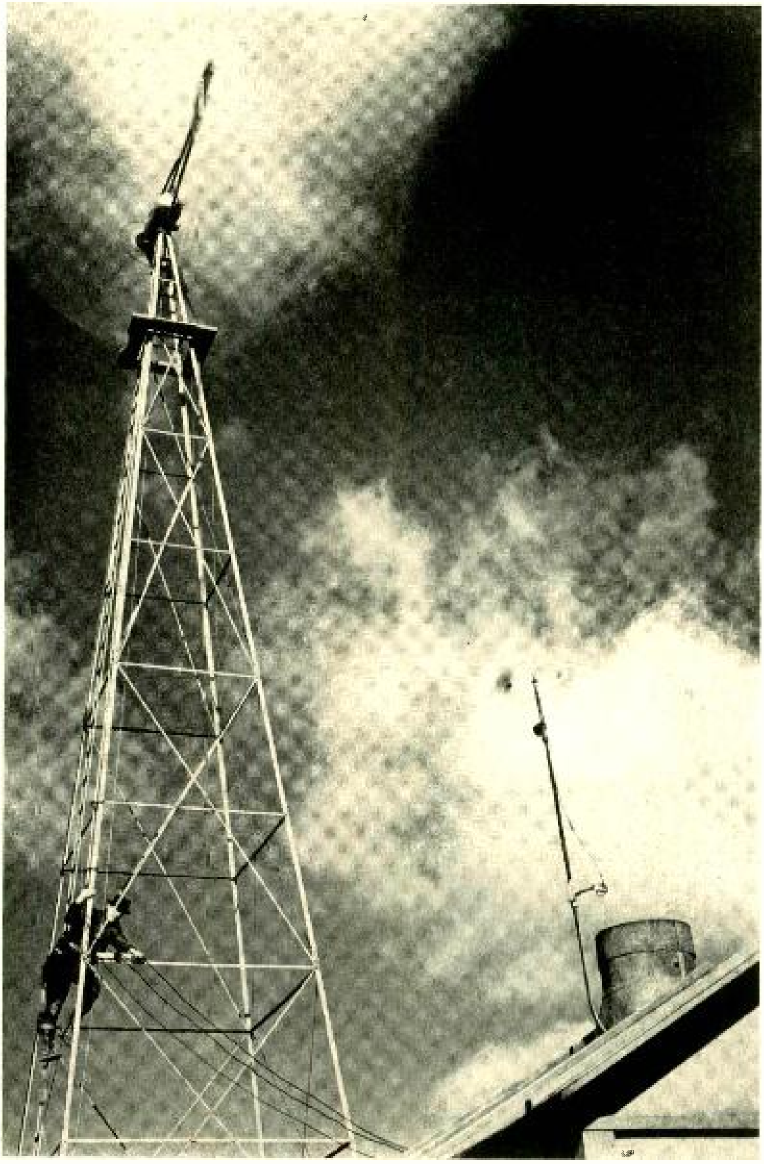
BELL LABORATORIES RECORD



MARCH
1938

VOLUME XVI

NUMBER VII

The wind may prove a power source for repeater stations on the southwestern deserts

Applying the Type-H Carrier Telephone System to Railroads

By J. T. O'LEARY
Toll Transmission Development

FOR a number of years the telephone has found increasing use in railroad communication systems, and the Bell System, with its long background of telephone experience, has naturally been solicited for help in solving the problems that have arisen. Several of the development problems solved by the Laboratories have previously been discussed in the RECORD.*

Traffic growth during recent years, coupled with the need for faster train movements, has accelerated the demand for additional facilities, and many inquiries have been received from railroads concerning the application of carrier systems to railroad lines. The recent development of the H-1 carrier system* makes available a system that can be applied to railroad lines with a minimum of modification of their existing facilities, and several railroad installations have already been made. The new carrier system is also finding application among power, oil and pipe-line companies, some of which provide their own communication networks.

This new system provides a single additional channel and has the advantage of requiring little space at the terminals. Its top frequency is only

*RECORD, *April*, 1932, *p.* 283; *May*, 1934, *p.* 281; *and Feb.*, 1936, *p.* 198.

*RECORD, *November*, 1937, *p.* 76.

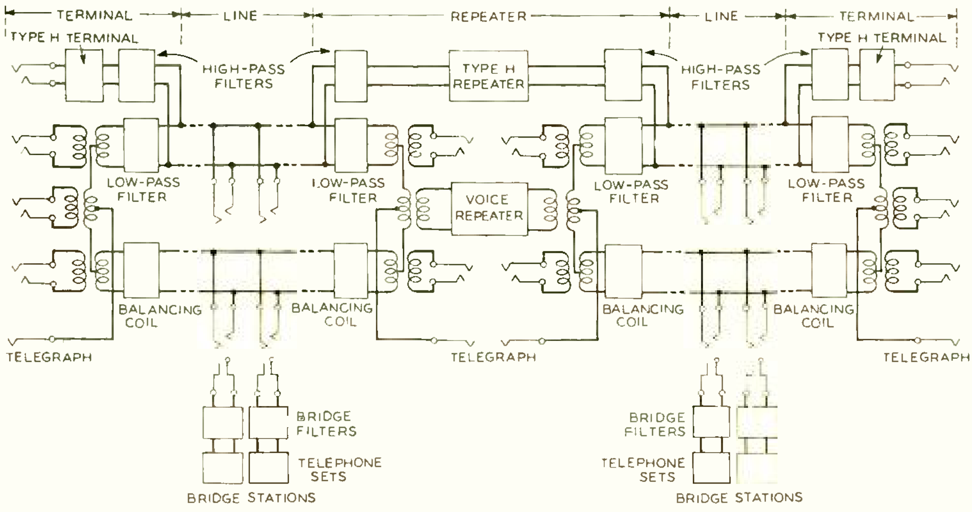


Fig. 1—Application of the type-H carrier system to one side circuit of a railroad dispatching phantom group

about ten kilocycles so that the line attenuation is comparatively small, and the variation in line loss between dry and wet weather is minimized. As a result fairly long distances can be spanned without repeaters, and the problem of regulation is simplified. The low upper frequency also results in less crosstalk, with the result that there is better chance of operating more than one system on a pole line without extensive changes in the line transposition system. With a low upper frequency, the impairments introduced by short sections of cable in the line are less serious, and remedial measures, such as loading, are less costly. In addition the new system operates on a-c as well as on d-c, which simplifies the installation of terminals and repeaters where the usual telephone office battery supply is not available.

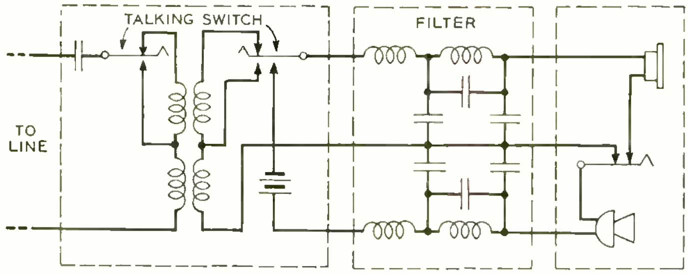


Fig. 2—Bridging arrangement at a way station, showing the filter employed to minimize interference between the voice-frequency and carrier channels

Although the railroads have need for a variety of types of circuits, for the most part they are either dispatching circuits with telephone sets bridged at each station along the line, or through trunk circuits used for communication between main railroad centers. When a type-H carrier system is applied to an open-wire pair used as a trunk circuit between two points, the application of the system differs very little from its use in the Bell System. The carrier apparatus is connected to the line at terminals and repeater points through line filters, which prevent interference between the carrier and voice circuits. The principal difference is that in the railroad case the systems are likely to be used for longer distances than in Bell System practice and therefore more frequently require the use of repeaters. Intermediate cables will also be found more frequently on the lines of the railroad companies.

A large percentage of the applications, however, will not be on trunk circuits. A circuit layout which is very common in the railroad communication plant is a phantom group arrangement, on which only the phantom is used as a trunk circuit, and on which the side circuits are equipped with bridged telephone sets at intervals along the route. These bridged sets permit the train dispatcher or others at the control points to communicate with intermediate signal towers, passenger stations, and switch points. Telephones are frequently mounted in boxes on the poles at sidings and other remote points from which it is desirable to have the train crew call in for orders from the dispatcher.

A layout showing a carrier system applied to one side circuit of such a phantom group arrangement is given on Figure 1. One intermediate carrier repeater is shown. The system is applied to the line in the conventional manner by means of line filters. Networks are shown in the other side circuit to preserve the phantom balance to ground. At the carrier repeater

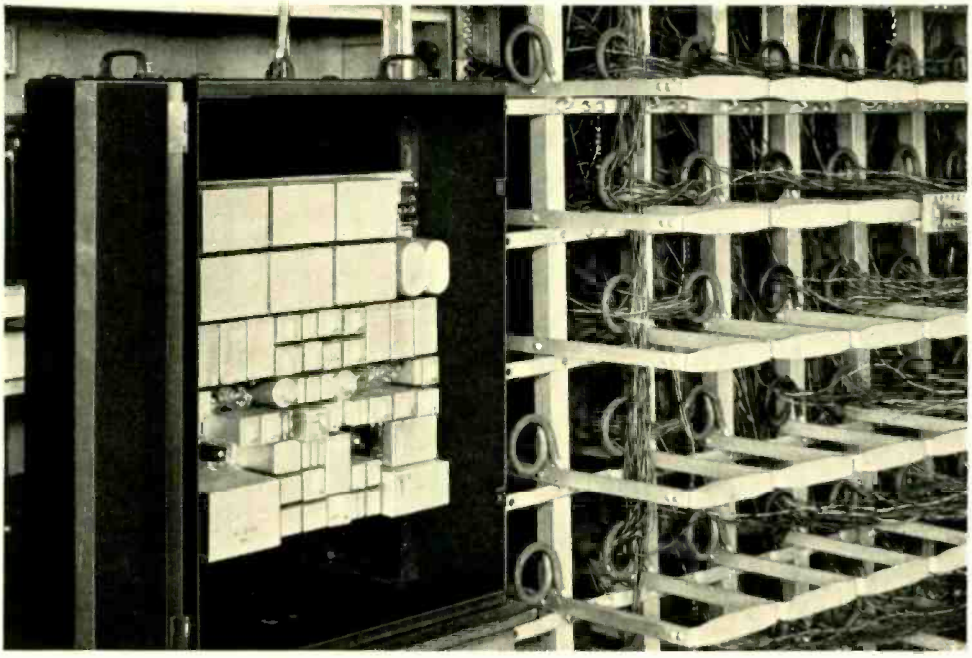


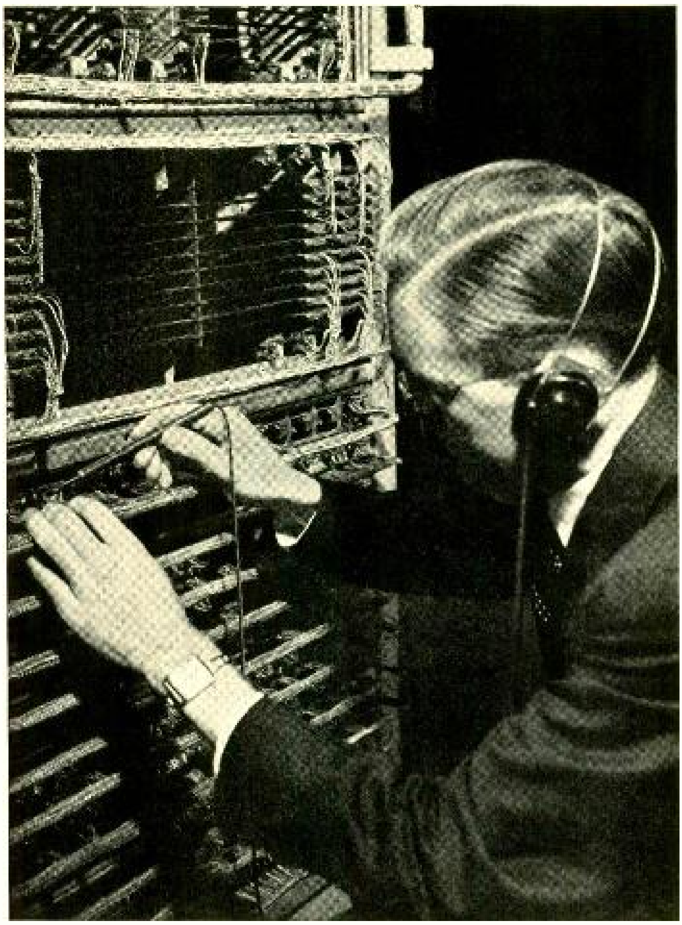
Fig. 3—Boston terminal equipment installed for the New Haven railroad

point the phantom circuit is shown as connected through by means of a telephone repeater. The other circuits are shown as terminating. Any or all of these could, of course, be connected through, either with or without repeaters, as required. When telephone repeaters are used, appropriate equipment is added to the repeater balancing circuit.

The presence of the bridged telephone sets on the side circuit used for the carrier introduces several problems. The carrier sidebands may not only be audible in the telephone receiver, but there will also be a tendency for them to demodulate there against the small carrier leak that will be present. The higher frequency components of the speech and signaling currents from the bridged station will tend to interfere with the carrier. A filter is necessary at each bridge station, as shown, to minimize this mutual interference. This filter must also keep the bridging loss to the through carrier circuit very low at each point, since the aggregate of a large number of such stations might be fairly serious. This latter condition must hold irrespective of whether the telephone subset at that particular point is in the talking, monitoring, or "on the hook" condition.

A filter to meet these requirements has been developed for use with the 501-type way-station telephone set. Its circuit is shown in Figure 2. Actually there are two filters involved, one for the transmitter and the other for the receiver. The large change in the subset impedance when switching from talking to monitoring makes the separate filters desirable.

Shortly after the type-H system was developed, trial installations were made on two railroads to obtain a better picture of the performance of the system under typical operating conditions. Both of these systems are now in regular operation and are giving satisfactory service. One is on the line of the New York, New Haven and Hartford Railroad between New Haven and Boston, a distance of about 150 miles. The Boston terminal equipment is shown in Figure 3. An intermediate repeater is located at Providence. The presence of the repeater in this short distance is accounted for by the fact that about 21 miles out of the total of 150 miles is in non-loaded cable. This system is applied to one side circuit of a phantom group, and there are no intermediate way stations bridged on the voice circuit. The other trial system is on a line of the Missouri Pacific Railroad between Little Rock and Fort Smith, Arkansas, a distance of about 175 miles. The circuit to which the type-H system is applied in this case is used for train dispatching, and there are about twenty stations along the line at which the special filters described above are required.



