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Calibrating a crosstalk-measuring set with the new reference standard

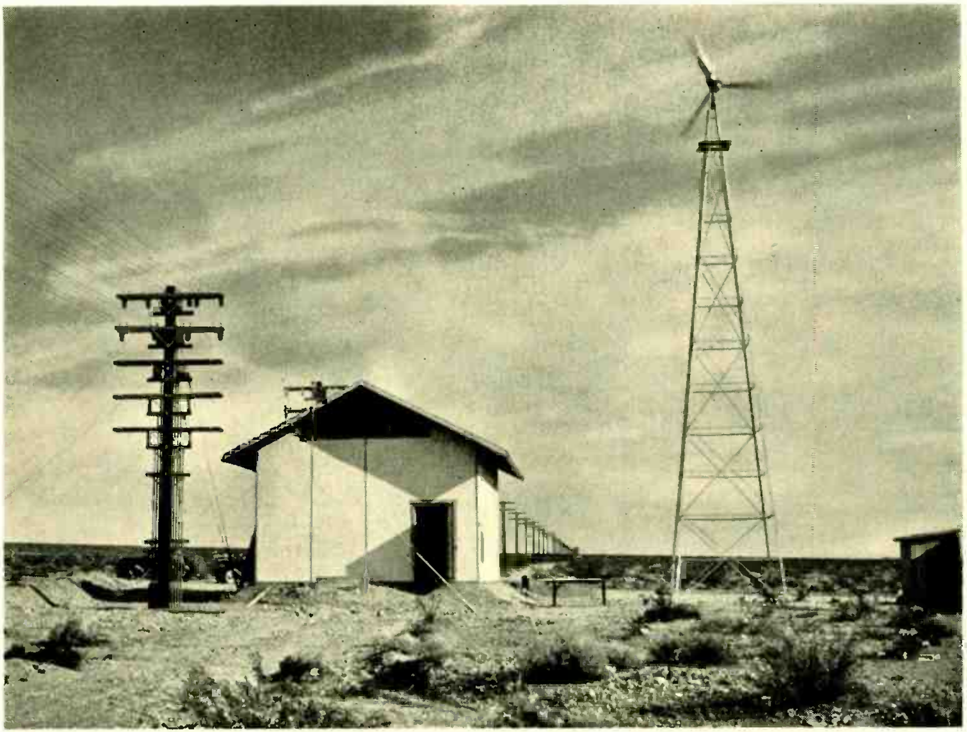

Photo by M. Kirkwood, A. T. & T.

A Broad-Band Carrier System for Open-Wire Lines

By H. R. MOORE
Toll Transmission Development

SIXTEEN conversations over a single open-wire pair have been made possible by the recently introduced Type-J carrier-telephone system. This represents a fourfold increase in the telephone utility of suitable line pairs, and is accomplished by the addition of the twelve channels of the Type-J system in the frequency range above that used for the three-channel Type-C system and the voice-frequency circuit. Already, twelve Type-J systems have been placed in service, including five on the transcontinental line that has recently been built between Oklahoma City and White Water, California.

Development of the Type-J system proceeded side by side with that of a companion broad-band system for cables, the Type-K.* Common use is made of a basic twelve-channel terminal† to translate twelve voice-frequency bands into twelve sidebands of carrier frequencies ranging from 64 to 108 kilocycles, and vice versa. Identical carrier generators‡ supply the necessary frequencies for these translations. Subsequently, the entire twelve-channel band is translated as a group

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*Record, *April*, 1938, *p.* 260; †*May*, 1938, *p.* 315; ‡*July*, 1938, *p.* 365.

to the frequency range chosen for transmission over the line. In Type-J, the range between 36 and 84 kilocycles is used for one direction of transmission and that between 92 and 143 for the other. The latter frequency is nearly five times the maximum used in the Type-C system.

At the frequencies employed for Type-J transmission, the high attenuation of open-wire pairs requires closer spacing of repeaters than was necessary for Type-C or voice. As with Type-K, the additional repeaters have been housed in small auxiliary stations designed for minimum maintenance attention. Such an auxiliary station is shown in the headpiece. Automatically controlled power arrangements and alarm trunk circuits for conveying trouble warnings to maintenance forces at nearby offices have helped make this possible. The feasibility of this method of operation, however, depended largely upon the provision of automatic gain regulators which would compensate for wide changes in line attenuation. The attenuation of an open-wire line is affected by changes in temperature, by rainfall, and by the accumulation of ice, frost, or wet snow, the latter effect being particularly large. Field observations* covering several years were required to establish the range of attenuation-frequency characteristics which would be encountered at Type-J frequencies. Based on these data, examples of which are shown in Figure 1, the design of a regulating system followed precedents set by Type-C practice.

Crosstalk between open-wire circuits tends to increase rapidly with increasing frequency. As a result, the extension of transmission frequencies upward from the thirty-kilocycle maximum of Type-C to over 140 kilocycles for Type-J has required careful attention to the line circuits. New transposition designs were developed and tested extensively in the field. For the control of crosstalk due to reflections at junctions of the open-wire and intermediate cables, a new type of cable using spaced disc-insulated conductors was developed and loading units were designed for use with it. Interaction crosstalk, due to coupling paths existing between the two sides of a repeater station, was an important problem, since such crosstalk is amplified by the gain of the repeaters. To minimize this type of crosstalk a physical gap in the open-

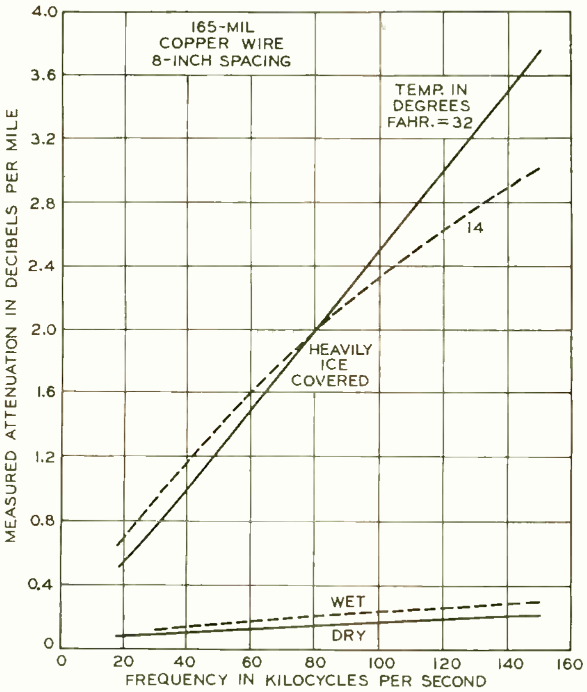

Fig. 1—Typical attenuation characteristics of open-wire lines

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*Record, *Nov.*, 1937, *p.* 95; *also*, *Dec.*, 1938, *p.* 121.

wire line was found to be necessary, the line being brought into the station by cables. In addition, special suppression devices, including choke coils and filters, were cut into the line circuits. Recently installed Type-J systems employ four different frequency allocations, the channel bands being inverted and displaced as shown in Figure 3 to reduce the interference between different systems and to render it unintelligible.

A complete installation of a Type-J system, a Type-C system, and a voice-frequency circuit, which together provide sixteen two-way telephone circuits on a single pair of wires, is illustrated schematically in Figure 2. At terminal and repeater points, line filters separate the frequencies used for the Type-J systems from those used for the Type-C and voice-frequency facilities. Where the open-wire line terminates at some distance from an office, these filters may be housed in a small filter "hut" as shown in Figure 4, from which non-loaded entrance cable pairs are used to carry the Type-J frequencies into the office, and loaded pairs to carry the Type-C and voice frequencies. Filters in the offices separate the Type-C and the voice frequencies as required. Composite sets derive two grounded telegraph legs for each pair. In the Type-J branches, directional filters separate the frequency bands employed in the two directions of transmission, permitting their separate amplification and regulation at

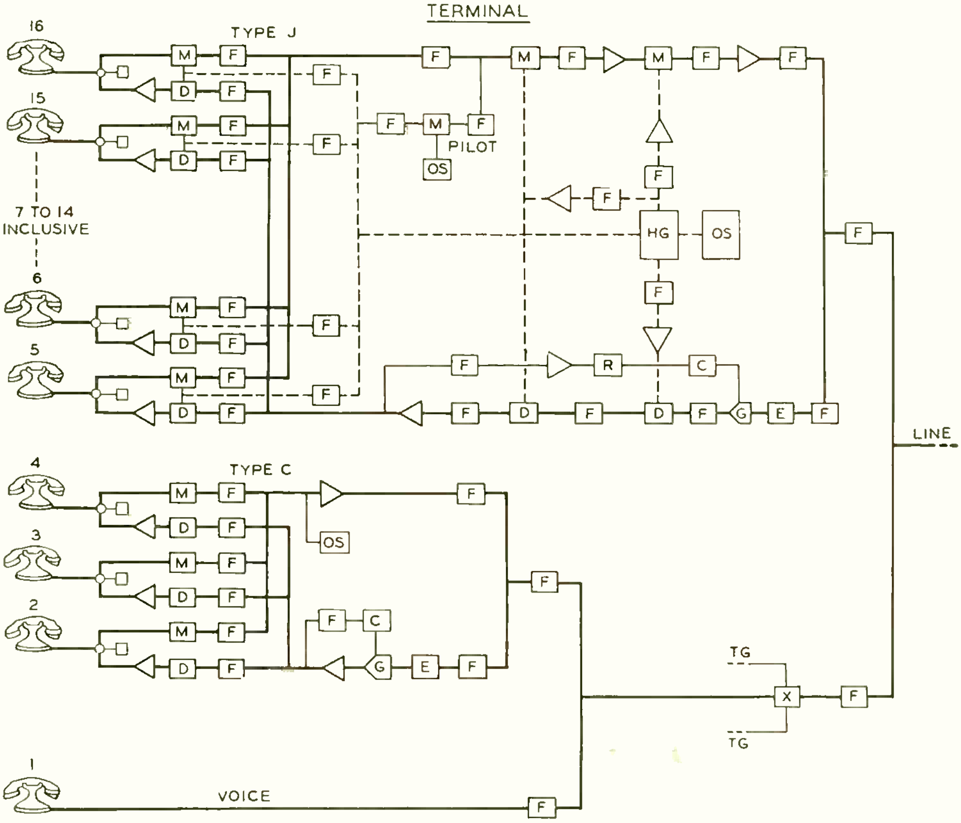
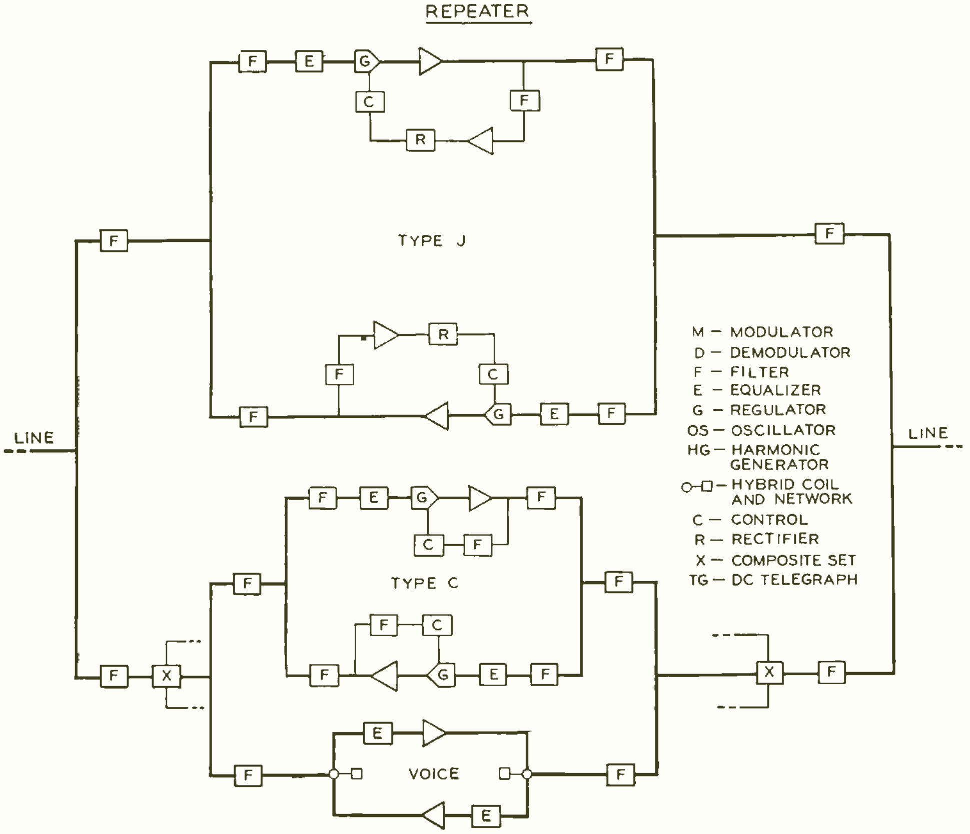


