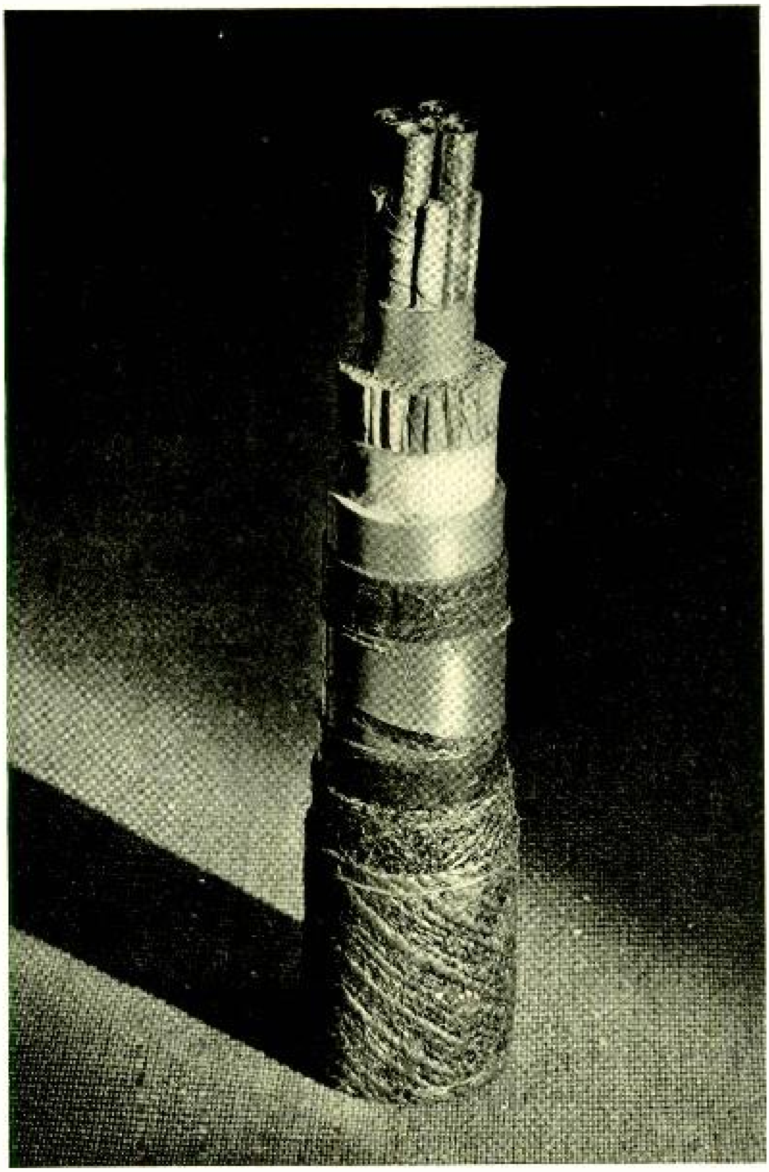
ELL LABORATORIES RECORD



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Section of the Stevens Point-Minneapolis coaxial cable

Weather by Telephone

By W. BENNETT
Switching Development

ON APRIL 8, the New York Telephone Company inaugurated a new service. In the metropolitan area, one can now dial WEather 6-1212 and hear the latest weather prediction, including the anticipated temperature, winds, and rain or snow conditions. The bulletins are based on direct teletype reports from the United States Weather Bureau; at present they are changed hourly between seven in the morning and eleven at night. In case of important changes special bulletins may also be given. All the equipment used for this service is installed in the West Fiftieth Street Central Office building, and weather-announcing trunks are run to all the central offices in Manhattan, while other parts of the metropolitan area reach the announcing bureau through subcenters or tandem offices.

Unlike the time-announcing system, in which a special operator makes each announcement herself, the weather system makes use of a tape recorder. Machines of this type have been used for a number of applications as already described in the Record.* The machine used for the weather announcements is described in an accompanying article.† Three of these machines are employed; the announcement is put on two of them, one in service and one as a stand-by, while the third is available for the new announcement when it comes in from the weather bureau. The third machine is also available during maintenance on the other machines.

These three machines, together with all control and trunk circuits, are mounted on a set of bays on the third

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**June*, 1933, *p.* 308; *Mar.*, 1935, *p.* 200; *Sept.*, 1937, *p.* 2. †*Page* 70, *this issue.*

floor of the building, but control of the system is concentrated in a small desk-mounted turret in a sound-proof room just off the information bureau on the thirteenth floor. The photograph at the head of the article shows the interior of this room and one of the special operators preparing to put a new announcement on the tape. At the right is the teletypewriter over which the announcements come from the weather bureau; in front of the operator is the control turret and the microphone with which she records the bulletin on the tape. A set of headphones is provided with which she listens to the announcement immediately after recording. The operator does this to make sure it is correct and of the proper volume.

The method of operation can be followed with the help of the simplified schematic of Figure 1, and the photograph of the front of the control cabinet in Figure 2. Each machine has allotted to it two keys and three lamps on the front of the cabinet, which also carries several other keys, lamps, and jacks used for the system as a whole. The lighted "in service" lamp shows which machine is in use.

To record a new bulletin, the operator moves the fourth key from the left in the bottom row up to the erase position and holds it there for about thirty seconds as timed by the electric clock. This starts the other two machines and energizes their erasing magnets to remove the previous records. She then operates the same key

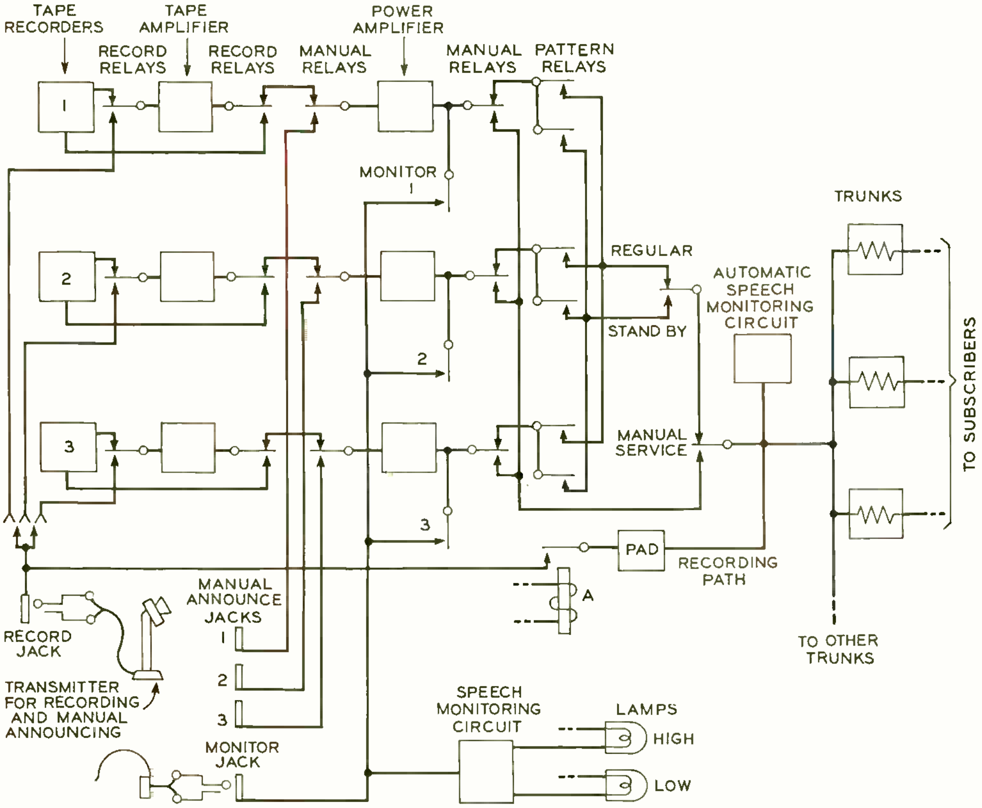

Fig. 1—Simplified schematic of the main transmission paths of the announcing system

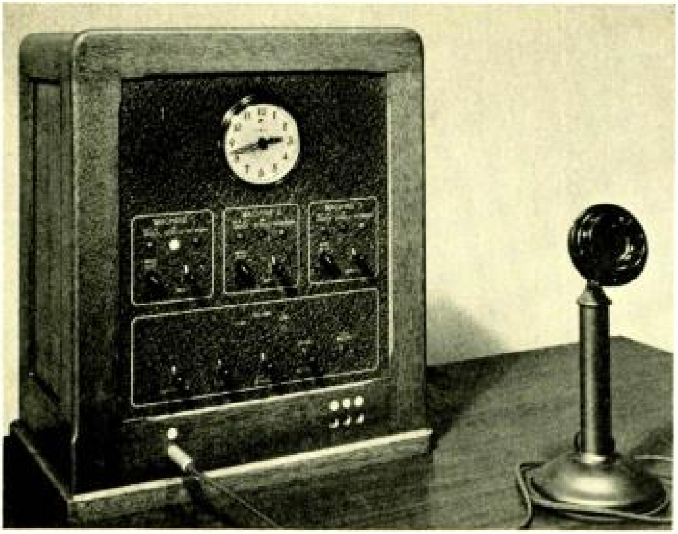

Fig. 2—Front view of control turret

to the down, or record, position and makes her announcement into the microphone. Operation of the key has actuated the "record" relay of each of the two machines not in use to the down position, as indicated in Figure 1, and established a path from the microphone through the "tape" amplifiers. After completing the announcement she restores this key to the normal positon. She then operates the "monitor" keys, successively for the two machines, and listens to the announcement. If it is too high or low in volume one or the other of the two lamps above the lower row of keys will light. If unsatisfactory the announcement will be erased by the operator and re-recorded; but if neither lamp lights, and if the record is correct, she will operate the "cut-in-service" key—the third from the left. This cuts out of service the machine with the previous announcement, cuts one of the machines with the new announcement into service, and arranges for the other to be used as a stand-by. Lamps in the squares on the front of the panel light automatically as the machines are put in a "recording" or "service" condition, so that the operator has an indication at all times as to how the various machines are being employed. After the system has been put in service with a new recording, it requires no more attention until a new announcement is to be recorded.

From Figure 1 it may be seen that besides the "tape" amplifier, there is a second amplifier for each machine in the reproducing circuit only. These raise the level of the reproduced speech for transmission over the trunks and are known as power amplifiers. Their output is branched through two "pattern" relays, one along a "regular" path and one along a "stand-by" path. These are controlled by an automatic circuit associated with the "cut-in-service" key on the turret, and select the machines for use in a definite rotation, so that each machine is in service, held as a stand-by, and out of service the same amount of time, except for the occasional maintenance that is required.

