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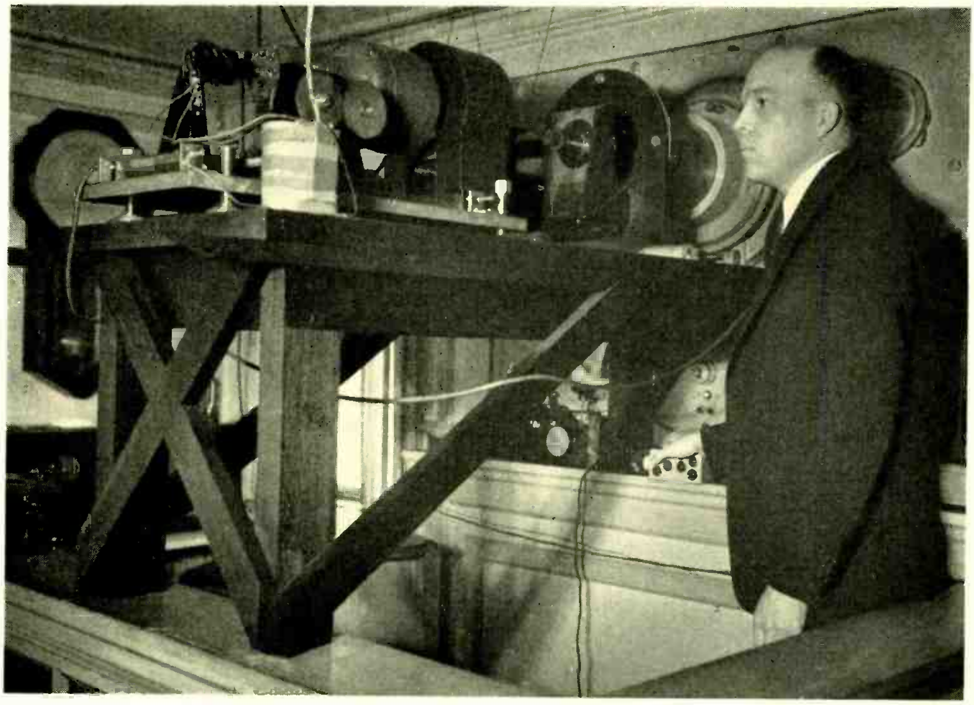
Magnetic strain gauge for aerial cable sheath



The Coronaviser

By A. M. SKELLETT
Electronics Research

IT IS well known that the major disturbances in long-distance radio transmission have their origin in the sun as do also the terrestrial magnetic storms which accompany them. However, just what form of solar activity is responsible has not as yet been ascertained. Sunspots, prominences, faculae and flocculi have been exhaustively studied in this connection and while each of these is closely associated with the unknown form of activity that is responsible, none of them is identical with it. What type of solar activity is left to be studied? Obviously the corona is indicated. It shares in the general cyclic activity of the other phenomena and in addition its streamers are very suggestive of those hypothetical streams of charged particles emanating from the sun by which the terrestrial disturbances may best be explained.

A cloud of electrons and broken-up atoms shot off from the sun and made luminous by it, so tenuous is the corona, as compared with the earth's atmosphere, that it is masked by sunlight scattered by the atmosphere. Stars too are masked by daylight in the same way, but fortunately the sun and the stars have a different apparent motion in the sky, and at some time in the year each star is above the horizon during darkness. The corona, however, goes around with the sun and an adequate view can be seen only when an eclipse shuts off the sun's light from the earth's upper atmosphere.

The advent of television has supplied a method which is very promising because it converts an optical image into a varying electric current, in which new state it may be altered in ways that are impossible by purely optical methods. When several years ago the television method was proposed,* it was realized that the rectangular scanning so well adapted to pictorial television images was unsuitable for this work. What was needed was a means of scanning in a spiral fashion so that a ring-shaped area around the sun could be efficiently covered. A scanner incorporating this principle was developed at the Laboratories along with the rest of the apparatus needed and through the courtesy of Dr. G. W. Cook the method was given a practical trial in his observatory which is located at Wynnewood, Pennsylvania.

Starting at the left of Figure 1 the large plane mirror coupled to a driving mechanism forms a siderostat so that sunlight may be continuously held on the axis of the telescope. The solar disc is focussed by the objective on the small tilted mirror (R, Figure 2) which reflects the direct sunlight out through a hole in the side of the telescope and into a light trap consisting of a black-walled tube with a black velvet end where it is absorbed and thus prevented from introducing spurious effects in the scanning apparatus. As a further precaution the mirror is backed up by a black masking disc D. This mirror and disc are supported by means of the plate glass P so that there is no obstruction in the field around the sun. Silvered on the back, the lens L is equivalent to a concave mirror and brings a portion of the sky image that lies in the plane of D to focus on the scanning hole H which is on the axis of the telescope and scanner. Light that enters the scanning hole passes through the lens S, the prism, and the light tunnel U into the photocell E.

When the lens L is rotated about the axis by the motor, successive portions of the sky image are focussed on the scanning hole and the effect is the

*Bell Laboratories Record, *p.* 113, *Dec.*, 1934.

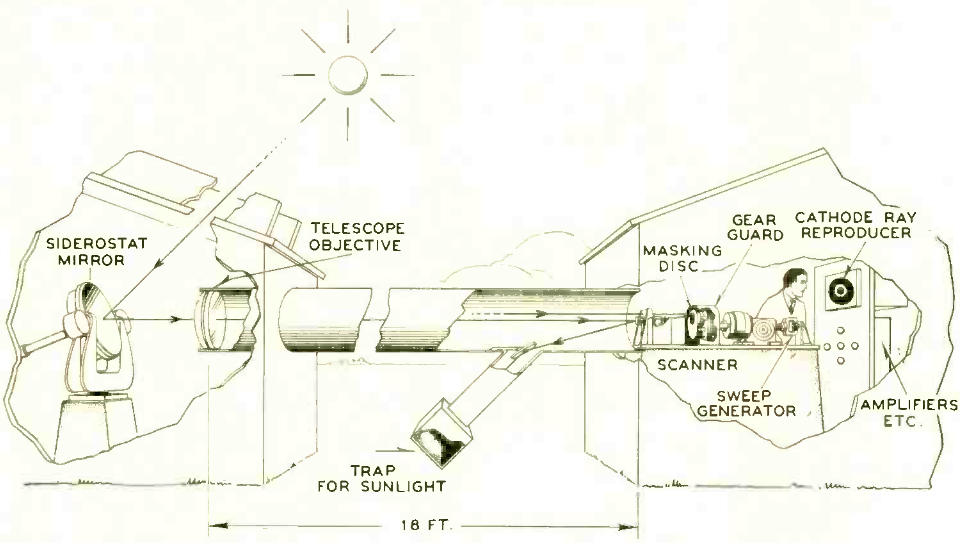


Fig. 1—This diagram shows the application of the Coronaviser to a horizontal telescope

same as moving the scanning hole around in the image plane at D. This takes care of the circular component of the scanning motion. The radial component is obtained by changing the angle of tilt of the lens L while it is rotating. A worm W is mounted on the motor shaft but held stationary so that as the gear G revolves as a whole about the axis of the scanner it is turned more slowly about its own axis. A hardened pin Q attached to the arm of the lens mounting rides on a cam which is fixed to this gear and thus imparts a cyclic tilt to the lens.

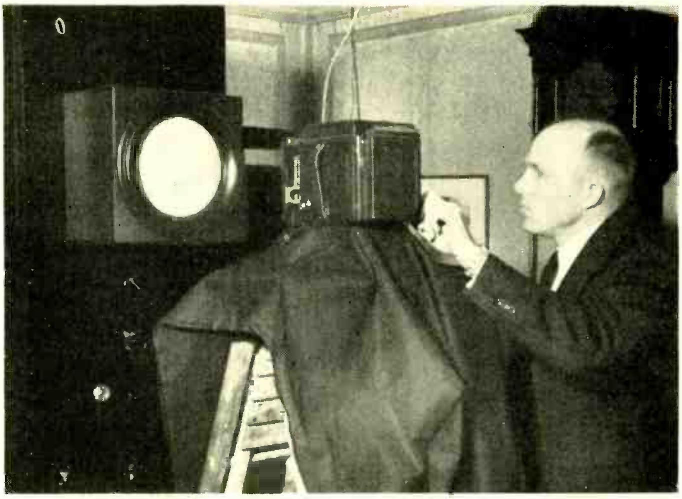


Fig. 3—Exposures of a half-minute yielded a number of good pictures of coronal details

Reproduction of the image is entirely by electrical means. At the opposite end of the motor a C-shaped permanent magnet J rotates about a cylindrical iron core around which there is wound a coil of wire C. The electric current thus generated in the coil is smoothed into a true sine wave by tuning the circuit of the coil so that it resonates at the frequency of circular scanning which is approximately 30 cycles per second. The resulting wave is split into two components 90° apart in phase; and these, after amplification, are impressed on the deflector plates of the reproducing cathode-ray tube so that the spot may move in a circular path.

At the generator end of the motor there is also a reduction gear box, the slow speed shaft of which turns once for a complete cycle of the radial scanning motion, i.e. once a second. This shaft is geared to that of the potentiometer unit B so that its sliding contact also revolves at this rate. The potentiometer winding is continuous around the circle and connec-

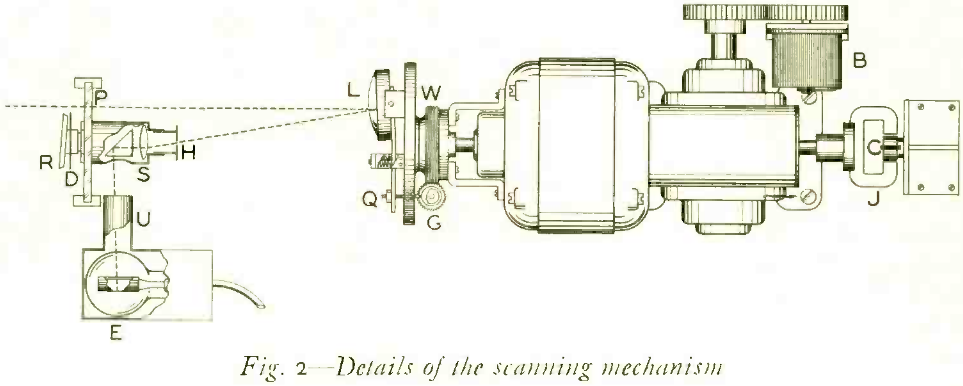


Fig. 2—Details of the scanning mechanism

tions are made at the opposite ends of a diameter. The scanning voltage from the generator circuit is fed into this unit and as the arm revolves the amplitude of the sine wave is made to vary uniformly between its minimum and maximum values so that the spot on the reproducing screen spirals in and out to cover the field.

Since light from the corona must pass through the intensely illuminated atmosphere of the earth, glare from the latter must be eliminated or the corona could not be seen. Fortunately the glare is uniform around the field, so it is represented in the photo-electric current by a uniform direct current which is eliminated by resistance-capacity coupling of the cell to the amplifier. In addition a filter is inserted between the first and second stages which may be adjusted to eliminate some of the low frequency components that arise from the glare because of inaccuracy of lineup or other factors.

