Editors Note: this 10G BiDi Clause is modeled after Cl ~~52 with the following changes:~~
~~1)~~ 52. Magenta Font indicates text that has;
a) been changed (excluding internal links),
b) been replaced with placeholder text,
c) will need editorial attention (link updates typically), or
d) is in need of TF review, agreement and/or changes~~.~~
~~2) PMD names have been replaced with; 10GBASE-BLR for 10GBASE-S, 10GBASE-BMR for 10GBASE-L, and 10GBASE-BER for 10GBASE-E. 10GBASE-BxR is used to refer to the entire family.~~
~~3) Specifications pertinent to multi-mode fiber PMDs and WIS PMDs have largely been removed (per 2/21 ad hoc call suggestions).~~
~~4) References to Clauses which will likely remain outside our draft have been highlighted with Green Font per WG template.~~
~~5) References to figures, sections, and tables internal to this clause have all been updated with live links; please inform the editor of any that were missed.~~

Insert new clauses and corresponding annexes as follows:

158. Physical Medium Dependent (PMD) sublayer and medium, types 10GBASE-BLR, 10GBASE-BMR, and 10GBASE-BER

158.1 Overview

This clause specifies the PMDs and baseband media, using one single-mode optical fiber, for the 10BASE-BLR, 10GBASE-BMR, and 10GBASE-BER serial PHYs, shown in Table 158–1. Within this clause these PMDs are jointly referred to by the term 10GBASE-BxR. The 10GBASE-BxR PHYs are divided into two variants based on the direction of transmission; Optical Line Terminal (OLT) PHYs transmit in the downstream direction and Optical Network Unit (ONU) PHYs transmit in the upstream direction. PHY variant is indicated with a suffix of D for OLT PHYs and U for ONU PHYs.

Table 158–1—10GBASE-BxR serial PHYs

Name	Description
10GBASE-BLR	description
10GBASE-BMR	description
10GBASE-BER	description

In order to form a complete Physical Layer, each PMD is combined with the appropriate physical sublayers indicated in Table 158–2 and optionally with the management functions that may be accessible through the management interface defined in ~~Clause 45~~Clause 45.

Figure 158–2 depicts the relationships of the serial PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

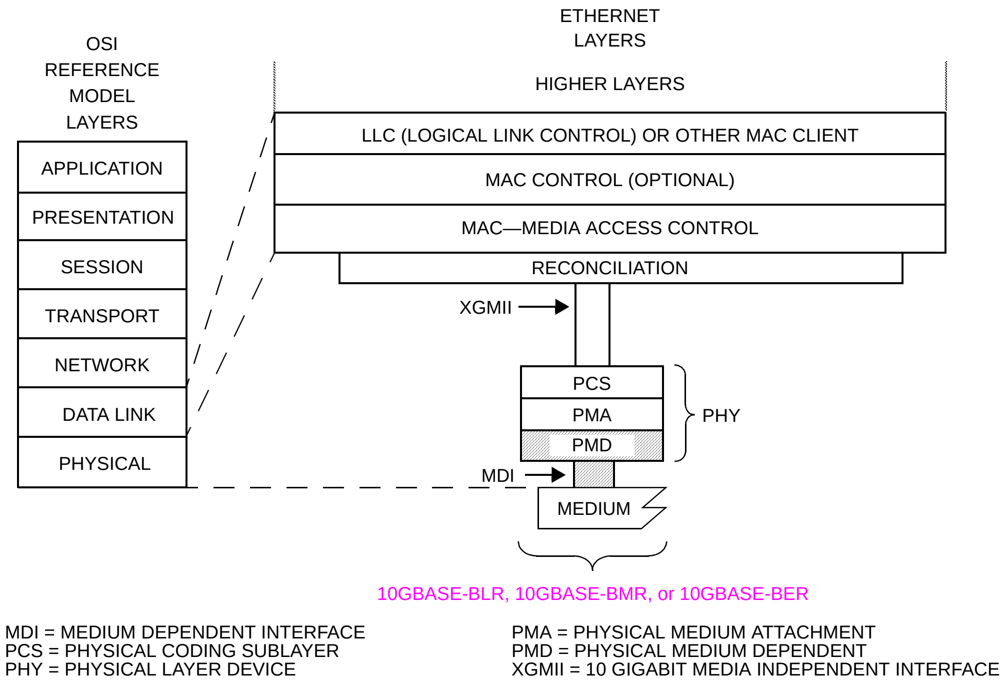


Figure 158–1—10GBASE-BxR PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

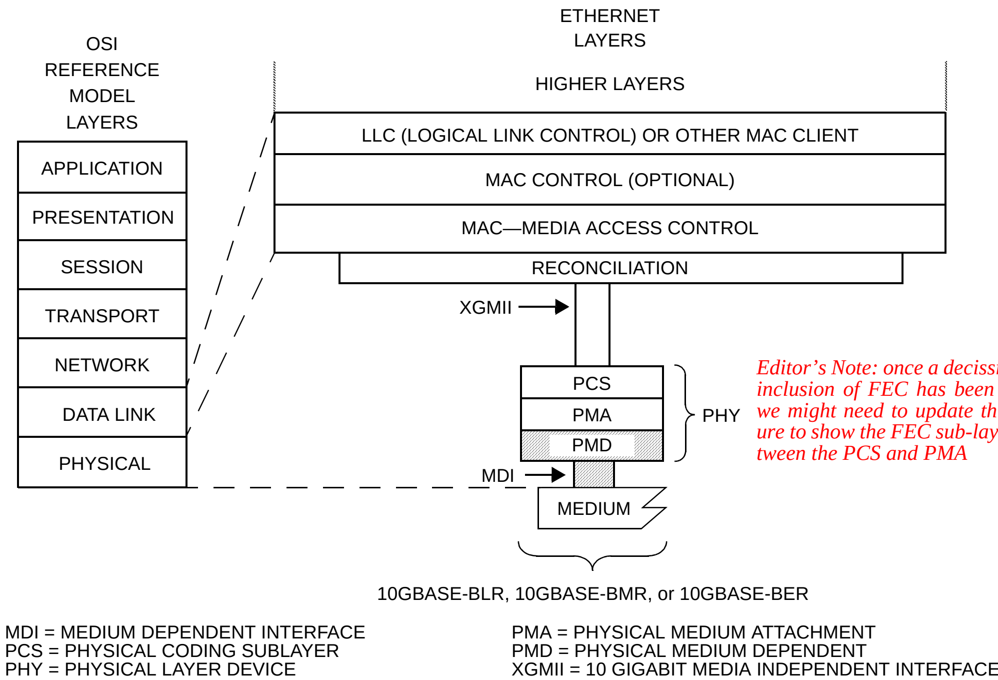
Table 158–2—PMD type and associated clauses

Associated clause	10GBASE-BLR	10GBASE-BMR	10GBASE-BER
46—RS	Required	Required	Required
46—XGMII	Optional	Optional	Optional
47—XGXS and XAUI	Optional	Optional	Optional
49—Type R PCS	Required	Required	Required
51—Serial PMA	Required	Required	Required

158.1.1 Bit error ratio

The bit error ratio (BER) shall be less than 5×10^{-5} provided that the error statistics are sufficiently random that this results in a frame loss ratio (see 1.4.275) of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap when processed according to Clause 108.

If the error statistics are not sufficiently random to meet this requirement, then the BER shall be less than that required to give a frame loss ratio of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap when processed according to Clause 74.



Editor's Note: once a decission on inclusion of FEC has been made we might need to update this figure to show the FEC sub-layer between the PCS and PMA

Figure 158–2—10GBASE-BxR PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

158.2 PMD sublayer service interface

~~The following specifies the services provided by the 10GBASE-BxR PMDs. These PMD sublayer service interfaces are described in an abstract manner and do not imply any particular implementation.~~

~~The PMD Service Interface supports the exchange of encoded and scrambled 64B/66B blocks between the PMA and PMD entities. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium.~~

~~The following primitives are defined:~~

~~PMD_UNITDATA.request~~

~~PMD_UNITDATA.indication~~

~~PMD_SIGNAL.indication~~

~~NOTE—Primitives are described in 1.2.2.~~

~~*Editor's Note: we might want to just ref Cl 49 rather than adapt/reiterate the text below from Cl 52. Depending on how the Silent Start feature is specified we might need to define a new primitive (I suggest this be avoided by tying the feature to the PMD_global_transmit_disable feature and making that mandatory).*~~

158.2.0.1 ~~PMD_UNITDATA.request~~

~~This primitive defines the transfer of a serial data stream from the PMA to the PMD.~~

158.2.0.1.1 ~~Semantics of the service primitive~~

~~PMD_UNITDATA.request(tx_bit)~~

~~The data conveyed by PMD_UNITDATA.request is a continuous stream of bits. The tx_bit parameter can take one of two values: ONE or ZERO.~~

158.2.0.1.2 ~~When generated~~

~~The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 10.3125 GBd signaling speed for 10GBASE-BxR PMD types and 9.95328 GBd signaling speed for 10GBASE-W PMDs.~~