On the output circuit, just ahead of the trunks, is an automatic speech monitoring circuit. Every thirty seconds the circuit monitors the announcement to make sure that speech is being transmitted and that it is of the correct volume. If it does not find conditions satisfactory, it automatically transfers the load to the stand-by machine and gives an alarm to attract the attention of the maintenance force. This speech-monitoring equipment is the same as that used by the operator in monitoring a new recording, and may be interchanged with it in event of trouble.

In the remote eventuality that all machines should be out of service at the same time, the operator can give the announcement herself by plugging her transmitter into one of the three jacks in the lower right-hand corner of the turret. This automatically operates one pair of the "manual relays" and also the "manual service" relay, which establishes a path directly from her microphone to the outgoing trunks. As soon as one or more of the machines is ready for service, a recording will be made by way of the contacts of relay A without the necessity of plugging into the recording jack. Normal service may then be restored in the usual manner.

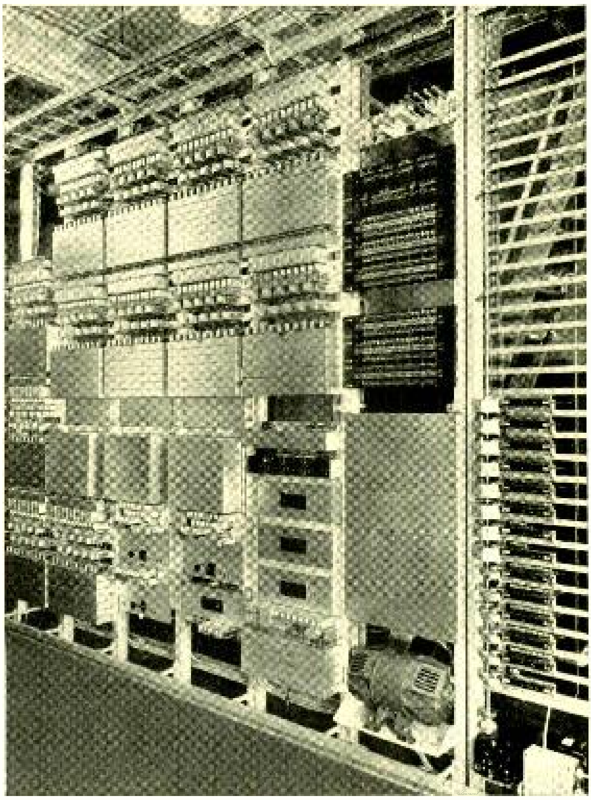

Fig. 3—Equipment bays for the weather-announcing installation in New York City

The equipment arrangement is shown in Figure 3. The three tape machines are under the rectangular covers on the three bays near the left center of the photograph. The three "tape" amplifiers are immediately above them, and the three "power" amplifiers are mounted one above the other on the bay at the right. Below the two right-hand tape machines are the two automatic speech monitors. The rest of the control circuit is mounted below the "power" amplifiers. Outgoing trunks are arranged in groups of ten; two of such groups are above each of the "tape" amplifiers.

The tape machines and both types of amplifiers operate on commercial 110-volt a-c power, but a motor-generator is provided—second bay from the right—which in case of failure of the commercial source will operate from the office battery and provide the needed a-c power. The upper part of this bay carries fuses for the various circuits. The right-hand bay carries interrupters used to disconnect calling lines automatically after a period varying from one to six minutes. These are provided to prevent trunks from being held busy by a failure to hang up.

Weather-Announcing Tape Machine

By R. A. CUSHMAN

Commercial Products Development

A WEATHER-ANNOUNCING machine is now installed at the West Fiftieth Street central-office building of the New York Telephone Company. With this machine, telephone subscribers throughout greater New York may receive authoritative forecasts of weather conditions. Information for these announcements is supplied hourly between seven A.M. and eleven P.M. by the local office of the United States Weather Bureau over a direct teletype connection.

Magnetic tape recording is well suited to services of this type where it is necessary to change the recorded message frequently and where permanent preservation of the record is of no importance. The record is made by producing in a moving steel tape* of high retentivity a magnetic pattern corresponding to the voice current coming from the microphone circuit. This pattern remains in the tape and can be "picked up" electrically many thousands of times until erased, which is done by saturating the tape with a heavy magnetic field. The entire process of erasing, recording a new message, and reproducing is controlled by a few keys at the operating turret. No experience or technique is required to obtain faithful reproduction of the announcement, and since the steel tape may be used again and again indefinitely, there is no continuing expense for record material and there is no processing cost involved.

Three of these machines are mounted, each with its associated amplifier, on the relay-rack bays that carry the apparatus for control and distribution of the service. The tape machine employs slightly over forty feet of tape wound on three accurately machined brass drums. The two ends of the tape are electrically welded to form a single tape loop, which is driven at a very uniform velocity. About twenty-five seconds is required for the passage of the tape between the recording and reproducing pole pieces. Figure 1 shows the general arrangement of the machine, which is mounted on a steel panel bolted to the relay rack. The brass drums for holding the tape are arranged in a triangle, as shown, with their front ends supported by the triangular plate attached by channel struts to the main panel. The drum shafts run in large wick-oiled bearings. Variations in the length of the tape due to temperature changes are compensated by a spring idler, which appears behind the circular hole in the front plate and maintains a light but uniform tension in the tape. Certain improvements in fundamental design of the equipment, which have had notable effect on the quality of the recording, were contributed by D. E. Wooldridge of the Research Department.

A unique method was developed for storing the long tape loops in a small space. The design employs combs, consisting of spaced washers, for maintaining the position of the tape

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*RECORD, *Sept.*, 1937, *p.* 2.

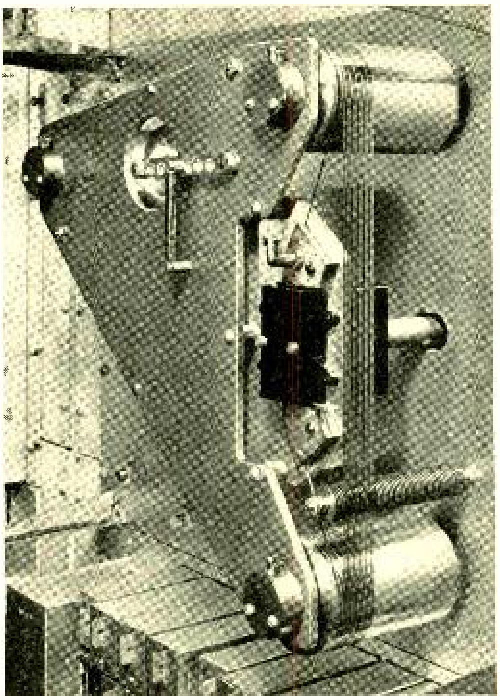


Fig. 1—Front view of tape machine with cover removed

on the drums; and it requires no cross-over idlers. One of the combs is visible just above the lower drum in Figure 1. (Space is provided for a tape loop of three times the present length if a longer message appears desirable in the future.) The drums above and below the pole-piece unit are driven by the tape. The drum whose bearing appears at the extreme left of the figure is driven by the large pulley which may be seen in Figure 2, showing the back of the main panel. A small split-phase induction motor is mounted on a hinged support so that its weight maintains proper tension in the driving belt. To maintain the extremely constant speed required in all forms of satisfactory recording apparatus, a flywheel is attached to the motor shaft, which runs at 1725 rpm.

On the rear of the panel there is also a condenser used with the split-phase motor, and beneath it, a relay to permit control of the motor (110-volt, 60-cycle) from the 48-volt d-c control circuits of the system. Two covers have been removed for the view of Figure 2; the one on the right protects the pulley and the belt from accidental contact, and the one on the left covers the exposed a-c terminals on the condenser and relay. The plug, shown in the foreground, is used to supply a-c from a standard conduit outlet. The terminal board on the left provides connection to the control circuits and to the pole pieces. The pole-piece circuits are fed, by the cable shown, through the panel to a plug and jack which facilitates the removal of the pole-piece unit for any necessary servicing.

The amplifier, shown in Figure 3, is mounted immediately above the machine on the rack. Since it is used both in recording a message and in reproducing it, input and output relays are

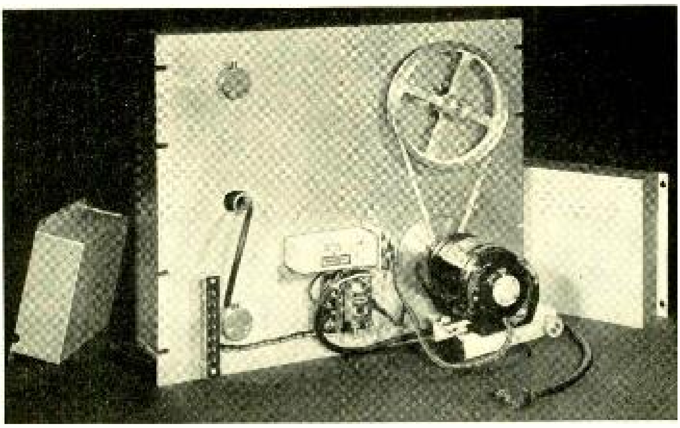


Fig. 2—Rear view of machine showing driving arrangement

provided which during recording enable the low-level microphone current to be amplified to the correct level and supplied to the recording pole pieces. The self-contained rectifier which supplies d-c power for the tubes of the amplifier also supplies the erasing and biasing currents for the pole pieces as switched by these relays. In reproducing, the relays reconnect the amplifier to amplify the relatively weak potentials obtained by the pole pieces from the magnetic patterns on the tape to a sufficient level for feeding the power amplifiers associated with the distribution system. The amplifier—like the tape machine—requires a 110-volt, 60-cycle a-c power supply. Separate controls are provided for adjusting recording and reproducing levels.

Since the machines are mounted on racks containing amplifiers and other vacuum-tube apparatus, it was essential that vibration and acoustic noise be reduced to low levels. This has been accomplished by mounting the motor assembly on rubber pads. As a result, the machines have proved to be unusually quiet in operation.

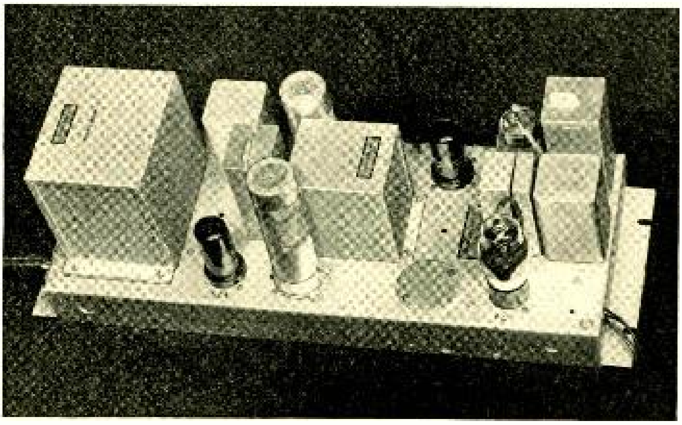


Fig. 3—Recording and reproducing amplifier used with the tape machine for the weather-announcing system

An Artificial Mastoid for Audiphone Measurements

By M. S. HAWLEY
Transmission Instruments Engineering

IN DEVELOPING bone-conduction audiphone receivers, it is necessary to make frequent measurements of response-frequency characteristics. The time required to develop a receiver is largely dependent on the speed with which these tests can be made. Simple and easy tests of the receivers after manufacture are likewise highly desirable. The obvious way of making response measurements would be to place the receiver on someone's head, and then obtain the response either by a listening test or by measuring the vibrational velocity of the receiver, which can be correlated to the auditory response. Either of these methods requires two people, however, and the listening test is further handicapped by being laborious and difficult to duplicate because of variations in hearing acuity of different people and of the same person from time to time. Some simple testing procedure in which these types of variations would not occur was highly desirable.