Fig. 2—Simplified block

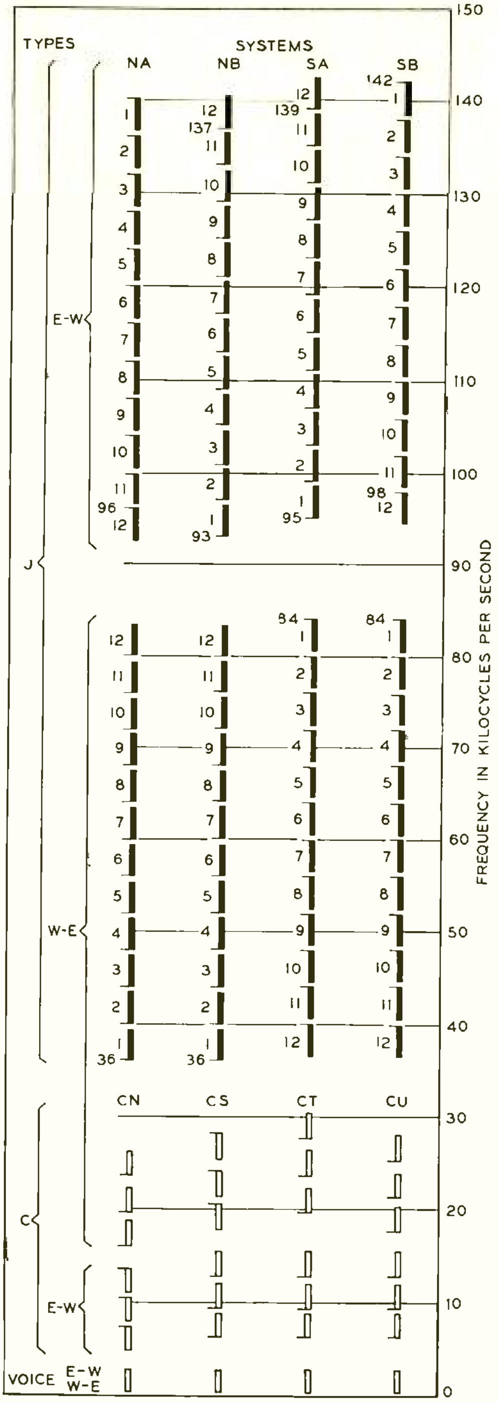
repeaters, and their appropriate treatment at terminals.

In the terminals, outgoing speech in each channel is translated upward in frequency by modulation with its particular channel carrier frequency, as was mentioned earlier. Then, together with the eleven other channel bands, modulation with a 340-kilocycle carrier translates the entire group as a unit. The upper sideband of this modulation is then modulated with a second group carrier whose frequency depends upon the allocation of the system and the direction of transmission. The lower sideband of the second group modulation is used for transmission over the line. Incoming speech goes through the inverse of this process, the line frequencies being translated in two stages of group demodulation and thereafter separated into the twelve constituent channel bands. Thence, each channel is demodulated with its own channel carrier, producing the original speech frequencies.

Type-J systems in the plant are of two types—the initial design known as the J1 and the present design called the J2. Type-J2 systems, the first of which have just gone into service, differ from the Type-J1 principally in that features are included to improve the performance under extreme weather conditions when heavy ice or frost is present on the line. The available gain in the repeaters and terminals was increased by about seventy per cent, and the transmission regu-



schematic of the system



NOTE:— E-W ALSO IMPLIES TRANSMISSION N-S, AND W-E IMPLIES S-N

Fig. 3—Frequency allocation for the Type-J carrier system

lating arrangement modified so that it will adjust the gain characteristics automatically to fit a wide variety of line attenuation characteristics. Furthermore, Type-J2 systems provide a choice of four frequency allocations whereas the J1 system employed a single allocation. Future systems will be of the J2 type.

Regulation of transmission on both J1 and J2 systems is obtained by the use of pilot frequencies lying outside the channel bands. These are transmitted over the line in both directions at all times. Picked off by highly selective filters at repeaters and receiving terminals, these pilots are employed to control the gains as required to maintain a constant pilot level. In the Type-J1 systems, a single pilot is used in each direction, approximately centered in the particular group band. The gain-regulating mechanisms effect gain changes at frequencies other than the pilot which are proportioned according to the differences in the attenuation frequency characteristics of wet and dry lines. This results in the maintenance of practically constant repeater output at all frequencies under both wet and dry line conditions. Differences in the characteristics of wet and ice-coated lines, however, result in equalization deficiencies with this system under sleet conditions. In J2 systems, two pilots located near the extreme ends of the transmitted bands are used. One governs a flat-gain adjustment and the other a gain-slope control, thereby providing a means for making the gain-frequency characteristics closely complementary to the line losses for all conditions. The available repeater gains have been raised to a maximum of about 75 db to care for severe ice conditions.

Performance of the Type-J1 systems was carefully tested in the field before commercial operation was attempted, first with laboratory-built equipment between Wichita, Kansas, and Lamar, Colorado, and subsequently on an initial Western Electric installation between Jacksonville and West Palm Beach. A laboratory field trial of the Type-J2 equipment, involving the new regulating arrangements and higher gains as well as the staggered frequency allocations, was carried on between Dallas and San Antonio during the past summer.

Both on trial and in commercial service the Type-J systems have given creditable performance with respect to stability, noise, crosstalk, and nonlinear distortion. The band widths of the individual channels are considerably greater than those provided by previous open-wire carrier facilities, affording essentially flat transmission for frequencies from 150 to 3500 cycles.

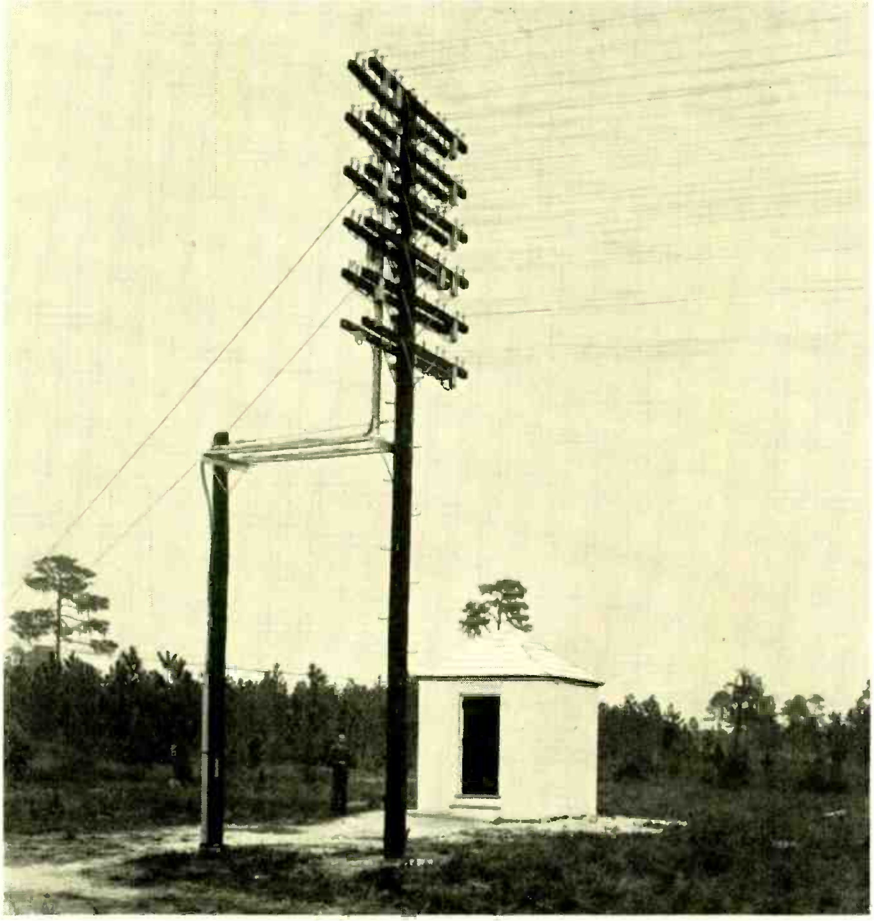


Fig. 4—A filter hut used with the Type-J system at Jacksonville, Florida

A Crosstalk Reference Standard

By J. E. NIELSEN
Electrical Measurements and Design

TO DETERMINE whether crosstalk in loading coils and loading units is within manufacturing requirements, the Western Electric Company uses crosstalk measuring sets. These sets are precision apparatus and their maintenance at the required accuracy has demanded elaborate tests. To reduce the high cost of this maintenance, the Laboratories recently developed a reference standard to check the measuring sets by introducing known amounts of crosstalk where the loading coils tested are usually connected.

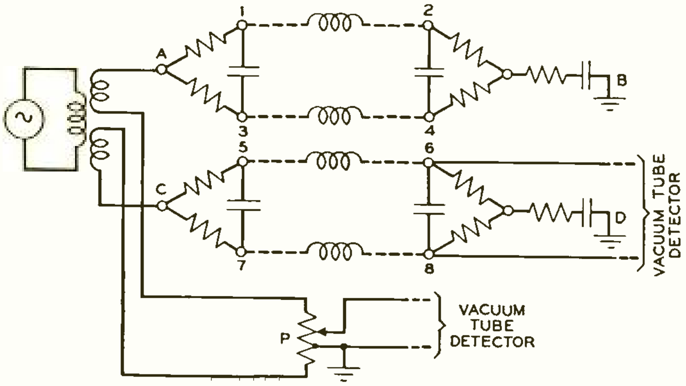


Fig. 1—Schematic of loading-coil test set. It simulates the impedances of a group of cable circuits with two side circuits and a phantom circuit

With the standard, simple and rapid overall checks of the measuring equipment can be made.

