GTE LENKURT

DEMODULATOR

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WORLD-WIDE E&M SIGNALING PARTS 1&2

The rapid growth of intercontinental telephone traffic, coupled with competition among the world's equipment suppliers to provide telephone systems to developing nations, has helped to emphasize the differences which exist in signaling techniques. Many of the problems have been resolved by establishing signaling criteria, yet there remains much misunderstanding regarding signaling interface compatibility, especially interfaces that use E & M leads.

PART 1

As soon as the handset of a subscriber's telephone is removed from its cradle, the signaling process begins, with the telephone instrument transmitting a signal toward the central office which indicates to the switching equipment that a call is to be placed. In normal circumstances, the subscriber receives a tone from the central office indicating that dialing can begin. Once dialing is complete, the signaling equipment at the terminating office will indicate, by returning signals, whether the called number is busy or ringing. In some cases, the caller receives a signal indicating that all trunks are busy. (For a more complete discussion, see the *GTE Lenkurt Demodulator* for July 1974.) Thus, signaling circuits serve as interfaces between switching systems; they must, therefore, use a common "language," or set of signals, for a call to be completed. In the United States alone, five different "languages" are used for numerical signaling to allow various types of switching equipment to communicate. On the international and intercontinental levels, the situation becomes even more complex, although the basic functions of making (seizure or connect) and breaking (release or disconnect) of the connection remain the same. This process may also be referred to as call set-up and take-down.

Types of Signals

Signaling equipment must generate and recognize several different signals in order to establish a voice path from the originating station to the called subscriber's telephone. *Seizing*, or *connect*, signals, sent in the forward direction (from originating to terminating end), initiate circuit operation. Two types of seizing signals are recognized: terminal seizing, which connects the terminating switch to the called subscriber's line, and transit seizing, which permits the dial pulses to make their way through intermediate switching equipment groups.

Proceed-to-send signals, sent in the backward direction (from terminating to originating end), indicate that the equipment at the distant end is ready to receive numerical signals. Again, both terminal and transit seizing signals are recognized.

Numerical signals, also known as *interregister* or *address* signals, are sent forward and are necessary to affect switching of the call along the proper route. There is always a succession of numerical signals.

End-of-pulsing signals are sent in the forward direction to show that no more numerical signals are to follow, while *number-received* signals are sent backward when the incoming register at the far end has recognized all the digits required for routing the call.

Busy-flash signals are sent backward to show that either the route or the subscriber's number is busy. An *answer* signal traveling the same route indicates that the called party has answered.

Clear-back signals, sent backward, indicate termination of the call (disconnect) by the called party.

E&M Terms and Systems

Since signaling circuits form interfaces between switching facilities, the term *interface* can be used here to refer to circuits, with *signaling system* denoting standardized systems, such as R1, R2, No. 4 and No. 5, that are recognized by the International Telegraph and Telephone Consultative Committee (CCITT). Furthermore, signals which pertain to the status of the line or trunk may be referred to as *line* signals, although they are also called *supervisory* and *control* signals. Line signaling refers, here, only to signals between switching facilities, and not to signals on the subscriber's loop or drop.

Signaling interfaces can be divided broadly on the basis of whether they use pulsed dc or ac to convey information. Direct current systems may be further classified as balanced (two-wire) or unbalanced (one-wire). Alternating current systems may be classified as in-band, out-of-band or common-channel. (In common-channel systems, all the signaling for a group of voice channels is transmitted over a separate path.)

The term "E&M" derives from certain historical designations used on the circuit drawings of early dc systems in the United States. Traditionally, the E&M interface has consisted of two leads between the switching equipment and the signaling equipment, with the M lead carrying dc signals from the switching equipment and the E lead carrying dc signals to the switching equipment. For example, signals from office A to office B leave on the M lead of the trunk circuit in office A and arrive on the E lead in office B. Some recent E&M interfaces have more than two leads.

In-band signaling refers to the use of frequencies within the range of 300-3400 Hz, roughly equivalent to the transmitted voice frequency spectrum. The North American toll network and most international systems use in-band frequencies for both line and numerical signaling.

Out-of-band signaling uses frequencies situated outside the frequency bands reserved for speech in multichannel systems, and the signaling equipment is normally an integral part of the terminal multiplexing equipment.

dc Interfaces

Historic E&M lead signaling circuits had only one lead for each direction of transmission, which meant that current flowing between switching and signaling equipment returned over a common ground path. It also meant that the signaling leads had a greater noise influence than if they had been balanced transmission circuits. The traditional two-wire E&M interface, now also called Type I, was the original interface for electromechanical switches (see Figure 1).

Signaling from the trunk circuit to the signaling circuit is by means of battery and ground signals over the M lead. The on-hook (idle) signal is ground on the M lead, while the off-hook (busy) signal is resistance battery supplied to the M lead. Signaling from the signaling circuit to the trunk circuit is by open and ground signals over the E lead. The on-hook signal is an open E lead, while the off-hook signal is ground on the E lead.

Although these E&M circuits performed well in electromechanical systems, they did not always provide satisfactory performance in electronic systems. As a result, two new E&M interfaces were designed for electronic switching systems. By mutual agreement among the telephone operating companies in the United States, these three interfaces are designated as Types I, II, and III, with the traditional interface being Type I. The Type II interface is actually a newer design than the Type III. In order to identify each system, it helps to remember that Type I has one lead for the M-lead function, Type II has two leads, and Type III has three leads.

