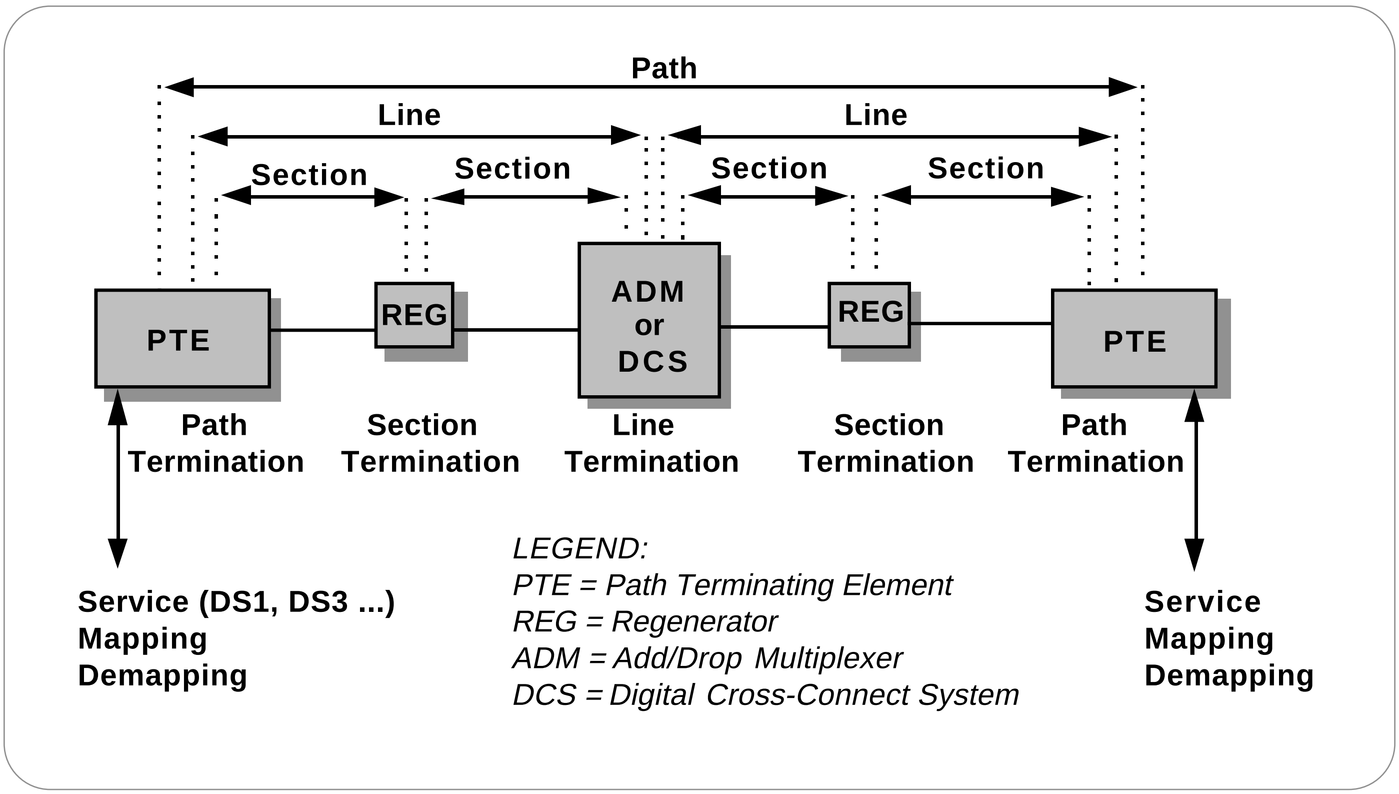
Overheads

SONET provides substantial overhead information, allowing simpler multiplexing and greatly expanded OAM&P (Operations, Administration, Maintenance, and Provisioning) capabilities. The overhead information has several layers, which are shown in Figure 6. Path-level overhead is carried from end-to-end; it's added to DS1 signals when they are mapped into virtual tributaries and for STS-1 payloads that travel end-to-end. Line overhead is for the STS-N signal between STS-N multiplexers. Section overhead is used for communications between adjacent network elements, such as regenerators.

