



ATIS-0100302.1989(R2006)

**DIGITAL PROCESSING OF VOICE-BAND SIGNALS LINE FORMAT FOR 32-KBITS ADAPTIVE DIFFERENTIAL PULSE-CODE MODULATION (ADPCM)**

**AMERICAN NATIONAL STANDARD FOR TELECOMMUNICATIONS**



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# Foreword (This Foreword is not part of American National Standard T1.302-1989)

For over 20 years, Pulse-Code Modulation (PCM) at 64-kbit/s has been considered the standard for quality digital encoding of voice channels. New 32-kbit/s Adaptive Differential Pulse-Code Modulation (ADPCM) terminals have recently been made available for use in the network, which yield only slightly lower quality of speech than 64-kbit/s PCM and which permit voice-band data up to 2.4 kbit/s without significant degradation. High-speed data at 4.8 kbit/s can be accommodated when used in accordance with American National Standard for Telecommunications — Network Performance — Tandem Encoding Limits for 32-kbit/s Adaptive Differential Pulse-Code Modulation (ADPCM), ANSI T1.501-1988. These terminals use the known statistics of the voice signal and feature speech processing made possible by very-large-scale-integration (VLSI) technology. With these currently available low bit-rate voice (LBRV) terminals, it is possible to double the voice channel capacity of existing digital facilities. Various line formats are used by the various vendors of LBRV products to transport signaling in the ADPCM channel.

The purpose of this American National Standard is to standardize three line formats so that vendors can provide compatible equipment for the U.S. marketplace and so that both exchange and interexchange carriers may operate compatibly. The three line formats are Bundle, Transition, and Robbed-Bit Signaling. The algorithms that are necessary for these line formats are specified in American National Standard for Telecommunications — Digital Processing of Voice-Band Signals — Algorithms for 24-, 32-, and 40-kbit/s Adaptive Differential Pulse-Code Modulation (ADPCM), ANSI T1.303-1989. This standard, together with ANSI T1.303-1989, supersedes American National Standard for Telecommunications — Digital Processing of Voice-Band Signals — Algorithm and Line Format for 32-kbit/s Adaptive Differential Pulse-Code Modulation (ADPCM), ANSI T1.301-1987. It is expected that equipment manufacturers and carriers will utilize both ANSI T1.302-1989 and T1.303-1989.

Suggestions for improvement of this standard will be welcome. They should be sent to the Exchange Carriers Standards Association, 5430 Grosvenor Lane, Bethesda, MD 20814.

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# American National Standard for Telecommunications –

## Digital Processing of Voice-Band Signals – Line Format for 32-kbits Adaptive Differential Pulse-Code Modulation (ADPCM)

### 1.1 Scope, Purpose, and Application

#### 1.1 Scope

1.1.1 This standard applies to Adaptive Differential Pulse-Code Modulation (ADPCM) telecommunications systems where the channel pulse rate is 32 kbit/s.

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1.1.2 This standard provides for line formats used in Bundle, Transition, and Robbed-Bit Signaling modes for transcoded channels comprising channel pulse rates of 32 kbit/s combined in a line format operating at a pulse rate of 1544 kbit/s.

Section 3 of American National Standard for Telecommunications — Digital Processing of Voice-Band Signals — Algorithms for 24-, 32-, and 40-kbit/s Adaptive Differential Pulse-Code Modulation (ADPCM), ANSI T1.303-1989, specifies the 24- and 32-kbit/s ADPCM algorithms. Therefore

the low bit-rate voice (LBRV) terminals that use the Bundle and Transition signaling line formats shall comply with the 32-kbit/s algorithm and those terminals that use the Robbed-Bit signaling line format shall comply with the 24- and 32-kbit/s algorithms as described in that section.

1.1.3 This standard provides for interface specification defining bit formats and actions associated with transcoder interfaces that use these line formats.

1.2 Purpose and Application The 48-channel transcoder provides for the conversion between two 24-channel 1544-kbit/s PCM streams (ports X and Y) and one 48-channel 1544-kbit/s ADPCM stream (port Z). In the 24-channel 1544-kbit/s streams, the voice frequency signals are coded at 64 kbit/s according to the PCM  $\mu$ -law defined in CCITT Red Book Volume III, Recommendation G.711, Pulse Code Modulation (PCM) of Voice Frequencies. In the 48-channel 1544-kbit/s stream, the voice frequency signals are coded using 4 bits per channel according to the ADPCM algorithm in ANSI T1.303-1989.

Figure 1 represents the nomenclature used for the three different signal ports X, Y, and Z.

This standard contains the interface requirements associated with the line formats for 44- to 48-channel transcoders and is divided into four parts: Section 2 provides a listing of referenced

standards, Sections 3, 4, and 5 describe the line formats for transcoders using the Bundle Format, Transition Signaling, and Robbed-Bit Signaling, respectively. Selection of a transcoder employing a particular line format will be based upon the specific application needs.

## 2. Referenced Standards

### 2.1 Referenced American National Standards.

This standard is intended to be used in conjunction with the following American National Standards.

ANSI T1.102-1987, Telecommunications — Digital Hierarchy — Electrical Interfaces

ANSI T1.107-1988, Telecommunications — Digital Hierarchy — Formats Specifications

ANSI T1.303-1989, Telecommunications — Digital Processing of Voice-Band Signals — Algorithms for 24-, 32-, and 40-kbit/s Adaptive Differential Pulse-Code Modulation (ADPCM)

ANSI T1.501-1988, Telecommunications — Network Performance — Tandem Encoding Limits for 32-kbit/s Adaptive Differential Pulse-Code Modulation (ADPCM)

**2.2 Other Referenced Standards** This standard is also intended to be used in conjunction with the following standards.

CCITT Recommendation G.711, Pulse Code Modulation (PCM) of Voice Frequencies, Red Book Volume III, Fascicle III.3, pp 85–93<sup>1</sup>

CCITT Recommendation G.721, 32 kbit/s Adaptive Differential Pulse Code Modulation (ADPCM), Red Book Volume III, Fascicle III.3, pp 125–159<sup>1</sup>

## 3. Transcoders Using Bundle Format

This section concerns 48-channel transcoders using channel-associated signaling where the signaling bits are transported in signaling channels called delta channels. This signaling is called the Bundle Format.

<sup>1</sup> Available from: American National Standards Institute, 1430 Broadway, New York, NY 10018, (212) 642-4995

### 3.1 Characteristics of a 1544-kbit/s Signal Organized in 32-kbit/s Time-Slots, 64-kbit/s Time-Slots or Both (Port Z)

**3.1.1 Interface Z.** The electrical characteristics of the 1544-kbit/s interface shall be in accordance with ANSI T1.102-1987.

**3.1.2 Frame Structure.** The 1544-kbit/s signal is organized in frames of 193 bits. The frame repetition rate is 8000 Hz. Each frame is comprised of forty-eight 4-bit time-slots, numbered from 1 to 48, plus the framing bit in the first bit position. The bit ordering of the 32-kbit/s signals is such that the 4-bit words are transmitted in numbered order starting with bit 1, the sign bit, as specified in 2.2.3 and 2.2.4 of CCITT Recommendation G.721.

**3.1.2.1 DS1 Frame and Multiframe Alignment Signal.** The first bit conveys the DS1 frame alignment signal and multiframe alignment signal, as specified in ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe. Selection of either the 24-frame multiframe or 12-frame multiframe format at port Z is independent of frame formats selected at ports X and Y.

**3.1.2.1.1 24-Frame Multiframe.** The F-bit shall be used for transport of framing and CRC-6 information, as defined in ANSI T1.107-1988. The use of the F-bit for transport of the 4-kbit/s data link, as defined in ANSI T1.107-1988, is a subject for further study.

**3.1.2.1.2 12-Frame Multiframe.** The frame alignment signal occupies the first bit position of every other frame, as defined in ANSI T1.107-1988. The S-bit is used to carry the multiframe alignment signal, as defined in ANSI T1.107-1988. The S-bit is in the frames that do not carry the frame alignment bits.

**3.1.2.2 Loss and Recovery of Frame and Multiframe Alignment.** The criteria for loss and recovery of the frame alignment and multiframe alignment signal for port Z shall be in accordance with ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe.