The Type II interface (see Figure 2) is the preferred interface, though not all electronic switches can be used with this type since it is a four-wire, fully-looped arrangement that uses open and closure signals in each direction. Signaling from the trunk circuit to the signaling circuit is over the pair designated M and SB. The signaling circuit must supply −48-volt resistance battery on the SB lead and sense for the open and closure signals on the M lead. Signaling from the signaling cir-

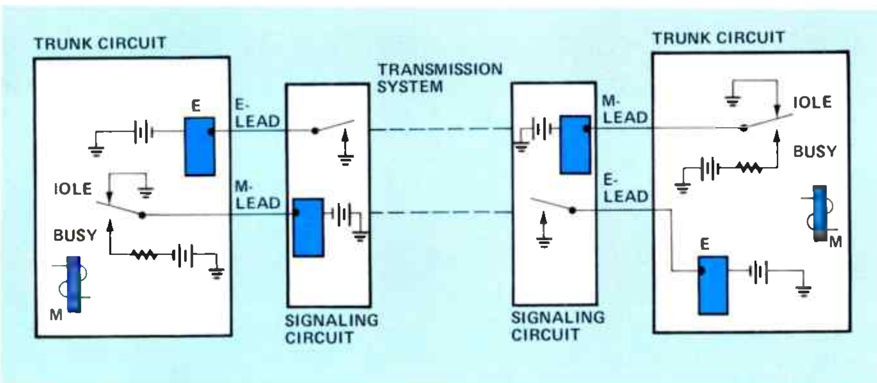

Figure 1. Traditional two-wire E&M interface (Type I) designed for electromechanical switches. Current between switching and signaling equipment returns over a common ground.

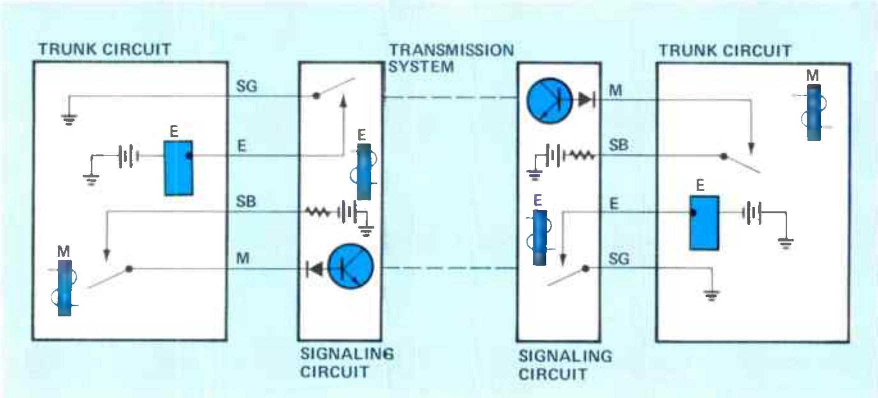

Figure 2. The Type II E&M interface for use with electronic switches has two leads for the M-signaling function.

cuit to the trunk circuit is by means of opens and closures on the leads E and SG. The trunk circuit must apply ground to the SG lead, and a sensing device to the E lead. On-hook signals are opens in both directions and off-hook signals are closures in both directions. The Type II interface has the advantage that trunk circuits can be interconnected directly without converters. Neither the Type I nor Type III offers this advantage.

The Type III interface is a compromise partially-looped, four-wire arrangement for use in electronic switching applications where the fully-looped Type II interface cannot be used. The loop portion uses three leads (SB, M, and SG) for signaling from the trunk circuit to the signaling circuit. The signaling over the M lead is exactly the same as in Type I, except that the trunk circuit obtains signaling battery and ground from the signaling circuit over the leads SB and SG, respectively.

Signaling equipment determines the M-lead range, while the trunk circuits determine the E-lead range. The objective for E&M leads in new Type I and Type III interfaces is 100 ohms (older types have ranges as low as 25 ohms). The objective range for Type II interfaces is 300 ohms loop (150 ohms one way).

While the operation of these circuits is two-way (signaling in both directions at once), it must be noted that compatible signaling circuits are required at both ends of a signaling section. Other dc signaling interfaces such as composite (CX), duplex (DX), and simplex (SX) also employ E&M leads but require converter circuits when used with Types I, II, and III.

Both composite and duplex signaling were developed to provide dc signaling and dial pulsing beyond the range available with loop signaling methods. Their operation is two-way and their circuits are fundamentally those used in full-duplex telegraph and teletypewriter operations, in that a sensitive polar relay at each end of the line receives signals from the distant end. Balancing networks are provided which must be adjusted for each circuit.

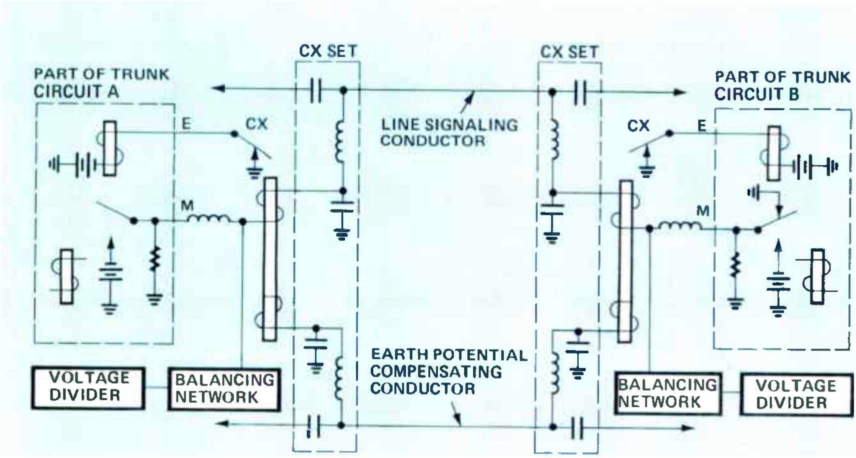

Figure 3. A composite signaling circuit with E&M lead control for one voice channel.

Composite Signaling

Composite signaling employs a single line conductor with ground return for each signaling channel (see Figure 3). A balanced polar relay at each end permits two-way operation. Higher frequency voice currents are separated from the low-frequency signaling currents by a filter arrangement called a CX, or "composite," set.

