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the Lenkurt® Demodulator

SIGNALING
over telephone trunks

LENKURT ELECTRIC ... specialists in VOICE, VIDEO & DATA transmission

Signaling provides the means for operating and supervising a telephone communications system; it establishes connections, announces incoming calls, reports the fact that a line is busy. The functions of signaling are indeed most vital to the basic operation of the telephone plant.

Trunk signaling involves many considerations that are quite different from the basic techniques employed in signaling over a subscriber loop. This article reviews some of these considerations and describes the major techniques used to transmit signaling information over physical and carrier-derived trunk circuits.

Without signaling, a telephone system cannot operate. Even the simplest system, such as two local battery telephones connected by field wire, requires some means for the users to attract one another's attention when they want to talk. In early telephone systems, users simply cranked a hand magneto which caused a bell to ring at the subscriber station or a flag to drop at a switchboard. Over the years, signaling systems have had to keep pace with the advances made in telephone switching and transmission systems. The increasing complexity of the worldwide telephone plant has had a tremendous influence on the evolution of signaling techniques, from the simple hand cranked magneto to the many techniques employed today.

Many different signaling methods have evolved during the transition from one type of switching office or transmission system to another. Today's telephone plant includes various types of local exchange and toll switching offices, such as manual, step-by-step, panel, crossbar, and the modern electronic switching offices. In addition, there are many types of open-wire, cable and microwave radio transmission systems interconnecting the various switching offices.

Signaling Functions

There are a multitude of signaling functions that must be transmitted between the various manual and dial switching offices. These include functions whereby people must communicate with machines, machines must communicate with other machines, and machines must communicate with people.

The major functions can be somewhat arbitrarily classified as *ringing, supervisory,* and *address* (or dialing). Ringing signals are used to operate a visible or audible alarm to alert someone of an incoming call. Supervisory signals are used to convey information regarding switchhook conditions (on-hook or off-hook) at either end of a telephone circuit. Address signals convey dialing or digital information which is necessary to establish the desired connection.

In subscriber loops, supervisory and address signals are accomplished by means of direct current, while alternating current is used for ringing. Direct current signaling is also used on short-haul trunks between switching offices. However, such methods are not adequate for signaling on longer trunks, such as inter-toll, or on trunks derived from carrier or multiplex systems. As a result, various alternating current signaling systems have been developed for use over long-haul v-f and carrier-derived trunks.

Ringdown Trunks

In certain trunks, especially those interconnecting manual offices, it is necessary to transmit a ringing current to signal the switchboard operators. This type of signaling is known as *ringdown.* The ringing alternating current used in subscriber loops is at a frequency of 20 Hz. This same frequency is also used in certain short-haul trunks. On trunks equipped with composite telegraph, 20-Hz ringing cannot be used because of interference. In these circuits, a signaling frequency of 135 Hz is used. Neither of these frequencies, however, is suitable for long trunks because voice-frequency repeaters cannot pass them. Consequently, a 1000-Hz signaling tone, well within the v-f amplifier passband, has been adopted for use on longer circuits. To prevent voice signals from falsely operating the signaling equipment, the 1000-Hz tone is interrupted (modulated) at a 20-Hz rate.

Address Signals

Probably the most important and the most complicated signaling function is address or dialing. This function directs the operation of the switching equipment in the automatic offices. Consequently, the evolution of the various switching systems has brought about changes in address signaling techniques. Address signals originate at the telephone dial and consist of a train of dc pulses corresponding to the number dialed. Modern "touch calling" systems, which use keys or pushbuttons instead of a dial, employ tones at different frequencies rather than dc pulses.

In the step-by-step systems, the switching equipment responds directly to the dc pulses. However, in panel and crossbar systems, the switches cannot be controlled directly by the dial pulses. Consequently, these systems require a device known as a *sender* which stores the dial pulses and then controls the movement of the switches.

