SIGNALING

7.1 WHAT IS THE PURPOSE OF SIGNALING?

The IEEE (Ref. 1) defines *signaling* as the exchange of information specifically concerned with the establishment and control of connections and the transfer of user-to-user and management information in a telecommunication network.

Conventional signaling has evolved with the telephone network. Many of the techniques we deal with in this chapter are applicable to a telecommunication network that is principally involved with telephone calls. With telephony, signaling is broken down in three functional areas:

1. Supervisory
2. Address
3. Call progress audible-visual

Another signaling breakdown is

A. Subscriber signaling
B. Interswitch (interregister) signaling

7.2 DEFINING THE FUNCTIONAL AREAS

7.2.1 Supervisory Signaling

Supervisory signaling provides information on line or circuit condition. It informs a switch whether a circuit (internal to the switch) or a trunk (external to the switch) is busy or idle, when a called party is off-hook or on-hook, and when a calling party is on-hook or off-hook.

Supervisory information (status) must be maintained end-to-end on a telephone call, whether voice data or facsimile is being transported. It is necessary to know when a calling subscriber lifts her/his telephone off-hook, thereby requesting service. It is equally important that we know when the called subscriber answers (i.e., lifts her telephone off-hook) because that is when we may start metering the call to establish charges. It is also important to know when the calling and called subscribers return their telephones to the on-hook condition. Now is when charges stop, and the intervening trunks comprising the talk path as well as the switching points are then rendered idle for use by another pair of subscribers. During the period of occupancy of a speech path end-to-end, we must know that this particular path is busy (i.e., it is occupied) so no other call attempt can seize it.

7.2.2 Address Signaling

Address signaling directs and routes a telephone call to the called subscriber. It originates as dialed digits or activated push-buttons from a calling subscriber. The local switch accepts these digits and, by using the information contained in the digits, directs the call to the called subscriber. If more than one switch is involved in the call setup, signaling is required between switches (both address and supervisory). Address signaling between switches is called *interregister signaling*.

7.2.3 Call Progress: Audible-Visual

This type of signaling we categorize in the *forward direction* and in the *backward direction*. In the forward direction there is *alerting*. This provides some sort of audible-visual means of informing the called subscriber that there is a telephone call waiting. This is often done by ringing a telephone's bell. A buzzer, chime, or light may also be used for alerting.

The remainder of the techniques we will discuss are used in the backward direction. Among these are audible tones or voice announcements that will inform the calling subscriber the following:

1. *Ringback.* This tells the calling subscriber that the distant telephone is ringing.
2. *Busyback.* This tells the calling subscriber that the called line is busy.
3. *ATB—All Trunks Busy.* There is congestion on the routing. Sometimes a recorded voice announcement is used here.
4. *Loud Warble on Telephone Instrument—Timeout.* This occurs when a telephone instrument has been left off-hook unintentionally.

7.3 SIGNALING TECHNIQUES

7.3.1 Conveying Signaling Information

Signaling information can be conveyed by a number of means from a subscriber to the serving switch and between (among) switches. Signaling information can be transmitted by means such as

- Duration of pulses (pulse duration bears a specific meaning)
- Combination of pulses
- Frequency of signal
- Combination of frequencies
- Presence or absence of a signal
- Binary code
- For dc systems, the direction and/or level of transmitted current

7.3.2 Evolution of Signaling

Signaling and switching are inextricably tied together. Switching automated the network. But without signaling, switching systems could not function. Thus it would be better said that switching with signaling automated the network.

Conventional subscriber line signaling has not changed much over the years, with the exception of the push-button tones that replaced the dial for address signaling. ISDN, being a full digital service to the subscriber, uses a unique digital signaling system called DSS-1 (Digital Subscriber Signaling No. 1). In the ATM world there is digital subscriber signaling system No. 2, Q.2931 and RFC3033.

In the 1930s and 1940s, interregister and line signaling[1] evolved into many types of signaling systems, which made international automatic working a virtual nightmare. Nearly every international circuit required special signaling interfaces. The same was true, to a lesser extent, on the national level.

In this section we will cover several of the more utilized signaling techniques used on the analog network which operated with frequency division multiplex equipment (Section 4.5.2). Although these signaling systems are obsolete in light of the digital network, the concepts covered here will help in understanding how signaling works.

7.3.2.1 Supervisory/Line Signaling

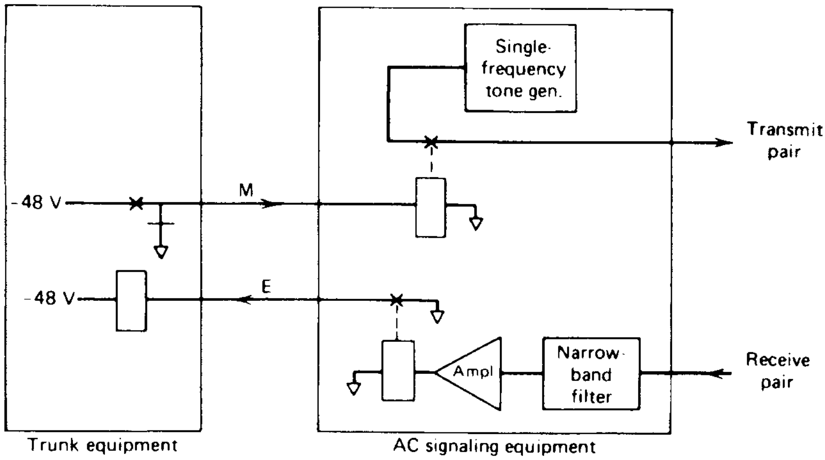
7.3.2.1.1 Introduction. Line signaling on wire trunks was based essentially on the presence or absence of dc current. Such dc signals are incompatible with FDM equipment where the voice channel does not extend to 0 Hz. Remember the analog voice channel occupies the band from 300 to 3400 Hz. So the presence or absence of a dc current was converted to an ac tone for one of the states and no tone for the other state. There were two ways to approach the problem. One was called *in-band signaling* and the other was called *out-of-band signaling*.[2]

7.3.2.1.2 In-Band Signaling. In-band signaling refers to signaling systems using an audio tone, or tones, inside the conventional voice channel to convey signaling information. There are two such systems we will discuss here: (1) one frequency (SF or single frequency) and (2) two frequency (2VF). These signaling systems used one or two tones in the 2000- to 3000-Hz portion of the band, where less speech energy is concentrated.

