
Linear Token Passing Multiplex Data Bus

AS4074.1

High Speed Ring Bus (HSRB)

SAE also publishes a standard on a High Speed Ring Bus (HSRB). This high speed ring bus standard (HSRB) is a fault tolerant, real time high speed data communication standard based on a ring topology and the use of a Token passing access method with distributed control. The requirements for the HSRB standard have been driven predominantly, but not exclusively, by military applications. Particular attention has been given to the need for low message latency, deterministic message priority and comprehensive reconfiguration capabilities. This document contains a definition of the semantics and protocol including delimiters, tokens, message priority, addressing, error detection and recovery schemes; and is written to be independent of bit rate and media. Parameters related to particular media and bit rates are defined in the Appendix.

LINEAR TOKEN PASSING MULTIPLEX DATA BUS

CONTENTS

	<u>Page No.</u>
ACRONYMS AND ABBREVIATIONS	12
1. SCOPE	12
2. REFERENCES	12
2.1 Applicable Documents	12
3. GENERAL REQUIREMENTS	13
3.1 General Description	13
3.2 Media Interface Unit (MIU)	16
3.2.1 Symbol Set	16
3.2.1.1 Line States	16
3.2.1.2 Control Symbols	16
3.2.1.3 Data Symbols	17
3.2.1.4 Violation Symbols	17
3.2.2 Transmitter, Receiver and Media Definition	18
3.2.2.1 Fiber Optic Bus Media Definition	18
3.2.2.1.1 Fiber Optic Media Common Characteristics	18

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Page No.

3.2.2.1.1.1	Fiber Optic Media Station Input/Output Ports	18
3.2.2.1.1.2	Fiber Optic Media Data Rate	18
3.2.2.1.1.3	Fiber Optic Media Signaling Rate	18
3.2.2.1.1.4	System Minimum Intertransmission Gap	18
3.2.2.1.1.5	System Minimum Preamble Size	19
3.2.2.1.1.6	Fiber Optic Media Wavelength and Spectral Bandwidth	19
3.2.2.1.2	Fiber Optic Transmitter (FOTX) Characteristics	19
3.2.2.1.2.1	FOTX Output Power	19
3.2.2.1.2.2	FOTX Maximum Residual Power ...	19
3.2.2.1.2.3	FOTX Maximum Leakage Power	19
3.2.2.1.2.4	FOTX Output Waveform	19
3.2.2.1.2.5	FOTX Data Streaming Timeout	19
3.2.2.1.3	Fiber Optic Receiver (FORX) Characteristics	21
3.2.2.1.3.1	FORX Sensitivity	21
3.2.2.1.3.2	FORX Operating Range and Margin	21
3.2.2.1.3.3	FORX Bit Error Rate	21
3.2.2.1.3.4	FORX Input Waveform	21
3.2.2.1.4	Fiber Optic Transmission Media Characteristics	21



		<u>Page No.</u>
3.2.2.1.4.1	Fiber Physical Characteristics ..	24
3.2.2.1.4.2	Fiber Numerical Aperture	24
3.2.2.1.4.3	Fiber Chromatic and Modal Dispersion	24
3.2.2.1.4.4	Fiber Optic Transmission Media Attenuation	24
3.2.2.2	Electrical Bus Media Interface Definition	24
3.2.2.2.1	Electrical Media Common Characteristics	24
3.2.2.2.1.1	Electrical Media Station Input/Output Ports	24
3.2.2.2.1.2	Electrical Media Data Rate	24
3.2.2.2.1.3	Electrical Media Signaling Rate	24
3.2.2.2.1.4	System Minimum Intertransmission Gap	25
3.2.2.2.1.5	System Minimum Preamble Size	25
3.2.2.2.1.6	Electrical Media Surge Voltage	25
3.2.2.2.2	Electrical Transmitter (ELTX) Characteristics	25
3.2.2.2.2.1	ELTX Output Voltage Level	25
3.2.2.2.2.2	ELTX Peak Residual Output Voltage Level	25
3.2.2.2.2.3	ELTX Output Waveform	25
3.2.2.2.2.4	ELTX Data Streaming Timeout	25

	<u>Page No.</u>
3.2.2.2.3 Electrical Receiver (ELRX) Characteristics	27
3.2.2.2.3.1 ELRX Sensitivity and Waveform Compatibility	27
3.2.2.2.3.2 ELRX Dynamic Range	27
3.2.2.2.3.3 ELRX Common Mode Rejection Ratio ..	28
3.2.2.2.3.4 ELRX Input Impedance	28
3.2.2.2.3.5 ELRX Bit Error Rate	28
3.2.2.2.4 Electrical Media Characteristics	28
3.2.2.2.4.1 Electrical Media Return Loss	29
3.2.2.2.4.2 Electrical Media Frequency Response	29
3.2.2.2.4.3 Electrical Media Attenuation	29
3.2.2.2.4.4 Electrical Media Group Propagation Delay	29
3.2.2.2.4.5 Electrical Media Jitter	29
3.2.3 Media Redundancy	29
3.2.4 Transmission Monitoring	30
3.3 Media Access Protocol Facilities	30
3.3.1 Protocol Data Units (PDU)	30
3.3.1.1 Start Delimiter (SD)	32
3.3.1.2 Frame Control (FC)	32
3.3.1.2.1 Frame Type (FT)	32
3.3.1.2.2 Priority (Px)	33
3.3.1.2.3 Station Management Code (SMC)	33
3.3.1.3 Source Address (SA)	33
3.3.1.4 Destination Address (DA)	33
3.3.1.5 Word Count (WC)	33