The light of the corona is practically identical with that of the sun in its spectral characteristics; and a gas-filled caesium sulphide photocell which has a maximum sensitivity in the green was used. The inner corona has a surface brightness of about the same magnitude as the full moon and the sensitivity of the apparatus was checked by obtaining images of the moon in its varicus phases.

On days when the haze in the sky was very noticeable but yet not in the form of clouds, the brightness of the glare near the edge of the sun was as high as 6000 millionths of the sun's brightness or approximately 6000 times as bright as the corona. On very clear days the brightness was as low as 1250 millionths and this limit may have been set by the scattered light from the telescope parts, particularly the siderostat mirror, rather than the sky. The images were photographed with exposures of from 20 to 30 seconds during which there were reproduced 40 to 60 images; although the noise patterns might be very noticeable in a single scan, the fluctuations balanced out in a statistical manner, leaving a uniform field.

Theoretically the limiting amount of glare through which it is possible to work with this method is determined by the "shot noise" in the photo-electric current but there are practical limits which were the important factors in this case. One of these was set by the cleanness of the plate glass used to support the scanning hole unit. This plate is also near the focal

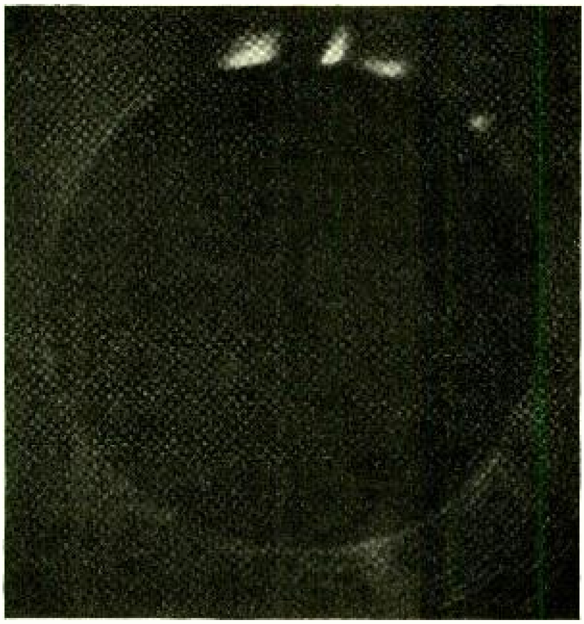


Fig. 4—How the prominences look when viewed through a television system. Picture made at half-past one on an October afternoon with a red filter

plane and the slightest smudge or speck of dust on its surfaces gives rise to an overloaded image on the cathode-ray screen. The glass itself was specially selected to be free from bubbles or blemishes and was carefully washed at frequent intervals.

Occasionally tiny specks of brilliant light would float across the screen, the sources of which were very puzzling at first. They were usually referred to as "angels" and were finally traced to insects or wind-borne seeds which drifted across the sky in the path of the shaft of light. Being illuminated by direct sunlight, they scattered enough light in the direction of the telescope to give a bright diffraction pattern resembling an angel's wings. They ruined many photographs.

Since the glare decreased in the direction outward from the sun, patterns that were caused by instrumental defects took on at times appearances which might easily have been confused with that of a coronal image. It was necessary therefore to have an absolute criterion by which one could distinguish between these parasitic images and others which were associated with the sun. The siderostat mounting of the telescope furnished such a test. With this type of mounting the celestial field rotates about the optic axis of the telescope with time. Thus by taking a series of photographs over a period of several hours it was possible to determine definitely whether or not the image in question was associated with the sun or with the apparatus. In addition to this test, for the prominences, there was the spectrohelioscope at hand by which a direct comparison could be made. Another test applied to the prominence images was furnished by their color. A special red glass filter reduced the general glare level by about 30 times whereas its reduction of the light of the prominences was not nearly so great.

Although the development of an adequate instrument and the proving in of the method have been achieved, the real capabilities of the device will only be realized when it is used under the crystal clear skies encountered on a mountain top in conjunction with a telescope which, by pointing directly at the sun, will eliminate most of the glare that was introduced by the horizontal mounting. These conditions will be satisfied in the continuation of the work at the McDonald Observatory on Mount Locke in Texas. Work has been started on the installation of the coronaviser at this site by Drs. C. T. Elvey and E. T. Rogers who will continue the investigation under the supervision of Dr. Otto Struve, Director of the Yerkes and of the McDonald Observatories.

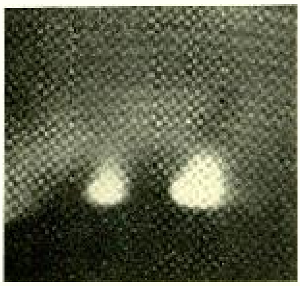


Fig. 5—Prominences taken with a red filter

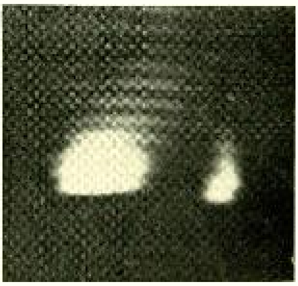


Fig. 6—Prominences taken without a filter

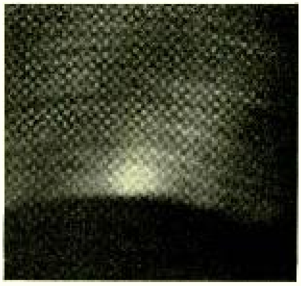


Fig. 7—A jet or flare in the corona

Circuit Features of the 3B Toll Board

By H. F. SHOFFSTALL
Toll Switching Development

MANUAL tandem switchboards are equipped with plug-ended cords, and the operators need only insert the plug into the jack of an idle trunk as requested by the originating operator. With this simple operating procedure, they can handle calls very rapidly. This type of operation has been possible because most of the outgoing trunks were of the same type, and so the operating procedure could always be the same. With the introduction, however, of new facilities such as dialing trunks different procedures are required depending on the type of trunk. In the new 3B board is a discriminator. This automatically determines both the type of trunk calling and the type of trunk being called. It then sets up in the position circuits such connections as are required to secure simple operating procedures for the different types of trunks.

When a call comes in on one of the cords, a lamp associated with that cord lights, as an indication to the operator, and a relay operates to connect the operator's telephone set to the cord. On receiving the request from the originating operator, the 3B operator inserts the plug into the required jack. The discriminator then connects itself to the cord, supplies a temporary termination at the incoming circuit, determines the types of incoming and outgoing circuits, and establishes all the required connections in the position circuits. If the circuits are such that the 3B operator herself is required to dial or key pulse, the discriminator will connect the dial or key set to the cord and light a lamp to indicate that it is ready for her use. As soon as the operating procedure is finished, the discriminator disconnects itself from the cord, and is ready to handle another call.

Each cord has a relay by which it may connect itself to the discriminator. There is one discriminator for each operator's position, and it is multipled to all the cord-connecting relays of the position, but after a cord has been seized and the necessary operating procedure carried out, the connecting relay is locked open until the cord is taken down. The operation of the connecting relay of a cord connects six leads from the cord circuit to the discriminator. A test is made first to determine that the plug is fully seated in the jack, and then a test is made to determine whether battery or ground is connected to either the "tip" or "ring" conductors of the outgoing trunk. Certain types of trunks have battery connections and others have ground, so that the possible type of trunk is narrowed by this test. Depending on the results of this test, the discriminator then tests for various battery conditions or for various resistances to ground, since for each type of trunk a different set of conditions will exist.

Depending on the condition found, a combination of register relays will be operated, and as a result ground will be placed on one or more of a group of wires. This ground will operate a relay or combination of relays that will set up the correct connections for handling this type of call, properly signal the calling operator, and then—after "cutting through" the talking circuit—will release the connecting relay for that cord.

The circuit used for these preliminary tests is shown in Figure 1. The sleeve leads of all outgoing trunks are grounded, and when a plug is inserted in one of their jacks, this ground operates relay S of the cord circuit. This relay, in turn, operates the "connecting," or D, relay through its P winding and battery on a back contact of the S relay of the discriminator circuit. When D operates, a circuit is completed through its S winding and the winding of the S relay of the discriminator circuit; and the latter relay operates. This opens the circuit of the "operate" winding of D, but D is now held operated by its "hold" winding.

The operation of S connects ground, through a back contact of PS, to the timer, which starts a timing period. If the plug has not been properly seated in the jack, no connection will be established by the "ring" conductor. Under such conditions, no other relays will operate for two seconds. At the end of this interval, the timer will close a contact to ground, and thus operate relay TM. This relay will operate FN, which—in turn—will open the circuit to the holding winding of the D relay, thus releasing D, and allowing the discriminator to be seized by another cord.

Had the plug been properly seated, however, either the ground or battery found on the "ring" conductor would have operated PS, and thus opened

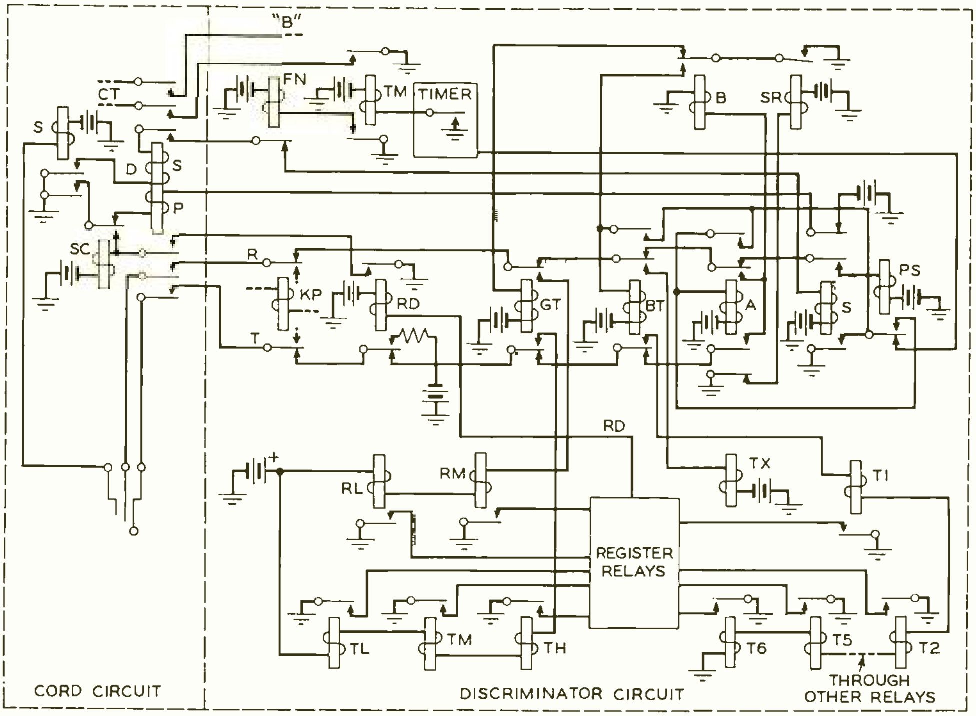


Fig. 1—Simplified schematic of the testing circuits of the discriminator

the path to the timer. The closure of PS would also have operated relay A, and connected both "ring" and "tip" conductors of the trunk to the B relay. This tests for either battery or ground. If battery was not found on either of the conductors, B would not operate, and after a short interval required for the release of the slow-release relay SR, which is released by the operation of A, relay GT would be operated through the back contact of B. Closure of this relay connects the tip and ring conductors to the ground-test relays, and one or more of them will operate depending on the ground conditions that are found.