Single-frequency (SF) signaling is used exclusively for supervision, often with its adjunct called *E&M signaling*, which we cover in Section 7.3.2.1.4. It is used with FDM equipment, and most commonly the tone frequency was 2600 Hz. Of course, this would be in four-wire operation. Thus we would have a 2600-Hz tone in either/both directions. The direction of the tone is important, especially when working with its E&M signaling adjunct. A diagram showing the application of SF signaling on a four-wire trunk is shown in Figure 7.1.

Two-frequency (2VF) signaling can be used for both supervision (line signaling) and address signaling. Its application is with FDM equipment. Of course when discussing such types of line signaling (supervision), we know that the term *idle* refers to the on-hook condition, while *busy* refers to the off-hook condition. Thus, for such types of line signaling that are governed by audio tones of which SF and 2VF are typical, we have the conditions of "tone on when idle" and "tone on when busy." The discussion holds equally well for in-band and out-of-band signaling methods. However, for in-band

[1] *Line signaling* is the supervisory signaling used among switches.
[2] Called *out-band* by CCITT and in nations outside of North America.



Signal	Tone	Operation	Lead	Condition
On hook	On	Transmitting	M	Ground
		Receiving	E	Open
Off hook	Off	Transmitting	M	Battery
		Receiving	E	Ground

Figure 7.1 Functional block diagram of an SF signaling circuit. *Note:* Wire pairs "receive" and "transmit" derive from the FDM multiplex equipment. Note also the E-lead and M-lead.

signaling, supervision is by necessity tone-on idle; otherwise subscribers would have an annoying 2600-Hz tone on throughout the call.

A major problem with in-band signaling is the possibility of "talk-down," which refers to the premature activation or deactivation of supervisory equipment by an inadvertent sequence of voice tones through the normal use of the channel. Such tones could simulate the SF tone, forcing a channel dropout (i.e., the supervisory equipment would return the channel to the idle state). Chances of simulating a 2VF tone set are much less likely. To avoid the possibility of talk-down on SF circuits, a time-delay circuit or slot filters to by-pass signaling tones may be used. Such filters do offer some degradation to speech unless they are switched out during conversation. They must be switched out if the circuit is going to be used for data transmission (Ref. 2).

It becomes apparent why some administrations and telephone companies have turned to the use of 2VF supervision, or out-of-band signaling, for that matter. For example, a typical 2VF line signaling arrangement is the CCITT No. 5 code, where f_1 (one of the two VF frequencies) is 2400 Hz and f_2 is 2600 Hz. 2VF signaling is also used widely for address signaling (see Section 7.3.2.2 of this chapter; Ref. 3).

7.3.2.1.3 Out-of-Band Signaling. With out-of-band signaling, supervisory information is transmitted out of band (i.e., above 3400 Hz). In all cases it is a single-frequency system. Some out-of-band systems use "tone on when idle," indicating the on-hook condition, whereas others use "tone off." The advantage of out-of-band signaling is that either system, tone on or tone off, may be used when idle. Talk-down cannot occur because all supervisory information is passed out of band, away from the speech-information portion of the channel.

The preferred CCITT out-of-band frequency is 3825 Hz, whereas 3700 Hz is commonly used in the United States. It also must be kept in mind that out-of-band signaling is used exclusively on carrier systems, not on wire trunks. On the wire side, inside an exchange, its application is E&M signaling. In other words, out-of-band signaling is one method of extending E&M signaling over a carrier system.

In the short run, out-of-band signaling is attractive in terms of both economy and design. One drawback is that when channel patching is required, signaling leads have to be patched as well. In the long run, the signaling equipment required may indeed make out-of-band signaling even more costly because of the extra supervisory signaling equipment and signaling lead extensions required at each end, and at each time that the carrier (FDM) equipment demodulates to voice. The major advantage of out-of-band signaling is that continuous supervision is provided, whether tone on or tone off, during the entire telephone conversation. In-band SF signaling and out-of-band signaling are illustrated in Figure 7.2. An example of out-of-band signaling is the regional signaling system R-2, prevalent in Europe and nations under European hegeonomy (see Table 7.1).

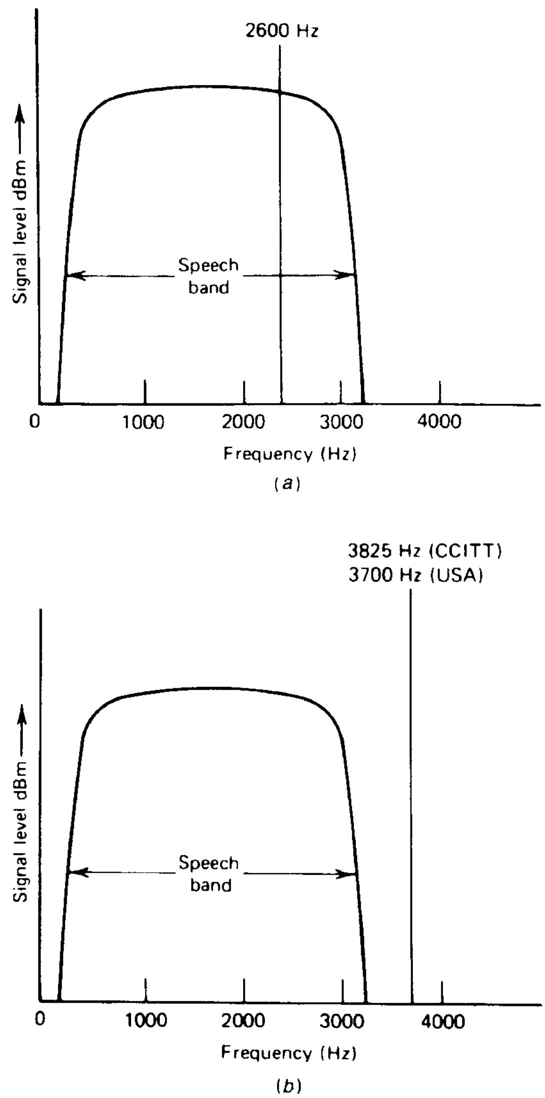


Figure 7.2 SF signaling (*a*) in-band and (*b*) out-of-band.