Enough information is contained in the overhead to allow the network to operate and allow OAM&P communications between an intelligent network controller and the individual nodes.

The following sections detail the different SONET overhead information:

- Section Overhead
- Line Overhead
- STS Path Overhead
- VT Path Overhead



▶ ***Figure 6.*** *Overhead layers.*

Section Overhead

Section Overhead contains nine bytes of the transport overhead accessed, generated, and processed by section-terminating equipment. This overhead supports functions such as:

- Performance monitoring (STS-N signal)
- Local orderwire
- Data communication channels to carry information for OAM&P
- Framing

This might be two regenerators, line terminating equipment, and a regenerator, or two line terminating equipment. The Section Overhead is found in the first three rows of Columns 1 through 9 (see Figure 7). Table 3 shows Section Overhead byte-by-byte.

Line Overhead

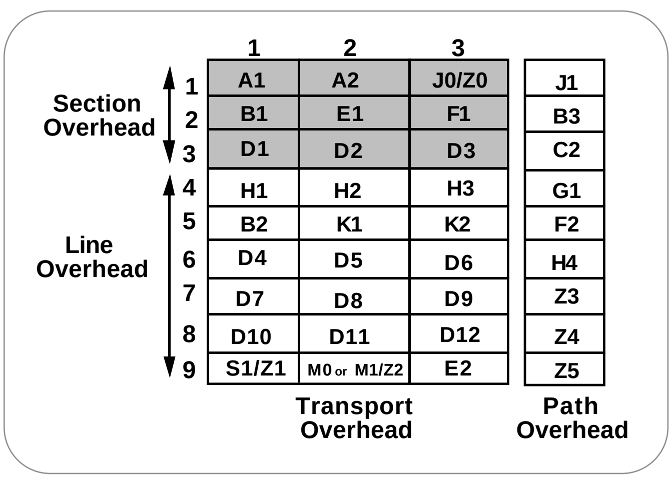
Line Overhead contains 18 bytes of overhead accessed, generated, and processed by line terminating equipment. This overhead supports functions such as:

- Locating the SPE in the frame
- Multiplexing or concatenating signals
- Performance monitoring
- Automatic protection switching
- Line maintenance

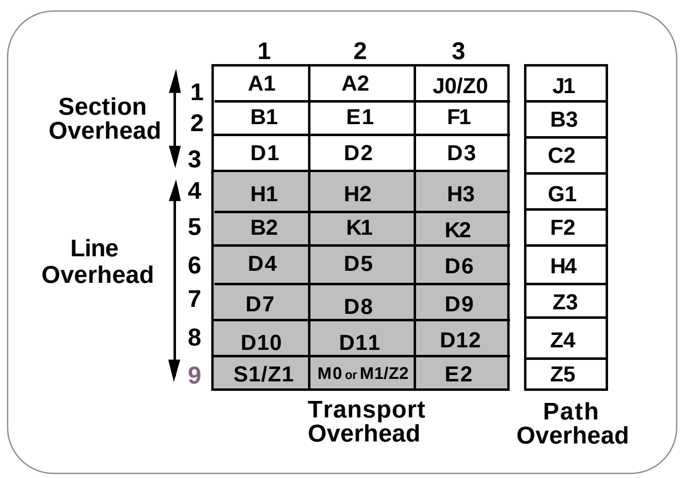
The Line Overhead is found in Rows 4 to 9 of Columns 1 through 9 (see Figure 8). Table 4 shows Line Overhead byte-by-byte.

