T3/E3 Essentials

WHITE PAPER

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1.0 INTRODUCTION TO DS3 AND E3

Digital transmission of voice and data telephony in the broadband arena has evolved into the implementation of two distinct communication protocol standard in the world. The North American and Japanese implementation is known as the DS3 framing format and the European and global implementation is known as the E3 framing format. Both of these implementations are also referred to as the Plesiochronous Digital Hierarchy or PDH due to their inherent timing characteristics.

The Following Framing Standards will be subject of this study.

- **DS3/M13 Framing Format**
- **DS3/C-bit Parity Framing Format**
- **E3/ITU-T G.751 Framing Format**
- **E3/ITU-T G.832 Framing Format**

1.1 A Brief History of the Emergence of the Digital Signal Hierarchy in North America

The need to transmit analog voice over digital transmission medium resulted in the formation of the Digital Signal Hierarchy in North America in the early 1960's. The DS0 constitute the smallest fundamental unit in the Digital Signal Hierarchy. Human hearing is able to sufficiently discern voice intelligibly between 300 Hz to 3300 Hz range resulting in a 4kHz voice baseband in telephony. A DS0 channel is an 8-bit quantization of this 4kHz voice baseband using pulse code modulation.

The DS1 framing structure compromises of 24 8-bit DS0 channels or timeslots and an overhead framing bit resulting in 193 bits per DS1 frame as shown in **Figure 1**. The most significant bit, Bit-0 is transmitted first in each DS0 time slot. To meet the Nyquist-Shannon minimum sampling theorem, the 4kHz voice baseband signal must be sampled at 8kHz frequency interval yielding a bit rate of 64 kbps in each DS0 timeslot. Thus a given DS1 channel bit-rate sampled at 8 kHz interval runs at 1.544 Mbps nominal bit rate.

FIGURE 1. DS1/T1 FRAME FORMAT

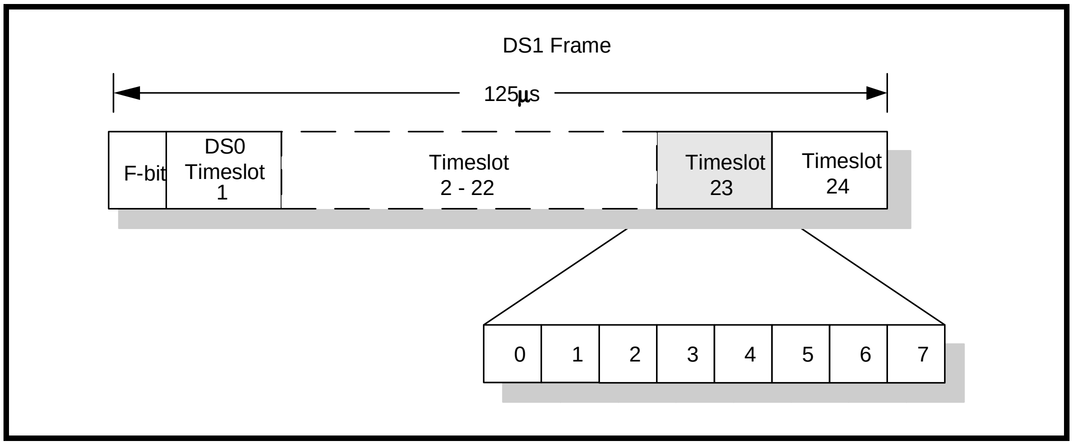


TABLE 1: DIGITAL SIGNAL HIERARCHY

DIGITAL SIGNAL LEVEL	BIT RATE	NUMBER OF VOICE CHANNELS	EQUIVALENT
DS0	64 kbps	1	-
DS1	1.544 Mbps	24	24 DS0's
DS2	6.312 Mbps	96	4 DS1's
DS3	44.736 Mbps	672	28 DS1's

2.0 THE DS3 FRAMING FORMATS

There are essentially two types of DS3 framing standard. Both are bit-oriented framing structure. First we will examine/discuss the DS3 M13 format. It is assumed that the reader is familiar with the basic understanding of the DS1 framing format. The DS3 M13 framing format is a result of the multiplexing of 28 seperate DS1 channels. The multiplexing of 28 DS1 channels requires an intermediary framing step referred to as a DS2 frame. A DS2 frame consists of four DS1 signals. Hence, a total of seven DS2 signals are multiplexed in a given DS3 M13 channel. Today the majority of the DS3 platforms are deployed in Central Offices for intra-network communication equipment.

2.1 The DS3 M13 Framing Format

The DS3 M13 framing format can be thought of as single M-Frame subdivided into 7 subframes called F-frames with each F-frame consisting of 680 bits. Each subframe consist of 572 payload bits and 8 overhead bits. Therefore, a DS3 M-frame with 7 subframes consist of 4704 payload bits with 56 overhead bits totalling 4760 bits per frame. The DS3 frame repetition rate is at 9398.3 Hz yielding 44.736 Mbps nominal bit rate.

FIGURE 2. THE DS3 M13 FRAMING FORMAT

X	[84]	F1	[84]	C11	[84]	F0	[84]	C12	[84]	F0	[84]	C13	[84]	F1	[84]
X	[84]	F1	[84]	C21	[84]	F0	[84]	C22	[84]	F0	[84]	C23	[84]	F1	[84]
P	[84]	F1	[84]	C31	[84]	F0	[84]	C32	[84]	F0	[84]	C33	[84]	F1	[84]
P	[84]	F1	[84]	C41	[84]	F0	[84]	C42	[84]	F0	[84]	C43	[84]	F1	[84]
M0	[84]	F1	[84]	C51	[84]	F0	[84]	C52	[84]	F0	[84]	C53	[84]	F1	[84]
M1	[84]	F1	[84]	C61	[84]	F0	[84]	C62	[84]	F0	[84]	C63	[84]	F1	[84]
M0	[84]	F1	[84]	C71	[84]	F0	[84]	C72	[84]	F0	[84]	C73	[84]	F1	[84]

The DS3 M13 Frame Summary

- **Frame Size: 4760 bits**
- **Number of Overhead Functions: 7**
- **Number of Overhead Bits: 56 bits**
- **Number of Payload Bits: 4704 bits**
- **Frame Repetition Rate: 9398.3 Hertz**
- **Nominal Bit Rate: 44.736 Mbps**

2.1.1 The DS3 M13 Overhead Bits

There are 5 types of overhead bits which has specific functions in a DS3 M13 framing format. These are the X-bits, the F-bits, the C-bits, the P-bits, and the M-bits.

2.1.1.1 The X-bits

The X-bits are used to carry the “FERF” (Far-End Receive Failure) or “Yellow Alarm” Status. A value of "1" denotes Normal Operation or No Alarm Condition. A value of "0" denotes FERF condition.

FIGURE 3. THE X-BITS

X	[84]	F1	[84]	C11	[84]	F0	[84]	C12	[84]	F0	[84]	C13	[84]	F1	[84]
X	[84]	F1	[84]	C21	[84]	F0	[84]	C22	[84]	F0	[84]	C23	[84]	F1	[84]
P	[84]	F1	[84]	C31	[84]	F0	[84]	C32	[84]	F0	[84]	C33	[84]	F1	[84]
P	[84]	F1	[84]	C41	[84]	F0	[84]	C42	[84]	F0	[84]	C43	[84]	F1	[84]
M0	[84]	F1	[84]	C51	[84]	F0	[84]	C52	[84]	F0	[84]	C53	[84]	F1	[84]
M1	[84]	F1	[84]	C61	[84]	F0	[84]	C62	[84]	F0	[84]	C63	[84]	F1	[84]
M0	[84]	F1	[84]	C71	[84]	F0	[84]	C72	[84]	F0	[84]	C73	[84]	F1	[84]

A given “Frame Generator block” will assert “FERF” whenever and for the duration that the “Corresponding” Receiver (Frame Synchronizer) block is declaring any of the following defect.