Because of the inherent difficulties of listening tests, measurements of the vibrational velocity of the receiver at various frequencies seemed the preferable method of test, if some satisfactory way of loading the receiver could be found. The load on the receiver during the test has a definite effect on the response obtained. If a golf ball, for example, is dropped on a hard cement sidewalk it will bounce freely up again, nearly the distance it was allowed to fall, but if it is dropped on a soft wood sidewalk or on an asphalt road softened by the sun, it will scarcely bounce at all. The response of the ball, in other words, depends on the characteristics of the material it strikes. In a similar manner the response of a bone-conduction receiver depends on the

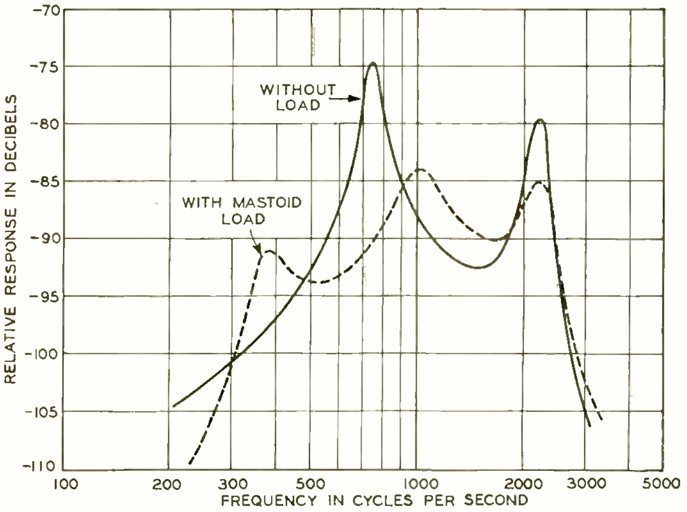


Fig. 1—Relative response of an experimental bone-conduction receiver with and without the mastoid load

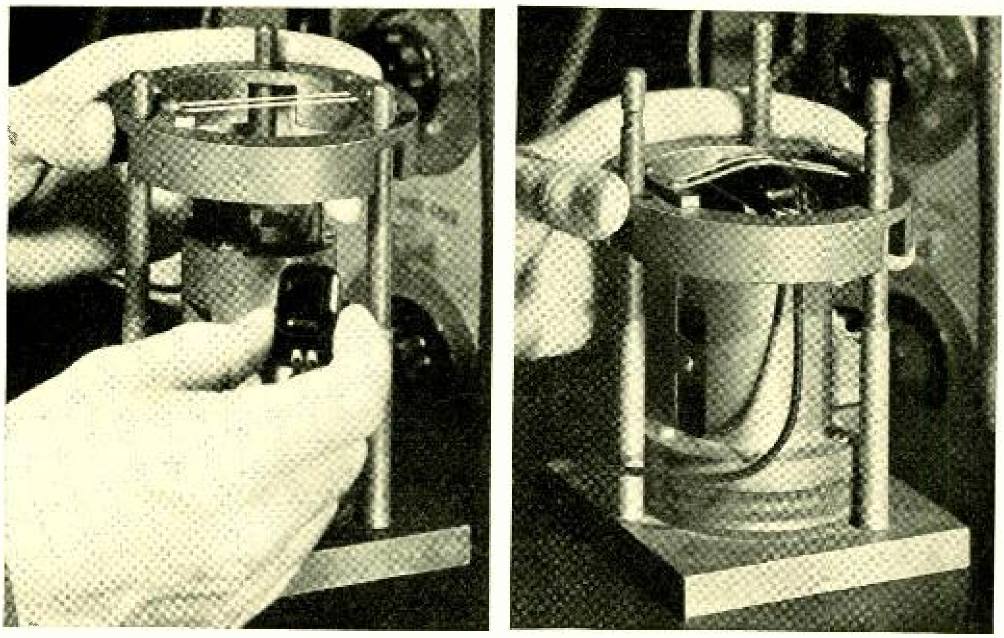


Fig. 2—Left, the artificial mastoid with weight raised ready for the insertion of the receiver; right, the artificial mastoid with receiver in place

load against which it works, which is supplied by the surface it rests on; its response when laid on a desk, for example, will be different from its response when pressed against the mastoid bone, which is the usual way of wearing it. The effect of the load on the receiver is indicated by Figure 1, which shows the relative response of an experimental receiver measured both with and without the mastoid load.

To provide a method of measuring the response of bone-conduction receivers under the correct mastoid load but without the inconvenience and inherent irregularities that would result from measurements taken on a human mastoid, an artificial mastoid was developed in the Laboratories. The impedance offered by the mastoid to a bone-conduction receiver was measured on a number of people, and then a rubber block was designed that presented to a receiver placed upon it approximately the same impedance as the average human mastoid. The arrangement is shown in Figure 3. The annular weight 3 of Figure 3, working through the rubber bands 2, holds the receiver against the rubber block 1. The weight of this ring is equal to the force which the headband furnishes in normal use.

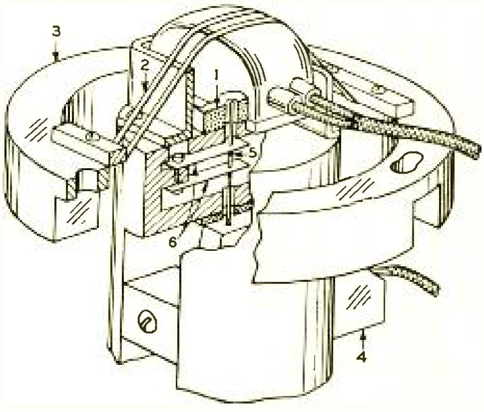


Fig. 3—Diagrammatic drawing of the artificial mastoid indicating operating parts

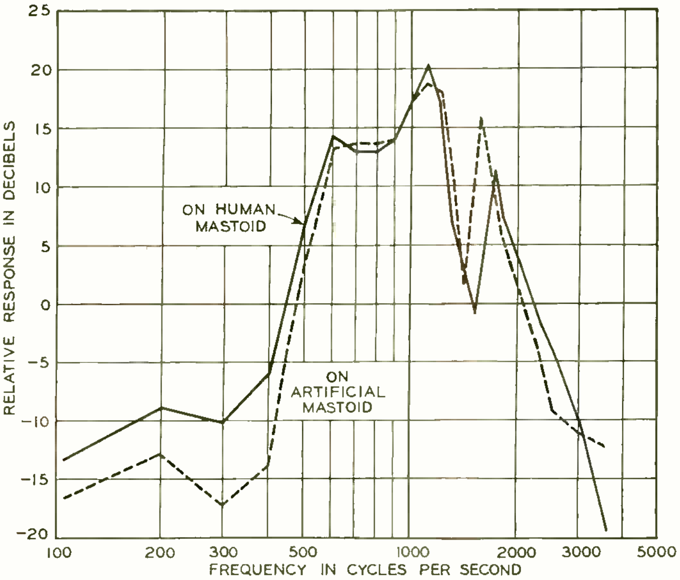


Fig. 5—Relative response of an experimental bone-conduction receiver on artificial mastoid and in actual use

The vibrational velocity of the receiver is measured by a vertical type phonograph reproducer, 4 in the diagram, which is connected to the receiver through the rod 5 supported by the springs 6. These latter merely guide the rod and carry its weight; they have no appreciable effect on the response.

Velocity measurements made on the artificial mastoid may be changed to acoustic response if desired by use of the curve shown in Figure 4, which is plotted from data gathered by the Laboratories. This curve shows, for the usual frequency range, the velocity of the bone-conduction receiver, relative to a velocity of one centimeter per second, that is required to produce a hearing sensation equivalent to one bar pressure in an open sound field.

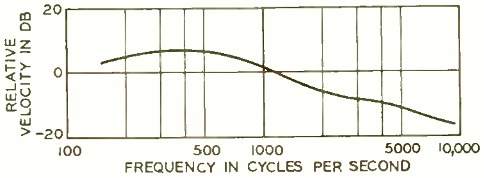
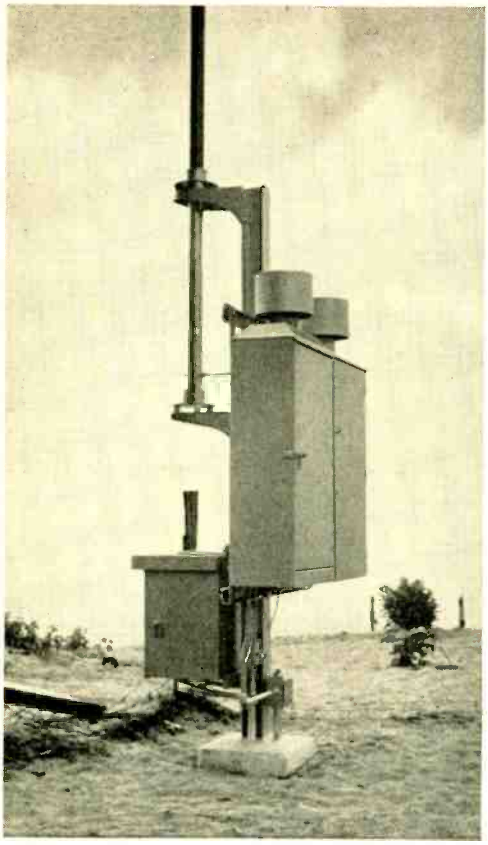


Fig. 4—Velocity of bone-conduction receiver required to produce a hearing sensation equivalent to one bar pressure in an open sound field

Since the artificial mastoid is based on average values of mastoid impedance, there may be slight variations in the results obtained with it and with some particular subject. The possible deviations are indicated by Figure 5, which shows a response obtained with the artificial mastoid and with one particular subject. There is a slight departure evident at the very low frequencies, but over the major part of the frequency range, the results are in close agreement, and are accurate enough for all practical purposes. Measurements on the same instruments made over a period of a year have shown very good correlation. Eventually, the rubber pad will age and change in impedance characteristics. The replacement of the old pad by a new one is a simple matter, however, so that the aging of the rubber pad should not be of considerable consequence.