A crosstalk measuring set* consists essentially of resistances and capacitances arranged so that their impedances simulate those of a cable quad with two side circuits and a phantom circuit. The loading unit under test is connected to the eight numbered terminals shown in Figure 1; terminals 1, 2, 3 and 4 are for one side circuit, and 5, 6, 7 and 8 for the other. A-B and C-D constitute the phantom circuit. The phantom circuit is shown energized, and the crosstalk in a side circuit is measured by comparing the voltage across either the near end or far end terminating impedance of the side circuit with a voltage obtained from a potentiometer P through which flows the same current as that in the phantom circuit. The comparison of the two voltages is made with a vacuum-tube detector and the potentiometer is adjusted until the two voltages are equal. The setting is then an indication of the magnitude of the crosstalk which may be expressed in either crosstalk units or decibels.

In loading units phantom-to-side crosstalk is much more difficult to control than crosstalk between side circuits and it is also more difficult to measure, because there are more sources of unbalance which contribute to phantom-to-side crosstalk. For maintenance purposes it is sufficient to check only the

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*Record, *October*, 1932, *page* 53.

phantom-to-side crosstalk and that is provided for in the standard by introducing in it predetermined amounts of unbalances and observing the amount of crosstalk indicated by the measuring sets.

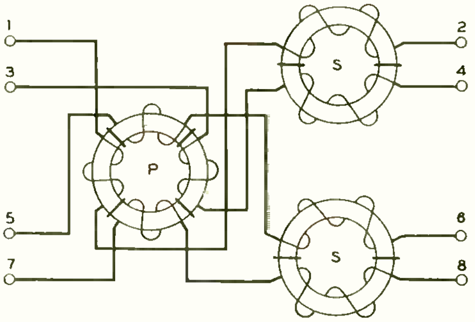


Fig. 2—A loading unit has a coil for each side circuit and another coil for the phantom circuit

To provide correct impedances in both phantom and side circuits the standard must have coils arranged essentially like those in the loading units which are tested. Simple resistances or single-winding inductance coils will not give the proper impedances. Arrangement of the coils in a loading unit is shown in Figure 2. The three coils add inductance independently to the two side circuits and the phantom circuit. A high degree of balance was required in the standard to control stray effects, and this made necessary a symmetrical structure which was obtained by splitting the coils in halves as illustrated in Figure 3 at ½s and ½p. Definite unbalances for producing the predetermined amounts of crosstalk are obtained by a resistance, an inductance, and two capacitances for each side circuit. The resistances and inductances are inserted in series with the circuit by removing plugs which normally short-circuit them; the capacitances are inserted as shunts by keys. Although these unbalances are rather small they can be adjusted to desired values with satisfactory accuracy by bridge methods available in the laboratory. The unbalances may be inserted singly and in combinations and provide a range of from two to thirty crosstalk units, which is satisfactory for checking the measuring sets.

That the crosstalk produced by the unbalances may be correct in amount when the standard is used in circuits of different impedances and for near-

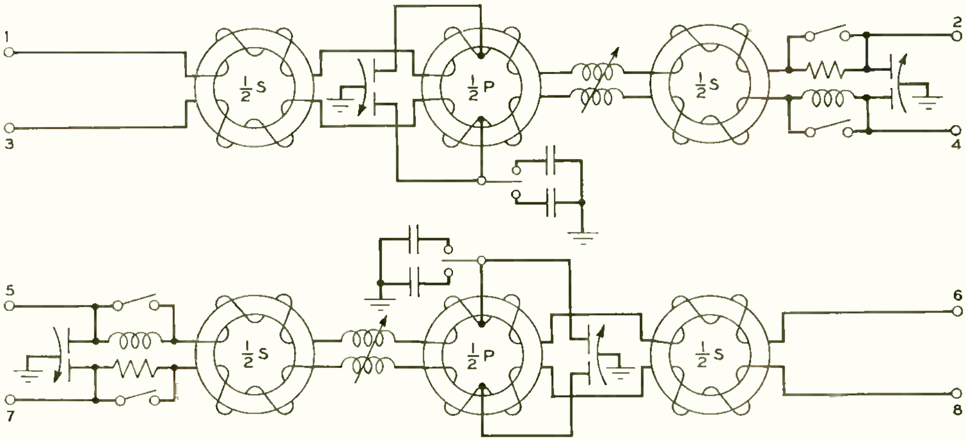


Fig. 3—The coils in the crosstalk reference standard are split in halves to give the high degree of balance required

end as well as far-end measurements, it is essential to reduce residual crosstalk from each individual source in the coils to zero. It is not sufficient to make a blanket compensation of combined reactive unbalances, since such adjustment in general will hold only while the standard is connected to one particular circuit. If the circuit impedance is changed or the measurements are made at the far end instead of the near end of the circuit, the crosstalk due to inductance and capacitance unbalances, which originally compensated each other, will have changed either in magnitude or in phase, from opposing to aiding, and the resultant will no longer be zero.

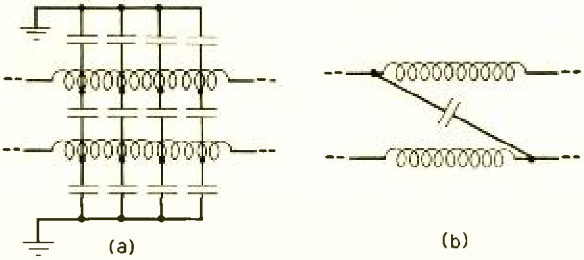


Fig. 4—The coils in the crosstalk standard are wound to distribute the capacitance and conductance from each winding to ground evenly as illustrated at (a). The capacitance, (b), across the coil is negligible

The important separate sources of unbalance in the standard are capacitance from each coil winding and terminal to ground, self-inductance and resistance of each of the four complete wires through the standard, and conductance from each coil winding and terminal to ground. The unbalances from these sources are reduced to insignificant amounts by various adjusting devices. The capacitance unbalances are adjusted by a differential air condenser connected to each coil. The self-inductance of the two wires in each branch of the phantom circuit is balanced by an adjustable inductance consisting of two adjacent coils mounted on a common axis with a movable core of permalloy powder. When the inductance in one coil is increased, that in the other decreases with only a negligible change in the resistance. The series resistance unbalance is adjusted by filing down the thickness of a small piece of resistance wire. To correct for conductance unbalance a small condenser with imperfect dielectric such as phenol fiber is placed in parallel with one of the condensers for adjusting the capacitance balance to ground.

The coils of the standard are unusual in that they have rather large cores and relatively few turns. The windings consist of two parallel and non-twisted wires applied in a single layer. By this arrangement the capacitance and conductance from each winding to ground and between windings become evenly distributed along the winding as illustrated in Figure 4a and there is only a negligible capacitance component lying diagonally across the coil as shown in Figure 4b. Such a component is present in appreciable amount in coils with ordinary types of piled up windings and would be particularly troublesome in the standard because it would cause crosstalk in phase with and therefore difficult to separate from that caused by resistance unbalance.

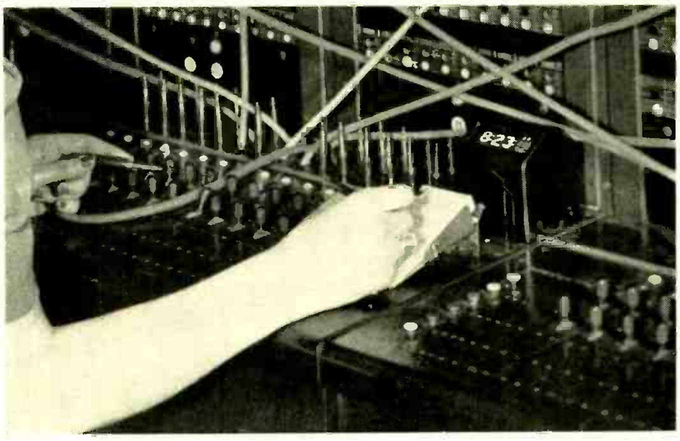
To shield them magnetically as well as electrostatically the coils are potted in individual containers of permalloy sheet. These containers are placed in a larger brass box which serves as a housing for the standard and holds besides the outside terminals, an inside terminal board, the various adjusting devices, and the crosstalk-producing unbalances. The inside terminal board is necessary when disconnecting the coils for adjustments, in order to avoid any unintentional changes in the wiring.

To make the terminal arrangement of the standard correspond to that of the test sets, the wires of the two side circuits of the standard have to cross each other inside the box. If this had not been necessary, each side circuit could have been confined entirely to its own compartment in the box, and there would have been no capacitance unbalance between the four wires of the phantom circuit. With the crossing, however, an additional source of capacitance unbalance was created. This unbalance was reduced by compensating the direct capacitances between the four wires of the phantom circuit considered as a quad rather than by shielding which would involve very elaborate construction because of the high electrical stability required. The compensating condensers consist of small pieces of glass tubing fitted on short pieces of No. 14 wire with a few turns of fine wire on the outside of the tubing to serve as the other electrode of the condenser.

Two of the standards described here have been constructed by the Laboratories. After a year's service one of these has been returned for checking and showed very little change. These standards permit better control of loading coil quality during manufacture.

Motor-Driven Switchboard Clock

A DIRECT reading motor-driven clock has been developed by the Laboratories, in conjunction with its manufacturer, for mounting on switchboards to time toll calls. It replaces the spring-driven clocks now used in small offices and generally those operated magnetically from a master clock in large ones. Time is shown by four rotating drums which carry the hour, minute and second numerals. The hour and minute drums advance periodically and the seconds drum rotates continuously. The figures, which indicate the time, are seen through an aperture in the top of the molded case. A 20-volt synchronous motor drives the clock through a transformer on 60-cycle controlled frequency. The new clock operates more quietly than the clocks now used and it shows the time to the nearest second instead of changing at six-second intervals like those magnetically driven.



Crossbar Call-Indicator Pulsing

By R. O. SOFFEL
Central Office Switching Development

IN TELEPHONE areas with both manual and dial central offices, numbers are transmitted from a dial to a manual office by sets of pulses. The system was developed in conjunction with call indicators,* which display the numbers to operators at the manual board. In the panel system, the pulses are controlled by sequence switches, and are formed by grounding one side of the line and connecting battery to the other. The battery may be connected through either high or low resistance and thus gives a current flow of either of two values. Provision for call-indicator pulsing had to be made also in crossbar offices, but since the senders of the crossbar system have no power-driven equipment, and thus no sequence switches, it was necessary to develop a call-indicator impulser and control circuit that consisted wholly of relays or other electromagnetic apparatus. Such a relay system was already in use in panel tandem offices, but it was not suitable for application to crossbar senders, and so a new system was developed.

Since the crossbar impulser must work into the same equipment in the manual offices as the panel impulser, the same types and combinations of pulses must be used. Each digit of a number is transmitted by a set of four pulses. The second and fourth pulses are always formed by grounding the "tip" conductor of the line and connecting negative battery to the "ring" conductor through a 6500- or 115-ohm resistance. The first and third pulses are formed by grounding the ring conductor and either connecting negative battery to the tip through a 6500-ohm resistance, or leaving the tip side open to form a blank pulse. In all cases the positive side of the battery is connected to ground. A single heavy pulse on the tip is used in addition to indicate the end of a code.

One of these four-pulse codes is transmitted for each of the four digits and for the station letter where one is used, although the station letter code is sent first. The combinations used are shown in Figure 1. When no station letters are used, a zero code is transmitted as the first digit.

Since each code consists of alternate ring and tip or blank pulses, the pulsing circuit must provide for alternately grounding each side of the line and holding it grounded long enough to provide the desired duration of the pulse. This is accomplished by the condenser-timed interrupter circuit shown in Figure 2. It consists of a pulse-generating polarized relay PG with a main winding, shown in heavy lines, and an auxiliary winding shown in light lines. The relay has no biasing spring; its armature is free to assume any position. After it is operated to one of its contacts, it will remain there until a reverse current operates it to the other.