Table 7.1 R-2 Line Signaling (3825 Hz)

	Direction	
Circuit State	Forward (Go)	Backward (Return)
Idle	Tone on	Tone on
Seized	Tone off	Tone on
Answered	Tone off	Tone off
Clear back	Tone off	Tone on
Release	Tone on	Tone on or off
Blocked	Tone on	Tone off

7.3.2.1.4 E&M Signaling. The most common form of trunk supervision in the analog network was E&M signaling. It derived from the SF or 2VF equipment as shown in Figure 7.1. It only becomes true E&M signaling where the trunk interfaces with the switch (see Figure 7.3). E-lead and M-lead signaling systems are semantically derived from the historical designation of signaling leads on circuit drawings covering these systems. Historically, the E and M interface provides two leads between the switch and what we call the *trunk signaling equipment* (signaling interface). One lead is called the E-lead which carries signals *to* the switching equipment. Such signal directions are shown in Figure 7.3, where we see that signals from switch A and switch B leave A on the M-lead and are delivered to B on the E-lead. Likewise, from B to A, supervisory information leaves B on the M-lead and is delivered to A on the E-lead.

For conventional E&M signaling (referring to electromechanical exchanges), the following supervisory conditions are valid:

Direction		**Condition at *A***		**Condition at *B***	
Signal A to B	***Signal B to A***	***M-Lead***	***E-Lead***	***M-Lead***	***E-Lead***
On-hook	On-hook	Ground	Open	Ground	Open
Off-hook	On-hook	Battery	Open	Ground	Ground
On-hook	Off-hook	Ground	Ground	Battery	Open
Off-hook	Off-hook	Battery	Ground	Battery	Ground

Source: Ref. 8.

7.3.2.2 Address Signaling. Address signaling originates as dialed digits (or activated push-buttons) from a calling subscriber, whose local switch accepts these digits and, using that information, directs the telephone call to the desired distant subscriber. If more than one switch is involved in the call setup, signaling is required between switches (both address and supervisory). Address signaling between switches in conventional systems is called *interregister signaling*.

The paragraphs that follow discuss various more popular standard ac signaling techniques such as 2VF and MF tone. Although interregister signaling is stressed where

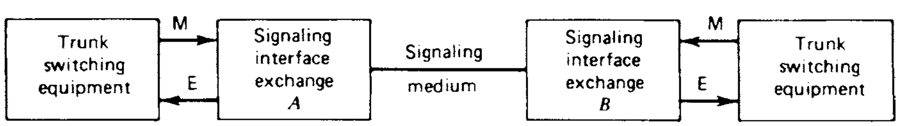


Figure 7.3 E&M signaling.

appropriate, some supervisory techniques are also reviewed. Common-channel signaling is discussed in Chapter 13, where we describe the CCITT No. 7 signaling system.

7.3.2.2.1 Multifrequency Signaling. Multifrequency (MF) signaling has been in wide use around the world for interregister signaling. It is an in-band method using five or six tone frequencies, two tones at a time. It works well over metallic pair, FDM, and TDM systems. MF systems are robust and difficult to cheat. Three typical MF systems are reviewed in the following:

MULTIFREQUENCY SIGNALING IN NORTH AMERICA—THE R-1 SYSTEM. The MF signaling system principally employed in the United States and Canada is recognized by the CCITT as the R-1 code (where R stands for "regional"). It is a two-out-of-five frequency pulse system. Additional signals for control functions are provided by frequency combination using a sixth basic frequency. Table 7.2 shows the ten basic digits (0–9) and other command functions with their corresponding two-frequency combinations, as well as a brief explanation of "other applications." We will call this system a "spill forward" system. It is called this because few backward acknowledgment signals are required. This is in contraposition to the R-2 system, where every transmitted digit must be acknowledged.

CCITT NO. 5 SIGNALING CODE. Interregister signaling with the CCITT No. 5 code is very similar to the North American R-1 code. Variations with the R-1 code are shown in Table 7.3. The CCITT No. 5 line signaling code is also shown in Table 7.4.

Table 7.2 North American R-1 Code[a]

Digit	Frequency Pair (Hz)
1	700 + 900
2	700 + 1100
3	900 + 1100
4	700 + 1300
5	900 + 1300
6	1100 + 1300
7	700 + 1500
8	900 + 1500
9	1100 + 1500
10 (0)	1300 + 1500

Use	Frequency Pair	Explanation
KP	1100 + 1700	Preparatory for digits
ST	1500 + 1700	End-of-pulsing sequence
STP	900 + 1700	
ST2P	1300 + 1100	Used with TSPS (traffic service position system)
ST3P	700 + 1700	
Coin collect	700 + 1100	Coin control
Coin return	1100 + 1700	Coin control
Ring-back	700 + 1700	Coin control
Code 11	700 + 1700	Inward operator (CCITT No. 5)
Code 12	900 + 1700	Delay operator
KP1	1100 + 1700	Terminal call
KP2	1300 + 1700	Transit call

[a]Pulsing of digits is at the rate of about seven digits per second with an interdigital period of 68 ± 7 msec. For intercontinental dialing for CCITT No. 5 code compatibility, the R-1 rate is increased to 10 digits per second. The KP pulse duration is 100 msec.

Source: Ref. 4.

Table 7.3 CCITT No. 5 Code Showing Variations with the R-1 Code[a]

Signal	Frequencies (Hz)	Remarks
KP1	1100 + 1700	Terminal traffic
KP2	1300 + 1700	Transit traffic
1	700 + 900	
2	700 + 1100	
3–0	Same as Table 7.2	
ST	1500 + 1700	
Code 11	700 + 1700	Code 11 operator
Code 12	900 + 1700	Code 12 operator

[a]Line signaling for CCITT No. 5 code is 2VF, with f_1 2400 Hz and f_2 2600 Hz. Line-signaling conditions are shown in Table 7.4.

Source: Ref. 5.

