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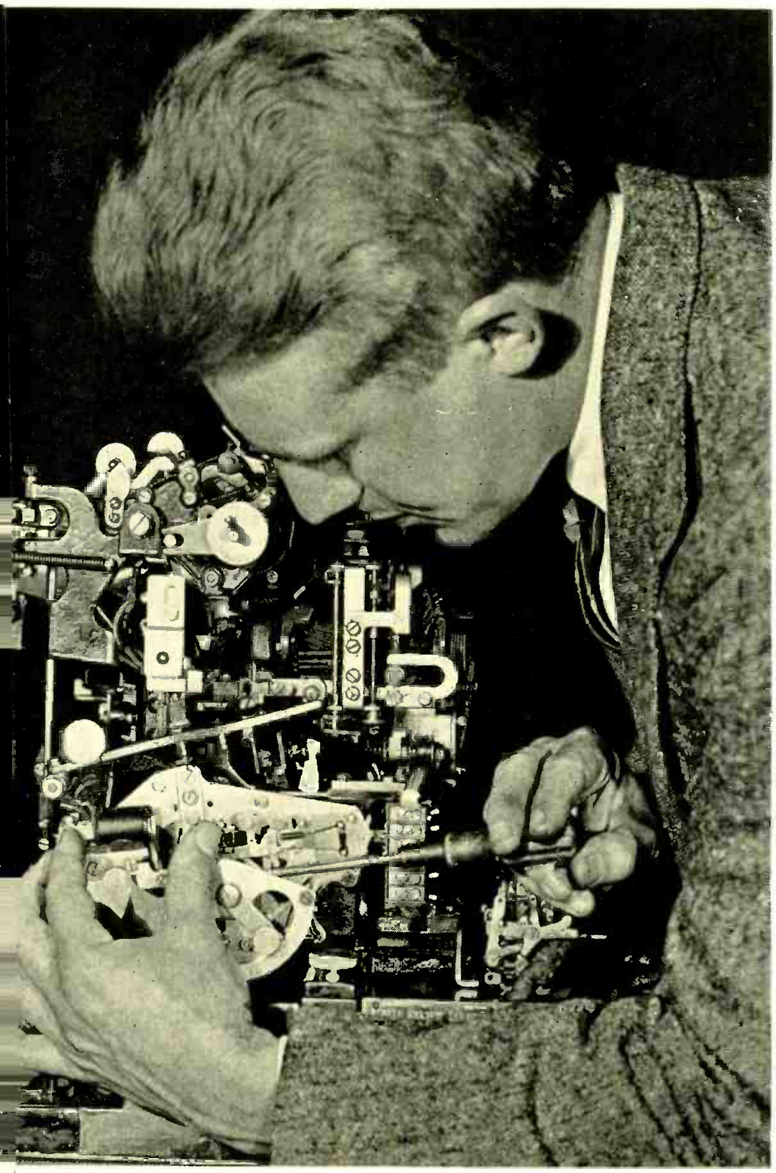

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Adjusting the holding magnet of a teletypewriter

Noise Prevention in Telephone Circuits

By R. A. SHETZLINE
Transmission Development

CLOSE association of speech channels with power and signaling circuits of the telephone plant complicates the problem of keeping telephone circuits quiet. Inductive disturbances are caused by these other circuits and have to be suppressed. This is accomplished by various means which depend on the origin of the disturbances and the characteristics of the circuits. They include the installation of central-office power leads so as to minimize stray magnetic fields; the addition of noise-suppression filters; shielding; balancing; suitable grounding of circuits; and the separation of quiet voice transmission leads from noisy signal leads.

Frequent sources of noise in large telephone repeater stations are the powerful commercial-type generators which are used to charge storage batteries. These generators produce, in addition to their direct currents, other currents whose disturbing effects have to be minimized. To accomplish this the positive and negative potential leads which extend to the battery fuse-panel are located in close proximity to reduce stray magnetic fields. Battery charge and discharge leads are separated as completely as practicable. Large open battery-loops are also avoided, as well as close coupling between noisy and filtered leads. Filters which consist of a large choke coil, like those shown in Figure 1, and condensers of large capacity help to keep generator noise from appearing in appreciable amount on the battery fuse panels. Small choke coils are also used to attenuate further the noise potentials caused by the battery supply and prevent them from appearing on the filaments and plates of associated repeaters. A filter is added to the supply

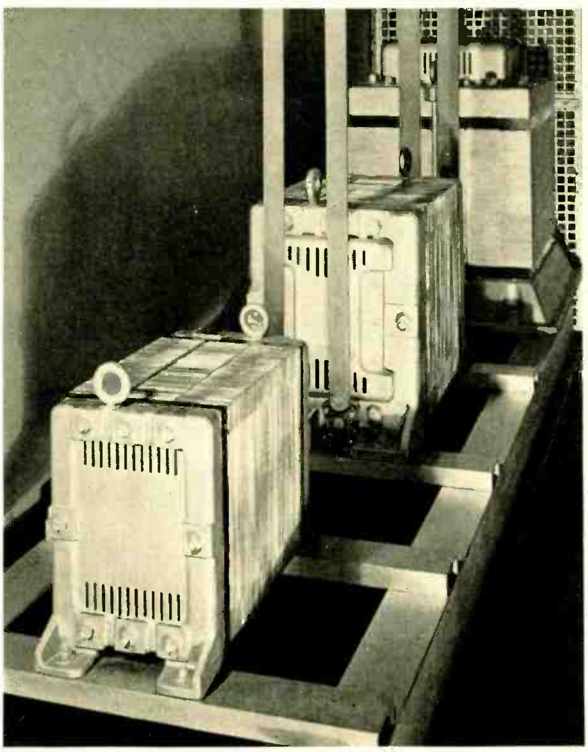


Fig. 1—Heavy choke coils are required in the filters used in central-office battery circuits to prevent noise from reaching telephone circuits

leads which connect the battery to the regulator-network relays to suppress battery noise on these leads, because they are close to transmission leads. Grounding the input circuit of repeaters to the positive terminal of the filament battery rather than to the relay-rack ground prevents alternating differences of potential between these grounds from appearing on the grid of the first tube.

Telephone and telegraph messages are sometimes transmitted simultaneously over the same circuit. When this is done means have to be provided to prevent the intermittent currents of the telegraph signals from interfering with the telephone message. This may be accomplished as shown in Figure 2. The noise level at point x is reduced considerably below that at point y by noise and spark killers. On the line at point z the noise level is reduced further by the filter action of the composite set where the telephone and telegraph currents merge.

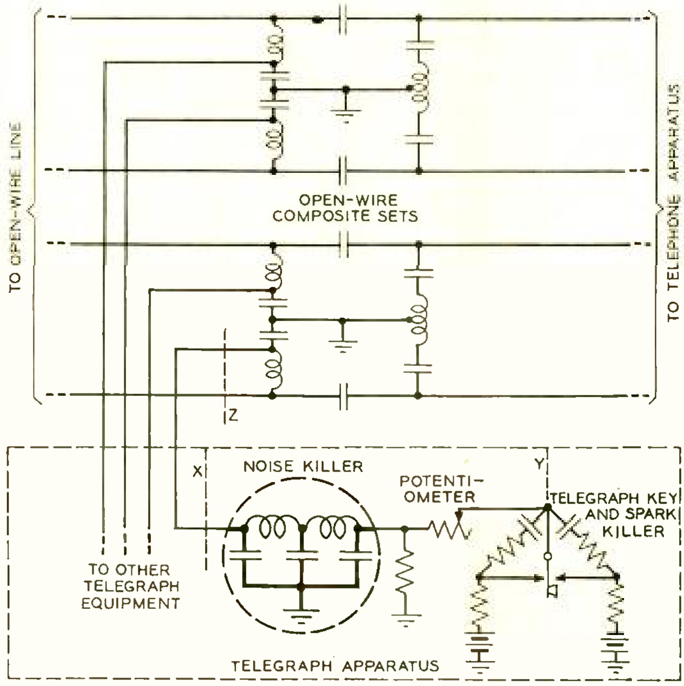


Fig. 2—"Noise killers" which consist of choke coils and condensers are used to quiet telegraph circuits

The examples discussed so far have dealt largely with the principle of restricting noise at the source by means of wiring details and choke coils or filters. There are two other principles commonly employed in telephone work which, in a broad sense, may be termed "balance-to-ground" and "segregation." The latter includes shielding and grounding. Balance-to-ground or circuit symmetry, with respect to ground, is of major importance in telephone design. This method is illustrated by the extensive use of twisted pair in the telephone plant to balance out disturbances from neighboring conductors. The frequent transpositions introduced by the twist expose the two conductors of a pair equally to disturbing voltages and currents. This greatly reduces the net disturbance in the speech channel, since there is a neutralization of the effect induced in one conductor of the pair by that induced in the other. Furthermore, at the terminals, the circuit elements which are directly connected to these line conductors must be symmetrical with respect to ground within closely prescribed limits if the balance-to-ground of the line conductors is not to be impaired by the terminations.

Where physical separation of noisy and quiet circuits is impracticable, the effect of physical separation may be obtained by shielding. This noise-preventive technique finds its greatest application where higher frequency circuits are involved, but limited use is made of it in low-level message and program circuits. For example, care is taken in program cable repeater offices to avoid telegraph and ringing induction in program transmission channels. This has been accomplished by using shielded wiring for ringing and telegraph circuits when brought into equipment mounting racks on which program amplifiers are located.

For many years it was standard practice to connect the metal frames on which equipment is mounted to the positive bus bar of the miscellaneous battery supply. These frames, and the ground bar which is mounted

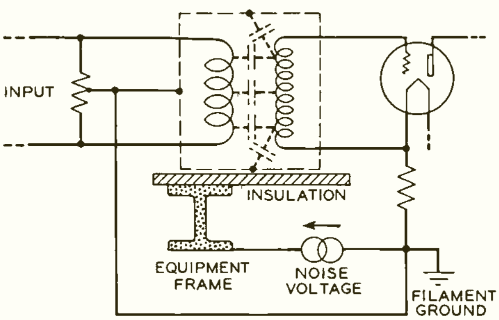


Fig. 3—Noise due to voltages between the filament and signal grounds can be avoided by insulating the sensitive equipment elements from the noisy equipment frame

on them, constitute a common path for the return of direct current from the relays in signaling and control apparatus. This current has an appreciable alternating current component which comes from the harmonics of the charging generators and from the making and breaking of relays and vibrating contacts in inductive circuits. Noise potentials which are materially larger than those on the quiet, or filament, ground may appear in this signal ground. They depend on the ground resistance and the magnitude of the extraneous cur-

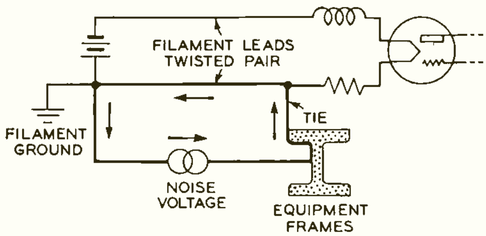


Fig. 4—Noise potentials between filament and signal grounds are sometimes minimized by short-circuiting ties

rents. Consequently, noise is quite likely to arise in vacuum-tube equipment in which different parts are connected to both grounds. Figures 3 and 4 illustrate two methods of making these potentials ineffective. In Figure 3 noise due to voltage between the filament and signal grounds is avoided by insulating the sensitive equipment elements from the noisy equipment frame. The insulation prevents the extraneous voltages on the frame from appearing on the grid of the tube through the stray capacitances between the coil windings and case. The weakness of this design is that, inadvertently, the insulation may become short-circuited. In the case illustrated by Figure 4 noise potentials between filament and signal grounds are shorted out deliberately by means of short-circuiting ties. As a result of this equalization of potentials, current flows over the ties and the positive filament-battery supply leads. Since the positive and negative filament-battery supply leads are inductively coupled as a result of pairing, the net voltage between these leads is approximately the resistance drop due to the current flow along the positive lead. When there are a large number of filament-ground to signal-ground ties, the alternating current over any given tie is relatively small. In the telephone plant the effect of tying together the various filament and signal grounds in vacuum tube equipment is quite beneficial.

Thus far the illustrations have dealt with circuits operating at voice frequencies, but the same principles apply also to circuits which operate at higher frequencies. This may be illustrated by a noise problem which arose several years ago in the reproduction of sound in auditory perspective between the Academy of Music, Philadelphia, and Constitutional Hall, Washington. In this demonstration the wide range of volume and carrier-current operation required that a very low circuit noise level be maintained. A survey of noise conditions on the circuits used to transmit this special program showed the presence of telegraph and other office noise in the Baltimore-Abington cable section due to parallelism in the outside cable between these circuits and other circuits. Within the office the auditory circuits were run in shielded leads and were well protected from noise. The trouble outside was overcome, as indicated in Figure 5, by installing choke coils in all the other circuits to reduce the induction in the low-level part of the auditory program circuits from direct-current telegraph lines in the Baltimore repeater station. This method of noise suppression is identical with that used today to suppress noise and crosstalk in the Type-K carrier-telephone system for cables.