Three types of CX sets are in common use. These are classified as Type C, used at intermediate and terminal points on open wire and cable; Type D, which is used on open wire and cable, but only at terminal points and cannot be used on intertoll trunks; and Type E, used at intermediate and terminal points on cable circuits only.

Composite sets are also classified as either short-haul (a maximum of 4800 ohms loop resistance on cable circuits, or 145-160 kilometers [90-100 miles] of open wire) or long-haul (a maximum of 12,000 ohms loop resistance). Long-haul circuits usually include a vf repeater around which the signaling is bypassed.

On all intertoll trunks, ac and dc earth potential compensation should be used, but its use on toll-connecting trunks is optional.

Dial signaling without intermediate senders or registers is not expected to be transmitted through more than four signaling links connected in tandem. This limitation applies to all types of trunk signaling except loop signaling.

Duplex Signaling

Duplex (DX) signaling is based upon a balanced and symmetrical circuit that is identical at both ends. It is patterned after CX signaling but does not require a composite set (see Figure 4).

Duplex signaling uses the same conductors as the vf path, with one conductor carrying the line and numerical signals. Both conductors carry currents resulting from differences in terminal ground potentials and battery

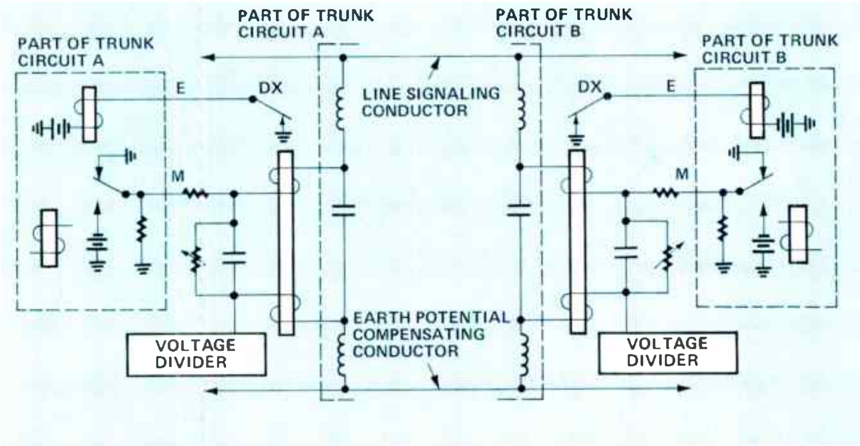

Figure 4. A duplex signaling circuit employing E&M lead control. The balanced circuitry provides self-compensation for ac and dc induced currents.

supply voltages. Current in the second conductor thus cancels the effect of this unwanted current in the first conductor, producing self-compensation. The circuit is also balanced against ac induction.

Duplex signaling may be used on both 10- and 20-PPS (pulses per second) dial pulsing trunks, performs better than most loop signaling arrangements, and is equal to CX in quality. Duplex signaling is often used instead of loop signaling on longer local and tandem trunks, and instead of CX or SX on short intertoll trunks. It can be used through E-type (negative impedance) repeaters, but if V-type repeaters are used, bypass equipment is required.

A single DX signaling section is limited to a maximum loop resistance of 5000 ohms. Although the range of DX is less than that of CX or SX, the signal distortion is so small that two DX circuits can be used in tandem for one trunk. Current DX circuit designs restrict its application to two- or four-wire line facilities composed of cable pairs equipped at both ends with repeating coils and having a minimum insulation resistance of 100,000 ohms.

When it is necessary to extend E&M leads beyond their normal limit, a signal lead extension circuit is used to secure adequate range. This circuit consists of a DX signaling circuit with an additional relay. Often designated DX2, this circuit converts signals from E-lead conditions to M-lead conditions.

Simplex Signaling

Simplex signaling, like CX, depends on ground conduction to complete the signaling path. It requires the use of two conductors for a single channel: a center-tapped coil, or its equivalent, is used at both ends of the pair for this purpose. It can function as a one-way signaling scheme for intra-office use, or the simplex legs can be connected to two-way signaling circuits which function like the CX signaling circuits with E&M lead control (see Figure 5).

Earth potential compensation requires the use of one conductor of an additional pair for each five signal channels. Thus, only five SX signaling circuits are derived from six physical pairs.

Private Line E&M Signaling

Private branch exchanges (PBX's) and private automatic branch exchanges (PABX's), which may be considered as switching machines, are connected to central office switching facilities by dial repeating tie trunks and may involve E&M signaling leads. Most dial repeating tie trunks are two-way, and loop signaling can be used end-to-end if the distance is not too great. If the loop resistance is too great for loop signaling end-to-end, loop-to-E&M signaling interfaces can be used for certain tie trunks, including two-way dial repeating trunks.

Tandem dial repeating tie trunks require pad switching and must be carefully engineered using four-wire designs with a toll-grade, four-wire terminating set located at each end when connecting to two-wire switching equipment. Some tie trunk circuits have the four-wire terminating set built into them, in which case a four-wire E&M arrangement would normally be used. Although pad switching is done differently on different tie trunks, a two-wire E&M interface with A, B, D, F and G leads can interface all E&M tie trunk circuits.

International E&M

The simplified circuit diagram shown in Figure 6 is considered to be representative of international E&M interfaces. Under idle conditions, the Sb lead from trunk circuit A (equivalent to the domestic M lead) is opened, and so is the Sa (or E lead) to trunk circuit B. When a subscriber served by trunk circuit A goes off-hook, the Sb lead is grounded. The signaling pattern is similar to Type I, except that the M lead uses open and ground signals instead of battery and ground.