**3.1.2.3 48-Channel Frame Format.** In the case in which streams X and Y are each carrying 24 voice-frequency signals and no channel-associated signaling information is present, stream Z shall transmit the full complement of 48 channels. Table 1 shows the correspondence between the 64-kbit/s PCM channels in streams X and Y and the 32-kbit/s ADPCM channels in stream Z. Time-slots 1–12 correspond to channels 1–12 from PCM stream X coded with

4 bits. Time-slots 13–24 correspond to channels 13–24 from PCM stream X coded with 4 bits. Time-slots 25–36 correspond to channels 1–12 from PCM stream Y coded with 4 bits. Time-slots 37–48 correspond to channels 13–24 from PCM stream Y coded with 4 bits.

**3.1.2.4 384-kbit/s Bundle Format.** The organization of the 1544-kbit/s stream associated with port Z is structured to provide four independent 384-kbit/s bundles. The bundles are numbered 1–4, and are transmitted in numbered order starting with bundle 1.

As shown in Table 1, each 384-kbit/s bundle consists of twelve 32-kbit/s time-slots providing the capacity to transport up to twelve 32-kbit/s voice frequency channels. When channel-associated a-b-c-d signaling is present in X and Y, the 384-kbit/s bundle will consist of eleven 32-kbit/s channels and a 32-kbit/s channel defined as the delta channel.

**3.1.2.4.1 Delta Channel.** The delta channel conveys the channel-associated a-b-c-d signaling information, the delta channel alarm information, the delta channel multiframe alignment signal and CRC-6 error detection information between transcoders.

The delta channels for bundles 1–4, when present in stream Z, occupy time-slots 12, 24, 36, and 48, respectively. As shown in Table 2, the channel capacity for stream X (respectively, Y) is reduced by one for each bundle associated with stream X (respectively, Y) configured with a delta channel. Selection of the bundle format to include the delta channel is made on a per-bundle basis, independent of the other bundles associated with stream X or Y.

**3.1.2.4.2 Unused Channels.** As explained in 3.1.2.4, the presence of a delta channel in a bundle causes a given channel in stream X or Y to be configured as unused.

The unused channels on the receive side of streams X and Y shall have their data conditioned in a way compatible with downstream equipment; for example, unequipped channel requirements shall be as defined in ANSI T1.107-1988 for channel banks.

For unused channels, the channel-associated signaling bits on the receive side of streams X and Y shall be set to 1 to simulate the seized condition.

The unused channels on the send side of streams X and Y are not processed.

**3.1.2.5 Delta Channel Multiframe Structure.** A delta channel is allocated 4 bits per

frame, providing for a 32-kbit/s channel. The bits are numbered 1 through 4 and are transmitted in order starting with bit number 1. The delta channel multiframe consists of 24 consecutive frames numbered from 1 to 24.

The channel-associated a-b-c-d signaling information is carried in bits 1 and 2. The delta channel alarm indication information is carried in bit 2. The delta channel multiframe alignment signal is carried in bit 3. The bundle CRC-6 error detection information is carried in bit 4. Capacity is reserved in bit 4 for future uses such as data links.

Table 3 shows the delta channel format including bundle alarm bits. In the case where no delta channel is provided, the strategy for responding to alarm conditions is for further study.

**3.1.2.5.1 Channel-Associated Signaling.** As indicated in Table 3, bits 1 and 2 of the delta channel convey the channel-associated signaling information present in all the channels of the associated bundle. The delta channel does not allocate bandwidth for the unused channel that is usurped by its presence.

The delta channel provides bandwidth for 16-state a-b-c-d signaling. Where only a-b signaling is present, the a-b signaling is repeated in the c-d signaling bits, respectively. No additional signaling distortion is introduced in stream Z since the delta channel signaling multiframe length is identical to the signaling multiframe length for ports X and Y.

**3.1.2.5.2 Delta Channel Alarm Indication Signals.** As indicated in Table 3, the delta channel contains three alarm indication bits (M1, M2, M3) and a summary bit (M4). M1, M2, and M3 are defined in 3.1.2.7. M4 is set by the send side whenever M1, M2, or M3 is set.

**3.1.2.5.3 Delta Channel Multiframe Alignment Signal.** Bit 3 of the delta channel, as shown in Table 3, contains the delta channel multiframe alignment signal used to associate the signaling bits in the delta channel with the proper channels of the associated bundle.

NOTE: The delta channel multiframe alignment signal is independent of and different from the framing bit of the 1544-kbit/s stream

**3.1.2.5.4 Bundle CRC-6 Error Detection Information.** As an option, a 2-kbit/s CRC-6 error detection code word may be transmitted in the bit positions indicated by CRC1 through CRC6 in Table 3. The CRC-6 generator polynomial is  $X^6 + X + 1$ . The first check bit, CRC1, is

the most significant bit (MSB) of the remainder; the last check bit, CRC6, is the least significant bit (LSB). The CRC-6 code word is a sequence of 1152 serial bits (4 bits/channel  $\times$  12 channels/frame  $\times$  24 frames/multiframe) that is coincident with a bundle multiframe. By definition, the  $N$ th code word begins at bit position 0 of bundle multiframe  $N$  and ends at bit position 1151 of bundle multiframe  $N$ . The delta channel is included in this calculation with bit 4 of the delta channel being set to 1. The CRC-6 code word is transmitted in the CRC1 through CRC6 bits of the next multiframe (bundle multiframe  $N + 1$ ).

The CRC-6 generator may be tested using the three patterns in Table 4 or the three test patterns shown in Table 5. The test patterns in Table 4 can only be used at the device level while those in Table 5 can be used at the DS1 interfaces of the ADPCM product. Each frame of the twenty-four frames within a multiframe is written with one test pattern. Bit 4 of the delta channel in each frame shall be set to 1. The CRC-6 generator shall generate the corresponding CRC-6 bits, when a test is performed correctly.

When not utilizing the option to transmit the CRC-6 error detection signal, CRC1 through CRC6 shall be set to 1. As an option, the receive side may utilize the incoming CRC-6 (if present) to determine bundle error performance.

#### 3.1.2.5.5 Delta Channel Data Links.

The bits marked U in Table 3 are currently unused and set to 1. These bits are reserved for future use as data links. The definition and allocation of these data links are for further study.

**3.1.2.6 Loss and Recovery of Delta Channel Multiframe Alignment.** Loss of the delta channel multiframe alignment signal is declared when 2 out of 4 delta channel framing bits are in error. The rare occurrence of a single instantaneous slip of  $\pm 11$  frames is undetected by this algorithm. When delta channel frame alignment is lost, updating of the channel-associated signaling bits on the receive side of streams X and Y shall be inhibited for the affected channels until frame alignment is regained.

Delta channel multiframe alignment shall be declared when the correct sequence of 24 valid delta channel framing bits are detected, beginning with the first frame of the multiframe. When frame alignment is declared, updating of the channel-associated signaling bits on the receive side of streams X and Y shall be enabled.

#### 3.1.2.7 Bundle Alarms.

A bundle Red alarm is declared when the delta channel multiframe alignment signal is lost for 2 to 3 seconds.

The bundle Red alarm is released when delta channel multiframe alignment has been reacquired for 10 to 20 seconds.

On the send side, M1 is used to transmit a bundle Yellow alarm to the remote end when the near end is in bundle Red alarm. On the receive side, a bundle Yellow alarm is declared when M1 has been set for 335 to 1000 milliseconds. Bundle Yellow alarm is released when M1 has been reset for 20 to 1000 milliseconds.

On the send side, M2 is used to indicate a DS1 Red or a DS1 AIS has been received on port X (bundles 1 or 2) or port Y (bundles 3 or 4). On the receive side, a bundle AIS-Red is declared when M2 has been set for 335 to 1000 milliseconds. Bundle AIS-Red is released when M2 has been reset for 20 to 1000 milliseconds.

On the send side, M3 is used to indicate a DS1 yellow has been received on port X (bundles 1 or 2) or port Y (bundles 3 or 4). On the receive side, a bundle AIS-yellow is declared when M3 has been set for 335 to 1000 milliseconds. Bundle AIS-yellow is released when M3 has been reset for 20 to 1000 milliseconds.

### 3.1.3 Fault Conditions and Consequent Actions Associated with Stream Z

**3.1.3.1 DS1 Fault Conditions.** A summary of the DS1 fault conditions associated with stream Z and the consequent actions are listed in Table 6.

The transcoder shall detect the following DS1 fault conditions associated with stream Z:

- (1) Loss of incoming signals at 1544 kbit/s
- (2) Loss of DS1 frame alignment
- (3) DS1 Alarm Indication Signal (AIS) received
- (4) Yellow alarm indication received from the remote end

All of these conditions are defined in more detail in ANSI T1.107-1988.