There are four basic methods commonly used to transmit address or dialing signals for use by the various switching offices. These are known as *dial pulsing, revertive pulsing, panel call indicator (PCI) pulsing,* and *multifrequency (MF) pulsing.*

Dial pulsing is the earliest and most commonly used method of transmitting address information — the numerical value of each digit is represented by the number of pulses in a train (ten pulses

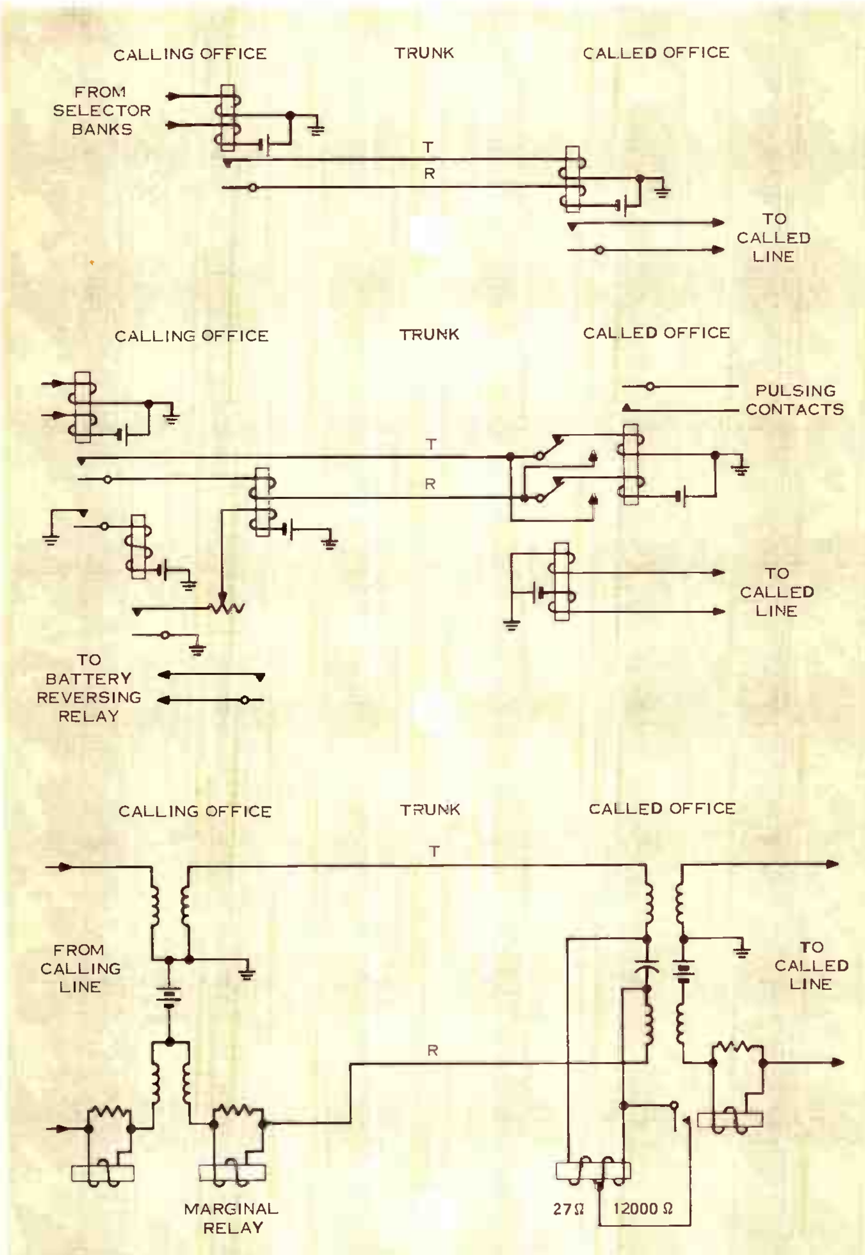

Figure 1. Loop signaling is accomplished by altering the flow of current in the trunk conductors. Three methods used to accomplish loop signaling are: (A) wet-dry, *(B)* reverse battery, *and (C)* high-low.

represents 0). Dial pulsing is used in all types of switching offices.

