RAD data communications

Technology Backgrounder

E1 Environment

1. E1 Line Signal

The E1 line signal is coded using the High-Density Bipolar 3 (HDB3) coding rules. The HDB3 coding format is an improvement of the alternate mark inversion (AMI) code.

In the AMI format, “ones” are alternately transmitted as positive and negative pulses, whereas “zeros” are transmitted as a zero voltage level. The AMI format cannot transmit long strings of “zeros”, because such strings do not carry timing information.

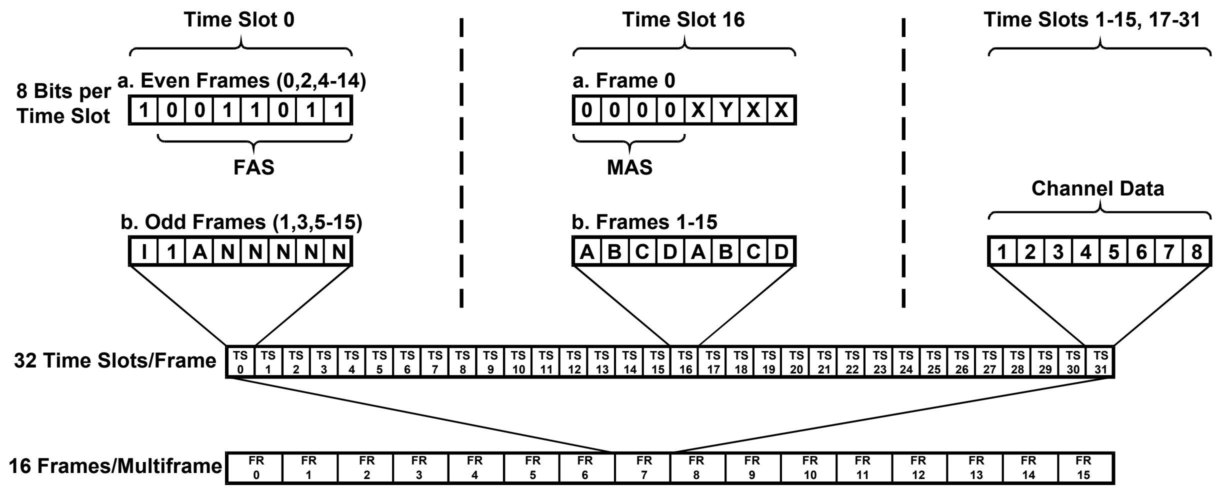
The HDB3 coding rules restrict the maximum length of a “zero” string to 3 pulse intervals. Longer strings are encoded at the transmit end to introduce non-zero pulses. To allow the receiving end to detect these artificially-introduced pulses and to enable their removal to restore the original data string, the encoding introduces intentional bipolar violations in the data sequence.

The receiving end detects these violations and when they appear to be part of an encoded “zero” suppression string – it removes them.

Bipolar violations which are not part of the HDB3 zero-suppression string are assumed to be caused by line errors, and are counted separately to obtain information on the link transmission quality when the CRC-4 function is not used.

2. E1 Signal Structure

The E1 line operates at a nominal rate of 2.048 Mbps. The data transferred over the E1 line is organized in frames. The E1 frame format is shown in *Figure 1*.



Notes

I	**International Bit**	**ABCD**	**ABCD Signaling Bits**
N	**National Bits (S_{a4} through S_{a8})**	**X**	**Extra Bit**
A	**Alarm Indication Signal (Loss of Frame Alignment - Red Alarm)**	**Y**	**Loss of Multiframe Alignment**
FAS	**Frame Alignment Signal, occupies alternate (but not necessarily even) frames**	**MAS**	**Multiframe Alignment Signal**

Figure 1. E1 Frame Format

Each E1 frame includes 256 bits. The 256 bits are arranged in 32 timeslots of eight bits each that carry the data payload. The frame repetition rate is 8,000 per second, and therefore the data rate supported by each timeslot is 64 kbps. The number of timeslots available for user data is maximum 31, because timeslot 0 is always reserved.

3. Timeslot 0

Timeslot 0 is used for two main purposes:

- Delineation of frame boundaries. For this purpose, in every second frame timeslot 0 carries a fixed pattern, called frame alignment signal (FAS). Frames carrying the FAS are defined as even frames, as they are assigned the numbers 0, 2, 4, etc. when larger structures (multiframes) are used.

  The receiving equipment searches for this fixed pattern in the data stream using a special algorithm, a process called frame synchronization. Once this process is successfully completed, the equipment can identify each bit in the received frames.

- Transmission of housekeeping information. In every frame without FAS (odd frames), timeslot 0 carries housekeeping information. This information includes:

  - Bit 1 - this bit is called the international (I) bit. Its main use is for error detection using the optional CRC-4 function.

- Bit 2 is always set to 1, a fact used by the frame alignment algorithm.
- Bit 3 is used as a remote alarm indication (RAI), to notify the equipment at the other end that the local equipment lost frame alignment, or does not receive an input signal.
- The other bits, identified as S_{a4} through S_{a8}, are designated national bits, and are actually available to the users, provided agreement is reached as to their use.