Table 7.4 CCITT No. 5 Line Signaling Code

Signal	Direction	Frequency	Sending Duration	Recognition Time (msec)
Seizing	→	f_1	Continuous	40 ± 10
Proceed to send	←	f_2	Continuous	40 ± 10
Busy flash	←	f_2	Continuous	125 ± 25
Acknowledgment	→	f_1	Continuous	125 ± 25
Answer	←	f_1	Continuous	125 ± 25
Acknowledgment	→	f_1	Continuous	125 ± 25
Clear back	←	f_2	Continuous	125 ± 25
Acknowledgment	→	f_1	Continuous	125 ± 25
Forward transfer	→	f_2	850 ± 200 msec	125 ± 25
Clear forward	→	$f_1 + f_2$	Continuous	125 ± 25
Release guard	←	$f_1 + f_2$	Continuous	125 ± 25

Source: Ref. 4.

R-2 CODE. The R-2 code has been denominated by CCITT (CCITT Rec. Q.361) as a European regional signaling code. Taking full advantage of combinations of two-out-of-six tone frequencies, 15 frequency pair possibilities are available. This number is doubled in each direction by having meaning in groups I and II in the forward direction (i.e., toward the called subscriber) and groups A and B in the backward direction, as shown in Table 7.5.

Groups I and A are said to be of primary meaning, and groups II and B are said to be of secondary meaning. The change from primary to secondary meaning is commanded by the backward signal A-3 or A-5. Secondary meanings can be changed back to primary meanings only when the original change from primary to secondary was made by the use of the A-5 signal. Turning to Table 7.5, the 10 digits to be sent in the forward direction in the R-2 system are in group I and are index numbers 1 through 10 in the table. The index 15 signal (group A) indicates “congestion in an international exchange or at its output.” This is a typical backward information signal giving circuit status information. Group B consists of nearly all “backward information” and, in particular, deals with subscriber status.

The R-2 line-signaling system has two versions: the one used on analog networks is discussed here; the other, used on E-1 PCM networks, was briefly covered in Chapter 6. The analog version is an out-of-band tone-on-when-idle system. Table 7.6 shows the line conditions in each direction, forward and backward. Note that the code takes advantage of

Table 7.5 European R-2 Signaling System

	Frequencies (Hz)						
	1380	1500	1620	1740	1860	1980	Forward Direction I/II
Index No. for Groups I/II and A/B	1140	1020	900	780	660	540	Backward Direction A/B
1	×	×					
2	×		×				
3		×	×				
4	×			×			
5		×		×			
6			×	×			
7	×				×		
8		×			×		
9			×		×		
10				×	×		
11	×					×	
12		×				×	
13			×			×	
14				×		×	
15					×	×	

Source: Ref. 6.

Table 7.6 Line Conditions for the R-2 Code

Operating Condition of the Circuit	Signaling Conditions	
	Forward	Backward
1. Idle	Tone on	Tone on
2. Seized	Tone off	Tone on
3. Answered	Tone off	Tone off
4. Clear back	Tone off	Tone on
5. Release	Tone on	Tone on or off
6. Blocked	Tone on	Tone off

Source: Ref. 6.

a signal sequence that has six characteristic operating conditions. Let us consider several of these conditions.

Seized The outgoing exchange (call-originating exchange) removes the tone in the forward direction. If seizure is immediately followed by release, removal of the tone must be maintained for at least 100 msec to ensure that it is recognized at the incoming end.

Answered The incoming end removes the tone in the backward direction. When another link of the connection using tone-on-when-idle continuous signaling precedes the outgoing exchange, the "tone-off" condition must be established on the link as soon as it is recognized in this exchange.

Clear Back The incoming end restores the tone in the backward direction. When another link of the connection using tone-on-when-idle continuous signaling precedes the outgoing exchange, the "tone-off" condition must be established on this link as soon as it is recognized in this exchange.

Clear Forward The outgoing end restores the tone in the forward direction.

Table 7.7 Audible Call Progress Tones Commonly Used in North America

Tone	Frequencies (Hz)	Cadence
Dial	350 + 440	Continuous
Busy (station)	480 + 620	0.5 sec on, 0.5 sec off
Busy (network congestion)	480 + 620	0.2 sec on, 0.3 sec off
Ring return	440 + 480	2 sec on, 4 sec off
Off-hook alert	Multifrequency howl	1 sec on, 1 sec off
Recording warning	1400	0.5 sec on, 15 sec off
Call waiting	440	0.3 sec on, 9.7 sec off

Source: Ref. 7.

Table 7.8 North American Push-Button Codes

Digit	Dial Pulse (Breaks)	Multifrequency Push-Button Tones
0	10	941,1336 Hz
1	1	697,1209 Hz
2	2	697,1336 Hz
3	3	697,1474 Hz
4	4	770,1209 Hz
5	5	770,1336 Hz
6	6	770,1477 Hz
7	7	852,1209 Hz
8	8	852,1336 Hz
9	9	852,1477 Hz

Source: Ref. 7

Blocked At the outgoing exchange the circuit stays blocked as long as the tone remains off in the backward direction.

7.3.3 Subscriber Call Progress Tones and Push-Button Codes (North America)

Table 7.7 shows the audible call progress tones commonly used in North America as presented to a subscriber. Subscriber subsets are either dial or push-button, and they will probably be all push-button in the next 10 years. A push-button actuates two audio tones simultaneously, similar to the multifrequency systems described previously with interregister signaling. However, the tone library used by the subscriber is different than the tone library used with interregister signaling. Table 7.8 compares digital dialed, dial pulses (breaks), and multifrequency (MF) push-button tones.

7.4 COMPELLED SIGNALING

In many of the signaling systems discussed thus far, signal element duration is an important parameter. For instance, in a call setup an initiating exchange sends a 100-msec seizure signal. Once this signal is received at the distant end, the distant exchange sends a "proceed to send" signal back to the originating exchange; in the case of the R-1 system, this signal is 140 msec or more in duration. Then, on receipt of "proceed to send" the initiating exchange spills all digits forward. In the case of R-1, each digit is an MF pulse of 68-msec duration with 68 msec between each pulse. After the last address digit an ST (end-of-pulsing) signal is sent. In the case of R-1 the incoming (far-end) switch register knows the number of digits to expect. Consequently there is an explicit acknowledgment that the call setup has proceeded satisfactorily. Thus R-1 is a good example of noncompelled signaling.