Broadly speaking, the United States has adopted the signaling standards set by one or two major equipment manufacturers, while in Europe a greater variety of standards exists because each country has a leading manufacturer whose standards have been adopted. There is, therefore, a multiplicity of signaling systems and interfaces in use around the world (see Figure 7). The signaling standards

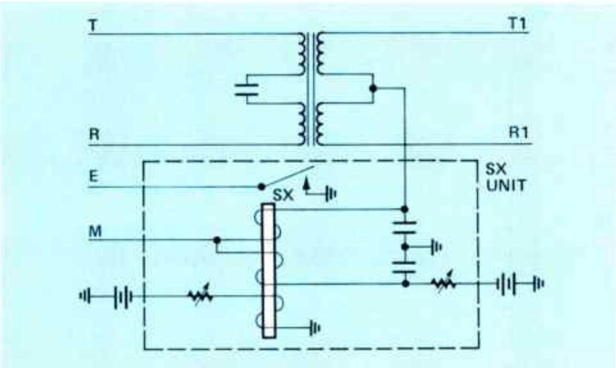

Figure 5. A simplex signaling circuit with E&M leads. This type of circuit has been largely superseded by DX in new installations.

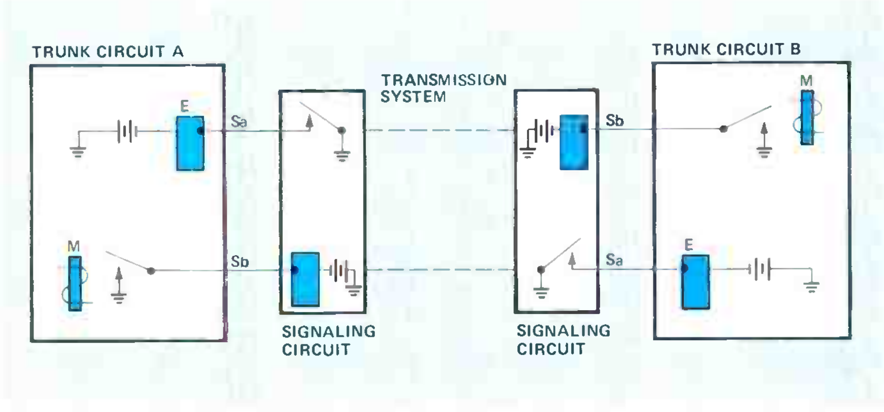

Figure 6. A representative international interface using E&M lead control. The Sa-Sb lead designations are typical of European products.

STANDARD	OFFICE A — SEND LEAD	OFFICE B — RECEIVE LEAD
NORTH AMERICAN (USA)	TYPE I M-GROUND (ON-HOOK) M-BATTERY (OFF-HOOK)	TYPE I E-OPEN (ON-HOOK) E-GROUND (OFF-HOOK)
	TYPE II M/SB-OPEN (ON-HOOK) M/SB-CLOSED (OFF-HOOK)	TYPE II E/SG-OPEN (ON-HOOK) E/SG-CLOSED (OFF-HOOK)
WEST GERMANY	SZ2-OPEN (ON-HOOK) SZ2-GROUND (OFF-HOOK)	SZ1-OPEN (ON-HOOK) SZ1-GROUND (OFF-HOOK)
	Sb-OPEN (ON-HOOK) Sb-GROUND (OFF-HOOK)	Sa-OPEN (ON-HOOK) Sa-GROUND (OFF-HOOK)
JAPAN (NORTH AMERICAN E & M TYPES ARE ALSO IN USE)	SS-OPEN (ON-HOOK) SS-GROUND (OFF-HOOK)	SR-OPEN (ON-HOOK) SR-GROUND (OFF-HOOK)
ITALY	GENERALLY THE SAME AS THE WEST GERMAN Sa-Sb. ITALY CALLS THESE LEADS E & M BUT THEY ARE NOT THE SAME AS THE NORTH AMERICAN STANDARD.	
IRAN AND BELGIUM	GENERALLY THE SAME AS THE WEST GERMAN Sa-Sb STANDARD.	

Figure 7. Some of the most commonly used North American E&M leads, their equivalents in other systems, and the status indicated by open/ground and battery/ground conditions.

agreed upon by the CCITT make it possible, however, to place intercontinental calls, even without the assistance of an operator.

Examination of the lead designations in Figure 7 reveals that all the E leads are the same (open/ground); the two types of M leads (ground/battery and open/ground), however, may lead to confusion. It must be stressed that conversion is required to make two interfaces with different M-lead functions work into one another. It is possible to find a domestic-type M lead on one end of a circuit and an international-type M lead on the other. The necessary signaling conversion can sometimes be made by selecting optional plug-in units for use at each end of the circuit.

In spite of the CCITT standards, equipment is sometimes ordered and installed before its incompatibility with the existing system is discovered. This situation occurs when the signaling interface is not properly specified, and is often due to differences in terminology and in lead designations.

In many cases, lead designations may be the same in different systems while their functions are exactly opposite. On the other hand, different lead designations may disguise the fact that two systems are actually compatible. Each part of the signaling interface must, therefore, be checked for compatibility with regard to voltage (–24, –48, –50 and –60 Vdc are all in use), polarity, pulse inversion, percent break of relay contacts, and the number of leads involved in the numerical and line functions.

The effects of different types of E&M signaling on test sets and loop-to-E&M or other converters must be considered, as well.

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Alternating current signaling systems provide the line and numerical signaling required by switching systems over distance dialing (toll) trunks where dc signaling is not feasible or economical due to the cost of repeaters and cable pairs.

PART 2

In the late 1940's, a single-frequency signaling system was developed which adapted dc signaling to carrier transmission in order to secure greater range and accuracy than dc signaling techniques could provide. Afterwards, multifrequency and multifrequency coded techniques were developed.

