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AMENDMENT 4
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Telecommunications and exchange between information technology systems — Requirements for local and metropolitan area networks —

Part 3: Standard for Ethernet

AMENDMENT 4: Physical layers and management parameters for 50 Gb/s, 200 Gb/s, and 400 Gb/s operation over single-mode fiber

Télécommunications et échange entre systèmes informatiques — Exigences pour les réseaux locaux et métropolitains —

Partie 3: Norme pour Ethernet

AMENDEMENT 4: Couches physiques et paramètres de gestion pour le fonctionnement à 50 Gb/s, 200 Gb/s et 400 Gb/s sur des fibres unimodales

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IEEE Std 802.3cn™-2019
(Amendment to IEEE Std 802.3™-2018
as amended by IEEE Std 802.3cb™-2018,
IEEE Std 802.3bt™-2018, and
IEEE Std 802.3cd™-2018)

IEEE Standard for Ethernet

Amendment 4: Physical Layers and Management Parameters for 50 Gb/s, 200 Gb/s, and 400 Gb/s Operation over Single-Mode Fiber

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 7 November 2019

IEEE SA Standards Board

Abstract: This amendment to IEEE Std 802.3-2018 adds Physical Layer (PHY) specifications and management parameters for 50 Gb/s, 200 Gb/s, and 400 Gb/s operation over single-mode fiber with reaches of at least 40 km.

Keywords: 50 Gb/s Ethernet, 50GBASE-ER, 200 Gb/s Ethernet, 200GBASE-ER4, 400 Gb/s Ethernet, 400GBASE-ER8, amendment, EEE, Energy-Efficient Ethernet, Ethernet, FEC, forward error correction, IEEE 802.3™, IEEE 802.3cn™, PAM4, physical medium dependent sublayer, PMD sublayer, single-mode fiber, SMF

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Introduction

This introduction is not part of IEEE Std 802.3cn-2019, IEEE Standard for Ethernet. Amendment 4: Physical Layers and Management Parameters for 50 Gb/s, 200 Gb/s, and 400 Gb/s Operation over Single-Mode Fiber.

IEEE Std 802.3™ was first published in 1985. Since the initial publication, many projects have added functionality or provided maintenance updates to the specifications and text included in the standard. Each IEEE 802.3 project/amendment is identified with a suffix (e.g., IEEE Std 802.3ba™-2010).

The half duplex Media Access Control (MAC) protocol specified in IEEE Std 802.3-1985 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was key to the experimental Ethernet developed at Xerox Palo Alto Research Center, which had a 2.94 Mb/s data rate. Ethernet at 10 Mb/s was jointly released as a public specification by Digital Equipment Corporation (DEC), Intel and Xerox in 1980. Ethernet at 10 Mb/s was approved as an IEEE standard by the IEEE Standards Board in 1983 and subsequently published in 1985 as IEEE Std 802.3-1985. Since 1985, new media options, new speeds of operation, and new capabilities have been added to IEEE Std 802.3. A full duplex MAC protocol was added in 1997.

Some of the major additions to IEEE Std 802.3 are identified in the marketplace with their project number. This is most common for projects adding higher speeds of operation or new protocols. For example, IEEE Std 802.3u™ added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3z added 1000 Mb/s operation (also called Gigabit Ethernet), IEEE Std 802.3ae added 10 Gb/s operation (also called 10 Gigabit Ethernet), IEEE Std 802.3ah™ specified access network Ethernet (also called Ethernet in the First Mile) and IEEE Std 802.3ba added 40 Gb/s operation (also called 40 Gigabit Ethernet) and 100 Gb/s operation (also called 100 Gigabit Ethernet). These major additions are all now included in and are superseded by IEEE Std 802.3-2018 and are not maintained as separate documents.

At the date of publication for IEEE Std 802.3cn-2019, IEEE Std 802.3 was composed of the following documents:

IEEE Std 802.3-2018

Section One—Includes Clause 1 through Clause 20 and Annex A through Annex H and Annex 4A. Section One includes the specifications for 10 Mb/s operation and the MAC, frame formats and service interfaces used for all speeds of operation.