A fully compelled signaling system is one in which each signal continues to be sent until an acknowledgment is received. Thus signal duration is not significant and bears no meaning. The R-2 and SOCOTEL are examples of fully compelled signaling systems.[3] Figure 7.4 illustrates a fully compelled signaling sequence. Note the small overlap of signals, causing the acknowledging (reverse) signal to start after a fixed time on receipt of the forward signal. This is because of the minimum time required for recognition of the incoming signal. After the initial forward signal, further forward signals are delayed for a short recognition time (see Figure 7.4). Recognition time is normally less than 80 msec.

Fully compelled signaling is advantageous in that signaling receivers do not have to measure duration of each signal, thus making signaling equipment simpler and more economical. Fully compelled signaling adapts automatically to the velocity of propagation, to long circuits, to short circuits, to metallic pairs, or to carrier and is designed to withstand short interruptions in the transmission path. The principal drawback of compelled signaling is its inherent lower speed, thus requiring more time for setup. Setup time over

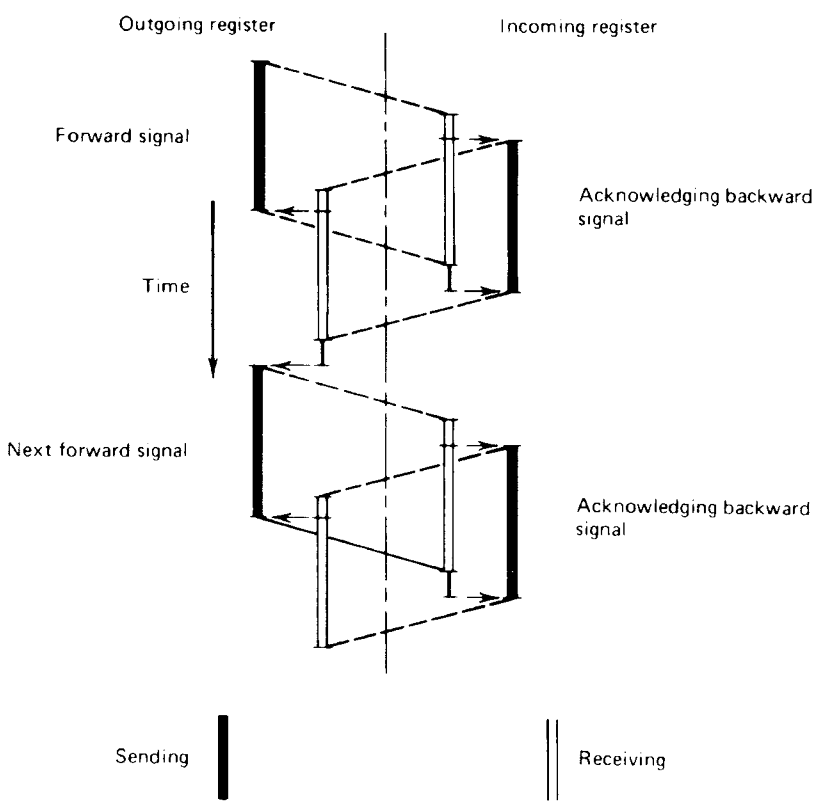


Figure 7.4 Fully compelled signaling procedure.

[3]SOCOTEL is a European multifrequency signaling system used principally in France and Spain.

space-satellite circuits with compelled signaling is appreciable and may force the system engineer to seek a compromise signaling system.

There is also a partially compelled type of signaling, where signal duration is fixed in both forward and backward directions according to system specifications; or the forward signal is of indefinite duration and the backward signal is of fixed duration. The forward signal ceases once the backward signal has been received correctly. CCITT Signaling System No. 4 (not discussed in this text; see CCITT Recs. Q.120 to 130) is an example of a partially compelled signaling system.

7.5 CONCEPTS OF LINK-BY-LINK VERSUS END-TO-END SIGNALING

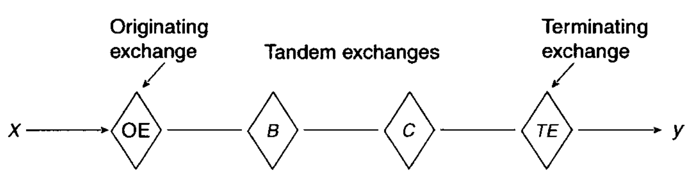
An important factor to be considered in switching system design that directly affects both signaling and customer satisfaction is postdialing delay. This is the amount of time it takes after the calling subscriber completes dialing until ring-back is received. Ring-back is a backward signal to the calling subscriber indicating that the dialed number is ringing. Postdialing delay must be made as short as possible.

Another important consideration is register occupancy time for call setup as the setup proceeds from originating exchange to terminating exchange. Call-setup equipment, that equipment used to establish a speech path through a switch and to select the proper outgoing trunk, is expensive. By reducing register occupancy per call, we may be able to reduce the number of registers (and markers) per switch, thus saving money.

Link-by-link and end-to-end signaling each affect register occupancy and postdialing delay, each differently. Of course, we are considering calls involving one or more tandem exchanges in a call setup, because this situation usually occurs on long-distance or toll calls. Link-by-link signaling may be defined as a signaling system where *all* interregister address information must be transferred to the subsequent exchange in the call-setup routing. Once this information is received at this exchange, the preceding exchange control unit (register) releases. This same operation is carried on from the originating exchange through each tandem (transit) exchange to the terminating exchange of the call. The R-1 system is an example of link-by-link signaling.

End-to-end signaling abbreviates the process such that tandem (transit) exchanges receive only the minimum information necessary to route the call. For instance, the last four digits of a seven-digit telephone number need be exchanged only between the originating exchange (e.g., the calling subscriber's local exchange or the first toll exchange in the call setup) and the terminating exchange in the call setup. With this type of signaling, fewer digits are required to be sent (and acknowledged) for the overall call-setup sequence. Thus the signaling process may be carried out much more rapidly, decreasing postdialing delay. Intervening exchanges on the call route work much less, handling only the digits necessary to pass the call to the next exchange in the sequence.