Two-state (on-off) ac signaling can handle line and numerical signaling if the latter is coded by dial pulsing. Three-state (either of two tones on or both tones off) ac signaling was designed to meet the requirements of revertive pulsing trunks. (In revertive pulsing, pulses are sent from the terminating office instead of the originating office.) Multifrequency pulsing systems are used for numerical signaling only, and must be coordinated with two-state systems, either ac or dc, for line signaling. The E&M leads in all these systems depend on dc potentials or logic 1-logic 0 (on-off) states for their operation.

Alternating current signaling systems serve as interfaces between mechanical, electronic and digital switching machines. Their frequencies may be in-band or out-of-band, although in some cases both are combined, with the numerical signaling using in-band frequencies while the line signaling uses frequencies that are out-of-band (see Figure 1). These ac systems contain circuits for converting the signal on the line to the form of dc signal (loop, E&M, ring, etc.) required by the terminating and/or switching equipment.

Single-Frequency Signaling

The first single-frequency (SF) signaling system used interruptions of a 1600-Hz tone; that is, it was a two-state system. This was superseded by a system using 2600 Hz, which has now become the standard frequency within the United States. Some early SF signaling units which were originally designed only for E&M dc signaling

CCITT NAME/ NUMBER	AREA WHERE USED	LINE SIGNALING FREQUENCY (IN HERTZ)	NUMERICAL SIGNALING FREQUENCY (IN HERTZ)	TYPE OF CIRCUIT REQUIRED
NO. 4* (2-FREQUENCY)	INTERNATIONAL WITHIN EUROPE	2040 2400	2040 2400	ONE-WAY
NO. 5*	INTERCONTI-NENTAL ON CABLE, MICRO-WAVE AND SATELLITE	2400 2600	700, 900 1100, 1300 1500, 1700	TWO-WAY
NO. 6 CCIS	INTERNATIONAL	COMMON CHAN-NEL DIGITAL STREAM AT 2400 b/s	COMMON CHAN-NEL DIGITAL STREAM AT 2400 b/s	TWO-WAY
R1 NORTH AMERICAN	AMONG THE CARIBBEAN IS., CANADA AND THE UNITED STATES	2600	700, 900 1100, 1300 1500, 1700	TWO-WAY
R2* BERN OR MFC	REGIONAL (WITHIN A WORLD NUMBERING ZONE)	3825	FORWARD 1380, 1500 1620, 1740 1860, 1980 BACKWARD 540, 660 780, 900 1020, 1140	ONE-WAY TWO-WAY OPTIONAL

Figure 1. Single-frequency, two-frequency and multifrequency signaling systems standardized by the CCITT for intercontinental, international and regional use. Systems marked by an asterisk are most widely used. (Adapted from a chart prepared by Karl F. Steinhauer of GTE Automatic Electric Laboratories, Inc., August 1972.)

used 1600, 2000, and 2400 Hz as well as 2600 Hz. In some cases they were designed to operate at one frequency in one direction and at another frequency in the opposite direction. Modern SF systems use 2600 Hz in both directions, so SF signaling may be applied to any voice-grade channel, provided the channel is four-wire end-to-end.

The SF signaling systems standardized in the United States deliver and receive dc signals to and from the switching equipment in the form of loop or E&M lead controls. The dc signals are transformed to ac tones on the line side, and *vice versa*. The tone converter is one of the two primary components of an SF signaling unit; the other is an interface which furnishes the timing functions for the converter's transmission and reception (see Figure 2). The converter applies the 2600-Hz tone generated by an

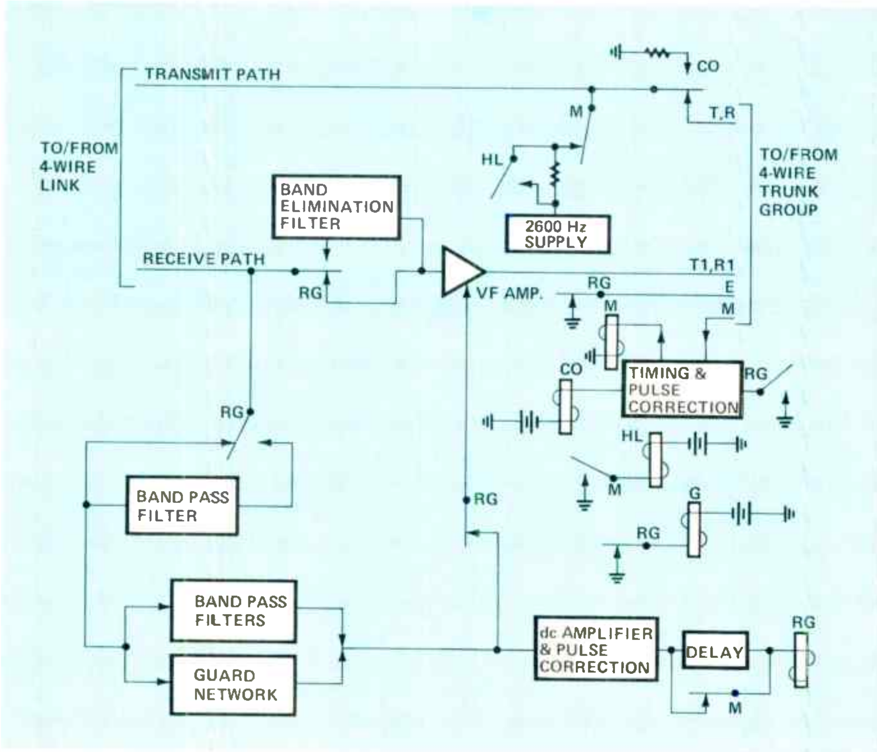

Figure 2. A typical SF signaling system using 2600 Hz as the signaling frequency. The primary function of the vf amplifier is to prevent noise or speech from interfering with the operation of the signal detector.

oscillator (built-in or external) to the line and detects tones from the distant end. The interface provides pulse correction and signal translation and also contains the vf transmission circuits.