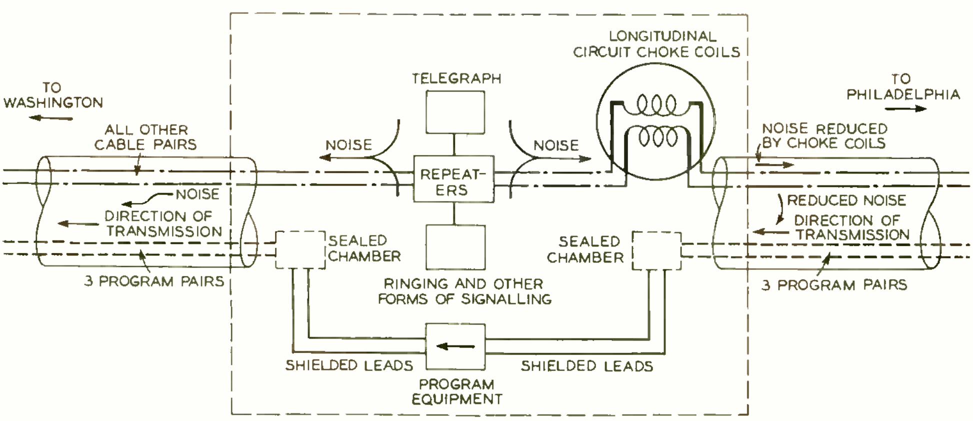


Fig. 5—Carrier circuits which run parallel to other circuits in outside cable are protected against noise by installing choke coils in all non-carrier circuits

A Call-Thru Test Set

By C. V. Taplin
Local Central Office Facilities

A VARIETY of equipment is provided in dial central offices for testing the various pieces of equipment so that faults may be discovered and removed promptly. These test sets indicate the condition of the major groups of apparatus, but do not test all paths through the central office, and thus do not give complete assurance that all calls placed will be correctly handled. To provide a means of making overall tests of the office equipment, call-thru test sets have been used for a number of years. These provide for placing test calls through various groups of office equipment exactly as subscribers would; and they give indications when the calls are not properly completed. Recently a new call-thru test set has been developed to incorporate a number of new features and certain improvements in the old, which experience over a number of years has suggested.

Like its predecessors, the new test set consists of a wooden cabinet that can be placed on a desk or table in the central office. The apparatus used by the operators, such as keys, lamps, and jacks are mounted on the front, and arranged as shown in Figure 1. The operator plugs in a telephone set as at a switchboard—the handset base shown being used only for dialing outgoing calls. Ten line circuits are provided for placing calls, each provided with a message register and alarm features. Jacks are provided for a pen register and certain special purposes such as making noise measurements, and a position clock is mounted at the right of the keys to be used chiefly in timing when measurements are made.

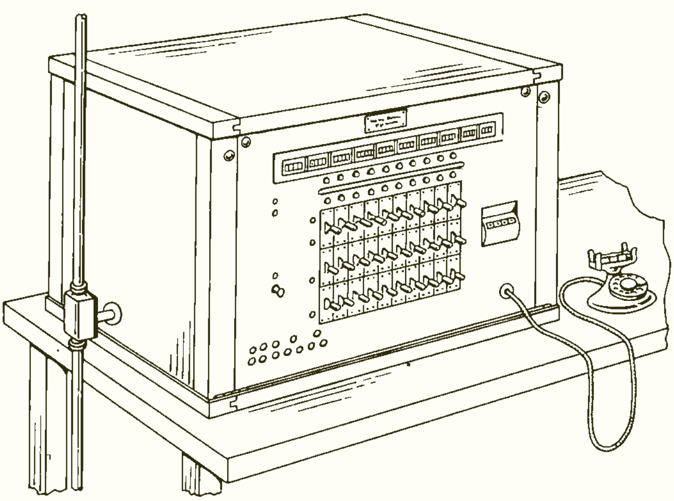


Fig. 1—The call-thru test set provides ten circuits for placing calls through various groups of office equipment

The call-thru test set is designed primarily for placing calls through the various groups of office equipment, and for determining that each call reaches its correct destination and is properly handled throughout. These calls are usually made to special test numbers with circuits arranged to send back signals to show that the call has been properly terminated. Calls may also be sent to company employees, such as test board operators, or back to the call-thru test set itself. Signals are provided to indicate that on such calls proper pulses have been sent for returning or collecting the coin on coin-box lines, or for line message register operation. Provision is also made for measuring noise on the connection when occasion warrants. Of considerable convenience is an associated jack panel which allows the outgoing lines to be readily changed to different line-finder groups so that the calls may be distributed over all groups of equipment.

Each of the ten circuits provided includes a key for originating, answering, or holding calls; a key for simulating the deposit of a coin and for releasing the associated relays when the coin collect or return pulse is not received; a key for transferring incoming calls to an intercepting operator when the test set is not attended; two lamps to indicate incoming calls and coin signals; and a message register. The operator's telephone set and the dial are common to all circuits, and are connected to them by operation of the talking key. Provision is also made for plugging in a pen register for recording the numbers dialed.

With the usual method of operation, the attendant operates the talking key of one circuit to the originating position, and dials a number. He can then move the key to the hold position, and at once place another call over another circuit. The progress of the call is indicated by the lighting of the lamps, the operation of the message register, or by tones over the circuit. A call that encounters trouble may be held until the source of the trouble has been located.

The terminals of the ten calling circuits are wired to ten sets of jacks

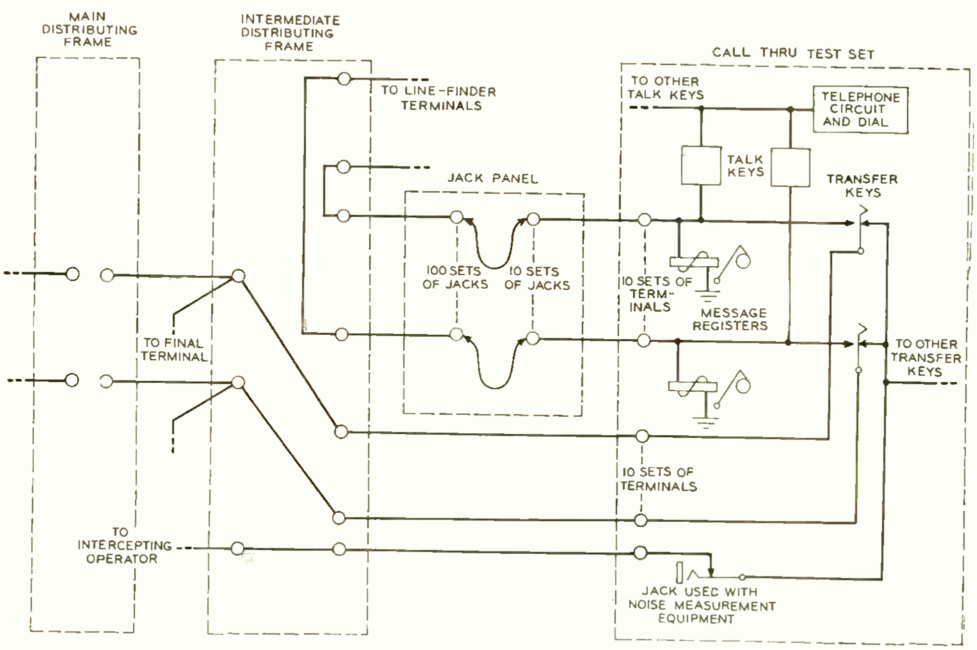


Fig. 2—Simplified diagram of an application of the call-thru test set to a panel office

on a separate jack panel, usually mounted on one of the relay-rack bays. On this same panel are provisions for one hundred sets of jacks wired to line-finder terminals at the intermediate distributing frame. These connections are made so as to distribute the one hundred jacks over different line-finder groups. By merely changing the patching cords at this jack panel, therefore, the attendant can distribute his ten test-set circuits over one hundred line-finder terminals. After placing as many calls as desired through the ten line-finder groups, the attendant goes to the jack panel, rearranges the patching cords, and then calls over a different set of ten line-finder groups, and so on.

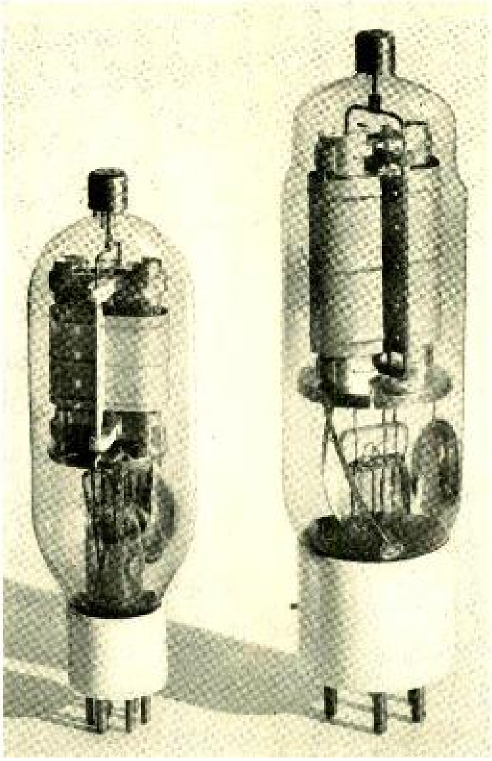
Besides the ten calling circuits that pass through the jack panel, the test set has ten sets of terminals for incoming calls. These are wired to the intermediate distributing frame, and there connected to unassigned numbers on the final frames, so that calls may be received. These are particularly useful for making noise measurements. The attendant plugs the noise-measuring equipment into the jack provided for it, and then places a call to one of the lines that terminate in the test set. When the call comes in, he operates the transfer key of that circuit, which transfers the call to the noise set, and the measurement is made. The noise-measuring jack is associated with the common intercepting trunk, but when the plug of the set is inserted in the jack, the connection to the intercepting trunk is opened.

A simplified diagram indicating the arrangement of the circuits as used in a panel office is shown in Figure 2. In the interest of simplification only two lines are shown and each circuit is represented by a single line. The relays, lamps, and pen register feature are omitted. Only a single trunk is provided to the intercepting operator because the chance of having two incoming calls at the same time is very remote, since calls would come into the set when it was unattended only because of some error in dialing.

This new test set supersedes the previous type, and will be furnished on all new orders. It incorporates a number of improved features, chief among them is the provision of separate signals to indicate coin collect and return, of message registers, and of a dial in a handset base instead of on the front of the set itself. This latter change permits the dial to be placed in the most convenient place for the operator to reach it, and is thus less tiring to use when a large number of calls are to be placed.

Suppressor-Grid Modulation

By C. B. GREEN
Vacuum Tube Development



ALL radio-telephone transmission—and a rapidly increasing portion of long-distance wire-telephone transmission — is of the "carrier" type. A high-frequency current generated by an oscillator is varied in amplitude by audio-frequencies, with the result that the transmitted signal is a varying high-frequency current conforming to an envelope that duplicates the audio-frequency wave. This process of modulation is usually accomplished by applying the carrier and audio frequencies to one or more electrodes of a vacuum-tube amplifier—the selection of the elements and the design of the tube being such that the carrier-frequency output will vary linearly with the audio-frequency input. Until recently there have been three major types of vacuum-tube modulation, which take their names from the tube element to which the voice-frequency is applied. More specifically they are grid modulation, plate modulation, and plate-and-screen modulation.

Each type has its own advantages and disadvantages. Both plate and plate-and-screen modulators are characterized by a high degree of linearity and a very high plate-circuit efficiency, but they are under the disadvantage that much of the output energy is obtained from the voice-frequency input rather than from the d-c power supply for the plate. As a result the audio-frequency power required is comparable to the modulated output, so that in these two cases large audio-frequency amplifiers are needed between the microphone and the modulator.

In grid modulation where the audio signal as well as the radio-frequency driving voltage is placed on the control grid, modulation is accomplished with much less audio power. This does not imply negligible audio-frequency driving power, since the potential of the control grid may be positive for a part of each radio-frequency cycle. The application of stabilized feedback* to the grid modulator has resulted in linearity equal or superior to that obtained in plate or plate-and-screen modulators, and many modern transmitters, especially in the broadcast field, utilize grid modulation.

*Record, *February*, 1937, *p.* 182.

A modulating system requiring neither stabilized feedback nor neutralization, and little or no audio-power amplification, would be a closer approach to the ideal, especially for use in mobile short-wave applications, where weight, size, and multi-frequency operation are complicating

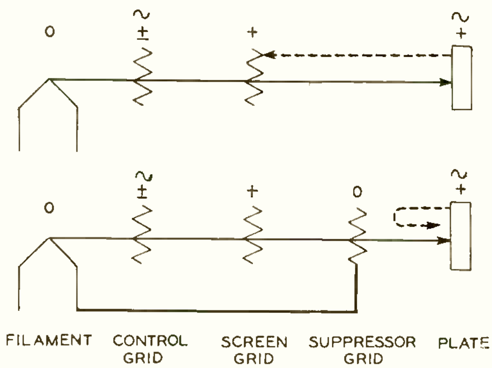


Fig. 1—(Above) In a tetrode tube secondary electrons from the plate will be collected by the screen grid at low swings of the plate voltage; (Below) With a pentode, the zero bias of the suppressor grid turns back the secondary electrons

factors. A fourth form of modulation, which is nearer this latter ideal, can be employed by taking advantage of the dependence of the output power on the potential of the suppressor grid in tubes which have three grids. These three-grid tubes, or pentodes as they are commonly called, have been used for several years as high-gain amplifiers, but only recently have they been especially designed for use as modulators. Their innermost grid serves as a control grid, as in a triode. The second, or screen, grid serves as a shield to lower coupling capacities and to accelerate the space current, as does the plate of a triode, but its wires are made small so that this grid will collect as little current as possible. The third, or suppressor grid, is usually held at filament potential and is thus negative with respect to both the screen grid and the plate. Its function is to return to the plate the secondary electrons knocked from it by the electron stream coming through the screen. Without it, the secondary electrons would be collected by the screen during the negative peaks of the output voltage, when the plate potential drops below that of the screen. The loss of these secondary electrons from the plate would reduce the net plate current during part of each cycle, and cause distortion and inefficiency.