The key to end-to-end signaling is the concept of "leading register." This is the register (control unit) in the originating exchange that controls the call routing until a speech path is setup to the terminating exchange before releasing to prepare for another call setup. For example, consider a call from subscriber X to subscriber Y:



The telephone number of subscriber Y is 345−6789. The sequence of events is as follows using end-to-end signaling:

- A register at exchange OE receives and stores the dialed number 345−6789 from subscriber X.
- Exchange OE analyzes the number and then seizes a trunk (junction) to exchange B. It then receives a "proceed-to-send" signal indicating that the register at B is ready to receive routing information (digits).
- Exchange OE then sends digits 34, which are the minimum necessary to effect correct transit.
- Exchange B analyzes the digits 34 and then seizes a trunk to exchange C. Exchanges OE and C are now in direct contact and exchange B's register releases.
- Exchange OE receives the "proceed-to-send" signal from exchange C and then sends digits 45, those required to effect proper transit at C.
- Exchange C analyzes digits 45 and then seizes a trunk to exchange TE. Direct communication is then established between the leading register for this call at OE and the register at TE being used on this call setup. The register at C then releases.
- Exchange OE receives the "proceed-to-send" signal from exchange TE, to which it sends digits 5678, the subscriber number.
- Exchange TE selects the correct subscriber line and returns to A ring-back, line busy, out of order, or other information after which all registers are released.

Thus we see that a signaling path is opened between the leading register and the terminating exchange. To accomplish this, each exchange in the route must "know" its local routing arrangements and request from the leading register those digits it needs to route the call further along its proper course.

Again, the need for backward information becomes evident, and backward signaling capabilities must be nearly as rich as forward signaling capabilities when such a system is implemented.

R-1 is a system inherently requiring little backward information (interregister). The little information that is needed, such as "proceed to send," is sent via line signaling. The R-2 system has major backward information requirements, and backward information and even congestion and busy signals sent back by interregister signals (Ref. 5).

7.6 EFFECTS OF NUMBERING ON SIGNALING

Numbering, the assignment and use of telephone numbers, affects signaling as well as switching. It is the number or the translated number, as we found out in Section 1.3.2, that routes the call. There is "uniform" numbering and "nonuniform" numbering. How does each affect signaling? Uniform numbering can simplify a signaling system. Most uniform systems in the nontoll or local-area case are based on seven digits, although some are based on six. The last four digits identify the subscriber. The first three digits (or the first two in the case of a six-digit system) identify the exchange. Thus the local exchange or transit exchanges know when all digits are received. There are two advantages to this sort of scheme:

1. The switch can proceed with the call once all digits are received because it "knows" when the last digit (either the sixth or seventh) has been received.

2. “Knowing” the number of digits to expect provides inherent error control and makes “timeout” simpler.[4]

For nonuniform numbering, particularly on direct distance dialing in the international service, switches require considerably more intelligence built in. It is the initial digit or digits that will tell how many digits are to follow, at least in theory.

However, in local or national systems with nonuniform numbering, the originating register has no way of knowing whether it has received the last digit, with the exception of receiving the maximum total used in the national system. With nonuniform numbering, an incompletely dialed call can cause a useless call setup across a network up to the terminating exchange, and the call setup is released only after time out has run its course. It is evident that with nonuniform numbering systems, national (and international) networks are better suited to signaling systems operating end to end with good features of backward information, such as the R-2 system (Ref. 5).

7.7 ASSOCIATED AND DISASSOCIATED CHANNEL SIGNALING

Here we introduce a new concept: disassociated channel signaling. Up to now we have only considered associated channel signaling. In other words, the signaling is carried right

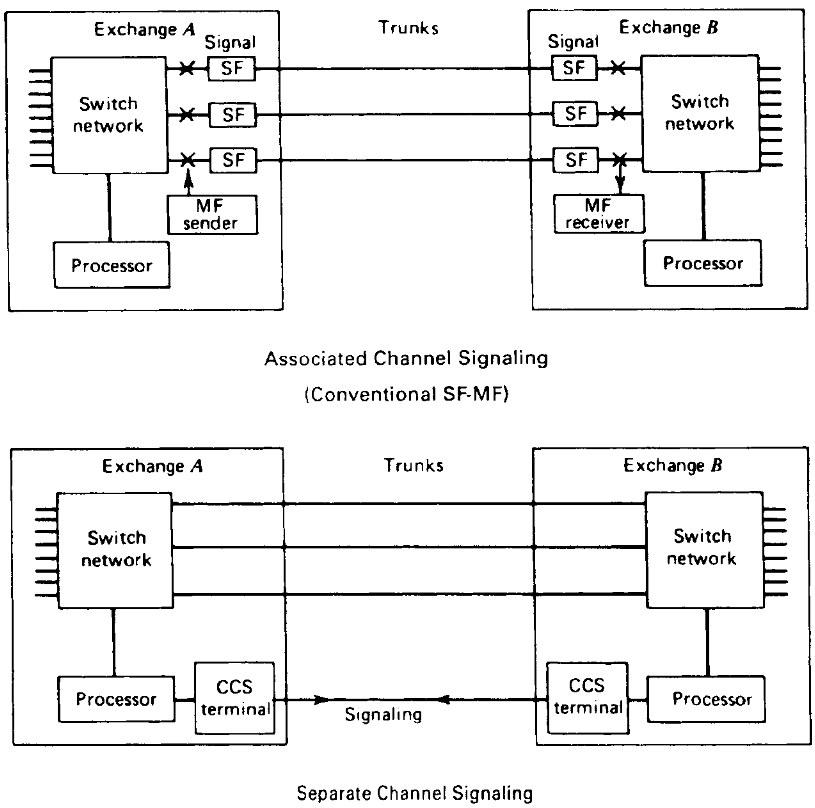


Figure 7.5 Conventional analog associated channel signaling (*upper*) versus separate channel signaling (which we call quasi-associated channel signaling) (*lower*). *Note*: Signaling on upper drawing accompanies voice paths; signaling on the lower drawing is conveyed on a separate circuit (or time slot). CCS stands for common channel signaling such as CCITT Signaling System No. 7.

[4]“Timeout” is the resetting of call-setup equipment and return of dial tone to subscriber as a result of incomplete signaling procedure, subset left off hook, and so forth.