The receiving portion of the SF unit consists of a voice amplifier, band elimination filters, and a signal detection circuit which includes a guard network to avoid "talk-off," or premature disconnect caused by speech components at the same frequency as the signaling tone. The guard network is insufficient by itself, however, and an additional electronic time delay is provided so the receiver will only operate the RG (receive guard) relay on a tone pulse of 35 milliseconds duration.

In the receive direction, voice signals enter the SF converter at the four-wire receive line. The vf amplifier, under the control of a pulse corrector, can either pass all of the received signals or it can place a 2600-Hz band elimination filter (BEF) in the receive path. During a tone-on condition, the BEF is bridged across the voice path to prevent the signaling tone from entering the vf receive line.

The E&M control portion contains three relays: M, HL and CO. The M relay applies the 2600-Hz tone to the transmit line during idle circuit conditions. The HL (high level) relay adds 12 dB to improve signal reliability. During dial pulsing, the CO (cut off) relay applies bursts of tone to the line, but no tone is present during talking conditions when both units are off-hook. The signaling information to the four-wire line is provided by the tone-on/tone-off pulses. The CO relay also functions to prevent noise originating in the switching equipment from interfering with signaling.

Single-frequency signaling units interrupt the voice path on both the receiving and transmitting sides, with the receiving path being opened every time 2600 Hz is first received, thus preventing the signaling tone from entering the next signaling link. The receiving path remains opened until the 2600-Hz band elimination filter is inserted by the RG relay, restoring the path. Not all units are identical, but typically the near-end path is re-established in 90-155 milliseconds and the far-end transmitting path is re-established in 500-750 milliseconds. If the called party's subset should go off-hook during this interval, the timing is reduced to the 90-155 millisecond level.

Since an SF system uses vf signals on the four-wire voice path, the characteristics of SF signaling are quite different from those of dc signaling systems. Single-frequency systems have a longer delay in signaling time, lower signaling speed, and a lower percent break range of the relay contacts.

Single-frequency systems are prone to malfunctions caused by continuous tones near 2600 Hz. For example, a pure tone near the signaling frequency may cause the far-end unit to go on-hook, while continuous tones that are not 2600 Hz may act as guard signals and keep the signaling units off-hook even though the 2600 Hz tone is present. Continuous tones can also hold a unit on-hook after the 2600-Hz signaling tone is removed.

These limitations of SF signaling led to the development of multifrequency signaling systems, which are faster and more accurate.

Multifrequency Signaling

A multifrequency pulsing (MF) system consists of transmitting and receiving equipment for signaling numerical information over telephone trunks using combinations of two—and only two—frequencies in the voice-band. The system is capable of transmitting only numerical information, and relies on another system, such as DX or SF, for line signaling. The function of the E&M leads in an MF signaling system is to establish a path for the MF pulses over the trunk circuit. Carrier systems, both cable and radio, using frequency division multiplexing (FDM) may employ MF signaling techniques.

The MF signaling system standardized for use on toll circuits in North America (CCITT R1) uses 2600 Hz for line signaling and combinations of five frequencies (700-1500 Hz), spaced 200 Hz apart, to indicate the digits one through zero. A sixth frequency (1700 Hz), when combined with 1100 Hz, indicates the beginning of pulsing (key pulse or KP); when combined with 1500 Hz, it indicates end of pulsing (signaling terminating pulse or ST). Three other combinations are available for special signals such as coin collect and coin return.

When a subscriber served by E&M trunk circuit A in Figure 3 dials a

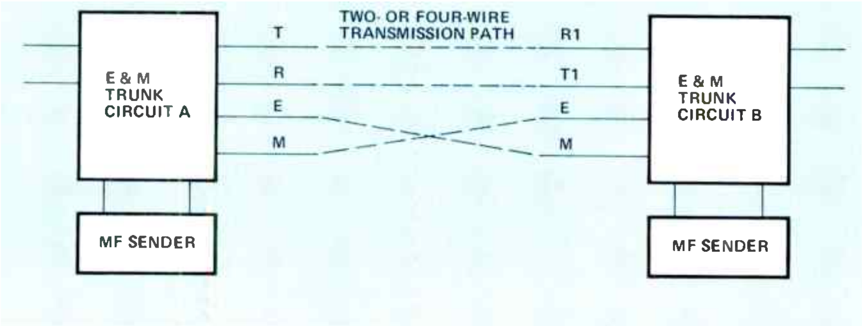

Figure 3. Block diagram of a multifrequency signaling system with E&M leads.

subscriber served by circuit B, the MF sender, or register, associated with circuit A stores the number and seizes the M lead. (In some operations, the calling number is also stored.) Trunk circuit B is arranged for delay-dial operation and generates an off-hook signal toward trunk circuit A when idle. This off-hook signal is maintained until the called office is ready to receive MF signaling. At that time, the called office sends a 100-millisecond wink-start signal which causes the idle line termination to be short-circuited during the wink-start signal. An on-hook signal is then sent to the originating end to indicate dial pulsing may begin. The sender associated with circuit A then sends a KP signal, "spills" the stored number, and adds an ST signal. No further operations occur in the trunk circuit during the MF pulsing.

When the called party answers, battery polarity is reversed and the M lead is transferred from normal to seized, the incoming register's idle line termination is shorted, and the access control is marked busy. If the originating subscriber goes on-hook (disconnects), the short is removed from the idle line termination, the M lead returns from seized to normal, and the trunk circuit returns to normal.

The principal advantages of MF pulsing are speed, accuracy, and range. Multifrequency signaling requires less holding time per call than SF, so a relatively small number of MF senders or registers can be used as common equipment for a larger number of trunks.

Carrier E&M

Many carrier trunks used in the toll network in the United States depend on SF signaling, but certain carrier equipment, such as GTE Lenkurt's 36A2 Multiplex System, has built-in E&M signaling capabilities. (The 36A2 can also use externally supplied in-band signaling.)