	<u>Page No.</u>
3.3.1.6 Information (INFO)	34
3.3.1.7 Message Frame Check Sequence (MFCS)	34
3.3.1.8 Token Frame Check Sequence (TFCS)	34
3.3.1.9 End Delimiter (ED)	34
3.3.2 Timers	34
3.3.2.1 Token Holding Timer	36
3.3.2.2 Token Rotation Timer	36
3.3.2.3 Ring Admittance Timer	37
3.3.2.4 Token Passing Timer	37
3.3.2.5 Bus Activity Timer	38
3.3.3 Traffic Summary	38
3.4 Station Management	40
3.4.1 Mode Control Command/Status Report	40
3.4.1.1 Mode Control Command	40
3.4.1.1.1 Reset	42
3.4.1.1.2 Disable	42
3.4.1.1.3 Enable	42
3.4.1.1.4 Report Status	42
3.4.1.1.5 Report Traffic	42
3.4.1.1.6 Reserved	42
3.4.1.1.7 Reserved	42
3.4.1.1.8 Execute BIT	42
3.4.1.1.9 Enable Time Master Mode	42
3.4.1.1.10 Disable Time Master Mode	42
3.4.1.1.11 Report Time	42
3.4.1.2 BIU Status Report	44
3.4.2 Load/Report Configuration Command and Configuration Report	45
3.4.3 Test Messages	45
3.4.4 Wrap-Around Message Echo	45
3.4.5 BIU Initialization	45
3.4.6 Built-In-Test Functions	51
3.4.6.1 Internal Diagnostic	51
3.4.6.2 External Interface Loopback Test	51
3.4.6.3 HOST/BIU Message Loopback	52
3.4.6.4 Background Diagnostic	52

	Page No.
3.4.7 Time Synchronization Report	52
3.4.7.1 BIU Time Clock Operation	52
3.4.7.2 Clock Value Latency	53
3.4.7.3 Message Period	54
3.4.7.4 System Application	54
4. QUALITY ASSURANCE	54
4.1 General	55
4.1.1 Responsibility for Verification	55
4.1.2 Failure Criteria	55
4.1.3 Verification Cross Reference Index	55
4.2 Quality Conformance Verification Methods	55
4.2.1 Inspection Verification Method	55
4.2.2 Review of Analytical Data	55
4.2.3 Demonstration Verification Method	55
4.2.3.1 Laboratory Demonstration	55
4.2.4 Test Verification Method	56
4.2.4.1 Laboratory Test	56
4.2.4.2 Test Categories	56
4.2.4.2.1 Engineering Test and Evaluation	56
4.2.4.2.2 Preliminary Qualification - Scan of Performance	56
4.2.4.2.3 Formal Qualification - Full Performance	56
4.2.4.2.3.1 Environmental Qualification	57
4.2.4.2.4 Reliability and Maintainability Analysis and Test	57
4.2.4.2.4.1 Built-In-Test	57
4.2.4.2.5 Operational Test - Installed on Prime Item	57
4.2.4.2.6 Acceptance Test - Production	57

Page No.

5.	TPIU STATE MACHINE DEFINITION	60
5.1	Idle State (S0)	63
5.2	Claim Token State (S1)	64
5.3	Check Token Address State (S2)	65
5.4	Send Message State (S3)	66
5.5	Pass Token State (S4)	67
5.6	Check Token Pass State (S5)	67
5.7	Check Message Address State (S6)	68
5.8	Receive Message State (S7)	68
6.	LIST OF FIGURES	
Fig. 3.1-1	Linear Token Passing Bus Block Diagram	13
Fig. 3.1-2	Logical Ring Superimposed on a Linear Bus	14
Fig. 3.2.1.2-1	Overall Frame Structure	16
Fig. 3.2.2.1.2.4-1	Fiber Optic Transmitter Output Waveform	20
Fig. 3.2.2.1.3.2-1	Transmitter/Receiver Optical Power Levels	22
Fig. 3.2.2.1.3.4-1	Fiber Optic Receiver Input Waveform	23
Fig. 3.2.2.2.2.3-1	Electrical Transmitter Output Waveform	26
Fig. 3.2.2.2.3.1-2	Electrical Receiver Test Configuration - Minimum Input Level.....	27
Fig. 3.2.2.2.3.3-1	Electrical Receiver Test Configuration - Noise Rejection	28
Fig. 3.3.1-1	Token Passing Protocol Frame Formats	31
Fig. 3.3.1-2	Frame Control Field Definitions	32
Fig. 3.3.2-1	Send Message State Flowchart	35
Fig. 3.4.1.1-1	Mode Control Command Format	41
Fig. 3.4.1.1.4-1	BIU Status Report Format	43
Fig. 3.4.2-1	Load/Report Configuration Command and Report Format	46
Fig. 3.4.3-1	Test Message Format	49
Fig. 3.4.4-1	Wrap-Around Message Echo Format	50
Fig. 3.4.7.1-1	Time Synchronization Message Format	53
Fig. 5-1	TPIU State Diagram	61
7.	LIST OF TABLES	
Table 3.3.2.5-1	Prime Numbers for BAT Period Determination	39
Table 4-1	Acceptance Test Requirements	58
Table 5-1	State Transition Table	62
8.	APPENDIX A	
	Transmission Media Slash Sheets	69
Fig. A-1	Manchester II Symbol Set	76

ACRONYMS AND ABBREVIATIONS

a	Ring Admittance Factor
A _{max}	Maximum end-to-end attenuation
A _{min}	Minimum end-to-end attenuation
A _r	Attenuation of reflected signals
AF	Ring Admittance Timeout Factor
b	Bus Length Factor (variable)
Bps	Bits per second
BAT	Bus Activity Timer
BF	BIU Fault
BFC	BIU Fault Code
BIT	Built-In-Test
BIU	Bus Interface Unit
BL	Bus Loopback
BF	Bus Length Factor (field used in Station Management Message to program the value for "b")
BW	Spectral Bandwidth
C	Clear Message Filter Table
CAF	Cumulative Aborted Frames
CM	Cumulative Messages
CMLR	Cumulative Messages, Local Receive
CMLT	Cumulative Messages, Local Transmit
CMW	Cumulative Message Words
CMWLR	Cumulative Message Words, Local Receive
CMWLT	Cumulative Message Words, Local Transmit
CR	Configuration Report Command
CRC	Cyclic Redundancy Check
CT _g	Claim Token Granule Size
CT _n	Cumulative Total "n"
CT	Cumulative Tokens
C/B	Center of Bit
dB	Decibel
dBm	Decibel referenced to 1 milliwatt
D _{clad}	Fiber Optic cladding diameter
D _{cm}	Maximum total dispersion
D _{core}	Fiber Optic core diameter
DE	Disable/Enable Status
D _{gp}	Group propagation delay difference
D _j	Jitter
DA	Destination Address field (may contain physical or logical address data depending on frame type)
exp	exponential value (raised to the power)
ED	End Delimiter
ELRX	Electrical Receiver
ELTX	Electrical Transmitter
E/T	End of Transmission