158.2.0.1.3 ~~Effect of receipt~~

~~Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals on the MDI.~~

158.2.0.2 ~~PMD_UNITDATA.indication~~

~~This primitive defines the transfer of data (in the form of serialized data) from the PMD to the PMA.~~

158.2.0.2.1 ~~Semantics of the service primitive~~

~~PMD_UNITDATA.indication(rx_bit)~~

~~The data conveyed by PMD_UNITDATA.indication is a continuous stream of bits. The rx_bit parameter can take one of two values: ONE or ZERO.~~

158.2.0.2.2 ~~When generated~~

~~The PMD continuously sends stream of bits to the PMA corresponding to the signals received from the MDI.~~

158.2.0.2.3 ~~Effect of receipt~~

~~The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.~~

158.2.0.3 ~~PMD_SIGNAL.indication~~

~~This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.~~

158.2.0.3.1 ~~Semantics of the service primitive~~

~~PMD_SIGNAL.indication(SIGNAL_DETECT)~~

~~The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication(rx_bit) is undefined.~~

~~NOTE—SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indication(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the 10–12 BER objective.~~

158.2.0.3.2 ~~When generated~~

~~The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT. If the MDIO interface is implemented, then PMD_global_signal_detect shall be continuously set to the value of SIGNAL_DETECT.~~

158.2.0.3.3 ~~Effect of receipt~~

~~The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.~~

The PMD service interfaces for 10GBASE-BxR are the same as PMD service interface for 10GBASE-R as described in 49.2 with the BER as specified in 158.1.1.

158.3 Delay constraints

An upper bound to the delay through the PMA and PMD is required for predictable operation of the MAC Control PAUSE operation. The PMA and PMD shall incur a round-trip delay (transmit and receive) of not more than 512 bit-times, or 1 pause_quantum, including 2 m of fiber. A description of overall system delay constraints and the definitions for bit-times and pause_quanta can be found in 44.3.

158.4 PMD MDIO function mapping

The optional MDIO capability described in ~~Clause 45~~Clause 45 defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 158–3, and MDIO status variables to PMD status variables as shown in Table 158–4 PMD functional specifications.

Table 158–3—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global Transmit Disable	Transmit disable register	1.9.0	PMD_global_transmit_disable

158.5 PMD functional specifications

The 10GBASE-BxR PMDs perform the Transmit and Receive functions that convey data between the PMD service interface and the MDI.

158.5.1 PMD block diagram.

For purposes of system conformance, the PMD sublayer is standardized at test points TP2 and TP3 as shown in Figure 158–4. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of a type consistent with the link type connected to the transmitter. Unless specified oth-

Table 158–4—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD ~~Receive~~ Receive signal detect	Receive signal detect register	1.10.0	PMD_global_signal_detect

erwise, all transmitter measurements and tests defined in 158.10 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 158.10 are made at TP3. TP1 and TP4 are informative reference points that may be useful to implementers for testing components (these test points will not typically be accessible in an implemented system).

~~TP1 and TP4 are informative reference points that may be useful to implementers for testing components (these test points will not typically be accessible in an implemented system).~~

~~*Editor's Note: it was suggested on the 2/21 ad hoc call that Figure 200-2 be modified to clearly show the bidirectional nature of the PMDs. The following is offered as a replacement figure for the original figure which follow immediately after. Give that TP1 & TP4 are added in the new figure the preceding sentence from Cl 114 was copied also.*~~

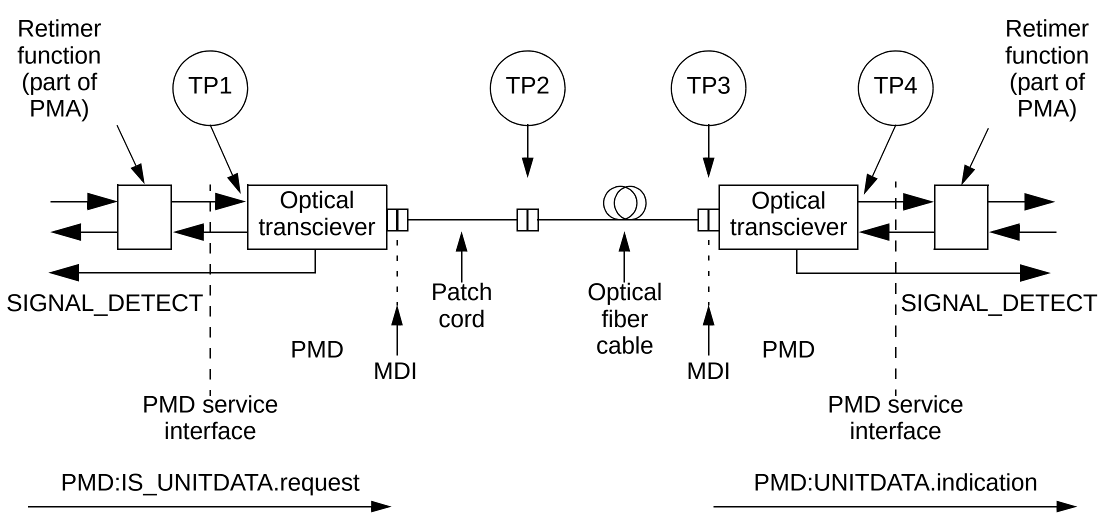


Figure 158–3—Block diagram for 10GBASE-BxR transmit/receive paths

Editor's Note: replace with duplicate of Figure 159-2 once that is agreed

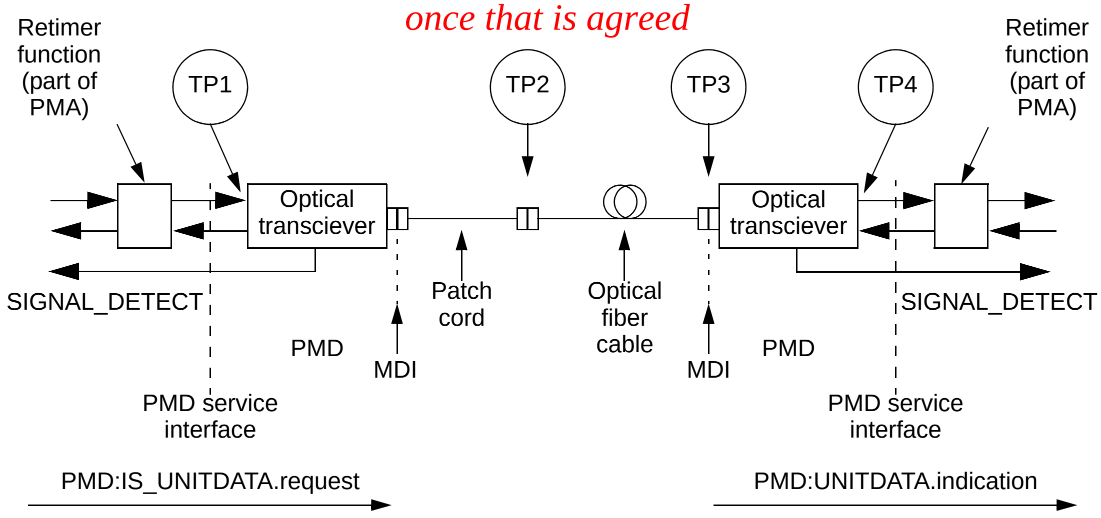


Figure 158–4—Block diagram for 10GBASE-BxR transmit/receive paths

158.5.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit = ONE.

158.5.3 PMD receive function

The PMD Receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level shall correspond to rx_bit = ONE.

158.5.4 PMD signal detect function

The PMD Signal Detect function shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT) which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence. If the MDIO interface is implemented, then PMD_global_signal_detect (1.10.0) shall be continuously set to the value of SIGNAL_DETECT as described in 45.2.1.9.7.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in ~~Table 52–5~~Table 158–5. The PMD receiver is not required to verify whether a compliant 10GBASE-BxR signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Table 158–5—SIGNAL_DETECT value definition

Receive conditions	Signal Detect value
Input_optical_power ≤ -30 dBm average power	FAIL
Input_optical_power ≥ Receiver sensitivity (max) in OMA in Table 52–9, Table 52–13, or Table 52–17 AND compliant 10GBASE-BxR signal input	OK
All other conditions	Unspecified

Various implementations of the Signal Detect function are permitted by this standard, including implementations that generate the SIGNAL_DETECT parameter values in response to the amplitude of the modulation of the optical signal and implementations that respond to the average optical power of the modulated optical signal.

158.5.5 PMD reset function

If the MDIO interface is implemented, and if PMD_reset is asserted, the PMD shall be reset as defined in 45.2.1.1.1.