Had battery been found on either the tip or ring conductors, relay B would have operated, and then as soon as SR had released, the BT relay would have operated. This would have connected the ring and tip conductors to a set of battery-test relays, and one or more of them would operate depending on the conditions found.

As a result of the operation of some of the battery-test, or of some of the ground-test, relays, certain of the register relays will be operated, and ground will appear on one of the leads leaving this group. To indicate the type of operations that follow, it may be assumed that the plug has been connected to a "ringdown" trunk. As a result, ground—after the tests outlined above—will appear on the RD lead leaving the register relays, and the RD relay will be operated.

Operation of this relay starts the timer to get a two-second interval, connects battery to the "tip" conductor over which it will operate the ringing relay in the outgoing trunk circuit, and also operates the SC relay in the cord circuit. The SC relay holds itself operated from ground on the S relay, which remains operated as long as the plug is in the jack. The operation of SC has also opened the circuit to the operate winding of D, so that it cannot be reoperated until the plug is withdrawn. At the end of the two-second ringing interval, TM will be operated by the timer. This relay connects ground to the CT lead to operate the relay in the cord circuit that will "cut through" the talking circuit and, through another contact, will operate FN. The operation of this relay opens the circuit to the hold winding of the D relay, which then releases, and makes the discriminator available for another call.

Had some other than a ringdown trunk been found, some other than the RD relay would have been operated. If a key-pulsing trunk had been found, for example, a relay would have operated to connect in the operator's key-pulsing set, and a similar procedure is arranged for other types of trunks. Following these operations, the cut-through relay of the cord will be operated and the D relay will be released by operation of FN. By connections to the B lead, the type of incoming trunk will also be determined, and the necessary circuits would be set up to provide for the proper signaling and operation for each particular combination of incoming and outgoing trunks.

The 3B board is also arranged so that when the originating operator takes down her cord at the completion of a call, the outgoing circuit at the 3B position will be automatically freed without waiting for the operator to pull out the plug. This makes the circuit more promptly available at the other positions, and thus insures more efficient use.

The circuit by which this is accomplished is shown in Figure 2. When the plug is in the jack and a call is in progress, all the relays except H are operated, but when the originating operator disconnects, SU is released. This connects ground to the P winding of relay H, which operates and holds itself operated through ground on one of its springs, two contacts, and the resistance *r*. In operating, it opens the circuit to the S relay, and both S and SC release, the release of the latter relay releasing CT, which opens the talking circuit and releases the trunk. The operation of H also lights the lamp in front of the 3B operator as an indication that the plug may be taken down. In the meantime, however, the outgoing circuit is released, and may be seized at other positions.

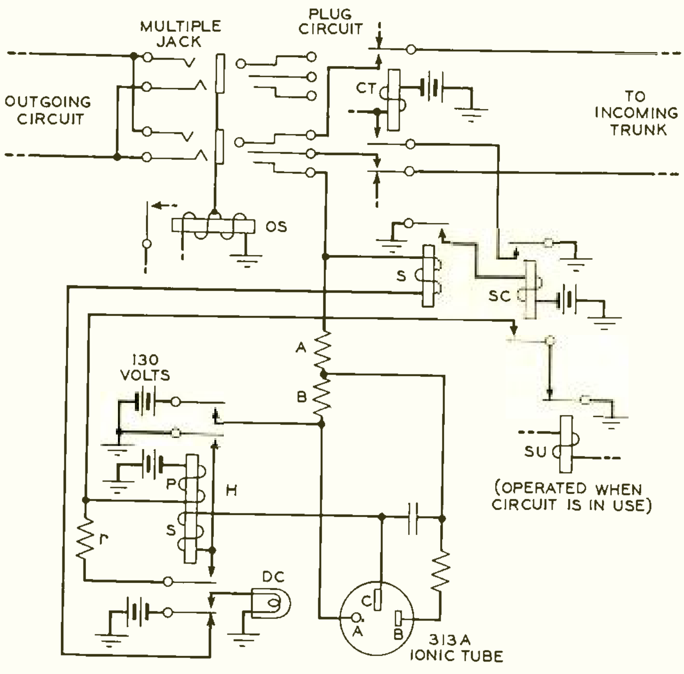


Fig. 2—Automatic release feature of the 3B toll board

The operation of H has also connected a 130-volt battery to a potentiometer consisting of resistances A and B and a connection to ground on the sleeve relay of the trunk circuit. A and B are of such high resistance that the current that flows has no appreciable effect on the sleeve relay. Due to the drop across A, which is much the smaller of the two resistances, a voltage is placed across the control gap B-C of an ionic tube, but the voltage is too low to break down the tube. When the plug is withdrawn, however, the connection to ground at the sleeve relay is opened, and the voltage across the control gap rises sufficiently to break the tube down. When this occurs current flows across the main gap A-C, and releases the H relay by flowing differentially through its S winding. This puts out the lamp, and restores the circuit to normal. Both of these features, the discriminator and the automatic disconnect feature, are very helpful in promoting rapid and efficient operation at the 3B toll switchboard.

Feedback Improves Electromechanical Recording

By L. VIETH
Electromechanical Apparatus Development

THE development of stabilized feedback* a few years ago has had a great influence on the design of broadcast transmitters and on amplifiers for a wide variety of uses. In the usual amplifier system certain noise and distortion components are introduced, causing the character of the output signal to differ from that of the input. In applying the principle of stabilized feedback, however, part of the output signal is fed back to the input in such phase relation as to greatly diminish or eliminate these effects without danger of instability or self-oscillation.

In the systems to which stabilized feedback has been applied so far, the output as well as the input is electrical in nature. The inclusion, in the amplifier system, of a transformation to a mechanical or other form of output in no way alters the feedback theory, although it may crease the difficulties of fulfilling t onditions necessary for stable tion. A practical system of this as been made possible with the oment of the 1A recorder, d for making vertical-cut re ich a system an amplified ele l is converted to a cor ne- chanical motion to cut a record on a disc or cylinder for later reproduction. Such recordings are used extensively, both for sound pictures and for the electrical transcriptions used widely in broadcast programs.

A block schematic of a feedback system as applied to the 1A recorder is shown in Figure 1. A moving coil in a strong magnetic field drives the cutting stylus, and a small pick-up coil, rigidly attached to the frame that carries the stylus, moves in another portion of the same field. The vibrational velocity of the pick-up coil is thus exactly the same as that of the stylus, so that the electrical signal fed back by it to the input is a replica of the signal cut on the disc. This feedback signal counteracts the distortion introduced, with the result that the record as cut closely corresponds to the input signal. Because of the very small value of the feedback current supplied by the pick-up coil, an amplifier is included in the feedback

*Record, *June*, 1934, *p.* 290 82.

circuit, which differs in this respect from the more usual all-electrical circuits in which the feedback circuit is generally a passive network.

The actual arrangement of the recorder is indicated in Figure 2. The driving coil is secured at the base of a

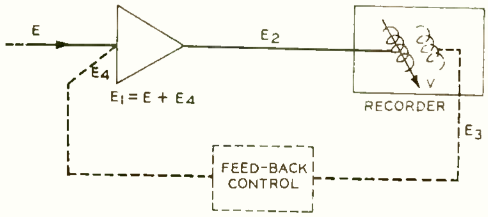


Fig. 1—Block schematic of the 1A recorder showing the application of feedback

cone-shaped vibrating element, and the restoring force is furnished by a cantilever spring and a diaphragm, which serve also to restrict the motion of the stylus to one mode. The feedback coil is secured to the cone near its apex, at which point the stylus is attached. Both coils are free to move in annular air-gaps of a common magnet. In the space between the two coils copper shielding is provided to reduce magnetic coupling. A photograph of the complete recorder is shown on page 171 and in Figure 3.

The use of the feedback feature in the new recorder greatly simplifies the design. In previous devices each of a number of resistive and reactive mechanical elements had to be controlled within narrow limits to hold the response-frequency characteristic of the assembly within acceptable limits. This was difficult to do particularly because the constants of certain of the elements tend to change with time. In the feedback device the response-frequency characteristic is controlled by the transmission characteristic of the electrical feedback circuit only, and this can be readily specified and maintained. The mechanical elements are few and simple, and need be controlled only within broad limits. The materials used are highly stable.

Another matter of importance in comparing the new device with previous ones is that since the transmission characteristic of the feedback circuit determines the response-frequency characteristic of the recorder, its useful band width is limited only by the power available to drive it and by its mechanical ability to be so driven. In earlier forms of recorders the response-determining elements were more or less fixed by other considerations, and the result was that it was difficult to effect a uniform response for frequencies above about five or six thousand cycles. In Figure 4 the solid curve (B) is a typical response-frequency characteristic of the feedback recorder as actually used. It will

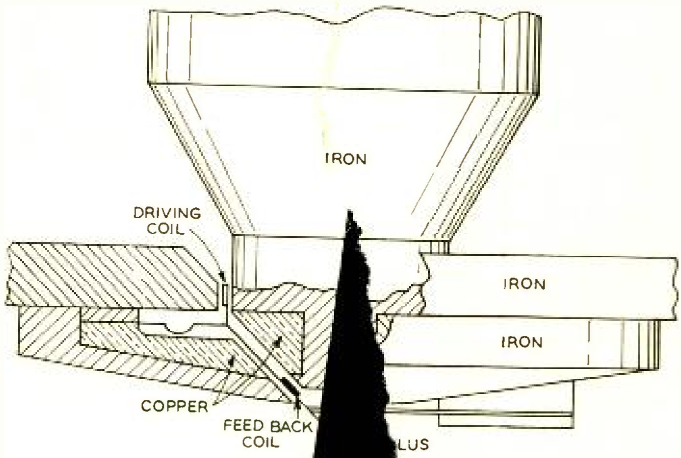


Fig. 2—Simplified cro… n of the 1A recorder

be observed that the response is substantially constant for frequencies between forty and 15,000 cycles. The dotted curve (A) shows what the response-frequency characteristic would be if the feedback circuit were made inoperative.

A further consideration in favor of the feedback recorder is that by nature it is ideally suited for cutting hard recording materials. Any obstruction to the motion of the stylus decreases the feedback to the driving amplifier, and since the feedback is in phase opposition to the input, its reduction allows more energy to flow to the recorder to overcome the obstruction. The 1A recorder has been used with many different types of recording materials, and careful measurements indicate that the stylus motion is substantially the same whether cutting in soft wax or hard record materials or whether merely vibrating in air.

With the feedback recorder properly wired into the recording system, the technique of recording is exactly the same as with non-feedback recorders. Inasmuch as the new device provides relatively flat response, it is customary to provide any desired alteration of the response characteristic by means of electrical circuits connected at convenient points in the recording system.