Table 3. Section Overhead

Byte	Description
A1 and A2	**Framing bytes –** These two bytes indicate the beginning of an STS-1 frame.
J0	**Section Trace (J0)/Section Growth (Z0) –** The byte in each of the N STS-1s in an STS-N that was formerly defined as the STS-1 ID (C1) byte has been refined either as the Section Trace byte (in the first STS-1 of the STS-N), or as a Section Growth byte (in the second through Nth STS-1s).
B1	**Section bit interleaved parity code (BIP-8) byte –** This is a parity code (even parity) used to check for transmission errors over a regenerator section. Its value is calculated over all bits of the previous STS-N frame after scrambling, then placed in the B1 byte of STS-1 before scrambling. Therefore, this byte is defined only for STS-1 number 1 of an STS-N signal.
E1	**Section orderwire byte –** This byte is allocated to be used as a local orderwire channel for voice communication between regenerators.
F1	**Section user channel byte –** This byte is set aside for users' purposes. It can be read and/or written to at each section terminating equipment in that line.
D1, D2, D3	**Section data communications channel (DCC) bytes –** These three bytes form a 192 kb/s message channel providing a message-based channel for Operations, Administration, Maintenance, and Provisioning (OAM&P) between pieces of section-terminating equipment. The channel is used from a central location for control, monitoring, administration, and other communication needs.