ACRONYMS AND ABBREVIATIONS (Continued)

F	Frequency
FC	Frame Control
FORX	Fiber Optic Receiver
FOTX	Fiber Optic Transmitter
FT	Frame Type
FW _n	Filter Page Word "n"
GCD	Global Clock Differential
h	Token Holding Factor
HEX	Hexadecimal
HF	Token Holding Timer Factor (field definition for programming "h" in Station Management Message)
IF	Interface Fault
INFO	Information Field
IR	Interface Reset
KHz	Kilohertz
L	Load
Len	Bus Length
LTPB	Linear Token Passing Bus
m	Bit position in FW field
M	Optical Margin
MBaud	Megabaud
MBPS	Mega Bits per Second
MCS	Mode Control Subcommand Code
MFCs	Message Frame Check Sequence
MFP	Message Filter Page
MHz	Megahertz
MIU	Media Interface Unit
MNS	Maximum Number of Stations in logical ring
MPDU	Message Protocol Data Unit
MUR	Time Synchronization Message Update Periodic Rate
N _{ct}	Number of words in Claim Token Frame
N _{ctw}	Claim Token Sequence Wait Time
NA	Numerical Aperture
NS	Next Station
px	Token Rotation Factor
P	Preamble
Px	Priority
PDU	TPIU Protocol Data Unit
PF1	Token Rotation Timer Factor - Priority Level 1
PF2	Token Rotation Timer Factor - Priority Level 2
PF3	Token Rotation Timer Factor - Priority Level 3
PN	Prime Number - Bus Activity Timer Multiplier

ACRONYMS AND ABBREVIATIONS
(Continued)

r	Data Rate Factor (variable utilized in computations; normalized to 50 MBPS)
Rber	Receiver Bit Error Rate
Rcmr	Receiver Common Mode Rejection Ratio
Rd	Data Rate (MBPS)
Rdr	Receiver Dynamic Range
Rdpw	Receiver Input Maximum Pulse Width Distortion
Rf	Fall Time (90% to 10%)
Ridr	Receiver Intertransmission Dynamic Range
Riz	Receiver Input Impedance
Rnv	Receiver Noise Voltage Input
Ror	Receiver Operating Range
Rous	Receiver Combined Over/Undershoot
Rpm	Receiver Minimum Optical Power Input
Rpo	Receiver Maximum Optical Power Input
Rr	Rise Time (10% to 90%)
Rs	Signaling Rate
Rtm	Start-of-Bit to Center-of-Bit
Rto	Start-of-Bit to Start-of-Bit
Rvm	Receiver Minimum Input Voltage
Rvo	Receiver Maximum Input Voltage
Rx	Receiver
RAT	Ring Admittance Timer
RC	Remote Command
RMS	Root Mean Square
RXE	Receiver Enable
Sd	Surge Voltage Duration
Sitg	System Minimum Intertransmission Gap
Sp	Preamble Minimum Size
Sv	Surge Voltage
S0	Idle State
S1	Claim Token State
S2	Check Token Address State
S3	Send Message State
S4	Pass Token State
S5	Check Token Pass State
S6	Check Message Address State
S7	Receive Message State
SA	Source Address
SD	Start Delimiter
S/B	Start-of-Bit
S/T	Start-of-Transmission
SMC	Station Management Code

ACRONYMS AND ABBREVIATIONS
(Continued)

Tba	Bus Activity Indication Time
Td	Clock Uncompensated Drift Rate
Tdpw	Transmitter Maximum Pulse Width Distortion
Tds	Data Streaming Timer
Tf	Transmitter Maximum Fall Time (90% to 10%)
Tifgm	Interframe Gap Time
Tiz	Transmitter Drive Impedance
Tm	Minimum Duration between Transitions
Tms	Master and Most Distant slave Station (Global Timer)
To	Nominal Bit Time
Tous	Transmitter Combined Over/Undershoot
Tpd	Propagation Delay Time
Tpl	Transmitter Optical Leakage Power
Tpo	Transmitter Optical Power
Tpr	Transmitter Residue Power
Tr	Transmitter Rise Time (10% to 90%)
Tsr	Station Response Time
Ttm	Start-of-Bit to Center-of-Bit
Tto	Start-of-Bit to Start-of-Bit
TFCS	Token Frame Check Sequence
TSM	Time Synchronization Message
Ttp	Token Passing Time Value
Tu	Time Master Update Rate (milliseconds)
Tvo	Transmitter Output Voltage Level
Tvr	Transmitter Peak Output Voltage
Tx	Transmitter
TBD	To Be Determined
THT	Token Holding Timer
TIME	Global Clock Value (48 bits)
TM	Time Master
TPIU	Token Passing Interface Unit
TRT	Token Rotation Timer
TRTx	Token Rotation Timer (for priority level "x")
TS	This Station
TXE	Transmitter Enable
V	Valid Time
W1	Optical Wavelength Lower
W2	Optical Wavelength Upper
WC	Word Count

1. SCOPE:

This standard specifies the characteristics of the SAE Linear Token Passing Bus (LTPB) Interface Unit.

The LTPB provides a high reliability, high bandwidth, low latency serial interconnection network suitable for utilization in real time military and commercial applications. Multiple redundant data paths can be implemented to enhance reliability and survivability in those applications that require these attributes. The Token passing and data exchange protocols are optimized to provide low latency and fast failure detection and correction. Physical configurations with bus lengths up to 1000 meters can be accommodated.