Section Two—Includes Clause 21 through Clause 33 and Annex 22A through Annex 33E. Section Two includes management attributes for multiple protocols and speed of operation as well as specifications for providing power over twisted pair cabling for multiple operational speeds. It also includes general information on 100 Mb/s operation as well as most of the 100 Mb/s Physical Layer specifications.

Section Three—Includes Clause 34 through Clause 43 and Annex 36A through Annex 43C. Section Three includes general information on 1000 Mb/s operation as well as most of the 1000 Mb/s Physical Layer specifications.

Section Four—Includes Clause 44 through Clause 55 and Annex 44A through Annex 55B. Section Four includes general information on 10 Gb/s operation as well as most of the 10 Gb/s Physical Layer specifications.

Section Five—Includes Clause 56 through Clause 77 and Annex 57A through Annex 76A. Clause 56 through Clause 67 and Clause 75 through Clause 77, as well as associated annexes, specify subscriber access and other Physical Layers and sublayers for operation from 512 kb/s to 10 Gb/s, and defines services and protocol elements that enable the exchange of IEEE Std 802.3 format frames between stations in a subscriber access network. Clause 68 specifies a 10 Gb/s Physical Layer specification. Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

Section Six—Includes Clause 78 through Clause 95 and Annex 83A through Annex 93C. Clause 78 specifies Energy-Efficient Ethernet. Clause 79 specifies IEEE 802.3 Organizationally Specific Link Layer Discovery Protocol (LLDP) type, length, and value (TLV) information elements. Clause 80 through Clause 95 and associated annexes include general information on 40 Gb/s and 100 Gb/s operation as well the 40 Gb/s and 100 Gb/s Physical Layer specifications. Clause 90 specifies Ethernet support for time synchronization protocols.

Section Seven—Includes Clause 96 through Clause 115 and Annex 97A through Annex 115A. Clause 96 through Clause 98, Clause 104, and associated annexes, specify Physical Layers and optional features for 100 Mb/s and 1000 Mb/s operation over a single twisted pair. Clause 100 through Clause 103, as well as associated annexes, specify Physical Layers for the operation of the EPON protocol over coaxial distribution networks. Clause 105 through Clause 114 and associated annexes include general information on 25 Gb/s operation as well as 25 Gb/s Physical Layer specifications. Clause 99 specifies a MAC merge sublayer for the interspersing of express traffic. Clause 115 and its associated annex specify a Physical Layer for 1000 Mb/s operation over plastic optical fiber.

Section Eight—Includes Clause 116 through Clause 126 and Annex 119A through Annex 120E. Clause 116 through Clause 124 and associated annexes include general information on 200 Gb/s and 400 Gb/s operation as well the 200 Gb/s and 400 Gb/s Physical Layer specifications. Clause 125 and Clause 126 include general information on 2.5 Gb/s and 5 Gb/s operation as well as 2.5 Gb/s and 5 Gb/s Physical Layer specifications.

IEEE Std 802.3cb™-2018

Amendment 1—This amendment includes changes to IEEE Std 802.3-2018 and its amendments, and adds Clause 127 through Clause 130, Annex 127A, Annex 128A, Annex 128B, and Annex 130A. This amendment adds new Physical Layers for operation at 2.5 Gb/s and 5 Gb/s over electrical backplanes.

IEEE Std 802.3bt™-2018

Amendment 2—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 145, Annex 145A, Annex 145B, and Annex 145C. This amendment adds power delivery using all four pairs in the structured wiring plant, resulting in greater power being available to end devices. This amendment also allows for lower standby power consumption in end devices and adds a mechanism to better manage the available power budget.

IEEE Std 802.3cd™-2018

Amendment 3—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 131 through Clause 140 and Annex 135A through Annex 136D. This amendment adds MAC parameters, Physical Layers, and management parameters for the transfer of IEEE 802.3 format frames at 50 Gb/s, 100 Gb/s, and 200 Gb/s.

IEEE Std 802.3cn™-2019

Amendment 4—This amendment includes changes to IEEE Std 802.3-2018 and adds 50 Gb/s, 200 Gb/s, and 400 Gb/s Physical Layer specifications and management parameters for operation over single-mode fiber with reaches of at least 40 km.

