International Photonics & Electronics Committee

50 Gb/s Duplex & BIDI PMD Implementation Agreement

IPEC-MFH50-IA V1.0

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50 Gb/s Duplex & BIDI PMD Implementation Agreement

Version 1.0

Date Approved

Sep. 5, 2024

Implementation Agreement created and approved

IPEC

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50 Gb/s Duplex & BIDI PMD Implementation Agreement

Summary

The objective of this document is to define a 50 Gb/s Duplex & Bidirectional（BIDI）PMD for operation over one or two single mode fiber (SMF) with lengths up to at least 10 km. Two transceivers communicate over single mode fibers of length from 2 km to at least 10 km.

Keywords

50 Gb/s, Duplex, BIDI, PMD, LR, PAM4,

Working Group: **PMD**

TITLE: **50 Gb/s Duplex & BIDI PMD Implementation Agreement**

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Document Revision History

Rev	Date	Description
D0.1	2023-2-8	The initial baseline of this IA.
D0.2	2023-3-18	
D0.3	2023-4-23	
D0.4	2023-6-30	
D0.5	2023-8-11	
D0.6	2023-11-23	1. Add the definition of SNR requirement; 2. Update the definition of management interface. 3. Add the definition of optical module general requirements; 4. Add the timing requirements part
D1.0	2023-12-15	The initial draft of this IA.
D1.1	2024-2-29	1. Update the optical specification of 50G LR & BIDI 2. Update the timing requirement 3. Update the measurement methods 4. Some editorial adjustment
D1.2	2024-4-30	1. Update the specification of SNR requirements 2. Some editorial adjustment
D1.3	2024-8-6	Attachment of the Management Interface spreadsheet
V1.0	2024-9-5	1. The official version of this IA. 2. The content is the same as that of D1.3

Table of Contents

Contents

List of Figures

List of Tables

1 Introduction

This IA specifies Physical Layer specifications and parameters for 50 Gb/s Duplex & BIDI optical interfaces.

The objective of the document is to define a 50 Gb/s Duplex & BIDI physical medium dependent (PMD) for operation over one or two single mode fibers (SMF) with lengths up to at least 10 km. Two transceivers communicate over single mode fibers of length from 2 m to at least 10 km.

1.1 Scope

This Implementation Agreement (IA) defines one optical interface for 50 Gb/s optical transceivers for CPRI/eCPRI applications. Forward error correction (FEC) is required to be implemented by the host to ensure reliable system operation. Two transceivers communicate over one or two single mode fibers (SMF) of length from 2 m to at least 10 km. The transceiver electrical interface is not specified by this IA.

A variety of form factors for the transceivers are possible and none are precluded by this MSA.

1.2 Hardware Signaling Pins

Hardware signaling pins are specified in the respective module form factor MSAs.

50 Gb/s Duplex & BIDI optical module hardware signaling pins definition see section 2.1 to section 2.6 in SFF-8431_R4.1A. No special requirement in this document.

Note:

1. The status of the TX_FAULT, TX_DISABLE, RX_LOS, RS0, and RS1 pins changes following to the register information. However, the circuit design of the module still needs to meet the requirements of SFF-8431_R4.1A.

2. The parallel capacitance between the VCCT/VCCR and the soft-start chip should not be greater than 1 μF.

3. The RS0 and RS1 pins should not be short connected by circuit.

1.3 Module Management Interface

The contents of the various ID registers shall comply with the requirements of the module MSA and the respective standards.

The detailed management interface content is defined in chapter 2.5 of this IA.

1.4 High Speed Electrical Characteristics

The detailed high speed electrical characteristics are not defined by this IA. 50 GE modules should be implemented in compliance with applicable electrical interface specifications. 50 Gb/s optical modules electrical characteristics comply with the clauses of OIF-CEI-04.0.

1.5 FEC Requirements

50 Gb/s links rely on the host system implementing the 50GBASE-R PCS layer in accordance the Ethernet Technology Consortium 25/50 Gb/s Specification along with clauses from the IEEE Std 802.3-2022.