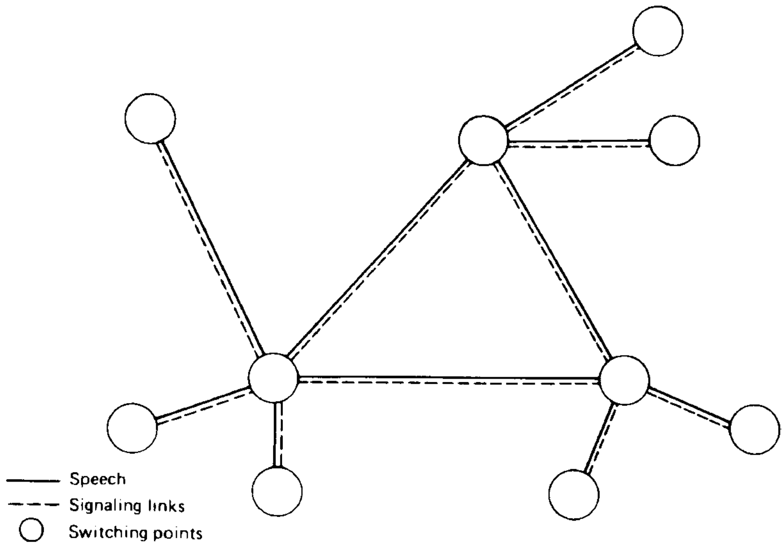


Figure 7.6 Quasi-associated channel signaling, typical of E-1 channel 16. As shown, the signaling travels on a separate channel but associated with its group of traffic channels for which it serves. If it were conventional analog signaling, it would be just one solid line, where the signaling is embedded with its associated traffic.

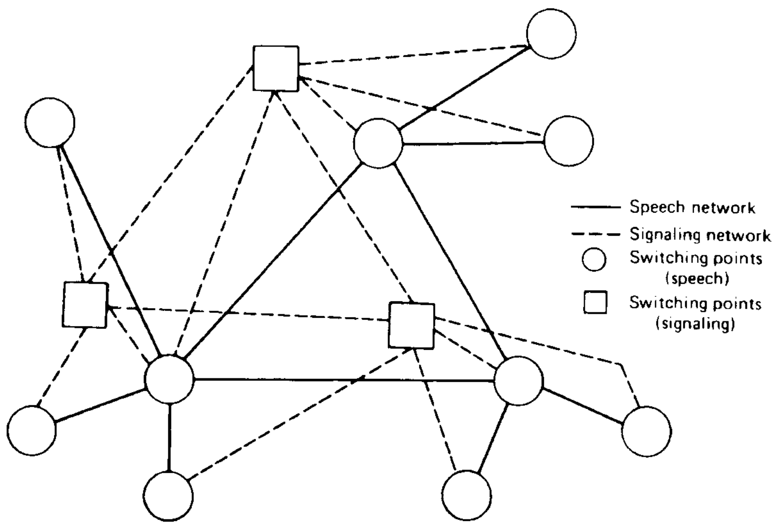


Figure 7.7 Fully disassociated channel signaling. This signaling may be used with CCITT Signaling System No. 7, described in Chapter 14.

on its associated voice channel, whether in-band or out-of-band. Figure 7.5 illustrates two concepts: associated channel and separate channel signaling, but still associated. E-1 channel 16 is an example. It is indeed a separate channel, but associated with the 30-channel group of traffic channels. We will call this *quasi-associated channel signaling*.

Disassociated channel signaling is when signaling travels on a separate and distinct route than the traffic channels for which it serves. CCITT Signaling System No. 7 uses either this type of signaling or quasi-associated channel signaling. Figure 7.6 illustrates quasi-associated channel signaling, whereas Figure 7.7 shows fully disassociated channel signaling.

7.8 SIGNALING IN THE SUBSCRIBER LOOP

7.8.1 Background and Purpose

In Section 5.4 we described loop-start signaling, although we did not call it that. When a subscriber takes a telephone off-hook (out of its cradle), there is a switch closure at the subset (see the hook-switch in Figure 5.3), current flows in the loop alerting the serving exchange that service is desired on that telephone. As a result, dial tone is returned to the subscriber. This is basic supervisory signaling on the subscriber loop.

A problem can arise from this form of signaling. It is called *glare*. Glare is the result of attempting to seize a particular subscriber loop from each direction. In this case it would be an outgoing call and an incoming call nearly simultaneously. There is a much greater probability of glare with a PABX than with an individual subscriber.

Ground-start signaling is the preferred signaling system when lines terminate in a switching system such as a PABX. It operates as follows: When a call is from the local serving switch to the PABX, the local switch immediately grounds the conductor tip to seize the line. With some several seconds delay, ringing voltage is applied to the line (where required). The PABX immediately detects the grounded tip conductor and will not allow an outgoing call from the PABX to use this circuit, thus avoiding glare.

In a similar fashion, if a call originates at the PABX and is outgoing to the local serving exchange, the PABX grounds the ring conductor to seize the line. The serving switch recognizes this condition and prevents other calls from attempting to terminate the circuit. The switch now grounds the tip conductor and returns dial tone after it connects a digit receiver. There can be a rare situation when double seizure occurs, causing glare. Usually one or the other end of the circuit is programmed to back down and allow the other call to proceed. A ground start interface is shown in Figure 7.8.

Terminology in signaling often refers back to manual switchboards or, specifically, to the plug used with these boards and its corresponding jack as illustrated in Figure 7.9. Thus we have tip (T), ring (R), and sleeve (S). Often only the tip and ring are used, and the sleeve is grounded and has no real electrical function.