The pulse-generating relay is so polarized that when negative battery is connected to the minus and ground

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*Record, *December*, 1929, *page* 171.

to the plus terminals of the main winding, the armature moves to contact 1, and when ground is connected to the minus and negative potential to the plus terminals, the armature moves to contact 2. With the connections shown, and considering only the main winding, the armature of the relay would move rapidly back and forth between contacts 1 and 2, because when it was on 1, the ground connection to the armature would move it to 2, and when it was on 2, the negative battery would move it to terminal 1. The auxiliary winding and condenser C, however, provide a pulse of current, controlled in duration by the size of C, that opposes the effect of the current in the main winding. With the armature against contact 2 as shown, the main winding tends to pull it to 1, but the reverse pulse due to charging the condenser delays its action for a short interval. When the armature does move to contact 1, the action of the main winding tends to move it to contact 2, but the discharge current of the condenser delays this action for a short interval. The continual repetition of this sequence of operation provides the required interrupter action.

DIGIT			PULSES							
STATION LETTER	THOUSANDS	HUNDREDS TENS UNITS	FIRST		SECOND		THIRD		FOURTH	
			TIP	RING	TIP	RING	TIP	RING	TIP	RING
0	0	0	O	G	G	L	O	G	G	L
I	2	1	L	G	G	L	O	G	G	L
W	4	2	O	G	G	H	O	G	G	L
R	6	3	L	G	G	H	O	G	G	L
J	8	4	O	G	G	L	L	G	G	L
M	1	5	O	G	G	L	O	G	G	H
	3	6	L	G	G	L	O	G	G	H
	5	7	O	G	G	H	O	G	G	H
	7	8	L	G	G	H	O	G	G	H
	9	9	O	G	G	L	L	G	G	H

G – GROUND
O – OPEN
L – BATTERY THROUGH 6500 OHMS
H – BATTERY THROUGH 115 OHMS

Fig. 1 — Codes used for call-indicator pulsing in the panel and crossbar system

As stated previously, each digit requires four pulses, which are produced by pulse-generating relay PG acting as an interrupter, closing its contact 2 for the first pulse, its contact 1 for the second, its contact 2 again for pulse 3, and its contact 1 again for pulse 4. These closures of contacts act to operate and release the secondary pulse-generating relay PG1 of Figure 3, which, disregarding for the moment the function of the GR relay, alternately opens the tip and puts ground on the ring to produce a blank pulse, and then grounds the tip and puts battery on the ring to produce a ring pulse. Thus, blank and ring pulses alternate with each other. By the operation of other relays—the pulse-tip, PT, and the pulse-ring, PR, as required by the code of the digit being sent—the blank pulse is made into a light tip pulse by substituting battery for the open condition on the tip, and the light ring pulse is changed to a heavy ring pulse by shunting a high resistance with a low one.

During the transfer from ring pulses to blank pulses, ground is held momentarily on the tip by the slow-operate relay GR, and this, together with the ground held on the ring by the front contact of the PG1 relay, discharges the cable to avoid a false pulse from cable capacity discharge when a blank pulse is to be sent.

This action of the circuit can be seen from Figure 3. With the armature of pulse-generating relay on contact 2, auxiliary relay PG1 is operated which places ground from its make contact on the ring of the line. The other make contact of relay PG1 has operated the "ground-out" relay GR, which with the pulse-tip relay PT unoperated opens the tip of the line and thus sends out a blank pulse. It is to be noted that since the ground-out relay GR is slow to operate it maintains the ground on the tip for a short time, and with ground also on the ring discharges the cable capacity before a blank pulse is sent out. If, however, the pulse-tip relay PT is operated, according to the requirements of the digit being sent, high-resistance battery is placed on the tip instead of an open condition, and with the ground on the ring produces a light tip pulse. When the pulsing action of the pulse-generating relay PG closes its contact 1, auxiliary relay PGI releases. Ground is now put out on the tip of the line and removed from the ring, which permits the high-resistance battery permanently connected to the ring to send out a light ring pulse. If the pulse-ring relay, PR, is operated, as determined by the pulse code to be sent, the high resistance is shunted by a low resistance, which sends a heavy ring pulse on the line. The actions outlined above for the operate and release of the PG and PGI relays are again repeated for the last two pulses of any code, and the process further repeated until all of the codes are sent.

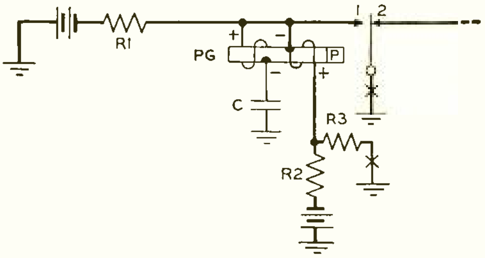


Fig. 2—The PG, or pulsing, relay used to ground the tip and ring sides of the line alternately

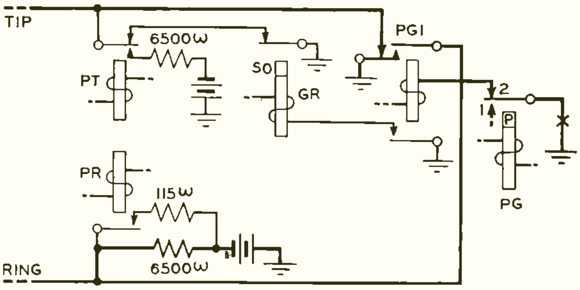


Fig. 3—Relays of the pulsing circuit that form the light and heavy ring, and tip pulses and blank pulses

The formation of a code for any digit, therefore, resolves itself into the proper combination of light, heavy, and blank pulses in the sequence indicated in Figure 1. While no codes are being sent, relay PG is held operated in the direction to hold the armature on contact 2 by a ground connection to the negative terminal of the main winding as can be seen in Figure 4. This operates relay PGI and grounds the tip and ring conductors, since at this time the operating circuit for relay GR is open. It can be seen that the cut-in relay CI at this time holds both sides of the line open at its make contacts. To send a code, the cut-in CI relay is operated. Since the PGI relay is held operated by the PG, as previously mentioned, a path is available for ground on the make contact of the CI to operate the GR relay, which in turn removes ground from the tip of the line. The break contact of the cut-in CI relay removes ground from the pulse-generating PG relay, and causes it to start its timed interruptions. If the pulse to be sent is a tip pulse instead of a blank pulse, the tip control relay PT is operated; if "heavy ring" instead of "light ring," the PR relay is operated. These latter relays are always operated during the pulse preceding the one they are to control. If the second pulse were to be a heavy ring pulse, for example, the pulse-ring relay PR would be operated during the first pulse. This would not affect the first pulse because during it the ring is held grounded. Similarly when the pulse tip relay PT is operated during a ring pulse, so as to make the next one a tip pulse instead of a blank pulse, the operation of PT also has no effect until the next pulse, since the tip conductor is grounded during a ring pulse. The heavy tip pulse, used at the end of a code, is obtained by interchanging the tip and ring leads, and sending a reversed heavy ring pulse. This is accomplished by operating the final pulse relay FP of Figure 4.

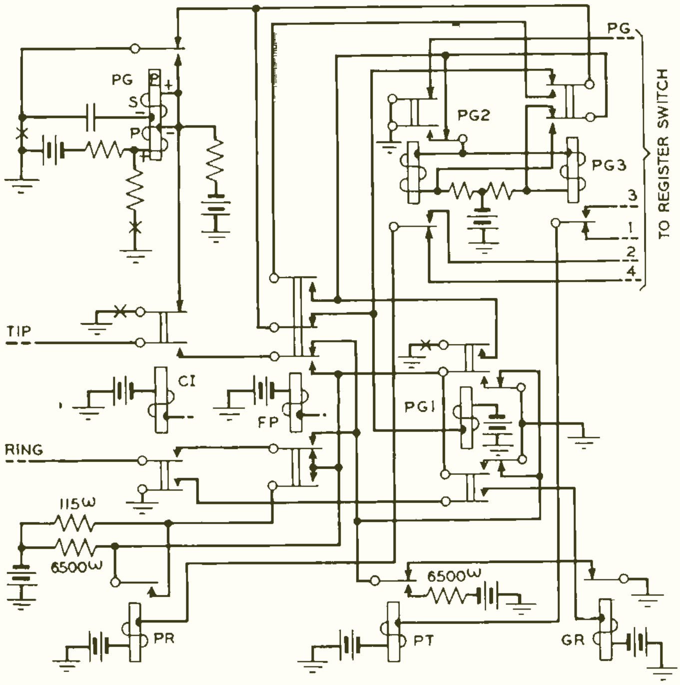


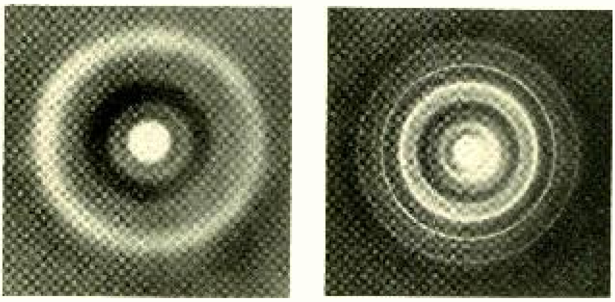
Fig. 4—The call-indicator impulser circuit used with the crossbar system

Auxiliary pulse-generating relays PG2 and PG3 of this diagram are used to connect the operating paths for the PR and PT relays to the dial register switch in the sender through a progress relay circuit, which advances these paths from one digit to the next under control of the PG2 relay.

Although the sequence-switch call-indicator impulser has been used commercially for a good many years, the all-relay call-indicator impulser represents a definite improvement in the art. This has been confirmed in large part by our laboratory tests and by the experience gained from the early crossbar installations. It was found, for example, that the relay impulser could guarantee a longer minimum pulse than the sequence-switch impulser, and at the same time maintain a lower average and maximum pulse cycle time because of better control of the variable factors. Because of this it was possible to increase the resistance used for generating the heavy ring pulses from 52.5, which had been used with the sequence-switch impulser, to 115 ohms. This move had always been considered desirable to reduce contact wear, but tests had shown that an increase in this resistance would require an increase in the length of the heavy ring pulse so as not to increase the risk of false registrations. With the sequence-switch impulser, the length of the heavy ring pulses could not be increased without shortening the length of the tip pulses, and so the change was never made.

Experience has also shown that the relay impulser requires considerably less maintenance than the sequence-switch impulser largely because the former uses no base-metal contacts and is therefore free from the possibility of shortened or mutilated pulses, which are possible should the sequence switch cams show contact trouble. Moreover, should it ever become desirable to change the lengths of the call-indicator pulses, either to meet some particular set of conditions or to meet a general situation, the relay impulser would require only a slight change in the timing network, two resistances and one condenser at the most, to effect a considerable change in the output pulse limits. With the sequence switch impulser it is very difficult to change the limits of the pulses to any great extent.

ELECTRON DIFFRACTION PATTERNS OF SILICA AND ALUMINUM HYDRATE



SILICOSIS, the lung disease to which stone cutters and others who work in dusty trades are subject, develops rather quickly in rabbits exposed to air containing moderate concentrations of fine quartz particles. It is completely prevented if there is as little as one-hundredth as much aluminum dust as silica in the air breathed. This preventative action was discovered at the McIntyre-Porcupine Mines, and has been ascribed to an extremely thin coating of an aluminum compound deposited on the poisonous silica particles. The action of the aluminum is sufficiently striking and important to justify a fuller understanding of the nature of the film which it forms upon quartz particles and Dr. Frary, Director of the Aluminum Research Laboratories, suggested that the answer might be forthcoming through a study of electron diffraction patterns.