1.6 Mechanical Dimensions

Mechanical dimensions are defined in module form factor MSA specifications. This IA does not specific any form factor.

1.7 Optical Specification

The detailed optical specifications are defined in chapter 2 of this IA.

2 50 Gb/s-LR Optical Module Specifications

2.1 50 Gb/s LR Duplex Optical Specifications

This IA defines 50 Gb/s-LR Duplex optical interface for 50 Gb/s Duplex optical transceiver. The following tables show the common function parameters: operating range, optical transmit characteristics, optical receive characteristics.

Table 1 50 Gb/s-LR Duplex general requirement

Paraments	Requirement
Form factor	SFP DSFP SFP-DD QSFP QSFP-DD
PMD type	50 Gb/s-LR
Applications(ETH、CPRI、eCPRI)	NRZ： 25.78125 GBd 24.33024 GBd; PAM4： 26.5625 GBd (53.125 Gb/s) 25.06752 GBd (50.13504 Gb/s).
Required operating range	2 m to 10 km
Operating Case Temperature	-40~85 ℃
Relative humidity(non-condensing)	≤95%
Total power consumption(max)	2 W
Power supply voltage	3.135~3.465 V

Table 2 50 Gb/s-LR Duplex optical transmit characteristics

Description	Value	Unit
Signaling rate (range)	26.5625 ± 100 ppm 25.06752 ± 100 ppm	GBd
Modulation format	PAM4	-
Wavelength (range)	1295 to 1325	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Average launch power (max)	4.5	dBm
Average launch power (min)	-2.3	dBm
Outer Optical Modulation Amplitude (OMA outer) (max)	4	dBm
Outer Optical Modulation Amplitude (OMAouter) (min)[a]	-1.5	dBm
Transmitter eye closure for PAM4 (TECQ) (max)	3.2	dB
Launch power in OMAouter minus TECQ （min）	-3.5	dBm
Average launch power of OFF transmitter (max)	-30	dBm
Extinction ratio (min)	3.5	dB
Transmitter transition time (max)	34	ps
$RIN_{15.6}$OMA (max)	-132	dB/Hz
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance (max)	-26	dB
a. This requirement should be satisfied if TECQ < 2 dB;		

Table 3 50 Gb/s-LR Duplex optical receive characteristics

Description	Value	Unit
Signaling rate (range)	26.5625 ± 100 ppm 25.06752 ± 100 ppm	GBd
Modulation format	PAM4	-
Wavelengths (range)	1295 to 1325	nm
Damage threshold, each lane	5.5	dBm

Average receive power, each lane(max)	4.5	dBm
Average receive power, each lane (min)	-10.8	dBm
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMAouter) (max)[a] @BER 2.4E-4	-8.9	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ)	3.2	dB
a. This requirement should be satisfied if SECQ < 3.2 dB and be inclusive of fiber link penalty;		

2.2 50 Gb/s LR Duplex Illustrative Link Power Budget

Table 4 50 Gb/s-LR DUPLEX optical link budget

Description	Value	Unit
Power budget (for max TECQ):	10.5	dB
Operating distance	10	km
Transmission loss (fiber + four connectors)	6.3	dB
Allocation for penalties (Including MPI)	1	dB
TECQ	3.2	dB