158.5.6 ~~PMD fault function~~

~~If the MDIO is implemented, PMD_fault is the logical OR of PMD_receive_fault, PMD_transmit_fault and any other implementation specific fault.~~

158.5.7 PMD global transmit disable function

The PMD_global_transmit_disable function is optional. When asserted, this function shall turn off the optical transmitter so that it meets the requirements of the average launch power of OFF Transmitter in ~~Table 52–7, Table 52–12, or Table 52–16~~Table 158–12.

If a PMD_transmit_fault (optional) is detected, then the PMD_global_transmit_disable function should also be asserted.

If the MDIO interface is implemented, then this function shall map to the PMD_global_transmit_disable bit as specified in 45.2.1.8.7.

NOTE—PMD Transmit Disable 0 is not used for serial PMDs.

158.5.8 PMD fault function

If the MDIO is implemented, PMD_fault is the logical OR of PMD_receive_fault, PMD_transmit_fault and any other implementation specific fault.

158.5.9 PMD transmit fault function

The PMD_transmit_fault function is optional. The faults detected by this function are implementation specific, but should not include the assertion of the PMD_global_transmit_disable function.

If a PMD_transmit_fault (optional) is detected, then the PMD_global_transmit_disable function should also be asserted.

If the MDIO interface is implemented, then this function shall be mapped to the PMD_transmit_fault bit as specified in 45.2.1.7.4.

158.5.10 PMD receive fault function

The PMD_receive_fault function is optional. PMD_receive_fault is the logical OR of NOT SIGNAL_DETECT and any implementation specific fault.

Editor's Note: we may want to incorporate PMD_receive_fault in the Silent Start feature hence I've marked it as optional.

If the MDIO interface is implemented, then this function shall contribute to PMA/PMD receive fault bit as specified in 45.2.1.7.5.

158.6 PMD to MDI optical specifications for 10GBASE-S

Editor's Note: Clause 52 used a separate sub-clause for each PMD type. We may want to combine all PMD types into a single clause as is done in Cl 114 and 139. I've removed 52.5 as this section covers a PMD intended form MMF applications and is not applicable to our work. The section heading and figure/table placeholders have been retained to allow reviewers easy cross referencing to Cl 52 sections.

Table 158–6—10GBASE-S operating range for each optical fiber type

10GBASE-S transmit characteristics

Table 158–7—Minimum 10GBASE-S optical modulation amplitude (dBm) ...

Editor’s Note: I’ve included a placeholder for Figure 158-3 to maintain consistent figure numbering with Clause 52. This fiigure is not applicable to Clause 158.

Figure 158–5—Triple tradeoff curve for 10GBASE-S (informative)

Table 158–8—10GBASE-S receive characteristics

Signaling speed (nominal)	9.95328	10.3125	GBd

Table 158–9—10GBASE-S link power budgets

Table 158–10—10GBASE-S link power budgets

Editor’s Note: it was suggested on the 2/21 ad hoc call that all PMD specifications be combined in a single section. This has been done in 158.6 below. Table entries for 10GBASE-BER have been copied from 158.7.

158.7 PMD to MDI optical specifications for 10GBASE-BLR, 10GBASE-BMR, and 10GBASE-BER

The operating range for 10GBASE-BLR, 10GBASE-BMR, and 10GBASE-BER PMDs is defined in Table 158–11. A 10GBASE-BxR compliant PMD supports Types B1.1 and B1.3 single-mode fibers according to the specifications defined in 158.14. A PMD that exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., operating at 12.5 km meets the minimum range requirement of 2 m to 10 km).

Table 158–11—10GBASE-BLR, 10GBASE-BMR , and 10GBASE-BER operating range

PMD Type	Nominal Wavelength (nm)		Minimum range
	upstream	downstream	
10GBASE-BLR	1270	1310	2 m to 10 km
10GBASE-BMR	1270	1310	2 m to 20 km
10GBASE-BER	1270	1310	2 m to 40 km

158.7.1 10GBASE-BLR, 10GBASE-BMR, and 10GBASE-BER transmitter optical specifications

The 10GBASE-BLR, 10GBASE-BMR, and 10GBASE-BER transmitters shall meet the specifications defined in Table 158–12 per measurement techniques defined in 158.10.

Table 158–12—10GBASE-~~BLR, 10GBASE~~BxR-~~BMR , and 10GBASE-BER~~ D transmit characteristics

Description	10GBASE-BLR-D	10GBASE-BMR-D	10GBASE-BER-D	Unit
Signaling speed (nominal)	10.3125			GBd
Signaling speed variation from nominal (max)	± 100			ppm
Center wavelength (range)	1260 to 1355		1530 to 1565	nm
Side Mode Suppression Ratio (min)	30		30	dB
Average launch power (max)	0.5		4.0	dBm
Average launch power[a] (min)	–8.2		–4.7	dBm
Launch power (min) in OMA minus TDP[b]	–6.2		–2.1	dBm
Optical Modulation Amplitude[c] (min)	–5.2		–1.7	dBm
Transmitter and dispersion penalty (max)	3.2		3.0	dB
Average launch power of OFF transmitter[d] (max)	–30		–30	dBm
Extinction ratio (min)	3.5		3	dB
$RIN_{12}OMA$ (max)	–128		–128	dB/Hz
Optical Return Loss Tolerance (max)	12		21	dB
Transmitter Reflectance[e] (max)	–12		1530 to 1565	dB
Transmitter eye mask definition[f] A {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}			
Transmitter eye mask definition[f] B {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} per sample	{0.235, 0.395, 0.45, 0.235, 0.265, 0.4}			

[a]Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b]TDP is transmitter and dispersion penalty.
[c]Even if the TDP < 1 dB, the OMA(min) must exceed this value.
[d]Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut down conditions.
[e]Transmitter reflectance is defined looking into the transmitter.
[f]Either transmitter eye mask definition A or B may be used. A transmitter is not required to comply with both definitions.

Table 158–13—10GBASE-BxR-U transmit characteristics

Description	10GBASE-BLR-U	10GBASE-BMR-U	10GBASE-BER-U	Unit
Signaling speed (nominal)	10.3125			GBd
Signaling speed variation from nominal (max)	± 100			ppm
Center wavelength (range)	1260 to 1355		1530 to 1565	nm
Side Mode Suppression Ratio (min)	30		30	dB
Average launch power (max)	0.5		4.0	dBm
Average launch power[a] (min)	–8.2		–4.7	dBm
Launch power (min) in OMA minus TDP[b]	–6.2		–2.1	dBm
Optical Modulation Amplitude[c] (min)	–5.2		–1.7	dBm
Transmitter and dispersion penalty (max)	3.2		3.0	dB
Average launch power of OFF transmitter[d] (max)	–30		–30	dBm
Extinction ratio (min)	3.5		3	dB
$RIN_{12}OMA$ (max)	–128		–128	dB/Hz
Optical Return Loss Tolerance (max)	12		21	dB
Transmitter Reflectance[e] (max)	–12		1530 to 1565	dB
Transmitter eye mask definition[f] A {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}			
Transmitter eye mask definition[f] B {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} per sample	{0.235, 0.395, 0.45, 0.235, 0.265, 0.4}			

[a]Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b]TDP is transmitter and dispersion penalty.
[c]Even if the TDP < 1 dB, the OMA(min) must exceed this value.
[d]Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut down conditions.
[e]Transmitter reflectance is defined looking into the transmitter.
[f]Either transmitter eye mask definition A or B may be used. A transmitter is not required to comply with both definitions.

158.7.2 10GBASE-BLR, 10GBASE-BMR, and 10GBASE-BER receive optical specifications

The 10GBASE-BLR, 10GBASE-BMR, and 10GBASE-BER receivers shall meet the specifications defined in Table 158–14 per measurement techniques defined in 158.10.

Editor's Note: cross check footnotes in Table 158-12 with those in Table 52-16 for 10GBASE-BER.