- LOS (Loss of Signal)
- OOF (Out of Frame)
- AIS (Alarm Indication Signal)

2.1.1.2 F1, F0, and Cxx Bits

The F1 Bits

These are "Framing Alignment" bits that are set to the value of "1". The Receive DS3 Framer will use these bits to acquire and maintain frame synchronization.

The F0 Bits

These are "Framing Alignment" bits that are set to the value of "1". The Receive DS3 Framer will use these bits to acquire and maintain frame synchronization.

The "Cxx" Bits

The "Cxx bits are used to indicate whether bit-stuffing has occurred on the seven DS2's that were multiplexed into the DS3 signal.

FIGURE 4. DS3 M13 FRAME STRUCTURE OVERHEAD BITS - F1, F0 AND CXX BITS

X	[84]	F1	[84]	C11	[84]	F0	[84]	C12	[84]	F0	[84]	C13	[84]	F1	[84]
X	[84]	F1	[84]	C21	[84]	F0	[84]	C22	[84]	F0	[84]	C23	[84]	F1	[84]
P	[84]	F1	[84]	C31	[84]	F0	[84]	C32	[84]	F0	[84]	C33	[84]	F1	[84]
P	[84]	F1	[84]	C41	[84]	F0	[84]	C42	[84]	F0	[84]	C43	[84]	F1	[84]
M0	[84]	F1	[84]	C51	[84]	F0	[84]	C52	[84]	F0	[84]	C53	[84]	F1	[84]
M1	[84]	F1	[84]	C61	[84]	F0	[84]	C62	[84]	F0	[84]	C63	[84]	F1	[84]
M0	[84]	F1	[84]	C71	[84]	F0	[84]	C72	[84]	F0	[84]	C73	[84]	F1	[84]

2.1.1.3 P, M0, and M1 Bits

The P-Bits

The “Even-Parity” is computed (by the Transmit DS3 Framer) over the Payload bits within a given DS3 frame. The resulting parity value is inserted into the “P-Bit” fields within the very next “outbound” DS3 frame.

The Receive DS3 Framer (at the remote terminal) will verify the value of the “P-Bits”, as it receives these DS3 frames.

The M0 Bits

These are “Multi-Framing Alignment” bits that are set to the value of “0”. The Receive DS3 Framer will use these bits to acquire and maintain frame synchronization.

The M1 Bits

These are “Multi-Framing Alignment” bits that are set to the value of “1”. The Receive DS3 Framer will use these bits to acquire and maintain frame synchronization.

FIGURE 5. DS3 M13 FRAME STRUCTURE OVERHEAD BITS -P, M0, AND M1 BITS

X	[84]	F1	[84]	C11	[84]	F0	[84]	C12	[84]	F0	[84]	C13	[84]	F1	[84]
X	[84]	F1	[84]	C21	[84]	F0	[84]	C22	[84]	F0	[84]	C23	[84]	F1	[84]
P	[84]	F1	[84]	C31	[84]	F0	[84]	C32	[84]	F0	[84]	C33	[84]	F1	[84]
P	[84]	F1	[84]	C41	[84]	F0	[84]	C42	[84]	F0	[84]	C43	[84]	F1	[84]
M0	[84]	F1	[84]	C51	[84]	F0	[84]	C52	[84]	F0	[84]	C53	[84]	F1	[84]
M1	[84]	F1	[84]	C61	[84]	F0	[84]	C62	[84]	F0	[84]	C63	[84]	F1	[84]
M0	[84]	F1	[84]	C71	[84]	F0	[84]	C72	[84]	F0	[84]	C73	[84]	F1	[84]

2.2 The DS3 C-bit Parity Framing Format

The DS3 C-bit framing format can be thought of as single M-Frame subdivided into 7 subframes called F-frames with each F-frame consisting of 680 bits. Each subframe consist of 572 payload bits and 8 overhead bits. Therefore, a DS3 M-frame with 7 subframes consist of 4704 payload bits with 56 overhead bits totalling 4760 bits per frame. The DS3 frame repetition rate is at 9398.3 Hz yielding 44.736 Mbps nominal bit rate.

FIGURE 6. DS3 C-BIT PARITY FRAME STRUCTURE

X	[84]	F1	[84]	AIC	[84]	F0	[84]	NA	[84]	F0	[84]	FEAC	[84]	F1	[84]
X	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
P	[84]	F1	[84]	CP	[84]	F0	[84]	CP	[84]	F0	[84]	CP	[84]	F1	[84]
P	[84]	F1	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F1	[84]
M0	[84]	F1	[84]	DL	[84]	F0	[84]	DL	[84]	F0	[84]	DL	[84]	F1	[84]
M1	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
M0	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]

The DS3 C-bit Parity Frame Summary

- **Frame Size: 4760 bits**
- **Number of Overhead Functions: 13**
- **Number of Overhead Bits: 56 bits**
- **Number of Payload Bits: 4704 bits**
- **Frame Repetition Rate: 9398.3 Hertz**
- **Nominal Bit Rate: 44.736 Mbps**

2.2.1 The DS3 C-bit Overhead Bits

There are 13 types of overhead bits which has specific functions in a DS3 C-bit framing format. The “X”, “F1”, “F0”, “P”, “M0” and “M1” bits have already been defined (per the DS3, M13 Framing Format). The role that these bit-fields play for C-bit Parity are identical to that defined for M13. However, the C-bit Parity Framing Format has some additional bit-fields that need to be defined. These are the AIC bits, the NA bits, the FEAC bits, the UDL bits, the CP bits, the FEBE bits, the DL bits and the UDL bits.

2.2.1.1 The AIC and NA Bits

The “AIC” Bit

The “AIC” is the “Application Identification” is set to “1” to strongly indicate that the framing format (for this DS3 frame) is “C-bit Parity”.

The “NA” Bit

The “NA” (or “Network Application” bit is set to “1” in the C-bit Parity Framing Format.

FIGURE 7. The AIC and NA Bits

X	[84]	F1	[84]	AIC	[84]	F0	[84]	NA	[84]	F0	[84]	FEAC	[84]	F1	[84]
X	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
P	[84]	F1	[84]	CP	[84]	F0	[84]	CP	[84]	F0	[84]	CP	[84]	F1	[84]
P	[84]	F1	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F1	[84]
M0	[84]	F1	[84]	DL	[84]	F0	[84]	DL	[84]	F0	[84]	DL	[84]	F1	[84]
M1	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
M0	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]

2.2.1.2 The FEAC Bit

FEAC (Far-End Alarm & Control) is a standard “Bit-Oriented Signaling” method that is defined by Bellcore GR-499-CORE.

The actual message that is to be sent, via the FEAC channel, consists of six (6) bits.

As a consequence, there are 64 possible FEAC message values that can be sent. Of these 64 values, 43 values have been defined (by the standards) to have some meaning.