Revertive pulsing was originally developed for use in panel switching offices. In this type of pulsing, the address pulses are not transmitted by the originating office. When a call is made, a loop to the distant office is closed. This starts the movement of a panel selector switch at the distant office. As the selecting wipers pass each terminal, a commutator transmits pulses back to the sender at the originating office. When the proper number of these *revertive* pulses, corresponding to the called number, are received by the sender, a signal is sent back to the distant end to stop the movement of the selector. Revertive pulsing is used in certain crossbar offices as well as panel offices.

Panel call indicator (PCI) pulsing is a method of transmitting address signals between a dial office and a manual office. This technique converts pulses received from a dial office to lamp indications which appear on a switchboard. The switchboard operator then connects the incoming call to the called number and rings the subscriber.

Multifrequency (MF) pulsing is the newest method of transmitting address pulses between switching offices. Digital information is transmitted in the form of short tone bursts. Six signaling frequencies are used, each digit being represented by a combination of two of the six frequencies. The signaling frequencies fall within the speech band and are simply processed through the trunk in the same manner as speech signals. (A different form of multifrequency pulsing has recently been introduced to subscriber loop circuits through the use of telephones with pushbuttons instead of the conventional dial.)

Historically, signaling systems designed to transmit supervisory and address information have evolved from simple dc systems operating over 2-wire short-haul interoffice trunks, to complicated ac systems operating over multichannel carrier and microwave transmission systems. Today, there are essentially two fundamental techniques used to derive signaling paths on trunk circuits. The first of these is known as *loop signaling*. This technique requires a dc loop, and is the method used in all subscriber loops and in most short-haul 2-wire trunks. The second signaling technique, known as *E & M*, is used with both ac and dc signaling systems on 2-wire or 4-wire physical trunk circuits, and on carrier-derived trunk circuits. This type of signaling is standard for use in all intertoll trunks.

Loop Signaling

Loop signaling is the simplest of the two, and is used in certain exchange trunks, short-haul toll-connecting trunks, and one-way dialing toll trunks, where 2-wire voice-frequency circuits are employed. The dc signaling current flows over the same conductors used for voice transmission.

This type of signaling is accomplished by simply interrupting the condition of a dc voltage applied to the line to transmit both supervisory signals and dialing information. The range of loop signaling is usually limited to about 25 miles because of the dc resistance of the conductors.

There are three methods currently used to apply loop signaling to a 2-wire voice-frequency trunk: *wet-dry, reverse battery,* and *high-low.* (See Figure 1.)

In the wet-dry method, signaling information is indicated by the presence (wet) or absence (dry) of a battery and ground condition on the line at the called end of the trunk. Normally in the wet condition, the battery is placed on the ring conductor and ground on the tip conductor.

As its name implies, reverse-battery loop signaling is accomplished by reversing the polarity of the battery on the line to indicate supervisory conditions. For one condition, battery is on the ring conductor and ground on the tip conductor. The opposite supervisory condition is indicated by reversing the polarity of the battery, thus causing a polar relay to operate or release at the distant end of the trunk. This is the most prominent type of loop signaling used between exchange offices. To increase the operating range of reverse-battery loop signaling, batteries are sometimes placed at both ends of the circuit, in series. This variation of reverse-battery operation is called *battery and ground* signaling.

The third method, high-low, is used principally for supervisory signaling within a central office or from an automatic to a manual office. This type of signaling employs a marginal relay. During on-hook condition, a high resistance is placed in the loop. For off-hook, the resistance in the loop is reduced to a low value allowing more current to flow, and thereby causing the marginal relay to operate.

E & M Signaling

As mentioned previously, loop signaling is limited to trunks of about 25 miles in length. Also, such systems do not provide simultaneous signaling in both directions. In order to overcome these limitations, and especially to extend the dialing range of telephones, another type of signaling was developed.

This method of signaling employs two leads to connect the signaling equipment to the trunk circuit. These two leads are designated E and M, respectively. The name for the two leads was probably acquired from designations appearing in early drawings for this type of signaling circuit. The M lead transmits battery or ground signals to the distant end of the circuits, while incoming signals are received on the E lead as either a ground or open condition. Thus, the M lead reflects conditions at the near end of the circuit while the E lead reflects conditions at the far end.