In a screen-grid tube that has no suppressor grid, distortion and a loss in efficiency occur whenever the plate voltage swings too low. The arrangement of such a tube is indicated in the upper part of Figure 1. The filament is considered to be at zero, or reference, potential, and the screen grid, which is at a constant positive potential, accelerates the electrons toward the plate. The potential of the control grid varies with the carrier frequency, and may be positive during part of the cycle. Electrons accelerated by the screen

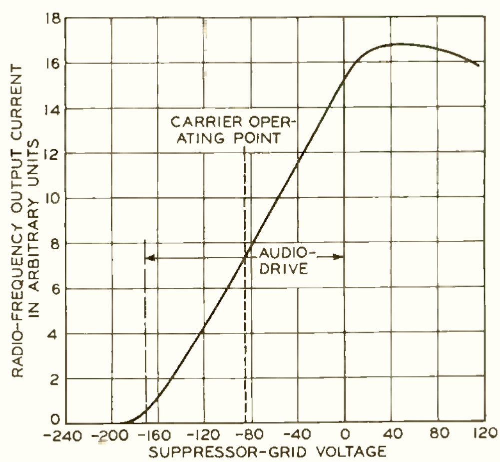


Fig. 2—Dynamic suppressor-grid characteristic of the 312A tube

pass through it and strike the plate, giving rise to secondary electrons. The potential of the plate, although biased more highly positive than the screen, varies with the signal, and if it swings below the screen bias these secondary electrons—indicated by the dotted arrow—will be drawn to the screen. With a suppressor grid, however, as shown in the lower part of Figure 1, the secondary electrons are turned back by the effect of the zero bias, and distortion is avoided.

Hence, when a suppressor grid is used, the plate voltage may be allowed to swing lower with respect to the screen voltage. The losses in the plate circuit are proportional to the product of the instantaneous voltage and current, and since the maximum plate current occurs when its voltage is lowest, the losses are decreased by allowing the voltage to drop to lower values, which is another advantage of this type of tube. This lowering of the instantaneous plate voltage also permits an increase in the amplitude of the radio-frequency plate potential for a given d-c plate voltage.

If the suppressor grid is disconnected from the filament and given a separate negative bias, it will be found that the plate current varies linearly with the suppressor bias over a wide range of negative values. It is thus possible to use the suppressor grid as a modulating electrode. A new type of modulator is obtained in this way which retains the high plate efficiency of the pentode. It is possible to design such a tube so that approximately the maximum output is obtained with zero potential on the suppressor grid. Since no positive swing is required, no current is drawn by the suppressor grid, and negligible power is needed for modulation. This constitutes the principal superiority of suppressor-grid modulation over both plate and grid modulation. Since the suppressor can be driven on a voltage basis, without the expenditure of appreciable energy, it is not necessary to supply high amplification for the audio-frequency power.

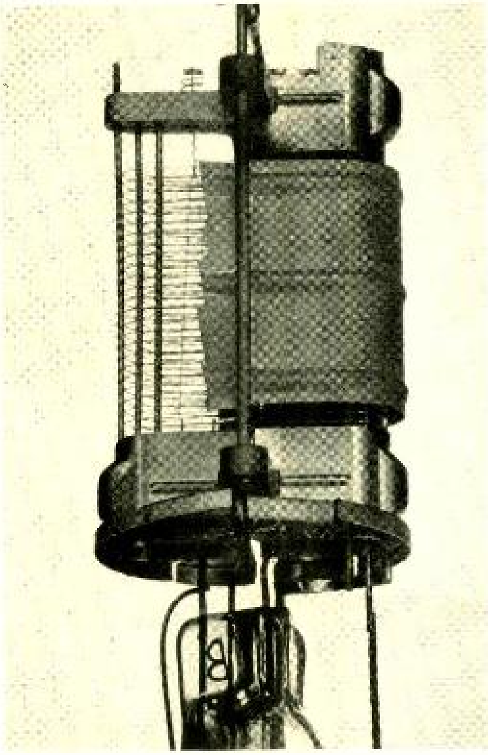


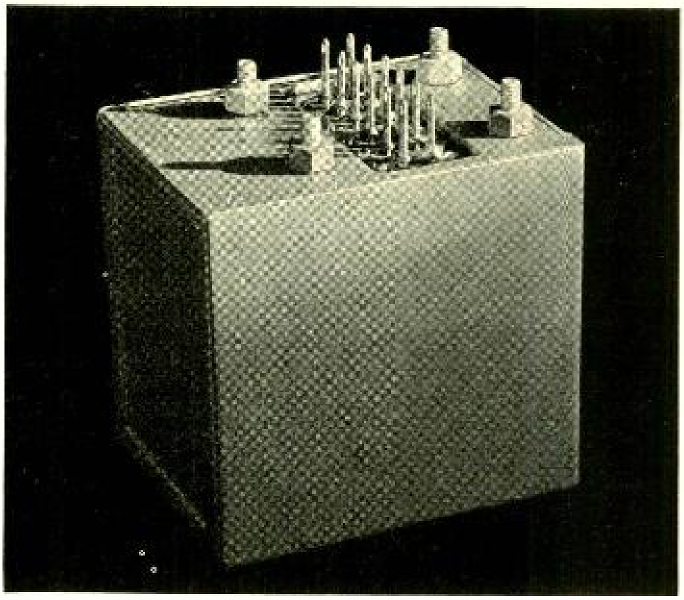
Fig. 3—The elements of the 312A tube with part of the plate and half of one of the end shields cut away

The Western Electric 312A tube, shown at the left in the photograph at the head of this article, was designed for such use, and has the suppressor-grid characteristic shown in Figure 2. The upper end is purposely saturated in the positive region very near zero bias, so as to obtain maximum power without driving the grid positive. The shape of the characteristic near its lower end is affected by the degree of screening furnished by the suppressor grid. At the negative peaks of audio modulation, practically all the electrons should be repelled, reducing the plate current to zero. If the suppressor grid does not shield the plate adequately, as at the end of the grid structure, a non-linear "toe" of the characteristic appears, and the plate current cannot be reduced to zero, which prevents attaining one hundred per cent modulation. In the 312A tube, metal shields, which may be seen in Figure 3, are attached to the ends of the grid structure to reduce the "toe" of the characteristic to insignificant proportions.

In addition to this function, the suppressor end shielding assists the screen grid in reducing the grid-to-plate capacitance. If this capacitance is too high, there will be regenerative feedback from plate to grid and singing may occur. In tubes with a high grid-to-plate capacitance this effect is avoided by neutralization: the circuit is adjusted so that a voltage equal to the feedback but opposite in phase is also applied to the grid. Such neutralization requires additional apparatus, needs adjustment when the carrier frequency is changed, and in addition is a source of distortion in broad-band transmission. In tubes with sufficiently small grid-to-plate capacitance, all these disadvantages are avoided. In the 312A tube, where the capacitance is a tenth of what it would be without the end shields, it is unnecessary to neutralize for any normal use of the tube. This is especially advantageous in mobile radio transmitters where multi-frequency operation, together with severe weight and space limitations, demands a minimum of adjustment in band changing or tuning. The small size and light weight of the 312A also contribute to its usefulness in the mobile transmitter field.

The 322A tube, shown at the right in the photograph at the head of this article, is a later development, and is capable of providing more than twice the output power of the 312A. It has the additional advantage of somewhat higher overall efficiency due to the relatively lower screen-grid current needed. This is secured by lining up the wires of the control grid and the screen grid so that the latter, while having normal electrostatic influence upon the space current, does not intercept as many electrons as it otherwise would.

Although these tubes were developed primarily for use as suppressor-grid modulators, they may also be operated with high plate efficiency as oscillators, as amplifiers, or as either of the other three types of modulators. Like other pentodes they have a high gain and thus require little radio-frequency driving power. These advantages of the new tubes, combined with their comparatively high output for the plate voltage used, give them a wide field of usefulness.



Filters for H-1 Carrier Telephone System

By J. O. ISRAEL
Transmission Networks Development

ALTHOUGH fewer filters are required in single-channel carrier systems than in multi-channel systems, their use is equally important. Each terminal for the H-1 system,* for example, requires seven filters, which are inserted in the circuit as indicated in Figure 1, where single boxes are used to indicate two directional and two line filters. In the H-1 system the lower sideband is transmitted in the west-to-east direction and the upper sideband in the east-to-west direction. The terminal shown is a "west" terminal, and thus uses the lower sideband in the transmitting branch. The modulator and demodulator filters A, B, and C are used principally for the suppression of unwanted products of modulation and demodulation. The attenuation characteristics of these three filters are shown in Figure 2.

In the transmitting branch, the A filter passes the voice band, extending up to about 3000 cycles, but suppresses all the higher frequencies that might otherwise pass back into the voice circuit. The B filter cuts off just above the carrier frequency of 7150 cycles, and thus attenuates the upper sideband and other unwanted modulation products of higher frequency. The other, or "east," terminal has in the B position a band-pass filter that transmits frequencies in the range from 7000 to 10,000 cycles. The C filter is employed to attenuate high-frequency modulation products that might otherwise pass to the hybrid coil and out on the voice circuit, causing noise. Only a moderate amount of suppression is required of this filter,

*Record, *November*, 1937, *p.* 76.

and in fact of most of the others, because there are several filters in each direction of transmission, and the suppression obtained is a function of all of them rather than of any one alone.

Filters A and C are held to a high degree of balance to prevent the carrier from appearing in the voice channel as noise. As indicated in Figure 1, the carrier is supplied at the mid-points of the transformers at both sides of the modulator and demodulator and flows through the filter longitudinally, and is thus largely balanced out.

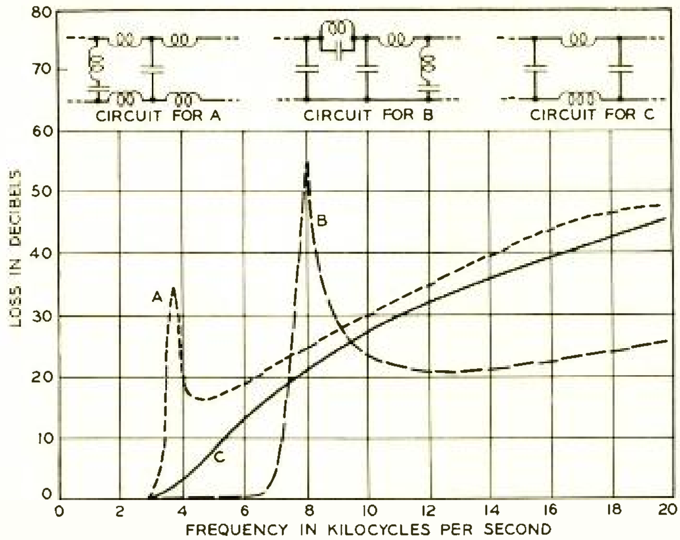


Fig. 2—Attenuation-frequency characteristics of the modulator and demodulator filters

The directional filters, which separate the incoming and outgoing sidebands, are both band-pass filters. Their attenuation characteristics are shown in Figure 3. They are required to be highly selective, since the upper and lower sidebands lie only 500 cycles apart. This high selectivity not only requires a considerable number of coils and condensers, but also necessitates precise adjustment and good stability with aging and variations of temperature. As already noted the selectivity in the transmitting path results from the combination of filters B and D and thus is really greater than the amount indicated by Figure 3 alone.

The line filters separate the voice-frequency channel from the two carrier sidebands. Like the directional

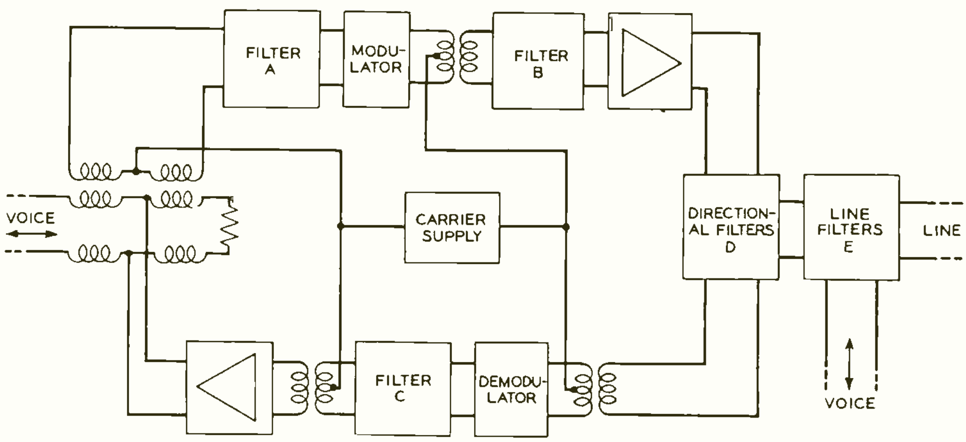


Fig. 1—Block schematic of the H-1 carrier system showing the location of various filters

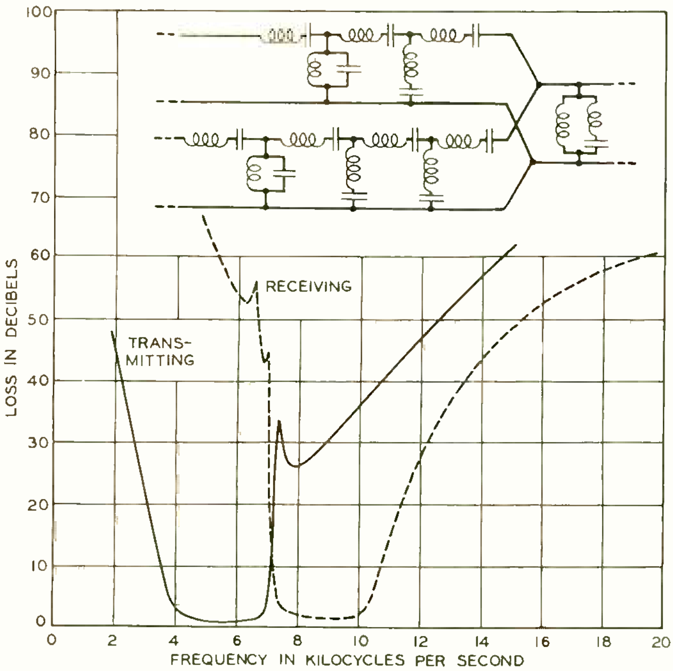


Fig. 3—Attenuation-frequency characteristics of the directional filters

the coils of the filter.

