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(Amendment to IEEE Std 802.3.-2002)

IEEE

Standards

802.3ap™

**IEEE Standard for Information technology.
Telecommunications and information exchange between
systems.**

Local and metropolitan area networks.

Specific requirements

**Part 3: Carrier Sense Multiple Access with
Collision Detection (CSMA/CD) Access Method
and Physical Layer Specifications**

**Amendment: Physical Layer and Management
Parameters for 10Gb/s Operation,
Type 10GBASE-BX1**

54. Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-BX1

54.1 Overview

This clause specifies the 10GBASE-BX1 PMD (including MDI) and the baseband medium. In order to form a complete PHY (physical layer device), a PMD is combined with the appropriate sublayers (see Table 54–1) and with the management functions, which are optionally accessible through the management interface defined in Clause 45, or equivalent.

Table 54–1—PHY (physical layer) clauses associated with the 10GBASE-BX1 PMD

Associated clause	10GBASE-BX1
46 - XGMII	Optional
47 – XGXS and XAUI	Optional
48 – 10GBASE-X PCS/PMA	Required

The XGMII is an optional interface. However, if the XGMII is not implemented, a conforming implementation must behave functionally as though the RS and XGMII were present.

Figure 54–1 shows the relationship of the 10GBASE-BX1 PMD sublayers and MDI to the ISO/IEC Open System Interconnection (OSI) reference model.

Layer Model

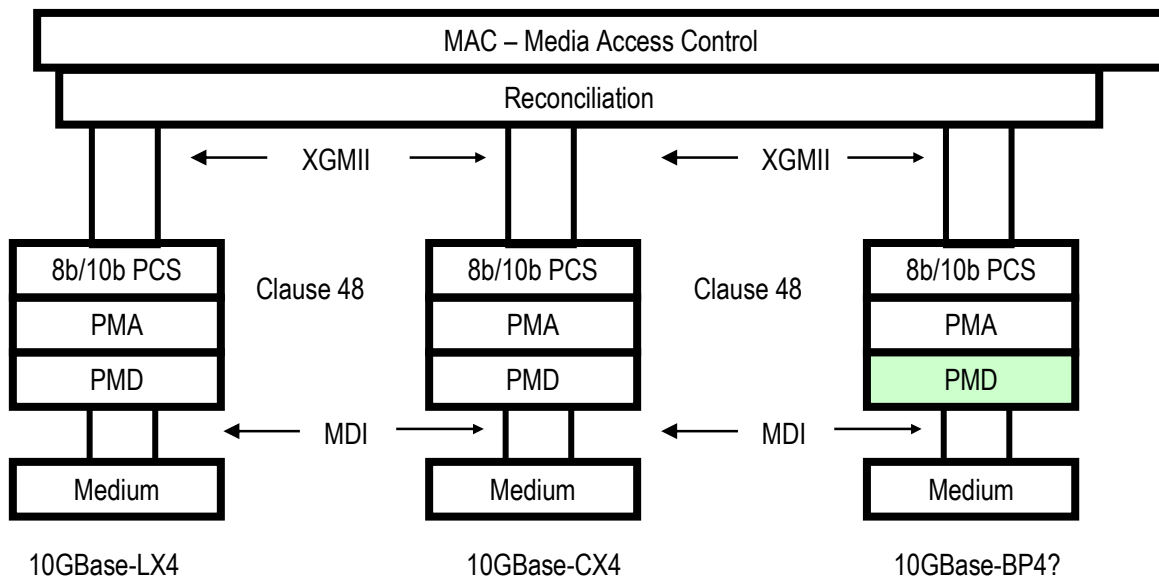


Figure 54–1—10GBASE-BX1 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

54.2 Physical Medium Dependent (PMD) service interface

The 10GBASE-BX1 PMD utilizes the PMD service interface defined in 53.1.1. The PMD service interface is summarized below:

```
PMD_UNITDATA.request
PMD_UNITDATA.indicate
PMD_SIGNAL.indicate
```

54.3 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that implementers of MAC, MAC Control, and PHY must consider the delay maxima, and that network planners and administrators consider the delay constraints regarding the cable topology and concatenation of devices. A description of overall system delay constraints and the definitions for bit-times and pause_quantum can be found in 44.3.