Table 158–14—10GBASE-~~BxR~~ BxR-D receive characteristics

Description	10GBASE-BLR-D	10GBASE-BMR-D	10GBASE-BER-D	Unit
Signaling speed (nominal)	10.3125			GBd
Signaling speed variation from nominal (max)	± 100			ppm
Center wavelength (range)	1260 to 1355		1530 to 1565	nm
Average receive power[a] (max)	0.5		–1.0	dBm
Average receive power[b] (min)	–14.4		–15.8	dBm
Maximum receive power (for damage)			4.0	
Receiver sensitivity (max) in OMA[c]	0.055 (–12.6)		0.039 (–14.1)	mW (dBm)
Receiver Reflectance (max)	–12		–26	dB
Stressed receiver sensitivity (max) in OMA[d, e]	0.093 (–10.3)		0.074 (-11.3)	mW (dBm)
Vertical eye closure penalty[f] (min)	2.2		2.7	dB
Stressed eye jitter[g] (min)	0.3		0.3	UI pk-pk
Receive electrical 3 dB upper cutoff frequency (max)	12.3		12.3	GHz

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average receive power (max) plus at least 1 dB.
[b]Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Receiver sensitivity is informative.
[d]Measured with conformance test signal at TP3 (see 52.9.9.3) for BER = 10^{-12}.
[e]The stressed sensitivity values in the table are for system level BER measurements, which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effect of CDR circuits.
[f]Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[g]Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

Table 158–15—10GBASE-BxR-U receive characteristics

Description	10GBASE-BLR-U	10GBASE-BMR-U	10GBASE-BER-U	Unit
Signaling speed (nominal)		10.3125		GBd
Signaling speed variation from nominal (max)		± 100		ppm
Center wavelength (range)	1260 to 1355		1530 to 1565	nm
Average receive power[a] (max)	0.5		–1.0	dBm
Average receive power[b] (min)	–14.4		–15.8	dBm
Maximum receive power (for damage)			4.0	
Receiver sensitivity (max) in OMA[c]	0.055 (–12.6)		0.039 (–14.1)	mW (dBm)
Receiver Reflectance (max)	–12		–26	dB
Stressed receiver sensitivity (max) in OMA[d, e]	0.093 (–10.3)		0.074 (-11.3)	mW (dBm)
Vertical eye closure penalty[f] (min)	2.2		2.7	dB
Stressed eye jitter[g] (min)	0.3		0.3	UI pk-pk
Receive electrical 3 dB upper cutoff frequency (max)	12.3		12.3	GHz

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average receive power (max) plus at least 1 dB.
[b]Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Receiver sensitivity is informative.
[d]Measured with conformance test signal at TP3 (see 52.9.9.3) for BER = 10^{-12}.
[e]The stressed sensitivity values in the table are for system level BER measurements, which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effect of CDR circuits.
[f]Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[g]Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

Editor's Note: cross check footnotes in Table 158-13 with those in Table 52-17 for 10GBASE-BER.

158.7.3 10GBASE-~~BLR, 10GBASE-BMR, and 10GBASE-BER~~ BxR link power budgets (informative)

~~An example~~ Example power ~~budget~~ budgets and penalties for a 10GBASE-~~BLR, 10GBASE-BMR, and 10GBASE-BER~~ BxR channel are shown in Table 158–16.

Table 158–16—10GBASE-BxR link power budget[a, b]

Parameter	10GBASE-BLR	10GBASE-BMR	10GBASE-BER	Unit
Power budget	9.4		15	dB
Operating distance	10		40[c]	km
Channel insertion loss[d, e]	6.2		10.9	dB
Maximum Discrete Reflectance (max)			–26	dB
Allocation for penalties	3.2		4.1	dB
Additional insertion loss allowed	0.0		0.0	dB

[a]Budget numbers are rounded to nearest 0.1 dB.
[b]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[c]Links longer than 30 km are considered engineered links. Attenuation for such links needs to be less than that guaranteed by B1.1 or B1.3 single-mode fiber.
[d]The channel insertion loss is calculated using the maximum distance specified in Table 52–11 and cabled optical fiber attenuation of 0.4 dB/km at 1310 nm plus an allocation for connection and splice loss given in 158.14.2.1.
[e]A transmitter wavelength of 1260 nm with a TDP of 3 dB is used to calculate channel insertion loss, and allocation for penalties in this table.

158.8 PMD to MDI optical specifications for 10GBASE-BER

Editor's Note: Clause 52 used a separate sub-clause for each PMD type. This section represents such a section from Cl 52. If we decide to use a single section for all PMDs as in 158.6 then this section should be removed in it's entirity.

The operating range for 10GBASE-BER PMDs is defined in Table 158–17. A 10GBASE-BER compliant PMD supports Types B1.1 and B1.3 single-mode fibers according to the specifications defined in 158.14. A PMD which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., operating at 42.5 km meets the minimum range requirement of 2 m to 30 km).

Table 158–17—10GBASE-BER operating range

PMD Type	Nominal Wavelength (nm)	Minimum Range
10GBASE-BER	1270 upstream, 1310 downstream	2 m to 30 km
		2 m to 40 km[a]

[a]Links longer than 30 km for the same link power budget are considered engineered links. Attenuation for such links needs to be less than the minimum specified for B1.1 or B1.3 single-mode fiber.

Link attenuation requirements are specified in 158.14.3.

158.8.1 10GBASE-BER transmitter optical specifications

The 10GBASE-BER transmitter shall meet the specifications defined in Table 158–18 per measurement techniques defined in 158.10.

Table 158–18—10GBASE-BER transmit characteristics

Description		10GBASE-BER	Unit
Signaling speed (nominal)		10.3125	GBd
Signaling speed variation from nominal (max)		± 100	ppm
Center wavelength (range)	1530 to 1565		nm
Side Mode Suppression Ratio (min)	30		dB
Average launch power (max)	4.0		dBm
Average launch power[a] (min)	–4.7		dBm
Launch power (min) in OMA minus TDP[b]	–2.1		dBm
Average launch power of OFF transmitter[c] (max)	–30		dBm
Optical Modulation Amplitude[d] (min)	–1.7		dBm
Transmitter and dispersion penalty (max)	3.0		dB
Extinction ratio (min)	3		dB
$RIN_{21}OMA$[e] (max)	–128		dB/Hz
Optical Return Loss Tolerance (max)	21		dB
Transmitter eye mask definition[f] A {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}		
Transmitter eye mask definition[f] B{X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} per sample	{0.235, 0.395, 0.45, 0.235, 0.265, 0.4}		

[a]Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b]TDP is transmitter and dispersion penalty.
[c]Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut-down conditions.
[d]Even if the TDP < 0.4 dB, the OMA(min) must exceed this value.
[e]RIN measurement is made with a return loss at 21 dB.
[f]Either transmitter eye mask definition A or B may be used. A transmitter is not required to comply with both definitions.

158.8.2 10GBASE-BER receive optical specifications

The 10GBASE-BER receiver shall meet the specifications defined in Table 52–17 per measurement techniques defined in 158.10.

Table 158–19—10GBASE-BER receive characteristics

Description		10GBASE-ER	Unit
Signaling speed (nominal)		10.3125	GBd
Signaling speed variation from nominal (max)		± 100	ppm
Center wavelength (range)	1530 to 1565		nm
Average receive power (max)	–1.0		dBm
Average receive power[a] (min)	–15.8		dBm
Maximum receive power (for damage)	4.0		dBm
Receiver sensitivity (max) in OMA[b]	0.039 (–14.1)		mW (dBm)
Receiver Reflectance (max)	–26		dB
Stressed receiver sensitivity (max) in OMA[c,d]	0.074 (-11.3)		mW (dBm)
Vertical eye closure penalty[e] (min)	2.7		dB
Stressed eye jitter (min)[f]	0.3		UI pk-pk
Receive electrical 3 dB upper cutoff frequency (max)	12.3		GHz

[a] Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b] Receiver sensitivity is informative.
[c] Measured with conformance test signal at TP3 (see 52.9.9.3) for BER = 10^{-12}.
[d] The stressed sensitivity values in the table are for system level BER measurements which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effects of CDR circuits.
[e] Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[f] Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

158.8.3 10GBASE-BER link power budgets (informative)

Example power budgets and penalties for a 10GBASE-BER channel are shown in Table 52–18.

Table 158–20—10GBASE-BER link power budgets[a,b]

Parameter	10GBASE-BER		Unit
Power budget	15.0		dB
Operating distance	30	40[c]	km
Channel insertion loss[d, e]	10.9	10.9	dB
Maximum Discrete Reflectance (max)	–26		dB
Allocation for penalties	3.6	4.1	dB
Additional insertion loss allowed	0.5	0.0	dB

[a] Budget numbers are rounded to nearest 0.1 dB.
[b] Link penalties are built into the transmitter specifications by testing the PMD with a maximum dispersion fiber.
[c] Links longer than 30 km are considered engineered links. Attenuation for such links needs to be less than that guaranteed by B1.1 or B1.3 single-mode fiber.
[d] Operating distances used to calculate the channel insertion loss are the maximum values specified in Table 158–17.
[e] A wavelength of 1565 nm and 3dB transmitter and dispersion penalty (TDP) is used to calculate channel insertion loss, and allocation for penalties.

158.9 Jitter specifications for 10GBASE-BxR

Acceptable transmitted jitter is achieved by compliance with 158.10.7, transmitter optical waveform, and 158.10.10, transmitter and dispersion penalty. Tolerance to received jitter is achieved by compliance to 158.10.9, stressed receiver conformance, which includes sinusoidal jitter as in the following subclause. There is no jitter transfer specification.

158.9.1 Sinusoidal jitter for receiver conformance test

The sinusoidal jitter is used to test receiver jitter tolerance. Sinusoidal jitter may vary over a magnitude range as required to accurately calibrate a stressed eye per 158.10.9. The range is limited by the constraints of Table 158–21 as illustrated in Figure 158–6.