There are several methods of deriving an E and M circuit to permit signaling between offices on a dc basis. These arrangements are known as simplex (SX), composite (CX), and duplex (DX). A simplex signaling circuit is obtained by means of a center-tap coil placed at both ends of the voice-frequency trunk circuit, as shown in Figure 2A. Signaling currents flow in both directions through the coils and, therefore, do not induce any interfering voltages into the voice channel. Conversely, voice currents do not flow through the simplex conductors (or legs) extending from the center tap of the coils. Since the two trunk conductors provide a parallel path for the signaling current, the dc resistance is approximately one-fourth of that presented to a loop-signaling arrangement over the same trunk. Thus, the dc signaling range is extended considerably. However, simplexing has certain disadvantages and has been largely superseded by the duplex arrangement.

In the composite method, a filter is used at each end of the trunk to separate the signaling current from the speech signals. The filter is called a *composite set*. Two composite signaling paths can be obtained from the two conductors of a v-f trunk and four can be obtained from a phantom circuit arrangement. This type of signaling, shown in Figure 2B, is used typically

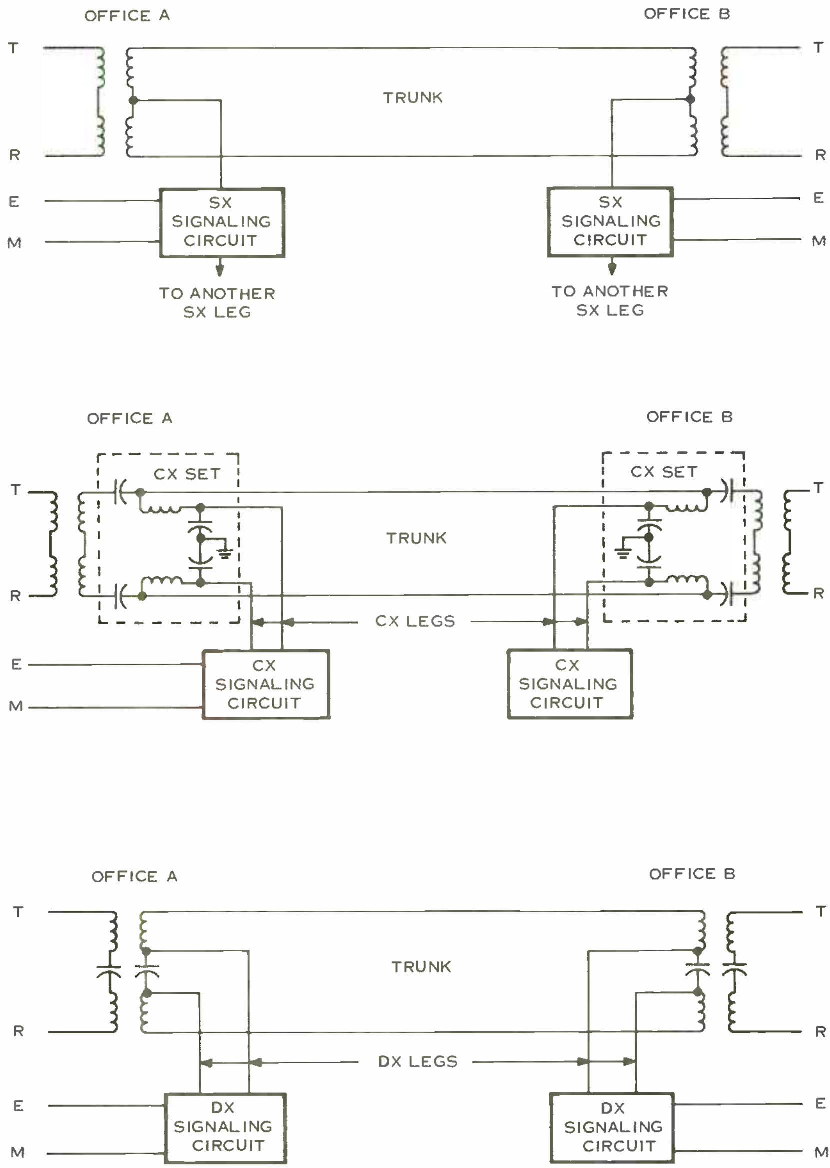

Figure 2. There are a number of different circuit arrangements designed for E & M signaling over telephone trunks. The three most prominent d-c arrangements are: (A) simplex. *(B)* composite. *and (C)* duplex.

on trunks derived from quadded cable where the conductors are arranged in phantom groups.