FIGURE 8. THE FEAC BIT

X	[84]	F1	[84]	AIC	[84]	F0	[84]	NA	[84]	F0	[84]	FEAC	[84]	F1	[84]
X	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
P	[84]	F1	[84]	CP	[84]	F0	[84]	CP	[84]	F0	[84]	CP	[84]	F1	[84]
P	[84]	F1	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F1	[84]
M0	[84]	F1	[84]	DL	[84]	F0	[84]	DL	[84]	F0	[84]	DL	[84]	F1	[84]
M1	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
M0	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]

The “six-bit” FEAC message value is encapsulated into a 16-bit serial expression in the form of 0xxxxxx011111111. This "16-bit" data structure is serially inserted into the "FEAC" bit-field of each "outbound" DS3 frame. The “1” bit (or the right-most bit, within the 16-bit FEAC data structure) will be transmitted first.

Note: Since there is only one “FEAC” bit-field per each DS3 frame, it will require 16 DS3 frames to transmit this 16 bit data structure.

In all, the Transmit DS3 Framer will transmit this 16-bit data structure 10 times (requiring 160 DS3 frames).

Afterwards, the Transmit DS3 Framer will continue to transmit this particular FEAC Message repeatedly for an indefinite period.

FIGURE 9. AN ILLUSTRATION OF THE SEQUENCE OF TRANSMISSION OF THE FEAC MESSAGE.

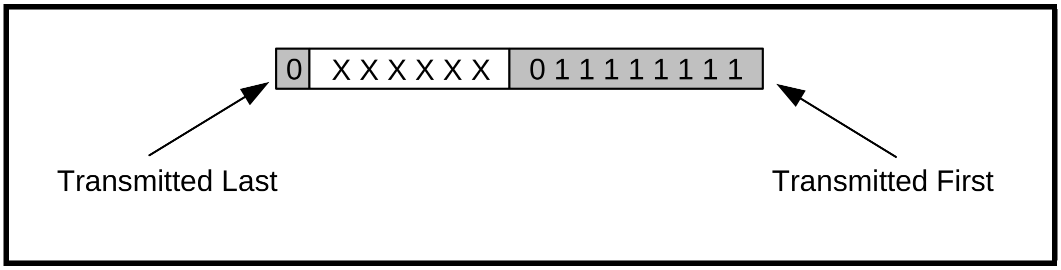


TABLE 2: FEAC CODE WORD

FEAC CODE WORD	MEANING
011001	DS3 Equipment Failure Service Affecting
001110	DS3 Loss of Signal (LOS)
000000	DS3 Out-of-Frame (OOF)
010110	DS3 AIS Received
011010	DS3 Idle Signal Received
001111	DS3 Equipment Failure (Non-Service Affecting)
011101	Common Equipment Failure (Non-Service Affecting)
010101	Multiple DS1 LOS
000101	DS1 Equipment Failure (Service Affecting)
011110	Single DS1 LOS
000011	DS1 Equipment Failure (Non-Service Affecting)
000111	Line Loopback Activate
011100	Line Loopback De-activate

TABLE 3: FEAC CODE WORDS UPON INVOKING THE LINE LOOPBACK ACTIVATE OR LINE LOOPBACK DEACTIVATE

FEAC CODE WORD	MEANING
011011	DS3 Line
100001	DS1 Line Number 1
100010	DS1 Line Number 2
100011	DS1 Line Number 3
100100	DS1 Line Number 4
100101	DS1 Line Number 5
100110	DS1 Line Number 6
100111	DS1 Line Number 7
101000	DS1 Line Number 8
101001	DS1 Line Number 9
101010	DS1 Line Number 10
101011	DS1 Line Number 11
101100	DS1 Line Number 12
101101	DS1 Line Number 13
101110	DS1 Line Number 14
101111	DS1 Line Number 15
110000	DS1 Line Number 16
110001	DS1 Line Number 17
110010	DS1 Line Number 18
110011	DS1 Line Number 19
110100	DS1 Line Number 20
110101	DS1 Line Number 21
110110	DS1 Line Number 22
110111	DS1 Line Number 23
111000	DS1 Line Number 24
111001	DS1 Line Number 25
111010	DS1 Line Number 26
111011	DS1 Line Number 27
111100	DS1 Line Number 28
010011	DS1 Line - ALL

2.2.1.3 The UDL Bits

The UDL (or "User Data Link") bits are some additional channels that can be used (by the user) to carry their own proprietary "Data Link" information. Its exact use is not defined by any standards.

FIGURE 10. C-BIT PARITY - THE UDL BITS

X	[84]	F1	[84]	AIC	[84]	F0	[84]	NA	[84]	F0	[84]	FEAC	[84]	F1	[84]
X	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
P	[84]	F1	[84]	CP	[84]	F0	[84]	CP	[84]	F0	[84]	CP	[84]	F1	[84]
P	[84]	F1	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F1	[84]
M0	[84]	F1	[84]	DL	[84]	F0	[84]	DL	[84]	F0	[84]	DL	[84]	F1	[84]
M1	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
M0	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]

2.2.1.4 The FEBE Bits

Each DS3 frame consists of three (3) FEBE bit-fields.

The FEBE (Far-End Block Error) bits are used to indicate whether or not a “local” Receiving Terminal is receiving DS3 data (from the “remote” Transmitting Terminal) in an “Error-Free” manner or not.

The Local Receiving Terminal will verify the integrity of the DS3 frame data, by verifying the P-bits.

If the Local Receiving Terminal detects no errors, then the Local Transmitting Terminal will set the three FEBE bit-fields, (within the very next “outbound” DS3 frame) to the value [1, 1, 1].

Conversely, if the Local Receiving Terminal detects “P-bit” errors, in the DS3 frames, then the “local” Transmitting Terminal will set the three FEBE bit-fields (within the very next outbound DS3 frame) to values other than [1, 1, 1].

FIGURE 11. C-BIT PARITY - THE FEBE BITS

X	[84]	F1	[84]	AIC	[84]	F0	[84]	NA	[84]	F0	[84]	FEAC	[84]	F1	[84]
X	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
P	[84]	F1	[84]	CP	[84]	F0	[84]	CP	[84]	F0	[84]	CP	[84]	F1	[84]
P	[84]	F1	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F1	[84]
M0	[84]	F1	[84]	DL	[84]	F0	[84]	DL	[84]	F0	[84]	DL	[84]	F1	[84]
M1	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
M0	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]

2.2.1.5 The Data Link Bits

The DL (Data Link) bits are used to transport "PMDL" (Path Maintenance Data Link) Messages from one terminal to the next.

FIGURE 12. C-BIT PARITY - THE DL BITS

X	[84]	F1	[84]	AIC	[84]	F0	[84]	NA	[84]	F0	[84]	FEAC	[84]	F1	[84]
X	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
P	[84]	F1	[84]	CP	[84]	F0	[84]	CP	[84]	F0	[84]	CP	[84]	F1	[84]
P	[84]	F1	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F0	[84]	FEBE	[84]	F1	[84]
M0	[84]	F1	[84]	DL	[84]	F0	[84]	DL	[84]	F0	[84]	DL	[84]	F1	[84]
M1	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]
M0	[84]	F1	[84]	UDL	[84]	F0	[84]	UDL	[84]	F0	[84]	UDL	[84]	F1	[84]

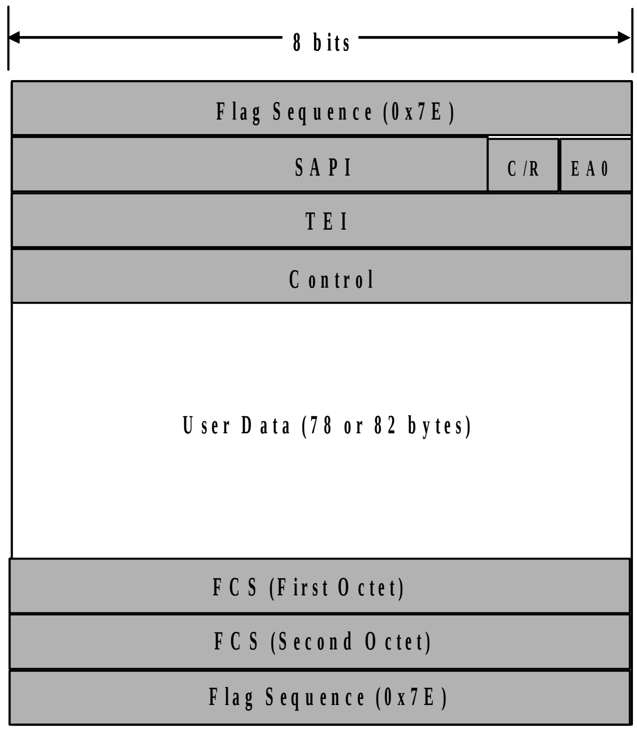
These PMDL Messages are encapsulated into LAP-D (Link Access Protocol - D) or ITU-T Q.921 Type Messages, and are then transported to the remote terminal equipment.