Some frequency division multiplexed (FDM) systems use out-of-band signals, such as 3700 or 3825 Hz, to modulate the channel or twin-channel carrier frequency associated with the vf channel. In many systems, when the trunk is idle, the out-of-band tone is present in both directions and line signals are transmitted by interrupting the tone. (In other systems, the tone is

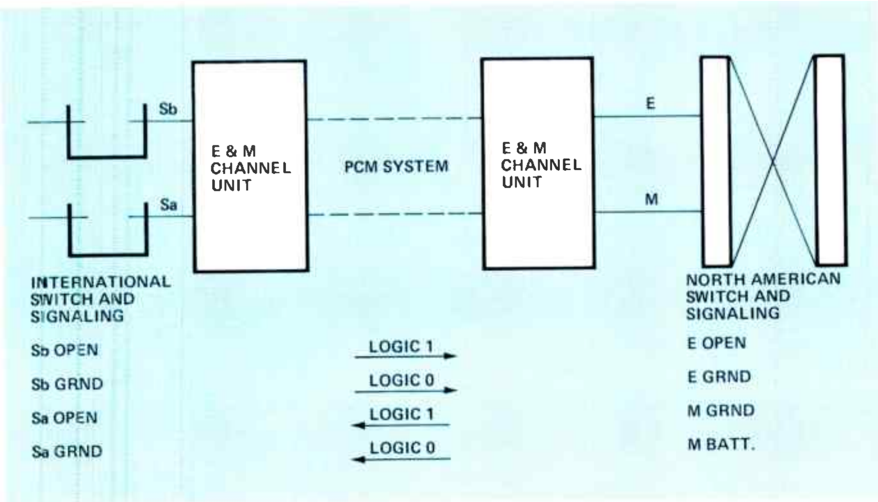

Figure 4. Block diagram of a North American switching and signaling system interfaced with an international type of system, both having E&M or equivalent leads.

off during idle conditions.) Since the frequency is outside the voiceband, no provision is required for protection against voice operation. Speech and signaling frequencies are separated by a filter.

Other FDM systems, like GTE Lenkurt's 46A3 Multiplex System with 11A signaling, use in-band signaling equipment with loop or E&M lead control. (The 46A3 may also use 11A common channel signaling as an alternative to in-band signaling.) Common Channel Interoffice Signaling (CCIS or CCITT No. 6) uses a digital stream at 2400 bits per second and may be applied to pulse code modulated (PCM) carrier channels.

Most internationally manufactured carrier equipment with built-in E&M signaling cannot be strapped to interface with domestic E&M signaling equipment. However, equipment of recent manufacture using solid-state E&M circuitry may be interfaced, but the compatibility of the logic voltages must be checked carefully. Some PCM systems with built-in signaling converters offer a variety of channel units which permit the interfacing of two switching devices having different E&M leads, provided the PCM logic state is the same for both interfaces (see Figure 4).

The problem of interfacing switches of international design with domestic switches, though both use signaling interfaces with E&M leads, is compounded by the fact that some of the former invert the pulsing in their trunk repeaters. For example, 40 milliseconds closure and 60 milliseconds open from the originating subset is converted to 60 milliseconds closure and 40 milliseconds open on the transmission system's E&M leads. Signaling units with pulse correctors must not be used with this type of circuit, as the pulses will be inverted and the signaling circuit will not work.

The leads which carry dc signals to and from the switching equipment have several designations, depending on where the equipment was manufactured (see Figure 6 in Part I). As noted in Part I, these differences complicate the task of purchasing equipment that will interface properly with existing telephone systems, especially in expanding older switching networks.

Repeaters and Converters

A trunk may consist of two or more signaling sections in tandem, each using some type of signaling system. If two adjacent sections of a trunk have the same E&M signaling interface, an auxiliary pulse link, like the one shown in Figure 5, is generally included to repeat the signals. During on-hook (idle) conditions, the E and E1 leads are open, the relays are de-energized and the M and M1 leads are grounded. Information received on each E lead (open or ground) from one signaling system is converted to M lead information (ground or battery) for transmission over the other signaling system.

Whenever two trunks with incompatible E&M signaling must be interconnected, a trunk link repeater like the one shown in Figure 6 is commonly used.

If a trunk using loop signaling must be connected to a trunk using E&M lead control, a converter circuit is used to make the change from loop to E&M signaling and *vice versa*.

Ringdown converters are used to interconnect E&M signaling circuits and ringdown relay circuits for ringdown operation, and may also be used to interconnect E&M signaling circuits with 20-, 135-, or 1000-Hz signaling circuits. This type of converter (see Figure 7) is always used in pairs, one at each end of the E&M signaling channel.

Under idle conditions, relay A in Figure 7 is de-energized, the M lead is connected to the battery, and there is no 20-Hz signal from the tie trunk circuit. At the same time, the R relay is energized, due to an external ground on the E lead, and there is no 20-Hz signal toward the tie trunk circuit. On an incoming call (from the PABX to the tie trunk), the E lead is opened and the R relay de-energized to supply 20 Hz across T and R. On an outgoing call (from the tie trunk to the PABX),

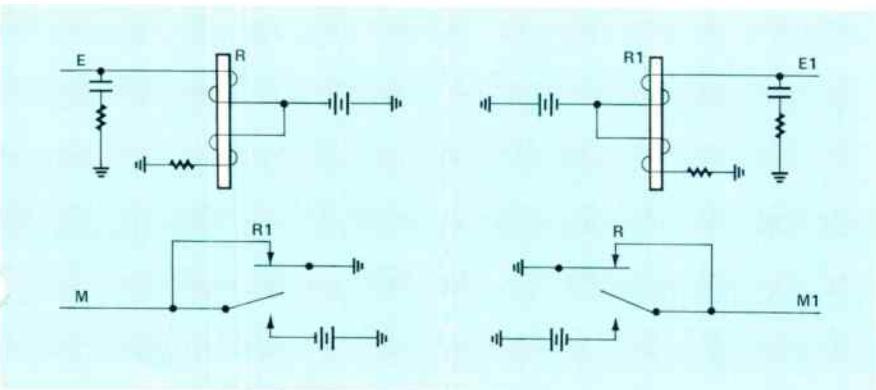

Figure 5. Pulse link repeater between two E&M interfaces of the same type.