The sum of the transmit and the receive delays contributed by the 10GBASE-BX1 PMD shall be no more than 512 BT or 1 pause_quantum.

54.4 PMD MDIO function mapping

The 10GBASE-BX1 PMD uses the same MDIO function mapping as 10GBASE-3R, as defined in 53.3.

54.5 PMD functional specifications

The 10GBASE-BX1 PMD performs the transmit and receive functions (which convey data between the PMD service interface and the MDI), and provides various management functions if the optional MDIO is implemented.

54.5.1 Link block diagram

A 10GBASE-BX1 link is shown in Figure 54–2. For purposes of system conformance, the PMD sublayer is standardized at the points described in this subclause. The electrical transmit signal is defined at the output end of the AC coupling capacitor (TP1). Unless specified otherwise, all transmitter measurements and tests defined in 54.6.3 are made at TP1. Unless specified otherwise, all receiver measurements and tests defined in 54.6.4 are made at the input end of the mated connector (TP4). A mated connector pair has been included in both the transmitter and receiver specifications defined in 54.6.3 and 54.6.4. Two mated connector pairs have been included in the backplane specifications defined in 54.7.

Recommended Model for Simulation

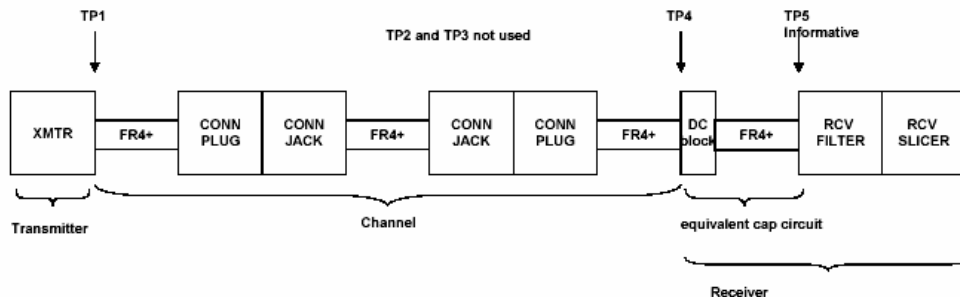


Figure 54–2—10GBASE-BX1 link (half link is shown)

NOTE—SLn<p> and SLn<n> are the positive and negative sides of the transmit differential signal pair and DLn<p> and DLn<n> are the positive and negative sides of the receive differential signal pair for lane n (n = 0, 1, 2, 3).

54.5.2 PMD Transmit function

The PMD shall convey the bits received from the PMD service interface using the message PMD_UNITDATA.request(tx_bit) to the MDI according to the electrical specifications of this clause.

A positive output voltage of SLn<p> minus SLn<n> (differential voltage) shall correspond to tx_bit = ONE.

54.5.3 PMD Receive function

The PMD shall convey the bits received from the MDI, all according to the receive electrical specifications in 54.6.4. A positive input voltage level in each signal stream of $DLn<p>$ minus $DLn<n>$ (differential voltage) shall correspond to a $rx_bit = ONE$.

54.5.4 Global PMD signal detect function

The `Global_PMD_signal_detect` function shall report the state of `SIGNAL_DETECT` via the PMD service interface. The `SIGNAL_DETECT` parameter is signaled continuously, while the `PMD_SIGNAL.indicate` message is generated when a change in the value of `SIGNAL_DETECT` occurs.

`SIGNAL_DETECT` is a global indicator of the presence of electrical signals. The PMD receiver is not required to verify whether a compliant 10GBASE-BX1 signal is being received; however, it shall assert `SIGNAL_DETECT = OK` within 100 ns after the absolute differential peak-to-peak input voltage at the MDI has exceeded 175 mV for at least 1 UI (unit interval).