These PMDL Messages are typically used to transport the following types of messages:

Commands (for the Remote Terminal Equipment) to Execute a particular diagnostic test.

Responses (from the Remote Terminal Equipment) with the results of executing such a test.

FIGURE 13. THE ITU-T Q.921 (LAP-D) MESSAGE FRAME



The LAPD messaging frame structure includes a flag sequence delimiter or idle pattern to denote the location of the LAPD message boundary and header bytes encapsulating a user data ranging from 76 to 82 bytes in length. All LAPD Message Frames must start and end with the flag sequence. The Flag Sequence is of value “0x7E” (0111 1110). The first header byte consists of a 6-bit field SAPI or Service Access Point Indentifier, the C/R or Command/Response bit field, and the E/A or Initial Address Extension bit field. The SAPI bit-fields identifies the type of "Data Link Layer" service and is assigned the value of 001111b or 15 (decimal). The Initial Address Extension bit-field is assigned the value of 0, therefore a typical value transmitted for the first header octet is usually either 0x3C or 0x3E. The second header byte consists of the 7-bit field TEI or Terminal Endpoint Identifier and the E/A or the Final Address Extension bit-field. The TEI bit-fields are assigned the value of 0x00. The TEI field is used in N-ISDN systems to identify a terminal out of multiple possible terminal. The third header byte called the Control Byte indicates the type of frame being transmitted. There are three general types of frame formats: Information, Supervisory, and Unnumbered.

The first byte of the Information Payload portion of the LAPD messaging must denote the type of LAPD Message Frame. The value of the control byte is defined in the table below.

TABLE 4: LAPD MESSAGE TYPE

LAPD MESSAGE TYPE	FIRST PAYLOAD INFORMATION BYTE VALUE	MESSAGE SIZE
Test Signal Identification	0x32	76
IDLE Signal Identification	0x34	76
CL Path Identification	0x38	76
ITU-T Path Identificatiton	0x3F	82

The trailing end immediately following the payload portion of the LAPD message are occupied by the FCS bytes. The Frame Check Sequence field contains the “Checksum” value also known as the CRC-16 value computed over the “Header” bytes and “Payload” portion of the LAPD Message Frame by using the CRC-16 polynomial, x16 + x12 + x5 + 1.

2.2.2 The Alarm Indication Signal Pattern for DS3

During an "Service Affecting" fault condition, a DS3 AIS patten is often transmitted to downstream circuitry, warning other equipment that there is a “Service Affecting” fault condition nearby.

The characteristics of the AIS Pattern for DS3 are:

- Valid M-, F-, and P-Bits.
- All C-Bits are set to “0”.
- All X-Bits are set to “1”.
- A repeating “1010…” pattern is written into the payload portion of each outbound DS3 frame.

FIGURE 14. DS3 M13/C-BIT PARITY - AIS PATTERN

X=1	[1010]	F1	[1010]	0	[1010]	F0	[1010]	0	[1010]	F0	[1010]	0	[1010]	F1	[1010]
X=1	[1010]	F1	[1010]	0	[1010]	F0	[1010]	0	[1010]	F0	[1010]	0	[1010]	F1	[1010]
P	[1010]	F1	[1010]	0	[1010]	F0	[1010]	0	[1010]	F0	[1010]	0	[1010]	F1	[1010]
P	[1010]	F1	[1010]	0	[1010]	F0	[1010]	0	[1010]	F0	[1010]	0	[1010]	F1	[1010]
M0	[1010]	F1	[1010]	0	[1010]	F0	[1010]	0	[1010]	F0	[1010]	0	[1010]	F1	[1010]
M1	[1010]	F1	[1010]	0	[1010]	F0	[1010]	0	[1010]	F0	[1010]	0	[1010]	F1	[1010]
M0	[1010]	F1	[1010]	0	[1010]	F0	[1010]	0	[1010]	F0	[1010]	0	[1010]	F1	[1010]

2.2.3 The Idle Signal Pattern for DS3 C-bit Parity

The purpose of the “Idle Pattern” is to let the equipment (that is receiving this pattern), that the DS3 C-bit Parity Transport Media (carrying this pattern) is functional, but has not been assigned any “user” traffic.

This alarm condition is functionally equivalent to an Unequipped “UNEQ-P” condition.

Characteristics of the Idle Pattern for DS3 C-bit Parity

- Valid “M-”, “F-” and “P-bits”.
- The three CP-Bits are set to “0”.
- The “X” bits are set to “1”.
- A repeating “1100….” pattern is written into payload portion of the outbound DS3 frames.

FIGURE 15. DS3 M13/C-BIT PARITY - IDLE PATTERN

X=1	[1100]	F1	[1100]	AIC	[1100]	F0	[1100]	NA	[1100]	F0	[1100]	FEAC	[1100]	F1	[1100]
X=1	[1100]	F1	[1100]	UDL	[1100]	F0	[1100]	UDL	[1100]	F0	[1100]	UDL	[1100]	F1	[1100]
P	[1100]	F1	[1100]	0	[1100]	F0	[1100]	0	[1100]	F0	[1100]	0	[1100]	F1	[1100]
P	[1100]	F1	[1100]	FEBE	[1100]	F0	[1100]	FEBE	[1100]	F0	[1100]	FEBE	[1100]	F1	[1100]
M0	[1100]	F1	[1100]	DL	[1100]	F0	[1100]	DL	[1100]	F0	[1100]	DL	[1100]	F1	[1100]
M1	[1100]	F1	[1100]	UDL	[1100]	F0	[1100]	UDL	[1100]	F0	[1100]	UDL	[1100]	F1	[1100]
M0	[1100]	F1	[1100]	UDL	[1100]	F0	[1100]	UDL	[1100]	F0	[1100]	UDL	[1100]	F1	[1100]

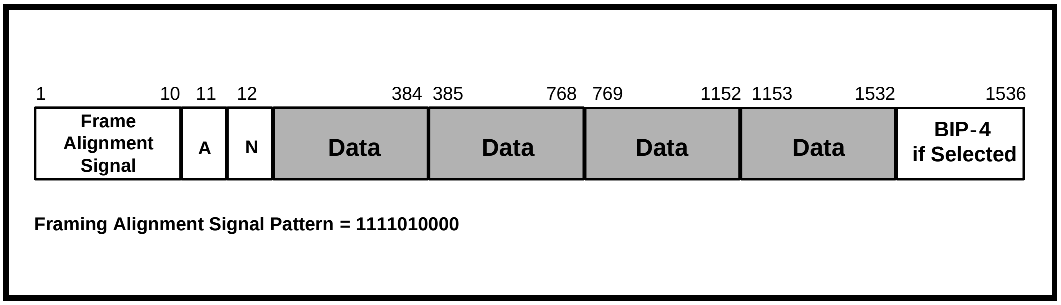
3.0 THE E3 FRAMING FORMATS

The E3 framing formats are the European functional equivalent to the North American Digital Signal 3 standard. The E3 is widely used in the European theatre and globally with the exception of North America and Japan.