Testing the line link circuit in the local crossbar system laboratory

Hearing Impairment and Sound Intensity

By M. B. GARDNER
Physical Research

WHEN an otologist of a few decades ago needed to make a hearing test he might choose to talk at various distances from his patient, to click two coins, or blow a whistle, or hold a watch near his ear. These classical methods, and the audiometer technique which is gradually replacing them, concerned themselves with the threshold of hearing; that is, the minimum audible sound in quiet surroundings. Average threshold intensities having been determined for people of normal hearing, the ratio between the normal and an observed value is taken as the degree of hearing-impairment. This ratio, expressed in decibels, has been found significant in the diagnosis and treatment of deafness, and generally as a measure of an individual's perception of sound-waves.

Recently a new approach to the measurement of hearing impairment has been made by determining the hearing loss for sounds that have intensities above the threshold. In this study persons with one normal and one impaired ear were asked to balance a tone heard by the normal ear against the same tone heard with the impaired one. When the tone was just perceptible in each ear, the intensity levels became the usual threshold measurements. For louder tones, the excess intensity required for the impaired ear gave its hearing loss at that particular intensity. After a number of people had been tested, it became evident that in some cases the hearing loss was constant for all levels, while in others the loss became less as the level was raised.

In Figure 1 a typical case of so-called constant-type hearing loss is illustrated. The upper left-hand chart shows an ordinary air-conduction audiogram for an essentially normal ear. The circles in the right-hand chart give the loss for the impaired right ear of the same individual. The three lower charts show the levels above threshold on the impaired and normal ears for equal loudness. Since zero level corresponds to the normal hearing threshold of the Western Electric audiometer, the scale gives db above normal threshold. The observed data are shown by the circles. If both ears are normal at all levels the circles should fall on the dotted line through the origin. The horizontal displacement of the points to the right of this line are the hearing losses of the impaired ear for the corresponding levels above threshold.

Figure 2 illustrates a case which showed for a 2000-cycle tone an unusual degree of recovery at the higher intensities. The left-hand chart gives the hearing loss for the left (x) and the right (o) ears. The circles in the right-hand chart indicate the levels which have to be applied to the normal (right) and the impaired (left) ears, respectively, to produce the

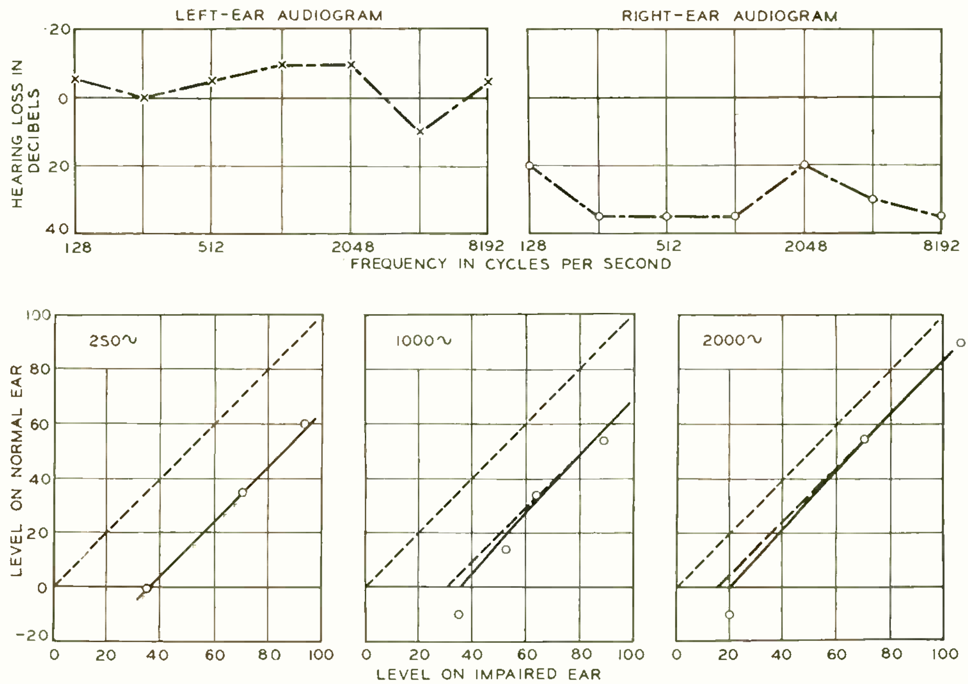


Fig. 1—The two ordinary air-conduction audiograms (above) show that the right ear is defective. The displacement of the curves (below), relative to the dotted lines, indicates that the deafness is of the constant type

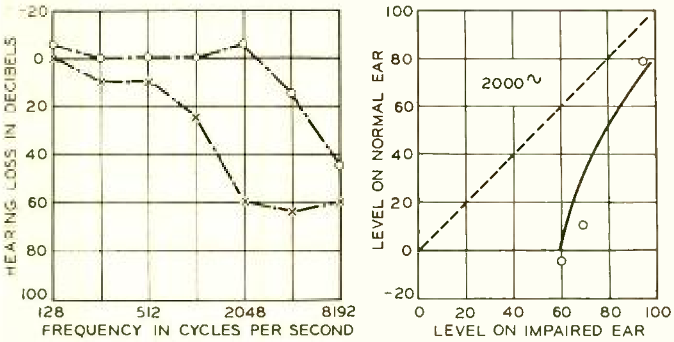


Fig. 2—The audiogram at the left gives the characteristics of the left (x) *and right* (o) *ear. The relative levels required for equal loudness on the normal and impaired ears, shown plotted on the right graph, indicate that the deafness is of the variable type, since it disappears for loud sounds*

same loudness in each. The displacement of the points to the right of the dotted line indicates the amount of loss at the various levels above normal threshold. It will be seen that this loss decreased from sixty db at threshold to approximately fifteen db for high-intensity levels. The recovery is not complete but theory indicates that the maximum possible variation in respect to level has taken place in this case.

Figure 3 shows the effect of a combination of the constant and variable types of deafness. The amount of the constant type is indicated in the lower charts by the displacement of the dashed line to the right of the dotted line. The variable type impairment loss is the difference between the x-axis intercepts of the

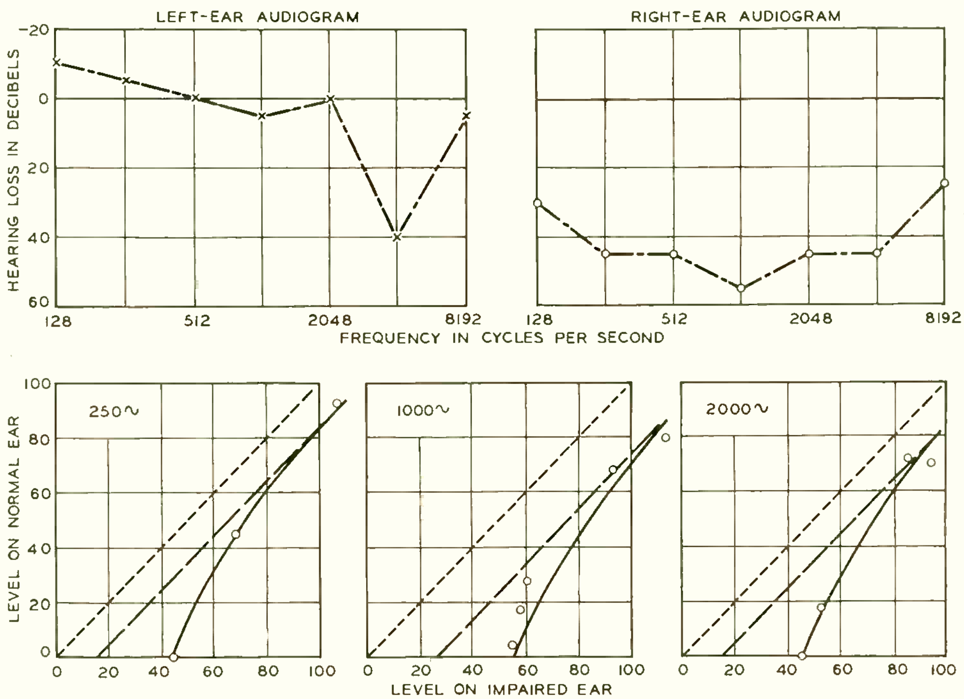


Fig. 3—The relative level measurements on the defective right ear show that the deafness in this case is a combination of the variable and constant types because it decreases for loud sounds but does not disappear

solid and dashed lines.

That a person with normal hearing experiences the variable type of hearing loss in the presence of noise has been shown by masking tests with thermal noise.* In this test a normal observer wore a head-band which held a closely fitting receiver to each ear. Into one of the receivers thermal noise was introduced in an amount just sufficient to mask a tone forty db above threshold. The observer then adjusted a pure tone in the other (unmasked) ear until it sounded as loud as a tone of the same frequency heard in the masked ear. As the pure tone and the thermal noise were very different in tonal character it was not difficult to sense the loudness of the tone when heard in the presence of the noise. The results of the tests are given in Figure 4 where the x-axis shows the level of tone on the masked ear and the y-axis that on the unmasked ear for equal loudness. The individual results of three to four observers are plotted for the level which caused a masking effect of approximately forty db. The data show definitely that the loss due to noise is of the variable type.

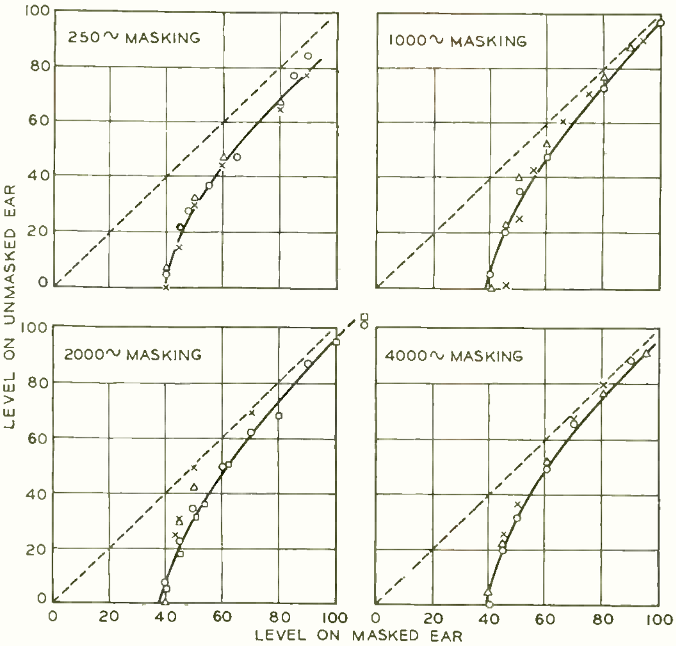


Fig. 4—Experiments on persons with normal ears showed that hearing loss due to masking is of the variable type

It is now not difficult to understand why individuals with impaired hearing often comment on their ability to hear better in the presence of noise. They do, but the noise itself does not make the impaired ear more sensitive to sounds that could not otherwise be heard. The improved intelligibility results from the increased level of conversational speech in a noisy place. The noise introduces an artificial deafness in the normal ear, and the person with normal hearing raises his voice to compensate for this induced loss so that he himself may hear. That the voice is raised in the presence of noise considerably more than one realizes becomes evident when the noise ceases abruptly and the speaker finds he has been literally shouting.

A simple test which will prove to a deafened observer that noise does not improve his hearing can be made by dropping a coin on a hard surface both in the presence and in the absence of noise. It will be found that the average distance that the coin must be dropped to be just audible will never

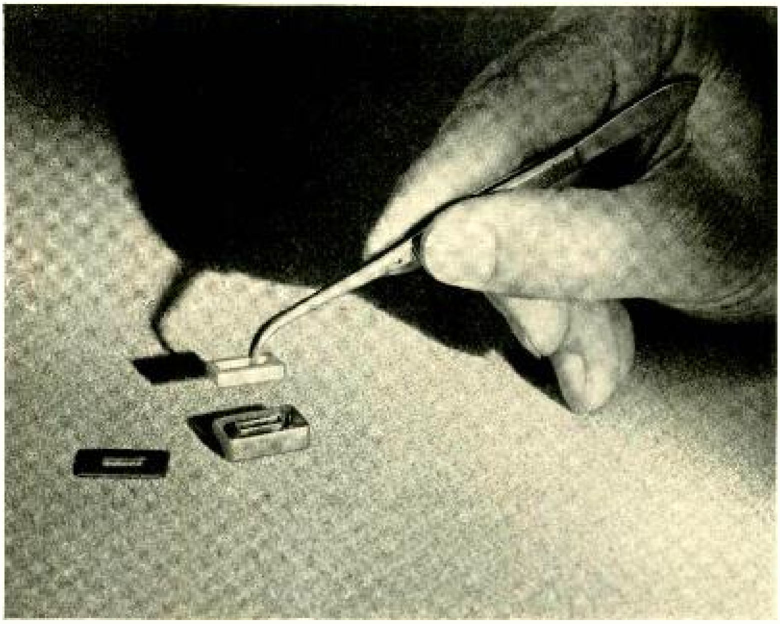
*Thermal noise is an unpitched sound obtained from the potential generated by the thermal motion of electrons. It is frequently heard as background noise in high-gain vacuum tube circuits and is somewhat similar to the noise of escaping steam.

be less in the presence of noise. This would not be the fact if noise improved the hearing.

Deafened observers also comment on the tendency of raised speech to become annoying, particularly when the level is high enough for the weaker speech sounds to be heard. This can be explained if the hearing loss is of the variable type. For example, in the case illustrated in Figure 3, a twenty-db increase in level above threshold in the right ear results in a forty-db increase in loudness even though only part of the impairment present is variable. When someone shouts, a person having a preponderance of this type of hearing impairment suffers practically as much discomfort as a person with normal hearing would under the same circumstances.

The hearing losses described in this article are representative of the impairments usually encountered, but the combination of one normal and one impaired ear is rather infrequent. Ordinarily the impairment of both ears is of somewhat the same character and consequently such observers cannot be used for direct subjective comparisons of differences in the sound perception of the normal and impaired ear. The presence of this unilateral hearing loss presents an only recently appreciated method of approach to this general problem.