▶ ***Figure 7.*** *Section Overhead – Rows 1 to 3 of Transport Overhead.*



▶ ***Figure 8.*** *Line Overhead – Rows 4 to 9 of Transport Overhead.*

Table 4. Line Overhead

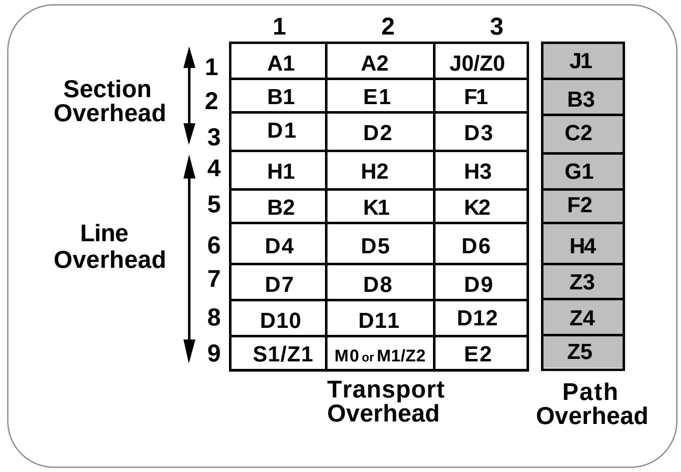
Byte	Description
H1, H2	**STS Payload Pointer (H1 and H2) –** Two bytes are allocated to a pointer that indicates the offset in bytes between the pointer and the first byte of the STS SPE. The pointer bytes are used in all STS-1s within an STS-N to align the STS-1 Transport Overhead in the STS-N, and to perform frequency justification. These bytes are also used to indicate concatenation, and to detect STS Path Alarm Indication Signals (AIS-P).
H3	**Pointer Action Byte (H3) –** The pointer action byte is allocated for SPE frequency justification purposes. The H3 byte is used in all STS-1s within an STS-N to carry the extra SPE byte in the event of a negative pointer adjustment. The value contained in this byte when it's not used to carry the SPE byte is undefined.
B2	**Line bit interleaved parity code (BIP-8) byte –** This parity code byte is used to determine if a transmission error has occurred over a line. It's even parity, and is calculated over all bits of the Line Overhead and STS-1 SPE of the previous STS-1 frame before scrambling. The value is placed in the B2 byte of the Line Overhead before scrambling. This byte is provided in all STS-1 signals in an STS-N signal.
K1 and K2	**Automatic Protection Switching (APS channel) bytes –** These two bytes are used for Protection Signaling between Line Terminating entities for bi-directional automatic protection switching and for detecting alarm indication signal (AIS-L) and Remote Defect Indication (RDI) signals. K1 Byte Bits 1-4 Type of request 1111 Lock out of Protection 1110 Forced Switch 1101 SF – High Priority 1100 SF – Low Priority 1011 SD – High Priority 1010 SD – Low Priority 1001 (not used) 1000 Manual Switch 0111 (not used) 0110 Wait-to-Restore 0101 (not used) 0100 Exercise 0011 (not used) 0010 Reverse Request 0001 Do Not Revert 0000 No Request Bits 5-8 Indicate the number of the channel requested K2 Byte Bits 1-4 Selects channel number Bit 5 Indication of architecture 0 1+1 1 1:n Bit 6-8 Mode of operation 111 AIS-L 110 RDI-L 101 Provisioned mode is bidirectional 100 Provisioned mode is unidirectional 011 Future use 010 Future use 001 Future use 000 Future use
D4 to D12	**Line Data Communications Channel (DCC) bytes –** These nine bytes form a 576 kb/s message channel from a central location for OAM&P information (alarms, control, maintenance, remote provisioning, monitoring, administration, and other communication needs) between line entities. A protocol analyzer is required to access the Line-DCC information.
S1	**Synchronization Status (S1) –** The S1 byte is located in the first STS-1 of an STS-N, and bits 5 through 8 of that byte are allocated to convey the synchronization status of the network element.
Z1	**Growth (Z1) –** The Z1 byte is located in the second through Nth STS-1s of an STS-N (3≤N≤48), and is allocated for future growth. Note that an OC-1 or STS-1 electrical signal does not contain a Z1 byte.
M0	**STS-1 REI-L (M0) –** The M0 byte is only defined for STS-1 in an OC-1 or STS-1 electrical signal. Bits 5 through 8 are allocated for a Line Remote Error Indication function (REI-L – formerly referred to as Line FEBE), which conveys the error count detected by an LTE (using the Line BIP-8 code) back to its peer LTE.
M1	**STS-N REI-L (M1) –** The M1 byte is located in the third STS-1 (in order of appearance in the byte-interleaved STS-N electrical or OC-N signal) in an STS-N (N≥3), and is used for a REI-L function.
Z2	**Growth (Z2) –** The Z2 byte is located in the first and second STS-1s of an STS-3, and the first, second, and fourth through Nth STS-1s of an STS-N (12≤N≤48). These bytes are allocated for future growth. Note that an OC-1 or STS-1 electrical signal does not contain a Z2 byte.
E2	**Orderwire byte –** This orderwire byte provides a 64 kb/s channel between line entities for an express orderwire. It's a voice channel for use by technicians and will be ignored as it passes through the regenerators.

STS Path Overhead

STS Path Overhead (STS POH) contains nine evenly distributed Path Overhead bytes per 125 microseconds starting at the first byte of the STS SPE. STS POH provides for communication between the point of creation of an STS SPE and its point of disassembly. This overhead supports functions such as:

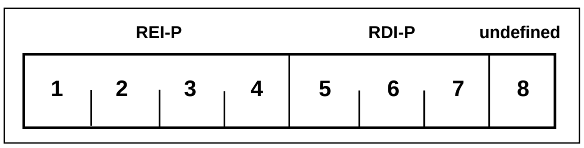
- Performance monitoring of the STS SPE
- Signal label (the content of the STS SPE, including status of mapped payloads)
- Path status
- Path trace

The Path Overhead is found in Rows 1 to 9 of the first column of the STS-1 SPE (see Figure 9). Table 5 describes Path Overhead byte-by-byte.