The duplex signaling arrangement, like the composite method, uses one conductor of the v-f circuit for signaling on a ground return basis, and the other conductor for ground potential compensation. Ground potential compensation is required because of the inherent instability of ground-return circuits. The composite set or filter, however, is not used with the duplex circuit. Instead, the signaling circuit is connected to the trunk pairs by means of a center-tap transformer and a capacitor, as shown in Figure 2C. This signaling arrangement is used primarily in paired cable trunks.

AC Signaling

The dc signaling systems described thus far are limited to relatively short v-f trunks containing a dc path. These systems are not suitable for use on long v-f trunks employing repeaters, or for carrier or multiplex trunk circuits because a dc path is not available. As a result, ac signaling systems had to be developed for use over the more modern exchange trunks and on the longer toll-connecting and intertoll trunks, especially where carrier is used.

The ac signaling systems use frequencies within the voice-frequency range so that the signals can be transmitted directly over the same path used for voice transmission. These ac systems usually employ E and M leads to connect the signaling circuit to the trunk. If the signaling frequency falls within the band used for speech transmission (typically 300 to 3400 Hz) the system is referred to as an *in-band* system. If the signaling frequency falls outside the speech band, the system is called an *out-of-band* system.

The ac systems must process the dc supervisory and address signals received from the switching office and convert them into ac signals for transmission over the trunk circuit. At the other end of the trunk, the ac signals must be converted back to dc signals before being applied to the switching equipment. Only one signaling frequency is required on 4-wire trunks. However, on 2-wire trunks two frequencies are required, one for each direction of transmission.

Early ac signaling systems used a frequency of 1600 hertz. On 2-wire trunks, 1600 hertz was used for one direction and 2000 hertz for the opposite direction. Later in-band systems used a frequency of 2600 hertz, with a second frequency of 2400 hertz for use with 2-wire trunks. The ac signaling frequencies easily pass through the same path used for voice transmission, and are amplified in repeaters in the same manner as speech signals. These so-called single-frequency (SF) signaling systems are used to transmit both supervisory signals and address or dial pulses. Multifrequency (MF) address pulsing, described previously, uses tones that are already in the voice band, so they do not require additional processing before being transmitted over a long-haul or carrier-derived trunk.

Signaling Over Carrier Channels

All trunk circuits equipped with carrier or multiplex equipment require some type of ac system for signaling. There are many different carrier signaling systems in use today employing either an in-band or out-of-band signaling frequency.

The most prevalent type of carrier signaling is accomplished with in-band frequencies. In-band signaling systems