In experiments carried on by L. H. Germer and K. H. Storks, a beam of high-speed electrons was shot through thin films of silica which had previously been exposed to aluminum and water at body temperature. The diffraction patterns obtained showed a layer of aluminum hydrate less than one-millionth of an inch thick on the silica. Although extremely thin, this layer is sufficient to keep the poisonous silica from injuring the lungs. The photograph at the right shows the pattern of aluminum hydrate on silica; that at the left of silica alone.

Dielectric Loss in Ice

By E. J. MURPHY
Chemical Laboratory

COATINGS of ice, sleet or hoar frost on an open-wire telephone line, field measurements show, can increase the line losses for high-frequency currents to several times those of the bare wires.* This increase in attenuation is largely due to the ice deposits on the wires and not to leakage over the associated insulators. In the main the losses are not conduction losses but are dielectric losses caused by the distortion of the molecular structure of the ice by the electric field. In some materials, of which ice is an excellent example, such losses vary with frequency and temperature in a simple manner. This is of value in predicting the effects of ice deposits.

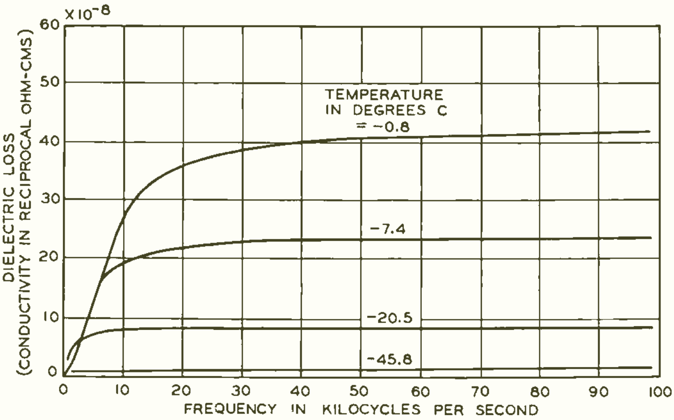


Fig. 1—The dielectric loss, which may be expressed in terms of alternating minus direct-current conductivity, approaches a limiting value as the frequency increases. This limiting value decreases with the temperature

Within the temperature range of practical interest in communication the dielectric loss for the lower audio frequencies varies comparatively little with temperature but rapidly with frequency. On the other hand, in the Type-J carrier range, the dielectric loss changes rapidly with temperature but is practically independent of frequency. This is shown in Figure 1, where the dielectric loss is taken to be proportional to the difference between the alternating and the direct-current conductivity. Few dielectric materials exhibit so simple a behavior as shown in Figure 1.

The molecular mechanism which is responsible for the variation of dielectric properties with frequency and temperature depends mainly on two characteristics of the water or ice molecule: it is polar,* and it is capable of rotating† or of spontaneously changing its orientation in the crystal in consequence of thermal agitation. It was discovered a few years ago that in certain solids containing polar molecules, the molecules are able to rotate and make an important contribution to the dielectric constant similar in general nature to the effect

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*Record, *Nov.*, 1937, *p.* 95; *Dec.*, 1938, *p.* 121.

*Record, *June*, 1931, *p.* 463; *July*, 1931, *p.* 535.
†Record, *Sept.*, 1936, *p.* 11.

of rotating polar molecules in a liquid.

To explain the dielectric properties of ice it is generally assumed that the molecules may be oriented in several alternative directions in the crystal. Under the influence of thermal agitation, the molecules jump at random from one orientation to another and when no electric field is impressed on the ice a molecule remains on the average the same time in each of these orientations. In an electric field, however, each molecule experiences a slight torque which tends to align its electrical axis with the direction of the applied electric field. This holds the molecule slightly longer in the orientations favored by the impressed field than in other directions. Electrical energy is stored on an increasing voltage when the molecules' orientation is made more orderly and is released on a diminishing voltage as the orientation returns toward its random state. Some electrical energy is dissipated in the dielectric as heat in producing these changes of orientation; and that accounts for the dielectric loss.

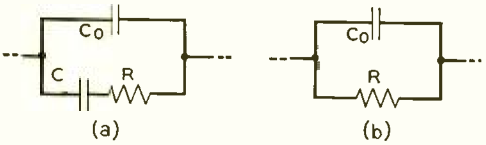

Fig. 2—For a wide range of frequencies, an ice condenser is equivalent to two capacities c *and* c_0, *one of which is in series with a resistance* R, *Figure (a). In the carrier frequency range the effect of* c *becomes negligible and the equivalent circuit reduces to a capacity shunted by a resistance, Figure (b)*

The dependence of the dielectric constant and loss on frequency of ice may be described by the simple electrical network, Figure 2. A condenser which contains ice is equivalent, in an electric circuit, to the capacitance and resistance network shown in Figure 2a. This circuit applies to the range of frequencies in which the curves for dielectric constant and for dielectric loss have the forms shown in Figure 3 which is plotted from data obtained at 2.6 degrees C. In the range of frequencies in which the a-c conductivity and dielectric constant are practically independent of frequency, the equivalent circuit of Figure 2b represents sufficiently the dielectric behavior of ice at a given temperature. For other temperatures the values of c and R are different.

The behavior illustrated by the figures is that of pure ice in a condenser. When ice is deposited on wires the air-gap which separates the two wires of a pair acts as an air condenser in series with two ice condensers. This modifies the behavior both qualitatively and quantitatively, but the modifications can be calculated and are in satisfactory agreement with attenuation data obtained in field tests.*

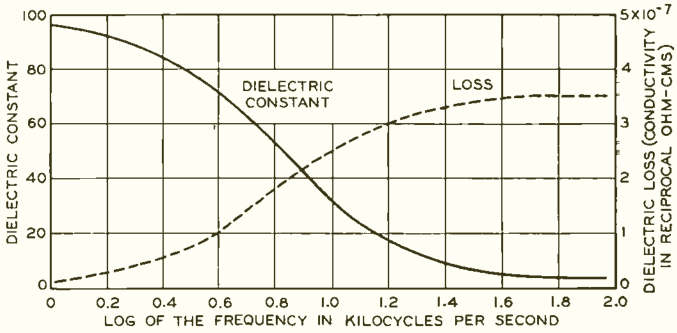

Fig. 3—The dielectric constant and dielectric loss of ice vary rapidly with frequency in the audio range but are practically independent of frequency in the carrier range

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*Record, *Dec.*, 1938, *p.* 121.

Code Ringing Supply for Community Dial Offices

By J. M. DUGUID
Power Development

WITH code ringing, each subscriber on a multi-party line is called by a particular sequence of "rings." This is in contrast to ordinary machine ringing, which on selective lines uses only one signal and on semi-selective lines two signals. With code ringing as many as twenty subscribers are connected to a single line. In "divided" code ringing a maximum of ten subscribers are connected from ground to the tip side, and ten from ground to the ring side. In bridged ringing, up to twenty subsets are bridged across the line. In the former case ten distinct codes are required, while the latter requires twenty codes, the additional ten being formed by adding a short pulse ahead of the ten existing codes.

In addition to the ringing codes, machine ringing for full and semi-selective lines, and revertive ringing signals are also required. It has been the practice in the past to generate the machine ringing for full and semi-selective lines on ringing machine interrupters as already described in the RECORD.* The more intricate signals for code ringing, shown in Figure 1, have been generated by relay chains, which interrupt ringing current to generate the codes. A modification of the machines mentioned above has now been developed, and as shown in Figure 2 equipped with interrupter springs which produce all the required codes, thus making the use of the relay chain unnecessary.

A new ringing power plant incorporating these machines and associated control equipment has been made available. It will supply small dial offices up to a capacity of 3000 busy-hour calls with twenty-cycle ringing current, tones, and signals in addition to the machine and code ringing interruptions. The machines are inverted rotary converters to be driven by a central office battery. On shaft extensions at each end are commutators and interrupters for supplying the high and low tone signals. Two

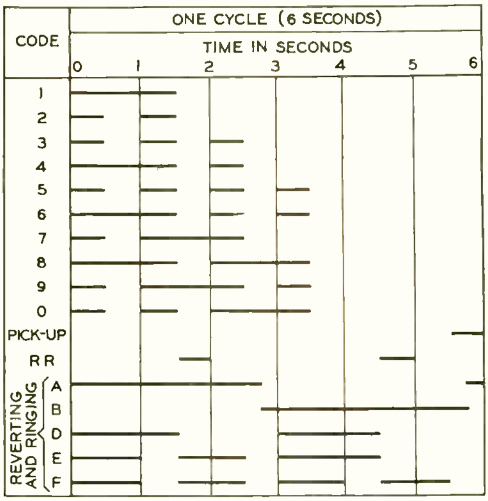

Fig. 1—Some of the more complicated codes provided for in the new ringing plant for community dial offices

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*July, 1939, page 363.

machines are mounted adjacent to each other as shown in Figure 3. One will be in service while the other is a spare. Provision is made to enable an attendant to interchange the machines from time to time so as to have each of them in service for about the same total time.

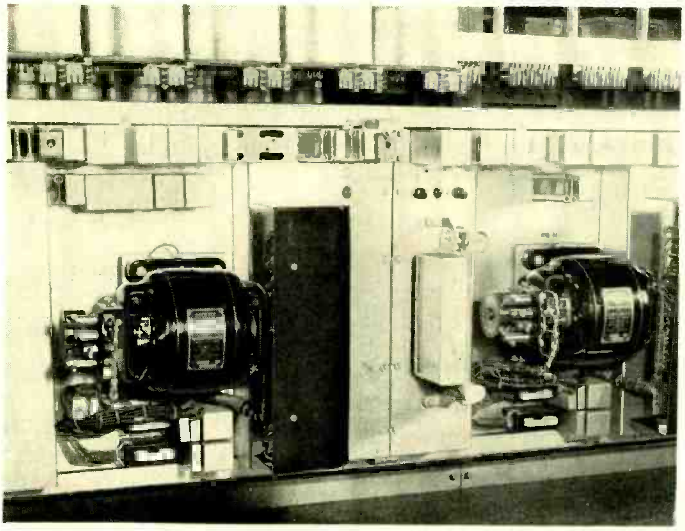


Fig. 3—Two ringing machines with their associated control relays are mounted on a switch frame

The set is arranged to run only when calls are in progress. When a call comes in, a circuit associated with the two machines starts whichever machine has been selected for use and holds it in operation as long as there is a call being handled in the office. Should the ringing voltage drop below a predetermined limit for any reason whatsoever, the circuit will at once start the spare machine and transfer the load to it; at the same time it will give a "minor" alarm to indicate that a transfer has taken place so that the trouble can be cleared. Should the spare machine subsequently fail, a "major" alarm will be given to indicate that immediate attention is needed.