Laboratories expenditures are recorded and summarized by these Hollerith Key Punch Machines. The original data are transcribed on tabulating cards in the form of punched holes



Higher Magnetic Permeabilities

By R. M. BOZORTH
Physical Research

SINCE the discovery, over twenty years ago, that certain alloys of iron and nickel have remarkable magnetic properties, the factors which control the unusual behavior of these materials have been carefully studied at the Laboratories and elsewhere. One of the outstanding characteristics of these alloys is their high magnetic permeability*—hence the name permalloy. Recently, by combining in a single material several of the factors on which high permeability depends, a substance has been obtained experimentally which has ten times the permeability of the best commercial permalloys available.

*The magnetic permeability of a substance is defined as the ratio of the magnetic flux density through the substance to that through air for the same magnetizing force.

The material used was a single crystal of permalloy which contained sixty-six per cent nickel. This was purified by heat treatment at a high temperature in hydrogen, cut so that its permeability could be measured accurately in a chosen direction in the crystal, then heat-treated again at a high temperature and finally at a relatively low one in a magnetic field. After this preparation the permeability of the crystal was 1,330,000. An idea of what this means can be gathered from the fact that a magnetic field strength equal to one per cent of that of the earth will make the flux through the crystal's four square millimeters about equal to that through a square foot of the earth's field.

The starting point for this experiment dates back several years to the time when permalloy was first heat-treated in a magnetic field* after it had been purified in hydrogen at a high temperature†. This treatment increased the permeability to over 500,000. The next step was to prepare a single crystal of this alloy and measure it parallel to one of the crystal axes, since it magnetizes especially easily in that direction. Such a single crystal was made by P. P. Cioffi by slowly cooling the pure molten alloy through the freezing point, 1450 degrees Centigrade, in an atmosphere of pure hydrogen. The crystal axes, as shown in Figure 1, were located by F. E. Haworth by means of X-Rays.

To measure high permeabilities with accuracy it is desirable to have a closed magnetic circuit so that there will be no free magnetic poles to counteract the applied field. Usually this is done by cutting the specimen in the form of a ring, but it is obviously impossible to cut a single crystal so that the circumference of the ring will always be parallel to a crystal axis. H. J. Williams overcame this difficulty by cutting the specimen in the form of a hollow rectangle oriented so that each side was parallel to one of the cubic axes of the crystal. A photograph of the crystal after this had been done is shown in the headpiece and a drawing which illustrates the method of cutting with respect to the crystal axes is given in Figure 1. The specimen was etched lightly with acid to remove surface strains which might have resulted from the cutting, and then annealed for eighteen hours at 1300 degrees Centigrade in an atmosphere of pure hydrogen.

Before further heat-treatment the rectangle was wound with wire so that a field could be produced in it by passing a current through the wire. It was then maintained at 500 degrees Centigrade in a field of ten oersteds, after which it was cooled to room temperature. These last two treatments were repeated several times, and the B-H curve of Figure 2 was then obtained in the laboratory by O. L. Boothby. These measurements gave the maximum permeability of 1,330,000.

The chief value of these experiments at present is that they confirm the principles which have been arrived at by other studies, and, as a result, show that the separate factors which determine the remarkable magnetic characteristics of the permalloys are additive in their actions.

Factors which favor ease of magnetization are (1) absence of strains associated with hard-working, dissolved impurities and grain boundaries; (2) choice of a proper crystallographic direction for magnetization; (3) presence of a magnetic field in the direction chosen for test; (4) appro-

*Record, *April*, 1936, *p.* 265.

†Record, *January*, 1932, *p.* 159.

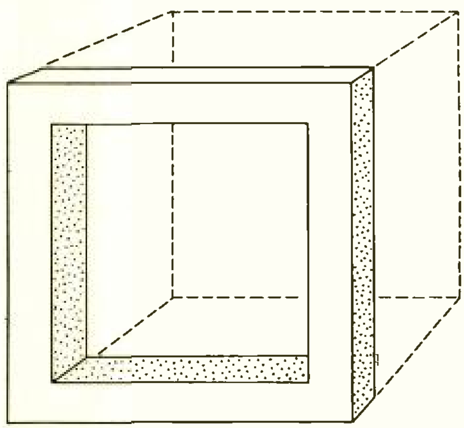


Fig. 1—*To make it magnetize easily the permalloy crystal was cut in such a manner that each side of the rectangle was parallel to one of the cubic axes of the crystal* priate composition for the application of (3). In reference to the last two items, it should be stated that heat-treatment in a magnetic field is applicable only under limited conditions which in the iron-nickel alloys occur in compositions ranging between fifty and eighty per cent nickel. There appears to be no upper limit to the value of maximum permeability although there is a limit to the saturation of magnetization attainable and possibly also to the initial permeability.

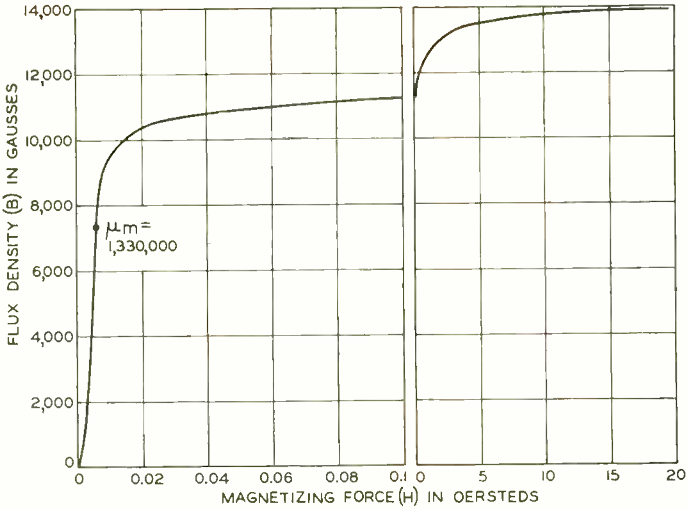


Fig. 2—B-H curve of permalloy crystal after heat-treatment in a magnetic field. The permeability was 1,330,000, *coersive force* 0.0007 *oersted and remanence* 10,400 *gausses*

Although it seems improbable now that commercial use will be made of single permalloy crystals, some of the factors which make for high permeability, such as crystal orientation, heat-treatment and chemical composition, are commonly used in manufacturing magnetic materials. Recently one or more concerns outside of the Bell System have begun to roll transformer sheet so that the crystallographic directions of easiest magnetization are aligned in desired directions with respect to the dimension of the sheet. There is the distinct possibility that heat-treatment in hydrogen at a high temperature, and in a magnetic field at a relatively low temperature, will some time be of value commercially.

The Willard Gibbs Medal

for 1938 *has been awarded to R. R. Williams, Chemical Director of the Laboratories, for "outstanding work in connection with the study and isolation of the beriberi vitamin (B_1)." This medal, founded by William A. Converse in* 1911, *is administered by the Chicago section of the American Chemical Society and awarded by a national jury of scientific men.*

Experimental Results from the Musa

By C. F. EDWARDS
Radio Research Department

OF the several difficulties which must be overcome in long-distance communication circuits, two of the most serious are noise and distortion. This is especially true of radio circuits, where no control over the connecting medium is possible, and where one is obliged to make the best use of whatever facilities nature provides. The development of the musa, described in previous articles,* permits the problem of reception to be attacked on a more fundamental basis than heretofore. By providing a highly directional and steerable antenna system for multiple-path reception, the musa gives substantial improvement both in signal-to-noise ratio and in distortion, as compared with existing facilities. That an improvement in both respects may be secured by the musa is evident from its design features, but the amount of improvement is only approximately calculable, and experimental results are needed to verify the correctness of the design, and to insure that important factors have not been overlooked.

Of the various improvements in reception that the musa should give, the increase in the signal-to-noise ratio is most readily subject to calculation. The musa consists of a number of directional antennas laid out on a straight line along the horizontal direction of the incoming signals. When a musa branch is steered to the vertical angle of an incoming wave, the signals picked up by all the antennas will be added "in phase" at the receiver, while noise—coming from all directions indiscriminately—will be in random phase relation. If N is allowed to stand for the number of the antennas in the array, it can be shown that the improvement in the signal-to-noise ratio will be proportional to $\sqrt{N}$, and expressed in decibels will thus be 10 log N. Since there are six antennas in the experimental musa, the improvement to be expected is of the order of 7.8 db.

To determine this improvement experimentally, a circuit was set up for determining the signal-to-noise ratio, and a switching system was provided to transfer this measuring circuit back and forth between the musa and a conventional single antenna system. The measuring circuit includes two meters: one to show the amplitude of the received carrier, and the other that of the demodulated noise output. Since noise cannot be measured in the presence of a demodulated signal, it was necessary to assume that the signal was proportional to the received carrier. By a series of such measurements, made alternately on the musa and single antenna, a measure of signal-to-noise improvement is obtained.

A set of such measurements made over a period of two and one-half minutes is shown in Figure 1, and gives a very good idea of the improvement that a musa system the size of that used experimentally makes possible. Adjustments were made so that the

*RECORD, *January*, 1938, *pages* 148 *and* 153, *and February*, 1938, *page* 203.

carrier output of the musa and the single antenna were the same, and thus the lower level of the noise from the musa system is plainly evident. As can be seen the noise is reduced some seven or eight db with the musa, which is in good agreement with the calculated value of 7.8 db. The sharp rises in noise are due to the action of the automatic gain control on carrier fades, and it will be observed that this rise is much more pronounced when a single antenna is used than it is with the musa.

The distortion of speech and musical quality that characterizes short-wave circuits is due entirely to the interference of differently delayed waves, each of which is essentially free from all kinds of distortion except non-selective fading. These differences in delay are caused by the multiple paths that the signal travels between transmitter and receiver. In general there are a number of more or less discrete paths resulting in delay differences of the order of one or two milliseconds, and the angles of reception of these different paths will differ by several degrees. With reception by a single antenna, these delay differences over the several paths result in considerable distortion, since frequencies over the signal band combine in varying phase relation at the receiver output. With the musa, on the other hand, each of the multiple signals is picked up by a separate branch of the musa, and combined substantially in phase at the receiver.

In so far as the reception of these multiple signals is concerned, therefore, this form of distortion is materially reduced by the musa. It is found, however, that the signals over the discrete multiple paths suffer more or less scattering with the result that they appear as bundles of waves of various degrees of compactness. These bundles possess a small spread of both angle and delay. The delay interval included in a bundle of waves is rarely less than 100 microseconds. Double refraction or "magneto-ionic splitting" occurring in the ionosphere doubtless accounts for the existence of a small minimum delay. The quality associated with one musa branch which selects one out of several bundles of waves is thus not perfect, but the major distortion due to multiple transmission paths is greatly reduced.

To determine experimentally the extent to which the musa reduces this distortion, a number of tests were carried out with the coöperation of the British Post Office, in which the voice-frequency characteristics of the musa

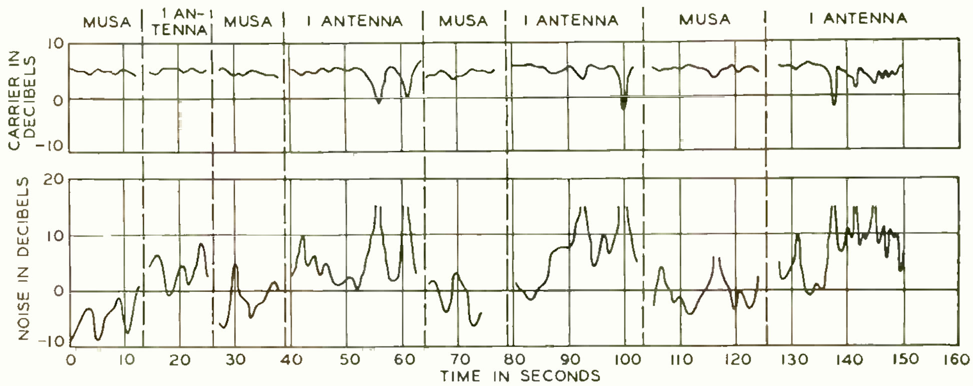


Fig. 1—Relative value of noise with the musa and a single antenna

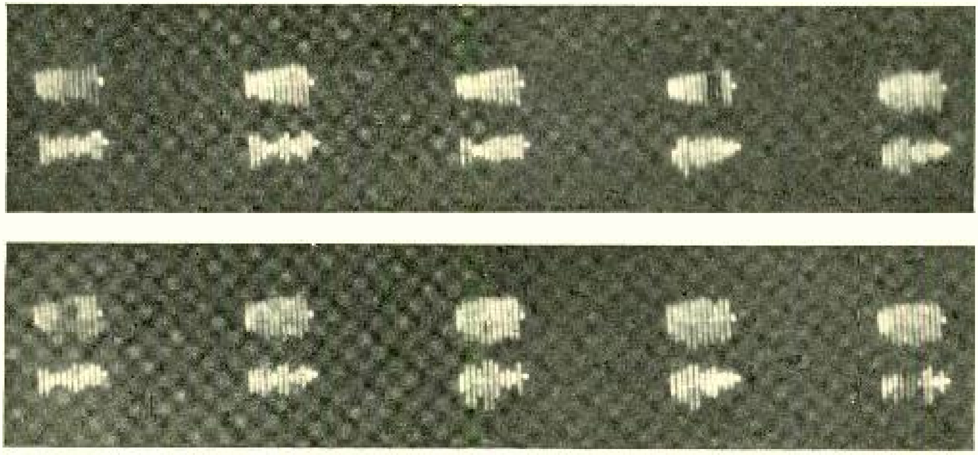


Fig. 2—Oscillograph patterns of eleven tones as received by the musa, above, and by a single antenna, below

output and of the output of a single antenna were alternately measured in rapid succession. This was accomplished by transmitting eleven non-harmonically related tones, which were separated by filters at the output of the receiver, and commutated to appear successively on an oscilloscope. Immediately after a pattern is executed for the musa, the receiver is switched to the single antenna and the pattern for it is exhibited below that of the musa.

A set of such oscilloscope patterns is shown in Figure 2, where the musa patterns are above, and those of the single antenna, below. The eleven lines of each of these patterns represent the eleven tones—the lower frequency of 425 cycles being at the left and the upper of 2125 cycles at the right. It will be noticed that while the patterns for the musa are not perfect, they are greatly superior to those of the single receiver. The increased naturalness that results from a reduction in distortion is, of course, pleasing to the ear, and gives improved intelligibility, particularly when noise is present. This increased intelligibility cannot be definitely evaluated, but in certain cases at least it permits the signal-to-noise ratio to be two or three decibels lower.