Since these filters are connected directly to the line, they may occasionally be exposed to high voltages caused by lightning or surges on power lines adjacent to the telephone line. Because of resonances among the coils and condensers within the filter, the voltage in some parts of the filter may rise to several times the normal voltage at certain frequencies. Because of these conditions those condensers on which the higher voltages might appear are made to withstand a

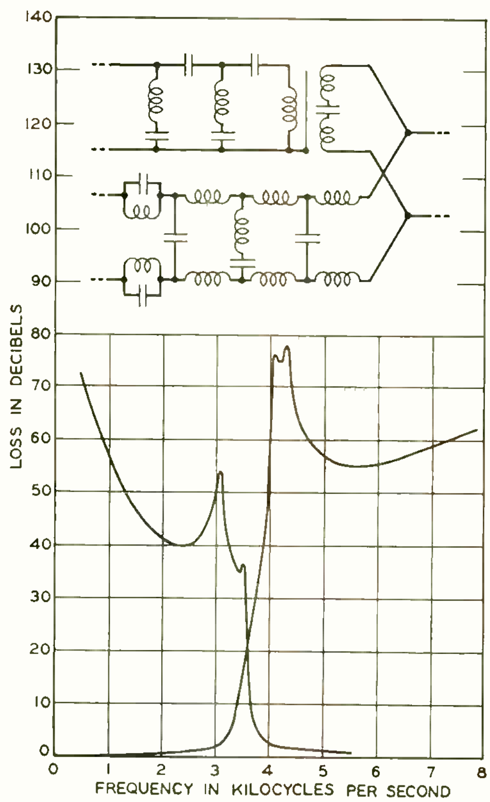


Fig. 4—Attenuation-frequency characteristics for the line filters

filters, they are highly selective, but one is a high-pass and the other a low-pass filter. Their characteristics are shown in Figure 4. These two line filters also differ in that the low-pass filter is balanced to ground while only part of the high-pass filter is balanced. The line itself is balanced, and all filters connected directly to it must also be balanced. A balanced filter requires more elements, however, and thus is more expensive. An appreciable saving, both in cost and space, has been made by incorporating a transformer near the line end of the high-pass filter, which allows the filter to present a balanced appearance to the line even though the portion of the filter behind the transformer is not balanced. The transformer itself is also utilized as one of

1500-volt test, instead of 1000 volts as has been employed before.

Since the H-1 carrier system provides only one additional talking circuit, and is designed for short distances, it was essential to keep the cost of all its elements as low as possible. To aid in meeting this requirement, these filters are all of the "potted" type, employing precision paper condensers and small toroidal coils. In this method of construction the coils and condensers for the three modulator and demodulator filters are assembled compactly in a can which is then filled with compound, providing a moisture-proof seal. The directional filters for each terminal are mounted in two cans of similar type, which are held together by a common cover. A similar double-can arrangement is employed for the line filters. The position of these filters in the terminal cabinet for the H-1 carrier telephone system is shown in Figure 5, where the small space that is occupied by the filters is evident.

An important factor in the design of these filters was the use of coils with cores of molybdenum-permalloy. Without this core material it would be necessary to use air-core coils in the band filters and high-pass line filters to avoid modulation. Although the filters for the H-1 system employ more coils and condensers and provide sharper discrimination than those used in the older D systems, their cost is substantially lower, and the space occupied is about one-sixth.

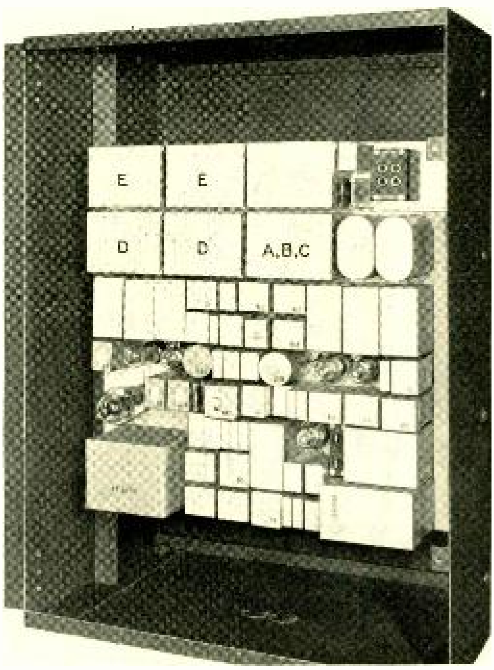


Fig. 5—Terminal for the H-1 carrier system showing the location of the modulator and demodulator (A, B, and C), directional filters (D), and line filters (E)

A Vogad for Radio-Telephone Control Terminals

By S. DOBA, JR.
Transmission Development Department

IN the transmission of speech over radio circuits, one condition that must always be met in practice is that the received signal shall be sufficiently greater than any disturbing noises to prevent serious impairment of the intelligibility. The generation of power at radio frequencies, on the other hand, is costly, so that economical operation does not justify the transmission of more power than is needed to produce a satisfactory signal at the receiver. Economy, therefore, would call for the radiation of a constant amount of power just great enough to give good reception. The range of intensities of speech sounds delivered to the toll terminal equipment, however, varies over a considerable range because of the natural variation in intensity of speech sounds of a single talker, which may amount to 30 or 40 db, and of the difference in volumes of some 30 db arising from the differences in speakers and in the connecting circuits and equipment.

With this situation, some form of volume control is required if efficient operation is to be secured. The usual practice is to have the technical operator adjust the potentiometer ahead of an amplifier so as to maintain the outgoing volume at a constant value as measured on a 203C volume indicator. In this way, the range of speech amplitudes applied to the radio circuit is reduced to 30 or 40 db. Quite often, however, the technical operator has a number of other functions to perform as well, such as tuning the radio receiver, adjusting its volume, and adjusting the sensitivities of the voice-operated devices that prevent echoes or singing. All these adjustments must be made at the beginning of a call, so that the volume control of the transmitter frequently suffers—particularly on calls of short duration.

For a number of years the Research Department has been engaged in determining the factors involved in the automatic adjustment of speech volume; and many different devices have been produced for that purpose. These have been called "vogads"—a word formed from the initial letters of the phrase "volume-operated gain-adjusting device." In general the performance of a vogad, as compared to a technical operator attentively supervising a circuit with the help of a volume indicator, is better in quickly detecting and reducing volumes that are too high, and possibly slower in deciding that a volume is too low. Lack of quickness in this latter respect, however, may be offset by permitting a certain amount of variability in the output amplitude.

Vogads differ widely depending on the type of circuits with which they are to operate; but they all consist of an amplifier, or "vario-repeater," the gain of which is adjusted by a number of control circuits. In function these circuits take the place of the volume indicator and the hands, ears, eyes, and brain of the operator. The operation of even the simplest vogad is necessarily involved, because there is no accurate way of quickly determining such a complex quantity as the volume of speech. Besides this basic difficulty, the characteristics of different voices vary over a wide range and the effects on the voice of the several types of telephone transmitters also differ. Moreover, some syllables are naturally much weaker than others; and one talker may emphasize the strong syllables and whisper the weak ones, while another may talk in a monotonous voice, which is tiresome to listen to but is quite desirable from the standpoint of good radio transmission.

Chance may decide that five or six weak syllables occur before an average strong syllable, and the vogad must determine quickly whether the low-intensity signals are weak syllables of speech at a certain volume or strong syllables at a much lower volume, because it is primarily the volume that is to be controlled. At the same time, the vogad should reduce strong syllables quickly enough to avoid overloading the radio transmitter, and increase the abnormally weak ones quickly enough to prevent the listener from losing them.

Although there are several ways of accomplishing volume control, the general principles involved may be illustrated by a description of a comparatively simple vogad recently developed for use with short-haul radio-telephone circuits. For such applications, economy in the first cost of the apparatus is an important factor.

A simplified schematic diagram of this vogad is shown in the figure. It consists of a vario-repeater and four control circuits, which use neon glow tubes to adjust the gain of the amplifier. The vario-repeater consists of a push-pull amplifier with variable-mu pentodes to supply the variable gain, and normal repeaters to provide a fixed amount of gain. The gain of the push-pull amplifier is controlled by varying the bias on two condensers, C1 and C2, in the control-grid circuit of the tubes V1 and V2. The bias on these condensers is changed in accordance with the energy at the input and output of the vogad by four control circuits. These are: 1—a gain decreaser, which increases the negative bias of the vario-repeater whenever the output signal exceeds a critical value; 2—a gain increaser, which decreases the negative bias of the vario-repeater whenever the output is low but above a value determined by the noise level; 3—a gain-increase disabler, which prevents operation of the gain increaser when the output signal is high enough; and 4—a gain-increase enabler, which permits operation of the gain increaser when the input signals are above the noise level, thus preventing normal line noise from increasing the gain during the time that no speech is present.

The operation of this vogad may be understood in a general way by assuming that its input is connected to a telephone circuit with a normal amount of line noise, and that a subscriber with a rather weak voice commences to talk. When speech of sufficient amplitude is present, part is rectified by the copper-oxide unit D in the gain-increase enabler circuit. This operates relay A, which closes the circuit through gas tube GT2 and a forty-volt enabling bias E2. The gain-increaser amplifier then causes the breakdown of gas tubes GT2 and GT3, and the resulting current flows through

C1 and decreases the negative bias on the grid condensers C1 and C2. This increases the gain of the vario-repeater, which continues to increase until the crests of some of the stronger syllables, appearing across transformer T2, are high enough to cause conduction through the gain-increase-disabler tube V4. Current flowing through this tube and R3 increases the negative bias of the gain-increaser amplifier tube V3 until the output of the latter is no longer great enough to break down GT2. When these conditions are reached, the gain of the vario-repeater remains constant.

Now assume that the talker emphasizes a syllable or two by pronouncing them loudly without raising the general level of his voice. This somewhat higher output now momentarily breaks down the gain-decreaser tube GT1, and the current that flows produces a sudden increase in the negative potential of condenser C1, which in turn causes a quick reduction in gain of the vario-repeater. As soon as the abnormally loud syllables have passed, however, current ceases to pass through GT1, and the charge on C2, which is of larger capacity than C1, restores the charge on C1 through the high resistance R1, so that the gain of the vario-repeater returns nearly to its original value. By this momentary reduction in gain, the subscriber's emphasis will have been somewhat reduced, but the radio transmitter will have been protected from overload.

Now assume that the talker gets excited and starts to shout, raising his volume considerably. The voltage across transformer T1 will rise and cause breakdown of GT1, and this voltage, in series with the enabling

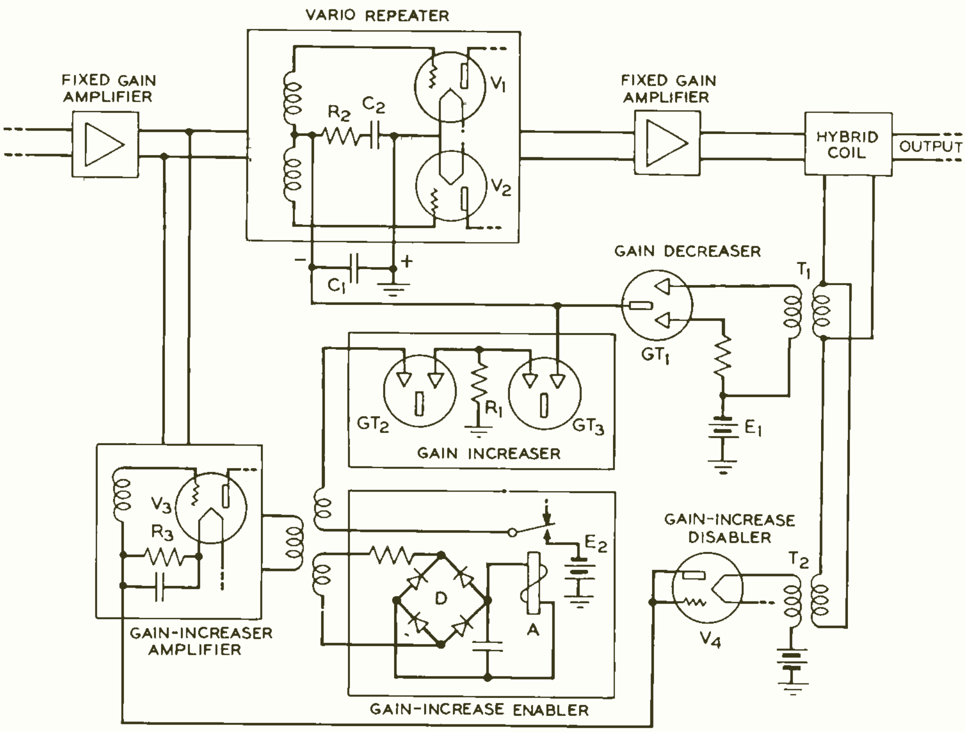
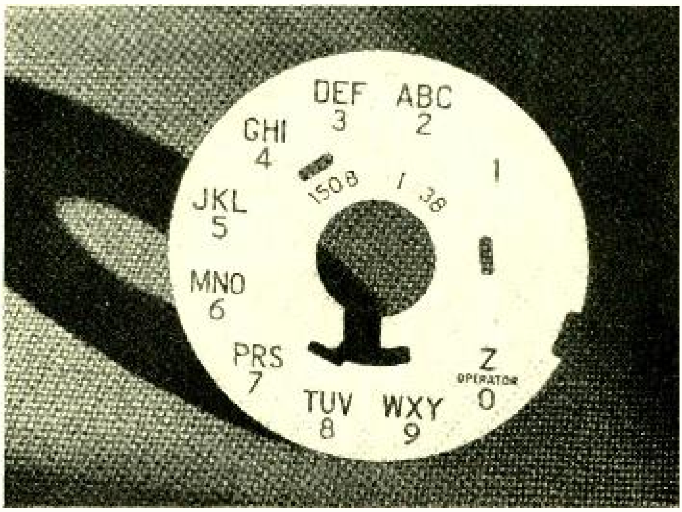