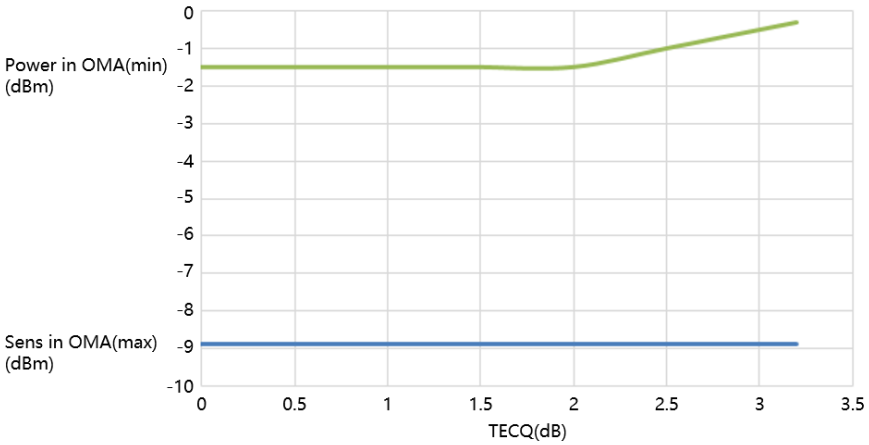

Figure 1 50 Gb/s LR Duplex optical link budget and sensitivity mask

2.3 50 Gb/s LR BIDI Optical Specifications

This IA defines 50 Gb/s-LR BIDI optical interface for 50 Gb/s BIDI optical transceiver. The following tables show the common function parameters: operating range, optical transmit characteristics, optical receive characteristics.

Table 5 50 Gb/s-LR BIDI general requirement

Paraments	Requirement
Form factor	SFP DSFP SFP-DD QSFP QSFP-DD
PMD type	50 Gb/s-LR
Applications(ETH、CPRI、eCPRI)	NRZ： 25.78125 GBd 24.33024 GBd PAM4： 26.5625 GBd (53.125 Gb/s) 25.06752 GBd(50.13504 Gb/s).
Required operating range	2 m to 10 km
Operating Case Temperature	-40~85 °C
Relative humidity(non-condensing)	≤95%
Total power consumption(max)	2 W
Power supply voltage	3.135~3.465 V

Table 6 50 Gb/s-LR BIDI optical transmit characteristics

Description	Value	Unit
Signaling rate (range)	26.5625 ± 100 ppm 25.06752 ± 100 ppm	GBd
Modulation format	PAM4	-
Wavelength (range)	1270 ± 10	nm
	1330 ± 10	
Side-mode suppression ratio (SMSR), (min)	30	dB
Average launch power (max)	4.9	dBm
Average launch power (min)	-1.9	dBm

Outer Optical Modulation Amplitude (OMA outer) (max)	4.4	dBm
Outer Optical Modulation Amplitude (OMA outer) (min)[a]	-1.1	dBm
Transmitter eye closure for PAM4 (TECQ) (max)	3.2	dB
Average launch power of OFF transmitter (max)	-30	dBm
Launch power in OMAouter minus TECQ （min）	-3.1	dBm
Extinction ratio (min)	3.5	dB
Transmitter transition time (max)	34	ps
$RIN_{15.6}$OMA (max)	-132	dB/Hz
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance (max)	-26	dB
a. This requirement should be satisfied if TECQ < 2 dB;		

Table 7 50 Gb/s-LR BIDI optical receive characteristics

Description	Value	Unit
Signaling rate (range)	26.5625 ± 100 ppm 25.06752 ± 100 ppm	GBd
Modulation format	PAM4	-
Wavelengths (range)	1330±10	nm
	1270±10	
Damage threshold, each lane	5.5	dBm
Average receive power when RXLOS(max)	-30	dBm
Average receive power, each lane(max)	4.5	dBm
Average receive power, each lane (min)	-10.8	dBm
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMAouter) (max)[a]	-8.9@BER 2.4e-4	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ)	3.2	dB
a. This requirement should be satisfied if SECQ < 3.2 dB and be inclusive of fiber link penalty;		

2.4 50 Gb/s LR BIDI Illustrative Link Power Budget

Table 8 50 Gb/s-LR BIDI optical link budget

Description	Value	Unit
Power budget (for max TECQ):	10.5	dB
Operating distance	10	km
Transmission loss (fiber + four connectors)	6.3	dB
Allocation for penalties (Including MPI)	1	dB
TECQ	3.2	dB