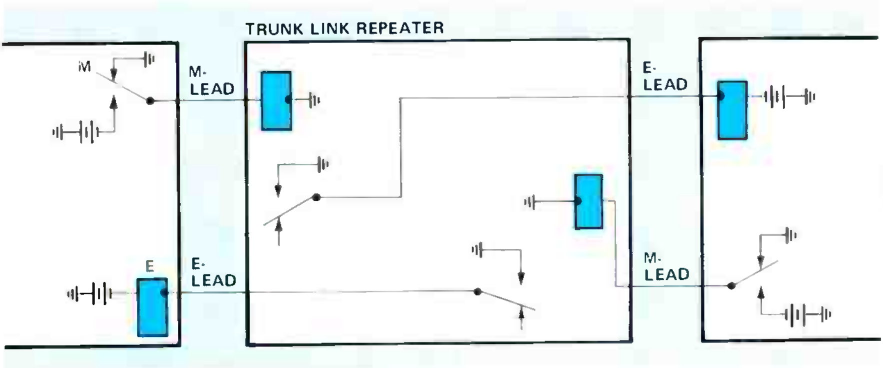

Figure 6. A typical trunk link repeater interconnecting two trunks which have incompatible E&M signaling interfaces.

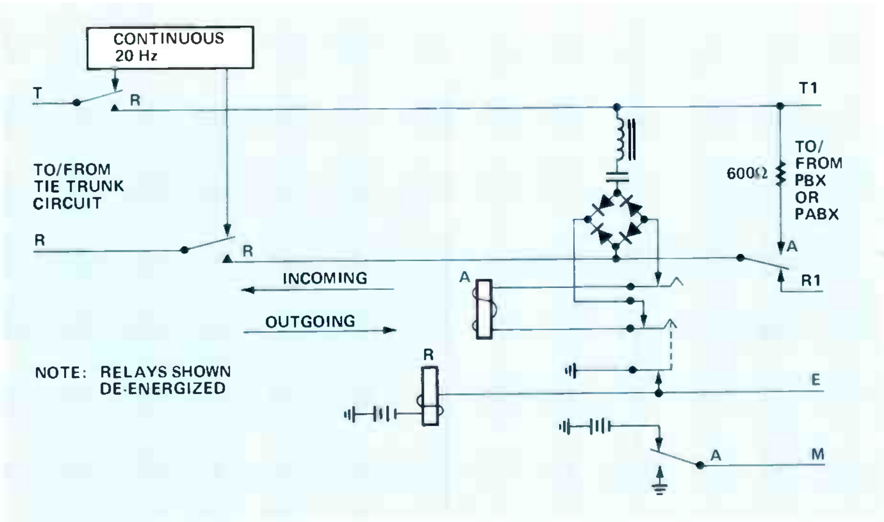

Figure 7. A typical converter used to convert from an SF or carrier section to 20-Hz, two-way ringdown operation.

the A relay is energized, the M lead is grounded, the T1-R1 pair is terminated by a 600 ohm resistor and 20 Hz from the tie trunk circuit is present on T and R. Talking conditions are identical to idle circuit conditions; that is, when the signaling procedure has been completed, the A relay is again de-energized while relay R is energized.

In addition to the converters mentioned above, two types of automatic ringdown converters have been developed. One, designed for use with trunk circuits or signaling interface, equipped to receive dc signals, is designated ARO. The other, designated, AR1, is intended for use with trunk circuits or signaling interfaces

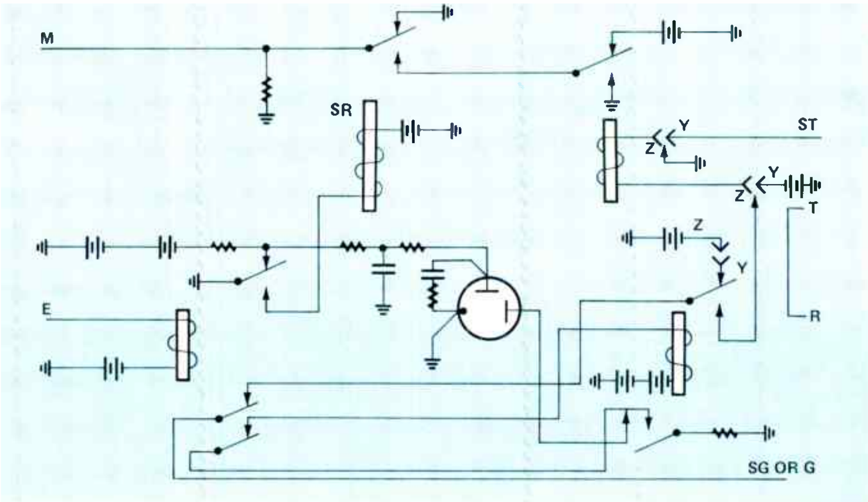

Figure 8. A typical AR1-type converter used with trunk circuits or signaling circuits equipped to receive 20-Hz signals.

equipped to receive 20-Hz signals (see Figure 8).

Many problems must be faced when switching systems using different types of E&M lead control signaling have to be interfaced. The standards agreed upon by the CCITT have helped solve some of these, but many others remain to be worked out among the numerous equipment manufacturers and their customers. Standardization of terminology, equipment function, and lead designations will help to reduce the difficulties encountered when interfacing switching machines at regional, national, and international levels.

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