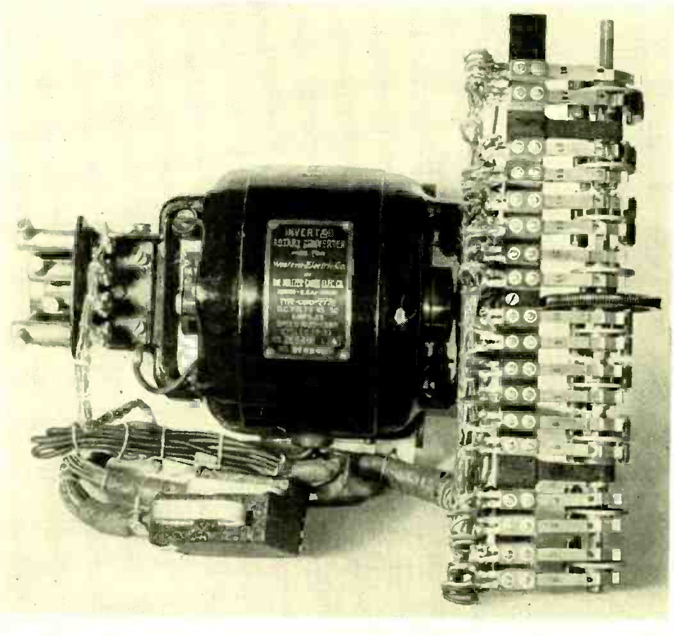


Fig. 2—Ringing machine equipped with interrupter springs which produce all the required codes

The main elements of this control circuit are shown in Figure 4. Because of the large number of ringing and tone circuits, three transfer relays, T1, T2 and T3, are sometimes employed; but their windings are all connected in parallel and only one is shown in the diagram. Transfer is accomplished, and alarms are rung, by relays L and J—one of

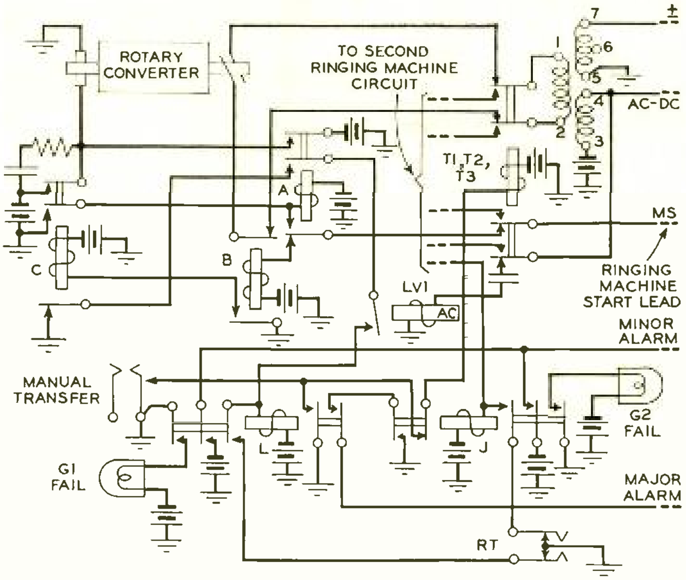


Fig. 4—Simplified schematic of control circuit

them making the transfer and giving the minor alarm and the other giving the major alarm for failure of the second machine. When No. 1 machine is in service L makes the transfer and J gives the major alarm, while when No. 2 is in service, the relay operations are interchanged. Relays A, B, and C are provided for each machine, B and C for starting and A for operation.

With machine No. 1 in service, the three transfer relays are released. Should a call come in, ground will appear on the MS lead and operate relay B of the machine selected for service. This open-circuits the generator so that it will start unloaded, and also operates relay C, which connects the set to battery. Through another contact, C also operates A, which connects battery to the ringing machine independently of the connection through C. Operation of A also releases B, and thence C, and holds itself in by the ground on the MS lead. The A, B, and C relays have slow-release characteristics. The slow release of B holds the generator open-circuited long enough for it to come up to speed, and the slow release of B and C combined holds open the transfer circuit until the machine is at full voltage. This transfer circuit runs from ground through a back contact on C and a front contact on A to the armature on LV1 where it is available for making a transfer whenever LV1 releases. Relay A has slow-release characteristics so that on a fuse failure the transfer circuit path will be held long enough to lock up the L or J relay.

Should ringing voltage fail while machine No. 1 is operating, the LV1 relay will release, and connect ground from C to relay L, which will operate, and hold itself in through ground from the RT key. Operation of L operates the transfer relays through a back contact on J, and also connects bat-

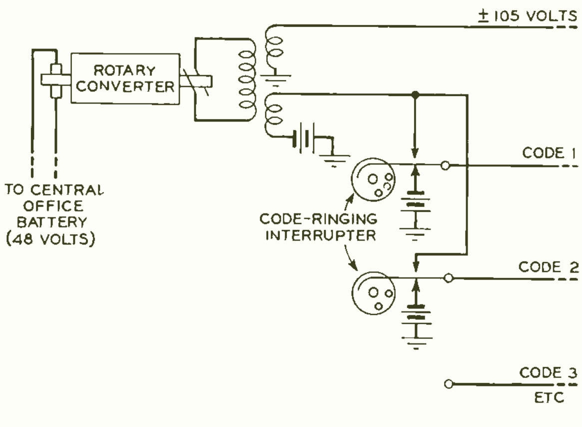


Fig. 5—Simplified schematic of interrupter circuit for code ringing

tery to the minor alarm circuit to indicate that a transfer has been made. Operation of the transfer relays will transfer the load to machine No. 2, and since a call is in progress, there will be ground on MS, and machine No. 2 will start by the operation of its E, F and G relays which correspond to A, B and C already described, the load being opened during the starting period.

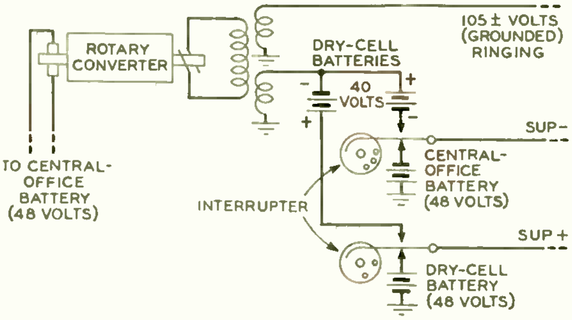


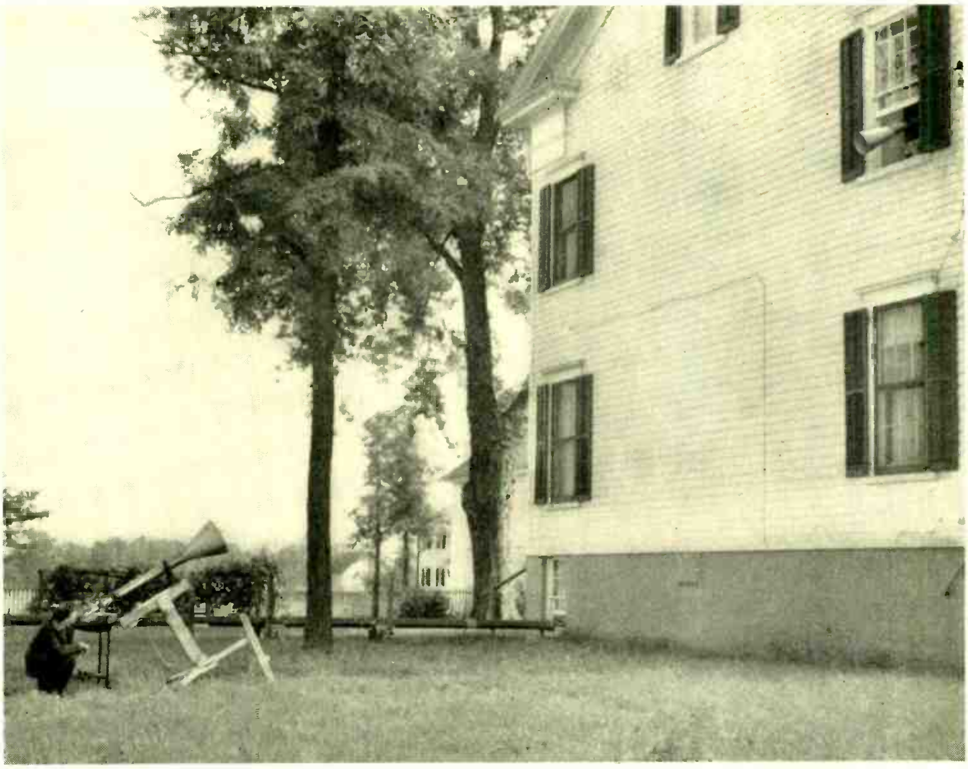
Fig. 6—Battery arrangement for four-party full selective ringing

If the ringing voltage should again drop too low, battery through LV2 (which corresponds to LV1) will operate J, which also holds itself operated through RT and completes a circuit through front contacts in L and J to the major alarm.

Had No. 2 machine been in use, with No. 1 as the spare, the release of LV2 would have operated J. This relay would connect battery to the minor alarm and open the circuit of the transfer relay to transfer the load to machine No. 1, which would start and carry the load in the usual manner. Should LV1 release, L would complete the circuit to the major alarm.

The code ringing supply is designed for four-party full selective lines as well as for direct, two-party, and four-party semi-selective lines, and thus batteries are required in addition to the regular office battery. The interrupter arrangement for code ringing is shown in Figure 5. The arrangement for four-party full selective ringing is indicated in Figure 6. Two forty-volt batteries are required in series with the ringing to give positive and negative superimposed ringing. A third forty-volt battery is supplied as a spare for either of these two. A forty-eight-volt battery is required in addition for both types of ringing to provide a voltage on the line for operating the tripping relay in case the subscriber answers during the silent interval. The regular office battery is employed for the negative silent-interval battery, but a separate battery is required for the positive. Dry cells are used for all these additional batteries. Two arrangements are provided: for smaller capacity offices, block type radio batteries are employed, and for the larger offices the batteries are the ordinary cylindrical type No. 6 cell. Separate racks are provided for each type. The drain on these batteries is small, and they last for approximately the shelf life of the batteries.

The complete ringing plant is compactly assembled, and requires little space. The duplicate ringing machines with automatic transfer arrangements insure continuous operation under all but the most unusual conditions, and the minor and major alarms provide prompt maintenance attention in emergencies.



Metal Horns as Radiators of Electric Waves

By A. P. KING
Radio Research

DURING studies of the transmission of electro-magnetic waves over wave guides, already discussed in the RECORD,* it was found that the waves could be projected into space from the end of the guide with considerable directivity. By flaring the end of the conductor to form a termination like an acoustic horn, this directivity can be considerably increased. As an extension of this earlier work, an investigation has been carried on of the directive characteristics of horns of various shapes and sizes using waves of the H_1 type. Such horns may be used with equal effect at either the transmitter or the receiver; and their effect is increased by use at both. For most of these studies, however, the horn was used only at the receiver, but even with this limitation, gains, over non-directional reception, were secured as great as 20 db.

In these studies there was employed a generator of continuous electric waves from ten to fifteen centimeters in length, corresponding to frequencies of from two to three thousand megacycles. Relative gains were determined either by comparing the received power with and without the horns attached, or by determining the

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*May, 1936, page 283.