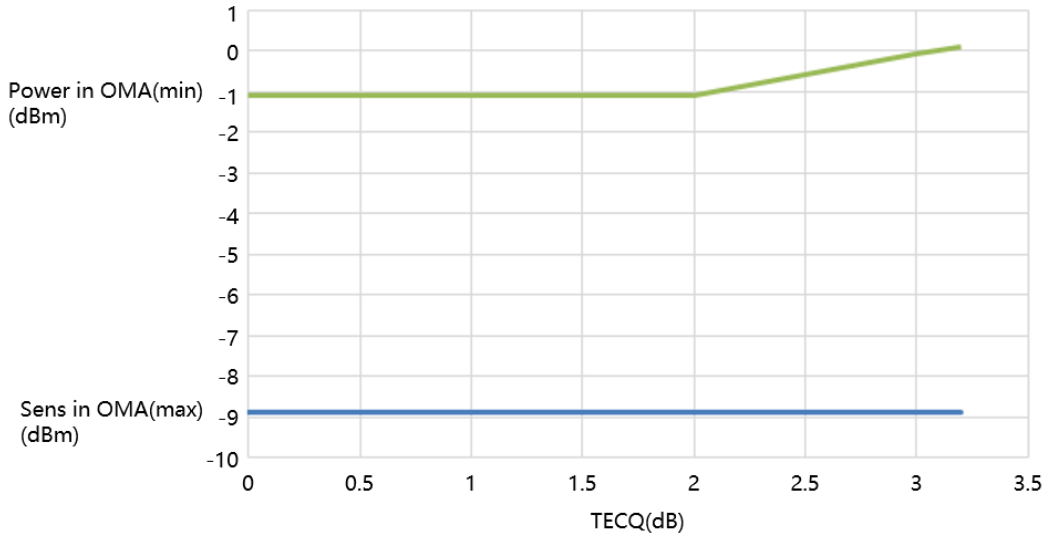

Figure 2 50 Gb/s LR BIDI optical link budget and sensitivity mask

2.5 50 Gb/s-LR Duplex & BIDI Management Interface

The management interface of 50 Gb/s Duplex & BIDI optical module is defined in the attached document below, which refer to SFF-8472 Rev 12.4 and IPEC-MFH50-IA-V1.0.

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2.6 50 Gb/s-LR Duplex & BIDI latency

Table 9 50 Gb/s-LR Duplex & BIDI Latency

	Electro-optical latency	Electro-optical latency variable	Opto-electronic latency	Opto-electronic latency variable
PAM4	1100 UI	±64 UI	1400 UI	±64 UI
NRZ	1500 UI	±64 UI	2000 UI	±64 UI

2.7 Timing Requirements

Table 10 50 Gb/s-LR Duplex & BIDI timing requirements

Parameter	Requirement	Note
Rate selection	TX : 6 s RX : 6 s	From the module receives the rate selection configuration to Completes the rate switching
Time to initialize(Module)	12 s	From power on or hot plug or Tx disable negated during power up, or Tx_Fault recovery, until non-cooled power level I part (or non-cooled power level III part already enabled at power level III for Tx_Fault recovery) is fully operational.
Tx Disable effective time	100 ms	Rising edge of Tx_Disable to fall of output signal below 10% of nominal. (Both Software and Hardware)
Rx power refresh time	100 ms	From command delivery to software reporting, or update Rx power within 100 ms of change on register.

3 Definition of Optical Parameter and Measurement Methods

The specific test patterns are defined in Table 139-9 of IEEE Std 802.3-2022.

3.1 Test Patterns for Optical Parameters

The detail information of test patterns for optical parameters are available in IEEE Std 802.3-2022.

Table 11 Test pattern definitions and related sub clauses

Parameters	Pattern	Reference
Wavelength	Square wave, 3, 4, 5, 6 or valid 50GBASE-R signal	3.3
Side mode suppression ratio	3, 5, 6 or valid 50GBASE-R signal	3.3
Average optical power	3, 5, 6 or valid 50GBASE-R signal	3.4

Optical modulation amplitude (OMAouter)	4 of 6	3.5
Transmitter and dispersion eye closure for PAM4 (TDECQ)	6	3.6
Extinction ratio	4 or 6	3.7
Transmitter transition time	Square wave or 6	3.8
$RIN_{17.1}$ OMA	Square wave	3.9
Stressed receiver conformance test signal calibration	6	3.11
Stressed receiver sensitivity	3 or 5	3.11
[a] IEEE Std 802.3-2022.		