A check was obtained on the principles underlying the design of the musa by receiving signals from a broadcasting station in Halifax, Nova Scotia. This station is 643 miles from Holmdel, and nearly on the great-circle path to London. At the time of the tests, it was operating on a wave-length of forty-nine meters. Because of the relatively short length of this circuit, it exhibited a degree of stability not ordinarily encountered in transatlantic circuits. Two wave bundles were generally received, and their earth-angles and delay differences remained sensibly constant over considerable periods. Since the distance between transmitter and receiver is known, it is possible by measuring the angle of arrival of the two bundles to calculate the delay for various numbers of reflections and for assumed conditions over the transmission path. This was done, and then the delay difference was measured by the musa. The two sets of figures were in general found to agree closely. In many instances the agreement in delay was within a tenth of a millisecond. Large discrepancies were sometimes found, but these were probably due to horizontal non-uniformity in the ionosphere so that the underlying assumptions no longer applied.

Short-wave propagation from England is, of course, subject to greater variation, and is more complex than that from Halifax. In studying transmission over this path, therefore, the pulse method of analysis* was used to advantage. In this method, pulses of carrier of about two tenths of a millisecond in duration are sent out from the transmitter at the rate of fifty pulses per second, and provision is made at the receiving station for viewing the received pulses on a cathode-ray oscilloscope. Due to multiple path propagation, a single pulse sent out from the transmitter will appear as a number of successively delayed pulses at the receiver, the number depending on the number of transmission paths.

A number of such oscilloscope records made when two wave bundles were present is shown in Figure 3. The top trace is a 1000-cycle timing wave, and the center and bottom traces show the outputs of two separate musa branches, each receiving at a different angle. Without the sharp directivity of the musa, the two pulses would appear in both outputs. The presence of only one pulse in each output, as in most of the oscillograms of Figure 3, shows that the musa system performs its function properly. Occasionally the pulse in the upper trace appears in the lower trace also. This is due to the fact that, contrary to the normal operating procedure, unequal gains were employed in the two branches which renders the branch receiving the weaker pulse less able to exclude the stronger one. Automatic gain control was not used during these tests, and as a result the oscillograms show some fading on the two paths, although usually not on both at the same time.

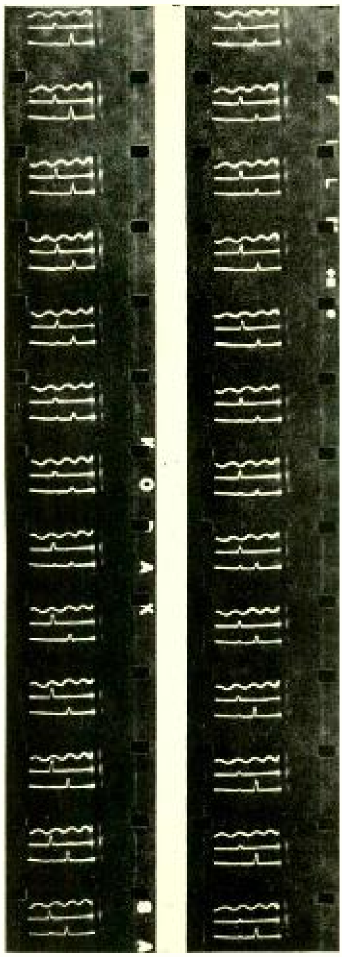


Fig. 3—Oscillograms of a pulse travelling over two paths and received by two branches of the experimental musa system

In addition to special tests, such as those described, routine observations on transatlantic signals have been made over a period of more than two years. It has been found that the number of paths as well as the average angle of arrival increases with decreasing frequency. While at eighteen megacycles a single bundle of waves at eight or ten degrees is common, at nine megacycles two or three bundles at from ten to twenty degrees are generally received. These factors are subject to wide variations as conditions affecting transmission change, and, consequently, only the broadest generalization can be made.

*Record, *June*, 1934, *p.* 305.

Permanent Magnet Machines for Telephone Offices

By R. D. de Kay
Power Development Department

FOR supplying ringing current to telephone offices, motor-driven 20-cycle alternators are commonly employed. In the larger sizes, these alternators are self-excited—a commutator being employed to rectify part of the output for supplying the field windings. In most offices a-c motors are normally used to drive the alternators to avoid adding load to the central office battery and to take advantage of the lower cost of a-c power. These alternator sets are made in several sizes, but one of the smallest—known as the KS-5430—is not self-excited, depending on the central office battery for its field excitation. This avoids the cost of the self-excitation equipment, which is relatively large for the smaller sets, and permits a short enough overall length to allow the sets to be mounted conveniently on a switchboard panel.

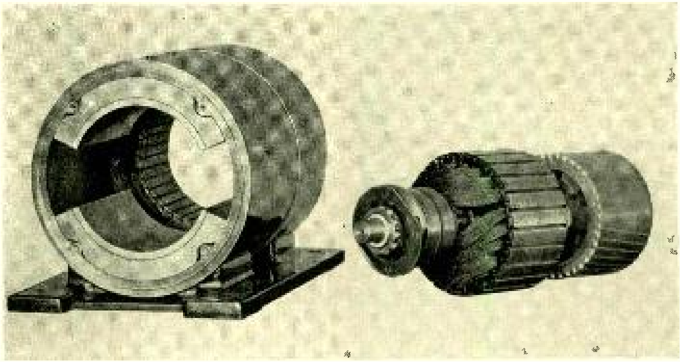


Fig. 1—The permanent-magnet alternator designed for reducing battery drain shown with its armature removed

The fields of these alternators are operated in a saturated condition, however, and as a result an exciting current of several amperes is required. Although a current of this magnitude is of minor importance in a large office, in small offices it may be the major part of the load. As a result it is often necessary to install larger batteries or to provide a rectifier for continuous charging.

This could be avoided by using alternators with permanent magnets to supply the field flux, like the ordinary hand magnetos, but the long horseshoe magnets necessary to secure sufficient permanency of the magnets has made this solution of the problem undesirable in the past. Recently, however, a new magnetic material with very high coercive force has been developed so that very short magnets can be made from it. This material is an alloy of aluminum, nickel, and cobalt steel and has been given the trade name "alnico." So effective is this material that it has been possible to provide permanent magnets for these small ringing alternators without appreciably changing the dimensions of the outer frame. In this way the mounting dimensions of the new sets are the same as the old.

The construction employed is indicated in Figure 1, which shows one of the new generator sets, called the KS-5430-01, with the armature removed. Alnico is a cast material and is very difficult to machine because of its hardness. Since machined surfaces are required for the pole faces and where the magnets fit within the outer shield, it was decided to cast the material between an outer iron sleeve and two cylindrical segments forming the pole faces. This gives essentially perfect magnetic contact between the permanent magnets and the two soft iron pole-pieces on one side, and the soft iron ring that forms the connecting yoke on the other. The inside surfaces of the pole-pieces are then machined to provide the proper air gap, and the outer surface of the sleeve is machined to fit snugly within the outer shell of the set. Tie bolts pass through lugs in the outer sleeve and the two end bells to hold the assembly together. The pole-piece and the soft iron sleeve serve merely to carry the magnetic flux; the magnet itself is only the short cast segment between them.

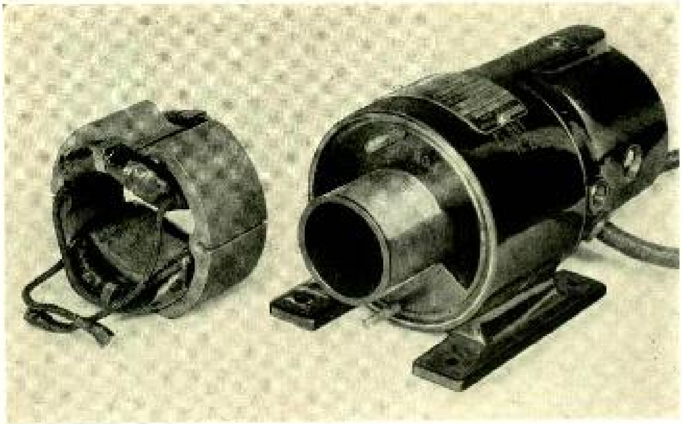


Fig. 2—The permanent-magnet regulator motor with "keeper" in place

Tests of these machines have shown that the output voltage of the alternator can be maintained under all load conditions within the limits set for the wound-field alternator. The only apprehension felt during this development was whether or not the magnetization of the field structure would gradually decrease under the influence of the strong demagnetizing field of the armature to a point where the desired output voltage could no longer be maintained. Tests running over a period of a year, however, have shown no discernible decrease in magnetization. It was also thought that demagnetization might result if the armature were removed and left out for any appreciable length of time, but tests have indicated that at least for short intervals there is no detrimental effect. Cylindrical keepers are available, however, for use when the armature is removed.

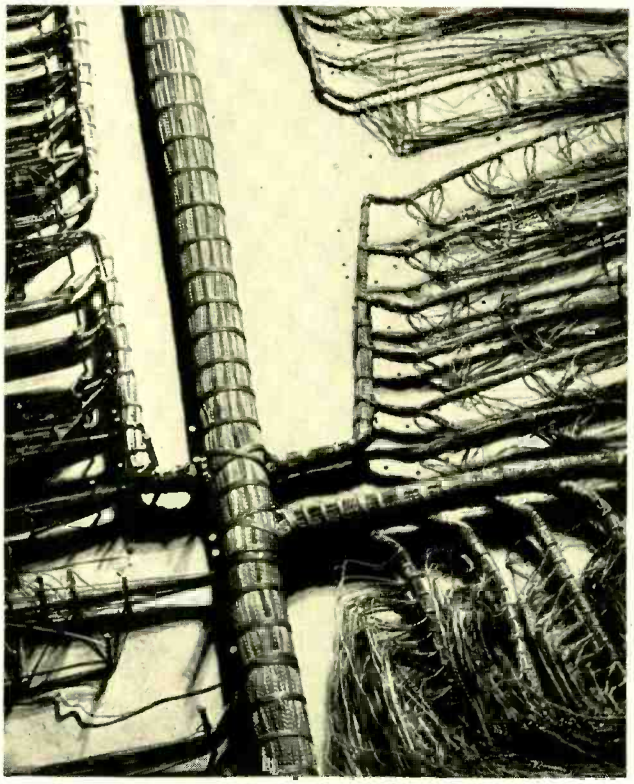
A similar construction was adopted for the d-c regulators used for regulating the floating voltage of battery-charging generators, and for the a-c regulators to regulate the voltage of the larger ringing machines. As already described in the RECORD,* these regulators are of the centrifugal type, and consist of a direct-current motor with a centrifugal switch attached to the end of the shaft. The armature of the motor is connected across the circuit to be regulated, and if the field flux remains constant, the speed of the motor is proportional to the arma-

*RECORD, *October*, 1935, *p.* 53.

ture voltage. Besides saving the current used for the field windings, permanent magnets on these regulators have the additional advantage of avoiding changes in the motor speed due to slight changes in battery voltage. In the wound field machines this result is partially secured by the use of ballast lamps. In addition alarm circuits and fuses are employed to give notice of an open-circuited field. All of this equipment is eliminated by the use of permanent magnet fields.

The construction employed is essentially the same as that for the ringing alternators, although the machines are appreciably smaller. One of the machines, with the permanent magnets in place and the wire wound magnets that they replace at one side, is shown in Figure 2. The cylindrical "keeper," used to avoid demagnetization when the armature is removed, is shown in place in this photograph.

In both regulators and ringing alternators the overall efficiency is considerably increased by the elimination of the exciting current for the fields. Further, the installation cost is reduced by the elimination of field rheostats, ballast lamps, the external wiring for supplying the field current, and the protecting circuits and alarms, so that the change is attractive from the economic point of view as well as from that of improved operation. These favorable results would indicate a wider use of permanent-magnet fields for the various small machines that are used in the Bell System Plant.



Power Supply for the Coaxial Repeaters

By J. L. LAREW
Equipment Development Department

IN the one-megacycle experimental coaxial system, installed between New York and Philadelphia, the coaxial repeaters were spaced at approximately ten-mile intervals. With present telephone practice, cable repeater offices are spaced about fifty miles apart, and so in general only one coaxial amplifier in five could be located where commercial sixty-cycle power and stand-by battery were already available. To make use of these installations a method was devised to supply the intermediate points in the system with the necessary electric current from the attended stations. The transmission of the required current could have been accomplished, of course, by incorporating an extra pair of conductors within the coaxial cable, but since the maximum distance of transmission is only twenty miles, and since the inner coaxial conductors themselves carry no current at frequencies below sixty kc, it seemed practical and desirable, for a number of reasons, to employ them for transmitting the sixty-cycle current. Besides making economical use of the existing conductors, such a

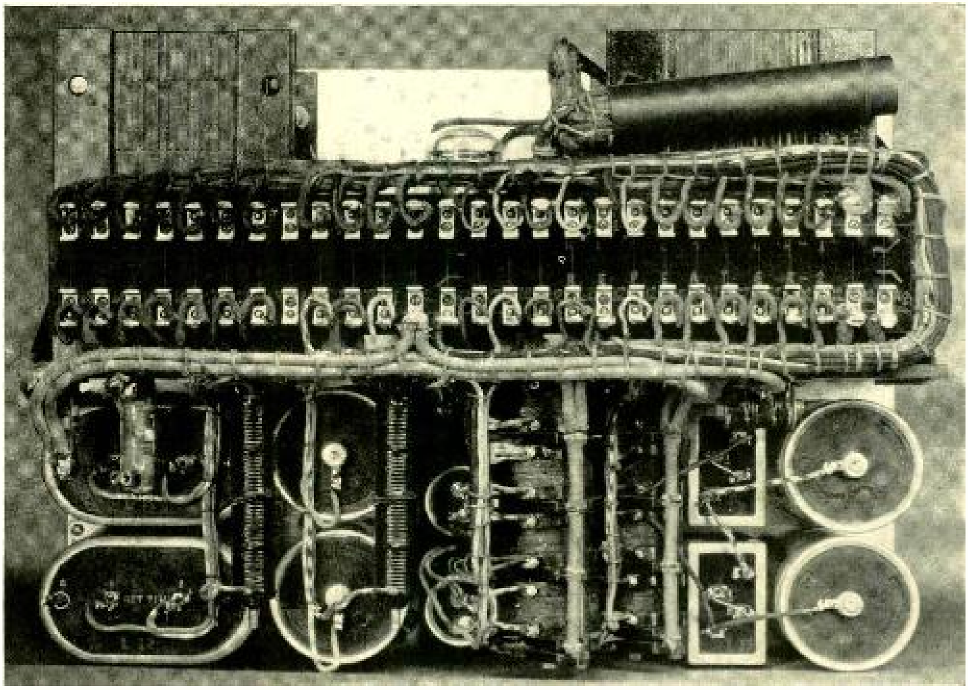


Fig. 1—By changing straps, the power pack, shown above, may be made to operate on either constant-current or constant-potential supply

system had the additional advantage that the circuit could also serve to give an indication of any fault, such as open or short circuit in the coaxial structure. It was decided, therefore,