3.1 The Legacy ITU-T G.751 Framing Format

The legacy ITU-T G.751 E3 framing format can be thought of as single bit oriented frame consisting of 1536 bits. Each frame consist of a 10-bit long Framing Alignment Signal preceeding 2 overhead bits and 1524 payload bits. An optional BIP-4 trailing nibble can also be optionally employed in place of payload bits. The G.751 E3 frame repetition rate is at 22.375 kHz yielding 34.368 Mbps nominal bit rate.

FIGURE 16. E3 ITU-T G.751 FRAMING FORMAT



The E3 G.751 Frame Summary

- **Frame Size: 1536 bits**
- **Number of Overhead Functions: 3**
- **Number of Overhead Bits: 12 bits**
- **Number of Payload Bits: 1524 bits**
- **Frame Repetition Rate: 22.375 kHertz**
- **Nominal Bit Rate: 34.368 Mbps**

3.1.1 The ITU-T G.751 E3 Framing and Overhead Bits

3.1.1.1 The Framing Alignment Signal

The first 10 bits, within each E3, ITU-T G.751 frame are known as the FAS (or Framing Alignment Signaling) bits. The Receive E3 Framer block, while trying to acquire or maintain framing synchronization with its incoming E3 frames, will attempt to locate the FAS bits. The FAS pattern is assigned the value [1111010000].

3.1.1.2 The A bit

The Alarm Bit or "A" bit typically functions as a FERF (Far-End Receive Failure) or Yellow Alarm indicator bit. In the E3, ITU-T G.751 framing format, the "Yellow Alarm" by sent by setting the "A" bit-field (within the outbound E3 frame) to "1". Conversely, setting the "A" bit to "0" will be an indication of normal operation. If the E3 frames are employing the BIP-4 value (located at the end of a given E3 frame), then this bit will also function as the FEBE indicator bit. This would be functionally equivalent to FEBE in the DS3 and ITU-T G.832 E3 framing format.

3.1.1.3 The N bit

The Data Link bit or "N" bit is typically used to transport PMDL (Path Maintenance Data Link) information such as LAP-D Message Frame from one terminal to another. A detailed discussion of ITU-T Q.921 LAPD messaging format can be found in Section 2.2.1.5. However, the "N" bit-field can also be used to transport a proprietary data link.

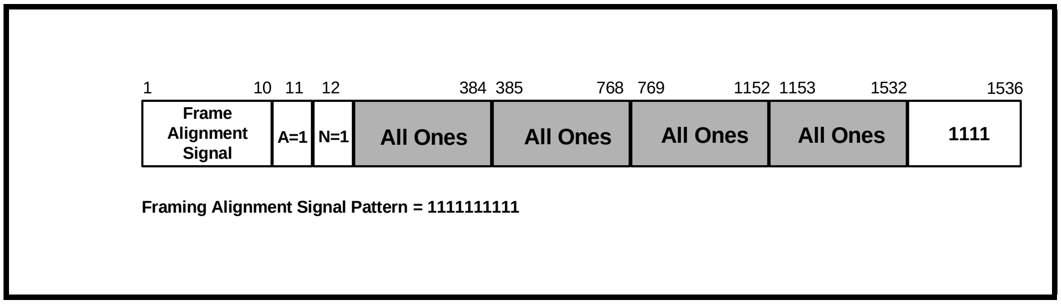
3.1.2 The Alarm Indication Signal Pattern for ITU-T G.751 E3 Framing Format

During an "Service Affecting" fault condition, an E3 AIS patten is often transmitted to downstream circuitry, warning other equipment that there is a "Service Affecting" fault condition nearby.

The characteristics of the AIS Pattern for ITU-T G.751 E3 Framing Format are:

- "All Ones" Pattern

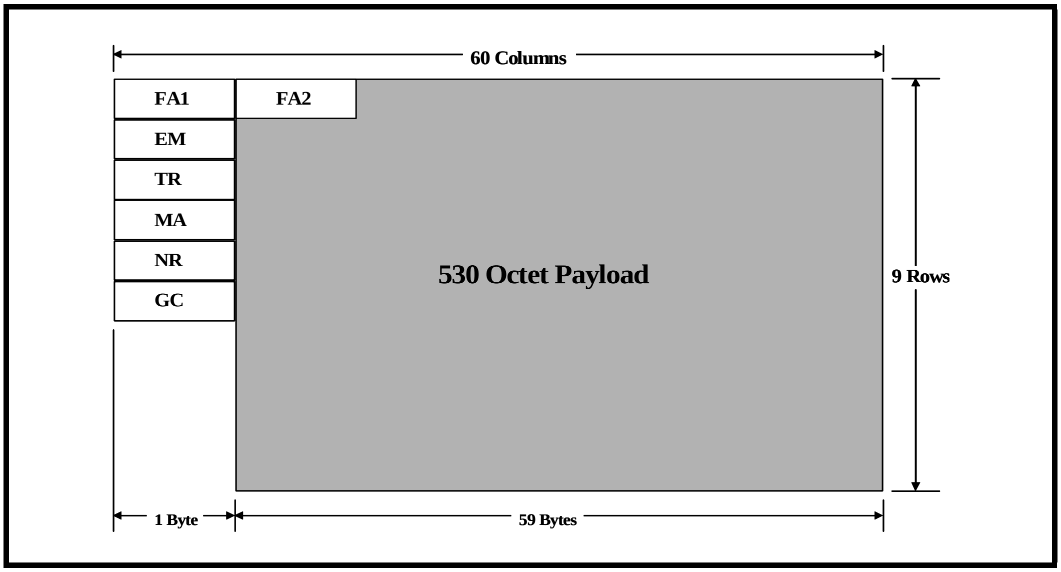
FIGURE 17. E3 ITU-T G.751 AIS SIGNAL PATTERN



3.2 The ITU-T G.832 E3 Framing Format

In contrast to DS3 and ITU-T G.751 E3 frame structure, the ITU-T G.832 E3 framing format can be thought of as a byte oriented frame structure consisting of 537 octets arranged in 9 rows of 60 columns each except for the last three rows which consists of only 59 columns. Each frame consist of 7 Overhead bytes of which 2 are Framing Alignment Bytes with the remaining constituting the 530 bytes of payload. The G.832 E3 frame repetition rate of 8 kHz yields a nominal bit rate of 34.368 Mbps.