3.2 Skew and Skew Variation

The Skew and skew variation are available in Clause 131.5 of IEEE Std 802.3-2022.

3.3 Wavelength and Side Mode Suppression Ratio

The wavelengths and single-mode suppression ratio (SMSR) of each optical lane are available in Clause 139.7.2 of IEEE Std 802.3-2022.

3.4 Average Optical Power

The specific average optical power is defined in Clause 139.7.3 of IEEE Std 802.3-2022.

3.5 Optical Modulation Amplitude (OMAouter)

The specific OMAouter are defined in Clause 139.7.4 of IEEE Std 802.3-2022.

3.6 Transmitter Eye Closure Penalty (TECQ)

The specific TDECQ are defined in Clause 139.7.5 of IEEE Std 802.3-2022. The Measurement method of TECQ is the TDECQ conformance test block without “Test fiber”.

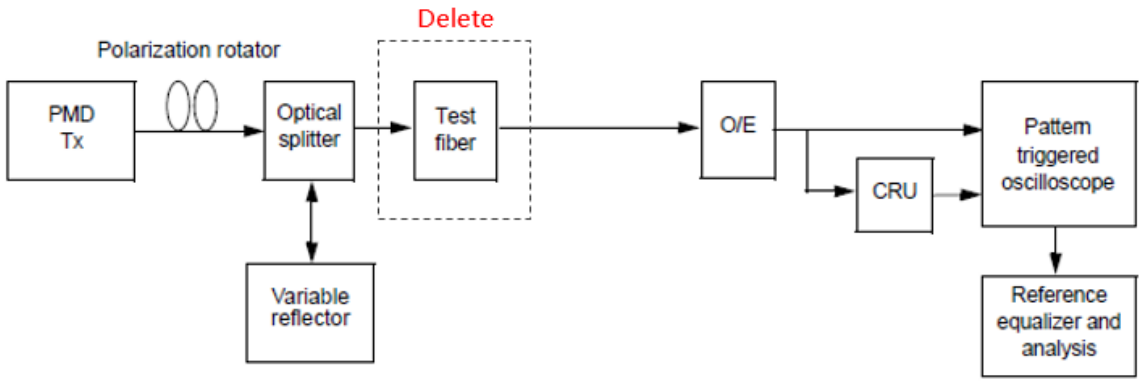


Figure 3 TECQ conformance test block diagram

3.6.1 TECQ Reference Equalizer

The specific TECQ reference equalizer defined in Clause 13.7.5.4 of IEEE Std 802.3-2022.

Table 12 Transmitter compliance channel specifications

	Dispersion [a] (ps/nm)		Insertion loss [b]	Optical return loss [c]	Max mean DGD
	Minimum	Maximum			
50GBASE-LR	0.2325*λ*[1-(1324/λ)^4]	0.2325*λ*[1-(1300/λ)^4]	Minimum	15.6 dB	0.8 ps

[a] The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 10 km for 50GBASE-LR.

[b] There is no intent to stress the sensitivity of the O/E converter associated with the oscilloscope.

[c] The optical return loss is applied at TP2.

3.7 Extinction Ratio

See Clause 139.7.6 of IEEE Std 802.3-2022.

3.8 Transmitter Transition Time

See Clause 139.7.7 of IEEE Std 802.3-2022.

3.9 Relative Intensity Noise (RIN)

See Clause 139.7.8 of IEEE Std 802.3-2022.

3.10 Receiver Sensitivity

See Clause 139.7.9 of IEEE Std 802.3-2022.

3.11 Stressed Receiver Sensitivity

See Clause 139.7.10 of IEEE Std 802.3-2022.