**3.1.3.2 Consequent Actions.** Upon detection of a DS1 fault conditions in stream Z, appropriate actions shall be taken that are in accordance with ANSI T1.107-1988. In addition, the following consequent actions shall be taken, as indicated in Table 6:

- (A) Declare a DS1 Red alarm on the receive side of port Z.
- (B) Send a DS1 Yellow alarm signal on the send side of port Z.
- (C) Apply an Alarm Indication Signal (AIS) to

the receive side of streams X and Y. The AIS consists of an all 1s signal in all channels, including the framing bit.

(D) Declare a DS1 AIS on the receive side of port Z.

(E) Declare a DS1 Yellow alarm on the receive side of port Z.

(F) Generate a DS1 Yellow alarm signal on the receive side of streams X and Y.

**3.1.3.3 Bundle Fault Conditions.** A summary of the bundle fault conditions associated with stream Z and the consequent actions are listed in Table 7.

The transcoder shall detect the following bundle fault conditions associated with stream Z:

(1) Loss of delta channel multiframe alignment on a single bundle associated with port X or a single bundle associated with port Y<sup>2</sup>

(2) Loss of delta channel multiframe alignment on both bundles associated with port X or both bundles associated with port Y

(3) Bundle Yellow alarm indication (M1) received from the remote end on a single bundle associated with port X or a single bundle associated with port Y

(4) Bundle Yellow alarm indication (M1) received from the remote end on both bundles associated with port X or both bundles associated with port Y

(5) Bundle AIS-Red (M2) received from the remote end on a single bundle associated with port X or a single bundle associated with port Y

(6) Bundle AIS-Red (M2) received from the remote end on both bundles associated with port X or both bundles associated with port Y

(7) Bundle AIS-Yellow (M3) received from the remote end on a single bundle associated with port X or a single bundle associated with port Y

(8) Bundle AIS-Yellow (M3) received from the remote end on both bundles associated with port X or both bundles associated with port Y

**3.1.3.4 Consequent Actions.** Upon detection of the bundle fault conditions in stream Z, the following consequent actions shall be taken, as indicated in Table 7:

(A) A bundle Red alarm condition shall be declared to signify that the delta channel multiframe alignment has been lost. A bundle Red alarm condition exists when the delta channel multiframe alignment signal has been lost for 2 to 3 seconds.

(B) A bundle Yellow alarm indication to the remote end shall be generated by forcing the M1 bit within the affected delta channel to 1.

(C) The data in the affected channels on the receive side of streams X or Y shall be conditioned to provide a signal that is compatible with downstream equipment. For example, ANSI T1.107-1988 provides restrictions on unequipped channel units in a channel bank.

(D) The channel-associated signaling bits in affected channels on the receive side of streams X or Y shall be conditioned to provide a signal that is compatible with downstream equipment. An example for most signaling types would be universal trunk conditioning, in which the signaling bits should be forced to the idle state for 2 to 3 seconds, and then conditioned to simulate the channel-seized condition.

(E) A DS1 AIS shall be applied to the receive side of stream X (for bundles 1 and 2) or stream Y (for bundles 3 and 4). The AIS consists of an all 1s signal in all channels including the framing bit.

(F) A bundle Yellow alarm condition shall be declared to indicate the reception of a bundle Yellow alarm indication in the M1 bit of the affected delta channel.

(G) A DS1 Yellow alarm signal shall be applied on the receive side of stream X (for bundles 1 and 2) and stream Y (for bundles 3 and 4).

(H) A bundle AIS-Red condition shall be declared to indicate the reception of a bundle AIS-red indication in the M2 bit of the affected delta channel.

(I) A bundle AIS-Yellow condition shall be declared to indicate the reception of a bundle AIS-Yellow indication in the M3 bit of the affected delta channel.

## 3.2 Characteristics of Ports X and Y

**3.2.1 Interfaces X and Y.** The electrical characteristics of the two interfaces X and Y at 1544 kbit/s shall be in accordance with ANSI T1.102-1987.

**3.2.2 Frame Structure of the 1544-kbit/s Streams X and Y.** The frame structure shall be in accordance with ANSI T1.107-1988. The 1544-kbit/s signal is organized in frames of 193 bits. The frame repetition rate is 8000 Hz. Each frame is comprised of twenty-four 8-bit time-slots, numbered from 1 to 24, plus the framing bit in the first bit position.

**3.2.2.1 DS1 Frame and Multiframe Alignment Signal.** The first bit shall convey the

<sup>2</sup> Bundles 1 and 2 are associated with port X Bundles 3 and 4 are associated with port Y

DS1 frame alignment signal and multiframe alignment signal as specified in ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe. Selection of either the 24-frame multiframe or 12-frame multiframe format at port X or Y is independent of frame formats selected at the other ports.

**3.2.2.1.1 24-Frame Multiframe.** The F-bit shall be used for transport of framing and CRC-6 information, as defined in ANSI T1.107-1988. The use of the F-bit for transport of the 4-kbit/s data link as defined in ANSI T1.107-1988 is a subject for further study.

**3.2.2.1.2 12-Frame Multiframe.** The frame alignment signal shall occupy the first bit position of every other frame, as defined in ANSI T1.107-1988. The S-bit shall be used to carry the multiframe alignment signal, as defined in ANSI T1.107-1988.

**3.2.2.2 Loss and Recovery of Frame and Multiframe Alignment.** The criteria for loss and recovery of the frame alignment and multiframe alignment signal for ports X or Y shall be in accordance with ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe.

**3.2.3 Channel-Associated Signaling in Streams X and Y.** Channel-associated signaling in streams X and Y shall be in accordance with ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe. Allocation of signaling bits in the signaling frames of streams X and Y shall be in accordance with ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe.

**3.2.4 Fault Conditions and Consequent Actions Associated with Streams X and Y**

**3.2.4.1 Fault Conditions.** A summary of the fault conditions associated with the frames of streams X and Y and the consequent actions are listed in Table 8.

The transcoder shall detect the following fault conditions associated with streams X and Y:

- (1) Loss of incoming signals at 1544 kbit/s
- (2) Loss of DS1 frame alignment
- (3) DS1 AIS received from remote end
- (4) Yellow alarm indication received from the remote end

**3.2.4.2 Consequent Actions.** Upon detection of the DS1 fault conditions in streams X and Y, the following consequent actions shall be taken, as indicated in Table 8:

(A) Declare DS1 Red alarm on the send side of port X or Y.

(B) Send DS1 Yellow alarm signal on the receive side of port X or Y.

(C) Send a bundle AIS-Red alarm signal to the remote end by forcing the M2 bit within the affected delta channel(s) to 1.

(D) Condition the affected channels on the send side of stream Z to provide a signal in all channels that is compatible with downstream equipment.

(E) Declare DS1 AIS on the send side of port X or Y.

(F) Declare DS1 Yellow alarm on the send side of port X or Y.

(G) Send a bundle AIS-Yellow alarm signal to the remote end by forcing the M3 bit within the affected delta channel(s) to a 1.

### 3.3 Other Characteristics of the 48-Channel Transcoder Equipment

**3.3.1 Synchronization.** It shall be possible to concurrently synchronize the outgoing streams of ports X, Y, and Z to any one of the following:

- (1) Timing signal associated with incoming PCM stream X
- (2) Timing signal associated with incoming PCM stream Y
- (3) Timing signal associated with incoming stream Z
- (4) Internal 1544-kbit/s timing signal

**3.3.2 Pass-Through of 64-kbit/s Channels.** Transcoders shall allow the capability to pass-through (i.e., directly transfer) 64-kbit/s channels from streams X and Y to stream Z. Provisions should also be made for  $N \times 64$ -kbit/s pass-through (e.g., 128 kbit/s, 384 kbit/s, 768 kbit/s, and 1536 kbit/s). Transcoders shall not allow the transfer of 64-kbit/s channels that cross a DS0 boundary on stream Z. For example, a 64-kbit/s channel may occupy channels 1 and 2 of Table 1, but may not occupy channels 2 and 3.

A wide range of combinations of 32-kbit/s and pass-through channels is possible. A defined subset of templates is under study.

**3.3.2.1 Channel-Associated Signaling in 64-kbit/s Pass-Through Time-Slots.** The transcoder should allow for selection of reinsertion or no reinsertion of channel-associated signaling bits into streams X and Y of the receive side for each channel that is passed through transparently at 64 kbit/s.

**3.3.2.2 Conditioning of Unused Channels.** When 64-kbit/s channels from streams X and Y are transferred transparently in stream Z, the transmission capacity of PCM

streams X and Y is reduced. The data and signaling in the unused channels in streams X and Y shall be conditioned to provide a signal that is compatible with downstream equipment.