FIGURE 18. E3 ITU-T G.832 FRAMING FORMAT



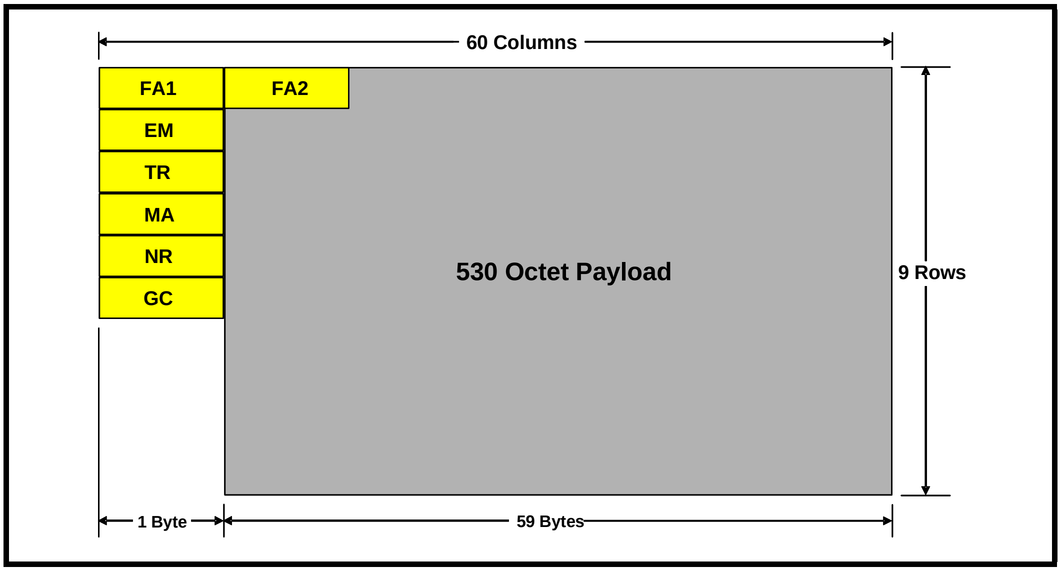
The E3 G.832 Frame Summary

- **Frame Size: 537 bytes**
- **Number of Overhead Functions: 6**
- **Number of Overhead Bytes: 7 bytes**
- **Number of Payload Bytes: 530 bytes**
- **Frame Repetition Rate: 8000 Hertz**
- **Nominal Bit Rate: 34.368 Mbps**

3.2.1 The ITU-T G.832 E3 Framing and Overhead Bytes

The seven (7) overhead bytes are shown in Figure 19, as FA1, FA2, EM, TR, MA, NR and GC.

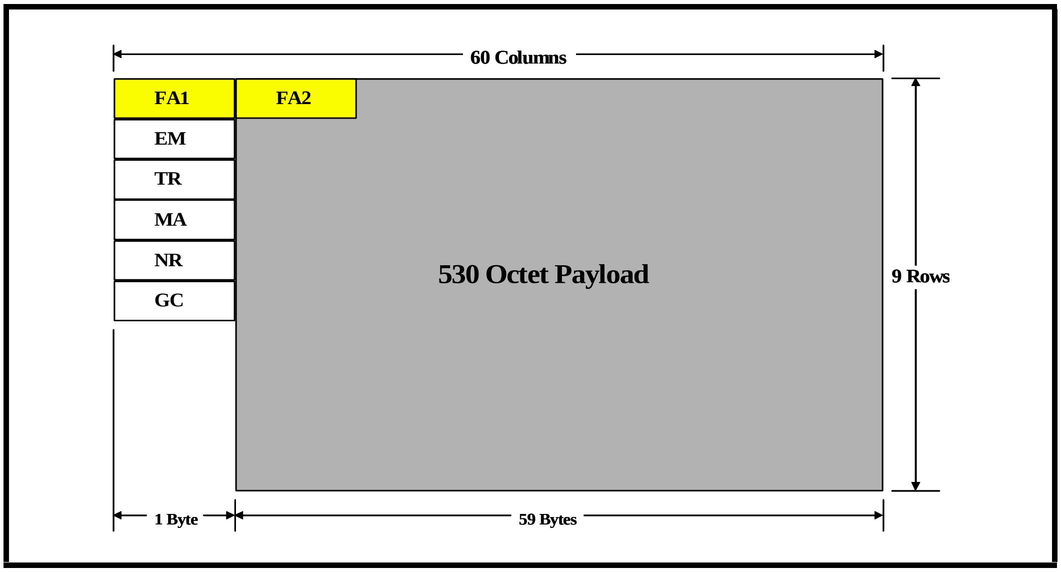
FIGURE 19. THE ITU-T G.832 E3 FRAMING AND OVERHEAD BYTE



3.2.1.1 The Frame Alignment Overhead Bytes - FA1 and FA2

FA1 and FA2 are known as “Framing Alignment” bytes. These framing bytes are used to acquire or maintain framing synchronization. The E3 framer receiver will attempt to locate these two bytes. FA1 is assigned the value of 0xF6 and FA2 is assigned the value of 0x28. This is later adopted in SONET and SDH protocol as the standard value for framing and alignment.

FIGURE 20. FA1 AND FA2 BYTE

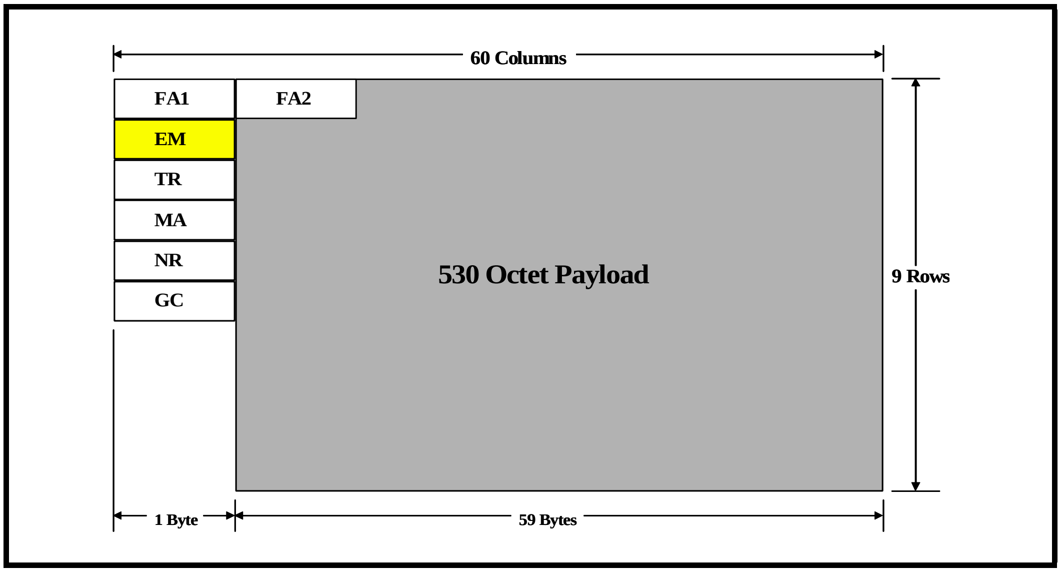


3.2.1.2 The Error Monitor Overhead Byte - EM

The EM (Error Monitor) byte contains the results of BIP-8 (Bit Interleaved Parity) calculations over an entire E3 frame. The Bit Interleaved Parity (BIP-8) byte field supports error detection, during the transmission of E3 frames. A BIP-8 value is computed over the 537 octet structure within a given E3 frame. The resulting BIP-8 value is then inserted into the EM byte field within the very next E3 frame.

BIP-8 is an 8-bit code in which the nth bit of the BIP-8 code reflects the even parity bit calculated with the nth bit of each of the 537 octets within the E3 frame. Thus, the BIP-8 value presents the results for 8 separate even-bit parity calculations. The EM byte is used to perform “Error-Checking” of the E3 frames at the termination point.