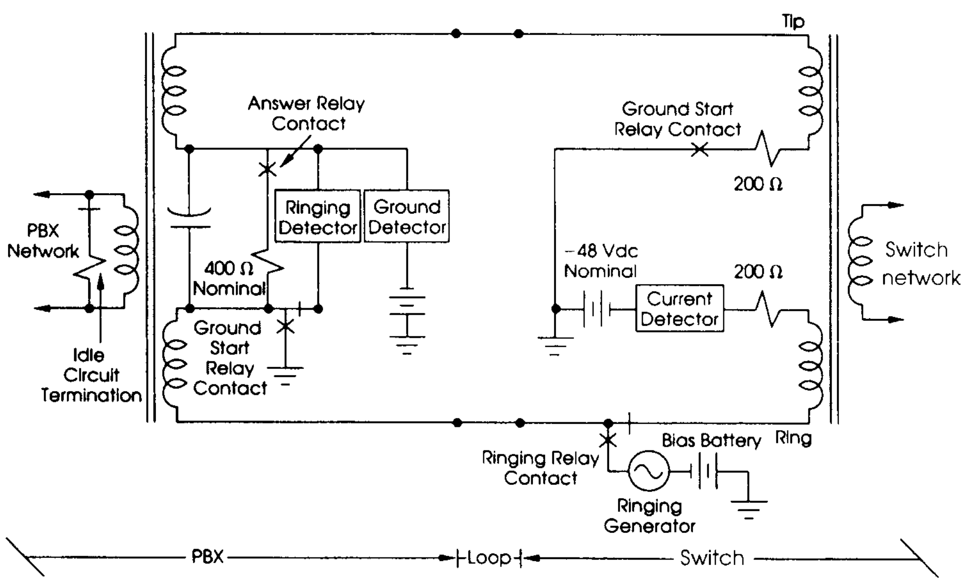


Figure 7.8 Ground-start interface block diagram. (From Figure 2-7 of Ref. 8, reprinted with permission.)

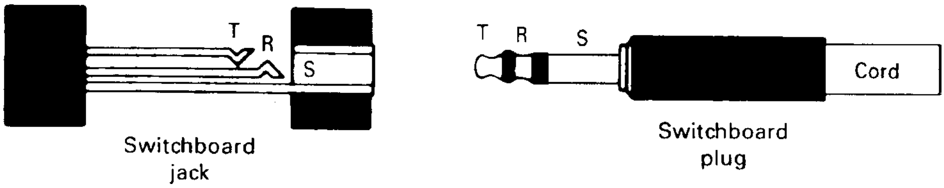


Figure 7.9 Switchboard plug with corresponding jack (R, S, and T are ring, sleeve, and tip, respectively).

7.9 METALLIC TRUNK SIGNALING

7.9.1 Basic Loop Signaling

As mentioned earlier, many trunks serving the local area are metallic-pair trunks. They are actually loops much like the subscriber loop. Some still use dial pulses for address signaling along with some form of supervisory signaling.

Loop signaling is commonly used for supervision. As we would expect, it provides two signaling states: one when the circuit is opened and one when the circuit is closed. A third signaling state is obtained by reversing the direction or changing the magnitude of the current in the circuit. Combinations of (1) open/close, (2) polarity reversal, and (3) high/low current are used for distinguishing signals intended for one direction of signaling (e.g., dial-pulse signals) from those intended for the opposite direction (e.g., answer signals). We describe the most popular method of supervision on metallic pair trunks below, namely, reverse-battery signaling.

7.9.2 Reverse-Battery Signaling

Reverse-battery signaling employs basic methods (1) and (2) just mentioned, and takes its name from the fact that battery and ground are reversed on the tip and ring to change the signal toward the calling end from on-hook to off-hook. Figure 7.10 shows a typical application of reverse-battery signaling in a common-control path.

In the idle or on-hook condition, all relays are unoperated and the switch (SW) contacts are open. Upon seizure of the outgoing trunk by the calling switch (exchange) (trunk group selection based on the switch or exchange code dialed by the calling subscriber), the following occur:

- SW1 and SW2 contacts close, thereby closing loop to called office (exchange) and causing the A relay to operate.
- Operation of the A relay signals off-hook (connect) indication to the called switch (exchange).

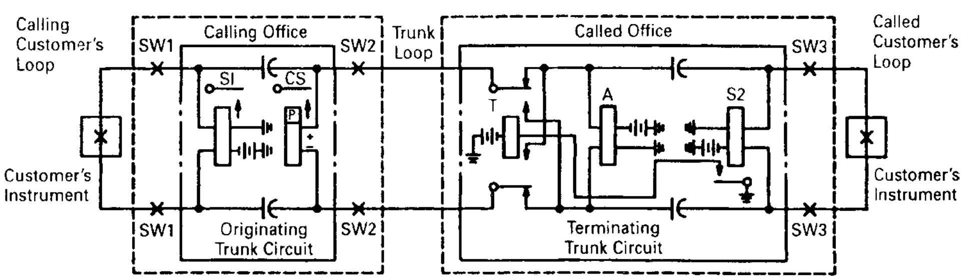


Figure 7.10 Reverse-battery signaling. (From Figure 6-27 of Ref. 7, reprinted with permission.)

- Upon completion of pulsing between switches, SW3 contacts close and the called subscriber is alerted. When the called subscriber answers, the S2 relay is operated.
- Operation of the S2 relay operates the T relay, which reverses the voltage polarity on the loop to the calling end.
- The voltage polarity causes the CS relay to operate, transmitting an off-hook (answer) signal to the calling end.

When the calling subscriber hangs up, disconnect timing starts (between 150 msec and 400 msec). After the timing is completed, SW1 and SW2 contacts are released in the calling switch. This opens the loop to the A relay in the called switch and releases the calling subscriber. The disconnect timing (150−400 msec) is started in the called switch as soon as the A relay releases. When the disconnect timing is completed, the following occur:

- If the called subscriber has returned to on-hook, SW3 contacts release. The called subscriber is now free to place another call.
- If the called subscriber is still off-hook, disconnect timing is started in the called switch. On the completion of the timing interval, SW3 contacts open. The called subscriber is then returned to dial tone. If the circuit is seized again from the calling switch during the disconnect timing, the disconnect timing is terminated and the called subscriber is returned to dial tone. The new call will be completed without interference from the previous call.

When the called subscriber hangs up, the CS relay in the calling switch releases. Then the following occur:

- If the calling subscriber has also hung up, disconnection takes place as previously described.
- If the calling subscriber is still off-hook, disconnect timing is started. On the completion of the disconnect timing, SW1 and SW2 contacts are opened. This returns the calling subscriber to dial tone and releases the A relay in the called switch. The calling subscriber is free to place a new call at this time. After the disconnect timing, the SW3 contacts are released, which releases the called subscriber. The called subscriber can place a new call at this time.