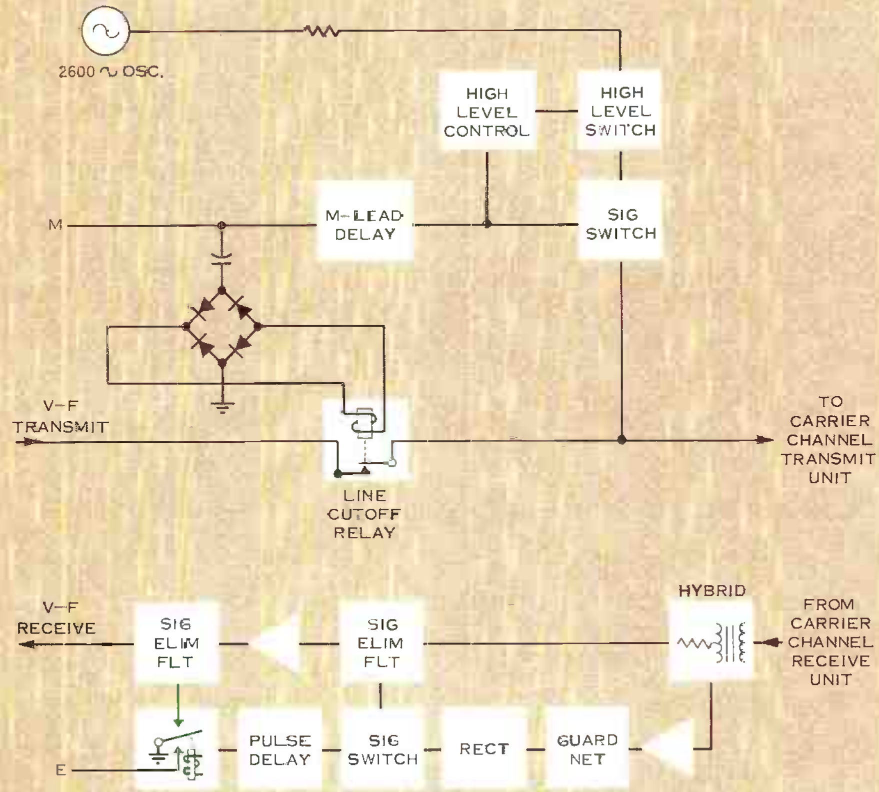

Figure 3. Simplified block diagram of a 2600-hz in-band signaling circuit applied to transmit channel and receive channel of a carrier system.

have an advantage over out-of-band systems in that they do not require extra bandwidth — the signals are passed directly through the voice channel. Another advantage is that signaling equipment is required only at the terminal stations of a trunk made up of several tandem links. Also, the in-band signaling system can be made a part of the office switching equipment rather than the particular carrier system, thus making it easier to patch trunk circuits to different carrier transmission systems.

The main disadvantage to in-band systems is that the signaling tones lie within the speech band. This leads to the possibility of speech energy at the signaling frequency "talking down" the signaling; that is, falsely operating the signaling equipment with speech energy. Protection against "talkdown" can be accomplished by using a time delay or guard circuit in the signaling system. By introducing a delay, the signaling circuit can be made insensitive to most voice energy or transient noise at the signaling frequency.

Additional protection is obtained by properly selecting the in-band signaling frequencies. Generally, it is desirable to use the highest possible frequency that will pass through the voice channel. Speech energy declines rapidly at the higher frequencies, thereby reducing the chances of "talkdown".

Most of the older voice-frequency telephone circuits use filters with an upper frequency cutoff of about 2800 hertz. For this reason, the most commonly used frequency for SF in-band supervisory and address signaling is 2600 hertz. In-band carrier signaling systems can be adapted for use with either loop signaling or E & M signaling arrangements.

Following the development of economical short-haul carrier systems, the need arose for inexpensive methods of signaling. This need resulted in the development of various out-of-band signaling systems. Out-of-band signaling equipment is generally less expensive than in-band equipment and also permits signaling during speech transmission, thus permitting extra functions such as regulation to be performed. Since the signaling frequency is outside of the speech band, there is no need for