Fig. 3—The 1A recorder

The 1A recorder has been subjected to an extensive field trial, and has met all expectations both as to mechanical reliability and technical performance. Recordings made with it have a tone clarity not always attained with earlier types of recorders. Harmonic analyses of the velocity of the stylus at a frequency of 300 cycles per second while cutting commercial nitrocellulose direct-recording materials show second and third harmonics 36 and 43 db below the fundamental—a great improvement over the possibilities of recorders heretofore available.

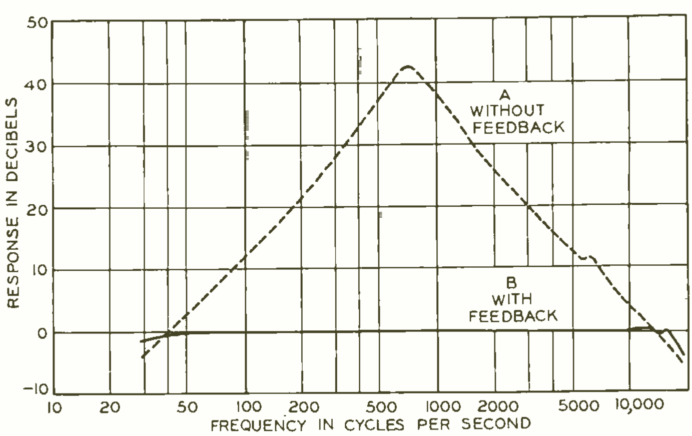


Fig. 4—Response characteristic of 1A feedback recorder

The Exponential Transmission Line

By CHARLES R. BURROWS
Radio Research

IN RADIO operation it is sometimes desirable to connect two antennas in parallel to a transmission line. If the impedance of each antenna alone matches that of the line, when both antennas are connected they will present an impedance of only half that of the line. Such a mismatch results in reflection and standing waves on the line, with greater line losses and less radiation. The match may be restored by inserting a transformer, or a section of line along which the impedance changes exponentially with length.

Experiments recently carried out by the Laboratories show that practical lines of the exponential type can be constructed. One of the experimental setups for such a line is illustrated in Figure 1. It consists of a pair of conductors whose distance apart decreases progressively from the high to the low impedance end. At the high impedance end the conductors are No. 6 wire. These are changed successively to tubes ¼" and ⅜" in diameter toward the low impedance end where the current is greater and tends to increase heating. Increasing the size of the conductor also increases the spacing and decreases the possibility of voltage breakdown.

The input impedance of an experimental 600 to 300-ohm exponential line terminated with a 300-ohm resistance is shown in Figure 2. Solid circles represent measurements made on a line nine meters long and open circles those on one three meters long. The curve gives the calculated value of the input impedance. The lower abscissa scale is the ratio of the frequency to that for which the line is one wave-length long and the upper scale gives the ratio of the frequency to that at the cut-off. At the higher frequencies the input impedance approaches the desired value of 600 ohms but at the lower frequencies the line merely serves as a connection between the input and the

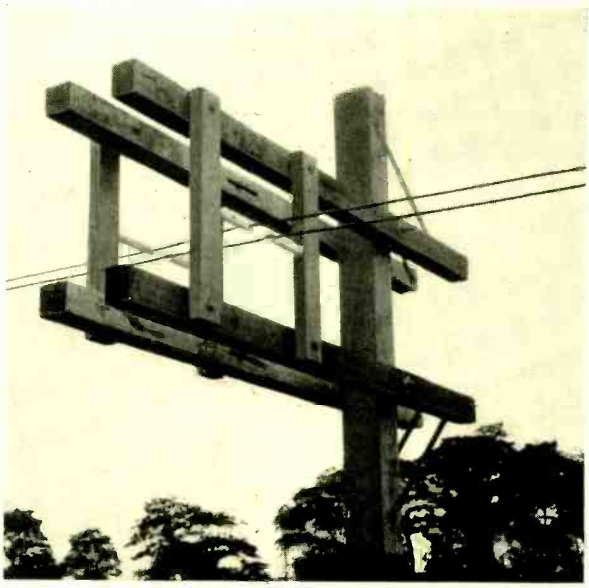


Fig. 1—The impedance of an open-air radio transmission line can be changed exponentially with distance by varying progressively the distance apart or the size of its two conductors

load. The agreement of these experimental results with the theoretical formulas was considered a sufficient check to justify constructing a full scale model for study on the commercial transoceanic frequencies.

Preliminary tests on a full-size model gave large deviations from the expected results, the major cause of which was found to be the inherent stray capacity of the mechanical support at the terminals. An auxiliary experiment on a uniform line showed that it was possible to reduce the effect of this stray capacity by adding the correct amount of inductance in series with the resistance load. When thus terminated the input impedance of the 600 to 300-ohm exponential line was that shown in Figure 3. The displacement between the theoretical and experimental curves at the higher frequencies is due to the deviation of the comparison resistance from its direct current value. Deviations of the input impedance from the desired 600-ohm value are not serious compared with those commonly found on uniform transmission lines in the transoceanic frequency range.

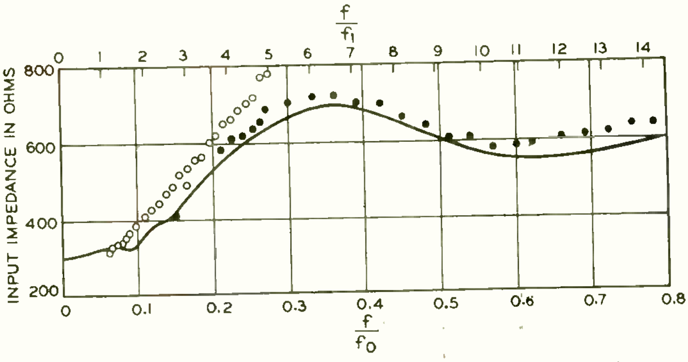


Fig. 2—Impedance characteristics of an experimental 600 to 300-ohm exponential transmission line. The lower abscissa scale is the ratio of the frequency to that for which the length of the line is one wave-length and the upper scale gives the ratio of the frequency to the cut-off frequency

The locations of these maxima and minima are the same as would be found with a uniform line terminated in approximately its characteristic impedance but with a small reactive component. This occurs because the characteristic impedance of the exponential line is not a constant resistance equal to the characteristic impedance of the corresponding uniform line except at infinite frequency. As the frequency decreases the characteristic impedance has an increasing reactive component and becomes a pure reactance at and below the cut-off frequency. To reduce reflection from the terminal and variations in the input impedance, the line can

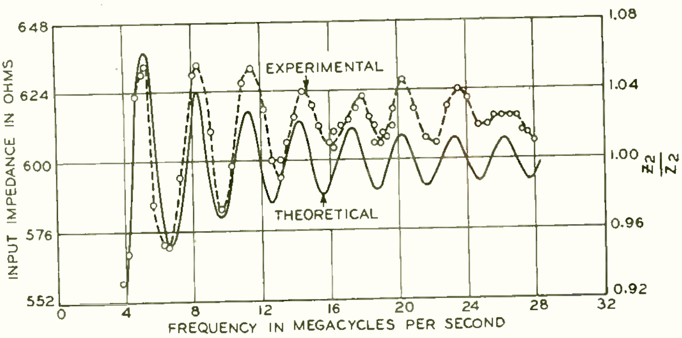


Fig. 3—Input impedance of an exponential line with series inductance to compensate for stray capacity at the terminals. The difference between the theoretical and experimental curves is due to deviation at high frequencies of the comparison resistance from its direct current values

be terminated by a condenser that is placed in series with the resistance load.

In Figure 4 curves A and B show respectively the measured and the calculated values of input impedance of a 600 to 300-ohm exponential line fifteen meters long with a resistance termination. Curves C and D give the input impedance when a series capacity was added at the high impedance end and an inductance was shunted across the resistance at the low impedance end. At the lower frequencies where the improvement is needed most the experimental curve C approaches the theoretical curve D, but at the higher frequencies it approaches the theoretical curve B for a resistance termination. This is because in the calculations for curve D, the distributed capacity of the inductance was ignored. That capacity, however, is sufficient to make its reactance anti-resonant with that of the inductance at the high-frequency end, thereby making the termination more nearly approach a pure resistance.

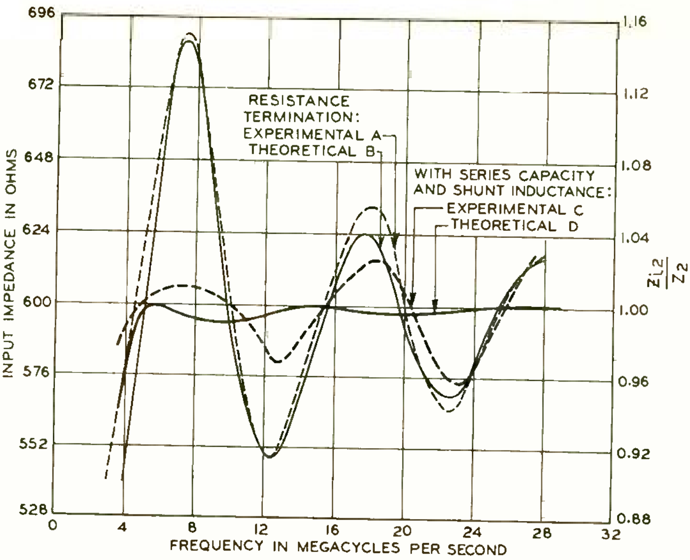


Fig. 4—Input impedance of a 600 to 300-ohm exponential line fifteen meters long with a resistance termination; also with a series capacity at the high impedance end and an inductance shunted across the resistance at the low impedance end

Results of measurements made on the exponential line illustrated in Figure 1 are given in Figure 5. The solid curve was calculated from theory and the two broken curves show the experimental values with and without insulators. Insulators change the input impedance but do not materially increase the amount of its variation.

Theory indicates that the exponential line may be used as an impedance transformer over a wide frequency range and experiment shows that the difficulties of constructing a line having these properties can be overcome.

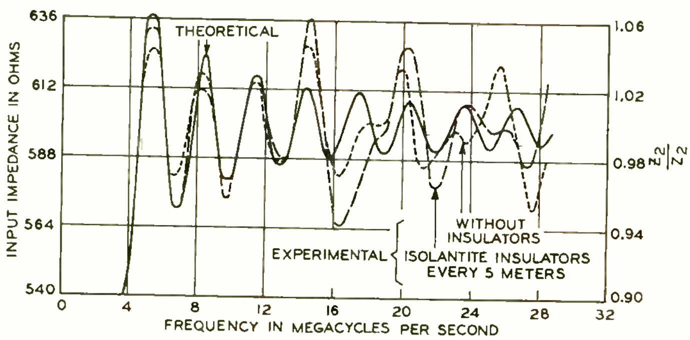


Fig. 5—Impedance of the exponential line shown in Figure 1

Frequency Modulation

By J. G. CHAFFEE
Radio Research

IN THE usual type of radio transmission, the amplitude of a constant-frequency carrier wave is varied, or modulated, to conform to the signal wave. Thus with a carrier as shown at (a) in Figure 1 and a signal as shown at (b), the modulated wave appears as at (c). Such amplitude modulation may be accomplished, for example, by varying the plate voltage of an oscillator or amplifier in accordance with the amplitude of the signal. In general, however, modulation is the modification of some property of a high-frequency wave in accordance with the instantaneous value of the signal wave. Instead of changing the amplitude of the carrier to conform to the signal, its frequency can be varied, giving rise to what is known as frequency modulation. With the same carrier and signal as at (a) and (b), a frequency-modulated wave would appear as at (d). Such frequency modulation might be accomplished by using a condenser microphone as part of the capacity of an oscillating circuit.