Fig. 1—Simplified schematic diagram of a vogad designed for radio transmitter circuits

battery EI, will cause a current to flow through CI and C2, raising the negative bias so that the gain of the vario-repeater is reduced to an amount that maintains the desired output volume with the increased input volume. This condition will persist until the talker lowers his volume. During the period that GTI is broken down, the gain-increase-disabler tube V4, is also conducting, and thus prevents the gain-increaser from operating. When the talker lowers his volume sufficiently, however, both GTI and V4 will cease conducting, and the negative bias on V3 will decrease so that the gain-increaser will again come into action. The result is that the gain of the vario-repeater is varying almost continuously and the speech volume delivered to the radio transmitter is kept within much closer limits than it otherwise would be. When the subscriber ceases to talk, or his volume drops practically to the noise level, the tubes GT2 and GT3 will be extinguished because of the decreased output, and thus further increase in gain is prevented.

The vogad here described is about as simple a circuit as justifies the name, and the drawing and description are still simpler than the actual device. It is, however, adequate for circuits where a range of volume of about 40 db is to be reduced to a range of possibly 5 db. For circuits having a greater input range or requiring a smaller output range, much more complex vogads are required.



The front of this new dial number-plate is finished with an improved ceramic material instead of cellulose acetate as at present. Comparative tests show that this enamel finish is superior in resisting wear and scratches. The new plate will improve the appearance of dials in service and effect economies in dial maintenance

General Features of Teletypewriters

By E. F. WATSON
Systems Development

TELETYPEWRITERS are not unlike ordinary typewriters in general appearance and in the record they make on paper as the operator presses the keys; but they also send at the same time pulses of current over a line to a distant station. These pulses are deciphered at the receiving end by another teletypewriter and converted into letters as fast as the signals are received.

In general, similar to that of the ordinary typewriter, the teletypewriter keyboard has a few added keys for controlling operations and three rows of keys instead of four because it sends only capital letters, numerals and punctuation marks. Thirty-two different signals are used to send the twenty-six letters of the alphabet and the machine functions—such as carriage return, space, and line feed. By sending a shift or "Figures" signal a second row of type can be brought into play to type ten numerals, fractions in eighths and the usual punctuation marks.

When the operator presses a teletypewriter key, projections on the lower side of the key bar select one or more of five circuits depending on the key pressed. To illustrate, the circuits may be assumed to be connected to the segments of a distributor with revolving brushes, as in Figure 3, so that each of the circuits, if selected, is closed in succession as the brushes rotate. Thus there are two conditions, "current off," or "current on," for each of five time-units, so that a total of 2^5 or 32 signals can be sent.* At the receiving end a second revolving distributor is provided which rotates in approximate synchronism with that at the sending end. As the brushes

*A six-unit code, which allows 64 different signals, is used where it is necessary to transmit capitals, small letters, numerals and punctuation marks.

sweep over its segments, each of a series of five receiving magnets is connected to the line, and if a pulse is sent at that moment, the armature of that magnet is pulled up. These armatures control the positions of five selector bars which are used to determine what type bar is released to strike the paper.

The sending and receiving units shown in Figure 3 are maintained in step by a start-stop system. Both sending and receiving brush arms are normally at rest but are maintained under torque, by constantly running motors which drive them through friction clutches and tend to rotate them in the direction of the arrows in

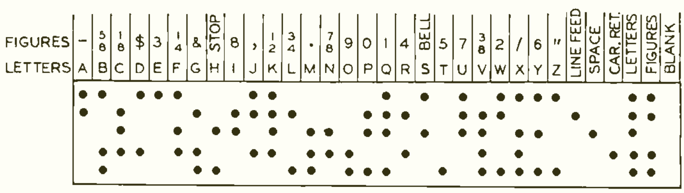


Fig. 1—Teletypewriters send code signals which consist of one or more of a series of five pulses of current for each letter, figure or sign

Figure 3. Normally the line circuit carries current but when a key of the keyboard is operated to send a signal, the start magnet of the sending distributor releases the sending brush arm and allows it to rotate. As this brush passes from the sixth to the seventh segment, the line circuit is opened. This releases the brush at the receiving station and allows it to rotate. Both sending and receiving brush arms move at approximately the same speeds since they are driven by small synchronous motors from commercial 60-cycle 110-volt power supply or by commutator-type motors, equipped with centrifugal governors to hold them at approximately constant speed. In modern machines the brush and segment distributors are replaced by simple mechanical devices with sending contacts and a single receiving magnet. They function in the same manner as the distributors but are cheaper, more reliable and easier to maintain.

The start-stop system has, in addition to simplicity, the advantages that highly accurate speed regulation of the motors is not required, and that to start a station it is only necessary to turn on the power. The lag compensation is automatic because the receiving distributor does not start until the start signal has been propagated and received and then the other signals always follow in a fixed definite time relation. This makes it possible to connect any number of stations to a single circuit and have signals sent from any station received and printed at all other stations without requiring adjustments, regardless of the distances or circuit complications due to repeaters and the like which may intervene.

Teletypewriter signals often become shortened or lengthened en route when transmitted over long lines. To

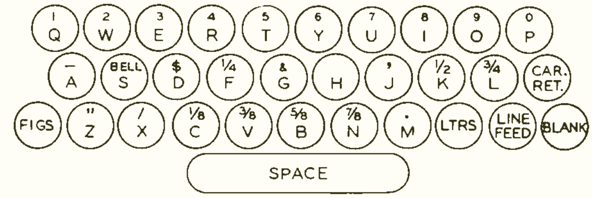


Fig. 2—The keyboard of a teletypewriter is similar to that of an ordinary typewriter except there are three rows of keys instead of four

enable the receiving distributors to interpret these distorted signals without error they are arranged to receive the selecting impulses only for a very short time at the middle of each impulse. The exact location of this sensitive period with relation to the incoming signals is adjustable in each receiving distributor so that it may have maximum tolerance for receiving distorted signals. Machines for use in the Bell System are all required to tolerate at least a forty per cent lengthening or shortening at the beginning of any current impulses and a thirty-five per cent deviation at the end.

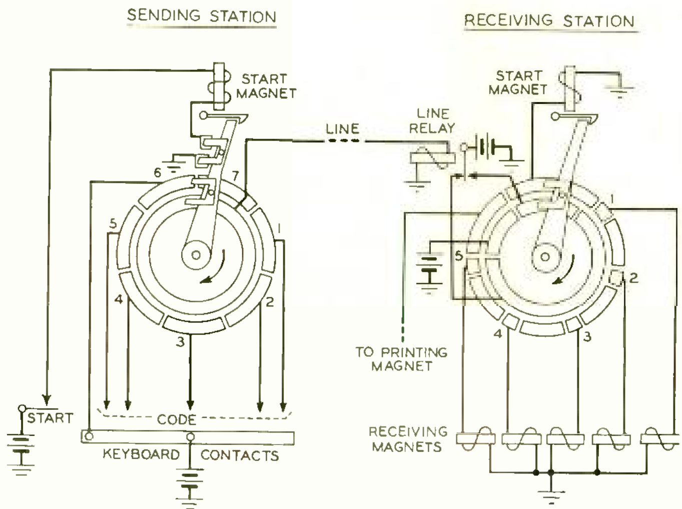


Fig. 3—The code signals are sent and received by distributors which rotate in approximate synchronism

Teletypewriters are normally set for a speed of 368 machine operations per minute, which is equivalent to about sixty words per minute. Messages are recorded either on a sheet or a narrow strip of paper, depending on whether a page or a tape machine is used. For the convenience of customers teletypewriters are designed in most cases as self-contained units which can be mounted on any table or desk.

Teletypewriters which make page records have been built with a moving or a stationary paper carriage and with a type wheel or type bars for printing. For general service in the Bell System the No. 15 type has been designed, which uses type bars and a stationary paper carriage and makes as many carbon copies as a regular typewriter. This combination was new in the art and required extensive development work because of the inherent difficulties of moving an automatically operated basket of type bars back and forth in front of a stationary paper. The present standard page teletypewriter, shown at the end of this article, employs a typewriter ribbon for inking, has the paper roll inside the machine cover and makes carbon copies. This machine will also type either single or duplicate copies on the organized printed forms used in modern business practice. By equipping the platen which supports the paper with sprocket teeth and having feeding perforations along one or both edges of the forms, all copies are automatically held in perfect registration during typing at all stations in the circuit. An automatic tabulating device is also provided to make all the carriages move over rapidly on the transmission of a certain signal to any predetermined position on the form and stop there for the typing of letters or figures in columns that are in perfect alignment.

In the new teletypewriter exchange service many of the machines were only required to operate for short periods at a time and to make a single copy. To render this service economically a new machine, the No. 26 type, shown in Figure 4, has been developed.* Low first cost has been attained by designing it to print only an original or at most one or two carbon copies. This machine has a moving carriage and uses ribbon inking and a type-wheel arrangement which is a cross between conventional

Fig. 4—No. 26 teletypewriter (cover removed) designed for service where only an original or at most one or two carbon copies are required. It has a movable carriage and the type characters are mounted on a wheel

type-bar and type-wheel design. This type wheel is an assembly which has a small individual type pallet for each separate character. In printing, a striking arm, somewhat like the shank of a type bar, comes forward and forces the individual type pallet against the ribbon to make an impression on the paper. The type wheel is rotated to different positions to select the different characters. In this way a clear-cut impression is obtained, which compares favorably with the record of a type-bar machine or typewriter.

*To be described in an early issue of the RECORD.

Fig. 5—No. 14 standard tape teletypewriter of the Bell System (cover removed). It is type-bar operated and uses an inking ribbon

Tape teletypewriters print the record on a narrow strip of paper normally three-eighths inch wide. The standard tape machine used by the Bell System is known as the No. 14 type, shown in Figure 5. It is type-bar operated and uses an inking ribbon. Occasionally there is a demand for carbon copies and one or two can be made either by providing a multiple wound roll of record and carbon strips or by leading tapes through the machine from two rolls of record paper and one roll of carbon paper. The tapes may be either gummed on the back for pasting on blanks for filing or left as plain paper tapes if the records are only of temporary interest. A tape-out signal is provided on the machine so that a bell rings when a roll of tape becomes nearly exhausted. Where a bell is not desired, the last few feet of tape on the roll are colored red to give similar warning. The platen wheel against which the type strikes is fed through differential gearing so that the typing comes in a different spot on a second revolution to distribute the wear uniformly over the entire circumference.

Where a heavy volume of traffic is transmitted, a machine known as a perforator, with a keyboard like that of the teletypewriter, is used for punching the code signals in a strip of paper. This punched tape may be prepared at practically any speed within the capabilities of the operator, and later fed through a device known as the tape transmitter which automatically sends the signals from the punched tape at maximum speed. The tape transmitter uses the line at maximum efficiency and also has the advantage that errors may be corrected in the tape before transmission. For teletypewriter exchange service a further advantage of the perforated tape is that the entire message may be punched and checked by printing before a call is placed.

The perforator keyboard is normally arranged so that it may be used also for direct keyboard sending without perforating, since short to and fro messages can be handled better directly. The message may also be simultaneously typed and punched so that the typed copy can be checked as it is perforated. The complete No. 19 teletypewriter set for page printing and arranged for tape transmission is illustrated in Figure 6.

To permit satisfactory control of intercommunication and interruption of the sending station when desired, a "break lock" is incorporated in many machines. This device, together with a break key located on each machine, permits any station at any time to interrupt a station which is sending, and take control of the circuit by temporarily locking out the sending mechanism.