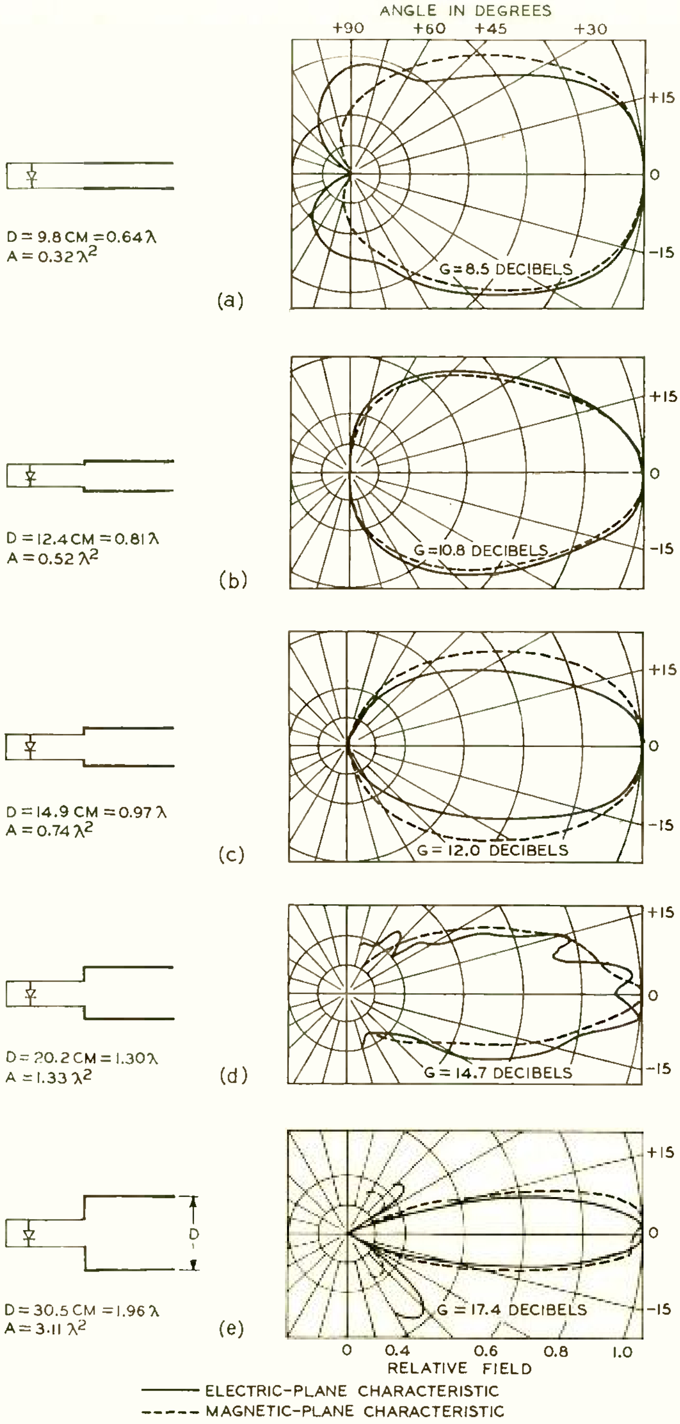


Fig. 1—Directional properties of the open ends of metal pipes of various diameters for wavelengths (λ) of 15.3 centimeters

directional pattern from measurements of the received power as the horns were pointed in various directions relative to the transmitter. The latter measurements were made in two planes at right angles to each other, one being that of the electric and the other that of the magnetic force. For some tests the transmitter and receiver were at opposite corners of the same room; for others the transmitter was in an upstairs window and the receiver on the ground some distance away, as shown in the photograph at the head of this article.

A certain amount of directivity, as already noted, can be secured with a straight section of pipe. Studies were made to determine the relationship between power gain and size of the pipe, with results shown in Figure 1. For any wavelength, there is a diameter, known as the cut-off diameter, below which no power can be transmitted through the pipe. Measurements made in the neighborhood of this diameter are shown at "a" in the figure. These are about the lower limit of directivity and give a gain of 8.5 db over a device of no directive properties.

For the pipe-like horns of Figure 1, the directivity increases lineally with the diameter, until a diameter of about twice the wavelength is reached. Beyond this the increase drops off, and a decrease in gain may be experienced. The lower diagram of Figure 1 represents about the maximum gain; it shows lobes being formed, at wider angles, indicating that the directivity is breaking down.

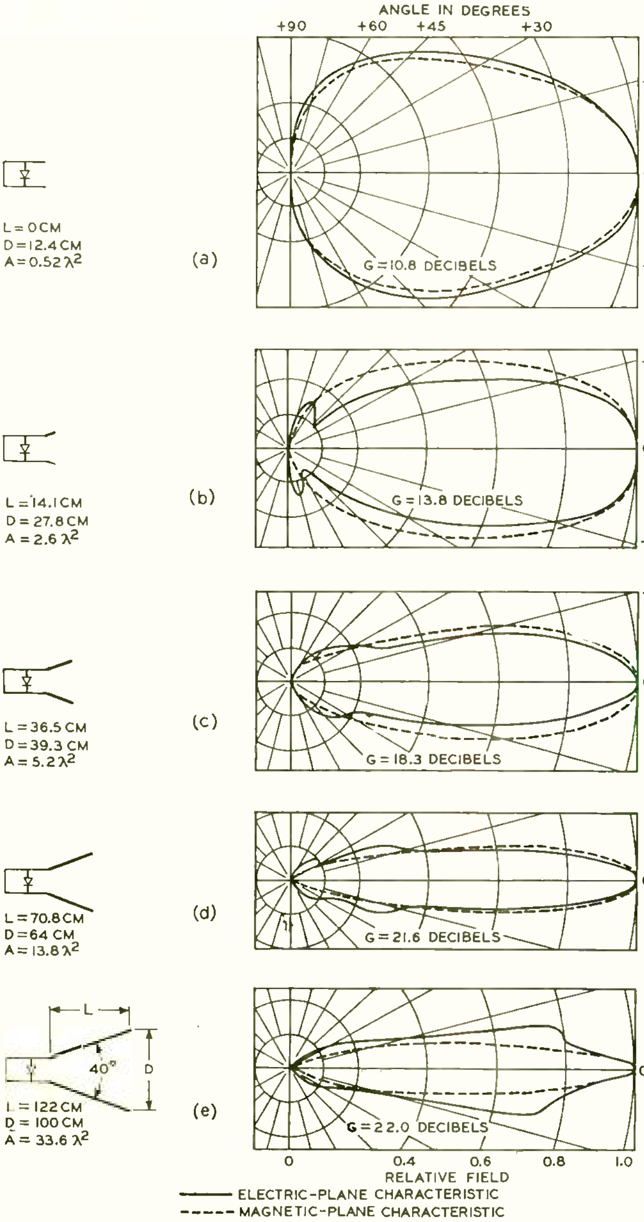


Fig. 2—Directional properties of 40-degree horns of various lengths using 15.3-centimeter waves

If a conical horn is substituted for the straight section of pipe, an increase of gain is also obtained as the opening of the horn is increased in diameter. Two factors are involved, however, for the angle, or rate of flaring, of the horn also affects the gain. Some of the results obtained are shown in Figure 3. These indicate that the most favorable angle is between fifty and sixty degrees, but this angle gives the maximum gain only for the range of lengths listed. In general, longer horns have smaller optimum angles. Another series of tests was made with horns of various diameters but all with an angle of flare of forty degrees. The results are shown in Figure 2. With a flare of this size, the optimum diameter is increased above two times the wavelength. Here again, however, there are indications that at larger diameters the gain would decrease. The shoulders of the bottom diagram of Figure 2 give evidence of this.

Since it is the ratio of diameter to wavelength that seems to be the determining factor, a horn of diameter below the optimum for some particular wavelength should give greater gains as the wavelength is decreased. Tests, with the same horn at various wavelengths, showed this to be true.

The most directive horn had a gain of some 22 db compared to a nondirectional device. This is roughly the same as the most directive antenna array at the Lawrenceville transmitting station. The very short waves launched from wave guides, however, would probably not follow the curvature of the earth, and thus would not be feasible for transoceanic telephony. The horns possess a moderately flat frequency characteristic, and should thus permit the transmission of a wide band of frequencies. At a wavelength of fifteen centimeters, the characteristic is flat to 1 db over a band width of 250 megacycles.

The results given above all apply to conical horns; but other types, some parabolic and some exponential in shape and of rectangular cross-section, were also tried. Some of them yielded gains of 28 db, and it is believed that even greater gains may be obtained.

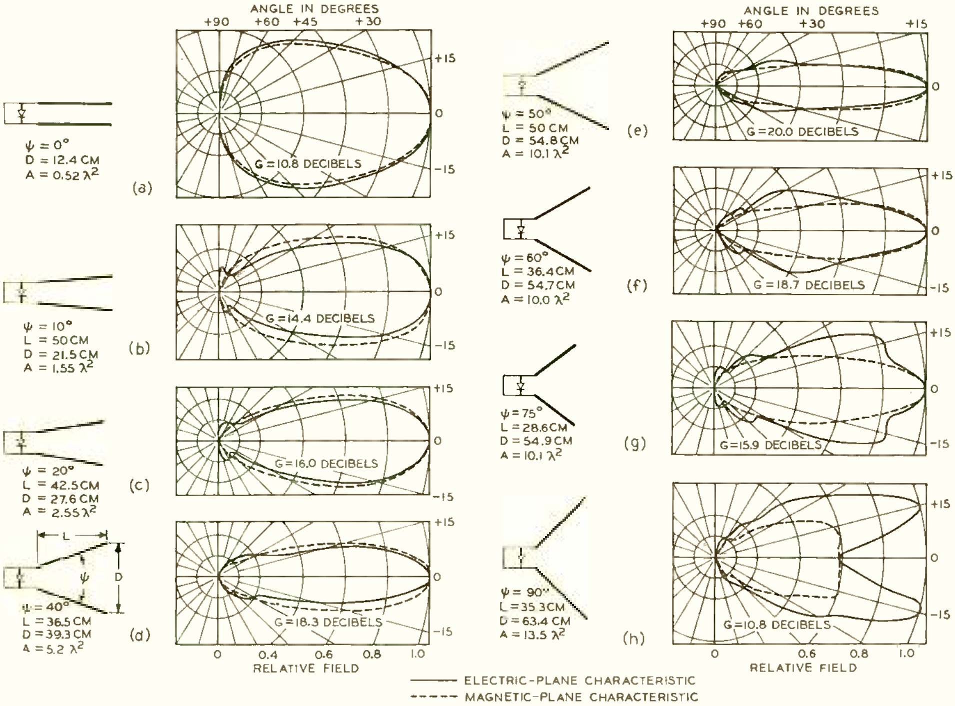


Fig. 3—Directional properties of metal horns of various angular openings (λ) *using* 15.3-*centimeter waves*

An Improved Loud-Speaking Telephone

By H. F. HOPKINS
Transmission Instruments

MANY high-quality sound-reproducing systems have been constructed in recent years with various loud-speaker elements designed to cover a wide frequency range. For the most part these systems have utilized multiple devices in which two or more loud-speaker units have been used in combination, each component unit reproducing only a part of the frequency spectrum. Other systems have been constructed in which a single loud speaker plays the double rôle of reproducing lower frequencies through a horn connected to one side of the diaphragm, and higher frequencies directly from the opposite side. In some cases, a rather wide frequency range has been reproduced, and very satisfactory quality has been obtained.

Several factors associated with sound radiation and vibrating systems have necessitated multiple systems for reproducing wide frequency ranges. The more important of these are the low-frequency radiation requirements, which demand large amplitudes even when large radiating surfaces are used; the inertia of the vibrating system which results in a loss of efficiency at the higher frequencies; and the directivity of sound radiators at higher frequencies, which is a function of the size of the radiator or diaphragm.

Multiple units generally involve complications both in the mechanical structure and in the associated circuits. These complications can be overcome by careful design, but the result is an instrument of relatively high cost. For some time a low-cost speaker of high quality, small size, and moderate power capacity has been needed. Such an instrument is required in broadcast monitoring rooms and in reproducing systems for small rooms.