4 Fiber Optic Cabling Model

The fiber optic cabling model of 50 Gb/s LR DUPLEX & BIDI is shown in Figure 4.

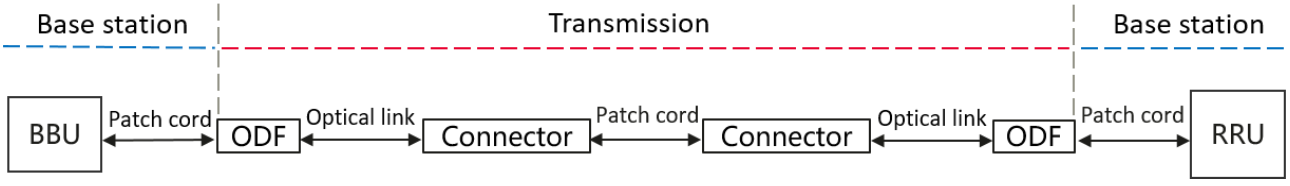


Figure 4 Fiber optic cabling model

5 Characteristics of the Fiber Optic Cabling (Channel)

The fiber optic cabling requirements for 50 Gb/s LR Duplex & BIDI are specified in Table 12 and 13.

Table 13 Fiber optic cabling characteristics

Description	50 Gb/s LR DUPLEX	Unit
Operating distance(max)	10	km
Channel insertion loss[a](max)	6.3	dB
Positive dispersion[b](max)	22.4	ps/nm
Negative dispersion[b](min)	-27.6	ps/nm
Optical return loss	22	dB

[a] The channel insertion loss includes connectors, splices etc.

[b] The wavelength range is from 1295 nm to 1325 nm

[c] 50 Gb/s optical cabling model includes optical distribution frames (ODF) and multiplexers / demultiplexers on both sides. Generally, a link contains six connectors. According to IEEE 802.3-2022, the return loss of each connector must be less than -35 dB. On the live network, it is complex and improper to measure the return loss of each connector to determine the link quality. Therefore, it is recommended that the optical link quality be evaluated based on the channel insertion loss. When the actual channel insertion loss exceeds 10% of the maximum value, the link quality deteriorates and the optical link needs to be checked.

Table 14 Fiber optic cabling characteristics

Description	50 Gb/s LR BIDI	Unit
Operating distance(max)	10	km
Channel insertion loss[a](max)	6.3	dB
Positive dispersion[b](max)	35.2	ps/nm
Negative dispersion[b](min)	-63.5	ps/nm
Optical return loss	22	dB

[a] The channel insertion loss includes connectors, splices etc.

[b] The wavelength range is from 1260 nm to 1340 nm

[c] 50 Gb/s optical cabling model includes optical distribution frames (ODF) and multiplexers/demultiplexers on both sides. Generally, a link contains six connectors. According to IEEE 802.3-2022, the return loss of each connector must be less than 35 dB. On the live network, it is complex and improper to measure the return loss of each connector to determine the link quality. Therefore, it is recommended that the optical link quality be evaluated based on the channel insertion loss. When the actual channel insertion loss exceeds 10% of the maximum value, the link quality deteriorates and the optical link needs to be checked.

6 Signal-to-Noise Ratio (SNR)

Signal-to-Noise Ratio (SNR) is a system indicator for measuring signal quality, 50 Gb/s fronthaul optical link quality can be measured by SNR.

Table 15 Theoretical SNR value at BER 2.4×10^{-4}

Description	Value	Unit
SNR @BER 2.4×10^{-4}	17.66	dB

- Application Condition: MPI intensity> 34 dB (MPI: Ratio of the power of pure signal to the power of the multipath interference at the receive end)

$$\text{MPI intensity} = \frac{Optical\ signal\ intensity}{Total\ reflected\ optical\ intensity\ at\ the\ receiver\ surface}$$

- Evaluate the quality of the fronthaul optical path
- Assist in demarcating optical line problems and eliminate optical line problems.

The optical module is required to support the function of reporting the SNR. For details about the reported register, see the definition in section 2.5. Figure 5 shows the standard SNR curve.