It is often desired to have a machine normally idle with the motor stopped but so arranged that a signal may be sent over the line to a receiving machine to start it for recording and to stop it automatically at the end of the communication. Various devices are available for this purpose, some of which operate over the regular signaling line while others require a

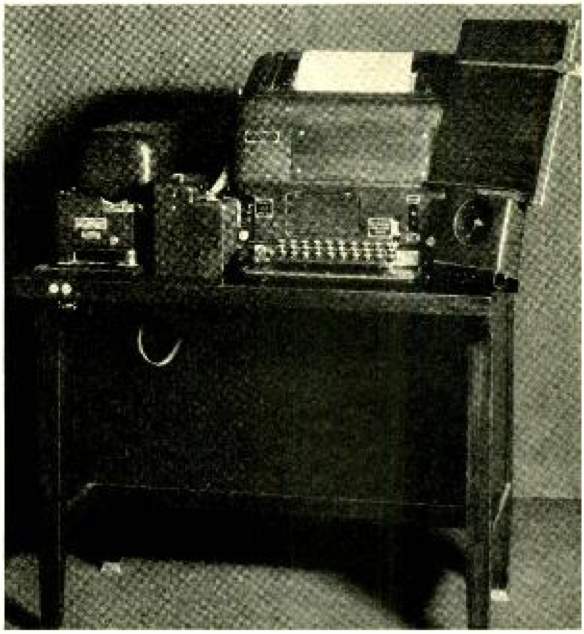


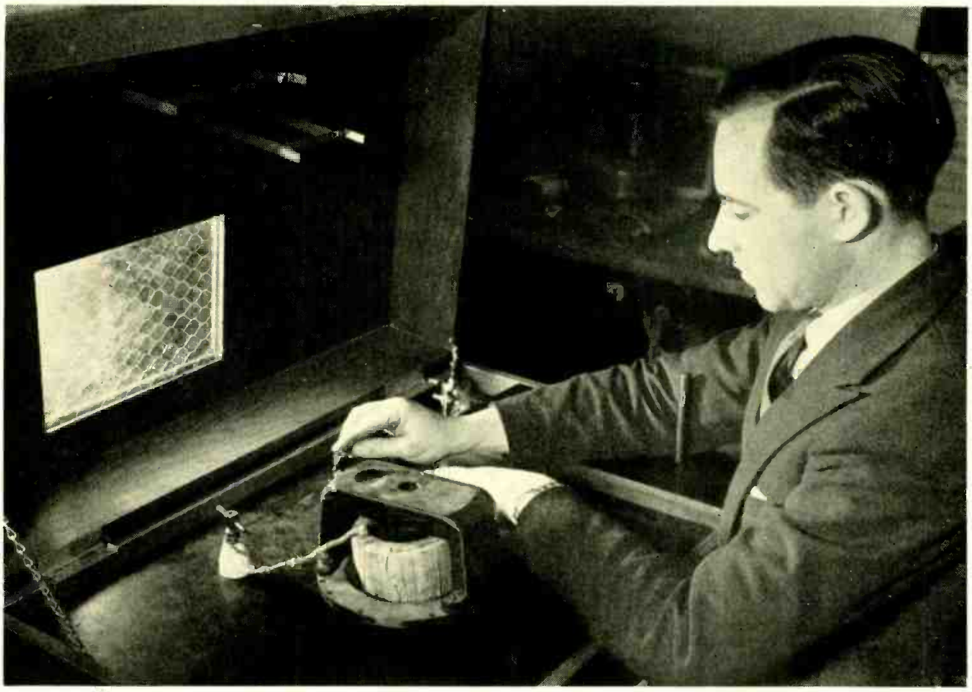
Fig. 6—No. 19 page-printing teletypewriter set arranged for tape transmission. The message can be typed on paper and punched in a tape simultaneously

separate circuit. Signal bells are usually provided on the machines to call an attendant or indicate that a specially important message is being received.

A general feature incorporated in all modern machines is the "overlap" which provides for typing one character while the selecting impulses for the next character are being received. This is done by storing the impulses temporarily in spring-controlled members which are released to control typing when the previous signal has been recorded.

The future should bring simpler machines with new electrical and mechanical arrangements, especially where the more difficult requirements do not have to be met. But some of the fundamental features of teletypewriters, such as the start-stop method of operation, the five-unit code, and perforated tape and keyboard transmission, will probably remain for many years to come.

Fig. 7—No. 15 teletypewriter arranged for typing on printed forms



Magnetizing by Condenser Discharge

By A. E. DIETZ
Electromechanical Apparatus Development

PERMANENT magnets are most easily magnetized by placing them between the poles of a powerful electromagnet. In some cases a strong permanent magnet may be used for this purpose. This latter method is commonly employed in magnetizing the ringer magnets at subscriber stations, and was described in the RECORD for February, 1937. Frequently, however, the core to be magnetized is of such a shape that another magnet cannot be employed to provide the desired flux. Under these conditions it is necessary to place a temporary winding around the core, and then secure the desired magnetization by passing a heavy current through this winding.

The windings, of course, serve no useful purpose once the desired magnetization has been obtained, and must be removed before the magnet can be used. It is desirable, therefore, to wind only as few turns as possible, and to attain the needed ampere-turns by using a very large current. Since magnetization takes place practically instantaneously, the duration of the magnetizing current is unimportant; and to reduce the cost of the process and the local heating of the core, it should be made as short as possible. One method* that has been employed is to connect the coil through a fuse across the terminals of a high-voltage large-capacity battery. The

*RECORD, *January*, 1934, *p.* 130.

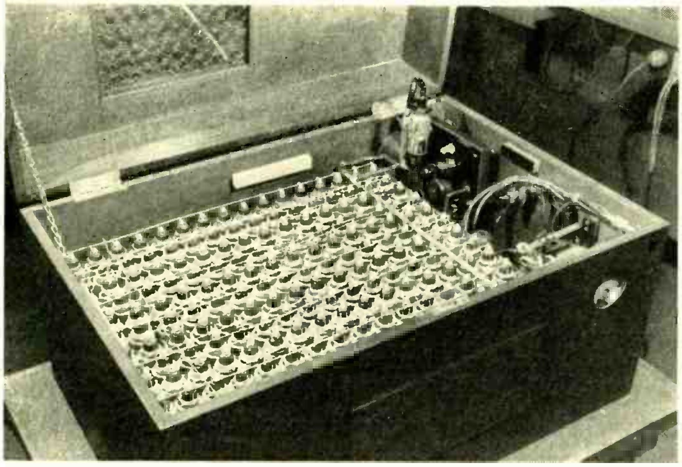


Fig. 1—When the magnetizer is in use a flat insulating shelf fits over the tops of the condensers, and the core to be magnetized is placed on it

oscillates back and forth with a steadily decreasing amplitude. Such a current would magnetize the core during the first half cycle, and then would partially demagnetize it during the next negative half cycle. At the termination of the discharge, although there would remain some magnetization in the core, it would be very slight compared to the desired value.

To make such a magnetizer perform satisfactorily, therefore, some means must be provided for eliminating this reversal of current. This could be done by using a resistance above a certain critical value, which would cause the discharge to be as indicated by the dotted line of Figure 2. The maximum value of current, however, would be much smaller because of the greater resistance, and as a result much of the advantage of this method of magnetizing would be lost.

very large current that passes through the winding blows the fuse in a small fraction of a second, but not before the core has been magnetized.

Large-capacity generators could also be used with this method of magnetization, but either a generator or a battery of the required capacity is expensive, and for only occasional use they would be uneconomical. To provide a less expensive source of current, a condenser magnetizer was recently developed. Four hundred electrolytic condensers, each of eight microfarad capacity, have been compactly arranged in a box about thirty inches on its longest side, as shown in Figure 1. The condensers, connected in parallel, provide a total capacity of 3200 microfarads, and are charged through a full-wave rectifier to a potential of 350 volts.

Since the magnetizing coil has both resistance and inductance, the discharge current of the condenser is usually an alternating one as shown by the solid line in Figure 2. It rises rapidly to a maximum value, decreases, becomes negative, and then

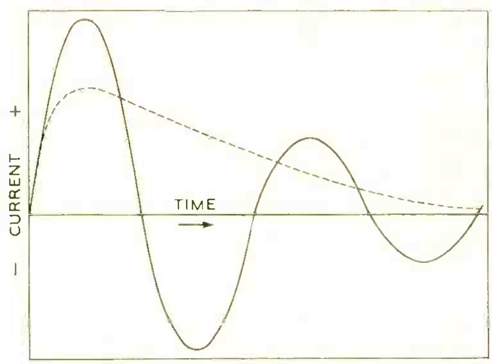


Fig. 2—The discharge current of a condenser into a circuit including a resistance and inductance oscillates from negative to positive with steadily decreasing amplitude

The arrangement actually provided avoids the difficulty by connecting an ignitron in the discharge circuit. This ignitron, which is an evacuated tube with mercury as one electrode, acts as a mercury-vapor rectifier—passing current in one direction only. With the ignitron in the circuit, the first positive half of the discharge is passed and then the circuit is opened so that no reverse current can flow.

A schematic diagram of the circuit employed is shown in Figure 3. In both positions the relay employed holds itself operated by the action of gravity; the operating current merely swings it from one side to the other. When the operating key is depressed, the relay swings to the opposite position and closes contacts 1 and 2. This connects the rectifier to the condenser which charges rapidly. When the operating key is released, the relay is swung to the other side and closes contacts 3 and 4. This applies the condenser potential to the very high-resistance ignitor electrode of the ignitron, and some of the mercury is vaporized to make the tube conducting. Current then flows to the magnetizing coil. As the current drops to zero at the end of the first half cycle, and starts to reverse, the tube ceases to conduct.

When the magnetizer is in use, an insulating shelf closes the box just above the condensers in Figure 1. Terminals A and B of Figure 3 pass through this shelf and terminate in heavy binding posts for connection to the coil, which is placed on the shelf. A coil is shown being connected in the photograph at the head of this article. The cover of the box is then lowered to prevent the operator from coming

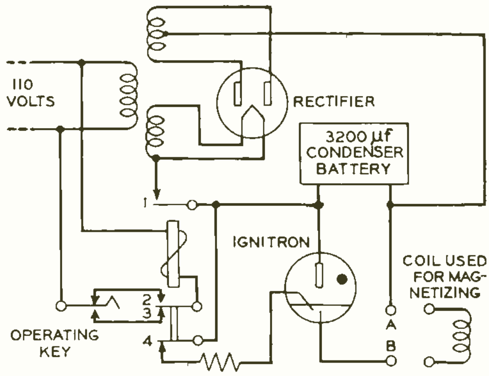


Fig. 3—Schematic diagram of the circuit used in the condenser magnetizer

in contact with the high potential. The operating key projects through the front of the box. As a safety precaution the cover is arranged so that when lifted it opens switches in both sides of the circuit, not shown in Figure 3, and places a short-circuit across the condenser.

Currents as high as 4000 amperes have been passed by this magnetizer, but since their duration is only about a thousandth of a second, no serious heating occurs. The apparatus has been found simple to operate, and it has simplified the magnetization of many types of cores that could not be magnetized with the permanent or electromagnet method.

Channel Crystal Filters for Broad-Band Carrier Systems: Electrical Features

By E. S. WILLIS
Filter Development Department

THE broad-band carrier telephone systems, of which the type-K system for cables is the first to go into commercial service, are designed to operate in groups of twelve channels. Two such groups, one comprising the transmitting channels and the other the corresponding receiving channels, provide twelve two-way circuits. Between each modulator and the line in the transmitting group is a filter designed to pass only the lower sideband resulting from the modulation; and between the line and each demodulator of the receiving group is an exactly similar filter which serves to select from the frequency bands on the line, the particular one to be passed to the demodulator. These twenty-four filters, two of each type, are the channel filters.

Since it is planned to employ the same type of channel filters for all the broad-band systems, they will appear in increasing numbers on the toll lines of the future, and for this reason considerable attention has been given to providing excellent transmission characteristics. Every effort, therefore, has been made to secure a small and inexpensive unit without sacrifice in performance.

Improvement in the intelligibility and naturalness of transmitted speech has been an objective of most of the major system changes from the beginning of the telephone. Still further improvement in speech transmission was undertaken in the development of these new broad-band systems. The carrier frequencies are spaced 4000 cycles apart, and the effective band width is considerably greater than that of the present three-channel open-wire carrier systems.

The design requirements for the channel filters are based on meeting acceptable limits for mutual interference between channels in an over-

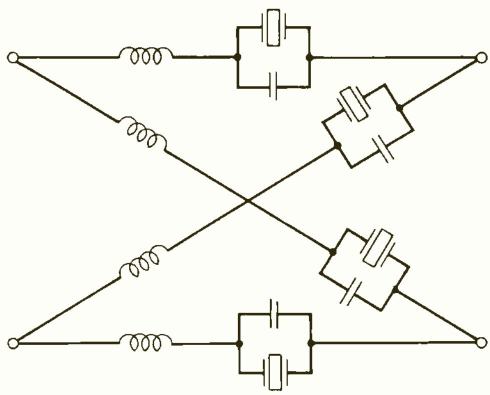


Fig. 1—Theoretical schematic for one section of the channel crystal filters

all system which, it is assumed, may comprise as many as five links, or a total of ten channel filters in series. In determining limits, the different interfering frequencies are weighted in accordance with their relative interfering effect, and the interference may be rated in terms of either crosstalk or noise. To meet acceptable limits, it was necessary that the losses

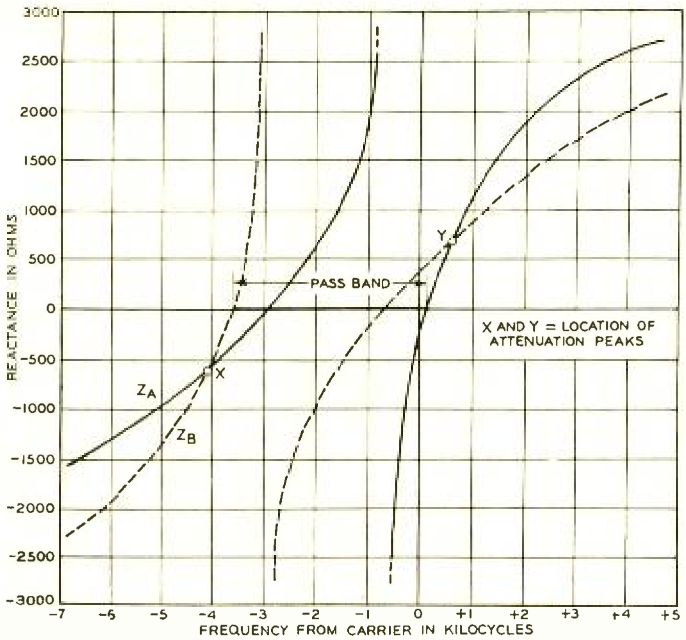


Fig. 2—Impedance characteristics for the two arms of one section of a channel crystal filter

of the channel filters at frequencies more than 600 cycles above the carrier be of the order of 60 to 70 db greater than the loss within the pass band. Similarly, for frequencies more than 4000 cycles below the carrier, losses of 50 to 60 db greater than the loss in the pass band were required. With these restrictions, it was desired to make the pass band as wide as possible, which means that the sides of the attenuation-frequency characteristic of the filter must be very steep. Such a characteristic could be most readily obtained by the use of crystal filters. The frequency range from 60 to 108 kc, which is favorable to the use of crystal filters, was selected for the 12-channel terminal unit.