FIGURE 21. EM BYTE



3.2.1.3 The Trail Trace Buffer Overhead Byte - TR

The TR byte-field or more commonly referred to as the Trail Trace Buffer byte is used to repetitively transmit a "trail access point identifier" so that a trail receiving terminal can verify its continued connection to the intended transmitter. The Trail Access Point Identifier uses a 16-byte numbering format. The first byte of this string is a "Frame Start Marker" and is typically of the form [1, C6, C5, C4, C3, C2, C1, C0]. The "1" in the MSB (Most Significant Bit) of this first byte is used to identify this byte as the "frame start marker" (e.g., the first byte of the 16-byte Trail Trace Buffer Sequence). The bits: C6 through C0 are the results of a CRC-7 calculation over the previous 16-byte frame. This CRC-7 value is calculated externally and inserted into the Frame Start Marker. The subsequent 15 bytes are used for the transport of the 15 ASCII characters required for E.164 numbering format.

FIGURE 22. EM BYTE

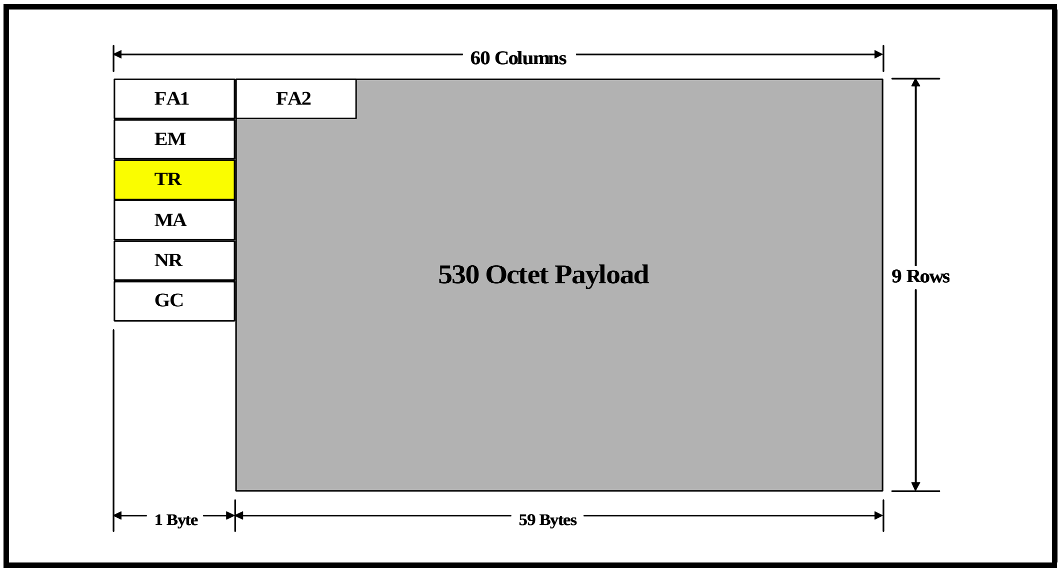


Table 5 shows the 16 Byte Trace Buffer Message Format. It is the precursor to SONET and SDH's Trace Indentifier Messaging format.

TABLE 5: 16 BYTE TRACE BUFFER MESSAGE FORMAT

BYTE NUMBER	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
1 (Frame Start Marker)	1	C6	C5	C4	C3	C2	C1	C0
2	0	X	X	X	X	X	X	X
3	0	X	X	X	X	X	X	X
4	0	X	X	X	X	X	X	X
5	0	X	X	X	X	X	X	X
6	0	X	X	X	X	X	X	X
7	0	X	X	X	X	X	X	X
8	0	X	X	X	X	X	X	X
9	0	X	X	X	X	X	X	X
10	0	X	X	X	X	X	X	X
11	0	X	X	X	X	X	X	X
12	0	X	X	X	X	X	X	X
13	0	X	X	X	X	X	X	X
14	0	X	X	X	X	X	X	X
15	0	X	X	X	X	X	X	X
16	0	X	X	X	X	X	X	X

3.2.1.4 The Maintenance Adaptation Overhead Byte - MA

The MA byte is responsible for carrying the FERF (Far-End Receive Failure) and the FEBE (Far-End Block Error) status indicators from one terminal to another.

The MA byte-field also carries the "Payload Type", the "Payload Dependent" and the "Timing Marker" indicators.

FIGURE 23. MA BYTE

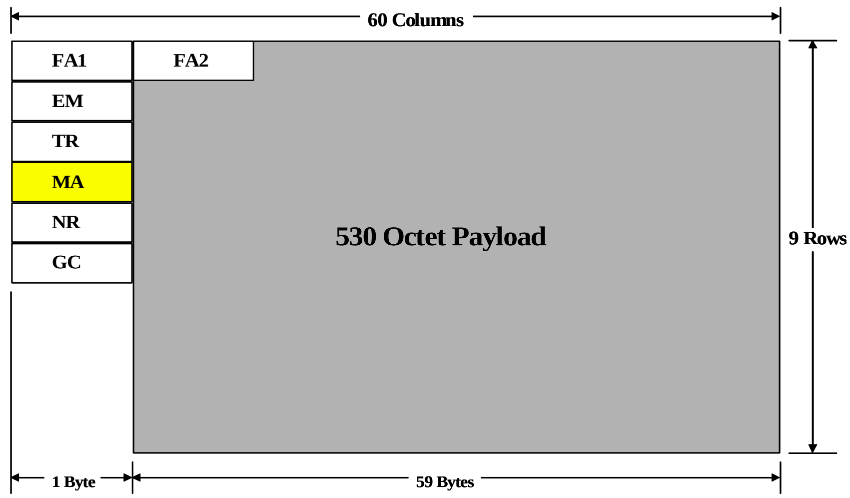


Figure 24 shows the Maintenance and Adaptation byte and the performance monitoring register bits residing within the byte.

FIGURE 24. MAINTENNANCE ADAPTATION BYTE

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FERF	FEBE	Payload Type			Payload Dependent		Timing Marker

3.2.1.4.1 Far-End Receive Failure

Bit 7 - FERF (Far-End Receive Failure)

This bit serves as the FERF or Far End Receive Failure or Yellow Alarm indicator. A value of "1" indicates a failure condition. A value of "0" indicates normal operation.

FIGURE 25. MAINTENNANCE ADAPTATION BYTE - FERF BIT

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FERF	FEBE	Payload Type			Payload Dependent		Timing Marker

3.2.1.4.2 Far-End Block Error

Bit 6 - FEBE (Far-End Block Error)

The FEBE or Far End Block Error is set to the value "1" whenever an error is detected in the EM byte. The EM byte is the calculated BIP-8 (bit interleaved parity byte) value of previous frame and an error is indicative of a compromised integrity of the E3 frame.

FIGURE 26. MAINTENNANCE ADAPTATION BYTE - FEBE BIT

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FERF	FEBE	Payload Type			Payload Dependent		Timing Marker

3.2.1.4.3 Bit [5:3] Payload Type, Bit[2:1] Payload Dependent, and Bit-0 Timing Marker

Bits 5 - 3 Payload Type Indicator

These bit-fields indicates to the "Remote" Receiver, what kind of data is being transported in the 530 bytes of E3 Frame payload data. Some of the defined payload types are listed below.

- 000 - Unequipped
- 001 - Equipped
- 010 - ATM
- 011 - SDH TU-12s.

Bits 2 - 1 Payload Dependent

Bit 0 - Timing Marker

This bit-field is set to "0" to indicate that the timing source is traceable to a Primary Reference Clock. Otherwise, this bit-field is set to "1".