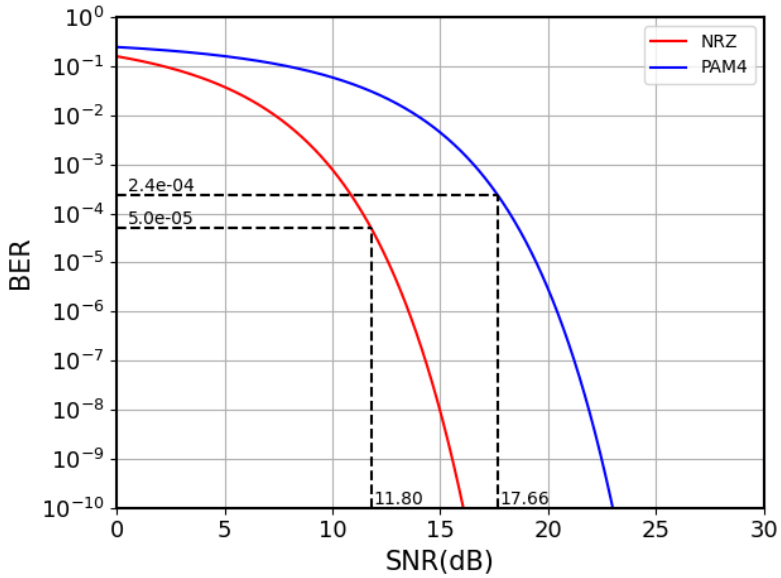


Figure 5 Standard SNR curve

The formula for calculating the BER-SNR standard curve is as follows:

BER-SNR standard curve formula	
PAM4(M=4)	**NRZ(M=2)**
$BER = \frac{3}{4}Q\left(\sqrt{\frac{1}{5}10^{\frac{SNR}{10}}}\right)$ $BER = \frac{3}{8}erfc\left(\sqrt{\frac{1}{10}10^{\frac{SNR}{10}}}\right)$ $SNR = 10\log_{10}\left(10 * \left[erfcinv\left(\frac{8}{3} * BER\right)\right]^2\right)$	$BER = Q\left(\sqrt{10^{\frac{SNR}{10}}}\right)$ $BER = \frac{1}{2}erfc\left(\sqrt{\frac{1}{2}10^{\frac{SNR}{10}}}\right)$ $SNR = 10\log_{10}(2 * [erfcinv(2 * BER)]^2)$
Q: Right tail function of the standard normal distribution，$erfc$: complementary error function， $erfcinv$: Complementary error function inverse function	

Note: In the formula, SNR needs to be converted to a linear value instead of a logarithmic value, that is

$$SNR = 10\log_{10}\frac{P_{signal}}{P_{noise}}\ (dB)$$

BER-SNR boundary specification definition：

50G（BER between 1e-6~2e-4）：

Intermediate variable：$SNR_{mid} = 10\log_{10}\left(10 * \left[erfcinv\left(\frac{8}{3}BER\right)\right]^2\right) - 16$

Upper boundary：$SNR_{upper} = SNR_{std} + 0.01743\ (SNR_{mid})^2 - 0.1098\ (SNR_{mid}) + 0.6996$

Lower boundary：$SNR_{lower} = SNR_{std} - 0.08457(SNR_{mid})^2 + 0.2840\ (SNR_{mid}) - 1.118$

BER	2.4e-4	1e-6
ΔSNR	Upper boundary：+0.57 Lower boundary：-0.88	Upper boundary：+0.55 Lower boundary：-1.52