This specification defines the following:

- a. General Description (See 3.1): An overview of the LTPB protocol.
- b. Physical Media Interface (See 3.2): This portion of the standard defines the physical interface to both optical and electrical bus media.
- c. Access Protocol Definition (See 3.3): This portion of the standard defines the symbols, frame formats, timing functions and traffic recording requirements of the Token Passing Interface Unit (TPIU).
- d. Network Protocol Definition (See 3.4): This portion of the standard defines the network control and station management functions.
- e. Test and Verification (See section 4): This paragraph defines the responsibilities and methods for test and verification of the LTPB. A cross matrix is provided.
- f. TPIU State Machine (See section 5): This section defines the TPIU States and state transition rules.

2. REFERENCES:

- 2.1 Applicable Documents: The following documents of the exact issue shown, form a part of this specification to the extent specified herein.

ISO

ISO/DIS 7498
22 April 1982

International Systems Organization
System Interconnect – Basic Reference
Model, Draft International Standard

N1406
March 1983

Working Draft for an Addendum to ISO
7498 Covering Connectionless Data Transmission

3. GENERAL REQUIREMENTS:

- 3.1 General Description: The LTPB shall consist of a set of stations connected by a broadcast transmission medium – that is, each station which transmits shall be heard by all of the other stations. Stations shall accept a transmission based upon either physical or logical addressing mechanisms.

The functional block diagram for the LTPB is shown in Fig. 3.1-1 along with its relationship to the ISO OSI Basic Reference Model. It shall consist of the following elements:

- a. Physical Media: The Physical Media shall be composed of one or two physical bus paths. Each bus path shall be characterized as a broadcast medium.
- b. Bus Interface Unit (BIU): The BIU interfaces to the bus media and the User. Each bus path shall be an independent entity requiring a Media Interface Unit (MIU). One TPIU shall serve all implemented MIUs. The remainder of the BIU shall perform station management, network management, and User interface functions.

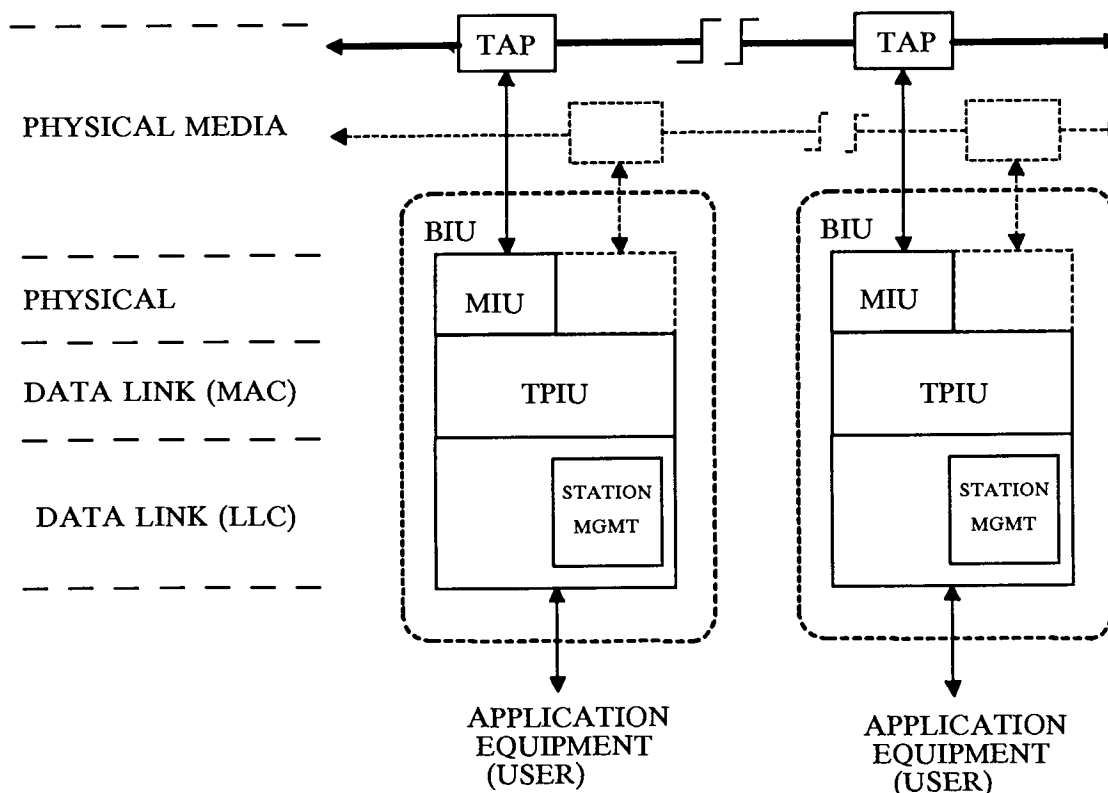


FIGURE 3.1-1 – Linear Token Passing Bus Block Diagram



3.1 (Continued):

Access to the media shall be controlled by the Token. The Token is continually passed around a logical ring (see Fig. 3.1-2) superimposed on the linear bus. A station receiving the Token gains the right to use the medium for a certain amount of time. This amount of time depends upon the following quantities:

- Value of the Token Holding Timer (THT), used for all messages of Priority 0, as well as;
- The residual value of the Token Rotation Timers (TRTs), one for each priority from 1 to 3.