The artificial mastoid may be used in making other tests on receivers in which it is desired that the receiver be coupled to an impedance load equal to that of the head. Such tests include electrical impedance measurements, rattle tests, and non-linear distortion measurements.



A Remotely Controlled Radio Receiver

By C. B. McKENNIE

Radio Development

IN COASTAL radio-telephone circuits, the shore transmitter is in frequent use, and equipment of moderately high power is justified. Any individual ship transmitter, however, is used far less frequently; the owner is naturally interested in keeping down its space requirements and its cost; and so ship transmitters of only a few watts output are common. To provide good reception from the low-power ship transmitters, which in addition usually have antennas of low efficiency because of the small size of the vessel, the shore receivers should be located in residential or country districts and should be spaced at short enough intervals to permit one always to be within close range. At the New York station, for example, is a single 400-watt transmitter, but receivers are located at Setauket, Sands Point; at Venetian Shores near Babylon, Long Island; and at Rosebank on Staten Island. Since attended telephone offices are not usually found at the isolated points selected for the receiver sites, the receivers have been designed to be mounted on telephone poles, and to operate for long periods without attention.

Arrangements have been provided for controlling the operation of the receiver over a single telephone line. The control circuit, which is described in an accompanying article,* controls two oscillators used for testing; and it gives an alarm when the receiver automatically switches to or from the emergency power supply. It also provides for the codan—a carrier-operated device used to disable the receiver when no carrier is being received—to signal the operator when carrier comes in, and to transfer the talking circuit between transmitter and receiver during a conversation.

When used for remote control, this new receiver, known as the 23AB, is mounted in a weatherproof cabinet together with the power supply and relay equipment essential for its operation. This cabinet is usually mounted on a pole, which also supports the antenna. The installation at Sands Point, with two pole-mounted receivers, is shown in the photograph

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at the head of this article. The complete equipment is known as the 223A Radio-Telephone Equipment, and includes—besides the receiver proper—a dynamotor panel, a control panel, a test oscillator panel, and a battery with trickle charger, which is used in event of failure of the commercial a-c supply normally employed. This emergency battery and charger is mounted in a separate weatherproof box shown in Figure 1.

The main cabinet with door open and dust covers removed is shown in Figure 2. The receiver, dynamotor, and relay equipment are mounted on 19-inch panels which fasten to a supporting frame similar to a short section of relay rack. The frame is hinged, slightly off center, at the top and bottom, and after removing two screws it may be rotated. Removing the rear covers gives easy access to all the wiring and equipment on the back.

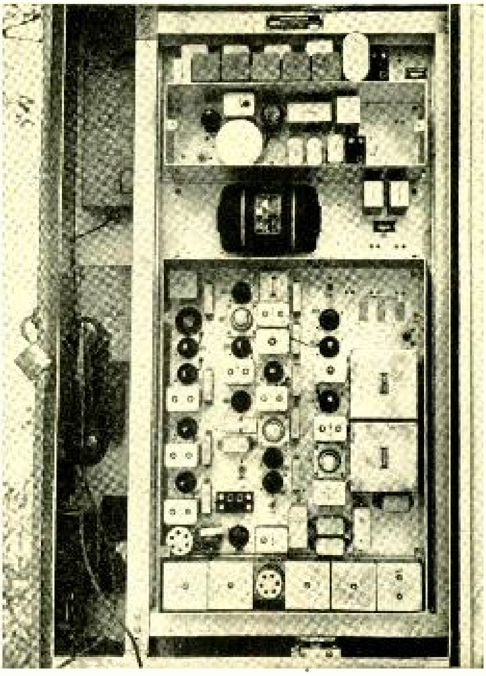


Fig. 2—*Main receiver cabinet*

A 110-volt commercial supply is brought to a switch to supply the receiver under normal conditions. From this switch a connection runs to the battery box where a charger keeps the battery fully charged under normal conditions. In the two boxes above the power switch are filters for the power and telephone lines to prevent radio-frequency disturbances picked up on the lines from interfering with the radio receiver.

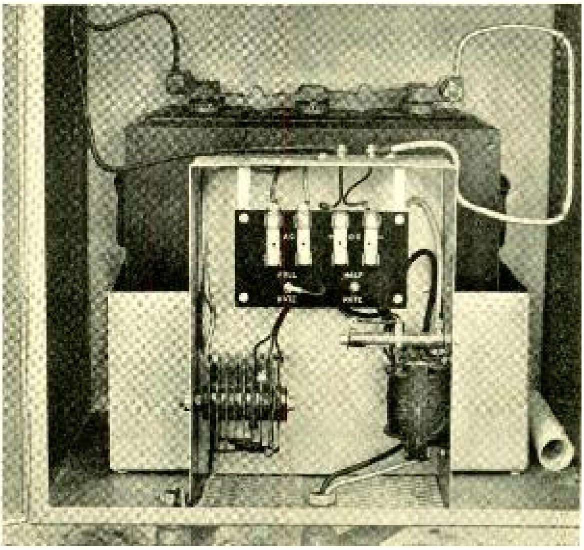


Fig. 1—*A 6-volt storage battery, trickle charged, for use in case of failure of the a-c supply*

The receiver is arranged so that when the a-c supply fails, the equipment is automatically shifted to the battery by relays. The dynamotor is then driven by the battery and furnishes the high-voltage supply, while the filaments and crystal heaters are transferred directly to the battery. When this occurs, a signal is sent over the connecting line to the control office to warn of the failure. When the supply comes on again, the equipment is automatically transferred back to it, and a similar signal is sent to the control office. It is thus possible to keep a record of the duration of the power interruptions so that steps may be taken to keep the set operating if a power failure is protracted.

The circuit of the receiver is indicated by the block schematic along the upper line of Figure 3. Three tuned circuits are provided ahead of the first radio-frequency amplifier to provide high selectivity, and two other tuned circuits are connected between the amplifier and the first detector. The overall selectivity characteristic is shown in Figure 4. These curves show the value of an undesired signal in microvolts that will be 20 db below the desired signal at various frequency separations from the desired frequency.

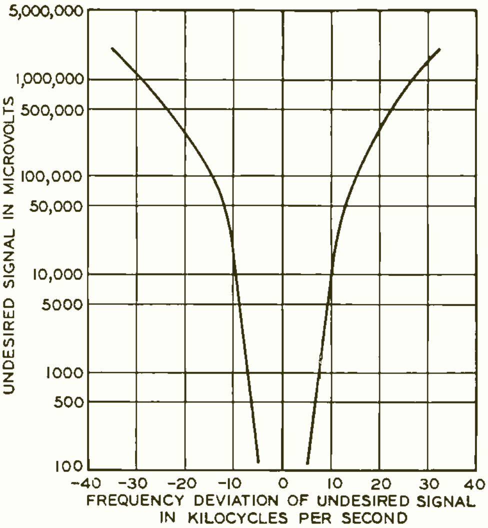


Fig. 4—Radio-frequency selectivity of the 23AB radio receiver

In the intermediate-frequency section of the circuit, double-tuned filters are connected between the first detector and the first intermediate-frequency amplifier, between the first and second intermediate-frequency amplifiers, and at both sides of the peak limiter. The detector-amplifier for the automatic volume control is connected at the input of the audio detector. A level-control potentiometer is inserted between the detector-audio-amplifier and the output tube. Intermediate and audio-frequency characteristics of the receiver are shown in Figures 5 and 6. The automatic volume control limits the

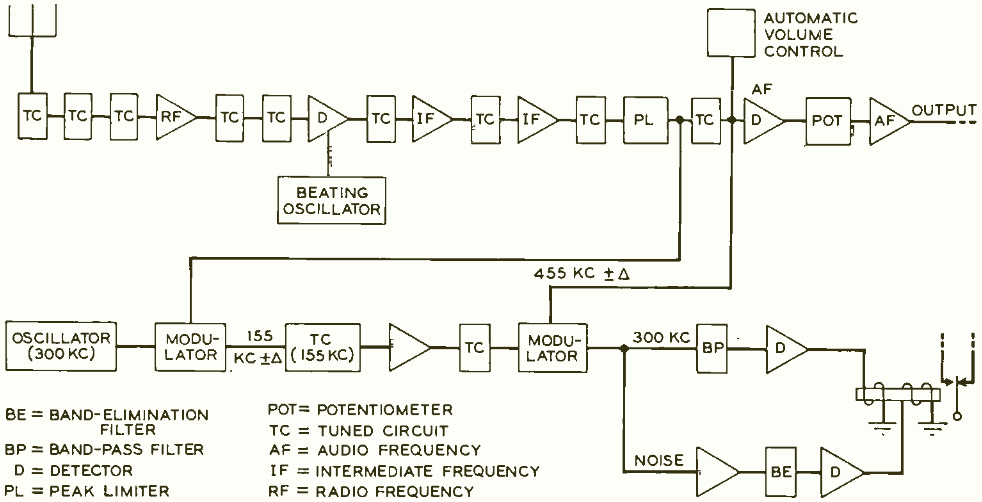


Fig. 3—Block schematic of receiver, above; and codan, below

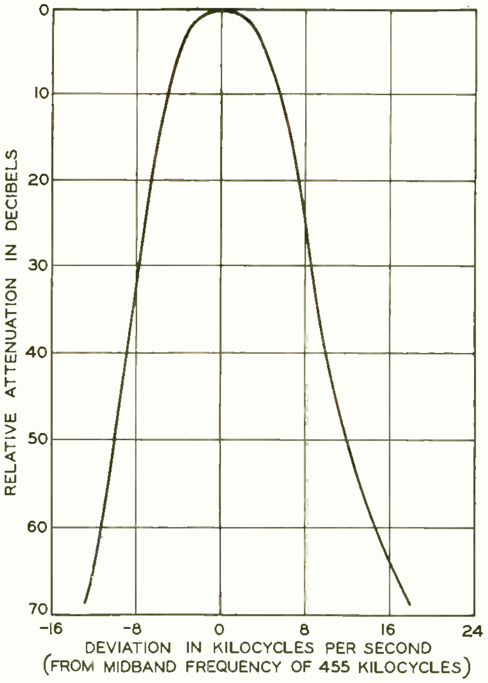


Fig. 5—Intermediate-frequency characteristic of the 23AB radio receiver

change in output for a 100-db change in input to about 5 db, so that a wide variation in signal input has a negligible effect on output level.