▶ ***Figure 9.*** *Path Overhead – Rows 1 to 9.*

Table 5. STS Path Overhead

<table>
<tr><th>Byte</th><th>Description</th></tr>
<tr><td>J1</td><td>STS path trace byte – This user-programmable byte repetitively transmits a 64-byte, or 16-byte E.164 format string. This allows the receiving terminal in a path to verify its continued connection to the intended transmitting terminal.</td></tr>
<tr><td>B3</td><td>STS Path Bit Interleaved Parity code (Path BIP-8) byte – This is a parity code (even), used to determine if a transmission error has occurred over a path. Its value is calculated over all the bits of the previous synchronous payload envelope (SPE) before scrambling and placed in the B3 byte of the current frame.</td></tr>
<tr><td>C2</td><td>STS Path signal label byte – This byte is used to indicate the content of the STS SPE, including the status of the mapped payloads.
<table>
<tr><th>Bits 1-4</th><th>Bits 5-8</th><th>Status</th></tr>
<tr><td>0000</td><td>0000</td><td>Unequipped</td></tr>
<tr><td>0000</td><td>0001</td><td>Equipped</td></tr>
<tr><td>0000</td><td>0010</td><td>VT-structured STS-1 SPE</td></tr>
<tr><td>0000</td><td>0011</td><td>Locked VT mode</td></tr>
<tr><td>0000</td><td>0100</td><td>Asynchronous mapping for DS3</td></tr>
<tr><td>0001</td><td>0010</td><td>Asynchronous mapping for DS4NA</td></tr>
<tr><td>0001</td><td>0011</td><td>Mapping for ATM</td></tr>
<tr><td>0001</td><td>0100</td><td>Mapping for DQDB</td></tr>
<tr><td>0001</td><td>0101</td><td>Asynchronous mapping for FDDI</td></tr>
</table></td></tr>
<tr><td>G1</td><td>Path status byte – This byte is used to convey the path terminating status and performance back to the originating path terminating equipment. Therefore, the duplex path in its entirety can be monitored from either end, or from any point along the path. Bits 1 through 4 are allocated for an STS Path REI function (REI-P – formerly referred to as STS Path FEBE). Bits 5, 6, and 7 of the G1 byte are allocated for an STS Path RDI (RDI-P) signal. Bit 8 of the G1 byte is currently undefined.


<table>
<tr><td>Bits `1-4</td><td>STS Path REI function</td><td></td></tr>
<tr><td>Bits 5-7</td><td>STS Path RDI function (Trigger & Interpretation)</td><td></td></tr>
<tr><td>111</td><td>AIS-P, LOP-P</td><td>Remote defect</td></tr>
<tr><td>110</td><td>UNEQ-P, TIM-P</td><td>Remote connectivity defect</td></tr>
<tr><td>101</td><td>AIS-P, LOP-P</td><td>Remote server defect</td></tr>
<tr><td>100</td><td>AIS-P, LOP-P</td><td>Remote defect</td></tr>
<tr><td>011</td><td>No defects</td><td>No remote defect</td></tr>
<tr><td>010</td><td>PLM-P, LCD-P</td><td>Remote payload defect</td></tr>
<tr><td>001</td><td>No defects</td><td>No remote defect</td></tr>
<tr><td>000</td><td>No defects</td><td>No remote defect</td></tr>
<tr><td>Bit 8</td><td>Undefined</td><td></td></tr>
</table></td></tr>
<tr><td>F2</td><td>Path user channel byte – This byte is used for user communication between path elements.</td></tr>
<tr><td>H4</td><td>Virtual Tributary (VT) multiframe indicator byte – This byte provides a generalized multiframe indicator for payload containers. At present, it’s used only for tributary unit structured payloads.</td></tr>
</table>

NOTE: The Path Overhead Portion of the SPE remains with the payload until it’s demultiplexed.

VT Path Overhead

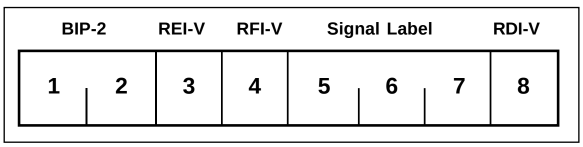
VT Path Overhead (VT POH) contains four evenly distributed Path Overhead bytes per VT SPE starting at the first byte of the VT SPE. VT POH provides communication between the point of creation of an VT SPE and its point of disassembly.