**3.3.3 Absolute Delay.** The overall absolute delay that may be introduced by a single transcoder (PCM to ADPCM or ADPCM to PCM) is variable and the maximum is implementation dependent. An objective is to keep delay to a minimum, and Appendix A of ANSI T1.501-1988 addresses allowable delays in various applications.

Frame integrity (i.e., equal delay) shall be maintained for adjacent 64-kbit/s channels to allow  $N \times 64$ -kbit/s services

## 4. Transcoders Using Transition Signaling

This section concerns 48-channel transcoders using channel-associated signaling implemented by signaling messages that preempt communication of the voice signal whenever signaling states change. This is called Transition Signaling.

### 4.1 Characteristics of a 1544-kbit/s Signal Organized in 32-kbit/s Time-Slots, 64-kbit/s Time-Slots, or Both (Port Z)

**4.1.1 Interface Z.** The electrical characteristics of the 1544-kbit/s interface shall be in accordance with ANSI T1.102-1987.

**4.1.2 Frame Structure.** The 1544-kbit/s signal is organized in frames of 193 bits. The frame repetition rate is 8000 Hz. Each frame is comprised of forty-eight 4-bit time-slots, numbered from 1 to 48, plus the framing bit in the first bit position. The bit ordering of the 32-kbit/s signals shall be such that the 4-bit words are transmitted in numbered order starting with bit 1, the sign bit, as specified in 2.2.3 and 2.2.4 of CCITT Recommendation G.721.

**4.1.2.1 DS1 Frame and Multiframe Alignment Signal.** The first bit shall convey the DS1 frame alignment signal and multiframe alignment signal, as specified in ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe. Selection of either the 24-frame multiframe or 12-frame multiframe format at port Z is independent of frame formats selected at ports X and Y.

**4.1.2.1.1 24-Frame Multiframe.** The F-bit shall be used for transport of framing and CRC-6 information, as defined in ANSI T1.107-1988. The

use of the F-bit for transport of the 4-kbit/s data link, as defined in ANSI T1.107-1988, is a subject for further study.

**4.1.2.1.2 12-Frame Multiframe.** The frame alignment signal shall occupy the first bit position of every other frame as defined in ANSI T1.107-1988. The S-bit shall be used to carry the multiframe alignment signal, as defined in ANSI T1 107-1988.

**4.1.2.2 Loss and Recovery of Frame and Multiframe Alignment.** The criteria for loss and recovery of the frame alignment and multiframe alignment signal for port Z shall be in accordance with ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe.

**4.1.2.3 48-Channel Frame Format.** In the case where streams X and Y are each carrying 24 voice-frequency signals, stream Z shall transmit the full complement of 48 channels. Table 1 shows the correspondence between the 64-kbit/s PCM channels in streams X and Y and the 32-kbit/s ADPCM channels in stream Z. Time-slots 1–12 correspond to channels 1–12 from PCM stream X coded with 4 bits. Time-slots 13–24 correspond to channels 13–24 from PCM stream X coded with 4 bits. Time-slots 25–36 correspond to channels 1–12 from PCM stream Y coded with 4 bits. Time-slots 37–48 correspond to channels 13–24 from PCM stream Y coded with 4 bits.

The references to delta channels or bundles in Table 1 do not apply here.

**4.1.3 Transition Signaling.** The characteristics that define the signaling messages and other parameters of Transition Signaling are specified in this section.

#### 4.1.3.1 Transition Signaling Messages

**4.1.3.1.1 Signaling Message Formats.** The signaling message shall be composed of eight nibbles (4-bit code words) in the following format:

0 0 S T 0 0 P Q

where the S and T nibbles contain signaling and maintenance information, the P and Q nibbles contain parity information for forward error-correction, and 0 represents 0000 binary.

Signaling messages shall be positively acknowledged by the four-nibble sequence:

0 0 F F

where F represents 1111 binary. The acknowledgment message shall use the offset arrangement discussed in 4.1.3.1.5.

**4.1.3.1.2 Encoding of Signaling and Alarm Information.** Signaling and alarm information shall be contained in the eight-bit byte composed of the S and T nibbles (Table 9).

In order to make the S and T nibbles that generate the alarm bits nonzero, the following codes shall be used:

S nibble	A	B	M1	~M1
T nibble	C	D	~M2	~M3

where ~ denotes logic inversion. A, B, C, and D are the signaling bits used for robbed-bit channel-associated signaling. M1, M2, and M3 are the alarm bits defined in 3.1.2.7. The M2 and M3 states will be made mutually exclusive in that both AIS-Red and AIS-Yellow shall not be sent in the same message and, therefore, both the S nibble and the T nibble are always nonzero. In a Red-over-Yellow alarm situation, where both a Red and Yellow exist, the AIS-Red (M2) shall be sent. At the receiver at which the AIS-Yellow was recorded first and then changed to AIS-Red, this sequence will result in red-over-yellow alarm indication.

In order to avoid all-zero bytes, a strategy of offsetting signaling messages between the high nibble and the low nibble of each byte shall be used with the following specific scheme, where x represents a speech bit, the F's are framing bits and M represents one of the M1, M2, or M3 alarm bits. F1 is the first bit transmitted and L in frame 10, nibble 48, is the last bit transmitted.

The signaling message in the high nibble is always offset from the message in the low nibble by two frames, or 250 μs (see 4.1.3.1.5). The S and T nibbles are each nonzero by construction. If the P or Q nibble is zero (they are never both zero in the same signaling message), bit-7 zero suppression can be used to force the bytes in frame 7 or 8 to be nonzero. For signaling messages without alarms, the error correction at the receiver will correct this intentional error. For signaling messages with alarms, only error-free messages shall be accepted (see 4.1.3.1.6). However, only the low-nibble alarm will be affected by the zero byte suppression; the alarm in the high nibble will get through. There will be no acknowledgment for the low-nibble alarm as it was not received correctly. The low-bit signaling message with the alarm shall be retransmitted after a 2-second delay.

The P and Q parity nibbles are formed by encoding S and T using a (17,9) BCH (Bose-

Chaudhuri-Hocquenghem) code, shortened to a (16,8) BCH code by forcing the ninth data bit of the (17,9) BCH code to a 0 and not transmitting it. In order to generate the eight parity bits, the polynomial formed by the ST byte is multiplied by  $X^8$  and then divided (Modulo 2) by the generator polynomial  $X^8 + X^5 + X^4 + X^3 + 1$ . The first parity bit,  $p_1$ , is the most significant bit of the remainder, and the last parity bit,  $q_4$ , is the least significant bit of the remainder.

Alternatively, the vector (STPQ) may be calculated by:

$$(STPQ) = (ST) * (G)$$

where (G) is the generator matrix:

1	0	0	0	0	0	0	0	1	0	0	1	1	1	0
0	1	0	0	0	0	0	0	0	1	0	0	1	1	1
0	0	1	0	0	0	0	1	0	0	0	1	1	1	1
0	0	0	1	0	0	0	1	1	0	1	1	0	1	1
0	0	0	0	1	0	0	1	1	1	1	0	0	0	1
0	0	0	0	0	1	0	0	1	1	1	0	0	1	0
0	0	0	0	0	0	1	0	0	1	1	1	0	0	1
0	0	0	0	0	0	0	1	0	0	1	1	1	0	0

where (ST) is a row vector, and where \* denotes matrix multiplication using modulo 2 arithmetic.

The resulting 256 possible 16-bit codewords STPQ are listed in hexadecimal in Table 10, where the first half of each word is an ST and the last half of the word is the corresponding PQ. The first column labeled ST gives the possible values of ST in decimal, and can be used as an index for the row with the desired PQ.

**4.1.3.1.3 Message Rules.** The following rules shall be observed with messages:

(1) Consecutive messages, either signaling or acknowledgment, shall be separated by at least two frames.

(2) A message specifying an alarm state shall preempt a signaling message currently being transmitted. That is, if a message without any alarm indications is being sent but not completed, and an alarm indication arrives, the message shall be aborted and a message with the alarm information should be sent.

(3) Acknowledgment messages shall not be sent until signaling message transmission is completed.