The PMD shall not have asserted `SIGNAL_DETECT = FAIL` until the absolute differential peak-to-peak input voltage on any of the four lanes at the MDI has dropped below 50 mV and has remained below 50 mV for at least 250 ns. The PMD shall have asserted `SIGNAL_DETECT = FAIL` when the absolute differential peak-to-peak input voltage on any of the four lanes at the MDI has dropped below 50 mV and has remained below 50 mV for longer than 500 ns.

Table 54-2-SIGNAL_DETECT summary (informative)

Parameter	Value	Units
<code>SIGNAL_DETECT = OK</code> level (maximum differential peak-to-peak amplitude)	?	mV
<code>SIGNAL_DETECT = OK</code> width (minimum)	?	UI
<code>SIGNAL_DETECT = OK</code> assertion time (maximum)	?	mV
<code>SIGNAL_DETECT = FAIL</code> de-assertion time maximum minimum	500 250	Us us

NOTE—`SIGNAL_DETECT` may not activate with a continuous 1010... pattern, such as the high-frequency pattern of 48A.1, but it will be activated by an inter-packet gap (IPG).

54.5.6 Global PMD transmit disable function

The `Global_PMD_transmit_disable` function is optional. When implemented, it allows all of the transmitters to be disabled with a single variable.

- When a `Global_PMD_transmit_disable` variable is set to `ONE`, this function shall turn off the transmitter such that the transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 54–3.
- If a `PMD_fault` (54.5.9) is detected, then the PMD may turn off the electrical transmitter.
- Loopback, as defined in 54.5.8, shall not be affected by `Global_PMD_transmit_disable`.

54.5.8 Loopback mode

Loopback mode shall be provided for the 10GBASE-BX1 PMD by the transmitter and receiver of a device as a test function to the device. When loopback mode is selected, transmission requests passed to the transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. The transmitters shall not be disabled when loopback mode is enabled. A device must be explicitly placed in loopback mode because loopback mode is not the normal mode of operation of a device. The method of implementing loopback mode is not defined by this standard.

Control of the loopback function is specified in 45.2.1.1.4.

NOTES

1—The signal path that is exercised in the loopback mode is implementation specification but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

2—Placing a network port into loopback mode can be disruptive to a network.

54.5.9 PMD fault function

If the MDIO is implemented, and the PMD has detected a local fault on the transmit or receive paths, the PMD shall set `PMD_fault` to ONE; otherwise, the PMD shall set `PMD_fault` to ZERO.

54.5.10 PMD transmit fault function

If the MDIO is implemented, and the PMD has detected a local fault on the transmitter, the PMD shall set the `PMD_transmit_fault` variable to ONE; otherwise, the PMD shall set `PMD_transmit_fault` to ZERO.

54.5.11 PMD receive fault function

If the MDIO is implemented, and the PMD has detected a local fault on the receiver, the PMD shall set the `PMD_receive_fault` variable to ONE; otherwise, the PMD shall set `PMD_receive_fault` to ZERO.

54.6 MDI Electrical specifications for 10GBASE-BX1

54.6.1 Signal levels

The 10GBASE-BX1 MDI is a low-swing AC-coupled differential interface. Transmitter to receiver path AC coupling, as defined in 54.6.4.3, allows for interoperability between components operating from different supply voltages. Low-swing differential signaling provides noise immunity and improved electromagnetic interference (EMI).

54.6.2 Signal paths

The 10GBASE-BX1 MDI signal paths are point-to-point connections. Each path corresponds to a 10GBASE-BX1 MDI lane and comprises two complementary signals, which form a balanced differential pair. There is a single differential path in each direction for a total of two pairs, or four connections. The signal paths are intended to operate on backplane cable assemblies up to 15 m in length, as described in 54.7.

54.6.3 Transmitter characteristics

Transmitter characteristics shall meet specifications at TP1, unless otherwise noted. The specifications are summarized in Table 54–3 and detailed in 54.6.3.1 through 54.6.3.9.