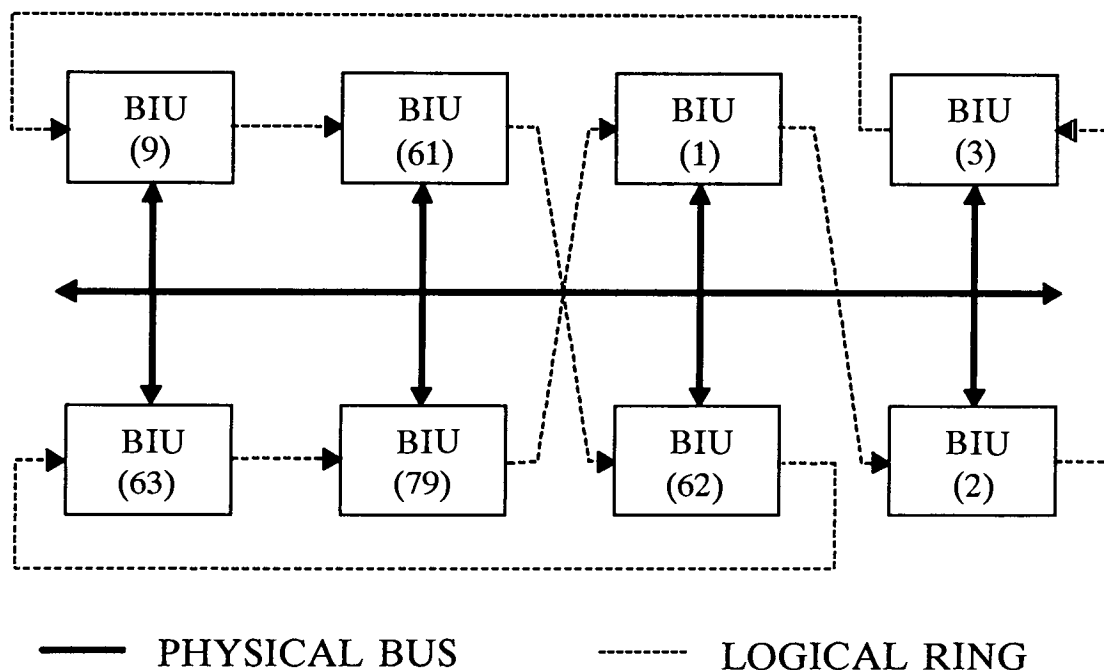


FIGURE 3.1-2 – Logical Ring Superimposed on a Linear Bus

This amount of time shall always be less than or equal to a predetermined maximum value, obtained for special circumstances of the bus traffic. When this amount of time has expired, or the station has sent all of its messages, then the station shall forward the Token to the next member of the logical ring.

Low latency for high priority messages shall be assured by the use of message priority TRTs. A station that has a message at the highest priority (Priority 0) shall always send that message when it receives the Token. Priority 0 messages continue to be sent until there are no Priority 0 messages or the THT expires. If that station has lower priority messages to send, it shall send those messages as long as the TRT associated with that priority level has not expired. Otherwise, the station must forward the Token to its successor. In this way the Token passing bus Users shall defer to higher priority traffic when the traffic load becomes heavy.

3.1 (Continued):

Station failures shall be handled by the station immediately preceding the failed station in the logical ring sequence. The station passing the Token shall verify that there is Bus Activity. After two consecutive attempts at passing the Token, the station shall automatically increment the destination address in the Token and try again. This incremental bridging shall continue until the station finds a successor or the destination address wraps around and matches the local station address, at which time the station shall cease its attempts to find a successor.

Stations shall be allowed admittance to the logical ring on a periodic basis. Each station shall contain a Ring Admittance Timer (RAT). When this timer expires and there is a gap between the local station's address and that of its successor then the Token shall be passed to the sequential address following that of the local station. The normal Token passing rules shall then be applied. Therefore, if any of the stations in the gap desire admittance, they shall be granted an opportunity during this time period.

Initialization of the logical ring shall occur after the Token is lost or upon power-up. Each station that powers up and completes its own internal diagnostic and startup procedures shall activate a Bus Activity Timer (BAT). If the station hears any bus activity, it shall reset this timer. This indicates that some portion of the logical ring is active and the station shall defer to this activity. The station may receive a valid Token, addressed to it, because the RAT of a station numerically preceding it in the logical ring has expired. In this case, the station shall begin to hunt for a successor using the normal Token passing rules. If the BAT expires, the station shall attempt to gain control of the Token. It shall transmit a frame whose length is determined by the station address. After completing its transmission and waiting for a suitable period (based upon bus length), it shall listen. If the station hears another transmission, it has lost the claiming process and shall wait for the Token. If the station hears nothing, it shall assume that it has won the Token and begin to hunt for a successor. In this case the normal Token passing rules shall apply.

System Monitoring shall be provided by monitoring the passage of the Token throughout the logical ring and Station Management status messages. The User shall be notified whenever a change has occurred or when commanded to do so. Station Management status messages shall be utilized by a station to report specific, non-fatal, failures such as a receiver failure, transmitter failure, etc.

3.2 Media Interface Unit (MIU): The MIU shall provide connection between the TPIU and the bus medium. One MIU shall be required for each bus path. This section defines the following characteristics of the MIU:

- a) Symbol set
- b) Transmitter, Receiver, and Media characteristics
- c) Media redundancy requirements

This standard shall encompass both fiber optic and electrical transmission media, as well as redundant data paths, if necessary.

The general characteristics of the MIU shall be as defined in this section. Specific parameter values for each characteristic of the interface are summarized in tabular form as slash sheets in Appendix A.

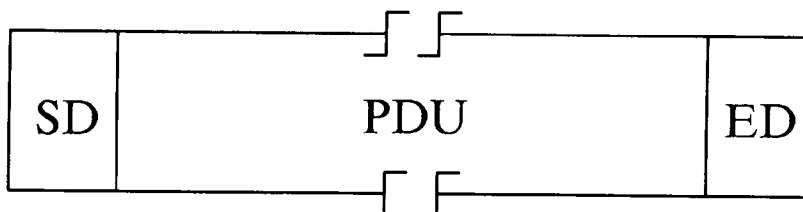
3.2.1 Symbol Set: The peer TPIU entities exchange Protocol Data Units (PDU) via the MIU. The MIU provides the direct interface to the media through the following:

- a) Line States
- b) Control Symbols
- c) Data Symbols
- d) Violation Symbols

3.2.1.1 Line States: Two line states (mutually exclusive) are defined for the physical medium:

- a. Quiet/Idle: Indicates the state of the medium when no Bus Activity is present.
- b. Active: Indicates that a signal is being transmitted on the physical medium. This is defined by the presence of at least three signal transitions in a period of four bit times.