Four bytes (V5, J2, Z6, and Z7) are allocated for VT POH. The first byte of a VT SPE (i.e., the byte in the location pointed to by the VT Payload Pointer) is the V5 byte, while the J2, Z6, and Z7 bytes occupy the corresponding locations in the subsequent 125 microsecond frames of the VT Superframe.

The V5 byte provides the same functions for VT paths that the B3, C2, and G1 bytes provide for STS paths; namely error checking, signal label, and path status. The bit assignments for the V5 byte are described in Table 6.

Table 6. VT Path Overhead

Byte	Description	
V5	**VT path overhead byte.**	



Byte	Description	
	Bits 1-2	Allocated for error performance monitoring.
	Bit 3	Allocated for a VT Path REI function (REI-V – formerly referred to as VT Path FEBE) to convey the VT Path terminating performance back to an originating VT PTE.
	Bit 4	Allocated for a VT Path Remote Failure Indication (RFI-V) in the byte-synchronous DS1 mapping.
	Bits 5-7	Allocated for a VT Path Signal Label to indicate the content of the VT SPE.
	000	Unequipped
	001	Equipped – non-specific payload
	010	Asynchronous mapping
	011	Bit synchronous mapping (no longer valid for DS1)
	100	Byte synchronous mapping
	101	Unassigned
	110	Unassigned
	111	Unassigned
	Bit 8	Allocated for a VT Path Remote Defect Indication (RDI-V) signal.
J2	**VT Path trace identifier –** This byte is used to support the end-to-end monitoring of a path.	
Z6	The Z6 byte is known as N2 in the SDH standard and is allocated to provide a Lower-Order Tandem Connection Monitoring (LO-TCM) function.	
Z7	The Z7 byte is known as K4 in the SDH standard. Bits 1-4 are allocated for APS signaling for protection at the Lower-Order path level. Bits 5-7 are used in combination with V5 bit 8 for ERDI-V. Bit 8 is reserved for future use and has no defined value.	

SONET Alarm Structure

The SONET frame structure has been designed to contain a large amount of overhead information. The overhead information provides a variety of management and other functions such as:

- Error performance monitoring
- Pointer adjustment information
- Path status
- Path trace
- Section trace
- Remote defect, error, and failure indications
- Signal labels
- New data flag indications
- Data communications channels (DCC)
- Automatic Protection Switching (APS) control
- Orderwire
- Synchronization status message

Much of this overhead information is involved with alarm and in-service monitoring of the particular SONET sections.

SONET alarms are defined as follows:

Anomaly – The smallest discrepancy which can be observed between the actual and desired characteristics of an item. The occurrence of a single anomaly does not constitute an interruption in the ability to perform a required function.

Defect – The density of anomalies has reached a level where the ability to perform a required function has been interrupted. Defects are used as input for performance monitoring, the control of consequent actions, and the determination of fault cause.

Failure – The inability of a function to perform a required action persisted beyond the maximum time allocated.

Table 7 describes SONET alarm anomalies, defects, and failures.