Table 54–3—Transmitter characteristics’ summary (informative)

DRIVER CHARACTERISTICS TABLE				
	PARAMETER	VALUE	UNITS	
	Baud rate tolerance	10.3125GBd +/- 100ppm	GBd	
	Diff. Amplitude (1) Max/Min	1200 800	mVp mVp-p	
	Common –Mode Voltage	TBD	V	
	Diff. Output Return Loss min	Figure	dB	
	Output Template	Figure	V	
	Transition Time min Measured between 20% & 80%	24	ps	
	Output Jitter (2) Random Deterministic Total	.15 0.15 0.3	Ulp-p Ulp-p Ulp-p	

(1) Measured at Peak of the Output Waveform

(2) With Jitter Filter Applied

54.6.3.1 Test fixtures

The test fixture of Figure 54–3, or its functional equivalent, is required for measuring the transmitter specifications described in 54.6.3.

Figure 54-3-Transmit test Fixture

54.6.3.2 Test-fixture impedance

The nominal differential impedance of the transmit test fixture depicted in Figure 54–3 shall be 100 Ω with a return loss greater than x dB from 100 MHz to 5000 MHz.

54.6.3.3 Signaling speed range

The 10GBASE-BX1 MDI signaling speed shall be 10.3125 GBd \pm 100 ppm. The corresponding unit interval is nominally 100 ps.

54.6.3.4 Output amplitude

While transmitting the test pattern specified in 48A.2:

54.6.3.4 Output amplitude

While transmitting the test pattern specified in 48A.2:

- a) The transmitter maximum differential peak-to-peak output voltage shall be less than 1200 mV.
- b) The minimum differential peak-to-peak output voltage shall be greater than 800 mV.

See Figure 54–4 for an illustration of the definition of differential peak-to-peak output voltage. DC-referenced logic levels are not defined since the receiver is AC-coupled. The common-mode voltage of $SLn<p>$ and $SLn<n>$ shall be between $-x$ V and y V as measured at V_{com} in Figure 54–3.

Use CX4 diagram

Figure 54–4—Transmitter differential peak-to-peak output voltage definition

NOTE— $SLn<p>$ and $SLn<n>$ are the positive and negative sides of the differential signal

54.6.3.5 Output return loss

For frequencies from 100 MHz to 2000 MHz, the differential return loss, in dB with f in MHz, of the transmitter shall meet Equation (54–1) and Equation (54–2). This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ω .

(54–1)

for 100 MHz $\leq f < 625$ MHz and

(54–2)

for 625 MHz $\leq f \leq 2000$ MHz.

Figure 54–5—Minimum transmit differential output return loss (informative)

54.6.3.6 Differential output template

The transmitter differential output signal is defined at TP1, as shown in Figure 54–2. The transmitter shall provide equalization such that the output waveform falls within the template shown in Figure 54–6 for the test pattern specified in 48A.2. Voltage and time coordinates for inflection points on Figure 54–6 are given in Table 54–4. The signal on at TP1 shall meet the transmit template specifications when connected to the transmitter test fixture shown in Figure 54–3. The waveform under test shall be normalized by using the following procedure:

- 1) Align the output waveform under test, to achieve the best fit along the horizontal time axis.
- 2) Calculate the +1 low frequency level as V_{lowp} = average of any 2 successive unit intervals (2UI) between 2.5 UI and 5.5 UI.
- 3) Calculate the 0 low frequency level as V_{lowm} = average of any 2 successive unit intervals (2UI) between 7.5 UI and 10.5 UI.
- 4) Calculate the vertical offset to be subtracted from the waveform as $V_{off} = (V_{lowp} + V_{lowm}) / 2$.
- 5) Calculate the vertical normalization factor for the waveform as $V_{norm} = (V_{lowp} - V_{lowm}) / 2$.
- 6) Calculate the normalized waveform as $Normalized_Waveform = (Original_Waveform - V_{off}) \cdot (0.69/V_{norm})$.
- 7) Align the $Normalized_Waveform$ under test, to achieve the best fit along the horizontal time axis.