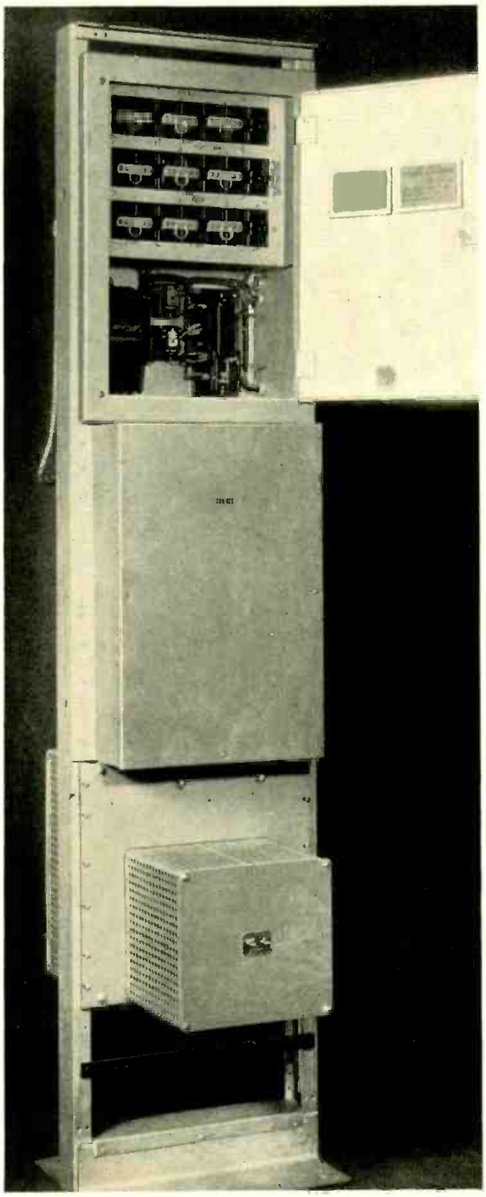


Fig. 2—The bay consists of a fuse and relay cabinet, at the top, a constant-current supply unit, in the middle, and, at the bottom, a line-voltage regulator

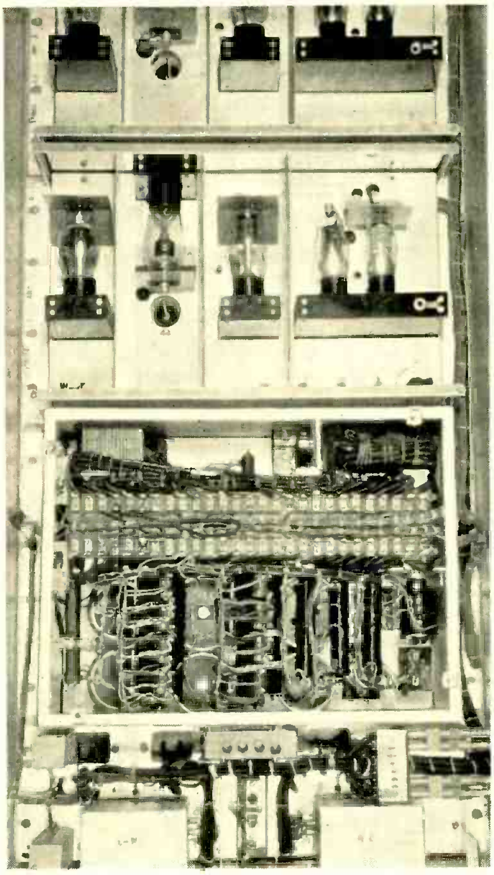


Fig. 3—Arrangement of power pack assembled with its associated repeater

to use the central conductors of the two coaxial units as the two sides of the supply circuit.

Instead of the constant-voltage system commonly used for transmitting electrical energy, a constant-current system somewhat similar to that used for certain types of street lighting was used for the coaxial system. This furnished the regulation required to compensate for changes in the resistance of the transmission line due to temperature. In place of the familiar moving-coil current transformer, a "monocyclic square" constant-current regulator was designed to meet the needs of the system.

The constant-current regulator consists of a step-up transformer and a resonant bridge comprising inductive and capacitative reactances. The energy, applied at a constant potential to the primary of the regulator, is stored in the capacitative reactances and returned at a constant current ninety degrees later in the secondary circuit. This regulator is supplied from a sixty-cycle circuit through a voltage regulator and transformer. Since a constant-current system attempts to maintain a constant current under all conditions, an open circuit would result in high potentials across the line if protective measures were not provided. By the use of a specially designed coil shunted across the output of the regulator, however, this rise in voltage on open circuit is avoided, since with the line open-circuited, the coil acts as the load to prevent an abnormal voltage rise. Under normal conditions, the coil requires very little current, and does not seriously affect the efficiency of transmission.

A maximum of 325 volts to ground is required to transmit the power at 1.2 amperes. When the constant-current system is short-circuited there is a decided drop in voltage, and when it is open-circuited the voltage tends to rise. These effects are used to provide protection by installing a high-low relay at the supply bay, which operates to disconnect the constant-current regulator whenever the transmission voltage varies above or below normal by more than fifty volts, a tolerance largely necessary due to variations of the cable resistance. The relay thus gives full protection from either short or open circuits.

The circuit is arranged to be disconnected before making tests or re-

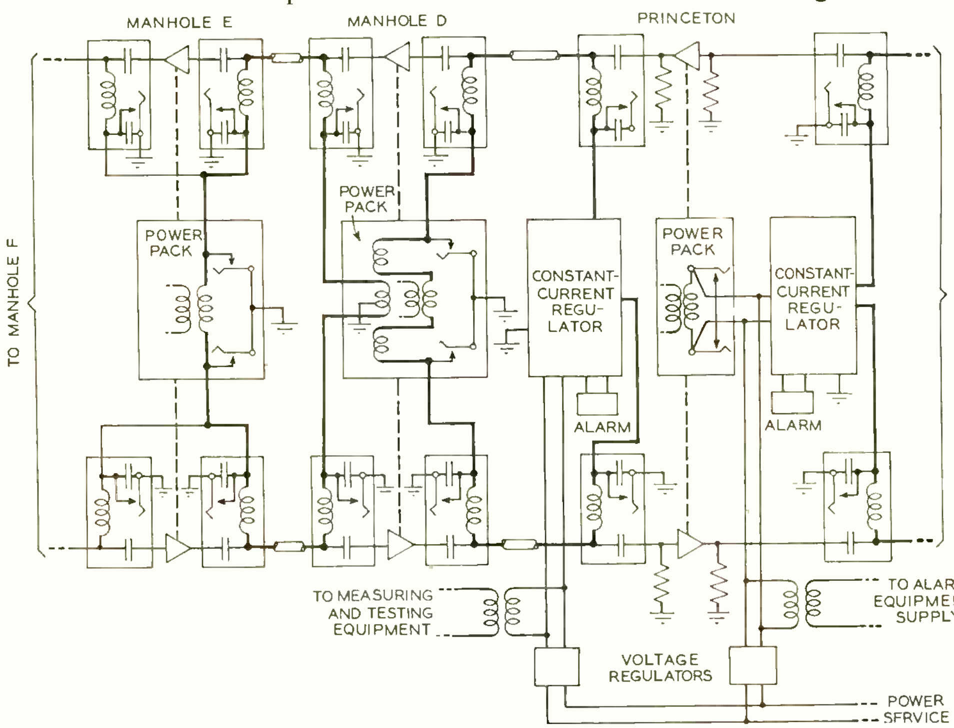


Fig. 4—Simplified schematic of the supply and utilization equipment that is installed at Princeton and at two manholes located to the south of it

pairs directly involving the coaxial conductors. In addition, special short-circuiting switches, which operate when enclosures are removed, are provided. This insures that the circuit is de-energized and remains de-energized while tests or repairs are being made.

The complete supply bay is shown in Figure 2, where the middle case encloses the constant-current supply unit. Access to the unit is gained by removing the rear cover, but arc-proof plug connectors are provided so that when the cover is removed, all power is automatically disconnected. The high-low relay, which removes power on either a short or open circuit, is mounted in the lower part of the fuse and relay cabinet on the upper part of the bay. The bottom unit on the bay is the voltage-regulator unit.

At the repeaters a unit is required to convert the constant-current supply to the needs of the amplifiers. A small power pack, only twelve by sixteen inches, has been developed for this purpose. This unit supplies five volts a-c for the amplifier filaments, three and six volts a-c for biasing the tubes in the regulating circuit of the amplifiers, ten volts d-c for the regulator networks, 130 volts d-c for the regulator-tube plates, 260 volts d-c for the amplifier plates, and 150 volts d-c for the screen grids. The power pack was designed to be operated interchangeably at either constant current or constant voltage, so that it could be used either at the intermediate repeaters where the supply is at constant current or at the terminals and attended repeater stations where the constant-potential local supply is used. Only a change in the connecting straps is required to change the power pack from constant-current to constant-voltage operation.

The circuit arrangement of the supply and utilization equipment is indicated in Figure 4, which shows the Princeton repeater station and the two manholes to the south of it. At Princeton there is a power pack, supplied at constant potential, which cares for the amplifiers located there. In addition there are two constant-current regulators: one to supply two manholes to the north, and the other,

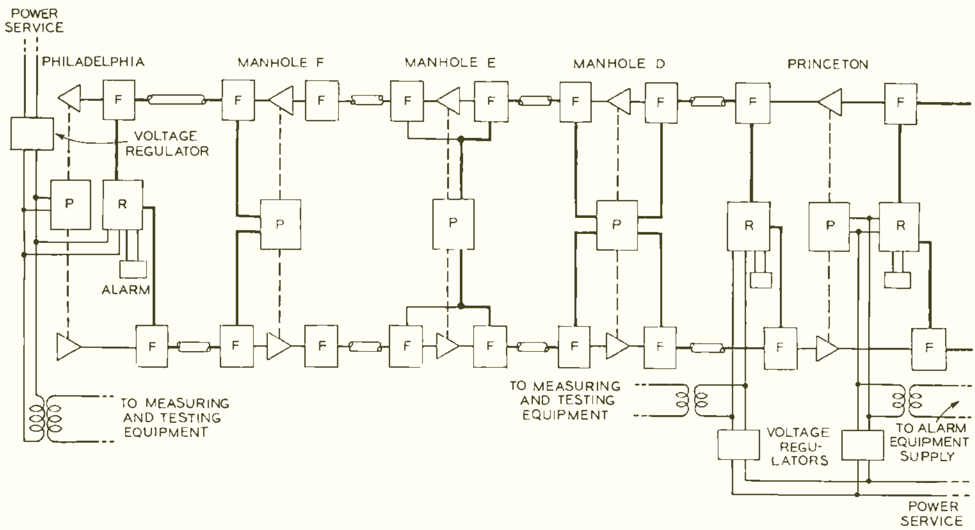


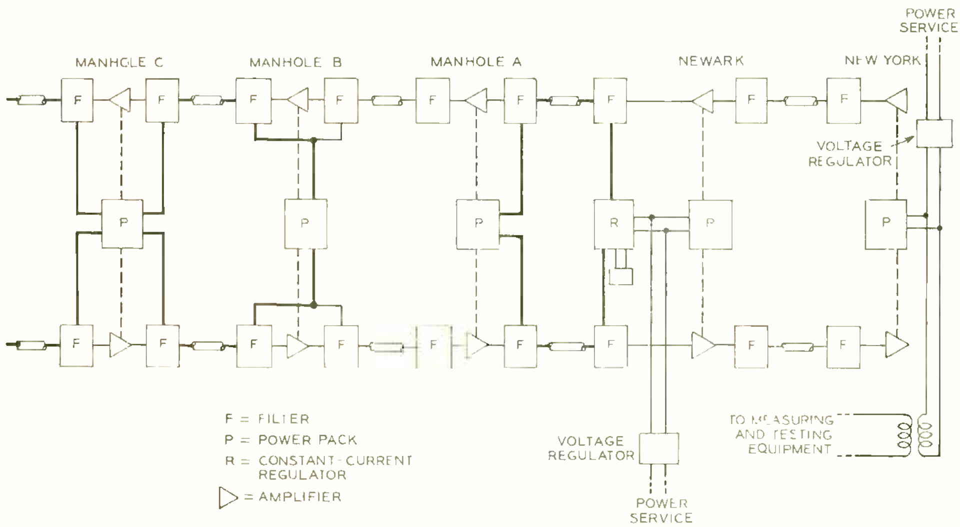
Fig. 5—Simplified schematic of the experimental

two manholes to the south. The regulator unit simulates a low-pass filter, thus attenuating any harmonics of the sixty-cycle supply that might be present. Filters are also installed at each side of each repeater to pass the carrier frequencies into the repeater, and to shunt off the sixty-cycle current to the power packs.