In its simplest form a codan employs a relay adjusted to operate when carrier is on, and not to operate on noise alone. In this simple form, however, frequent readjustment is necessary since both carrier and noise vary in level. If such adjustments are not made, an increase in noise level may actuate the relay without any carrier present, or a decrease in carrier level may result in a failure to operate. Since the 23AB receivers are to be unattended, a codan was desired that would be operated only by the carrier and that would always operate whenever the noise level permitted the circuit to be used for commercial service. Both of these requirements indicated the necessity of a narrow-band filter to pass the carrier but to reject the noise. Since, however, ship transmitters are not under the supervision of a shore station, their carrier frequencies will vary somewhat, and means must be found for eliminating any variation before the current enters the filter. This was done, in effect, by using the incoming carrier to control the output from a local oscillator as described below.

In the schematic of Figure 3 the receiver is seen to be of the double-detection type. The beating oscillator is set to such a value that the intermediate frequency is 455 kc, if the ship station's carrier is at its assigned value. Some of this 455-kc current is combined with a 300-kc current generated in the codan, and the lower sideband at 155 kc is selected by a filter. After amplification, this frequency is modulated with the 455-kc current and the lower sideband, at 300 kc, taken off. It will be observed that any variation in the frequency of the ship's carrier will appear in the intermediate frequency; but since the intermediate frequency is first added to and then subtracted from the 300 kilocycles, any variations cancel out, and the frequency applied to the

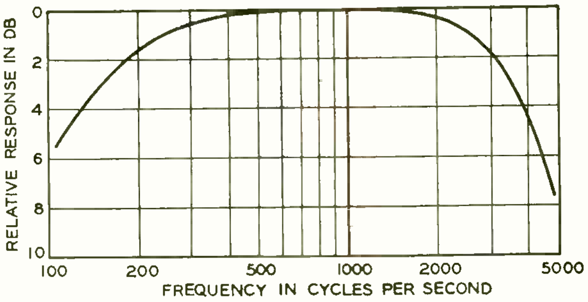


Fig. 6—Audio characteristics of the 23AB radio receiver for remotely controlled service

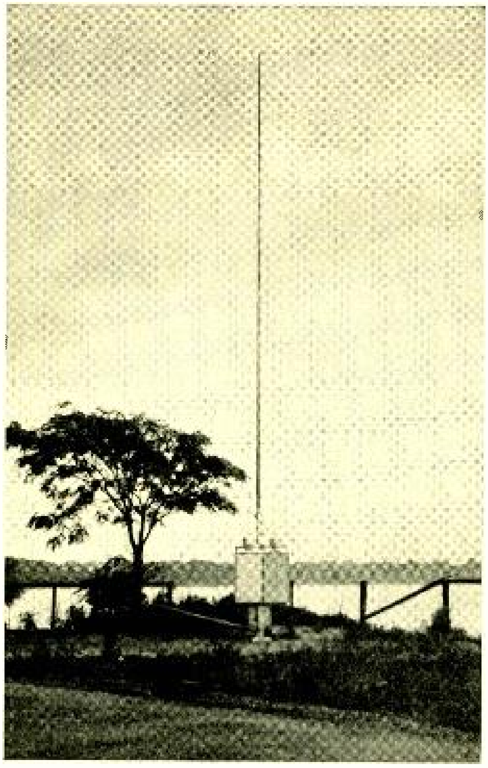
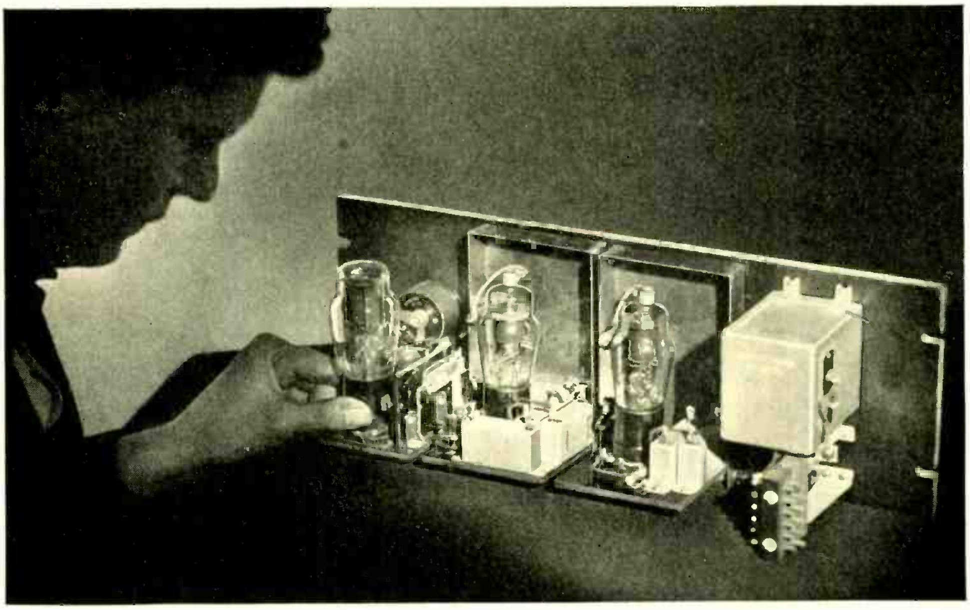


Fig. 7—Installation at Sands Point

narrow band filter is exactly 300 kc. Amplitude of the 300-kc current is substantially proportional to that of the ship's carrier.

To make the codan operate when the carrier exceeds the noise by a fixed amount, the small amount of noise which comes through with the 300 kc is separated from it by a band-elimination filter, rectified, and used to bias a relay against the pull of the rectified 300-kc current. When no carrier is being received, the relay is held operated in one direction by the rectified noise output and disables the audio output of the receiver. When the carrier comes on, the energy from the narrow band in the second winding opposes the effect of the noise current in the first winding, releases the relay, and removes a short circuit from the receiver output.

Actual operating experience in a trial installation has shown that the performance of the receiver is highly satisfactory. Among advantages noted are the elimination of high-level noise from telephone cables and from the monitoring loudspeaker; appearance of a lamp signal at the toll board when a ship calls; and acceptance of calls from more and more distant stations as the noise level falls. No adjustment is required for a wide range of noise conditions and reliable operation of the codan is obtained even from radio circuits that are normally too noisy for commercial service.



Gas-Tube Noise Generator for Circuit Testing

By E. PETERSON
Circuit Research

ONE of the important problems in the design of multi-channel carrier-telephone systems is the avoidance of interference between channels. This particular type of interference may arise from cross-modulation in vacuum tubes and in coils with ferromagnetic cores, since the several channels traverse line amplifiers and terminating networks in common. It may appear as intelligible or unintelligible crosstalk, either of which lowers the quality of transmission. For this reason stringent limitations are imposed upon cross-modulation.

To test whether or not a system meets these requirements is a relatively simple matter when only a few channels are involved. The customary procedure in that case is to load some of the channels with talkers arranged to simulate practical conditions, and then to make observations in one of the unoccupied channels. These observations may consist of either noise meter readings or of listening tests. When a system with a large number of channels is involved, such as the 240 provided for in the New York-Philadelphia trial coaxial cable, it becomes exceedingly cumbersome and expensive to provide enough talkers to load the system. For these conditions a comparatively simple testing means is needed.

Before a suitable testing wave can be devised, it is necessary to establish the properties of the waves transmitted under practical operating conditions. The wave form can hardly be dealt with directly because it is a highly fluctuating affair, which varies in form and magnitude from moment to moment, since it is the composite of modulated speech currents from many active channels. The information needed can be gotten, however, from statistical studies of such waves, which yield their voltage distributions. These tell the fraction of time during which any given voltage is exceeded.

Studies of this nature have been carried out by H. K. Dunn and M. E. Campbell for composite speech produced by different numbers of talkers. Figure 1 shows some of their results for one, four, sixteen and sixty-four talkers respectively. The ratio of the observed to the root-mean-square voltage is plotted in db against the percentage of time during which that voltage ratio is exceeded. These curves become progressively flatter over the greater part of the range as the number of talkers increases, until finally, when sixty-four or more talkers are used, the distribution curve approximates more and more closely the normal distribution illustrated by the dashed line in Figure 1. The approximation to the normal distribution as a limiting form is to be expected on the basis of probability theory.

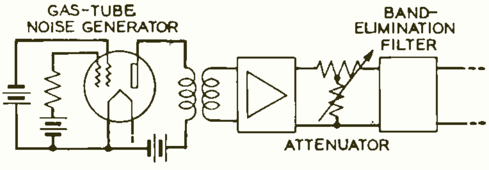


Fig. 2—Circuit of the noise generator used in testing multi-channel telephone systems

These results indicate that a test wave suitable for a large number of channels should have a normal distribution of amplitudes, and should be spread out more or less uniformly along the frequency band occupied by the carrier systems. Fortunately voltage sources with these characteristics are obtainable. One such source, which is sometimes referred to as resistance noise, is developed by the random motion of electrons in conductors. To produce a uniform output of resistance noise over a band extending to one megacycle at a level sufficient to load the system would require a carefully constructed high-gain amplifier. Another source more easily adapted to the purpose is found in the gas-tube noise generator. In this device an arc is formed and confined within the space between the cathode of the tube and a grid next to it. Electrons which escape from the arc-space through the

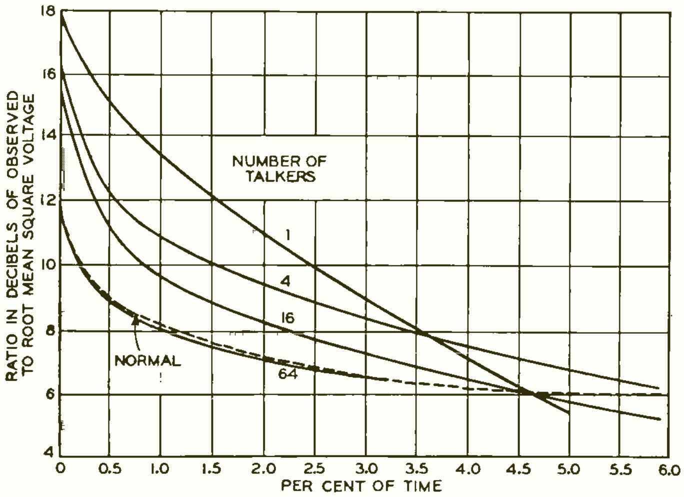


Fig. 1—The voltage distribution of the voice currents from a group of talkers approaches a normal distribution more closely as the number of talkers increases

inner grid-mesh are drawn over to the plate. The tube circuit used is shown in Figure 2. In an experimental model of this noise generator the output power developed stayed constant within two db for frequencies up to one megacycle, close enough for present purposes.

The method adopted for using this source in laboratory testing is one previously applied to the measurement of cross-modulation effects associated with transatlantic radio circuits. A band-elimination filter is connected to the noise generator output so that the noise output remains unaltered over the whole frequency range except for the eliminated band, where the output voltage is reduced to a negligibly small value. The eliminated part must be at least one channel wide. By connecting the output of the filter to the coaxial system to be tested and measuring the output of the system over the frequency range covered by the eliminated band, we obtain a measure of the cross-modulation. It should be noted that other kinds of interference, such as background noise, can be separated from the cross-modulation by measurements taken with the noise generator removed. Results of this kind make it possible to determine the cross-modulation expected when a system is loaded by talkers, without incurring the physical complications of tests that are involved with a large number of talkers.