**4.1.3.1.4 Detection of Signaling Messages.** A signaling message shall be detected whenever two consecutive 0 nibbles are preceded or succeeded by a 0 nibble, with either two or three intervening nibbles. Thus the following

patterns will be detected, as shown below:

```
X 0 0 X X 0 0 X X X 0 0 S T 0 0 P Q
X X 0 X X 0 0 X X X 0 0 S T 0 0 P Q
X 0 X X X 0 0 X X X 0 0 S T 0 0 P Q
X 0 0 X X X 0 X X X 0 0 S T 0 0 P Q
X 0 0 X X 0 X X X X 0 0 S T 0 0 P Q
```

A signaling message with all of S, T, P, and Q equal to zero shall be ignored.

An acknowledgment message shall be detected when 00FF is received.

#### 4.1.3.1.5 Decoding of Signaling

**Messages.** When a signaling message is determined to be present, according to the criteria of the previous section, decoding consists of finding the 16-bit code word (data plus parity bits) that has the smallest Hamming distance from the actual 16-bit word received.

One method of doing the decoding is by calculating the syndrome (SD) from the received signaling message (STPQ) by:

$$(SD) = (STPQ) * (HT)$$

where (HT) is the parity checking matrix:

```
0 1 0 0 1 1 1 0
0 0 1 0 0 1 1 1
1 0 0 0 1 1 1 1
1 1 0 1 1 0 1 1
1 1 1 1 0 0 0 1
1 1 1 0 0 1 0 0
0 1 1 1 0 0 1 0
0 0 1 1 1 0 0 1
1 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0
0 0 1 0 0 0 0 0
0 0 0 1 0 0 0 0
0 0 0 0 1 0 0 0
0 0 0 0 0 1 0 0
0 0 0 0 0 0 1 0
0 0 0 0 0 0 0 1
```

where (STPQ) is a row vector, and where \* denotes matrix multiplication using modulo 2 arithmetic.

The resulting (SD), interpreted as a binary integer, can then be used as an index to a table of error codes. These error codes, exclusively OR'd with the received STPQ, will correct all single and double errors and about 21% of those cases with three bits in error. Although many tables can be constructed, Table 11 implements the correction for the three-bit errors with the most clustering.

Feedback shift register decoders may be used instead of table look-up techniques.

**4.1.3.1.6 Signaling Procedures.** The signaling part of the transmitting terminal maintains a record of the "stable state" (see below) of the A, B, C, and D (or A and B only) signaling channels of the received PCM circuit on the X or Y port. The "stable state" is defined to be the state previously sent by message to the distant terminal. The "current state" is defined to be the most recently available information as to the signaling states. The "previous state" is defined to be the status of the A, B, C, and D bits 24 frames prior to the most recent observation. When both the "current state" and the "previous state" of the A, B, C, or D signaling bits has a bit that differs from the "stable state," a transition signaling message containing the "current state" shall be sent to the distant terminal, starting in the next frame for the low nibble and delayed two frames for the high nibble. Of course, after the message is sent, the "stable state" will change to reflect this message in accordance with the definition of "stable state."

A change in the state of any of the M bits, as already defined for the bundled format (3.1.2.5.2) shall cause the sending of three consecutive signaling messages. Signaling messages sent while any of the M bits indicate an alarm shall also be sent as three consecutive signaling messages.

The signaling part of the receiving terminal monitors the incoming nibble stream, and upon detecting and decoding the signaling message, resets the outgoing A, B, C, and D signaling channel states on the outgoing PCM X or Y port. The receiving terminal also examines the alarm bits of each received signaling message, and it takes actions in accordance with 4.1.3.4 or 4.1.4 when the syndrome value of the message is zero, which indicates that the message was received without error. Signaling messages having alarm bits indicating an alarm condition shall be ignored unless the syndrome value of the message is zero.

The receiving terminal also sends a signaling acknowledgment message to the transmitting terminal unless the message decoded to a disallowed message. The transmitting terminal shall consider outstanding messages to be acknowledged in the order sent, if two or more are outstanding. The transmitting terminal shall have a counter to indicate the number of unacknowledged messages outstanding. This counter shall be capable of counting to at least 40. If the

transmitting terminal does not receive an acknowledgment of a signaling message in 2 seconds,  $\pm 50$  milliseconds, the transmitting terminal shall set the number of outstanding unacknowledged messages to zero, and resend the current signaling and alarm state.

If an acknowledgment message is received when no signaling messages are outstanding, then the current signaling and alarm state shall be resent.

Six hours,  $\pm 15$  minutes, following the last transition signaling message, the current signaling state should be confirmed by resending. No further resending of stable states is desirable.

**4.1.3.1.7 Out-of-Frame and High Error Rate Conditions.** If the Z port is out-of-frame, then signaling messages shall be ignored.

To protect signaling from error bursts or high error rates on individual 32-kbit/s channels, the rate of arrival of zero nibbles, not associated with signaling, shall be monitored. This may be done by implementing an up-down counter with a maximum of 32767 and a minimum of 0. The counter is incremented by 512 for each zero nibble received, decremented by 1 for each nibble received, decremented by 2048 when a signaling message is received, and decremented by 1024 when an acknowledgment is received. If the counter is above 4095 after the signaling message is received, the signaling message is ignored. If the counter is above 24575, the circuit's signaling should be conditioned as specified for bundle alarms, and conditioning should be maintained until the counter falls below 16384.

If the Z port is out-of-frame, the zero nibble monitor is reset and held at 0.

**4.1.3.1.8 Line Formats.** The line formats for a mix of ADPCM channels and PCM (with or without Robbed-Bit signaling) or through channels shall follow the line formats already defined in 3.1.2.3. The disabling of signaling (but not alarm communication) should be administerable on an individual PCM channel basis.

**4.1.3.1.9 Idle Code for Digital Cross-connect System.** The transition signaling equipment shall provide the option that the zero-byte counter for the low nibble in each DS0 channel control trunk conditioning for both channels in the channel-pair. This option is intended for use when it is desired to use existing Digital Cross-connect System (DCS) (without DS1 ports specifically designed for ADPCM compatibility) to switch 32-kbit/s ADPCM at the DS0 rate, that is, channel-pair switching. For these applications, the DCS shall be set to produce a

PCM idle code of "11110000" during an alarm state.

**4.1.3.2 Transmission Considerations.** The signaling part of the transmitting terminal sends messages by overwriting the ADPCM stream, as described above. The operation of the ADPCM encoder is not modified.

The signaling part of the receiving terminal monitors and reads signaling messages from the received ADPCM stream. However, the code words representing signaling messages are passed on to the ADPCM decoder, and the operation of the ADPCM decoder is not modified. The signaling messages will appear as a very low-level noise burst at the output of the ADPCM decoder, whenever a change occurs in the signaling state of the connection or the alarm status of the facilities.

**4.1.3.3 Zero Suppression.** The signaling message formats and timing are arranged to avoid the occurrence of the zero-byte whenever the two 32-kbit/s ADPCM channels in a 64-kbit/s channel are formed by the same terminal. When this is not the case, possibly due to cross-connection at the 32-kbit/s rate, zero bytes will occur rarely. The arrangements for signaling message detection, and for error correction, will overcome the single errors introduced by equipment providing zero-byte suppression.

**4.1.3.4 Channel-Pair Bundle Alarms.** A bundle Red alarm is declared when the zero nibble counter exceeds 24575 on either of the paired ADPCM channel numbered  $2n$  and  $2n-1$ . A bundle Red alarm is released when the zero nibble counter falls below 16384 on both of the paired ADPCM channels.

M1, M2, and M3 shall be as defined in 3.1.2.7 and 4.1.3.1.2, except that the term *bundle* now denotes a channel-pair bundle.

**4.1.4 Fault Conditions and Consequent Actions Associated with Stream Z**

**4.1.4.1 DS1 Fault Conditions.** A summary of the DS1 fault conditions associated with stream Z and the consequent actions are listed in Table 6.

The transcoder shall detect the following DS1 fault conditions associated with stream Z:

- (1) Loss of incoming signals at 1544 kbit/s
- (2) Loss of DS1 frame alignment
- (3) DS1 Alarm Indication Signal (AIS) received
- (4) Yellow alarm indication received from the remote end

All of these conditions are defined in more detail in ANSI T1.107-1988.

**4.1.4.2 Consequent Actions.** Upon detection of a DS1 fault conditions in stream Z,

appropriate actions shall be taken that are in accordance with ANSI T1.107-1988. In addition, the following consequent actions shall be taken as indicated in Table 6:

- (A) Declare a DS1 Red alarm on the receive side of port Z.
- (B) Send DS1 Yellow alarm signal on the send side of port Z.
- (C) Apply an Alarm Indication Signal (AIS) to the receive side of streams X and Y. The AIS consists of an all 1s signal in all channels, including the framing bit.
- (D) Declare DS1 AIS on the receive side of port Z.
- (E) Declare a DS1 Yellow alarm on the receive side of port Z.
- (F) Generate a DS1 Yellow alarm signal on the receive side of streams X and Y.