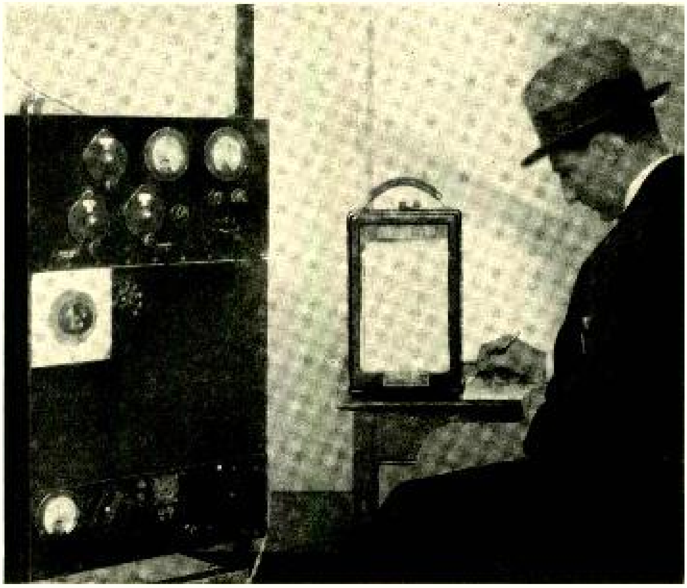
Through one set of such filters, power is connected to the coaxial cable at Princeton, and through another set at manhole D, is taken off at the power pack. Besides supplying power for the repeaters at manhole D, the power pack, through a booster transformer, passes it on through the section of coaxial cable to manhole E. The arrangement here is the same as at manhole D except that the booster transformer is not used since power is not transmitted to more than two manholes in any one direction. Although no current is transmitted over the cable between manholes E and F, sixty-cycle potential is connected to the coaxial conductor at manhole E for alarm purposes.

The current-supply arrangements for the experimental coaxial installation are shown in Figure 5, where the main path of the constant-current supply is indicated by heavy lines. The power pack at the New York terminal supplies only the repeaters there, and no constant-current supply is included, since the next repeater station is at Newark where power is available. Newark has a constant-current regulator for supplying manhole A to the south of it. Princeton, the next source of primary supply—as already noted—has two constant-current regulators, one supplying two manholes to the north and the other, two to the south. Booster transformers are used at both manholes C and D to extend the supply to manholes B and E respectively. Philadelphia has a single constant-current regulator that is used for supplying manhole F only.

This current-supply arrangement was in service on the experimental installation between New York and Philadelphia for the entire trial period and operated in a generally satisfactory manner during this time.



coaxial circuit showing the supply path in heavy lines



Stability of Reception at Two Meters

By A. DECINO
Radio Research

ULTRA-SHORT waves which are transmitted to points well beyond the optical horizon undergo variations in the received field intensity that usually are not observed over the shorter distances. This fading is attributed to variations in the amount the waves are bent back to the earth by the refracting property of the lower atmosphere. An experimental study of the extent of these variations, undertaken by the research department of the Laboratories, has been carried out over a sixty-kilometer path between Lawrenceville and Deal with two-meter waves.

Typical patterns of the fading it revealed are given in Figure 3. Record 1 shows fairly steady reception with slow changes of a fraction of a decibel. Such steadiness was of frequent occurrence and has been observed on several successive days. Record 2 shows more rapid variations but still small in amount. The third type of fading produces a gradual variation in received field upon which are superimposed changes more pronounced and of somewhat longer periods than those of the other two records. Most of the fading which was observed was of this general type. A striking and interesting pattern is that of Record 4, where a relatively slow fading accompanies a very slow change amounting to as much as twenty db. In the fifth case the pattern, when the speed of the chart was increased sixty times, was found to involve a succession of very rapid variations in amplitude. Fading of this character, which occurred more often during the colder days of the year, may have b roduced by an air mass moving across the path and redirecting some of the energy to the receiver. A large object might have the same effect; and in fact a similar flutter has been noticed coincident with the passing of an airplane. There were occasions during the tests when the field dropped out completely for a few seconds.

A clearer picture of variations in the received field over a period of several days can be gained from Figure 4 where the data on fading has been summarized. The locus of the average field for each hour is shown, with vertical lines indicating the range of fading for that hour. On some days when reception was stable only small variations occurred while on others the fading range was of the order of fifteen db. For one watt radiated from a half-wave antenna the field strength during these days was from fifteen to forty-five db above one microvolt per meter, and throughout the year it nearly always remained within these limits. The average value of the corresponding field strength for the whole year was twenty-eight db above one microvolt per meter. Thus the field that was measured varied within a range of about fifteen db above and fifteen db below the averaged value.

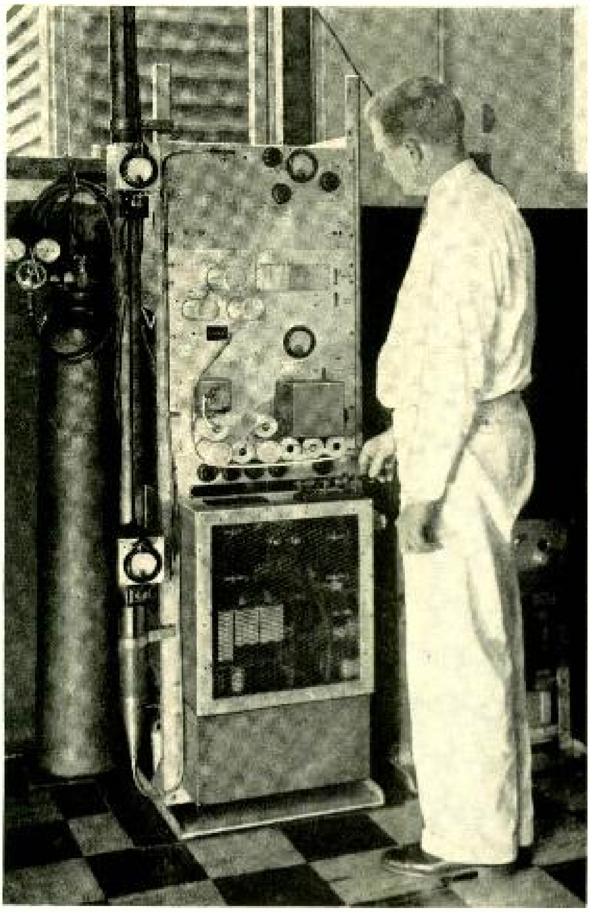


Fig. 1—Transmitting equipment for making fading tests at Lawrenceville, New Jersey

The instability of these ultra-short waves can be attributed to variations in the refracting power of the lower atmosphere which depends on changes of dielectric constant with altitude. The dielectric constant is dependent on the pressure, temperature and humidity of the air. In general, it decreases gradually with height above the earth. The result is a gradual bending of the waves

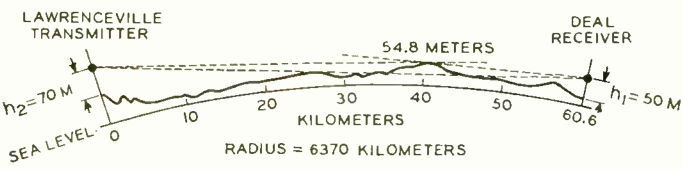


Fig. 2—Fading tests were made between Lawrenceville and Deal, New Jersey, over a sixty-kilometer path which was obstructed by a hill 54.8 meters high

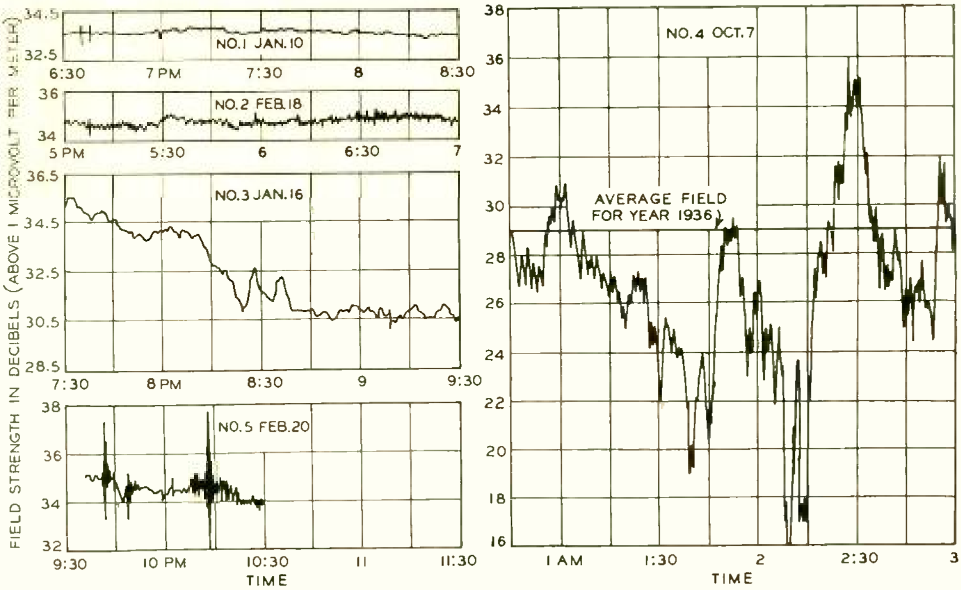


Fig. 3—Various types of fading observed on two-meter waves at a distance of sixty kilometers from the sending station. Received field strength values are for radiation transmitted at the rate of one watt from a half-wave antenna

toward the surface. In practice, the average field strength will vary as atmospheric conditions change this refracting property.

At times, the gradient of the dielectric constant—that is, its rate of change with altitude—may change abruptly or become large enough to bend the wave sharply back toward the receiver. This gives a multi-path transmission which results in fading by interference, analogous to that experienced by the longer waves where the received field consists of a ground wave and a wave that is reflected from the ionosphere.

The large amount of data available made it feasible to analyze the distribution of fading with time. Figure 5 shows the time distribution for four fading ranges for each hour of the day. For 1936 the field for any hour of the day stayed within a range of five db for eighty per cent of the time. It had a range greater than ten db about five per cent of the time. These curves also show that the fading was least around the mid-day period from ten to four o'clock. Most fading of large amplitude occurred in the evening and early morning hours. In the first part of 1937, reception was more stable than in 1936.

Fading is a factor which must be considered in ultra-short wave trans-

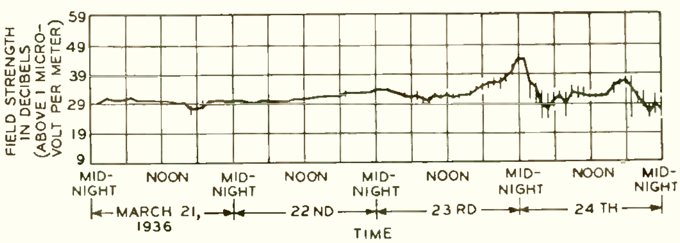


Fig. 4—Fading of two-meter waves observed over a four-day period. Vertical lines indicate the range of fading

mission when determining what power is needed to insure a given minimum field intensity at the receiving terminal. Theoretical formulas, which have been verified experimentally, are available for calculating the average field strength. The phenomenon of fading, however, requires an increase in power to maintain the minimum field intensity at that average value. Since the depth of the fading is variable, the required increase in power depends on the percentage of time the field must be above that value. This increment can be obtained from data on the distribution of the field intensity for a representative period. Over the Lawrenceville-Deal path, as shown approximately in Figure 6, the actual intensity was below the average value about fifty per cent of the time; and an increase in transmitted power of eight decibels would have maintained the intensity above that average approximately ninety-nine per cent of the time.

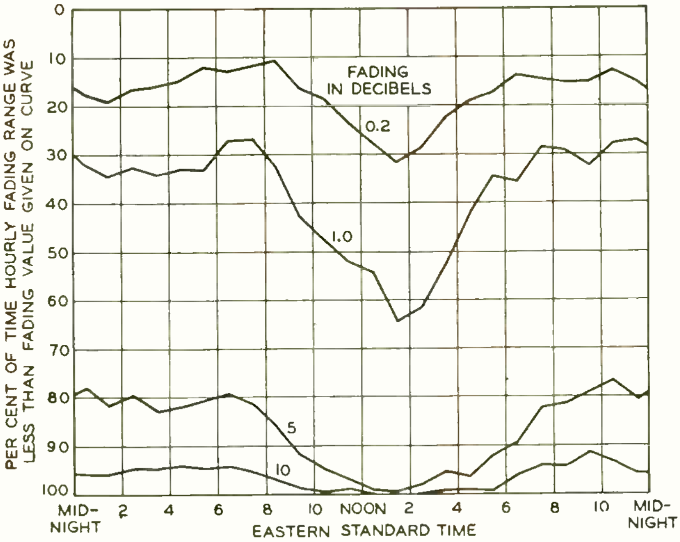


Fig. 5—The field strength remained within a range of 5 db 80 per cent of the time for any hour of the day during 1936 and exceeded 10 db about 5 per cent of the time

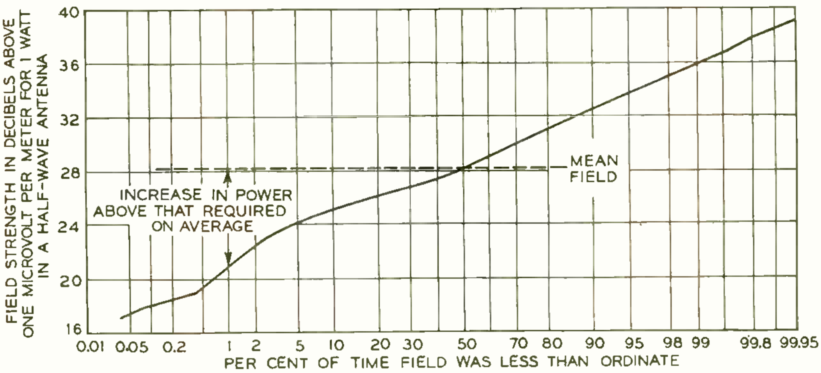
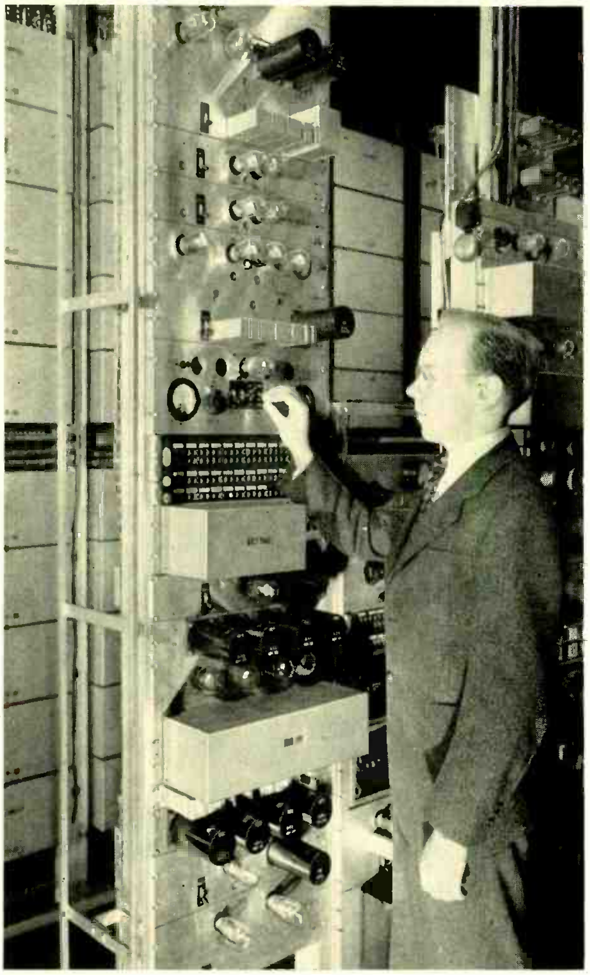


Fig. 6—An increase of 7 db in power would raise the received field to 34 db above one microvolt per meter 50 per cent of the time and above 28 db 99 per cent of the time. The average value observed for the year 1936 was 28 db



Noise Protection for Voice-Operated Devices

By S. B. WRIGHT
Radio Transmission Development

TWO types of voice-operated switching devices are in common use in the Bell System. One is the echo suppressor, which is used mainly on long cable circuits; the other is the "voice-operated device, anti-singing," or "vodas," which is employed chiefly at the control terminals of radio-telephone circuits. With the echo suppressor, the telephone circuit is normally free to transmit in either direction, but the return path is blocked automatically when the speech waves in the outgoing path are strong enough to produce an objectionable echo. With the vodas, on the other hand, the circuit must be blocked in one direction or the other at all times to prevent singing, so that the voice waves are required to remove the blocking from the transmitting path and to block the return path. While both types of voice-operated devices must be sensitive to voice signals, it is essential that they do not operate on noise, even though the noise may be present in considerable volume.