Table 7. Anomalies, Defects, and Failures

Abbreviation	Description	Criteria
LOS	**Loss of Signal**	LOS is raised when the synchronous signal (STS-N) level drops below the threshold at which a BER of 1 in 103 is predicted. It could be due to a cut cable, excessive attenuation of the signal, or equipment fault. The LOS state clears when two consecutive framing patterns are received and no new LOS conditions detected.
OOF	**Out of Frame Alignment**	OOF state occurs when four or five consecutive SONET frames are received with invalid (errored) framing patterns (A1 and A2 bytes). The maximum time to detect OOF is 625 microseconds. OOF state clears when two consecutive SONET frames are received with valid framing patterns.
LOF	**Loss of Frame Alignment**	LOF state occurs when the OOF state exists for a specified time in milliseconds. The LOF state clears when an in-frame condition exists continuously for a specified time in milliseconds.
LOP	**Loss of Pointer**	LOP state occurs when N consecutive invalid pointers are received or "N" consecutive New Data Flags (NDF) are received (other than in a concatenation indicator), where N = 8, 9, or 10. LOP state is cleared when three equal valid pointers or three consecutive AIS indications are received. LOP can also be identified as: ▶ LOP-P (STS Path Loss of Pointer) ▶ LOP-V (VT Path Loss of Pointer)
AIS	**Alarm Indication Signal**	The AIS is an all-ONES characteristic or adapted information signal. It's generated to replace the normal traffic signal when it contains a defect condition in order to prevent consequential downstream failures being declared or alarms being raised. AIS can also be identified as: ▶ AIS-L (Line Alarm Indication Signal) ▶ AIS-P (STS Path Alarm Indication Signal) ▶ AIS-V (VT Path Alarm Indication Signal)
REI	**Remote Error Indication**	An indication returned to a transmitting node (source) that an errored block has been detected at the receiving node (sink). This indication was formerly known as Far End Block Error (FEBE). REI can also be identified as: ▶ REI-L (Line Remote Error Indication) ▶ REI-P (STS Path Remote Error Indication) ▶ REI-V (VT Path Remote Error Indication)
RDI	**Remote Defect Indication**	A signal returned to the transmitting Terminating Equipment upon detecting a Loss of Signal, Loss of Frame, or AIS defect. RDI was previously known as FERF. RDI can also be identified as: ▶ RDI-L (Line Remote Defect Indication) ▶ RDI-P (STS Path Remote Defect Indication) ▶ RDI-V (VT Path Remote Defect Indication)
RFI	**Remote Failure Indication**	A failure is a defect that persists beyond the maximum time allocated to the transmission system protection mechanisms. When this situation occurs, an RFI is sent to the far end and will initiate a protection switch if this function has been enabled. RFI can also be identified as: ▶ RFI-L (Line Remote Failure Indication) ▶ RFI-P (STS Path Remote Failure Indication) ▶ RFI-V (VT Path Remote Failure Indication)
B1 error	**B1 error**	Parity errors evaluated by byte B1 (BIP-8) of an STS-N are monitored. If any of the eight parity checks fail, the corresponding block is assumed to be in error.
B2 error	**B2 error**	Parity errors evaluated by byte B2 (BIP-24 x N) of an STS-N are monitored. If any of the N x 24 parity checks fail, the corresponding block is assumed to be in error.
B3 error	**B3 error**	Parity errors evaluated by byte B3 (BIP-8) of a VT-N (N = 3, 4) are monitored. If any of the eight parity checks fail, the corresponding block is assumed to be in error.
BIP-2 error	**BIP-2 error**	Parity errors contained in bits 1 and 2 (BIP-2: Bit Interleaved Parity-2) of byte V5 of an VT-M (M = 11, 12, 2) is monitored. If any of the two parity checks fail, the corresponding block is assumed to be in error.
LSS	**Loss of Sequence Synchronization**	Bit error measurements using pseudo-random sequences can only be performed if the reference sequence produced on the receiving side of the test set-up is correctly synchronized to the sequence coming from the object under test. In order to achieve compatible measurement results, it's necessary that the sequence synchronization characteristics are specified. Sequence synchronization is considered to be lost and resynchronization shall be started if: ▶ Bit error ratio is ≥0.20 during an integration interval of 1 second; or ▶ It can be unambiguously identified that the test sequence and the reference sequence are out of phase

NOTE: One method to recognize the out-of-phase condition is evaluation of the error pattern resulting from the bit-by-bit comparison. If the error pattern has the same structure as the pseudo-random test sequence, the out-of-phase condition is reached.