#### 4.1.4.3 Channel-Pair Bundle Fault

**Conditions.** A summary of the channel-pair bundle fault conditions associated with stream Z and the consequent actions are listed in Table 12.

The transcoder shall detect the following bundle fault conditions associated with stream Z:

- (1) A bundle Red alarm condition on a single bundle associated with port X or a single bundle associated with port Y.
- (2) A bundle Red alarm condition on all 12 bundles associated with port X or all 12 bundles associated with port Y.
- (3) Bundle Yellow alarm indication (M1) received from the remote end on a single bundle associated with port X or a single bundle associated with port Y.
- (4) Bundle Yellow alarm indication (M1) received from the remote end on all 12 bundles associated with port X or all 12 bundles associated with port Y.
- (5) Bundle AIS-Red (M2) received from the remote end on a single bundle associated with port X or a single bundle associated with port Y.
- (6) Bundle AIS-Red (M2) received from the remote end on all 12 bundles associated with port X or all 12 bundles associated with port Y.
- (7) Bundle AIS-Yellow (M3) received from the remote end on a single bundle associated with port X or a single bundle associated with port Y.
- (8) Bundle AIS-Yellow (M3) received from the remote end on all 12 bundles associated with port X or all 12 bundles associated with port Y.

**4.1.4.4 Consequent Actions.** Upon detection of bundle fault conditions in stream Z, the following consequent actions shall be taken as indicated in Table 12:

(A) A bundle Red alarm condition shall be declared to signify that the zero nibble counter has exceeded 24575, and that effective signaling between terminals is not possible.

(B) A bundle Yellow alarm indication (M1=1) shall be sent to the remote end using the signaling procedures of 4.1.3.1.6.

(C) The data in the affected channels on the receive side of streams X or Y shall be conditioned to provide a signal that is compatible with downstream equipment. For example, ANSI T1.107-1988 provides restrictions on unequipped channel units in a channel bank.

(D) The channel-associated signaling bits in affected channels on the receive side of streams X or Y shall be conditioned to provide a signal that is compatible with downstream equipment. An example for most signaling types would be universal trunk conditioning in which the signaling bits should be forced to the idle state for 2 to 3 seconds, and then conditioned to simulate the channel-seized condition.

(E) A DS1 AIS shall be applied to the receive side of stream X (for bundles 1 and 2) or stream Y (for bundles 3 and 4). The AIS consists of an all 1s signal in all channels including the framing bit.

(F) A bundle Yellow alarm condition shall be declared to indicate the reception of a bundle Yellow alarm indication in the M1 bit of received transition signaling messages.

(G) A DS1 Yellow alarm signal shall be applied on the receive side of stream X and stream Y.

(H) A bundle AIS-Red condition shall be declared to indicate the reception of a bundle AIS-red indication in the M2 bit of received transition signaling messages.

(I) A bundle AIS-Yellow condition shall be declared to indicate the reception of a bundle AIS-Yellow indication in the M3 bit of received transition signaling messages.

**4.2 Characteristics of Ports X and Y.** The characteristics of ports X and Y are the same as specified in 3.2, except that the alarms M1, M2, and M3 are sent to the distant terminal using transition signaling messages according to the procedure of 4.1.3.1.2 instead of delta channel procedures.

**4.3 Other Characteristics of the 48-Channel Transcoder Equipment.** Other characteristics are as specified in 3.3.

## 5. Transcoders Using Robbed-Bit Signaling

This section concerns 48-channel transcoders using channel-associated signaling in which the signaling bits are transported in the least significant bit of the corresponding communication channel during the signaling frames. This is called the Robbed-Bit signaling.

### 5.1 Characteristics of a 1544-kbit/s Signal Organized in 32-kbit/s Time-Slots, 64-kbit/s Time-Slots, or Both (Port Z)

**5.1.1 Interface Z.** The electrical characteristics of the 1544-kbit/s interface shall be in accordance with ANSI T1.102-1987.

**5.1.2 Frame Structure.** The 1544-kbit/s signal is organized in frames of 193 bits. The frame repetition rate is 8000 Hz. Each frame is comprised of forty-eight 4-bit time-slots, numbered from 1 to 48, plus the framing bit in the first bit position. During every sixth frame, the least significant bit (i.e., 4th bit) shall be used for the usual DS1 signaling, as specified in ANSI T1.107-1988. During the signaling frames, 7-level ADPCM coding shall be used instead of 15-level coding. The bit ordering of the 32-kbit/s signals shall be such that the 4-bit words are transmitted in numbered order starting with bit 1, the sign bit, as specified in 2.2.3 and 2.2.4. of CCITT Red Book, Recommendation G.721.

**5.1.2.1 DS1 Frame and Multiframe Alignment Signal.** The first bit shall convey the frame alignment signal and multiframe alignment signal as specified in ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe. Selection of either the 24-frame multiframe or 12-frame multiframe format at port Z is independent of frame formats selected at ports X and Y.

**5.1.2.1.1 24-Frame Multiframe.** The F-bit shall be used for transport of framing and CRC-6 information, as defined in ANSI T1.107-1988. The use of the F-bit for transport of the 4-kbit/s data link, as defined in ANSI T1.107-1988, is a subject for further study.

**5.1.2.1.2 12-Frame Multiframe.** The frame alignment signal shall occupy the first bit position of every other frame as defined in ANSI T1.107-1988. The S-bit shall be used to carry the multiframe alignment signal, as defined in ANSI T1.107-1988.

**5.1.2.2 Loss and Recovery of Frame and Multiframe Alignment.** The criteria for loss and recovery of the frame alignment and multiframe alignment signal for port Z shall be in accordance with ANSI T1.107-1988 for the 24-frame multiframe and the 12-frame multiframe.

**5.1.2.3 48-Channel Frame Format.** Table 13 shows the correspondence between the 64-kbit/s PCM channels in streams X and Y and the 32-kbit/s ADPCM channels in stream Z. Time-slots 1–12 correspond to channels 1–12 from PCM stream X coded with 4 bits. Time-slots 13–24 correspond to channels 13–24 from PCM stream X coded with 4 bits. Time-slots 25–36 correspond to channels 1–12 from PCM stream Y coded with 4 bits. Time-slots 37–48 correspond to channels 13–24 from PCM stream Y coded with 4 bits.

**5.1.2.4 Channel-Associated Signaling in Stream Z.**

**5.1.2.4.1 24-Frame Multiframe.** In the 24-frame multiframe format channel-associated signaling is carried in frames 6, 12, 18, and 24, as defined in ANSI T1.107-1988.

**5.1.2.4.2 12-Frame Multiframe.** In the 12-frame multiframe format channel-associated signaling is carried in frames 6 and 12, as defined in ANSI T1.107-1988.

**5.1.3 Fault Conditions and Consequent Actions Associated with Stream Z.**

**5.1.3.1 DS1 Fault Conditions.** A summary of the DS1 fault conditions associated with stream Z and the consequent actions are listed in Table 6.

The transcoder should detect the following DS1 fault conditions associated with stream Z:

- (1) Loss of incoming signals at 1544 kbit/s
- (2) Loss of DS1 frame alignment
- (3) DS1 Alarm Indication Signal (AIS) received
- (4) Yellow alarm indication received from the remote end

All of these conditions are defined in more detail in ANSI T1.107-1988.

**5.1.3.2 Consequent Actions.** Upon detection of DS1 fault conditions in stream Z, appropriate actions shall be taken that are in accordance with ANSI T1.107-1988. In addition, the following consequent actions shall be taken as indicated in Table 6:

- (A) Declare a DS1 Red alarm on the receive side of port Z.
- (B) Send DS1 Yellow alarm signal on the send

side of port Z.

(C) Apply an Alarm Indication Signal (AIS) to the receive side of streams X and Y. The AIS consists of an all 1s signal in all channels including the framing bit.

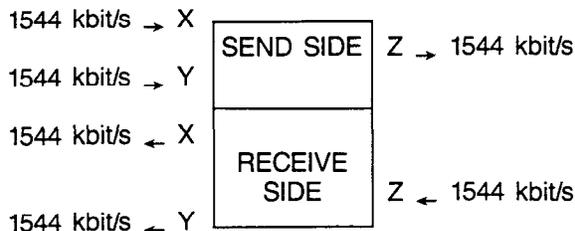
(D) Declare a DS1 AIS on the receive side of port Z.