As a result of these and other requirements, it was decided to use two sections of the lattice type for each filter—the theoretical arrangement of elements for each section being as shown in Figure 1. The impedance characteristics of the series and shunt arms of such a filter section are shown in Figure 2. The pass band of a lattice section is the frequency range over which the impedances of the two arms differ in sign. In the figure this is indicated by the heavy line along the axis of zero reactance. Attenuation peaks occur where the impedances of the two arms are equal. This type of network permits the location of two attenuation peaks per section, and, as shown in Figure 2, one of them is placed just below the pass band and the other just above it. Also, the theoretical attenuation is made to approach an infinite value at infinite frequency, which permits a simplification in the filter circuit. At infinite frequency, since the reactance of a condenser is zero, the inductances of the two arms must be equal to make their impedances equal. This permits the inductance to be cut in half by placing the coils outside the lattice, as shown in Figure 3. Also part of the capacitance shunting the crystals may now be placed in shunt outside the lattice.

The impedance of the filter was selected from a consideration of desirable constants for the coils and crystals rather than of the impedance of the associated circuits. The coil and crystal inductances vary directly with the mid-band impedance of the filter. The inductance of a crystal, however, varies with its thickness, which for mechanical reasons cannot be made too small. To obtain optimum inductance values for the coils, the filter impedance should be about 300 ohms, while to obtain the most

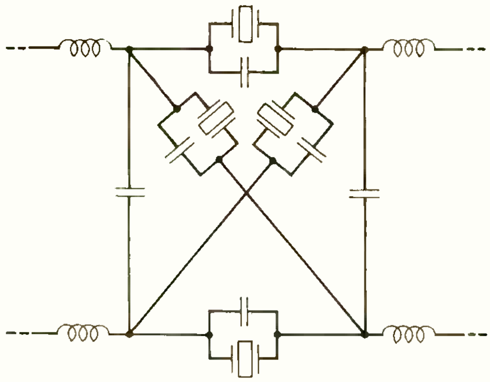


Fig. 3—Since the inductances of the two arms are equal, they may be combined to form a single inductance in series with each side of the network

desirable crystal thickness, the impedance should be 1500 ohms. The value of 800 ohms was selected as a satisfactory compromise for the mid-band impedance of ten of the filters. The impedance for the two lowest-frequency filters had to be made somewhat higher to secure adequate thickness for the larger crystals. The line-end impedance of these two filters is stepped down to the same value as the other ten by a modification of the elements external to the lattice, and by the addition to the circuit of a shunting condenser.

The greater portion of the loss over the pass band of the filter is caused by the dissipation of the coils; and since the inductances of all coils are made the same to secure the same impedance level, the coils should all have the same effective resistance to obtain the same loss in all filters. The lowest resistance possible, therefore, will be determined by the lowest resistance value that can be obtained for the coils of the highest-frequency filter, which is 100 ohms.

The impedance-frequency characteristic of the filter is given in Figure 4, which shows the 800-ohm impedance at the middle of the pass band. The filter is operated between 600-ohm terminations, but the 100-ohm resistance of the end coils adds effectively to the terminations, and thus raises the value of the impedances between which the filter operates to 700 ohms. There is thus an impedance match at each side of the mid-band frequency, and at no point in the useful band is there a large mismatch in impedance. The small reflection losses due to mismatch at the mid-band frequencies tend to equalize the losses over the pass band.

A shunting resistance has been connected between the two sections of the filter to form with the resistance

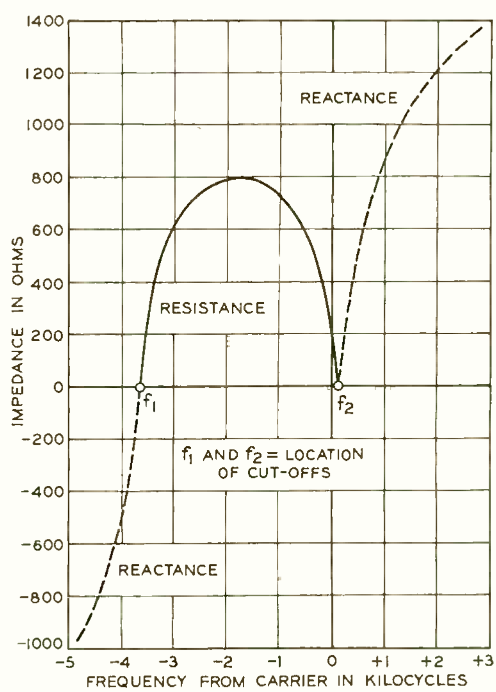


Fig. 4—Impedance-frequency characteristic of the channel crystal filter

components of the two adjacent coils a resistance pad to match the impedance of the two sections. These coil resistances produce a loss which is substantially constant over the entire pass band of the filter. By varying the size of the shunt resistance, the loss level is adjusted over a small range to obtain the same loss in each filter. The complete filter schematic incorporating this intersection coupling pad is shown in Figure 5.

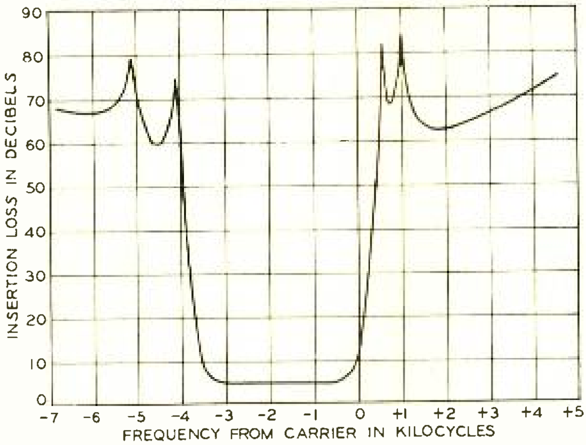


Fig. 6—Representative insertion loss-frequency characteristic for the channel crystal filters

Since twelve of these filters are connected in parallel on the line side, their individual impedance characteristics at both sides of the pass band should rise rapidly so that very little shunting effect will result to frequencies of the other channels. From Figure 4 it may be seen that above the upper cut-off point the impedance is a positive reactance, and below the lower cut-off point it is a negative reactance. Twelve such impedances are connected in parallel on the line side. Over the pass band of each intermediate filter there are in shunt both positive and negative reactances of about equal values —the former being due to the lower-frequency filters and the latter to the higher. This results in a condition approaching anti-resonance, so that no appreciable shunting effect exists. This is not true, of course, for the lowest and highest-frequency filters, but by the provision of a network designed to compensate for this lack of reactance balance at the two ends of the group, the situation is corrected. In this way the transmission quality of the whole group of filters is maintained uniform.

A representative insertion-loss-frequency characteristic of these filters is shown in Figure 6. On the basis of a 10 db cut-off as compared with 1000-cycle transmission, the voice-frequency band for a single carrier link—including two filters with their associated modulator and demodulator—extends approximately from 150 to 3550 cycles. For five links, the band extends from about 200 to 3350 cycles, being narrowed somewhat by the presence of a number of filters in series in the circuit.

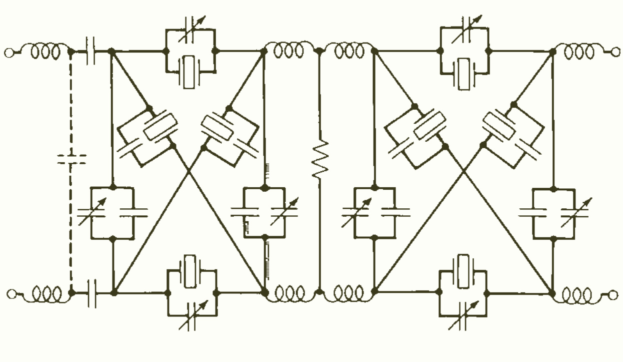
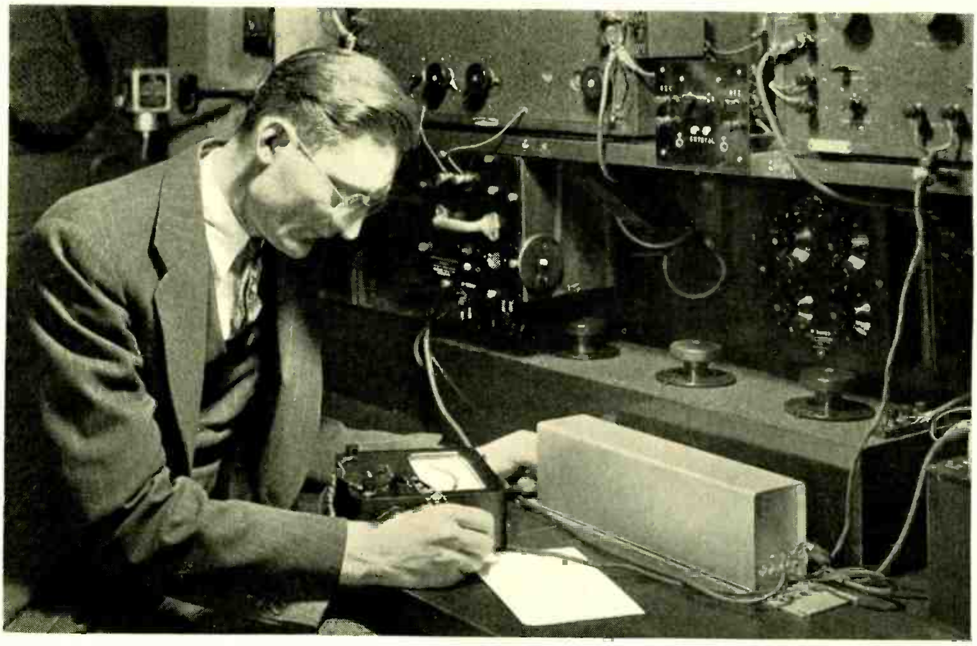


Fig. 5—Schematic for the two-section channel crystal filters—the dotted line refers to a condenser used only in the two lowest-frequency filters



Channel Crystal Filters for Broad-Band Carrier Systems: Physical Features

By A. W. ZIEGLER
Filter Development

FROM the outside, the channel filters for the new broad-band carrier systems do not appear unusual. The rectangular metal box about 14½ inches long, 3¼ high, and 4½ deep, which encloses the filter, gives no indication of the extended development that has gone into its creation. This metal box is colloquially known as a "can," and in this application the name is particularly apt, since the filter is literally canned to preserve it in a stable state for a long period of time. The can itself is a seamless tube, and is soldered to two flanged end plates. Through one of these plates, the five leads, one of which is a ground connection, are brought through copper-glass seals, with the result that the entire filter is in a hermetically tight compartment. Regardless of atmospheric conditions, no moisture can enter this compartment, and the relative humidity inside remains low—varying only over a narrow range as the temperature changes.

The arrangement of the filter elements inside the can follows closely their arrangement in the schematic, given as Figure 5 of the immediately preceding article. Each section of the filter has a pair of coils at each end, each pair being wound on a single annular core of compressed molybdenum-permalloy powder. Each coil is potted in a drawn copper container, and the containers for the two middle coils furnish the necessary shielding between filter sections. Between the end coils of each section, supported on a common base, are the crystals and the condensers. This base is made of a high-grade ceramic that gives low leakage between condenser terminals. All the apparatus is securely fastened by rivets to two strips of angle brass which, in turn, are fastened to the two end plates. The appearance of a filter before the can is put on is shown in Figure 1.

Each section of the filter has two quartz plates coated with a thin layer of aluminum to form the contact surfaces. On each side of the crystal plate this coating is divided into two parts so that each becomes electrically two plates vibrating in unison. One plate thus provides the crystals for the two series arms of each section, and the other, for the two lattice arms. As a result, for both filter sections, a total of four plates are made to take the place of eight.