Frequency modulation is a relatively old idea and has been of interest to engineers for twenty years or more. Wide attention has recently been drawn to its possibilities by Professor E. H. Armstrong who points out that important advantages result from a combination of wide frequency bands together with severe amplitude limitation of received signal waves.

In these Laboratories, experiments with frequency modulation were made several years ago in the course of work with high-frequency oscillators of the Barkhausen type. When amplitude modulation was applied to one of these oscillators, it was

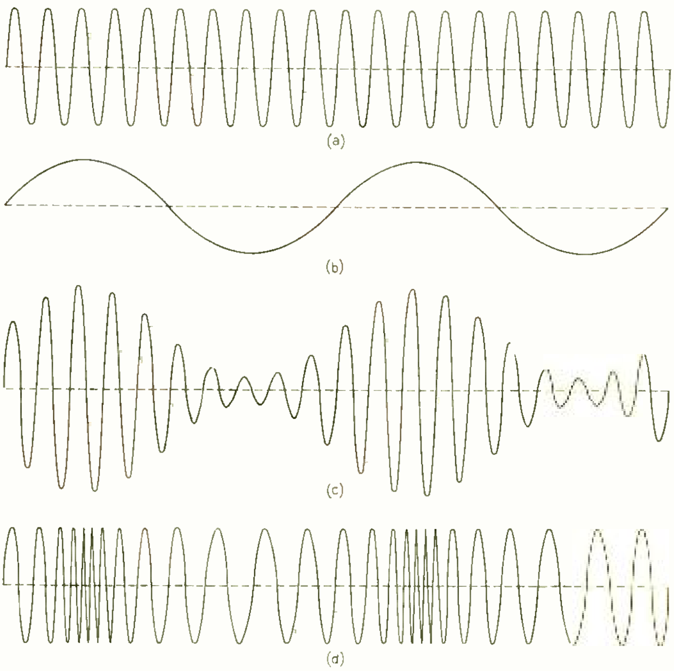


Fig. 1—A carrier wave of constant amplitude and frequency (a), when amplitude-modulated by a signal (b), appears as at (c). When frequency-modulated, it appears as at (d)

found that the frequency varied over wide limits. This quite naturally led to a study of this form of modulation in communication systems. One of the results of this study has been the development of a novel receiving system for frequency-modulated waves which very markedly reduces noise and distortion.

Although the difference between an amplitude- and a frequency-modulated wave can be illustrated as shown in Figure 1, some of the characteristics of these forms of modulation, particularly the effect of noise-producing disturbances, can be shown better by means of a vector diagram. A constant-amplitude alternating-current wave of fixed frequency, such as a carrier wave, can be represented by a rotating vector as indicated at (a) in Figure 2. The length of this vector represents the maximum value of the current, and the instantaneous value is represented by the projection of this vector on the horizontal axis. One revolution of the vector represents one cycle, since for each revolution its projected or instantaneous value passes from maximum positive, to zero, to maximum negative, and back through zero to maximum positive.

The effect of amplitude modulation is to shorten or lengthen the vector in proportion to the instantaneous amplitude of the signal. As the signal current increases on the positive side of the axis, the carrier vector will be increased beyond its normal value, and as the signal goes negative, the vector will be decreased below its normal value. Full, or one hundred per cent, modulation would vary it from zero to twice normal value. The rate of rotation, or frequency, would not be changed. If the vector were represented by an arrow that could actually be rotated at the carrier frequency, and be illuminated by a lamp that flashed just once for each revolution, the unmodulated vector would appear fixed as at (a), since each time the lamp flashed, the vector would have returned to the same position. The amplitude-modulated vector, under these conditions, would appear as

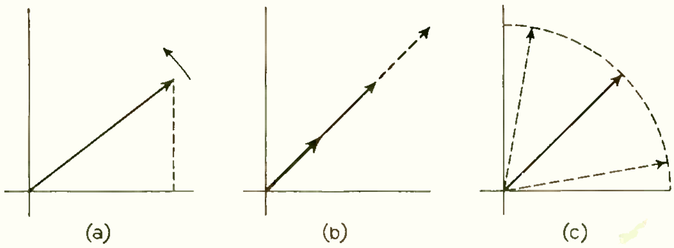


Fig. 2—An alternating current may be represented by a vector of constant length rotating counter-clockwise at a constant speed equal to the frequency. By illuminating this vector once each revolution, it would appear stationary as at (a). Amplitude modulation of such a wave would be indicated as at (b), and frequency modulation as at (c)

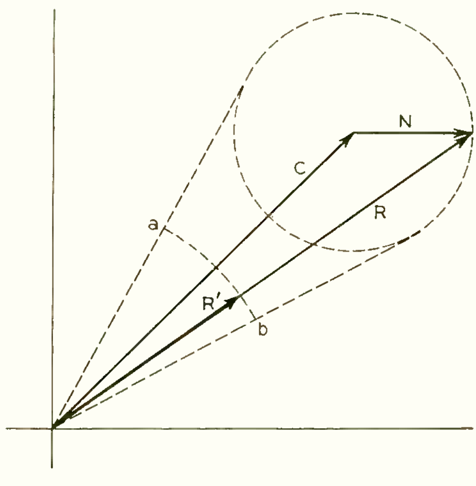


Fig. 3—Noise can be represented by a vector N added to the carrier vector, which produces both phase and amplitude changes in the resultant vector

at (b). Its position would remain fixed, because the frequency is constant, but its length would vary.

With frequency modulation, however, the length of the vector would remain constant, but its position would vary as shown at (c). As the signal wave increased on the positive side, the frequency would increase so that on successive rotations of the vector it would appear farther and farther to the left. As the signal went negative the vector would decrease in speed and thus appear farther and farther to the right at successive revolutions. The time required for a full swing from left to right and back is equal to the time, or period, of one cycle of the signal, while the distance moved to right or left is a function of the area under the signal wave, and thus depends on both frequency and amplitude. With frequency modulation, it will be noted, there is no such limitation as is represented by one hundred per cent modulation with amplitude modulation. The vector may increase in frequency to such extent that its phase is advanced by many complete revolutions before the process is reversed.

The effect of noise disturbances is to add a rotating vector N at the end of the carrier vector as indicated in Figure 3. This noise vector will not rotate at the same rate as the carrier vector. In general it will be rotating at an irregular rate and will also be constantly changing in length. The resultant wave can be represented by R, which will vary both in amplitude and phase with respect to the unmodulated carrier vector C. Except as modified by the method of reception, both of these variations would appear as noise in the output signal.

To provide for the detection of a frequency-modulated wave, a network is needed with an admittance that is a linear function of frequency. When the modulated wave is applied to such a network, the amplitude of the output current is directly proportional to the instantaneous frequency, so that the frequency modulation is converted to amplitude modulation, and may be detected in the usual manner. With such a conversion network, both the phase and amplitude changes of the resultant vector R appear as amplitude changes.

The effect of the high-frequency

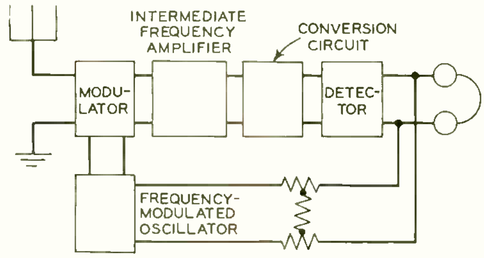


Fig. 4—Simplified block schematic of the Laboratories feedback receiver for frequency-modulated waves

disturbance N may be reduced by passing the received current through a current-limiting device before it reaches the conversion circuit. This current-limiting device, which can take the form of a severely overloaded amplifier, reduces the current and holds it at an essentially constant value. Its effect on the vector R of Figure 3 would be to reduce it to some value R′, and to hold it constant at that value, thus removing the amplitude variations produced by the disturbance. The only effect of the noise would therefore be to move the vector R′ over the small arc *a-b*, which, by an increase in signal modulation, can be made very small relative to the arc of frequency modulation. The frequency band, of course, will be increased in width, and this is the price that must be paid for the decrease in noise. At the ultra-high frequencies, however, ample frequency space is at present available, so that this is not now a particularly serious obstacle.

In these Laboratories a receiver has been developed that does not use the current limiter, but instead employs an unusual form of stabilized feedback that permits both the amplitude and phase effects of noise to be reduced to a very large extent. A block schematic of this circuit is shown in Figure 4. The incoming wave is combined in a modulator with the output of a local oscillator to produce an intermediate-frequency wave. This is then amplified, delivered to the conversion network, and finally detected. The local oscillator is of a type that can be frequency-modulated, and a portion of the output of the detector is fed back to modulate this oscillator.

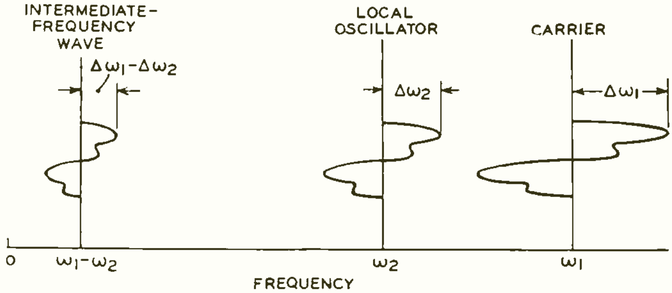


Fig. 5—By use of a frequency-modulated local oscillator, the frequency modulation at the intermediate frequency is reduced by the amount of the feedback

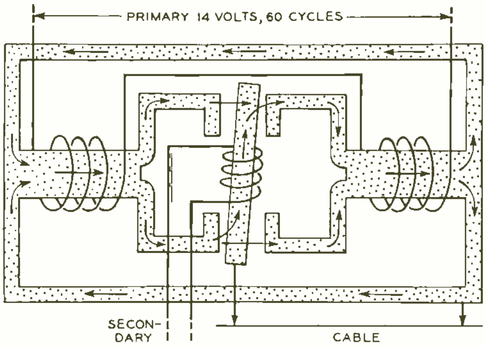
If the local oscillator were not modulated, the intermediate-frequency wave would be of the same form as the transmitted wave but would have a mean frequency equal to the difference between the frequency of the wave incoming to the modulator and the frequency of the oscillator. When the local oscillator is modulated, however, the variations about the mean frequency—which are also equal to the differences between the input and oscillator frequencies—become less. As the frequency of the carrier increases, for example, the detector output will increase in amplitude because of the action of the conversion circuit; and this amplitude increase, by frequency modulation, will increase the frequency of the oscillator. As a result the change in the intermediate frequency will be less than the full change in the carrier frequency, because it is the difference between the oscillator and carrier frequencies, and the oscillator frequency increases along with the carrier frequency but to a smaller extent. As a result also the frequency modulation at the intermediate stage, due both to signal and to noise, is less than that of the incoming wave, as shown in Figure 5.