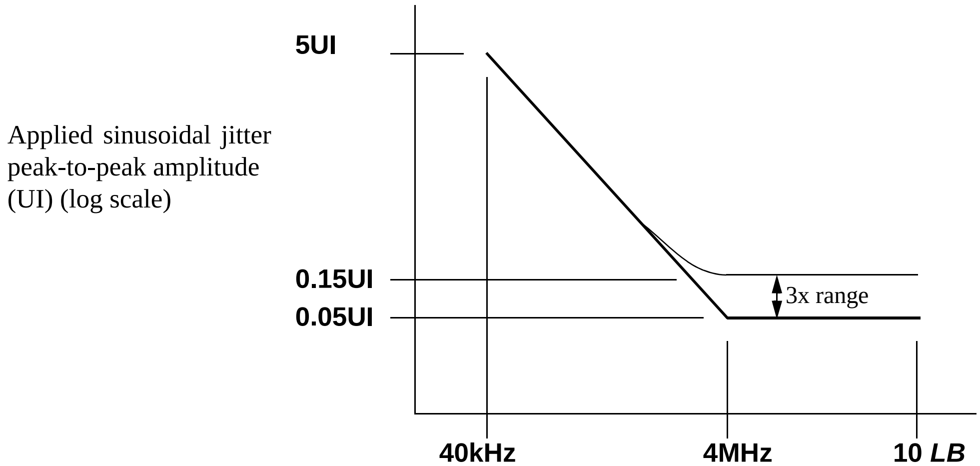


Figure 158–6—Mask of the sinusoidal component of jitter tolerance (informative)

~~*Editors's Note: I've included Figure 52-4 but there is no reference to this figure in Cl 52.*~~

Table 158–21—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter ($UI_{pk\ to\ pk}$)
$f < 40$kHz	NA
40 kHz $< f \leq$ 4MHz	$2 \times 10^5 / f + S - 0.05$[a]
4 MHz $< f <$ 10 *LB*[b]	$0.05 \leq S \leq 0.15$ [a]

[a]S is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 52.9.9.3.
[b]LB = Loop Bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

158.10 Optical measurement requirements

All optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

158.10.1 Test patterns

Compliance is to be achieved in normal operation. Two types of test ~~pattern~~ patterns are used, square wave (158.10.1.2) and other (158.10.1.1). Test patterns are as in Table 158–24 for 10GBASE-BxR unless specified otherwise.

NOTE—Test patterns for specific optical tests are designed to emulate system operation, which would entail passing valid 10GBASE-BxR data.

158.10.1.1 Test-pattern definition

Patterns 1, 2, and 3 are defined in Table 158–23. Pattern 3 is optional.

For 10GBASE-BxR, two test pattern segments are specified, in two variants, “normal” (n) and “inverted” (i). Both are 8448 bits long. They may be generated dynamically by the 58 bit scrambler and “control block” sync header generation defined in 49.2.6, and using the scrambler starting seeds specified in Table 158–22 and the method of generation in 49.2.8. The segments are assembled into patterns, each containing four segments, as described in Table 158–23. Each may be held as a static pattern in test equipment, or generated or detected dynamically using the methods of 49.2.8 and 49.2.12 respectively, or otherwise.

Each segment contains a sync header transition every 66 bits.

Table 158–22—Pattern segments

Segments	Seed[57:0][a]
A_n	0x3C8B44DCAB6804F
B_n	0x34906BB85A38884

[a]The “invert” segments A_i and B_i are generated using the inverted seeds for A_n and B_n, respectively.

The test pattern 1 is generated with the data input mode programmed to select LF data input. The test pattern 2 is generated with the data input mode programmed to select all zero data input.

Pattern 1 represents typical scrambled data while pattern 2 represents a less typical pattern that could happen by chance and is thought to be more demanding of the transmission process including the clock recovery subsystem. Both patterns are balanced over their length of 33 792 bits.

NOTE—While other test methods and patterns could be used it is the implementer’s responsibility to ensure that measurements carried out with the specified patterns achieve the requirements specified.

Table 158–23—Test patterns

Pattern	Pattern for 10GBASE-BxR
1	B_n $B_i B_n$ B_i
2	A_n $A_i A_n$ A_i
3	PRBS31[a]

[a]This is the test-pattern checker defined in 49.2.12.

158.10.1.2 Square wave pattern definition

A pattern consisting of four to eleven consecutive ones followed by an equal run of zeros may be used as a square wave. ~~These~~ The patterns have fundamental frequencies ~~between approximately 452 MHz (10GBASE-W) and~~ of 1289 ~~MHz (10GBASE-BxR)~~MHz.

Table 158–24—Test-pattern definitions and related subclauses

Test	Pattern	Related subclause
Average optical power	1 or 3	~~52.9.3~~158.10.2
OMA (modulated optical power)	Square	~~52.9.5~~158.10.5
Extinction ratio	1 or 3	~~52.9.4~~158.10.4
Transmit eye	1 or 3	~~52.9.7~~158.10.7
Receive upper cutoff frequency	1 or 3	~~52.9.11~~158.10.11
RIN$_x$OMA	Square	~~52.9.6~~158.10.6
Wavelength, spectral width	1 or 3	~~52.9.2~~158.10.2
Side mode suppression ratio	1 or 3	~~52.9.2~~158.10.2
Vertical eye closure penalty calibration	2 or 3	~~52.9.9~~158.10.9
Receiver sensitivity	1 or 3	~~52.9.9~~158.10.9
Receiver overload	1 or 3	—
Stressed receive conformance	2 or 3	~~52.9.9~~158.10.9
Transmitter and dispersion penalty	2 or 3	~~52.9.10~~158.10.10

158.10.2 Center wavelength, spectral width, and side mode suppression ratio (SMSR) measurements

The center wavelength, spectral width (RMS), and SMSR shall be measured using an optical spectrum analyzer per the centroidal wavelength, RMS spectral width, and SMSR definitions in IEC 61280-1-3 under modulated conditions using an appropriate PRBS or a valid 10GBASE-BxR signal, OC-192 signal, STM-64 signal, or another representative test pattern.

158.10.3 Average optical power measurements

Average optical power shall be measured using the methods specified in TIA/EIA-455-95. This measurement may be made with the node transmitting test pattern 1 or 3 or a valid 10GBASE-BxR signal, OC-192 signal, STM-64 signal, or another representative test pattern.

158.10.4 Extinction ratio measurements

Extinction ratio shall be measured using the methods specified in IEC 61280-2-2. This parameter is to be assured during system operation. However, measurements with an appropriate PRBS (223 – 1 or 231 – 1) or a valid 10GBASE-BxR or STM-64 signal will give equivalent results.

158.10.5 Optical modulation amplitude (OMA) test procedure

OMA is the difference in optical power for the nominal “1” and “0” levels of the optical signal, OMA in Figure 158–8, using waveform averaging or histogram means. OMA should be measured for a node transmitting the square wave pattern defined in 158.10.1.

The recommended technique for measuring optical modulation amplitude is illustrated in Figure 158–7. Optionally, a fourth-order Bessel-Thomson filter as specified in 158.10.7 can be used after the O/E converter. The measurement system consisting of the O/E converter, the optional filter and the oscilloscope has the following requirements:

a) The bandwidth of the measurement system shall be at least 3/T where T is the time at high or low (00001111 giving approximately T = 400 ps and 7.5 GHz as an example); and

b) The measurement system is calibrated at the appropriate wavelength for the transmitter under test.

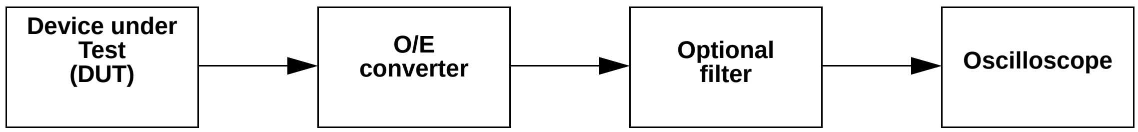


Figure 158–7—Recommended test equipment for measurement of optical modulation amplitude

With the device under test transmitting the square wave described above, use the following procedure to measure optical modulation amplitude:

c) Configure the test equipment as illustrated in Figure 158–7.

d) Measure the mean optical power P_1 of the logic “1” as defined over the center 20% of the time interval where the signal is in the high state. (See Figure 158–8.)

e) Measure the mean optical power P_0 of the logic “0” as defined over the center 20% of the time interval where the signal is in the low state. (See Figure 158–8.)

f) OMA = $P_1 – P_0$.

A method of approximating OMA is shown in Figure 52–11.