To prevent noise from operating voice-operated switching devices and to prevent it from seriously interfering with telephone conversation are quite different problems. Even though a telephone circuit is satisfactory with respect to noise reaching the listener, it may contain noise components that would falsely operate switching devices. These noises originate from several sources, both within and outside of the telephone plant, and to protect the voice-operated switches against operation by them, it is necessary to know something of their nature. Based on a knowledge of their distinctive characteristics, many schemes have been suggested and have been tried for making the various voice-operated devices sensitive to speech and insensitive to noise.

The satisfactory operation of such

a system depends on there being an adequate margin between speech sounds and the strongest noise currents, and on an accurate adjustment of the relays on the basis of this margin. Depending on the part of the circuit in which the apparatus is placed, this margin will vary somewhat. The vodas operates on speech to clear one path and to disable the return path. If it were located at the receiving end of the radio path, the margin between speech and noise would be much smaller than if it were at the transmitting end, because of the noise picked up over the radio path. For this reason, it is located at the transmitting end of the radio path, and the noise is thus only that due to the land lines. On a transatlantic channel, for example, the vodas in New York acts on speech outgoing to England to open that path and to disable the incoming path, while the vodas at London acts on speech outgoing to New York to open the westbound transmission path and to disable the receiving path from New York. Even those provisions do not always insure adequate margins, and additional means of discrimination have been sought.

One of the early improvements incorporated in these voice-operated devices was a slow-release action of the vodas relay. If the relay released as soon as the current dropped below its operating value, the trailing end of each syllable would be clipped off, giving an unpleasant effect. Another and very effective method of improving the operation of these devices was the use of a delay network, suggested years ago by the late Dr. H. D. Arnold. This delay network is connected in the outgoing voice circuit, but the circuit to the voice-operated device is connected ahead of it, with the disabling contacts after it. As a result, the voice currents are delayed long enough to allow the voice-operated relay to act before the beginning of the voice wave reaches the disabling contacts.

The effect of the delay network combined with the slow-release feature of the relay is indicated on Figure 1, which represents from left to right the voltage of a two-syllable word superimposed on typical noise voltage. The voltage at which the relay operates is indicated by the horizontal line marked S. Speech begins at A. The portion from A to A′ is lost in any case because its level is below the noise level. If no delay were used, the portion from A′ to B′ also would be lost because the relay would not have operated to clear the outgoing path. The network, however, delays the speech long enough so that the relay has operated and cleared the outgoing path by the time the first important speech sound reaches it.

Without the slow-release action, the relay would disable the circuit at point C, and a portion of the speech between the two syllabic peaks would be lost. The "hangover" period, however, bridges this valley in the speech wave and maintains the continuity

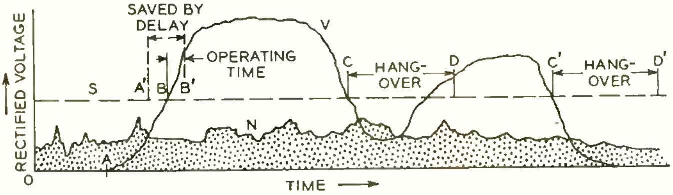


Fig. 1—Rectified voltage of two voice syllables showing the portions that would be lost without the delay network and slow-release feature of the voice-operated device

of the speech. It also prevents clipping at the end of a speech sound as at c′, and keeps the incoming path disabled long enough after the termination of speech to cut off returning echoes. Figure 2 shows an actual oscillogram of the word "sixteen" with the corresponding points indicated.

Although the delay network in conjunction with the slow-release relay greatly improves talking over circuits with voice-operated devices of the vodas type, they do not secure greater discrimination between noise and speech. About the same time that the use of a delay network was suggested, however, O. B. Blackwell proposed the use of frequency discrimination to make the voice-operated device more sensitive to voice and less sensitive to noise frequencies. Figure 3 shows a frequency spectrum of noise in which the height of the vertical lines indicates the average relative magnitudes of the components of noise currents measured on a large number of open-wire circuits. The normal telephone frequency range is indicated toward the top of the chart. The lower dashed curve shows the relative interfering effect of noises at different frequencies to a listener on a telephone circuit. Assuming that echoes have similar relative interfering effects, a sensitivity-frequency curve for the echo suppressor with the same values would suppress echoes equally at all frequencies, and would make the sensitivity to noise operation low at the extreme frequencies. The actual echo suppressor curve is shown for comparison. With the vodas it is more important to obtain complete operation on speech currents, so its characteristic is wider as shown.

It has been observed that in many types of noise, a large part of the long-time average power is steady. Speech, on the other hand, is formed as syllables, and thus comes as a series of impulses of definite duration. The normal syllabic frequency is below twenty-five cycles per second while the lowest noise frequency is usually sixty cycles. These facts led B. G. Bjornson, in 1924, to suggest a circuit for the voice-operated devices that would be operated by the envelope of the voice wave but not by noise.

A simplified schematic of an arrangement of this type to give line-noise protection to vodases such as used at the Miami end of Caribbean radio-telephone circuits is shown in Figure 4. Here the circuit within the dotted circle responds to pulses occurring less frequently than twenty-five per second but not to pulses occurring more frequently. Outgoing speech travels along the upper path from left to right. The relays S and T normally keep the outgoing path

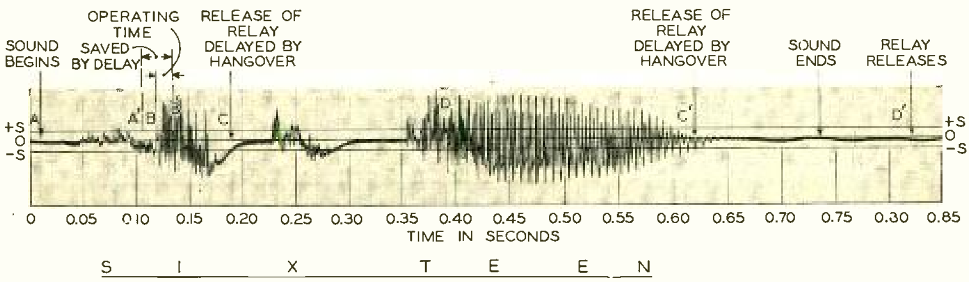


Fig. 2—Oscillogram of the word "sixteen" illustrating the effect of the delay network and the slow-release feature

short-circuited and the incoming path open, and the function of the vodas is to operate both of these relays, and thus clear the outgoing path and block the incoming path when voice currents start out over the upper path. Noise alone, however, should not operate these relays. Both S and T are slow-release relays to give the hangover action already discussed, and a delay circuit is shown in the outgoing voice path to retard the speech long enough to allow the voice-operated devices to operate.

Outgoing currents — both voice and noise—pass to the upper branch and divide at the upper hybrid coil, part passing through the delay circuit and part into the control circuit. The tuned input amplifier makes a frequency selection on the basis of the curve of Figure 3, and the resulting current is again divided by a hybrid coil—part passing to a detector to operate the relay K, which in turn operates relays S and T, and part passing to the sensitive detector, which is part of the syllabic device. The upper path, to relay K, includes a shunt resistance, part of which is short-circuited by relays I and F. When the current to the sensitive detector includes speech, and thus has a syllabic-frequency component, relays I and F operate, to increase the shunt resistance in the path to relay K, allowing K to operate at a lower input level. The relays I and F are connected in series, but are oppositely poled, and one operates on the increasing side of a syllabic pulse and the other on the decreasing side—the current in the relay circuit flowing in one direction with increasing current and in the other with decreasing current. Relays I, F, and K follow the syllabic pulsing, but the slow-release features of relays S and T hold them operated during the short periods between syllables and for a short interval after the completion of speech.

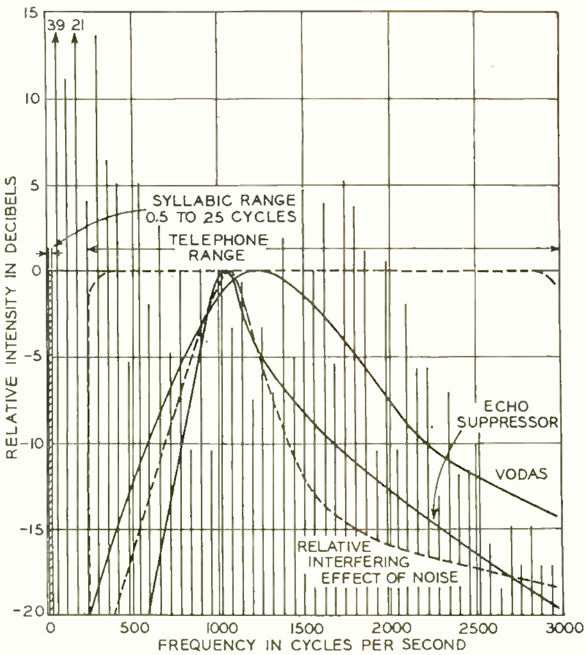


Fig. 3—Frequency spectrum of noise showing the telephone range, the curve of relative interfering effect of noise to a listener on a telephone circuit, and the sensitivity curves of the vodas and echo suppressor

By this combination of syllabic device and frequency discrimination the operation of the disabling relays S and T on many types of noise is practically eliminated, and their operation on speech passing out over the transmitting path is assured. When speech is being received, it is essential to make sure that these relays do not block the incoming path, an action that might be caused by echoes of the incoming speech reflected at the receiving terminal. To avoid this a detector with a tuned input and relay R are provided. Relay R operates on incoming speech and short-circuits the windings of relays S and T so that they cannot be operated while speech is coming in.

An experimental application of somewhat similar circuits to the four-wire echo suppressor on the overland circuit between New York and Los Angeles is shown in Figure 5. This echo suppressor is located at St. Louis, and provides normally a clear path for transmission in either direction. When speech is passing in one direction, however, the echo suppressor is designed to disable the opposite path so that echoes cannot travel back over it.

Current from the upper, or W-E, hybrid coil passes through the vario-repeater, the tuned-input amplifier, and the W-E detector to operate two slow-release relays, of which one disables the E-W path and the other disables the echo suppressor on the other path. The two vario-repeaters are normally set for high gain, but the circuit of the "nogad," or "noise-operated gain-adjusting device," is designed to decrease this gain when only noise is entering the circuit and to maintain the high gain when voice is entering.

Incoming currents pass to combining circuit A and thence to the gain reducer which, acting well on noise currents but poorly on voice currents, provides a rectified current to increase the charge on condenser C. This charge, acting through the bias-changing tube T, reduces the gain of the vario-repeaters by an amount cor-

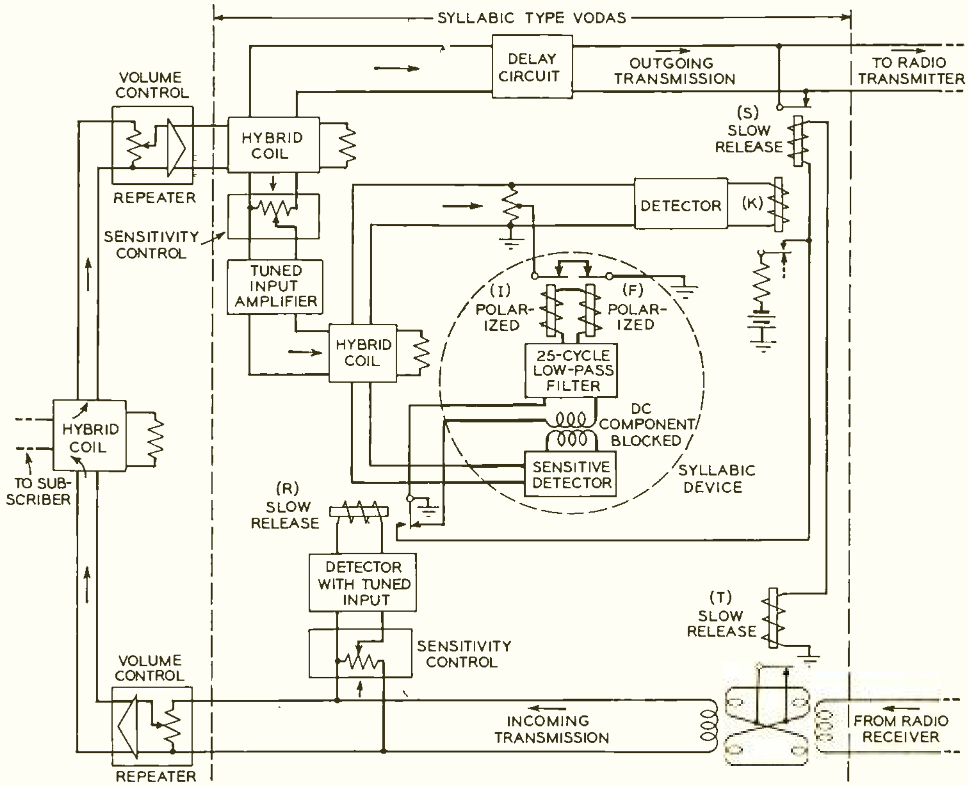


Fig. 4—Simplified schematic of a vodas circuit employing the syllabic discriminating device used at the Miami end of the Caribbean radio-telephone circuits