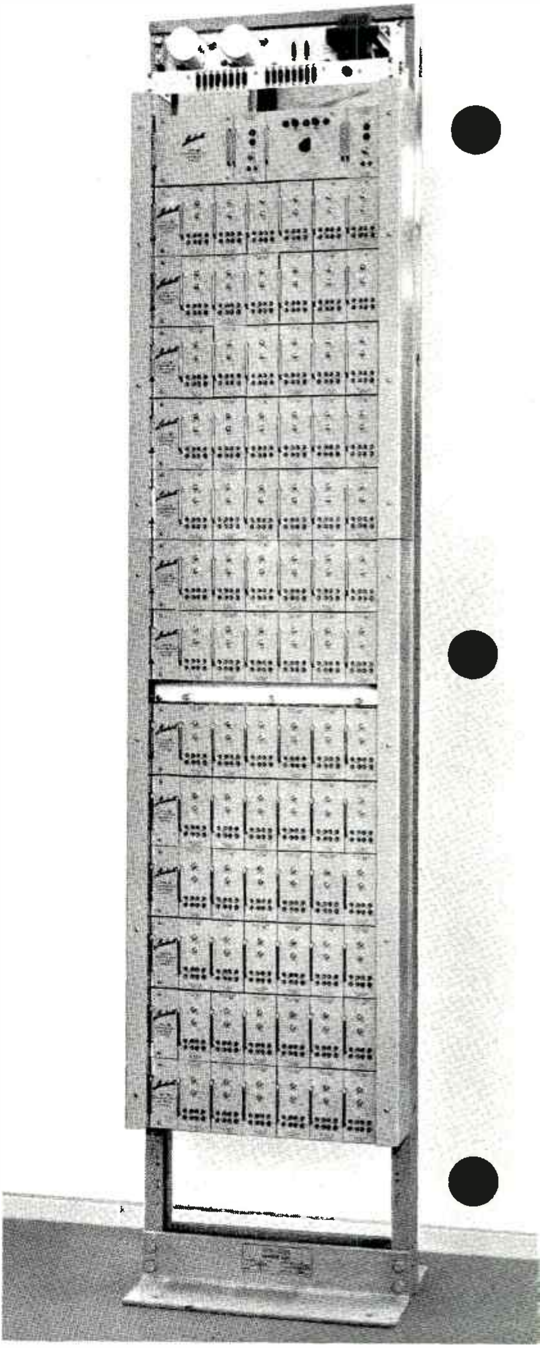

Figure 4. Photograph of typical in-band signaling units used with carrier systems. One signaling unit is required for each carrier channel. Many types of signaling units are required to accommodate the many different methods of signaling.

complicated guard circuits to prevent talkdown.

With out-of-band signaling, voice channel filters are designed with an upper cutoff frequency well below the top edge of the channel. This leaves the top portion of the channel passband available for transmitting out-of-band signaling tones. The most prevalent frequencies used for out-of-band signaling are 3700 hertz, which is standard throughout the Bell System, and 3825 hertz, which is recommended by the International Telegraph and Telephone Consultative Committee (CCITT) for use in international circuits.

Unfortunately, out-of-band signaling has certain disadvantages which tend to limit its use. Out-of-band signaling equipment has to be built-in to the carrier channel equipment and cannot be separated as in the case of in-band signaling equipment. This condition prevents randomly patching the circuit to other trunks.

Also, out-of-band signaling requires some sort of dc repeater at the end of each link of a multi-link trunk. As the signal passes from one link to another, the signal pulses must be detected and then made to operate a relay. The relay, in turn, keys the signaling equipment in the succeeding link. Thus, signaling equipment is required at both ends of each link in the trunk.

Another economical type of signaling, using time division multiplexing techniques, is used in Lenkurt's 81A exchange trunk carrier system. This unique method provides signaling for all 24 voice channels of the system using one common signaling channel. Each voice channel is assigned a specific time slot for signaling, and all 24 slots are scanned 500 times per second. The resulting signaling frequency modulates a pilot in the carrier system that is also used for slope regulation.

Although out-of-band and time division multiplex signaling techniques may be more economical for certain short-haul trunks, they lack the flexibility and other advantages offered by in-band signaling systems, especially when applied to long-haul trunks. As a result, single-frequency (SF) in-band signaling for supervisory functions and multifrequency (MF) pulsing for address functions have become the standard methods of signaling in modern interoffice, toll-connecting, and intertoll trunks.

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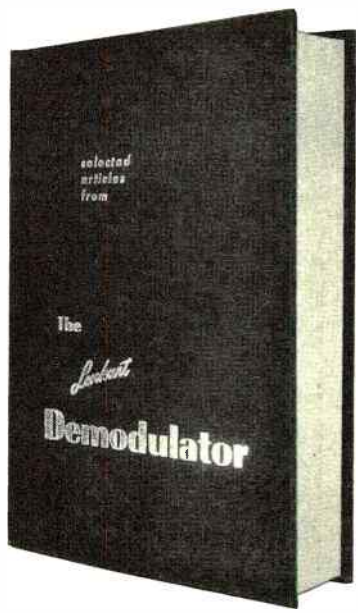

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