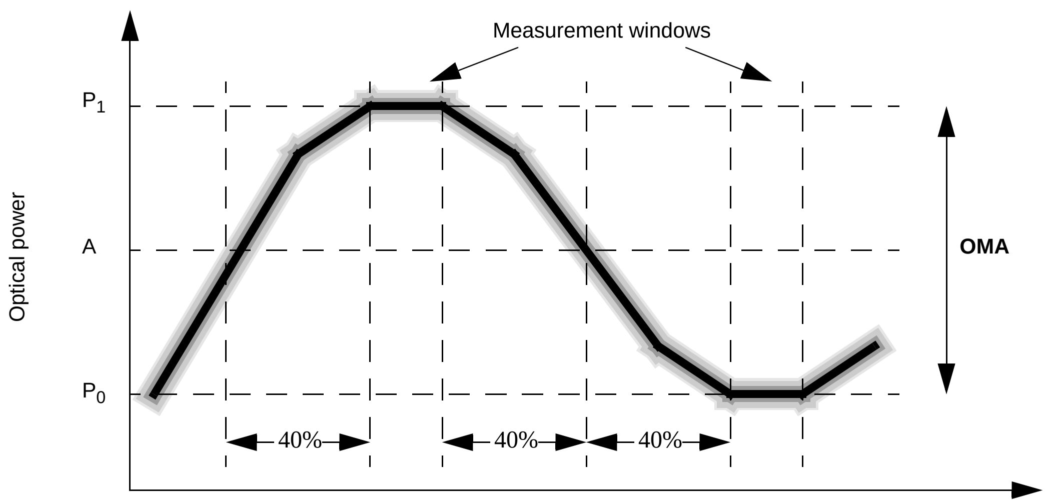


Figure 158–8—Optical modulation amplitude waveform measurement

158.10.6 Relative intensity noise optical modulation amplitude (RIN_xOMA) measuring procedure

This procedure describes a component test that may not be appropriate for a system level test depending on the implementation. If used, the procedure shall be performed as described in 52.9.6.1, 52.9.6.2, and 52.9.6.3.

Editor's Note: I have not included sections 52.9.6.1 through 52.9.6.3 as these could be include by reference. If needed they can be copied into the draft.

$$RIN_xOMA = 10\log\frac{P_N}{BW \times P_M} \text{ (dB/Hz)} \quad (158\text{–}1)$$

Editor's Note: Placeholder figure only, source not available to the editor this time.

Figure 158–9—RIN_xOMA measurement setup

158.10.7 Transmitter optical waveform

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 158–10. Compliance is to be assured during system operation. However, measurements with pattern 3 or 1 defined in 158.10.1, or other patterns such as a $2^{23} – 1$ PRBS or a valid 10GBASE-BxR, or STM-64 signal are likely to give very similar results. Measurements should be made as defined by IEC 61280-2-2 with the eye mask definition A coordinates, or as defined by 86.8.3.2 with the eye mask definition B coordinates. The two sets of coordinates (A and B) are given in Table 158–7, Table 158–12, or Table 158–18 as appropriate. A transmitter is not required to comply with both definitions. Measurement at 10.3125 GBd shall qualify for 10GBASE-BxR use.

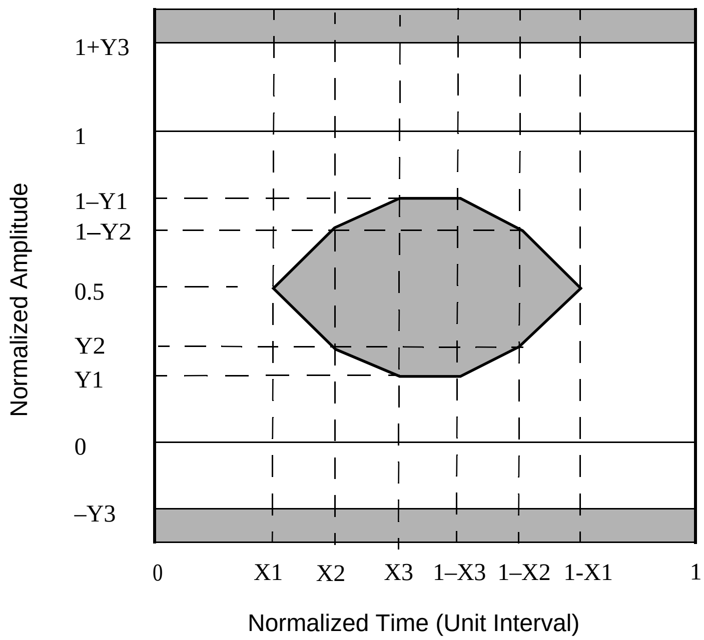


Figure 158–10—Transmitter eye mask definition

Normalized amplitudes of 0.0 and 1.0 represent the amplitudes of logic ZERO and ONE respectively. Normalized times of 0 and 1 on the unit interval scale are to be determined by the eye crossing means measured at the average value of the optical eye pattern.

A clock recovery unit (CRU) should be used to trigger the scope for mask measurements as shown in Figure 158–11. It should have a high-frequency corner bandwidth of less than or equal to 4 MHz and a slope of –20 dB/decade.

The eye shall be measured with respect to the mask of the eye using a receiver with a fourth-order Bessel-Thomson response having a transfer function given by Equation (158–1) and Equation (158–2):

$$H(y) = \frac{105}{105 + 105y + 45y^2 + 10y^3 + y^4} \quad (158\text{–}1)$$

where:

$$y = 2.114p \; ; \quad p = \frac{j\omega}{\omega_r} \; ; \quad \omega_r = 2\pi f_r \; ; \quad f_r = 7.5\text{GHz} \quad (158\text{–}2)$$

and where the filter response vs. frequency range for this fourth-order Bessel-Thomson receiver is defined in ITU-T G.691, along with the allowed tolerances (STM-64 values) for its physical implementation.

This Bessel-Thomson receiver is not intended to represent the noise filter used within a compliant optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

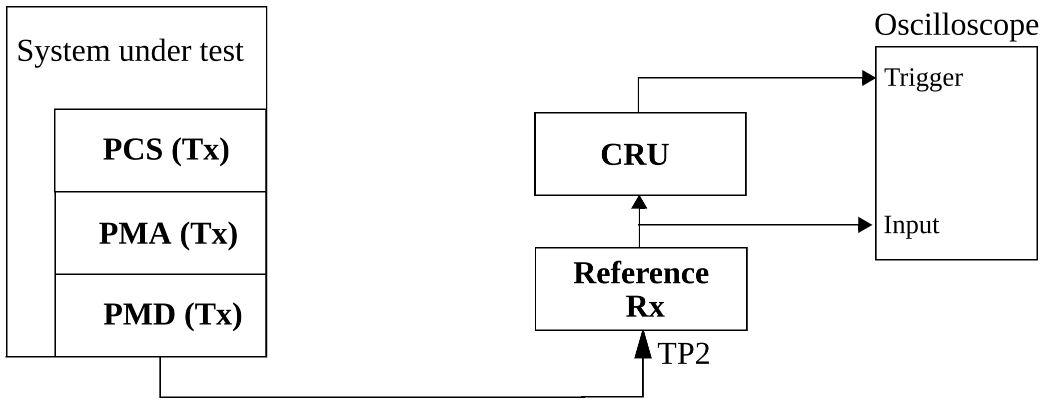


Figure 158–11—Transmitter optical waveform test block diagram

The fourth-order Bessel-Thomson filter is reactive. In order to suppress reflections, a 6 dB attenuator may be required at the filter input and/or output.

158.10.8 Receive sensitivity measurements

Receiver sensitivity, which is defined for an ideal input signal, is informative and testing is not required. If measured, the test signal should have negligible impairments such as intersymbol interference (ISI), rise/fall times, jitter and RIN. Instead, the normative requirement for receivers is stressed receiver sensitivity. Stressed sensitivity is measured with a conditioned input signal where both vertical eye closure and jitter have been added according to 158.10.9.

158.10.9 Stressed receiver conformance test

Stressed receiver tolerance testing shall be performed in accordance with the requirements of 52.9.9.1, 52.9.9.2, 52.9.9.3, and 52.9.9.4.

Receivers must operate with BER less than 10^{-12} when tested with a conditioned input signal that combines vertical eye closure and jitter according to this clause.

The measurements in this subclause are performed with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is to be the same pattern defined for this measurement in 52.9.1.

Editor's Note: I have not included sections 52.9.9.1 through 52.9.6.4 as these could be included by reference. If needed they can be copied into the draft.

Placeholder figure only.

Figure 158–12—Stressed receiver conformance test block diagram

Vertical eye closure penalty (158–1)

Placeholder figure only.

Figure 158–13—Required characteristics of the conformance test signal at TP3

158.10.10 Transmitter and dispersion penalty (TDP)

The transmitter and dispersion penalty (TDP) measurement tests for transmitter impairments with chromatic effects for a transmitter to be used with single-mode fiber.

The setup for measurement of transmitter and dispersion penalty is shown in Figure 158–14 and consists of a reference transmitter, the transmitter under test, a controlled optical reflection, an optical attenuator, a test fiber, a reference receiver, a transversal filter for 10GBASE-BLR, and a bit-error ratio tester. All BER and sensitivity measurements are made with the test patterns in 158.10.1.

158.10.10.1 Reference transmitter requirements

The reference transmitter is a high-quality instrument-grade device, which can be implemented by a CW laser modulated by a high-performance modulator. It should meet the following basic requirements:

a) The rise/fall times should be less than 30 ps at 20% to 80%.
b) The output optical eye is symmetric and passes the eye mask test of 158.10.7.
c) In the center 20% region of the eye, the worst case vertical eye closure penalty as defined in 52.9.9.3 is less than 0.5 dB.
d) Jitter less than 0.20 UI peak-peak.
e) RIN should be minimized to less than –136 dB/Hz.