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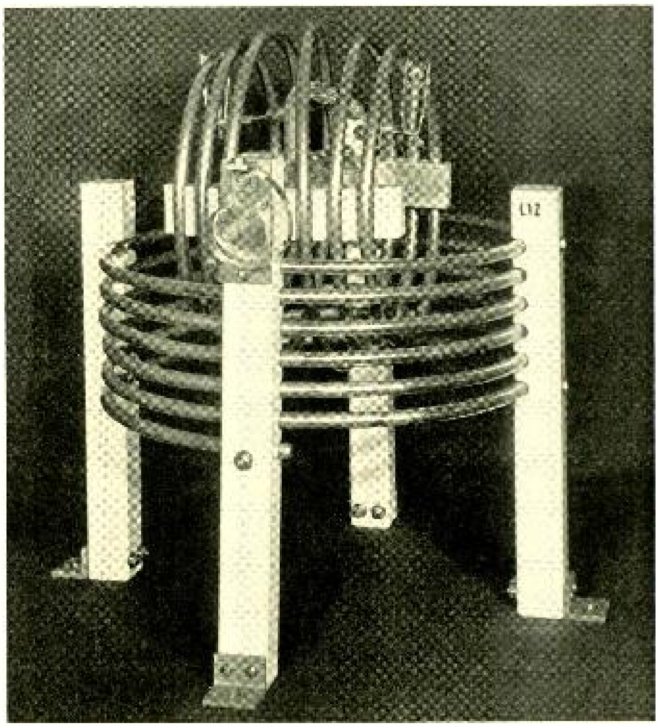

Branching circuit coil of the No. 33B directive antenna control unit in the Western Electric 50-kilowatt radio-transmitting equipment

Single-Sideband Short-Wave Receiver

By J. C. GABRIEL
Radio Research

SINGLE-SIDEBAND short-wave transmission has been a subject of experimental study by the Laboratories for many years. In 1934 practical trials were made, in conjunction with the British Post Office, which have led to certain commercial applications. As already described in the RECORD,* one of the sidebands resulting from modulation was suppressed; and the carrier was greatly reduced in volume so that practically all the energy transmitted was in the remaining sideband.

Because of the satisfactory results of these trials it was decided to use single-sideband transmission on some of the commercial transoceanic circuits. The requirements for a satisfactory receiver were obtained from these earlier studies; new apparatus has been designed and is now in operation on two of the circuits between New York and London and on the one between San Francisco and Honolulu. This new receiver differs from the earlier model,* however, in providing for the reception of two speech channels—one in the band above and the other in the band below the carrier.

By suppressing the carrier and using the entire amplitude capacity of a transmitter for the sideband, an improvement of 6 db is obtainable. This is equivalent to a four-fold increase in radiated power. The amount of noise at the receiver, on the other hand, is proportional to the width of the transmitted band; and by cutting this width in half, through use of only a single sideband, the noise is halved, or reduced by 3 db. The signal-to-noise ratio thus becomes 9 db greater. Put in practical terms, this means that for the same signal-to-noise ratio at the receiver, the radiated power can be reduced to one-eighth of that required for the usual double-sideband method of transmission.

The new receiver is designed to operate over the frequency range from

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*May, 1936, p. 303.

*RECORD, *August*, 1936, *p.* 405.

four to twenty-two megacycles. To simplify construction, this range is divided into two bands, one from four to ten and the other from ten to twenty-two megacycles, with a separate high-frequency amplifier and first demodulator for each. High selectivity is required in the separation of the two sidebands and the carrier. Since this is most readily obtained by crystal filters, it was desirable to have the frequency at the point of separation in the range most favorable to the manufacture of crystal filters. 100 kc was selected as the frequency of the carrier at this stage of the circuit. A crystal filter with a pass band only forty cycles wide is used to separate the carrier; two crystal channel filters—one with a band from 94 to 99.9 and the other with a band from 100.1 to 106 kc—are used for the two channels. Although each sideband is 6 kc wide, the voice channels under twin operation are somewhat under 3 kc wide. One is adjacent to the carrier, and the one on the other side is separated by about 2.5 kc from the carrier.

If the incoming carrier, of perhaps 20,000 kc, were reduced to the intermediate frequency of 100 kc in one step of modulation, the frequency of the beating oscillator would be separated from the carrier by only 0.5 per cent, since the difference between them would be only 100 kc. Under these conditions a disturbing frequency only one per cent away from the carrier, and on the same side as the beating oscillator, would also appear, after demodulation, at 100 kc. Since it is very difficult to make a filter at twenty megacycles that will attenuate a frequency only one per cent away sufficiently to make it negligible, two modulating steps are provided between the incoming carrier and the final intermediate frequency of 100 kc. The circuit arrangement is shown in block schematic form in Figure 1. The second beating oscillator is fixed at 3000 kc. The first beating oscillator is adjustable from seven to nineteen megacycles, and is tuned to 2900 kc above or below the carrier so that at the input to the second demodulator the carrier will have been reduced to 2900 kc. After the second demodulator—with a 3000-kc beating frequency—the carrier will thus be 100 kc.

If this were an ordinary double-sideband system, the frequency bands resulting from the second demodulation—assuming a 6000-cycle voice band—would extend from 94 to 106 kc and by making the output filter somewhat wider than the desired 12 kc, say from 90 to 110 kc, sufficient margin would be provided so that if the incoming carrier or the beating oscillators should vary somewhat from their nominal values, the band would still pass through the filter, and the full voice band would be available at the output of the final detector.

With twin sidebands, however, the situation is different. In the first place the carrier must be separated from the two sidebands so that it may be amplified separately to make up for the reduced value at which it is transmitted. Moreover, the carrier filter must have a very narrow pass band or the reduced carrier would be lost in the noise at adjacent frequencies. For this reason the pass band is made only forty cycles wide, and the frequency of the carrier at the output of the second demodulator must be held at 100 kc to within very close limits or it will not be passed. A variation in a ten-megacycle carrier of only one thousandth of one per cent would more than absorb this entire margin.

Such displacement is prevented by

use of a local 100-kc oscillator of very high precision to fix the carrier frequency at the output of the second demodulator. The locally generated 100 kc from the "reference oscillator" of the schematic is passed through a phase shifter to produce a two-phase voltage at 100 kc. The frequency of the carrier output of the second demodulator, which is also 100 kc if the two beating oscillators and the incoming carrier are at their nominal values, is combined with the two-phase oscillator output in a modulator using two pairs of push-pull pentodes. A two-phase output is thus secured which will have a frequency equal to the difference in frequency between the two nominally 100-kc inputs. A two-phase motor connected to this output is geared to a small variable condenser associated with the first beating oscillator. When the 100-kc oscillator and the carrier output of the second demodulator are at exactly the same frequency, this motor does not run. As the carrier deviates from the 100-kc oscillator frequency, however, the motor will run in one direction or the other depending on whether the carrier is higher or lower than the oscillator. The variation in capacity of the small condenser produces a change in the frequency of the first beating oscillator until the frequency of the demodulated carrier becomes equal to that of the 100-kc oscillator. It will be noted that this correction will be made regardless of whether the original frequency deviation was in the incoming carrier or in either the first or second beating oscillators.

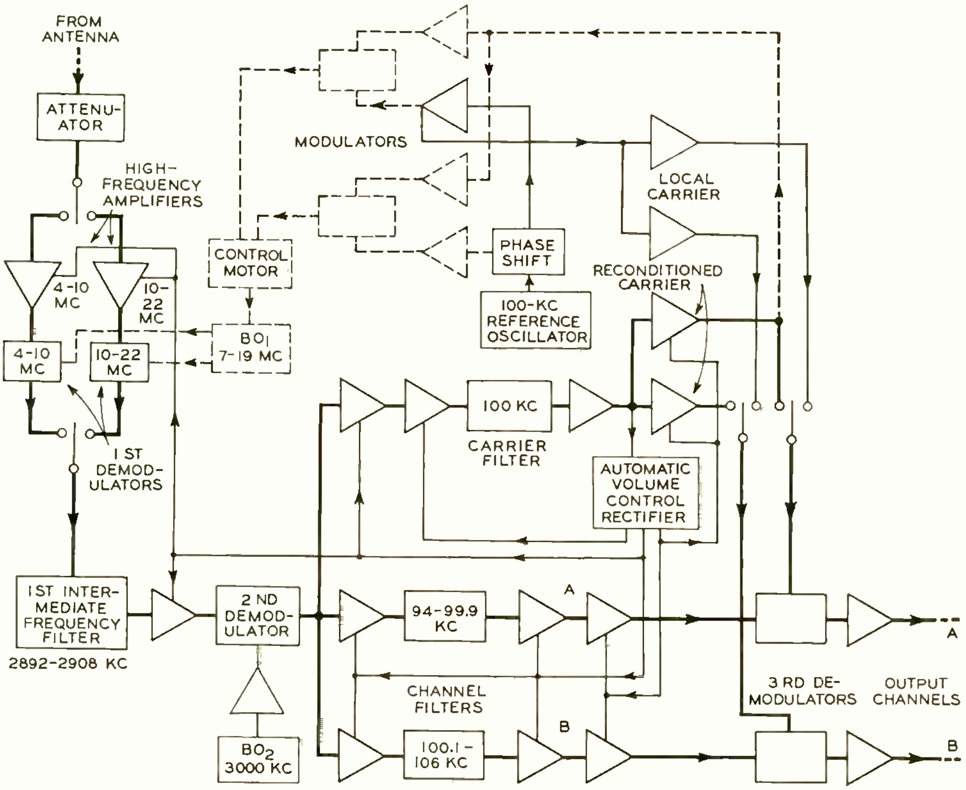

Fig. 1—Block schematic of the circuit arrangement

This 100-kc oscillator may also be used to supply the carrier in the third demodulator by operating a manually controlled switch indicated in Figure 1. Such an arrangement is very helpful during periods of deep fading when, without it, the signal would suffer large changes in volume because of the selective fading of the demodulating carrier and the sideband. Operation of this switch does not affect the frequency control of the first beating oscillator since there is an adequate incoming carrier except during the momentary fades, which are so short that there is no perceptible change in carrier frequency. Under these deep fading conditions the frequency control of the first beating oscillator is particularly important, since a variation of only a very few cycles would result in distortion of the output due to a shifting of the harmonics of the signal fundamentals. If, for example, the first or second oscillator should shift ten cycles, the output of a 200-cycle fundamental and its harmonics, when demodulated by the 100-kc oscillator, would be 210, 410, 610, 810, etc., each being increased by ten cycles. The fact that the fundamental was increased by ten cycles would not be serious, but noticeable distortion would be introduced because the demodulated harmonics were no longer exact multiples of the fundamental. The frequency control, however, is so accurate that these effects are entirely unnoticeable.