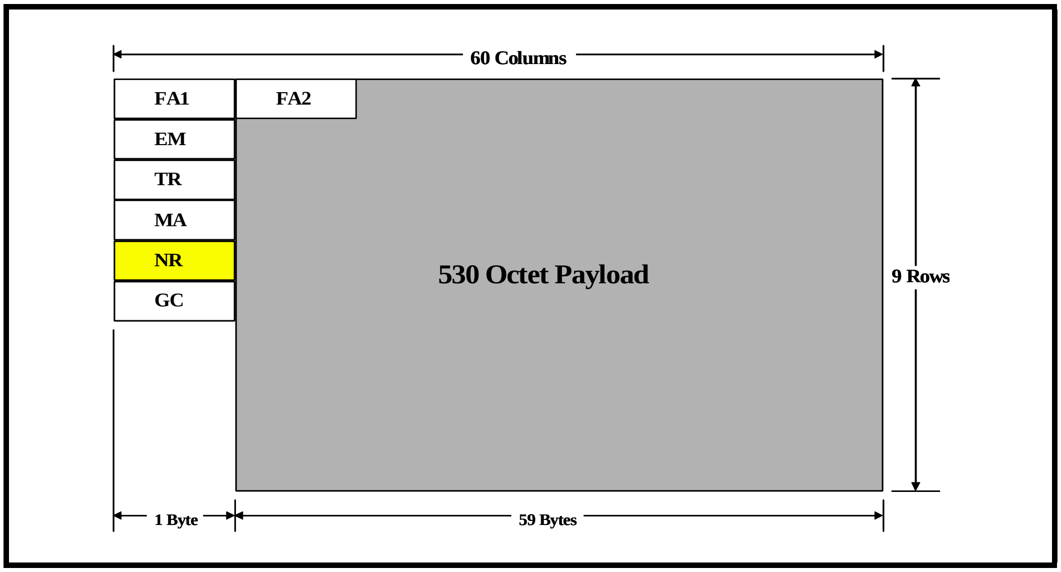
FIGURE 27. MA BYTE - *Bit [5:3] Payload Type, Bit[2:1] Payload Dependent, and Bit-0 Timing Marker*

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FERF	FEBE	Payload Type			Payload Dependent		Timing Marker

3.2.1.5 The Network Operator Overhead Byte - NR

The Network Operator or NR byte can be configured to transport LAPD Message frame octets from the LAPD Transmitter to the LAPD Receive (of a “remote” Receive E3 Framer) at a rate of 64kbps (1 byte per E3 frame).

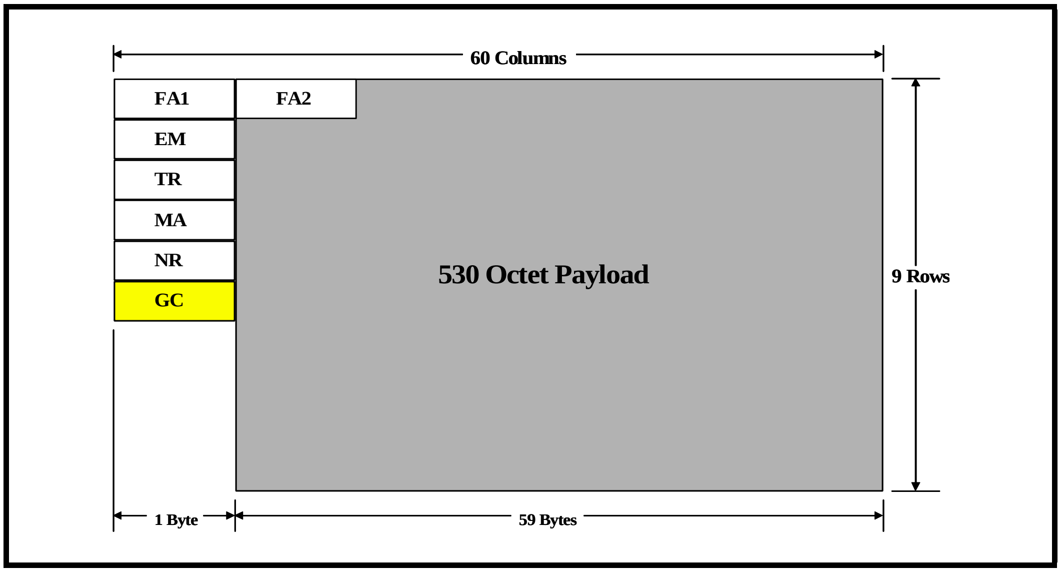
FIGURE 28. NR BYTE



3.2.1.6 The General Purpose Communication Channel Overhead Byte - GC

The General Purpose Communication Channel or GC byte can be configured to transport LAPD Message frame octets from the LAPD Transmitter to the LAPD Receive (of a "remote" Receive E3 Framer) at a rate of 64kbps (1 byte per E3 frame).

FIGURE 29. GC BYTE



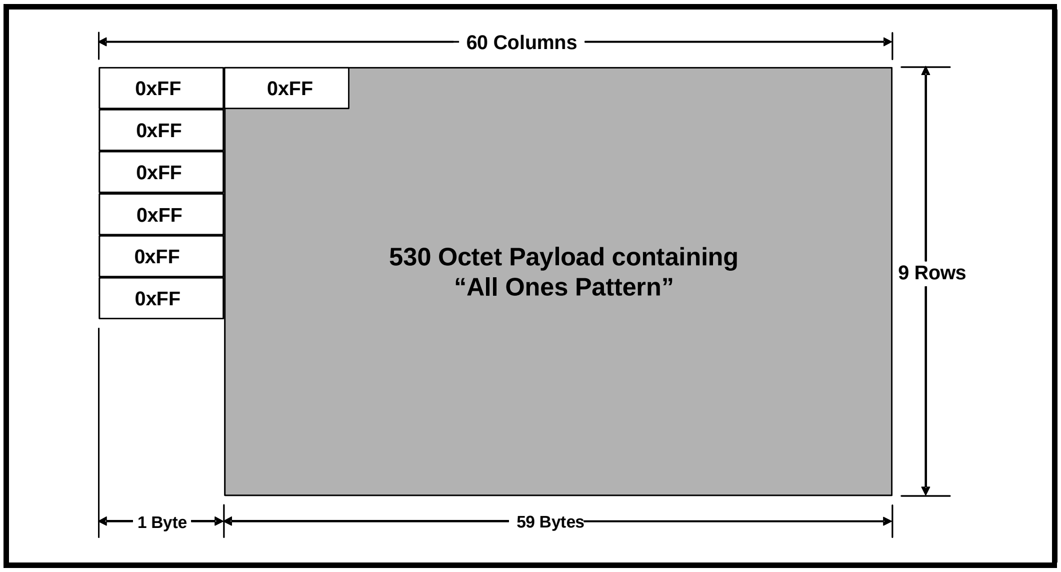
3.2.2 The Alarm Indication Signal Pattern for ITU-T G.832 E3 Framing Format

During an "Service Affecting" fault condition, an E3 AIS patten is often transmitted to downstream circuitry, warning other equipment that there is a “Service Affecting” fault condition nearby.

The characteristics of the AIS Pattern for ITU-T G.832 E3 Framing Format are:

- "An un-framed “All Ones” Pattern.

FIGURE 30. E3 ITU-T G.832 AIS SIGNAL PATTERN



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6. International Telecommunications Union, ITU-T G.703

   Series G: Transmission Systems and Media, Digital Systems and Networks: Digital Terminal Equipments - General

7. International Telecommunications Union, ITU-T G.751

   General Aspects of Digital Transmission Systems, Terminal Equipments: Digital Multiplex Equipments Operating at the Third Order Bit Rate of 34 368 kbits/s and the Fourth Order Bit Rate of 139 264 kbit/s and Using Positive Justification

8. International Telecommunications Union, ITU-T G.832

   Series G: Transmission Systems and Media, Digital Systems and Networks: Transport of SDH Elements on PDH Networks - Frame and Multiplexing Structures