158.10.10.2 Channel requirements

The transmitter is tested using an optical channel that meets the requirements listed in Table 158–25.

Table 158–25—Transmitter compliance channel specifications

PMD Type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c] (max)
	Minimum	Maximum		
10GBASE-BLR			Minimum	
10GBASE-BMR	$0.2325 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.2325 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	21 dB
10GBASE-BER	0 (maximum)	$0.93 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	See ORLT in TTable 158–18

[a]The dispersion is measured for the wavelength of the device under test. The coefficient assumes 10 km for 10GBASE-BMR and 40 km for 10GBASE-BER.

[b]There is no intent to stress the sensitivity of the BERT's optical receiver.
[c]The optical return loss is applied at TP2.

A 10GBASE-BLR, 10GBASE-BMR, or 10GBASE-BER transmitter is to be compliant with a total dispersion at least as negative as the "minimum dispersion" and at least as positive as the "maximum dispersion" columns specified in Table 158–25 for the wavelength of the device under test. This may be achieved with channels consisting of fibers with lengths chosen to meet the dispersion requirements.

To verify that the fiber has the correct amount of dispersion, the measurement method defined in ANSI/TIA/EIA-455-175A-92 may be used. The measurement is made in the linear power regime of the fiber.

The channel for 10GBASE-BLR is a 2 m to 5 m patch cord meeting the requirements in Table 158–27.

The channel provides a maximum optical return loss specified in Table 158–25. The state of polarization of the back reflection is adjusted to create the greatest RIN. The methods of 52.9.6.2 and 52.9.6.3 may be used.

158.10.10.3 Reference receiver requirements

The reference receiver should have the bandwidth given in 158.10.7. The sensitivity of the reference receiver should be limited by Gaussian noise. The receiver should have minimal threshold offset, deadband, hysteresis, baseline wander, deterministic jitter or other distortions. Decision sampling should be instantaneous with minimal uncertainty and setup/hold properties.

The nominal sensitivity of the reference receiver, S, is measured in OMA using the set up of Figure 158–14 without the test fiber and with the transversal filter removed. The sensitivity S must be corrected for any significant reference transmitter impairments including any vertical eye closure. It should be measured while sampling at the eye center or corrected for off-center sampling. It is calibrated at the wavelength of the transmitter under test.

For all transmitter and dispersion penalty measurements, determination of the center of the eye is required. Center of the eye is defined as the time halfway between the left and right sampling points within the eye where the measured BER is greater than or equal to 1×10^{-3}.

The clock recovery unit (CRU) used in the TDP measurement has a corner frequency of less than or equal to 4 MHz and a slope of 20 dB/decade. When using a clock recovery unit as a clock for BER measurements, passing of low-frequency jitter from the data to the clock removes this low-frequency jitter from the measurement.

158.10.10.4 Test procedure

To measure the transmitter and dispersion penalty (TDP) the following procedure shall be used. The decision threshold amplitude is defined to occur at the average signal level. The sampling instant is displaced from the eye center by ± 0.05 UI. The following procedure is repeated for early and late decision and the larger TDP value is used:

a) Configure the test equipment as described above and illustrated in Figure 158–14.
b) Adjust the attenuation of the optical attenuator to obtain a BER of 1×10^{-12}.
c) Record the optical power in OMA at the input to the reference receiver, P_DUT, in dBm.
d) If P_DUT is larger than S, the transmitter and dispersion penalty (TDP) for the transmitter under test is the difference between P_DUT and S, TDP = P_DUT – S. Otherwise the transmitter and dispersion penalty is zero, TDP = 0.

It is to be ensured that the measurements are made in the linear power regime of the fiber.

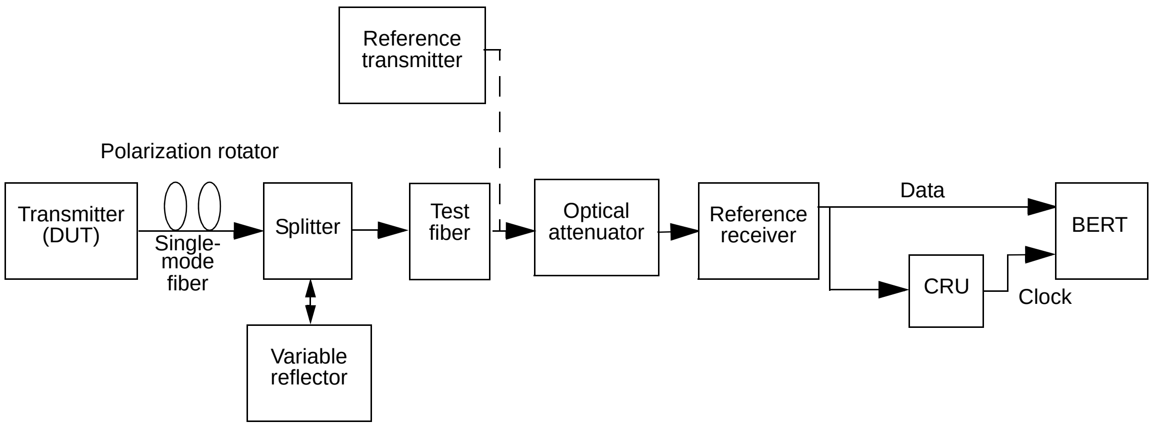


Figure 158–14—Test setup for measurement of transmitter and dispersion penalty

158.10.11 Measurement of the receiver 3 dB electrical upper cutoff frequency

The receiver 3 dB electrical upper cutoff frequency may be measured as described in Figure 52–13 and the list below. The test setup is shown in Figure 158–15. The test uses two optical sources and an optical combiner. One source is modulated by a digital data signal. The other, approximately linear, source is modulated with an analog signal. The analog and digital signals should be asynchronous. The recommended patterns are test patterns 1 or 3 of 158.10.1. An appropriate PRBS or a valid 10GBASE-BxR signal, OC-192 signal, STM-64 signal, or another representative test pattern may be used.

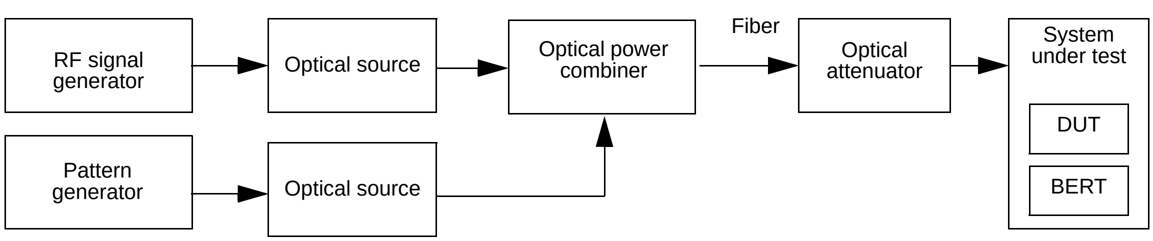


Figure 158–15—Test setup for receiver bandwidth measurement

The 3 dB upper cutoff frequency may be measured using the following steps:

a) Calibrate the frequency response characteristics of the test equipment including the analog radio frequency (RF) signal generator and laser sources. The digital optical source meets the requirements of this clause.

b) Configure the test equipment as shown in Figure 158–15. Take care to minimize changes to the signal path which could affect the system frequency response after the calibration in step “a)”. With the RF modulation turned off, and both optical sources turned on, set the Optical Modulation Amplitude to a level that approximates the stressed receiver sensitivity level in Table 158–9 for 10GBASE-BLR, Table 158–14 for 10GBASE-BMR, and Table 158–19 for 10GBASE-BER.

c) Turn on the RF modulation while maintaining the same average optical power and OMA established in step “b)”.

d) Measure the necessary RF modulation amplitude (in electrical dBm) required to achieve a constant BER (e.g., 10^{-8}) for a number of frequencies.

e) The receiver 3 dB electrical upper cutoff frequency is that frequency where the corrected RF modulation amplitude (the measured amplitude in "d)" corrected with the calibration data in "a)") increases by 3 dB (electrical).

158.11 ~~Environmental specifications~~

158.12 Safety, installation, environment, and labeling

158.12.1 General safety

All equipment meeting this standard shall conform to IEC-60950-1.

158.12.2 Laser safety

10GBASE-BxR optical transceivers shall conform to Hazard Level 1 laser requirements as defined in IEC 60825-1 and IEC 60825-2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore.

Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation is required to explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.[3]

158.12.3 Installation

Sound installation practice, as defined by applicable local codes and regulations, shall be followed in every instance in which such practice is applicable.

158.12.4 Environment

Normative specifications in this clause shall be met by a system integrating a 10GBASE-BxR over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

It is recommended that manufacturers indicate in the literature associated with the PHY the operating environmental conditions to facilitate selection, installation, and maintenance.