3.2.1.2 Control Symbols: Control symbols serve to synchronize the receiver to the signal and to delimit the boundaries of the TPIU PDU. The overall format of every frame, which is transmitted on the media, shall be as illustrated in Fig. 3.2.1.2-1. Three control symbols are defined (see Appendix A for the specific format and length of these symbols):



SD - START DELIMITER
PDU - TPIU PROTOCOL DATA UNIT
ED - END DELIMITER

FIGURE 3.2.1.2-1 - Overall Frame Structure

3.2.1.2 (Continued):

- a) Preamble (P): The MIU shall append a Preamble to the beginning of every transmission that is placed on the medium. Only one Preamble shall be sent per transmission, which consists of one (or more) Message Frames, a Claim Token Frame, or a Token Frame of the structure shown in Figs. 3.2.1.2-1 and 3.3.1-1. The receiving MIU shall use the Preamble to stabilize its receiver to the incoming signal, but shall remove it prior to passing the PDU to the TPIU. The Preamble length shall be equal to S_p data bits with a format as specified in the appropriate slash sheet of Appendix A. The receiver shall work properly with any Preamble that is at least as long as the minimum for which it was designed. The value of S_p shall be determined by a strapping option in the BIU according to the following:

Strap Option	S_p
0	0
1	4
2	8
3	16

- b) Start Delimiter (SD): The Start Delimiter shall uniquely define the beginning of the TPIU PDU. It shall be appended to the front of the PDU by the sending MIU prior to transmission. The receiving MIU shall align itself to the PDU by detecting the Start Delimiter. The Start Delimiter shall be removed from the frame by the receiving MIU prior to passing the PDU to the TPIU. The format and length of the Start Delimiter shall be as specified in the appropriate slash sheet of Appendix A.
- c) End Delimiter (ED): The End Delimiter shall uniquely define the end of the TPIU PDU. It shall be appended to the end of the frame by the sending MIU after transmission of the PDU. The receiving MIU shall terminate the reception of the PDU by detecting the End Delimiter. The End Delimiter shall be removed from the frame by the receiving MIU prior to passing the PDU to the TPIU. The format and length of the End Delimiter shall be as specified in the appropriate slash sheet of Appendix A.

3.2.1.3 Data Symbols: Each Data Symbol shall convey one or more binary digits. The specific encoding method shall be as defined in Appendix A.

3.2.1.4 Violation Symbols: The Violation Symbol shall be defined as any activity detected on the physical medium which does not conform to any of the defined symbols.

3.2.2 Transmitter, Receiver and Media Definition:

3.2.2.1 Fiber Optic Bus Media Definition: The fiber optic bus media characteristics shall be specified in four groups as follows:

- a) Common Characteristics
- b) Transmitter Characteristics
- c) Receiver Characteristics
- d) Transmission Media Characteristics

The general requirements for these characteristics are defined in 3.2.2.1.1 – 3.2.2.1.4. Specific numerical values for all quantities shall be as given in Appendix A which contains the slash sheets for this standard.

3.2.2.1.1 Fiber Optic Media Common Characteristics: The characteristics common to the transmitter, receiver, and medium, and independent of the specific implementation shall be as given in this paragraph. They shall include:

- a) Station Input/Output Ports
- b) Bus Data Rate
- c) Bus Signaling Rate
- d) Minimum Intertransmission Gap
- e) Minimum P Size
- f) Optical Wavelength and Spectral Bandwidth

3.2.2.1.1.1 Fiber Optic Media Station Input/Output Ports: Each station shall have a receiver input port and transmitter output port with connector(s) as specified in the slash sheet. Other signals, such as control or power, if required, shall be provided as specified in the slash sheet. A short circuit on any electrical signal shall not result in damage to the BIU.

3.2.2.1.1.2 Fiber Optic Media Data Rate: The bus data rate for continuous transmission shall be R_d MBPS. The nominal bit time shall be T_o nanoseconds ($T_o = 1000/R_d$).

3.2.2.1.1.3 Fiber Optic Media Signaling Rate: The signaling rate (R_s) continuous transmission on the fiber optic medium shall be R_s MBaud. The minimum duration between transitions shall be T_m nanoseconds ($T_m = 1000/R_s$).

3.2.2.1.1.4 System Minimum Intertransmission Gap: Under control of the TPIU, an optical transmitter shall remain in the off state between successive transmissions such that a system minimum intertransmission gap is guaranteed at the receiver. The optical receiver shall operate as specified in 3.2.2.1.3 with an intertransmission gap of S_{itg} nanoseconds under the worst case condition where the full intertransmission dynamic range R_{idr} exists between the end bit of the previous message and the start bit of the next message.