The separately amplified carrier also supplies automatic gain control to the entire receiver. The control for the carrier amplifier branch is supplied through a fast-acting circuit so that changes in gain are made promptly. The control for the two channel branches, however, is supplied through a slow-acting circuit, so that the full gain change will be applied to these amplifiers after an appreciable time interval. This arrangement avoids the sudden change in gain that might otherwise occur during carrier fades. By slowing down the action of this part of the automatic gain-control circuit, the fade has passed before more than a small part of the change in gain has been made, and these undesirable changes are avoided.

The receiver is assembled in three cabinets each seven feet high and twenty inches wide. Each has a door at the back; and the three cabinets are bolted together to form a single unit as shown in the photograph at the head of this article. The left-hand cabinet contains all the high-frequency circuits including the first intermediate-frequency filter and amplifier, the second demodulator, the first beating oscillator and its frequency control. The middle cabinet includes equipment for the two channel branches, and the 100-kc oscillator. In the right-hand cabinet is the complete carrier branch equipment, the second beating oscillator, and the rectifiers for plate and grid supplies. Power is taken entirely from a 110-volt a-c commercial supply; and each amplifier and modulator unit contains its own transformer for filament supply. The plate voltages and the grid-biasing voltage are supplied from separate rectifiers to prevent reaction between the various units.

Testing Shields for Carrier-Frequency Line Structures

By M. C. BISKEBORN
Outside Plant Development

SHIELDING is one of several methods used to prevent interference and reduce crosstalk between circuits in telephone cables. It is especially useful in carrier-telephone systems which cover broad-frequency bands and have repeaters of high gain. To study the effectiveness of different shields by manufacturing even relatively short lengths of cable is slow and expensive. Methods of measuring short samples and the application of these methods to specific interference problems have, therefore, been investigated.

Shields were first used on telephone circuits about 1915 to protect entrance cables on open-wire carrier lines. Measurements of the effectiveness of cylindrical shields were begun by the Laboratories some years later, and except for refinements the apparatus has remained practically unchanged. It consists essentially of two slender coils which are mounted in a frame and arranged so that a shield may be placed over one of the coils without changing their relative position. The other coil acts as a pick-up and the effectiveness of the shield is measured by the ratio of the current in the pick-up coil with and without the shield over the disturbing coil. In practice, this ratio is measured directly in db and the shielding effect is thought of as a loss expressed in this unit. Other factors not measured directly by this method affect the crosstalk in long cables, but the method is of great practical value because it permits comparison of different designs based on calculations from these other factors of the amount of shielding needed.

The accuracy of the test-coil method of measuring the shielding effect of solid cylindrical shields was demonstrated by the agreement found between experimental and calculated values of the shielding ratio. The difference in most cases was less than one db.* Materials which had different resistivities were checked over

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*Record, *Mar.*, 1936, *p.* 229.

a range of frequency and of thickness. Test results and calculations for composite shields which consisted of alternate layers of various materials also were in good agreement.

The test-coil method has been applied to short sections of cable shields, which generally consist of several metal tapes assembled in various ways to form a cylindrical structure. Short handmade samples of the taped shield have also been studied to determine the effect on shielding of structural variables such as length of helix, width, thickness, composition and arrangement and number of tapes and overlap or gap between the turns of each tape. A similar investigation would be expensive if carried out on complete cables long enough for crosstalk tests. Furthermore, an average of many crosstalk tests on a given cable would be required in studying the quality of a shield because differences in crosstalk between pairs tend to obscure differences due to the construction of the shield.

The test coils revealed the important fact that a composite shield, made of alternate layers of copper and iron, is more effective for ordinary thicknesses over the usual frequency range when the iron is sandwiched between layers of copper. This is because the reflection loss between copper and air is very much higher than that between iron and air, due to the difference in their impedance ratios.

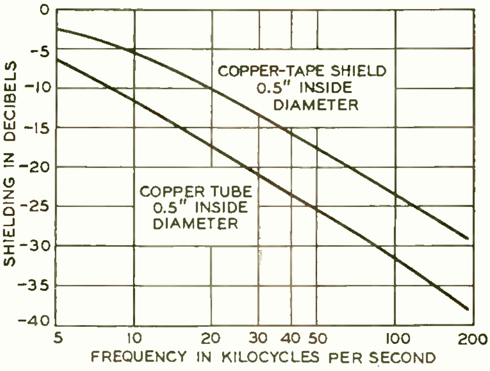

Fig. 1—Comparative shielding effect of two shields, one consisting of two layers of copper tape and the other of a copper tube of the same size. The outer tape covers the gap between the turns of the inner tape

For equal total thicknesses of iron and copper in a copper-iron-copper and an iron-copper-iron shield the total attenuation loss is the same but the extra reflection loss in the copper-iron-copper shield increases its shielding effect. Some, or even all, of this

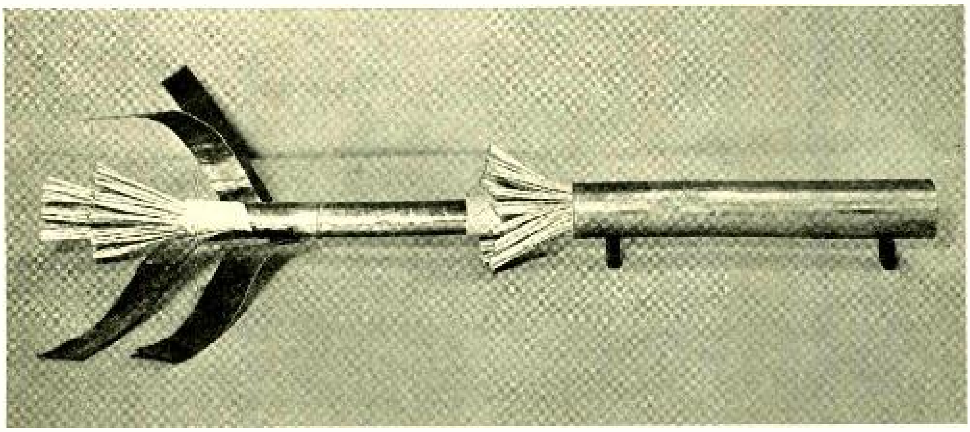

Fig. 2—Sample of a cable shielded with thin metal tapes

gain may be lost, however, if the amount of iron is made smaller in the copper-iron-copper than in the iron-copper-iron shield because the attenuation loss per unit thickness is higher for iron than for copper. This arrangement of layers has been used in many shields, and has the added advantage that the transmission characteristics of circuits in the vicinity of the shield are less affected by the proximity of copper than of iron.

With a simple and accurate means of measuring the effectiveness of cable shields available, there remains the problem of expressing quantitatively the effect of the shield on the interference or crosstalk in a given cable. In a cable with balanced pairs the insertion of a shield between two pairs or groups of pairs reduces the electrostatic crosstalk essentially to zero and the electromagnetic crosstalk by the shielding ratio. In a coaxial cable, on the other hand, the relation between shielding effect and crosstalk differs from that of a balanced-pair cable in that the shield forms one side of the circuit. In this case the transmission current tends to flow on the inner surface of the outside conductor because of the skin effect associated with high frequencies. A disturbing current, due either to crosstalk from another coaxial circuit or to induced voltages from sources outside of the cable, tends to flow on the outer surface of the outside conductor. If the wall of the outer conductor is thick and the frequencies are high, the two currents flow with more or less complete independence of each other. The transfer of energy between the two surfaces may be shown to be closely related to the shielding effect of the outer conductor as measured by test coils. Hence the degree of independence of the transmitted current from the interfering current may be expressed quantitatively in terms of the measured effectiveness of the shield. In both the balanced and the coaxial types of structure the total crosstalk over appreciable lengths of cable is complicated by the interaction of tertiary circuits which are present.

With the aid of test coils, shields have been designed to meet specific crosstalk limits for cables of different general classifications. The method has been of particular value in the design of cable shields for type-K carrier systems, which have go and return channels inside the same lead sheath but separated from each other by the shield. Shields have likewise been designed for broad-band carrier cables which have balanced pairs and quads individually shielded. Test coils have also been used extensively in the study and design of outer conductors that are used in coaxial cable.

Remote Control of Radio Systems

By H. M. PRUDEN
Switching Development

THE location of antennas is generally controlled by factors affecting radio reception or transmission, and thus the most favorable site may very likely be at some distance from the central office through which the radio and land channels will be connected. The radio receivers and transmitters must be near the antennas, and in the past this has required the establishment of the station operating force at some distance from the switching center. For the smaller radio links, where the equipment is simpler and the operating attention required is too small to justify the establishment of a permanent operating staff, the radio equipment has been designed for remote control, and all operating is done from the connecting central office. With this arrangement periodical visits to the radio station are all that is required for ordinary maintenance. This method, which was first used with aeronautical ground stations, has also proved effective for radio receivers in ship-shore or harbor craft service, and for both transmitters and receivers for such low-power radio links as that between Green Harbor and Provincetown.*

The operating functions that must be remotely controlled vary, for the most part, with each installation, so that standardization has not been feasible. In all cases, however, a variety of control pulses transmitted over the voice line between the radio terminal and the central office are employed to actuate a suitable set of relays. An example of one of the simpler forms of control circuit is that used for the pole-mounted radio receivers and transmitters at Provincetown. Here it was necessary to be able to turn on either the receiver alone, or the receiver and transmitter together, or to add to the circuit an oscillator for test purposes.

As shown in Figure 1, a simplex control circuit was formed by a connection to the midpoint of the transformers both at the telephone terminal and at the radio equipment. With this arrangement, the control current flows over both sides of the telephone line in the same direction, and by using a combination of positive and negative pulses to ground, with a suitable combination of relays at the radio terminal, either the receiver, or the transmitter and receiver, may be turned on, or both of them may be turned on together with the test oscillator to set up a test.

With this system two keys are provided at the telephone office: one to connect positive and one negative battery to the simplex circuit. With neither of these keys operated, relay A at the radio terminal is operated, and neither receiver, transmitter, nor oscillator is in operation. To bring in the receiver alone, the positive battery key is operated at the central office, and positive current flowing over the line operates the receiving relay at the radio terminal. This re-

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*Record, *Oct.*, 1934, *p.* 34.

leases the A relay though a back contact, thus putting ground on the receiver control lead and turning on the receiver, and operating the test relay to prevent operation of the test oscillator.

To bring in the transmitter in addition, the polarity of the control current is changed by operating the negative key. This releases the receiving and operates the transmitting relay, and the latter energizes the transmitter through its front contact. During this transition the A relay remains released because of its slow-operate characteristic, and thus the receiver remains in operation and the test relay is held operated to prevent the excitation of the test oscillator.