(E) Declare a DS1 Yellow alarm on the receive side of port Z.

(F) Generate a DS1 Yellow alarm on the receive side of streams X and Y.

**5.2 Characteristics of Ports X and Y.** The characteristics of ports X and Y are the same as specified in 3.2. The consequent actions shall be as listed in Table 14.

**5.3 Other Characteristics of the 48-Channel Transcoder Equipment.** Other characteristics shall be as specified in 3.3.



2 x 24 CHANNELS;  
EACH CHANNEL  
CODED AT 64 kbit/s

48/44 CHANNELS;  
EACH CHANNEL  
CODED AT 32 kbit/s

**Figure 1**  
**48-Channel Transcoder Ports**

**Table 1**  
**Organization of the 1544-kbit/s Frame for Up to 48 Channels**  
**at 32 kbit/s in Stream Z Using the Bundle Format**

4-bit time-slot of stream Z	1	2	3	4	5	6	7	8	9	10	11	12	Bundle 1
8-bit channel of stream X	1X	2X	3X	4X	5X	6X	7X	8X	9X	10X	11X	12X or Δ	
4-bit time-slot of stream Z	13	14	15	16	17	18	19	20	21	22	23	24	Bundle 2
8-bit channel of stream X	13X	14X	15X	16X	17X	18X	19X	20X	21X	22X	23X	24X or Δ	
4-bit time-slot of stream Z	25	26	27	28	29	30	31	32	33	34	35	36	Bundle 3
8-bit channel of stream Y	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	11Y	12Y or Δ	
4-bit time-slot of stream Z	37	38	39	40	41	42	43	44	45	46	47	48	Bundle 4
8-bit channel of stream Y	13Y	14Y	15Y	16Y	17Y	18Y	19Y	20Y	21Y	22Y	23Y	24Y or Δ	

NOTE: Definitions for Bundle 1-4 and Δ appear in 3.1.2.4 and 3.1.2.5.

**Table 2**  
**Unused Channels in Streams X and Y When the Delta Channel**  
**Is Present in a Bundle**

Delta Channel Present	Unused Channel
Bundle 1	Channel 12 in stream X
Bundle 2	Channel 24 in stream X
Bundle 3	Channel 12 in stream Y
Bundle 4	Channel 24 in stream Y

**Table 3**  
**Delta Channel Format**

Bundle Frame Number	Time-slot 12, 36 Bit Number				Time-slot 24, 48 Bit Number			
	1	2	3	4	1	2	3	4
1	A1	A2	0	U1	A13	A14	0	U1
2	A3	A4	1	U2	A15	A16	1	U2
3	A5	A6	0	CRC1	A17	A18	0	CRC1
4	A7	A8	1	U4	A19	A20	1	U4
5	A9	A10	0	U5	A21	A22	0	U5
6	A11	M1	1	U6	A23	M1	1	U6
7	B1	B2	0	CRC2	B13	B14	0	CRC2
8	B3	B4	1	U8	B15	B16	1	U8
9	B5	B6	0	U9	B17	B18	0	U9
10	B7	B8	1	U10	B19	B20	1	U10
11	B9	B10	0	CRC3	B21	B22	0	CRC3
12	B11	M2	1	U12	B23	M2	1	U12
13	C1	C2	1	U13	C13	C14	1	U13
14	C3	C4	0	U14	C15	C16	0	U14
15	C5	C6	1	CRC4	C17	C18	1	CRC4
16	C7	C8	0	U16	C19	C20	0	U16
17	C9	C10	1	U17	C21	C22	1	U17
18	C11	M3	0	U18	C23	M3	0	U18
19	D1	D2	1	CRC5	D13	D14	1	CRC5
20	D3	D4	0	U20	D15	D16	0	U20
21	D5	D6	1	U21	D17	D18	1	U21
22	D7	D8	0	U22	D19	D20	0	U22
23	D9	D10	1	CRC6	D21	D22	1	CRC6
24	D11	M4	0	U24	D23	M4	0	U24

**Table 4**  
**Bundle CRC-6 Test Patterns and Results - Device Interface**

Pattern per Frame	CRC-6 Results					
	CRC1 (MSB)	CRC2	CRC3	CRC4	CRC5	CRC6 (LSB)
FFFFFFFFFFFF <sub>16</sub>	0	0	1	1	1	0
555555555555 <sub>16</sub>	1	1	1	0	1	1
562ECD28A695 <sub>16</sub>	0	0	0	0	0	1

**Table 5**  
**Bundle CRC-6 Test Patterns and Results - DS1 Interface**

Test Patterns Written in Channels of Streams X or Y				CRC-6 Results					
1 thru 5 or 13 thru 17	6 or 18	Delta Channel*	MSB	CRC1	CRC2	CRC3	CRC4	CRC5	LSB CRC6
D1 - D8	D1 - D8	1 - 4							
01010101	11111111	11F1	0	1	0	0	0	1	0
01110011	11111111	11F1	1	0	1	1	1	0	0
10110101	11111111	11F1	0	1	1	1	1	1	0

\*F represents the multiframe alignment bits in bit 3 of the delta channel

**Table 6**  
**DS1 Fault Conditions Associated with Stream Z and Consequent Actions**

Consequent → Actions ↓ Fault Conditions	Declare DS1 Red on Z (A)	Send DS1 Yellow on Z (B)	Dens DS1 AIS on X and Y (C)	Declare DS1 AIS on Z (D)	Declare DS1 Yellow on Z (E)	Send DS1 Yellow on X and Y (F)
Loss of Incoming Signal at 1544 kbit/s (1)	YES	YES	YES	—	—	—
Loss of DS1 Frame Alignment (2)	YES	YES	YES	—	—	—
DS1 AIS Received (3)	—	YES	YES	YES	—	—
DS1 Yellow Received (4)	—	—	—	—	YES	YES

**Table 7**  
**Bundle Fault Conditions Associated with Stream Z and Consequent Actions**

Consequent Actions	Declare Bundle Red	Send Bundle Yellow	Condition Affected Channels on X or Y	Condition Signaling in Affected Channels on X or Y	Send DS1 AIS on X or Y	Declare Bundle Yellow	Send DS1 Yellow on X or Y	Declare Bundle AIS- Red	Declare Bundle AIS- Yellow
†Fault Conditions	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
Loss of Delta Channel Multiframe Alignment (Single Bundle) (1)	YES	YES	YES	YES	—	—	—	—	—
Loss of Delta Channel Multiframe Alignment (Bundle Pair) (2)	YES	YES	—	—	YES	—	—	—	—
Bundle Yellow Received (Single Bundle) (3)	—	—	YES	YES	—	YES	—	—	—
Bundle Yellow Received (Bundle Pair) (4)	—	—	—	—	—	YES	YES	—	—
Bundle AIS-Red Received (Single Bundle) (5)	—	—	YES	YES	—	—	—	YES	—
Bundle AIS-Red Received (Bundle Pair) (6)	—	—	—	—	YES	—	—	YES	—
Bundle AIS- Yellow Received (Single Bundle) (7)	—	—	YES	YES	—	—	—	—	YES
Bundle AIS- Yellow Received (Bundle Pair) (8)	—	—	—	—	—	—	YES	—	YES

**Table 8**  
**DS1 Fault Conditions Associated with Streams X and Y and Consequent Actions**

Consequent → Actions	Declare DS1 Red	Send DS1 Yellow	Send Bundle AIS-Red	Condition Affected Channels in Stream Z	Declare DS1 AIS	Declare DS1 Yellow	Send Bundle AIS-Yellow
↓Fault Conditions	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Loss of Incoming Signal at 1544 kbit/s (1)	YES	YES	YES	YES	—	—	—
Loss of DS1 Frame Alignment (2)	YES	YES	YES	YES	—	—	—
DS1 AIS Received (3)	—	YES	YES	YES	YES	—	—
DS1 Yellow Received (4)	—	—	—	—	—	YES	YES

**Table 9**  
**Signaling and Alarm Format**

Frame No	Frame Bit	Channel Nibble Sequence							
		1	2	3		2n-1	2n		48
1	F1	xxxx	xxxx	xxxx	xxxx	xxxx	0000	xxxx	xxxx
2	F	xxxx	xxxx	xxxx	—	xxxx	0000	xxxx	xxxx
3	F	xxxx	xxxx	—	—	0000	ABMM	—	xxxx
4	F	xxxx	—	—	—	0000	CDMM	—	xxxx
5	F	—	—	—	—	ABMM	0000	—	xxxx
6	F	—	—	—	—	CDMM	0000	—	xxxx
7	F	—	—	—	—	0000	PPPP	—	xxxx
8	F	—	—	—	—	0000	QQQQ	—	xxxx
9	F	—	—	—	—	PPPP	xxxx	—	xxxx
10	F	xxxx	xxxx	xxxx	xxxx	QQQQ	xxxx	xxxx	xxxL