- 3.2.2.1.1.5 System Minimum Preamble Size: Under control of the TPIU, a preamble shall be appended to every frame. It shall consist of a maximum transition density code for the specific implementation. The size of the preamble shall be S_p bit times in length.
- 3.2.2.1.1.6 Fiber Optic Media Wavelength and Spectral Bandwidth: The nominal wavelength of the emitted optical radiation shall be in the range W_1 to W_2 nanometers. The spectral bandwidth shall be less than BW nanometers as measured between the 3 dB power points. Therefore, the extreme (3dB) power points must both lie within $W_1 - BW/2$ and $W_2 + BW/2$.
- 3.2.2.1.2 Fiber Optic Transmitter (FOTX) Characteristics: This section defines the general characteristics which are applicable to the fiber optic transmitter of the MIU. These characteristics shall be measured at the output port connector of the MIU.
- 3.2.2.1.2.1 FOTX Output Power: The minimum optical output power shall be T_{po} dBm in the spectral range $W_1 - BW/2$ to $W_2 + BW/2$. This parameter shall be measured for a continuous transmission at R_s MBaud and shall constitute the peak optical power.
- 3.2.2.1.2.2 FOTX Maximum Residual Power: During any signaling event time slot corresponding to the off time of the optical source, the peak optical power shall reach a value of less than T_{pr} dBm peak in the spectral range $W_1 - BW/2$ to $W_2 + BW/2$.
- 3.2.2.1.2.3 FOTX Maximum Leakage Power: When any transmitting station completes its transmission, or is commanded not to transmit, its leakage power shall be less than T_{pr} dBm peak in the spectral range $W_1 - BW/2$ to $W_2 + BW/2$. This requirement shall also be satisfied during power-up and power-down conditions.
- 3.2.2.1.2.4 FOTX Output Waveform: The transmitter shall produce a waveform within the limits shown in Fig. 3.2.2.1.2.4-1 after application of the appropriate parameter values from the Appendix A slash sheets. There shall be no reversal of the signal during the 10% to 90% and 90% to 10% transition periods. Mid- and End-bit mid-amplitude crossings shall deviate less than T_d from the ideal crossing point as measured from the previous crossing point. The rise-time and fall-time shall be less than T_r and T_f nanoseconds, respectively, as measured between the 10% and 90% points. Mid-amplitude (50%) crossings shall deviate no more than T_{dpw} from the ideal crossing point as measured from the previous crossing point. Waveform distortion due to the cumulative effects of undershoot, overshoot, and ringing shall be less than T_{ous} .
- 3.2.2.1.2.5 FOTX Data Streaming Timeout: The transmitter shall monitor any outgoing signal. If an End Delimiter is not seen within T_{ds} the transmitter shall shut down and indicate a fault condition to the TPIU. No further transmission from that faulty MIU shall occur until a positive clear signal has been received from the TPIU.

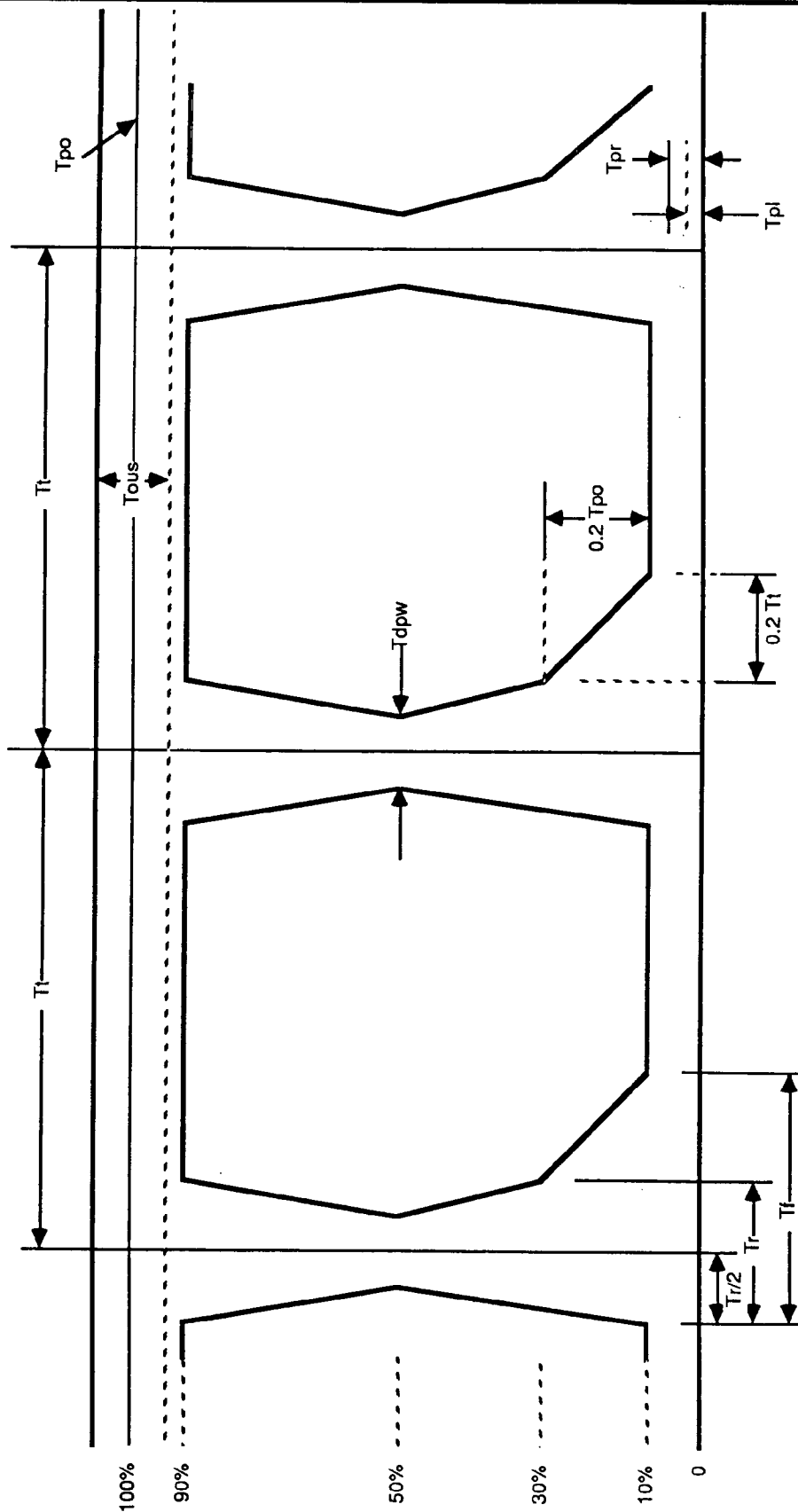


FIGURE 3.2.2.1.2.4-1 - Fiber Optic Transmitter Output Waveform

3.2.2.1.3 Fiber Optic Receiver (FORX) Characteristics: This section specifies the general characteristics of the FORX of the MIU. These characteristics shall be measured at the input port connector to the MIU.