It is recommended that manufacturers indicate, in the literature associated with the components of the optical link, the distance and operating environmental conditions over which the specifications of this clause are met.

[3] A host system that fails to meet the manufacturers requirements and/or usage restrictions may emit laser radiation in excess of the safety limits of one or more safety standards. In such a case, the host manufacturer is required to obtain its own laser safety certification.

158.12.5 Electromagnetic emission

A system integrating a 10GBASE-BxR PMD shall comply with applicable local and national codes for the limitation of electromagnetic interference.

158.12.6 Temperature, humidity, and handling

The optical link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

158.12.7 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 10GBASE-ER).

Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 158.12.2.

158.13 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 158–16.

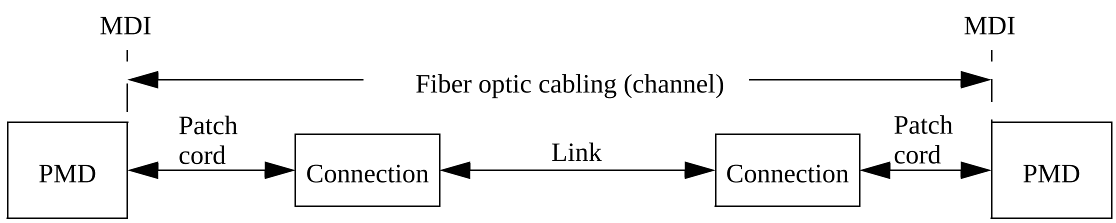


Figure 158–16—Fiber optic cabling model

The channel insertion loss is given in Table 158–26. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion, reflections, polarization mode dispersion and modal bandwidth meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A/method B, and ANSI/TIA/EIA-526-7/method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

Table 158–26—Fiber optic cabling (channel)

Description	Type B1.1, B1.3 SMF			Unit
Nominal wavelength	**1310**[a]	**1550**		**nm**
Operating distance (max)	10 km	30 km	40 km	
Channel insertion loss (max) [b,c,d]	6.0	11.0[e]		dB
Channel insertion loss (min)	0	5		dB
Dispersion (max)		546	728	ps/nm
DGD_max[f]	10	19		ps
Optical return loss		21		dB

[a]Channel insertion loss at 1310 nm includes cable, connectors, and splices.
[b]These channel insertion loss numbers are based on the nominal wavelength.
[c]Operating distances used to calculate channel insertion loss are those listed in this table.
[d]Maximum attenuation given in Table 158–27.
[e]Channel insertion loss at 1550 nm includes cable, connectors and splices.
[f]Differential Group Delay (DGD) is the time difference between the fractions of a pulse that are transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

158.14 Characteristics of the fiber optic cabling (channel)

The 10GBASE-BxR fiber optic cabling shall meet the specifications defined in Table 158–26. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together.

158.14.1 Optical fiber and cable

The fiber optic cable shall meet the requirements of IEC 60793-2, B1.1 (dispersion un-shifted single mode), or B1.3 (low water peak single mode).

NOTE—It is believed that for 10GBASE-BER, type B4 fiber with positive dispersion may be substituted for B1.1 or B1.3. A link using B4 fiber with negative dispersion should be validated for compliance at TP3.

Table 158–27—Optical fiber and cable characteristics

Description	Type B1.1, B1.3 SMF		Unit
Nominal fiber specification wavelength	**1310**	**1550**	**nm**
Cabled optical fiber attenuation (max)	0.4[a] or 0.5[b]	see footnote[c]	dB/km
Modal Bandwidth (min)	N/A		MHz km
Zero dispersion wavelength (λ_0)	$1300 \le \lambda_0 \le 1324$		nm
Dispersion slope (max) (S_0)	0.093		ps / nm^2 km

[a]For the single-mode case, the 0.4 dB/km attenuation for optical fiber cables is defined in ITU-T G.652.
[b]For the single-mode case, the 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3. Using 0.5 dB/km may not support operation at 10 km.
[c]Attenuation for 1550 nm links is based on the fiber channel and is specified in 158.14.3.

158.14.2 Optical fiber connection

An optical fiber connection, as shown in Figure 158–16, consists of a mated pair of optical connectors.

158.14.2.1 Connection insertion loss

The insertion loss is specified for a connection, which consists of a mated pair of optical connectors.

The maximum link distances for single-mode fiber are calculated based on an allocation of 2 dB total connection and splice loss at 1310 nm for 10GBASE-BMR, and 2 dB for 30 km total connection and splice loss at 1550 nm for 10GBASE-BER.

158.14.2.2 Maximum discrete reflectance

The maximum discrete reflectance for 10GBASE-BLR shall be less than –20 dB.

The maximum discrete reflectance for 10GBASE-BMR and 10GBASE-BER shall be less than –26 dB.

158.14.3 10GBASE-BER attenuator management

The 10GBASE-BER channel shall have an attenuation between 5 dB and 11 dB. If required, an attenuator can be added to comply with this specification. The ideal channel attenuation is 8 dB. Figure 52–15 graphically shows the compliant region.

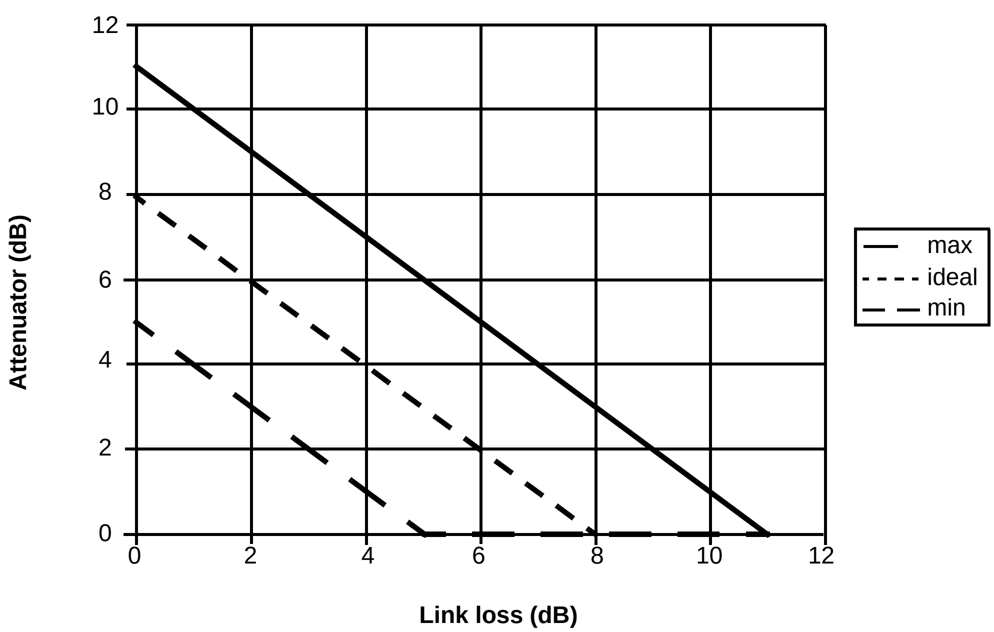


Figure 158–17—10GBASE-BER attenuator management (informative)

158.14.4 Medium Dependent Interface (MDI) requirements

The 10GBASE-BxR PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" (as shown in Figure 158–16). Examples of an MDI include the following:

a) Connectorized fiber pigtail.

b) PMD receptacle.

When the MDI is a connector plug and receptacle connection, it shall meet the interface performance specifications of the following:

c) IEC 61753-1-1—Fibre optic interconnecting devices and passive component performance standard—Part 1-1: General and guidance—Interconnecting devices (connectors).

d) IEC 61753-021-2—Fibre optic passive components performance standard—Part 021-2: Fibre optic connectors terminated on single-mode fibre for Category C—Controlled environment, performance Class S.

e) IEC 61753-022-2—Fibre optic passive components performance standard—Part 022-2: Fibre optic connectors terminated on multimode fibre for Category C—Controlled environment, performance Class M.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 158.5.1, not at the MDI.

158.15 Protocol implementation conformance statement (PICS) proforma for Clause 158, clause title[4]

Editor's Note: the recommended method for creating a requirement that originates in a references clause is to include a "shall" statement in the referencing clause (i.e., this clause) and tie the PICs requirement to that reference. For example "This PMD shall include the xyz function defined in 52.2.4 excepting the requirement to support multimode fiber."

158.15.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 158, clause title, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

158.15.2 Identification

158.15.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

158.15.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3xx-20xx, Clause 158, clause title
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3xx-20xx.)	

Date of Statement	

[4]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

158.15.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
					Yes [ ] No [ ]
					Yes [ ]

158.15.4 PICS proforma tables for clause title

158.15.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
					Yes [ ]
					Yes [ ] No [ ]
					Yes [ ] No [ ] N/A [ ]

158.15.4.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
					Yes [ ] N/A [ ]
					Yes [ ] No [ ] N/A [ ]

Example Table

Table 158–28—Title of table