**Table 10**  
**Two Hundred Fifty-Six Possible Code Words**

ST	STPQ							
0	0	139	272	34b	4e4	5dd	696	7af
8	8f1	9c8	a83	bba	c15	d2c	e67	f5e
16	10db	11e2	12a9	1390	143f	1506	164d	1774
24	182a	1913	1a58	1b61	1cce	1df7	1ebc	1f85
32	208f	21b6	22fd	23c4	246b	2552	2619	2720
40	287e	2947	2a0c	2b35	2c9a	2da3	2ee8	2fd1
48	3054	316d	3226	331f	34b0	3589	36c2	37fb
56	38a5	399c	3ad7	3bee	3c41	3d78	3e33	3f0a
64	4027	411e	4255	436c	44c3	45fa	46b1	4788
72	48d6	49ef	4aa4	4b9d	4c32	4d0b	4e40	4f79
80	50fc	51c5	528e	53b7	5418	5521	566a	5753
88	580d	5934	5a7f	5b46	5ce9	5dd0	5e9b	5fa2
96	60a8	6191	62da	63e3	644c	6575	663e	6707
104	6859	6960	6a2b	6b12	6cbd	6d84	6ecf	6ff6
112	7073	714a	7201	7338	7497	75ae	76e5	77dc
120	7882	79bb	7af0	7bc9	7c66	7d5f	7e14	7fd2
128	804e	8177	823c	8305	84aa	8593	86d8	87e1
136	88bf	8986	8acd	8bf4	8c5b	8d62	8e29	8f10
144	9095	91ac	92e7	93de	9471	9548	9603	973a
152	9864	995d	9a16	9b2f	9c80	9db9	9ef2	9fcb
160	a0c1	a1f8	a2b3	a38a	a425	a51c	a657	a76e
168	a830	a909	aa42	ab7b	acd4	aded	aea6	af9f
176	b01a	b123	b268	b351	b4fe	b5c7	b68c	b7b5
184	b8eb	b9d2	ba99	bba0	bc0f	bd36	be7d	bf44
192	c069	c150	c21b	c322	c48d	c5b4	c6ff	c7c6
200	c898	c9a1	caea	cbd3	cc7c	cd45	ce0e	cf37
208	d0b2	d18b	d2c0	d3f9	d456	d56f	d624	d71d
216	d843	d97a	da31	db08	dca7	dd9e	ded5	dfec
224	e0e6	e1df	e294	e3ad	e402	e53b	e670	e749
232	e817	e92e	ea65	eb5c	ecf3	edca	ee81	efb8
240	f03d	f104	f24f	f376	f4d9	f5e0	f6ab	f792
248	f8cc	f9f5	fabe	fb87	fc28	fd11	fe5a	ff63

**Table 11**  
**Correction of Error Bits Implementation**

SD	Error Correction Code							
0	0000	0001	0002	0003	0004	0005	0006	4020
8	0008	0009	000a	000b	000c	5800	8040	2080
16	0010	0011	0012	1900	0014	0c00	0016	0c02
24	0018	0120	b000	c200	001c	0c08	4100	4101
32	0020	0021	0022	4004	0024	4002	4001	4000
40	0028	0110	1800	1801	0d00	400a	4009	4008
48	0030	0108	0240	4014	0034	4012	4011	4010
56	0101	0100	0103	0102	8200	0104	1401	1400
64	0040	0041	0042	0043	0044	0045	8008	8009
72	0048	0049	8004	0300	8002	8003	8000	8001
80	0050	0051	0220	1088	3000	4200	3002	4202
88	1a00	6800	8014	1080	8012	4208	8010	8011
96	0060	c008	0210	4044	0480	4042	8028	4040
104	c001	c000	2401	2400	4300	c004	8020	8021
112	0202	0880	0200	0201	0206	8102	0204	8100
120	020a	0140	0208	0209	2802	0144	2800	2801
128	0080	0081	0082	0a00	0084	200a	2009	2008
136	0088	2006	2005	2004	2003	2002	2001	2000
144	0090	6100	0092	8500	9001	9000	0600	9002
152	c800	1042	2c00	1040	0000	9008	2011	2010
160	00a0	00a1	00a2	4084	0440	3800	4081	4080
168	6000	1200	8400	8401	6004	2022	8404	2020
176	3400	0840	d000	a200	2102	9020	2100	2101
184	6010	0180	0b00	8804	5040	8802	8801	8800
192	00c0	a000	4401	4400	0420	a004	8088	4404
200	0900	a008	1011	1010	8082	8a00	8080	2040
208	00d0	0820	4804	1008	4802	0824	4800	4801
216	1003	1002	1001	1000	0501	0500	1005	1004
224	0404	0810	1100	1101	0400	0401	0402	9200
232	040c	0818	1108	1030	0408	0409	80a0	4900
240	0801	0800	0280	0802	0410	0804	0412	0806
248	5004	0808	4500	1020	5000	2200	5002	2202

**Table 12**  
**Channel-Pair Bundle Fault Conditions Associated with Stream Z**  
**and Consequent Actions**

Consequent → Actions	Declare Bundle Red	Send Bundle Yellow	Condition Affected Channels on X or Y	Condition Signaling in Affected Channels on X or Y	Send DS1 AIS on X or Y	Declare Bundle Yellow	Send DS1 Yellow on X or Y	Declare Bundle AIS- Red	Declare Bundle AIS- Yellow
↓Fault Conditions	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
Bundle Red Alarm Declared (Single Bundle) (1)	YES	YES	YES	YES	—	—	—	—	—
Bundle Red Alarm Declared (12 Bundles) (2)	YES	YES	—	—	YES	—	—	—	—
Bundle Yellow Received (Single Bundle) (3)	—	—	YES	YES	—	YES	—	—	—
Bundle Yellow Received (12 Bundles) (4)	—	—	—	—	—	YES	YES	—	—
Bundle AIS-Red Received (Single Bundle) (5)	—	—	YES	YES	—	—	—	YES	—
Bundle AIS-Red Receive (12 Bundles) (6)	—	—	—	—	YES	—	—	YES	—
Bundle AIS- Yellow Received (Single Bundle) (7)	—	—	YES	YES	—	—	—	—	YES
Bundle AIS- Yellow Received (12 Bundles) (8)	—	—	—	—	—	—	YES	—	YES

**Table 13**  
**Organization of the 1544-kbit/s Frame for up to 48 Channels**  
**at 32 kbit/s in Stream Z**

4-Bit Time-slot of Stream Z	1	2	3	4	5	6	7	8	9	10	11	12
8-bit Channel of Stream X	1X	2X	3X	4X	5X	6X	7X	8X	9X	10X	11X	12X
4-Bit Time-slot of Stream Z	13	14	15	16	17	18	19	20	21	22	23	24
8-Bit Channel of Stream X	13X	14X	15X	16X	17X	18X	19X	20X	21X	22X	23X	24X
4-Bit Time-Slot of Stream Z	25	26	27	28	29	30	31	32	33	34	35	36
8-Bit Channel of Stream Y	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	11Y	12Y
4-Bit Time-Slot of Stream Z	37	38	39	40	41	42	43	44	45	46	47	48
8-Bit Channel of Stream Y	13Y	14Y	15Y	16Y	17Y	18Y	19Y	20Y	21Y	22Y	23Y	24Y

**Table 14**  
**DS1 Fault Conditions Associated with Streams X and Y**  
**and Consequent Actions**

Consequent → Actions	Declare DS1 Red	Send DS1 Yellow	Condition Affected Channels in Stream Z	Condition Signaling in Affected Channels in Stream Z	Declare DS1 AIS	Declare DS1 Yellow
†Fault Conditions	(A)	(B)	(C)	(D)	(E)	(F)
Loss of Incoming Signal at 1544 kbit/s (1)	YES	YES	YES	YES	—	—
Loss of DS1 Frame Alignment (2)	YES	YES	YES	YES	—	—
DS1 AIS Received (3)	—	YES	YES	YES	YES	—
DS1 Yellow Received (4)	—	—	YES	YES	—	YES