Each section also requires four fixed and four adjustable condensers. The former consist of glass tubes plated inside and out with silver. Two of these are the long black cylinders projecting from the front side of the chassis, and the other two are the shorter cylinders projecting from the rear. The adjustable condensers are of the air type, and may be seen beneath the crystal mountings in the lower part of Figure 1. Besides these condensers there are two high-grade mica condensers located at one end of the rear side of the chassis. These are the condensers shown in the schematic on each side of the filter at one end. Also on the rear of the chassis near the middle are six resistance units that form the matching pad between the two sections of the filter. The number of these units employed varies with the filter. In general they comprise a series resistance on each side and on each end of a shunt resistance grounded at its middle point, although in the schematic only one resistor is shown.

These filters must not only meet their distortion and discrimination requirements initially, but must remain stable with time and with variations in temperature and relative humidity. This stability is achieved by designing every element to maintain its characteristics for the entire range of temperatures found in the central offices, while variations in relative humidity have been greatly reduced by drying and hermetically sealing the filters. The amount of water vapor liberated by the component parts after the filter has been sealed is quite small, and the relative humidity will not exceed 40% even at the lowest anticipated temperature of 55° F. Hermetic sealing proved a great aid in solving the problem of stability, but it required the development of a new means for bringing wires from inside the filter to external terminals, which would not break the seal. This was done by the design of a special copper-glass seal terminal illustrated in Figure 2. It comprises an elongated copper tube closed by a glass bead and seal wire at one end and a ceramic bushing with terminal at the other end. This type of terminal is finding extensive use in other telephone applications besides filters.

To achieve stability in the coils, a special alloy is added to the molybdenum-permalloy constituents of the core so that the final composition gives a characteristic well-nigh independent of temperature, in the operating range. Since the capacitance be-

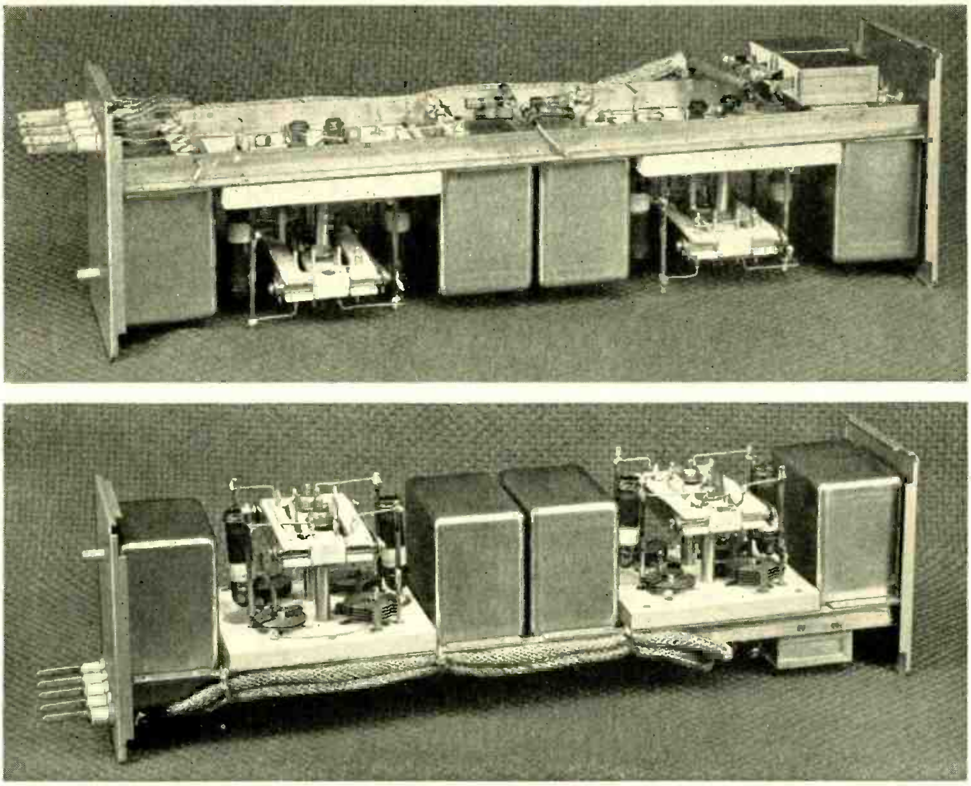


Fig. 1—A channel filter before being sealed in its can. The lower view shows the four adjustable condensers and two of the fixed condensers for each section

tween windings and the core of these coils, as well as the capacitance between the windings and container, has an appreciable effect upon the filter performance, the windings are designed not only to make these capacitances a minimum but to keep them stable with time and temperature. The windings of some of the coils for the higher-frequency filters are made of finely stranded wire to secure high reactance-resistance ratios, or Q's. The glass of the glass-tube condensers has a very small coefficient or expansion so that condensers made from it have temperature coefficients comparable with those of the retardation coils.

The inherent high ratio of reactance to resistance of the quartz crystal secures the desired abrupt discrimination between wanted and unwanted frequencies. Once adjusted, this characteristic must be maintained throughout the service life of the filter. Crystalline quartz possesses the necessary stable properties to satisfy these requirements, so that aging is a negligible factor. The temperature coefficient of the crystal plates designed for the channel filters is only about twenty-five parts per million per degree Centigrade.

The development of a means of holding these crystals constitutes an important chapter in the development of the channel filter. Such a crystal mounting is required to serve the dual purpose of providing four electrical contacts with each of two

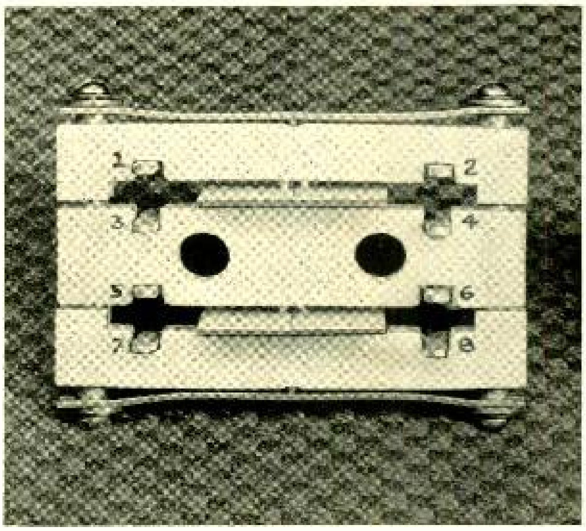


Fig. 3—The quartz-crystal mountings are designed to equalize the pressure on the four crystal contacts and to assure this coaxial alignment

quartz plates and of supporting each of these plates so that mechanical jar cannot dislodge them. The engaging of the contacts with the crystal plate must not reduce the plate's "Q" below 10,000; and the pressure of the contacts necessary for mechanical stability must not appreciably change the resonance frequency of the plate. Figure 3 shows the type of mounting developed for these filters.

Observation with a strain analyzer has shown the importance of making the adjacent pairs of contact points coplanar to avoid excessive strains within the crystal and consequently a lower "Q." For the same reason, it is essential that the opposing pairs of contact points be coaxial to avoid bending stresses. The three-piece mounting shown in the illustration is designed to maintain permanently the initial alignment of these contact points. The unit stress upon the crystal surface at the contact points is determined by the tension of the fixed springs seen at the top and bottom of the mounting and by the area of the contacts engaging the surface. With a given spring tension, minimum crystal strain and maximum mechanical stability are obtained when the pressure is equally divided between adjacent contact points. This is accomplished by means of the pressure-centering roller seen under the midpoint of each spring. The action of this roller may be visualized by assuming one contact point of an adjacent pair to be longer than the other. This longer point will act as a pivot around which the movable member of the mounting will rotate. This will cause a sliding action between the spring and the top of this movable member. The roller operating between these surfaces prevents the friction that otherwise would prevent pressure equalization. The ceramic used for the body of the crystal mounting secures high electrical insulation between each of the contact points.

The channel crystal filter as finally constructed is unaffected by mechanical shock

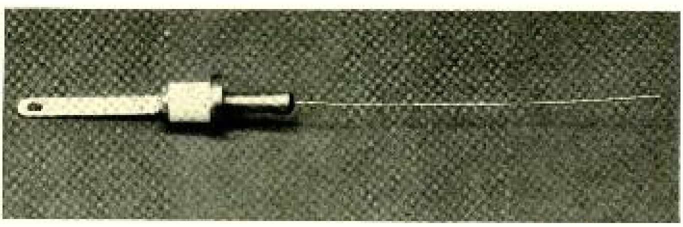


Fig. 2—Copper-glass lead-in seals are provided for the channel filters to prevent moisture from entering the assembly

such as normally attends shipping and handling. The quartz-crystal plates are protected by resilient cushions that separate the crystal mountings from the metal supporting rods. The crystals are also well protected against electrical shock, which might result from the application of excessive voltage. Although approximately twenty volts may be considered a maximum safe line voltage to apply to filter terminals, not more than one or two volts will be applied to the filter when operating in broad-band carrier systems. Because of the features described, these channel filters represent a very important advance not only in precision of design and stability, but in compactness and simplicity of arrangement.

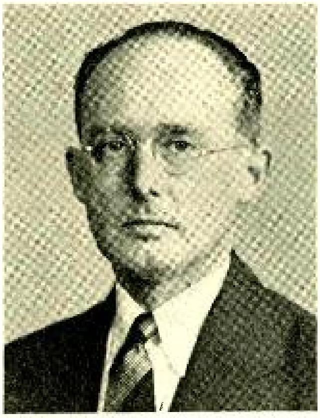
Contributors to this Issue

C. B. Green received a B.A. degree from Ohio State University in 1927 and an M.A. in physics the following year. He then joined the Technical Staff of the Laboratories, and for several years engaged in transmission research on carrier systems and on terminal equipment for telephotograph systems. Since 1934 he has been engaged in developing transmitting vacuum tubes, particularly those of the multi-grid type.

C. V. Taplin graduated from the University of Vermont in 1916 with a B.S. degree in Electrical Engineering. After a year with the General Electric Company and two years as an instructor at the University of Vermont, he joined the Department of Development and Research of the American Telephone and Telegraph Company and transferred to the Laboratories in 1934. Since joining the Bell System he has been concerned principally with the development of testing equipment and maintenance methods for panel and crossbar central offices.

S. Doba, Jr., joined the Laboratories in 1926, and for a brief time was engaged in low-frequency telegraph studies. For the past ten years, however, his work has been with the Research Department in connection with voice-operated devices. These include vogads and compandors for radio telephone circuits and echo suppressors for long toll systems.

C. B. Green



C. V. Taplin

S. Doba, Jr.

R. A. Shetzline *A. E. Dietz* *E. F. Watson*

R. A. Shetzline received a B.S. degree from the University of Pennsylvania in 1915 and a B.S. in E.E. from the same University in 1917. He joined the Engineering Department of the American Telephone and Telegraph Company in December, 1917, and began making coördination studies between electrified railways, power transmission lines and telephone systems. From 1924 to 1929 he was in charge, for the Bell System, of a coöperative field study with the National Electric Light Association of power and telephone circuit coördination. Since 1929, he has been in charge of a group of engineers, in the Transmission Development Department, responsible for studies of telephone apparatus from a noise and crosstalk standpoint including the evaluation of noise and crosstalk effects and the establishment of suitable standards.

A. E. Dietz joined the Engineering Department of the Western Electric Company in 1920. As technical assistant he was associated with the protection development group until 1926, when he left to attend Columbia University, returning to the Laboratories for the summers. In 1929 he received from Columbia the A.B. degree in physics and mathematics, and at once returned to the Laboratories. The next four years he spent with the protection development group, and then transferred to the magnetic materials group. Here he engaged in the testing of magnetic materials and in preparing specifications for commercial manufacture. In 1937 he returned to the protection development group where he has since been concerned with the development and testing of protection apparatus.

E. F. Watson joined the Engineering Department of the American Telephone and Telegraph Company in August, 1914, after receiving the degree of M.E. from Cornell University. He had an active part in the early tests and the first service trials of teletypewriters both in handling official company business and in news distribution by the press associations. Later, as a member of the equipment division of the Department of Development and Research, he was engaged for a number of years in the development of various types of telegraph equipment, particularly teletypewriters, telephotograph systems, telegraph maintenance and testing equipment, grounded telegraph systems and regenerative telegraph repeaters. Since the transfer of the Department of Development and Research to the Laboratories in 1934, he has continued the same type of work as Teletypewriter Engineer of the Telegraph Facilities Department.

E. S. Willis received an M.A. degree from the University of Missouri in 1927 and immediately joined the Technical

E. S. Willis

J. O. Israel

A. W. Ziegler

Staff of the Laboratories. Since then he has been engaged in the development of various types of transmission networks, such as electric wave filters and equalizers. Since the first use of quartz crystals as circuit elements, he has been concerned with their application to various types of filter circuits and has also developed methods of adjusting and testing such circuits. Recently, he has been engaged chiefly with problems associated with the channel crystal filters for broad-band systems.

J. O. Israel received the degree of B.S. in Electrical Engineering from Lafayette College in 1927, and spent the following year doing graduate work at Yale University, for which he received the master's degree in 1930. He joined the Laboratories in 1928, and has since been engaged in the development of filters and networks, principally for single-channel carrier telephone systems.

A. W. Ziegler left the University of Illinois in 1918 to serve in the Naval Air Corps, returning to receive his B.S. degree in 1921. Following his graduation, he joined the Engineering Department of the Western Electric Company and became one of the earlier designers of tungsten switchboard lamps, vacuum thermocouples and ballast resistors. Later he became engaged in the design of filters and networks for voice-frequency and power-line carrier circuits. For the last few years, he has been engaged in the development of crystal filters, particularly in the design of crystal mountings and hermetically sealed types that are used extensively in filter assemblies.