TX Mask

Test pattern is 0x17 repeating pattern

Masked based on tap values shown in simulation section of presentation

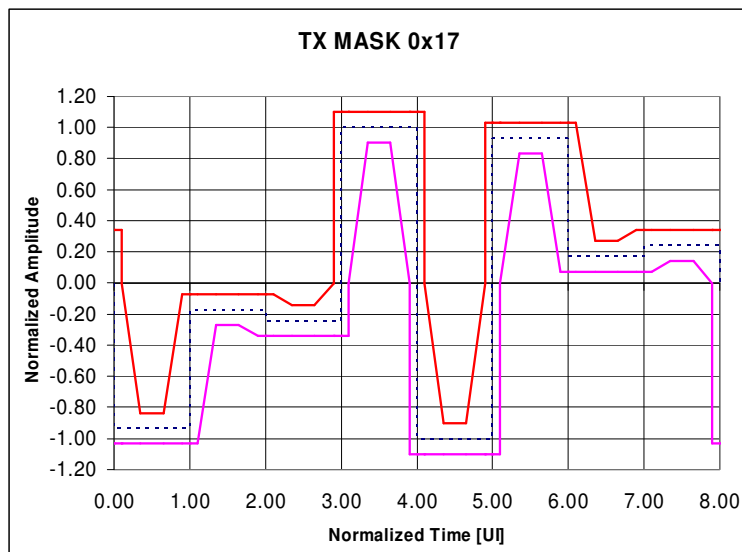


Figure 54–6—Normalized transmit template

54.6.3.7 Transition time

The rising-edge transition time shall be between 24 ps and x ps as measured at the 20% and 80% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 48A.1. The falling edge transition time shall be between 24 ps and x ps as measured at the 80% and 20% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 48A.1.

54.6.3.8 Transmit jitter

The transmitter shall satisfy the jitter requirements of 54.6.3.9 with a maximum total jitter of 0.30 UI peak-to-peak, a maximum deterministic component of 0.15 UI peak-to-peak and a maximum random component of 0.15 UI peak-to-peak. Jitter specifications include all but 10–12 of the jitter population. Transmit jitter test requirements are specified in 54.6.3.9.

54.6.3.9 Transmit jitter test requirements

Transmit jitter is defined with respect to a test procedure resulting in a BER bathtub curve such as that described in Annex 48B. For the purpose of jitter measurement, the effect of a single-pole, high-pass filter with a 3 dB point at x MHz is applied to the jitter. The data pattern for jitter measurements shall be the CJPAT pattern defined in Annex 48A.5. The 10GBASE-BX1 transceiver is active in both directions, and opposite ends of the link use asynchronous clocks. Crossing times are defined with respect to the mid-point (0 V) of the AC-coupled differential signal.

54.6.4 Receiver characteristics

Receiver characteristics are summarized in Table 54–5 and detailed in 54.6.4.1 through 54.6.4.5.

RX Characteristics Table

Parameter	Value	Units
Baud rate tolerance	10.3125GBd \pm 100 ppm	GBd
Diff. Peak Amplitude max.	1600	mVp-p
Error Rate	10^{-12}	
Diff. Return Loss Minimum	See TX Ret. Loss	dB
Jitter Tolerance	See Figure	UI

54.6.4.1 Bit error ratio

The receiver shall operate with a BER of better than 10^{-12} when receiving a compliant transmit signal, as defined in 54.6.3, through a compliant backplane as defined in 54.7.

NOTE—The BER should be met with a worst-case insertion loss, , as well as a low-loss, backplane. The lowloss backplane may be a more stringent requirement on the system due to higher reflections and crosstalk than with long backplanes.

54.6.4.2 Signaling speed range

A 10GBASE-BX1 receiver shall comply with the requirements of 54.6.4.1 for any signaling speed in the range $10.3125 \text{ GBd} \pm 100 \text{ ppm}$. The corresponding unit interval is nominally 100 ps.

54.6.4.3 AC-coupling

The 10GBASE-BX1 receiver shall be AC-coupled to the channel to allow for maximum interoperability between various 10 Gbps components. AC-coupling is considered to be part of the receiver for the purposes of this standard unless explicitly stated otherwise. It should be noted that there may be various methods for AC-coupling in actual implementations.

NOTE—It is recommended that the maximum value of the coupling capacitors be limited to 470 pF. This will limit the inrush currents to the receiver that could damage the receiver circuits when repeatedly connected to transmit modules with a higher voltage level.