4. Multiframes

To increase the information carrying capacity without wasting bandwidth, the frames are organized in larger structures, called multiframes. Two types of multiframes are generally used:

- 256N, which consists of 2 frames (one odd frame and one even frame). The 256N multiframe is generally used when timeslot 16 is to carry user's payload. In this mode, the maximum number of timeslots available for payload is 31 (maximum payload data rate of 1984 kbps). For systems which use the common-channel signaling (CCS) method, the CCS information is often transmitted in timeslot 16.
- 256S, which consists of 16 frames. The 256S multiframe is generally used when timeslot 16 serves for the transmission of end-to-end signaling using channel-associated signaling (CAS). CAS is typically used on links that transfer voice channels. In this mode, the maximum number of timeslots available for payload is 30 (maximum data rate of 1920 kbps).

5. Payload Encoding

Data Payload

Each payload timeslot in an E1 frame is transparent, that is, it does not modify the user's data in any way. Therefore, each timeslot can carry data at a rate of 64 kbps.

To carry data at higher rates, a service called fractional E1 can be used to distribute the original data stream among several specified timeslots (such a group of timeslots is called a ***bundle***). At the other end of the link, the data is collected from the specified timeslots and the original data stream is restored. This enables transparent transfer of data at rates which are multiples of 64 kbps.

Analog Payload

Analog signals, for example, voice, are digitized, to convert them to data streams that can be transferred over the link. The standardized approach is to digitize each analog channel using pulse code modulation (PCM) at a sampling rate of 8 kHz, with each sample represented by an 8-bit word. This yields a data rate of 64 kbps, which means that each voice channel can be carried in one timeslot.

To achieve the best possible voice quality over the widest practical range of analog signal amplitudes while using only 8 bits per sample, the signal is compressed at the transmitting end and expanded at the receiving end, to restore its original amplitude (this is called ***companding***). The non-linear companding law standardized in ITU-T Rec. G.713 for use in E1 frames is called ***A-law***.

The voice quality obtained using 64 kbps PCM encoding is quite good; it can even support data transmission using voiceband modems (including fax) at relatively high data rates.

To decrease the required rate needed to transport an analog channel, another encoding method, adaptive differentially-encoded PCM (ADPCM) has been standardized in ITU-T Rec. G.726. ADPCM compresses the data rate needed to carry one channel to only 32 kbps, thereby doubling the number of channels that can be carried at a given payload rate at the expense of a small degradation in quality.

6. E1 Line Statistics Using CRC-4 Error Detection

The CRC-4 function specified in ITU-T Rec. G.704 allows evaluating the quality of transmission over E1 links.

When the CRC-4 option is enabled, frames are arbitrarily grouped in groups of 16 (these groups are called CRC-4 multiframes, and do not bear any relationship to the 16-frame multiframe structures used with the 256S multiframe explained above). A CRC-4 multiframe always starts with a frame that carries the frame alignment signal. The CRC-4 multiframe structure is identified by a six-bit ***CRC-4 multiframe alignment signal,*** which is multiplexed into bit 1 of timeslot 0 of each odd-numbered (1, 3, 5, etc.) frame of the CRC-4 multiframe, up to frame 11 of the multiframe. Each CRC-4 multiframe is divided into two submultiframes of 8 frames (2048 bits) each. The detection of errors is achieved by calculating a four-bit checksum on each 2048-bit block (submultiframe). The four checksum bits calculated on a given submultiframe are multiplexed, bit by bit, in bit 1 of timeslot 0 of each even-numbered frame of the next submultiframe.

At the receiving end, the checksum is calculated again on each submultiframe and then compared against the original checksum (sent by the transmitting end in the next submultiframe). The results are reported by two bits multiplexed in bit 1 of timeslot 0 in frames 13, 15 of the CRC-4 multiframe, respectively. Errors are counted and used to prepare statistic data on transmission performance.

7. E1 Line Alarm Conditions

- Excessive bit error rate. The bit error rate is measured on the frame alignment signal. The alarm threshold is an error rate higher than 10^{-3} that persists for 4 to 5 seconds. The alarm condition is canceled when the error rate decreases below 10^{-4} for 4 to 5 consecutive seconds.
- Loss of frame alignment (also called loss of synchronization). This condition is declared when too many errors are detected in the frame alignment signal (FAS), e.g., when 3 or 4 FAS errors are detected in the last 5 frames. Loss of frame alignment is cleared after no FAS errors are detected in two consecutive frames. The loss of frame alignment is reported by means of the A bit (see *Figure 1*).

Note *For ATM equipment, the A bit is also used to indicate loss of ATM cell delineation.*

- Loss of multiframe alignment (applicable only when 256S multiframes are used). This condition is declared when too many errors are detected in the multiframe alignment signal (MAS), as for loss of frame alignment. The loss of multiframe alignment is reported by means of the Y bit (see figure C-1).

Alarm indication signal (AIS). The AIS signal is an unframed “all-ones” signal, and is used to maintain line signal synchronization in case of loss of input signal, e.g., because an alarm condition occurred in the equipment that supplies the line signal. Note that the equipment receiving an AIS signal loses frame synchronization.