3.2.2.1.3.1 FORX Sensitivity: The optical receiver shall operate at no greater than the maximum bit error rate R_{ber} with a received optical power of R_{pm} dBm. The received power shall be the minimum steady state peak power level, during the optical signal high state, required for the receiver to correctly signal an output logic level high state.

3.2.2.1.3.2 FORX Operating Range and Margin: The optical receiver shall operate as specified in 3.2.2.1.3 with any input signal ranging from R_{pm} dBm to $R_{pm} + R_{or}$ dBm. R_{or} shall be the Operating Range, in dB, of the receiver. The Operating Range shall not be confused with the Receiver Intertransmission Dynamic Range (R_{idr}), or interpreted as the optical margin (M) between the transmitter and receiver. The optical margin shall be defined as the difference between the mean Transmitter Peak Optical Power (Signal High) and the Receiver Minimum Optical Power Input (R_{pm}):

$$M = T_{po} - R_{pm} \text{ dB}$$

Optical margin shall be utilized for determining the required loss characteristics of the bus transmission system. Refer to Fig. 3.2.2.1.3.2-1 for clarification.

In no case shall the receiver be impaired, or otherwise damaged, by an optical input up to R_{po} dBm, a condition which may occur during Token Claim.

3.2.2.1.3.3 FORX Bit Error Rate: The overall bit error rate shall be less than R_{ber} . This error rate shall be sustained for the worst case waveforms and over the entire operating range of the receiver which includes signal variations up to the intertransmission dynamic range.

3.2.2.1.3.4 FORX Input Waveform: The receiver shall correctly process the optical input waveform shown in Fig. 3.2.2.1.3.4-1 after application of the appropriate parameter values as specified in the slash sheets of Appendix A.

3.2.2.1.4 Fiber Optic Transmission Media Characteristics: A minimum set of fiber optic transmission medium characteristics shall be specified in order to insure interoperability between stations in the same system:

- a) Fiber Physical Characteristics
- b) Numerical Aperture
- c) Media Chromatic and Modal Dispersion
- d) Attenuation

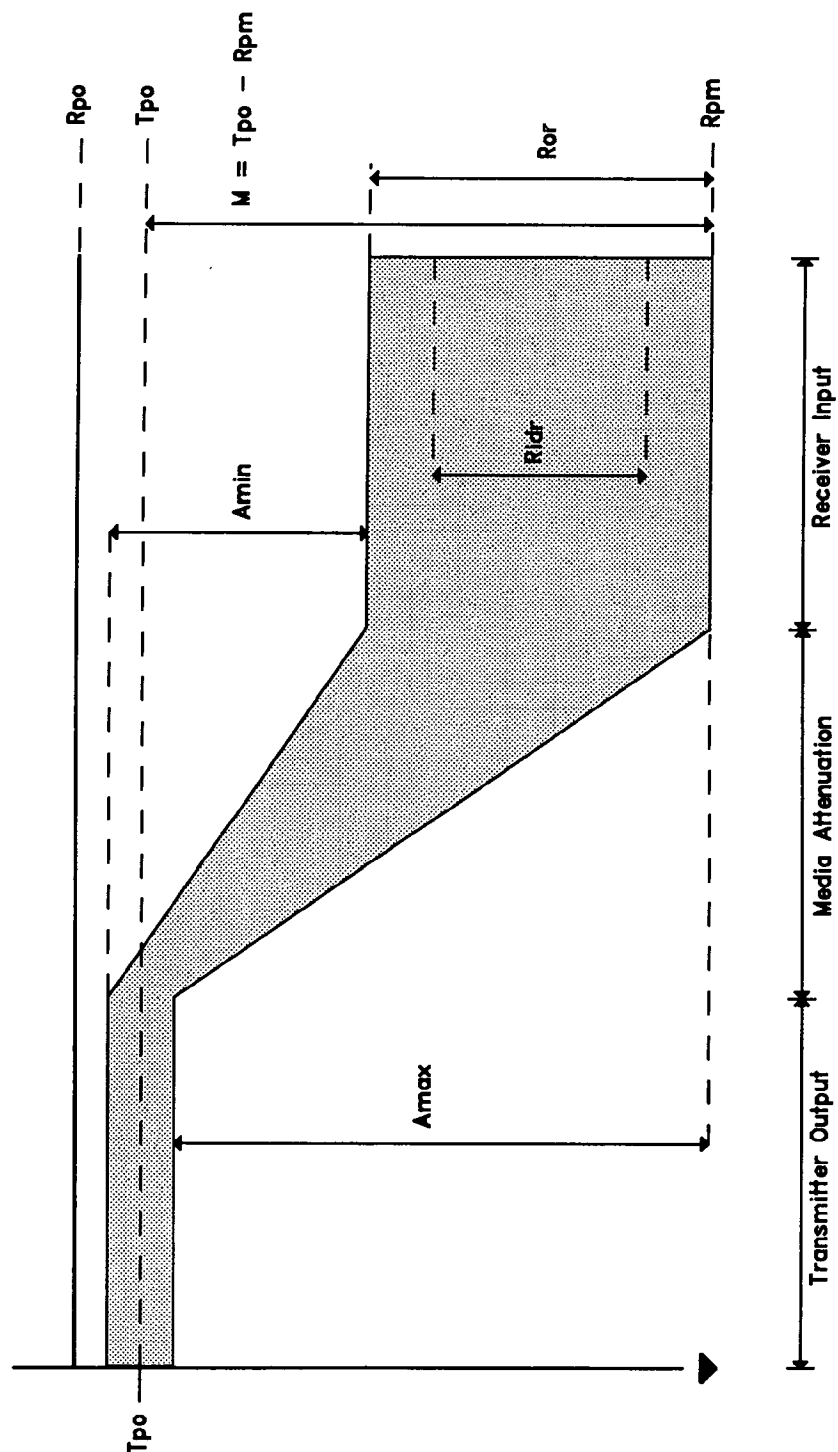


FIGURE 3.2.2.1.3.2-1 - Transmitter/Receiver Optical Power Levels