In the absence of feedback, frequency modulation can be applied at the transmitter to an extent determined by the linear range of the conversion circuit, since the incoming and intermediate waves will vary in frequency to exactly the same extent. The application of feedback reduces the variations experienced by the intermediate wave, thus decreasing the level of the received signal, and at the same time diminishes the noise at the output of the receiver. It then becomes possible to increase the modulation level at the transmitter, restore the signal to its former value, and improve the signal-to-noise ratio by the amount of the feedback. In addition to this, the feedback also reduces any distortion products generated during the process of amplification, conversion, or detection.

With an amplitude-modulated wave and a feedback receiver, a somewhat similar process can be carried out, but with an important difference. In ordinary practice, the transmitter is fully modulated at the peaks of signal power, so that the only way to obtain the equivalent of increased modulation is to increase the power of the transmitter, which—of course—is an expensive procedure. With frequency modulation, however, the amount of modulation has no such limit as is encountered in amplitude modulation, and except for limitations of frequency space in the transmitting medium may be increased over a very wide range provided the feedback keeps it within the range of the conversion network. Thus the ratio of signal-to-noise can be increased to a high degree without any increase in power.

Magnetic Strain Gauge for Cable Sheath

A MAGNETIC strain gauge has been developed by the Laboratories to measure small longitudinal movements in the sheathing of aerial cables. Although primarily intended for studying the daily movements



caused by temperature changes, it can detect vibratory strain caused by wind sway and passing vehicles. Between the poles of an electromagnet, excited by 60-cycle alternating current, there is an armature which is attached through a clamp to the cable, so that it moves in the magnetic gap when the cable expands or contracts. This motion changes the flux through the armature and varies the current induced in the coil surrounding it. The armature current is applied to a thermocouple and the millivolt output read on a potentiometer or recorded continuously on an autographic recorder. The gauge can detect motion of .00001 inch. Cable sheath may move from .000005 to .00012 inch per inch per degree Fahrenheit, depending upon the position of the gauge along the cable. The magnetic strain gauge has proved a most reliable instrument for determining, in the field, small movements in aerial cables. The frontispiece of this issue shows J. P. Guerard adjusting it on a cable.

Effect of Extended Signaling Range for Subscriber Loops

By G. C. REIER
Transmission Standards Department

A TELEPHONE central office serves as the switching point for a group of subscriber loops. Except in small areas, there will be a number of such central offices, each with an upper limit of about 10,000 lines, and all interconnected by trunks. In general the connection between any two subscribers will consist of two subscriber loops and one inter-office trunk. The loss over this three-link connection must not be so great as to prevent satisfactory conversation; and it is essential, therefore to provide standards for both loops and trunks so that no three-link combination will lead to unsatisfactory conditions. All loops and trunks are designed so that the transmission loss over any two loops and a trunk will not exceed the established standard.

The transmission loss in a loop is affected primarily by its length, the gauge of the wire used, and by the type and efficiency of the telephone set. Besides designing loops for satisfactory speech transmission, they must also be designed for the transmission of suitable signals. These are of four major types. First is the ringing current sent from the central office to ring the subscriber's bell. In addition there are three, and sometimes four, relays that are controlled from the subscriber's end of the line. One is the line relay, which operates when the subscriber lifts his receiver to place a call; another is the tripping relay, which operates to disconnect the ringing supply when the subscriber answers a call; and a third is a supervisory relay, which is used for signaling the operator or controlling dial equipment during the progress of a call and to indicate when the subscriber hangs up. In dial offices there is also a pulsing relay which is controlled from the subscriber's dial.

The correct operation of these relays depends chiefly on the d-c resistance of the loop, but satisfactory speech transmission depends on the loss of the loop at voice frequencies, which is a complex function of its resistance, capacitance, and inductance, and also on the efficiency of the subscriber's telephone set. Until comparatively recently the length of loop for the several gauges of cable has not generally been restricted by the signaling requirements. With the type of subscriber sets employed, the length of loop required to meet the speech-transmission requirements has been short enough and the resistance low enough not to interfere with signaling.

In recent years there has been a tendency to group more central offices into a single building, and this has naturally tended to increase the average length of loop. There has also been a progressive improvement in the transmitting and receiving efficiencies of the subscriber sets, which over the past ten years has amounted to a total of about 15 db. This large gain in efficiency has so reduced the overall transmission loss of the loops that it has been possible to make extensive use of finer gauge wire for the loops and trunks, and thus to decrease their cost. While 22- and 19-gauge wire, or larger, had formerly been used, 24 and 26 gauges became common in the local telephone plant. The combined effect of longer loops and smaller wire has been a considerable increase in loop resistance. With the introduction of the smaller gauges the signaling requirements became controlling in limiting loop length.

To secure satisfactory signaling, the resistance of loops has been limited to 635 ohms in the past; and a definite transmission gain for the loop has been set to meet the transmission requirement for the loop-trunk-loop connection. This gain may be taken as 4 db above that of a reference loop and subscriber set rather than as an absolute value of gain. The resistance of the loop increases directly with length, and the gain decreases with length, but since it is given relative to the reference set, it does not decrease uniformly and may even increase for certain values of loop length. It is possible to plot both resistance and relative transmission gain against the length of loop for all the usual sizes of wire. This is done in Figure 1, where the resistance curves for four sizes of wire are represented by the dotted lines sloping up to the right, and the transmission gain curves are the solid lines sloping down to the right. The rising gain for the 19- and 22-gauge loops occurs because the gain relative to the reference, rather than the absolute, gain is plotted. The maximum permissible resistance and the minimum permissible relative gain are indicated by horizontal dashed lines—the former at 635 ohms, and the latter at 4 db above the reference. With these curves, therefore, it is possible to determine the length of loop permitted by each requirement. Considering transmission gain alone, 26 gauge could be used up to a distance of two miles; 24 gauge up to 2.7 miles; 22 gauge up to 3.3 miles, and 19 gauge for distances above 4.3 miles. The signaling requirement of 635 ohms per loop, however, prevents the full use of the smaller sizes. With 26 gauge, for ex-

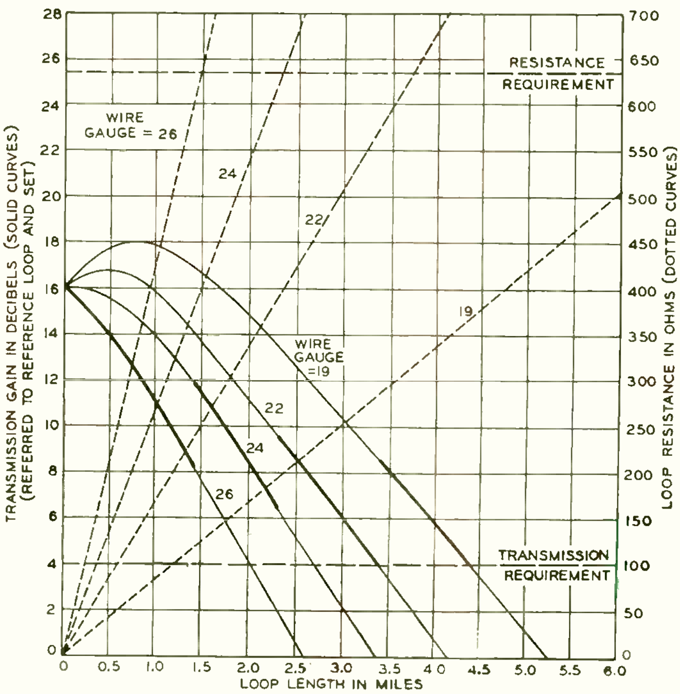


Fig. 1—Transmission loss in subscriber loops for various gauges and lengths of loop

ample, 635 ohms is reached in 1.45 miles so that 26-gauge loops can be employed only up to this distance rather than to the two miles that the transmission requirement would permit. With 24 gauge, also, signaling

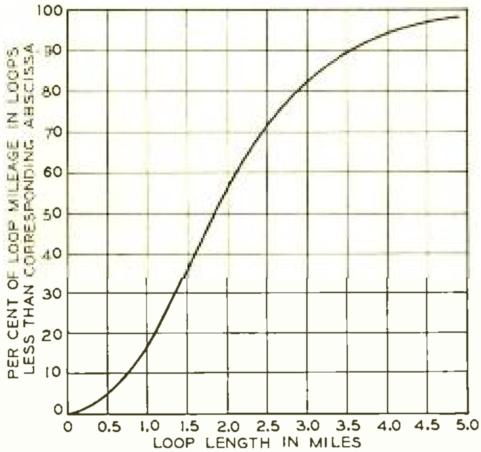


Fig. 2—Distribution of subscriber-loop mileage with respect to loop length

restricts the range, but for both 22 and 19 gauge, transmission is controlling. The net effect on the permissible lengths of the loops for the various gauges is indicated by the heavy line.

To make full use of the smaller gauges, and thus to secure the full value of the economies possible, it was obviously necessary to extend the signaling range of subscriber loops. Taking into account the capabilities of the signaling equipment as well as the probable limiting subscriber loop resistance which could be used to advantage with improved telephone sets, 1200 ohms was selected as the new limit. With this signaling range the limitations imposed by transmission and by signaling on the field of use of the various gauges of cable have been made comparable. The 1200-ohm limit is available in all types of switching except step-by-step, which is at present limited to 885 ohms. Even with this increased loop resistance neither ringing nor the operation of the line relay offers any difficulties, but changes were needed for tripping, supervision, and pulsing. The range of the tripping relay was extended by structural changes already described in the Record.* Depending on conditions, the supervisory range has been increased either by use of an improved supervisory relay or by an increase in battery voltage from twenty-four to forty-eight volts. The pulsing range in panel dial has been extended by making changes in the sender, including a different type of pulsing relay.

The relative amounts of loop mileage of subscriber loops of various lengths is indicated by Figure 2. This is a distribution curve for a typical central office area. The ordinate scale gives the percentage of total loop mileage in loops shorter than the distance found by running horizontally to the curve and then vertically down to the abscissa scale. Fifty-seven per cent of the loop mileage, for example, is in loops below two miles in length. Using this distribution, and the sizes

Table I

Gauge of Cable	Cable Resistance Ohms/Loop Mile	Relative Amounts of Cable Per Cent of Total Miles	
		635-Ohm Limit	1200-Ohm Limit
26	440	34	57
24	274	33	20
22	171	21	11
19*	85	12	12

*22-gauge loaded cable might be used instead of 19 gauge.