54.6.4.4 Input signal amplitude

10GBASE-BX1 receivers shall accept differential input signal peak-to-peak amplitudes produced by compliant transmitters connected without attenuation to the receiver, and still meet the BER requirement specified in 54.6.4.1. Note that this may be larger than the 1200 mV differential maximum of 54.6.3.4 due to the actual transmitter output and receiver input impedances. The input impedance of a receiver can cause the minimum signal into a receiver to differ from that measured when the receiver is replaced with a 100 Ω test load. Since the 10GBASE-Tx1 receiver is AC-coupled, the absolute voltage levels with respect to the receiver ground are dependent on the receiver implementation.

54.6.4.5 Input return loss

For frequencies from 100 MHz to 8000 MHz, the differential return loss (in dB with f in MHz) of the receiver shall be greater than or equal to Equation (54–1) and Equation (54–2). This input impedance requirement applies to all valid input levels. The reference impedance for differential return loss measurements is 100 ohms.

54.7 Channel characteristics

The 10GBASE-BX1 channel is primarily intended as a point-to-point interface of up to 1 m between network ports using controlled impedance traces and connectors. All channel measurements are to be made between TP1 and TP4 as shown in Figure 54–2. These channel specifications are based upon advanced FR4 characteristics, but other channel types are acceptable if the specifications are met.

54.7.1 Characteristic impedance and reference impedance

The nominal differential characteristic impedance of the backplane is 100 ohms. The differential reference impedance for backplane specifications shall be 100 ohms.

54.7.2 Channel insertion loss

The insertion loss (in dB with f in MHz) of each pair of the 10GBASE-BX1 channel shall be:

$$-(54-3)$$

for all frequencies from 100 MHz to 6000 MHz. This includes the attenuation of the backplane and the assembly connectors.

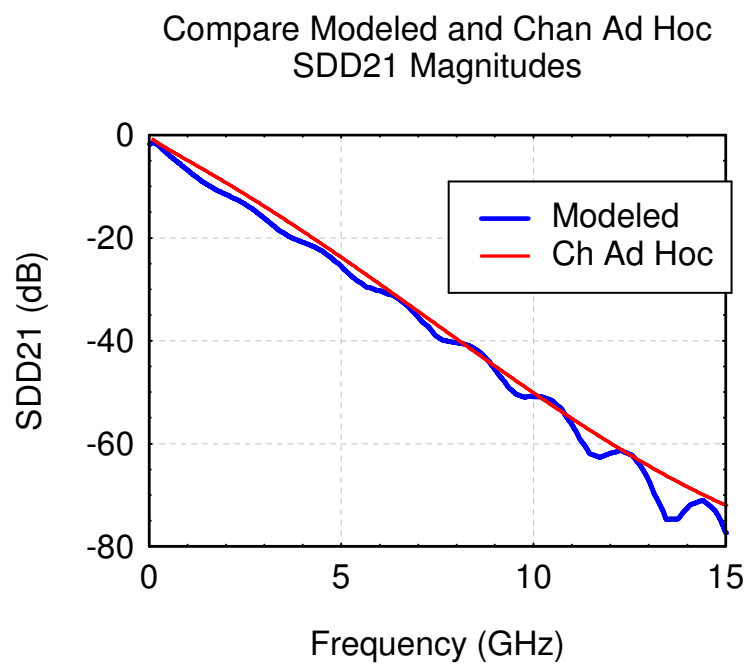


Figure 54-7—Maximum channel insertion loss (informative)

54.7.3 Channel return loss

The return loss (in dB with f in MHz) of each pair of the 10GBASE-BX1 channel shall be:
(54-4)