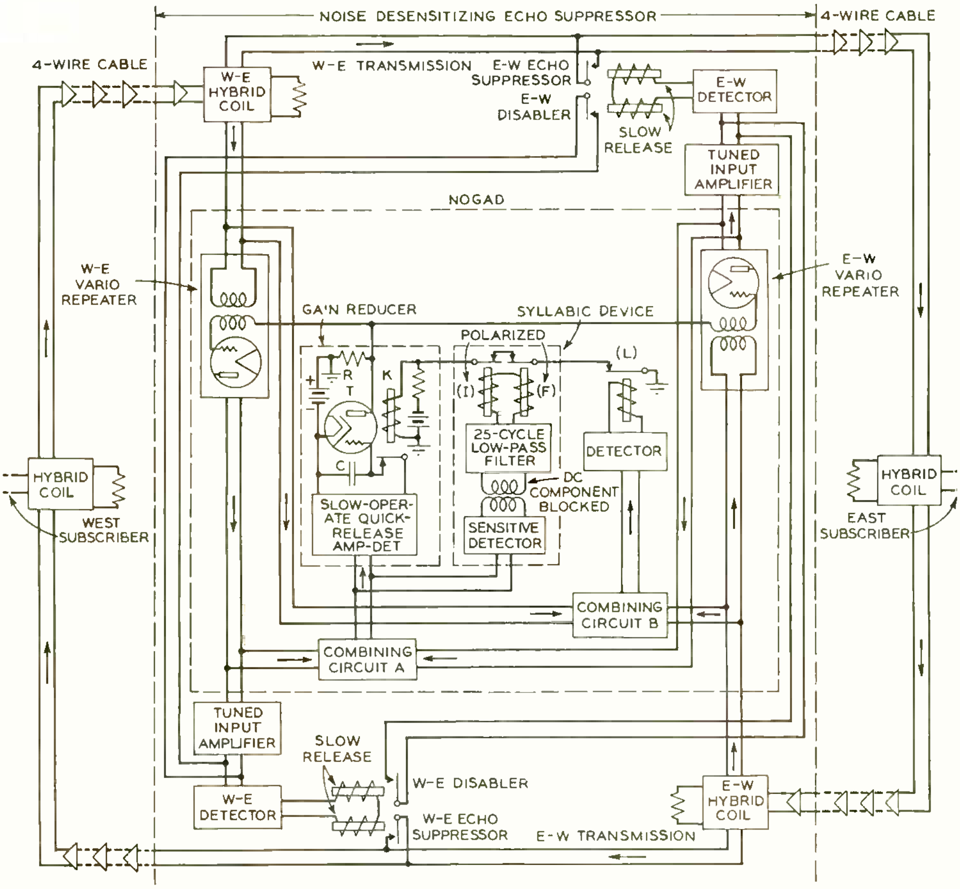


Fig. 5—Simplified schematic of an echo suppressor using the syllabic device in a nogad on the overland circuit between New York and Los Angeles

responding to the noise, so that the echo-suppressor relay will not operate from noise. If speech is passing over the W-E path, however, it will enter the syllabic device after leaving combining circuit A, and as already described, will operate relays I and F, causing relay K to open the circuit to condenser C. This maintains the high gain of the vario-repeaters, and the echo suppressor will operate. The action is exactly similar for speech passing in the opposite direction. The combining circuits are arranged to act on current from either side of the circuit, and the gain of the two vario-repeaters is increased or decreased at the same time. An additional provision, including combining circuit B and relay L, is incorporated to prevent desensitizing of the vario-repeater on strong sounds such as testing tone or loud speech. Relay L is made relatively insensitive, however, and so will not operate on noise currents. This allows the syllabic device to be built without regard to its action on strong speech currents, permitting a simpler device and better operation for weak speech currents. The extent to which this device will be applied in the long-distance telephone wire plant will depend on the results of the trial which is not yet completed.

Protective Circuits for Antenna-Coupling Networks

By F. C. ONG
Radio Development Department

"TIME off the air" during a commercial program is of great concern to owners and operators of radio broadcasting stations, since it detracts from the effectiveness of the programs and may mean a loss of revenue. Although even very short interruptions are objectionable, it is particularly important to avoid the longer shut-downs that become necessary when damaged apparatus has to be repaired or replaced. Under such conditions the loss of revenue may be considerable.

A common cause of program interruptions at the transmitter is a power arc to ground or across some piece of equipment following a transient disturbance induced by lightning. Direct strokes of lightning to the antenna sometimes occur, and in such an event it is impossible to prevent damage, but more commonly the lightning merely induces a high-voltage disturbance that causes a momentary arc. Arcs of this nature may also result from transient disturbances within the transmitter itself. Across the arcs so formed power from the transmitter will flow until the supply has been disconnected, and this radio-power current may do considerable damage. It is very desirable, therefore, to provide some protecting circuit that will disable the transmitter momentarily whenever one of these transient arcs is encountered.

With this objective in mind, the Laboratories have recently developed two protective circuits, one or both of which are being incorporated in all Western Electric broadcasting transmitters to assure continuity of service and to minimize damage to the apparatus. Both of the circuits include a relay that operates when a transient arc occurs, and disables the transmitter until the arc is extinguished. Since normal operation of the transmitter is restored in a few thousandths of a second, the interruption is hardly noticeable to the listener. The disabling of the transmitter for this short interval prevents the continuance of the arc, and thus avoids damage to the equipment and the long replacement period that might be required as a result.

One of the circuits is shown in heavy lines connected to the out-

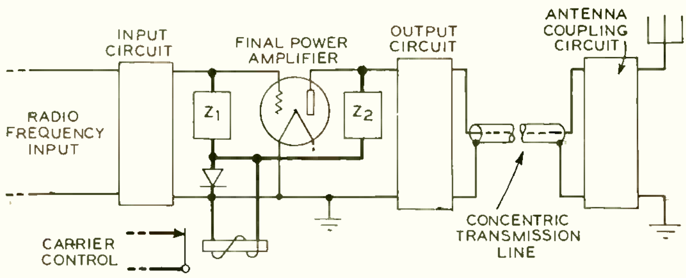


Fig. 1—Schematic of protective circuit that disables transmitter on any disturbance of the output tuning

pu ransmitter in Figure 1. Under normal operating conditions the radio-frequency plate voltage of a power amplifier is opposite in phase to the grid voltage, and proportional to it in magnitude. The current to ground through a high-impedance network connected to the plate circuit can thus be made equal to that through a similar network connected to the grid circuit by making the impedances of the networks proportional to the voltage of the circuit to which they are connected. Since the currents through these two networks are of opposite phase, no current will flow in the common ground connection. As illustrated in the circuits shown in Figure 1, these two networks, which are designed not to pass direct current, are z_1 and z_2, and the common ground connection passes through a rectifier with the winding of a relay bridged across it. The currents through z_1 and z_2 being equal and of opposite phase, no current flows through the relay winding under normal conditions. If the output circuit becomes untuned, however, due to an arc, short circuit, or the failure of one of the tuning elements, the impedance of the plate circuit will change, causing the radio-frequency plate voltage to change in phase or amplitude or both. Under this condition the currents through z_1 and z_2 no longer balance each other, and a current will flow in the ground circuit and operate the relay, which in turn will remove the carrier power. As soon as current ceases to flow through the relay winding, the relay will release, and the carrier power will be restored.

The second circuit is shown in Figure 2, and differs from the first in requiring an arc to ground for its operation. In this case one side of the relay is connected to ground and the other side to the outgoing transmission line through a potential source and a high impedance. Normally the circuit

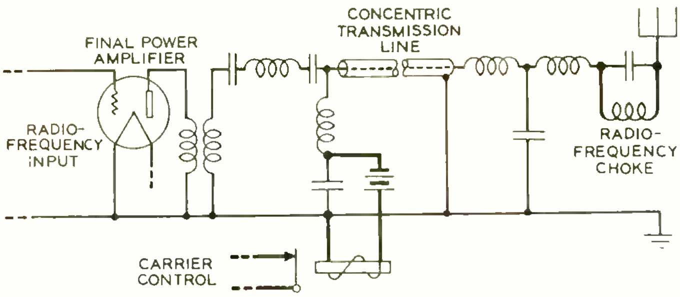


Fig. 2—Another form of protective circuit acts only on an arc to ground

through the relay winding is open by the high impedance between line and ground, illustrated in the diagram by the air gap between the central conductor and sheath of a coaxial line. If an arc should form to ground, however, current from the potential source in the relay circuit would flow through it and operate the relay. Here again, the circuit would be restored to normal as soon as current ceased to flow through the arc. In the diagram the relay potential is shown as a battery, but provision is made for using a sixty-cycle source if more convenient.

For the operation of this latter circuit, the d-c or sixty-cycle current must flow across the arc to ground, and so if there were a series condenser between the arc and the relay, the circuit would be inoperative. To avoid this condition, any series condenser in the circuit—as shown at the right of Figure 2—is bridged by a choke coil that has a very high impedance to radio frequencies but a low impedance to sixty cycles. The minor change in the tuning of the output circuit caused by the shunting effect of this coil is easily compensated by a slight retuning of the circuit.

These two circuits perform essentially the same function, but that shown in Figure 1 has the advantage of operating under any abnormal condition that disturbs the tuning of the output circuits, while that of Figure 2 operates only on an arc to ground. On the other hand, the first circuit requires somewhat more equipment. The second circuit is particularly suitable for protecting a coaxial-conductor transmission line, which might require a long replacement time if a protracted power arc occurred. These various factors are considered in selecting the particular circuit to be installed. In general, local conditions will determine which is the most suitable, and in some cases both may be installed to provide double insurance against shut-downs.

Numerous tests in the laboratory on both circuits have shown that very reliable protection is obtained. Arcs, produced artificially in the transmitter by severe over-modulation or by shorting a part of the output circuit, have been so quickly extinguished that no damage resulted even when the power of the transmitter was several hundred kilowatts. Experience with several field installations of each type of circuit has further demonstrated this reliability of operation. In some instances where lightning disturbances had previously been responsible for considerable "time off the air" because of apparatus being damaged by "follow-up" arcs, the use of one of these circuits has practically eliminated such shut-downs.

Contributors to this Issue

M. B. Gardner received the A.B. degree from Brigham Young University in 1930 and joined the Research Department of the Laboratories in June of that year. Since then he has devoted his time to problems in physiological acoustics, particularly as applied to the deafened individual. In the Spring of 1936 he acted as Technical Supervisor for the U. S. Public Health Service on a nation-wide hearing survey project in which the Laboratories was actively interested.

R. M. Bozorth graduated from Reed College, Oregon, in 1917 with the A.B. degree and spent the next two years in the Army. He then entered the California Institute of Technology where he received a Ph.D. in physical chemistry in 1922. After spending the next year as research fellow at that Institution Dr. Bozorth came to the Laboratories where as Research Physicist he has been engaged in research in magnetics and problems relating to the crystal structure and other physical properties of solids, particularly of metals.

C. F. Edwards received an A.B. degree from Ohio State University in 1929, and an M.A. degree from the same university in 1930, and immediately joined the Department of Development and Research of the American Telephone and Telegraph Company. Here he was assigned to a group engaged in shortwave transoceanic transmission studies. In 1934 he went to the Holmdel Radio Laboratory, where the studies described in the current issue of the Record were made.

Joseph T. O'Leary received the degree of B.S. in Electrical Engineering from Villanova College in 1918. After gradua-

M. B. Gardner

R. M. Bozorth

C. F. Edwards

tion he served in the U. S. Army until after the end of the World War. Then for a short period he was with the Linde Air Products Company, but in 1919 he joined the Development and Research Department of the American Telephone and Telegraph Company. During this entire period he has been engaged in studies of toll transmission problems with particular regard to carrier telephone and telegraph systems and program circuits.

S. B. Wright graduated from Cornell University in 1919 with the degree of M.E. in Electrical Engineering. He joined the American Telephone and Telegraph Company in January of that year, and began making field studies of transmission on various types of long-distance telephone circuits. In 1923 he assisted in placing the first echo suppressor in commercial service in Harrisburg, and in 1925 developed the requirements for the first vodas to be used later in commercial service between New York and London. Since transferring to the Laboratories, he has continued work on the application of voice-operated devices to overcome transmission limitations of various long-distance systems, and since January, last year, he has been in charge of the transmission development work on all types of radiotelephone systems.

J. L. Larew received a B.Sc. degree in mechanical engineering from Rutgers College in 1917, and during the following five years he held positions with several

J. T. O'Leary

S. B. Wright

J. L. Larew

F. C. Ong

R. D. de Kay

Alfred Decino

engineering and construction companies, gaining a varied engineering experience. In 1922 he joined the Laboratories and was assigned to the power division of the Systems group. For the past twelve years he has supervised a group engaged in the development of power plants for the toll system. Among these have been those for telephone and telegraph repeaters, transatlantic radio, picture transmission, and more recently for the coaxial system and the Type-J and Type-K carrier systems.

F. C. Ong received his B.S. degree in Electrical Engineering from Armour Institute of Technology in 1929 and immediately joined the Radio Development Department of the Laboratories. Previously, he had been employed by the Illinois Bell Telephone Company in Chicago during college vacation periods. For his first three years at the Laboratories, he was associated with the development of long-wave high-power radio transmitters for transatlantic telephone service. Since that time he has been engaged in development work on radio transmitting equipment for broadcasting purposes.

R. D. de Kay was graduated from the United States Naval Academy in 1918. He served in the war as engineer officer on destroyers, and after the war as commanding officer. In 1922 he left the Navy and joined the power development group of the Laboratories, where he supervises rectifier and machine development.

Alfred Decino graduated from the University of Colorado in 1928 with the degree of B.S. in Electrical Engineering. A few weeks later he came east and joined the Bell Telephone Laboratories where he became concerned with studies of short-wave radio transmission pertaining to the installation of the transatlantic and South American short-wave circuits. Since then his work has been principally associated with problems of ultra-short wave propagation. Mr. Decino spent about a year on the theoretical development of the multiple-tuned antenna.