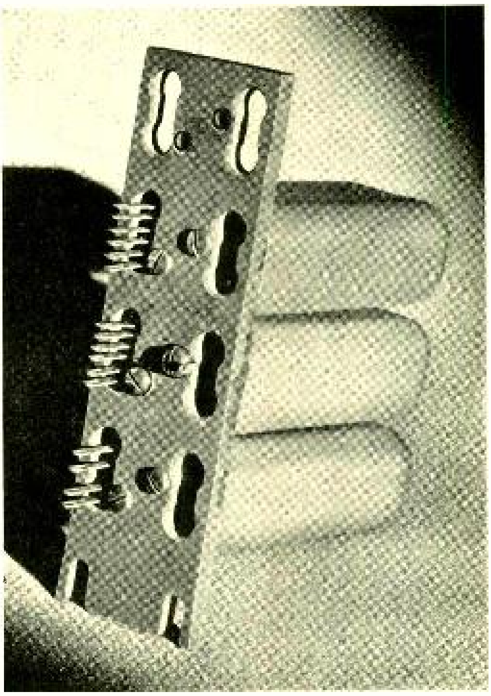
*July, 1939, p. 353.

of wire required for various lengths of loop, with both the 635- and 1200-ohm signaling requirement, one can calculate the percentage of the total loop mileage of the various sizes of wire. These values are shown in Table 1. The use of the longer signaling range has permitted twenty-three per cent of the total mileage to be shifted from 24 to 26 gauge and ten per cent from 22 to 24 gauge. This more extensive use of fine wire cable will of course result in savings in the outside plant. In addition, the extension of signaling range improves the possibility of using gauges of wire finer than 26 gauge.

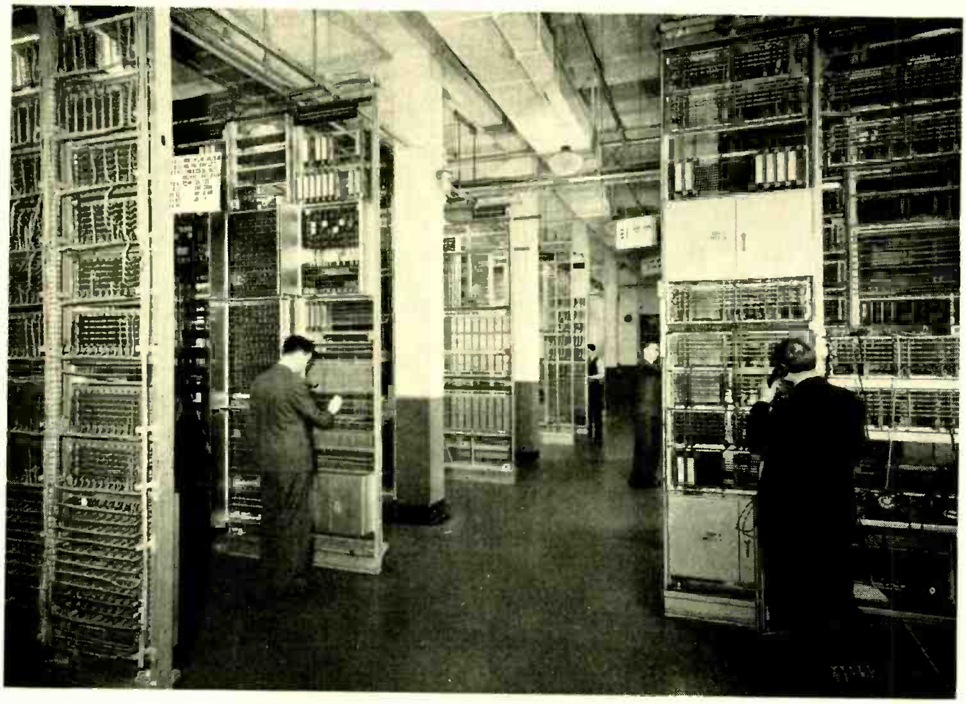
New Coils for Operators' Telephone Sets

IN MOUNTING the induction coils for operators' telephone sets, crosstalk has always to be considered; and with the older forms of coil this has imposed limitations on the equipment plans. To remove these limitations, particularly so that coils can be mounted on relay plates at a distance from the switchboard or desk where the operators' sets are located, two new induction coils and a monitoring coil have been developed. These have closed cores and are magnetically shielded. Their terminals project from the rear like relay terminals. The line winding in each coil is divided into two equal parts so that each half can be connected to one side of the line to balance the wiring where the operator's telephone set is far from the relay rack. One of the induction coils, coded 102B, is for positions where the operator may sometimes be connected simultaneously to two lines; the other, coded 102C, is primarily for terminating circuits where only one line is involved. Both of these induction coils are designed for use with the 396A transmitter for operators' telephone sets.

The new monitoring coil, coded the 161A repeating coil, will be used in all operators' telephone sets where a monitoring coil or a busy test coil is required. The monitoring windings are arranged as an auto-transformer; and two balanced primary windings



are provided for busy test. In the illustration the 102B induction coil is shown at the top. The middle coil is the 161A monitoring and busy test coil; and below a retardation coil.



Laboratory Tests of the Crossbar System

By W. E. VIOL
Switching Development Laboratory

THE introduction of a new central-office system, such as the crossbar, requires the development of many new circuits employing arrangements and apparatus that differ greatly from those of existing systems. Before these circuits are finally accepted as part of the new system, they are thoroughly analyzed and tested in the Systems Laboratory to insure that they will function correctly when installed in an actual office. While still under development, the circuits have been analyzed for possible faults by the circuit design engineers. Most of them are highly complex, however, and besides performing their own functions, they must work properly with a number of other complex circuits, not only of the crossbar, but of all other existing systems as well. Analysis alone, therefore, is not always sufficient, so the systems development laboratory actually sets up the circuits and subjects them to a series of complete tests.

During the preliminary design period, and before the circuits are ready for overall tests, the so-called "fundamental" or "feature" circuits must be analyzed and tested. There were a number of such new fundamental circuits in the crossbar system. One of these was the pulsing circuit that provides for longer dialing loops. This also involved the use of a crossbar switch in the sender, to register the number dialed. Other preliminary tests were made of the impedance type transmission, of the continuity test in the marker, and of the number checking feature for toll calls. In such developments, the laboratory engineer collaborates with the design engineer until the feature is successful.

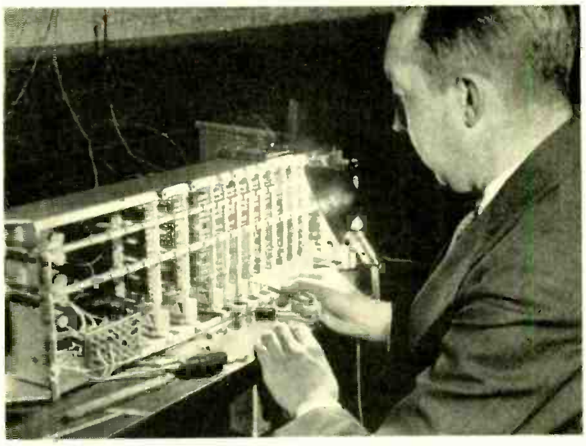


Fig. 2—One of the many tests of the crossbar switch to determine its behavior under varied conditions that may be encountered in central-office operation

There are also a number of new or improved apparatus designs that must be tested during this initial period. The principal ones in the crossbar system were the crossbar switch,* the multi-contact relay,† the U and Y type relays‡ and several new timers. Tests of the U and Y relays included investigation of their operating and releasing capabilities, of their freedom from vibration and contact chatter, and of the ease of adjustment. Their ability to perform the functions of existing critical relays with equal or greater margins, such as slow release or slow operate, was also determined. In addition, the Systems Laboratory engineers designed windings for the many relays used in the new system, and prepared adjustment and maintenance information for use by engineers in the field.

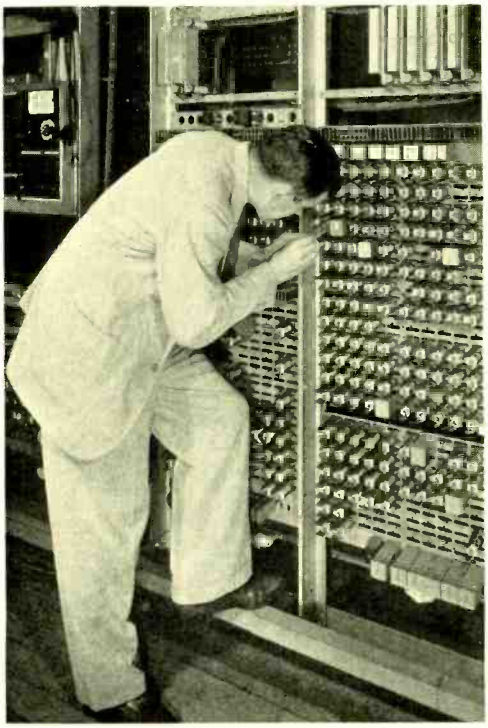


Fig. 1—A terminating marker as originally set up in the laboratory

The various designs of the crossbar switch were tested in similar fashion. Extensive studies were made of its operating and releasing characteristics, and of its functioning times. Specific items were the possibility of the select fingers catching or sticking and causing irregular operation, the rebounding or false closing of the crosspoints and off-normal contacts, and the possibility of contact chatter. It was necessary also to determine the interval between the operations of the select and hold magnets that would permit the vibration of the fingers to

*Record, *July*, 1937, *p.* 338.
†Record, *May*, 1939, *p.* 301.
‡Record, *May*, 1938, *pp.* 300 *and* 310.

die down so as not to be falsely trapped. There were tests of various designs to reduce finger vibration. Another study was of the time between the release of the hold magnet and its reoperation, which must be sufficient to prevent the released finger from being trapped on either the same or opposite set of contacts by the setting up of a new call. The maximum interval between the closure of the winding of the hold magnet and the closure of the last crosspoint or off-normal spring, and the maximum stagger time between off-normal contact closures or between off-normal and crosspoint spring closures was also studied for their effect on circuit operation. To secure full information, it was necessary to make tests at various average and extreme adjustments on a number of samples. Other new apparatus was gone over in a similar manner.