To test the receiver operation, the receiver, transmitter, and test oscillator must all be in operation at the same time. To bring about this condition, both keys at the telephone office are restored to the normal position, which allows the A relay to operate, and the test relay to release and start the oscillator. The negative key is then operated, which actuates the transmitter relay, bringing in the transmitter, and opens the circuit to the A relay—thus allowing it to release and bring in the receiver.

With such a simplex control circuit there are three possible conditions of current flow—positive current, negative current and no current—and by employing various sequences of two or three of these conditions, and suitable relay combinations at the radio terminal, a number of operations may be secured. A few years ago a circuit of this type was employed to control frequency and antenna selection at a radio transmitter.* A key at the control station connects a telephone dial to either an antenna-change or frequency-change circuit, and the subsequent dialing selects the antenna or frequency desired.

The arrangement of apparatus for this is shown in Figure 2. When the dial is pulled back, battery is connected to the line through the contacts of a pulsing relay, and, depending on whether this battery is positive or negative, the A relay at the transmitting station will operate the antenna or frequency-selecting relay. On release of the dial, the battery is reversed a number of times equal to the digit dialed, and the selector at the transmitter will move ahead an equal number of steps to make the desired selection. Relay B remains operated throughout the pulsing, while relay A follows the pulses in order to actuate the selecting relay.

Instead of using a simplex circuit, it is possible to send positive or negative pulses to ground over the two sides of the line separately, or a current may be circulated around the circuit in the usual manner. Both of these latter methods

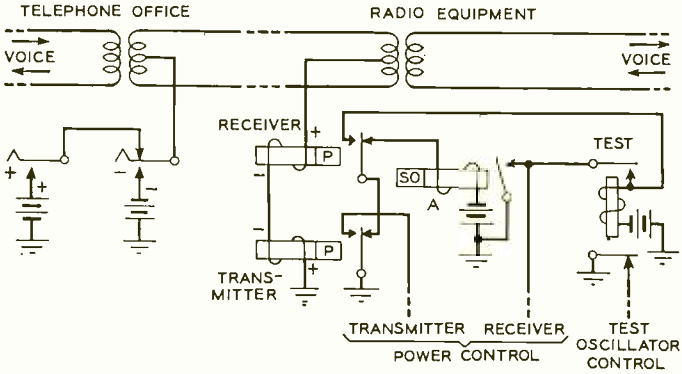

Fig. 1—Simplex control circuit used to control radio receiver and transmitter at Provincetown

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*Record, *Aug.*, 1933, *p.* 365.

were used recently to turn on and off a radio receiver and to control its gain.

For the 223 radio-receiving equipment,* a combination of simplex and circulating circuit is employed. This receiver is normally energized all the time, so that no arrangement need be provided for turning it on or off. It incorporates a codan, however, that operates a relay whenever carrier is being received, and a circuit must be provided over which the carrier-operated relay can operate a relay at the central office to perform a number of circuit functions. In addition means must be provided for operating a test oscillator, reducing the gain of the receiver to meet certain operating conditions, and operating or releasing a lock-up relay used in connection with the signals transmitted when the regular power fails.

The circuit, shown in Figure 3, employs a two-position emergency power-signal key and a three-position key. One is the unoperated position, and the other two are marked "gain control" and "test oscillator control." With the keys in the unoperated positions, a circuit is closed from the positive pole of the battery through both windings of a codan-controlled relay, a simplex line circuit, through two opposing windings on each of two polarized relays at the receiver, the primary winding of the power-control relay, and thence to a front contact of the codan relay. When the codan relay operates, current flows over this simplex circuit to operate the relay at the central office. This current has no effect on two of the polarized relays at the receiver because it divides equally between the opposing windings on each, and no effect on the power-control relay. It also has no effect on the operation of the line as a voice circuit; its only effect is on the codan-controlled relay.

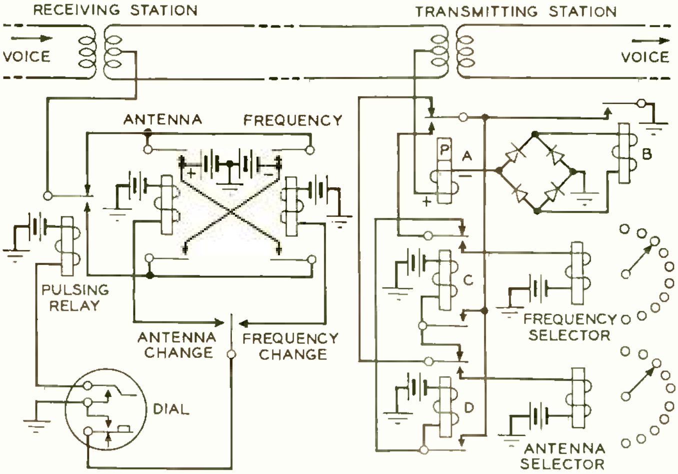

Fig. 2—Simplex dialing circuit used for selecting frequencies and antennas at Miami

When the three-position key is in either of the operated positions, current flows down one side of the line and back the other, and operates one or the other of the balanced polarized relays depending on the direction of flow. Operation of the gain-control key reduces the gain of the receiver to a predetermined point, and operation of the test-oscillator key in a similar manner operates the oscillator-control relay to the test oscillator.

The receiver includes an emergency power supply which is switched on automatically whenever the regular power fails, and is disconnected when the regular power comes back on. The central office is notified of a failure of

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**Page 76, this issue.*

the power by a circuit at the receiver that connects the test oscillator and transmits a steady tone. Since the circuit cannot be used while the tone is on, an additional control circuit is provided to disconnect the tone after the power failure has been noted at the central office. The tone is also applied when the regular power comes back on, and then another control circuit is required to remove the tone.

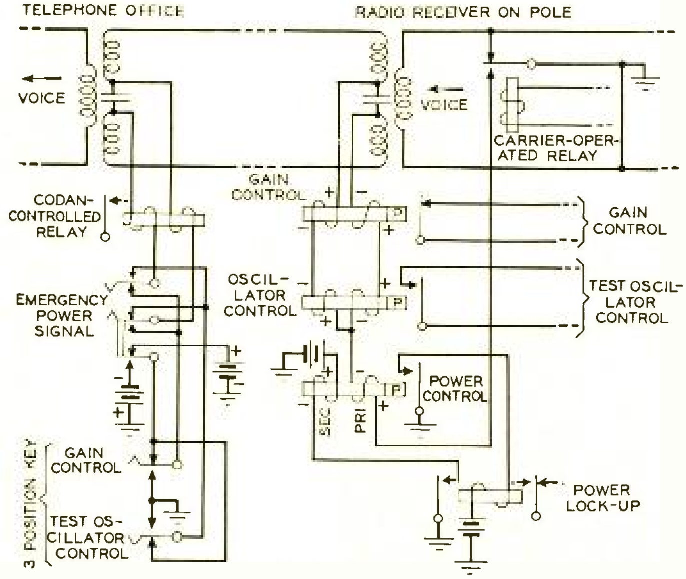

Fig. 3—Control circuit for 223A radio-receiving equipment

To stop the test tone after the receiver has transferred to the emergency battery, the emergency power-signal key at the central office is operated. This key switches the entire control system from negative-grounded battery to positive-grounded battery, and reverses the circuit so that the three-position key operates in the normal manner. Change in the polarity of the signaling battery operates the power-control relay at the next closure of the contacts of the carrier-operated relay. The power-control relay operates the power-lock-up relay, causing these relays to lock up under each other's control and release the signaling tone. To stop the test tone after commercial power has been restored, the emergency power-signal key at the central office is released. Release of this key restores the normal negative-grounded battery to the signaling circuit. At the next closure of the contacts of the carrier-operated relay, the current through the primary winding of the power-control relay is large enough to overcome the effect of the holding current in the secondary winding, so that this relay releases, and releases the power-lock-up relay to restore the circuit to its normal operating condition.

These circuits are typical of the various arrangements that can be provided for controlling radio equipment over a connecting voice-frequency line. The particular form they take is dictated for the most part by the number and type of operations that these circuits are required to perform.

Contributors to this Issue

Eugene Peterson received the degree of electrical engineer from the Polytechnic Institute of Brooklyn in 1917, and degrees of A.M. and Ph.D. from Columbia in 1923 and 1926. He joined the Western Electric Company in 1919, after two years in the Signal Corps. As circuit research engineer, he is engaged in studies of carrier systems and non-linear circuits.

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

E. Peterson

J. C. Gabriel received the E.E. degree from Columbia University in 1917, and then joined the Engineering Department of the Western Electric Company. During the war period he worked on the development of radio equipment for submarine chasers and aircraft. Since then he has been engaged continuously in general radio research and on the various radio developments for the American Telephone and Telegraph Company. These projects include both long-wave and short-wave transatlantic, ship-to-shore, the Green Harbor to Provincetown link, single sideband reception, and the musa.

M. C. Biskeborn joined the Technical Staff of the Laboratories in 1930 immediately after graduating from the South Dakota State School of Mines with a B.S. degree in E.E. As a

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member of the Outside Plant Department, he has been chiefly concerned with design and development work on carrier cables of various types, such as coaxial, balanced pair, type-K, and cables incidental to the type-J system. He has also been engaged in the development of testing methods for the determination of the electrical characteristics of cable circuits at carrier frequencies.

C. B. McKennie spent five years with the F. A. D. Andrea Company engaged in the design of radio equipment, and then joined the Technical Staff of the Laboratories. In the Radio Development Department he has been continuously engaged in the electrical design of radio equipment. He has worked on the development of aircraft receivers, direction finders, and receivers for ship-to-shore service.

R. A. Cushman joined the Laboratories in 1929 following a five-year period at the University of Nebraska where he had been Assistant Professor in Electrical Engineering. Previous to that time he had two years of sales engineering experience and a year of teaching at Cornell University, where he was granted M.E. and M.S. degrees. In the Radio Development Department he spent eight years in the design of transatlantic radio and high-power broadcasting equipment. For nearly two years he has been in charge of a group designing recording and reproducing equipment and systems in the Commercial Products Development Department.

H. M. Pruden joined the Engineering Department of the Western Electric Company during the summer of 1919 and engaged in laboratory work on voice-frequency signaling. As a member of the Technical Staff since 1924, he has been engaged in development of voice frequency signaling and dialing systems, and of voice-operated switching devices and control circuits for radio systems.

W. Bennett joined the Laboratories in 1920 and associated with the circuit laboratory, where he engaged in the testing of step-by-step circuits. During this period he studied at Brooklyn Polytechnic Institute in the evenings. Since 1931 he has been a member of the group engaged in the analysis of special central-office system requirements, and in undertaking the necessary circuit design.