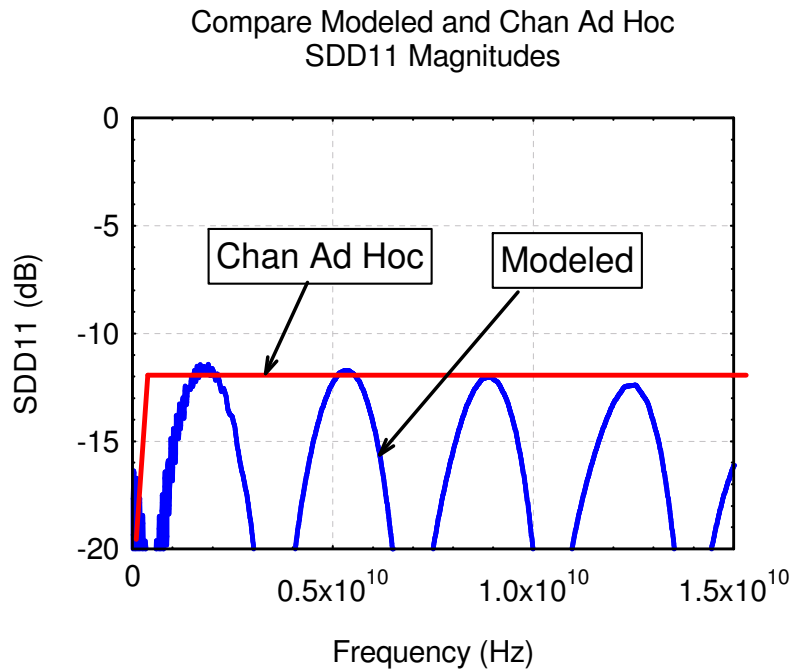


Figure 54–8—Minimum channel return loss (informative)

54.7.4 Near-End Crosstalk (NEXT)

54.7.4.1 Differential Near-End Crosstalk

In order to limit the crosstalk at the near end of a link segment, the differential Near-End Crosstalk (NEXT) loss and any of the four receive lanes is specified to meet the BER objective specified in 54.6.4.1. The NEXT loss between any transmit and receive in a link segment (in dB with f in MHz) shall be at least:

$$\text{NEXT}(f) \geq 30 - 17 \times \log(f/6000) \quad (54-6)$$

for all frequencies from 100 MHz to 6000 MHz.

Figure 54–9—Minimum Channel NEXT / MDNEXT loss (informative)

54.7.5 Far-End Crosstalk (FEXT)

54.7.5.1 Equal Level Far-End Crosstalk (ELFEXT) loss

Equal Level Far-End Crosstalk (ELFEXT) loss is specified in order to limit the crosstalk at the far end of each link segment and meet the BER objective specified in 54.6.4.1. Far-End Crosstalk (FEXT) is crosstalk that appears at the far end of a lane (disturbed lane), which is coupled from another lane (disturbing lane) with the noise source (transmitters) at the near end. FEXT loss is defined as

$$\text{FEXT_Loss}(f) = 20 \cdot \log(V_{\text{pds}}(f)/V_{\text{pcn}}(f))$$

and ELFEXT Loss is defined as

$$\text{ELFEXT_Loss}(f) = 20 \cdot \log(V_{\text{pds}}(f)/V_{\text{pcn}}(f)) - \text{SLS_Loss}(f)$$

where

$\text{FEXT_Loss}(f)$ is the FEXT loss at frequency f ,

$\text{ELFEXT_Loss}(f)$ is the ELFEXT loss at frequency f ,

V_{pds} is the peak voltage of the disturbing signal (near-end transmitter),

V_{pcn} is the peak crosstalk noise at the far end of the disturbed lane,

$\text{SLS_Loss}(f)$ is the insertion loss of the disturbed lane in dB,

f is frequency ranging from 100 MHz to 6000 MHz.

The worst pair ELFEXT loss between any two lanes shall be at least:

$$\text{ELFEXT}(f) \geq 20 \cdot \log(f/6000) \quad (54-9)$$

for all frequencies from 100 MHz to 6000 MHz.

Figure 54–10—Minimum channel ELFEXT loss (informative)

54.8 MDI specification

This subclause defines the Media Dependent Interface (MDI). The 10GBASE-BX1 PMD, as per 54.6, is coupled to the channel, as per 54.7, by the MDI.

54.8.1 MDI connectors

No specific connector is specified for the MDI.