Low cost and small size are most readily obtainable in a direct-radiator loud speaker: that is, one whose diaphragm radiates sound directly into the air, and which does not require a horn. To obtain the high-quality per-

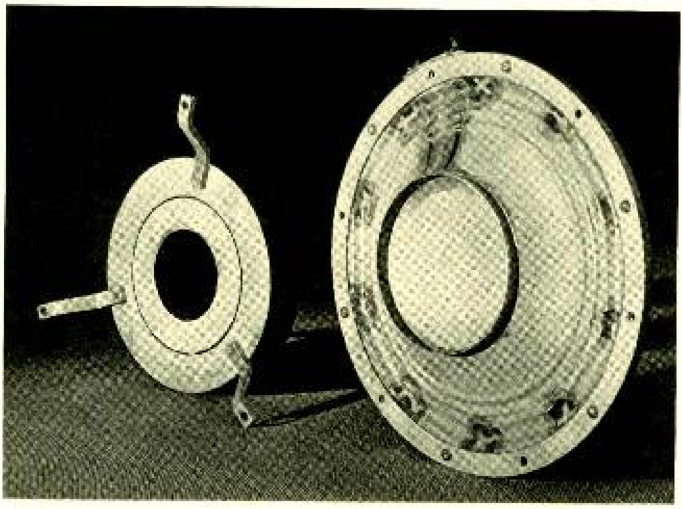


Fig. 1—The 750A loud-speaking telephone has a formed metal diaphragm, eight inches in diameter, to which a driving coil four inches in diameter is directly attached. The field is supplied by a permanent magnet

formance desired with a single loudspeaker of the direct-radiator type, the diaphragm must be small enough so that it will not be too directive at the higher frequencies. At the same time the diaphragm must be capable of operating at the large amplitudes required for radiating the lower frequencies. In addition, the effective mass of the diaphragm must be small enough to radiate the higher frequencies efficiently. Even with very thin metal diaphragms mass reaction is sufficient to cause excessive loss in the high-frequency range if the diaphragm operates as a piston: that is, if all parts of the diaphragm surface move in unison. This effect can be overcome by using a diaphragm in which all parts do not move in unison when operated at higher frequencies and such a diaphragm will radiate uniformly at all frequencies if properly designed. The problem then becomes one of determining the proper diaphragm material and shape to provide the desired high-frequency performance and at the same time to permit free piston vibration at low frequencies where large amplitudes must be provided for.

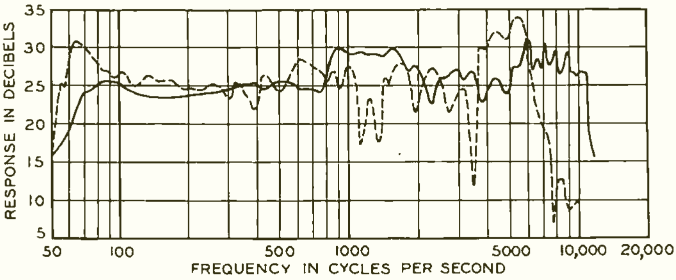


Fig. 2—Response-frequency characteristic of the 750A loud-speaking telephone in its cabinet (full line) compared with that of one of the best commercial instruments (dotted line)

Thin metallic diaphragms offered the most favorable properties for such a development as far as the desired effects are concerned but the problem of forming a diaphragm of this type, which would permit the necessary amplitudes at low frequencies, have the required high frequency performance, and be free from rattles and extraneous sounds, required considerable experimental work. The development of such a device, however, was finally successful in the Western Electric 750A loud speaker.

This instrument is a direct radiator with a formed metal diaphragm eight inches in diameter and a driving coil four inches in diameter which moves in a permanent magnet field. The loud speaker is intended for mounting in a closed cabinet of the proper design and capacity; when furnished so mounted the combination is known as the 751A loud speaker. Any cabinet of suitable design, however, may be used.

A representative response-frequency characteristic of the loud speaker when thus housed is shown by the solid curve in Figure 2. The sound pressures measured on the axis are relatively uniform from about 60 to 11,000 cycles, a frequency range sufficient for high-quality reproduction. The sound output is somewhat less uniform in the upper frequency range than for some horn-type speakers, but it is adequate for good reproduction. For comparative purposes, the response-frequency characteristic of the best commercial cone-type dynamic speaker which has come to our attention is shown in dotted line on the same drawing. Identical testing conditions were imposed in measuring the two speakers. One feature of the 750A loud speaker, the effect of which is indicated on the response curves, is the application of mechanical damping which reduces the low-frequency resonance peak so as to eliminate so-called "hang-over" effects.

An inherent limitation in a device of this type, as compared with a more elaborate combination of horn-type speakers, is the inability to control the distribution of the radiated sound. As previously indicated, the reproduction from a speaker of this type is more and more deficient in the higher frequency range as the observer moves away from the axis of the speaker. The best quality is observed within a thirty-degree angle, but satisfactory performance over a wider angle is obtained for many purposes. The diminution of high-frequency radiation is not serious up to an angle of forty-five degrees. In rectangular rooms of moderate size a single speaker usually suffices. For larger rooms, or rooms of considerable width, two or more speakers may be required for the best reproduction.

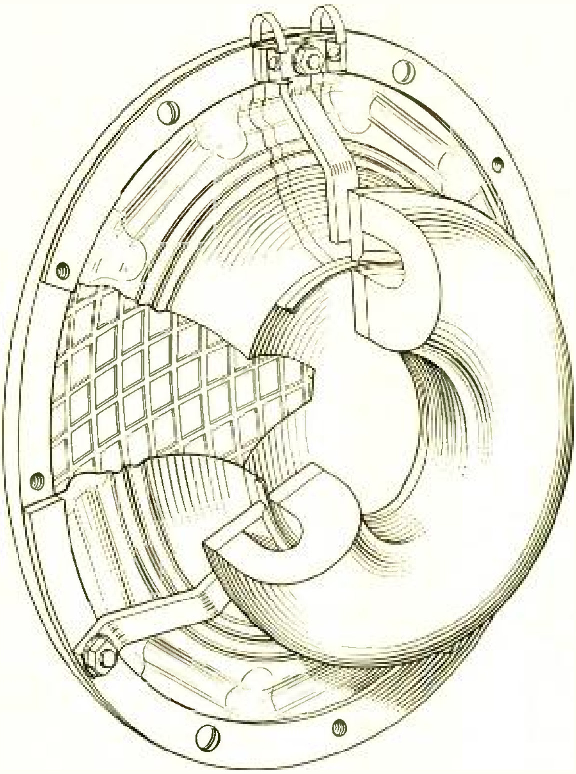


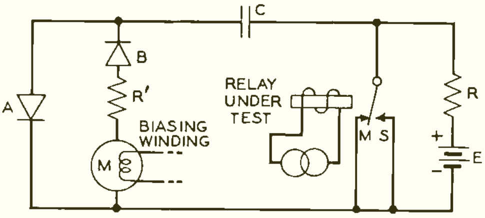
Fig. 3—The driving coil vibrates in a narrow slot in the ring-shaped field magnet

The efficiency of the new loud speaker is equal to that of commercially available cone-dynamic speakers of the same size and weight. When reproducing speech or music, it is capable of handling the maximum undistorted output of a twenty-watt amplifier at single-frequency rating.

The 750A loud speaker is not intended to replace existing multiple-unit systems, but rather to fill a long-felt need in situations where more elaborate devices are not required or may be prohibitive because of cost or size. In locations where high sound levels are not necessary, and where the angle of coverage is not too great, will reproduce speech and music with remarkable fidelity.

A Relay Chatter Meter

FOR rapid checking of contact chatter or bounce in telegraph relays, a meter has been designed by S. I. Cory which is simpler to operate and more satisfactory than an oscillograph. It counts the number of bounces of a relay armature, by measuring the charging current of a condenser which is charged once for each contact.



While the relay contacts M and S are open, the battery charges condenser C through resistance R. When the relay closes either contact the condenser discharges through the meter M. Should the armature bounce so as to close a contact more than once the meter reading will be increased. By adjusting the meter so that it reads zero at the frequency at which the armature is flipped back and forth the meter reading can be made to indicate directly the amount of chatter.

The circuit constants can be chosen so that a single instance of chatter will cause a large change in the meter indication. With a microammeter, for which the resistance is 55 ohms, this condition is met by making R, 250 ohms; E, 45 volts; C, 0.05 mf and R', 200 ohms. The rectifiers A and B are copper-oxide units. The meter will then indicate chatter which cannot easily be observed with an ordinary cathode-ray oscillograph. With other constants, the meter may be used when there will be a fairly large number of recurring bounces. Because the condenser must charge and discharge rapidly the time-constants of its circuit must be kept very low.

This simple device is applicable to many problems in the Laboratories where rapid impulses have to be counted, provided that their duration and wave form are not in question.

Contributors to this Issue

A. P. KING received the B.S. degree in physics and engineering from the California Institute of Technology in 1927. After three years with the Seismological Laboratory of the Carnegie Institution, he joined the Laboratories. Since then he has been at the Holmdel Laboratory where he has been engaged in research work on ultra-high frequencies.

J. M. DUGUID graduated from Stevens Institute of Technology in 1922, receiving the degree of Mechanical Engineer. Prior to graduation he worked during summer vacation with the Testing Laboratories of the Public Service Electric Corporation of New Jersey on electric power-plant testing. Upon graduation he had a few months' training in the Installation Department of the Western Electric Company and then joined the technical staff of the Laboratories where he was assigned to the Equipment Development Department. Since then he has been with the group working on the development of telephone power plants where he has been mainly concerned with ringing equipment.

E. J. MURPHY was graduated with the B.Sc. degree from the University of Saskatchewan in 1918. He studied engineering at McGill University in 1919 and 1920 and physics at Harvard University in 1922 and 1923. Following this he joined the Laboratories and has since been engaged in various investigations of the properties of dielectrics.

J. E. NIELSEN graduated from the Royal Technical College in Copenhagen, Denmark, in 1924 with the degree of B.S. In 1926 he joined the Technical Staff of the Laboratories as a member of the Apparatus Development Department. Mr. Nielsen has been engaged in the development of

A. P. King

J. M. Duguid

E. J. Murphy

J. E. Nielsen

H. F. Hopkins

R. O. Soffel

H. R. Moore

equipment for measuring attenuation, crosstalk and, more recently, impedance at high frequencies.

H. F. Hopkins joined the Laboratories in 1919. After completing the Technical Assistants' Course he continued his education at the Polytechnic Institute of Brooklyn, where he received an E.E. degree in 1932. His work has been chiefly concerned with the design and development of loud speakers and other special-product instruments.

R. O. Soffel joined the Laboratories in 1927, and took the Student Assistants' Course. Upon completing the course in 1930, he transferred to the Systems Development Laboratory where he has since been engaged in the development of subscriber pulsing circuits, in fundamental studies of condenser-timed relay-interrupter circuits, and on other panel circuits.

H. R. Moore received the A.B. degree from the University of Missouri in 1924 and remained there a year as a graduate student and Assistant in Physics. In 1925 he joined the magnetics research group of the Laboratories. After a brief absence from the Bell System, he engaged in low-frequency induction and shielding problems with the protection group of the Department of Development and Research which was consolidated with the Laboratories in 1934. Since 1936 he has been concerned in carrier systems development with the Transmission Development Department and has been field engineer for Type-J trials.