The critical tests of the crossbar switch, the relays, and other apparatus mentioned above, all deal with times measured in thousandths of a second. They are of vital importance, since they affect the holding time of the markers, the most important circuits of the system, and those requiring proportionately the greatest investment. The originating and terminating markers each perform their functions in the handling of a call in approximately one-half second. The addition of but one originating and one terminating marker represents a perceptible increase in the investment per line, and may be made necessary by a relatively small increase in the

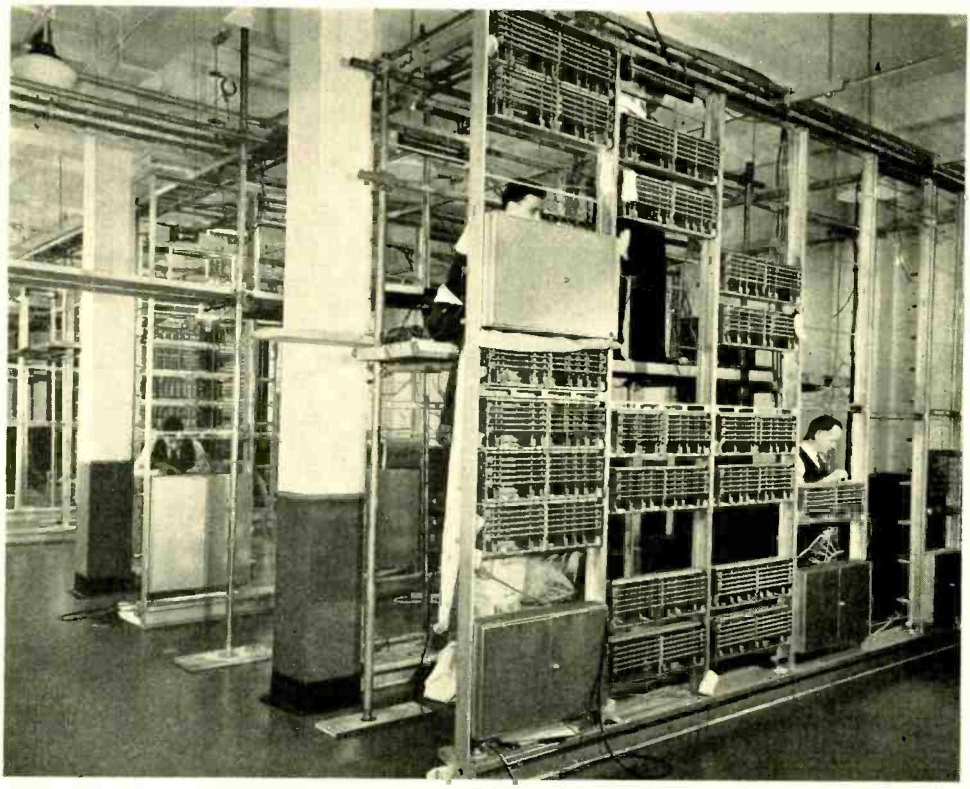


Fig. 3—Installing line-link frames in the laboratory for test

functioning interval that is involved.

After the preliminary design of a circuit has been completed, it is submitted to the Systems Laboratory for analysis and test. Here, one or more of the circuits is assembled for test. If it is a circuit used in large quantities in a central office, a number of them are set up so that the effects of the variables of the apparatus may be observed on a number of samples, and thus troubles be detected and corrected before the circuits go into service in a central office. The number of circuits provided must be sufficient to permit troubles arising from simultaneous operation of several circuits to be observed, and to allow several engineers to test associated circuits without undue interference. With test circuits only one is required.

In setting up frames, the regular Central Office layout cannot generally be followed. The number of circuits provided on fully equipped Central Office frames are very seldom required in the laboratory, and the necessity of conserving space requires doubling up of circuits on the frames. An example of this is shown in Figure 3 which shows two line-link frames being installed in a fraction of the space that would be required for the frames in a central office.

The general facilities required in the laboratories for testing circuits have already been described in the Record.* The introduction of the new crossbar system made it necessary to issue approximately 170 new circuits. The study of these in the Laboratories required setting up approximately 52 bays of framework, equipped with about 6500 U and Y type relays, 150 crossbar switches and 500 multi-contact relays. This was in addition to hundreds of resistances, condensers, coils, terminal strips, mounting plates, and other miscellaneous apparatus.

The test of a circuit is not merely the operation of a circuit in accordance with the circuit description. This phase of the test is usually performed in determining that the wiring has been properly done. The troubles that the laboratory needs to discover are usually much more obscure. A list prepared of the features that should be checked on tests of the subscribers' sender contained approximately 1250 items; and that circuit is not the most complex that is encountered.

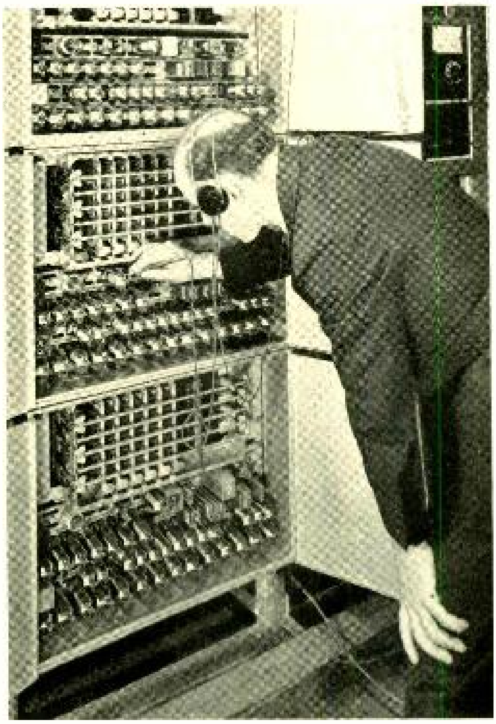


Fig. 4—A terminating sender under test in the systems laboratory

These obscure troubles deal with a large variety of conditions. They involve relay races, such as where one chain of relay operations parallels that of another chain. It is estimated

*Record, *April*, 1938, *p.* 253.

that approximately 250 of such races were studied in the system. Other tests involve the effects of contact chatter which might produce false pulses. Studies are made of the effect of literally hundreds of crosses and

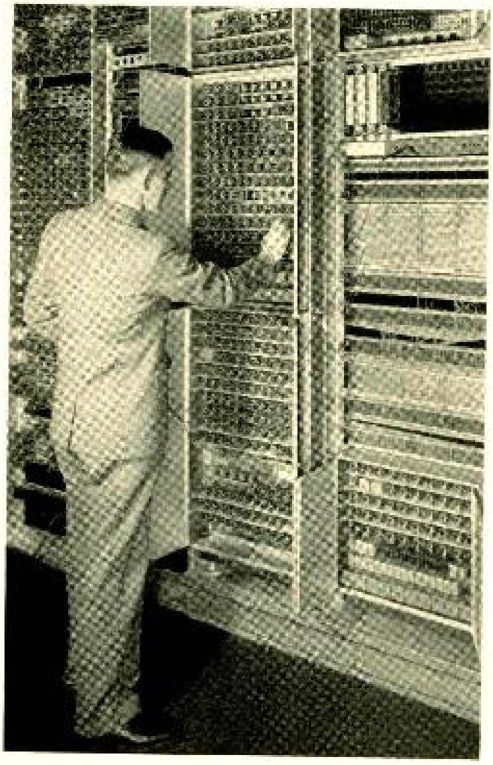


Fig. 5—A terminating marker

grounds, which should not put the circuits out of commission without bringing in alarms or causing other circuit reactions that would cause alarms. Investigations are made of the effect of sneak circuits; of unusual handling of the call by subscribers or operators; of the effect, as far as can be simulated, of heavy traffic, of simultaneous tests, of overlap operations, and of double connections.

Studies are made of differences in frame potentials, lead resistances, magnetic interference, vibration, fire hazards, and failures under extremes of permissible apparatus adjustments. The effects of relays sticking off normal, or being pushed up by hand are also investigated, as are the effects of calls abandoned at various stages of operation. It is tests of this nature that constitute much of the work.

By making their tests under the various extremes of apparatus adjustments, voltage variations, and interference conditions for all critical circuit operations, the systems development laboratories attempt to insure adequate margins for the successful functioning and maintenance of the circuits under the actual variations encountered in service. Even all this testing is not deemed sufficient, however, for a new system. Engineers of the Systems Laboratory, in conjunction with the other engineers of the Bell System, watch and observe the first jobs during installation, and subject them to preliminary call-through tests so as to obviate as far as possible the appearance of excessive trouble after the office is cut into service, and to give additional training to the maintenance force.

Like the panel system, the new crossbar system was conceived and developed by Bell Telephone Laboratories in association with the other interested departments of the Bell System, and it has been given to the public as a working achievement without the public's being aware that it is being served by a completely new system. There are, however, conditions in a Central Office in actual service, due to the quantities of equipment and apparatus available and to the large amount of traffic handled, that are almost impossible to duplicate in the Systems Development Laboratories. In the last analysis, therefore, the Central Office that is in actual service is the final test.

Contributors to this Issue

Walter E. Viol joined the Western Electric Company at Hawthorne in 1908 immediately after receiving the degree of B.S. in E.E. from Purdue University. The following year he was lent to the General Electric Company, to which the manufacture of power apparatus was transferred, and for a year he was at their Lynn, Massachusetts, plant concerning himself with telephone power machines, charging generators and ringing machines. On his return to Hawthorne he joined the Telephone Equipment Engineering Department. He came to West Street in 1919 for step-by-step engineering and participated in the development of the first dial central offices of this type that were standardized for the Bell System. In 1922 he transferred to local systems circuit development work, becoming head of the testing group in the local circuit laboratories, and a year later he took charge of the groups devoted to relay design, installation, and maintenance requirements of operation. In 1927 he again assumed charge of the testing groups of the local systems circuit laboratories and is at present in charge of the sender switching laboratories where he has had a part in the major local systems developments during the last twelve years.

W. E. Viol

J. G. Chaffee has been a member of the Research Department since his graduation from the Massachusetts Institute of Technology in 1923, when he received the degree of S.B. At first he was with a group engaged in the early investigation of short-wave radio transmission and reception problems, and until 1930 was concerned largely with the development of receiving and field-strength measuring and recording equipment. After partici-

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pating in the design and installation of the experimental ship-to-shore telephone equipment aboard the steamship *Leviathan* he became engaged in the investigation of radio problems at ultra-high frequencies. This work has included an extensive study of frequency modulation.

G. C. Rejer entered the Engineering Department of the American Telephone and Telegraph Company in 1916 immediately after graduating from Johns Hopkins University with the degree of B.S. in Engineering. His work with the American Telephone and Telegraph Company was concerned with wave filters, transmission rating, economic studies and local transmission problems. He is now in charge of the group working on local transmission development problems.

L. Vieth was associated with transmission instrument development and design from 1919, when he joined the Laboratories, until 1928 when he transferred his activities to the development of sound recording and reproducing instruments. During the past two years he has been concerned with the development of coin relays and associated apparatus.

H. F. Shoffstall graduated from Ohio State University in 1916 with the degree of B.E.E. and at once joined the D & R. He worked on telephone repeaters and on toll equipment for central offices. Since coming to the Laboratories in 1935, he has been associated with the group engaged in the design of toll-switching circuits.

Charles R. Burrows has been associated with the Laboratories since 1923 when he worked here during the summer prior to receiving his B.S.E. degree from the University of Michigan in 1924. After graduation he returned to the Laboratories and continued work on long-wave transmitters. Early in the development of short-wave radio he entered that field and made analyses of this type of propagation, which formed the bases for short-wave transoceanic service. From 1930 to 1938 he was in charge of a group investigating ultra-short-wave propagation. Since 1938 he has been working on the development of ultra-short-wave transmitters. Mr. Burrows received the A.M. degree from Columbia in 1927 and the Ph.D. in 1938. In 1935 he received an E.E. from the University of Michigan.

A. M. Skellett joined the Laboratories in 1929 after spending several years teaching, finally as instructor and assistant professor of physics at the University of Florida. Antenna design and radio transmission occupied Dr. Skellett's time when he first came to the Laboratories. Since 1934 he has been engaged in studying the application of atomic and electronic devices to telephony. Dr. Skellett received the A.B. and M.S. degrees from Washington University in 1924 and 1927, respectively, and the Ph.D. from Princeton in 1933.