Department, he has supervised the installation of several broadcasting stations.