50G（BER < 1e-6）：

Lower boundary：$SNR_{lower} = 18.91$

25G（BER between 1e-6~5e-5）：

Intermediate variable：$SNR_{mid} = 10\log_{10}(2 * [erfcinv(2 * BER)]^2) - 10$

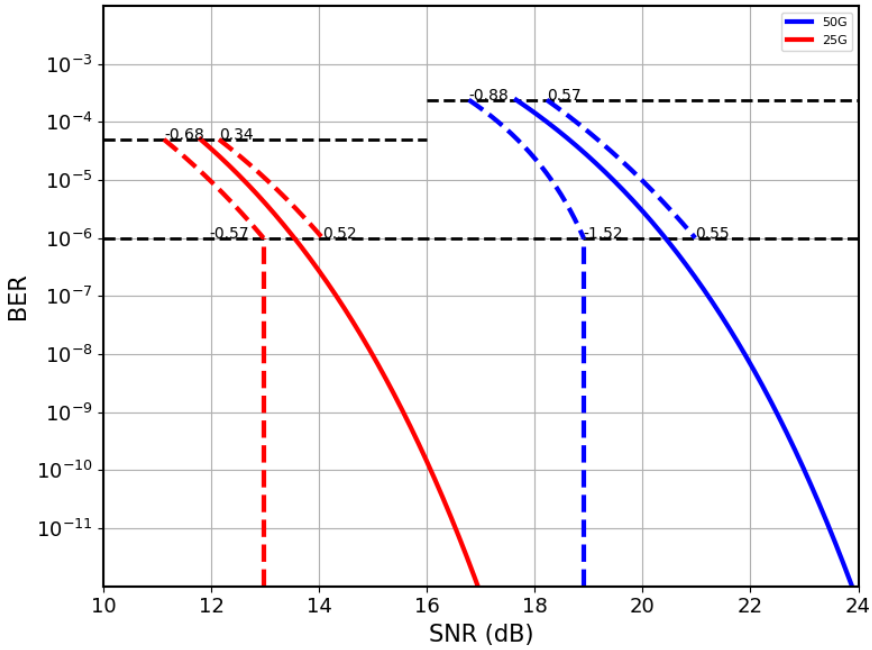
Upper boundary：$SNR_{upper} = SNR_{std} - 0.01029\ (SNR_{mid})^2 + 0.159\ (SNR_{mid}) + 0.08831$

Lower boundary：$SNR_{lower} = SNR_{std} - 0.0001918(SNR_{mid})^2 + 0.063\ (SNR_{mid}) - 0.7933$

BER	5e-5	1e-6
ΔSNR	Upper boundary：+0.34 Lower boundary：-0.68	Upper boundary：+0.52 Lower boundary：-0.57

25G（BER < 1e-6）：

Lower boundary：$SNR_{lower} = 12.97$



Requirements:

1. The BER-SNR points obtained by the test must be located above the lower boundary and below the upper boundary.

2. The relationship between BER and SNR must conform to the trend of the standard curve, and must be one-to-one correspondence, not one-to-many or many-to-one.

3. The relationship between BER and SNR must be one-to-one mapping.

4. The preceding requirements must be met in any MPI intensity lower than 34 dB and within the permitted temperature and dispersion range.

7 References

7.1 Normative References

1. SFF-8431 Rev. 4.1A
2. 25/50 Gb/s Specification (Final version June 14,2016), Ethernet Technology Consortium
3. IEEE Std 802.3-2022 Amendment 3: Media Access Control Parameters for 50 Gb/s and Physical Layers and Management Parameters for 50 Gb/s ,100 Gb/s, and 200 Gb/s Operation
4. OIF-CEI-04.0 -Common Electrical I/O (CEI) -Electrical and Jitter Interoperability agreements for 6G+ bps, 11G+ bps,25G+ bps I/O and 56G+ bps Specification (Final version June 14,2016), Ethernet Technology Consortium
5. CISPR32 V2.0 Electromagnetic compatibility of multimedia equipment — Emission requirements.
6. CFR TITLE 47 TELECOMMUNICATION PART 15—RADIO FREQUENCY DEVICES SUBPART B—Unintentional Radiators.
7. IEC 61000-4-2: Electromagnetic compatibility (EMC) –Part 4-2: Testing and measurement techniques — Electrostatic discharge immunity test.
8. IEC61000-4-3: Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test.

7.2 Informative References

8 Abbreviations and Acronyms

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