Two companion documents exist, IEEE Std 802.3.1 and IEEE Std 802.3.2. IEEE Std 802.3.1 describes Ethernet management information base (MIB) modules for use with the Simple Network Management Protocol (SNMP). IEEE Std 802.3.2 describes YANG data models for Ethernet. IEEE Std 802.3.1 and IEEE Std 802.3.2 are updated to add management capability for enhancements to IEEE Std 802.3 after approval of those enhancements.

IEEE Std 802.3 will continue to evolve. New Ethernet capabilities are anticipated to be added within the next few years as amendments to this standard.

Contents

IEEE Standard for Ethernet

Amendment 4: Physical Layers and Management Parameters for 50 Gb/s, 200 Gb/s, and 400 Gb/s Operation over Single-Mode Fiber

(This amendment is based on IEEE Std 802.3™-2018 as amended by IEEE Std 802.3cb™-2018, IEEE Std 802.3bt™-2018, and IEEE Std 802.3cd™-2018.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.

Cross references that refer to clauses, tables, equations, or figures not covered by this amendment are highlighted in green.[1]

[1] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

1. Introduction

1.4 Definitions

Insert the following new definition after 1.4.83 "200GBASE-DR4":

1.4.83a 200GBASE-ER4: IEEE 802.3 Physical Layer specification for 200 Gb/s using 200GBASE-R encoding and 4-level pulse amplitude modulation over four WDM lanes on single-mode fiber, with reach up to at least 40 km. (See IEEE Std 802.3, Clause 122.)

Insert the following new definition after 1.4.106 "400GBASE-DR4":

1.4.106a 400GBASE-ER8: IEEE 802.3 Physical Layer specification for 400 Gb/s using 400GBASE-R encoding and 4-level pulse amplitude modulation over eight WDM lanes on single-mode fiber, with reach up to at least 40 km. (See IEEE Std 802.3, Clause 122.)

Insert the following new definition between 1.4.128aa "50GBASE-CR" and 1.4.128ab "50GBASE-FR" as inserted by IEEE Std 802.3cd-2018:

1.4.128aa1 50GBASE-ER: IEEE 802.3 Physical Layer specification for 50 Gb/s serial transmission using 50GBASE-R encoding and 4-level pulse amplitude modulation over one wavelength on single-mode fiber, with reach up to at least 40 km. (See IEEE Std 802.3, Clause 139.)

30. Management

30.5 Layer management for medium attachment units (MAUs)

30.5.1 MAU managed object class

30.5.1.1 MAU attributes

30.5.1.1.2 aMAUType

APPROPRIATE SYNTAX:

Insert the following new PHY type into the "APPROPRIATE SYNTAX" section of 30.5.1.1.2 after 50GBASE-LR (as inserted by IEEE Std 802.3cd-2018):

50GBASE-ER	50GBASE-R PCS/PMA over single-mode fiber PMD with reach up to at least 40 km as specified in Clause 139

Insert the following new PHY type into the "APPROPRIATE SYNTAX" section of 30.5.1.1.2 after 200GBASE-LR4:

200GBASE-ER4	200GBASE-R PCS/PMA over 4 WDM lane single-mode fiber PMD with reach up to at least 40 km as specified in Clause 122

Insert the following new PHY type into the "APPROPRIATE SYNTAX" section of 30.5.1.1.2 after 400GBASE-LR8:

400GBASE-ER8	400GBASE-R PCS/PMA over 8 WDM lane single-mode fiber PMD with reach up to at least 40 km as specified in Clause 122

45. Management Data Input/Output (MDIO) Interface

45.2 MDIO Interface Registers

45.2.1 PMA/PMD registers

Change Table 45–3 (as modified by IEEE Std 802.3cd-2018) as follows (unchanged rows not shown):

Table 45–3—PMA/PMD registers

Register address	Register name	Subclause
…		
1.26	40G/100G PMA/PMD extended ability 2 ~~Reserved~~	45.2.1.21b
…		

45.2.1.6 PMA/PMD control 2 register (Register 1.7)

Change Table 45–7 (as modified by IEEE Std 802.3cd-2018) as follows (unchanged rows and bit description lines not shown):

Table 45–7—PMA/PMD control 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
…			
1.7.6:0	PMA/PMD type selection	6 5 4 3 2 1 0 ~~1 1 x x x x x = reserved~~ 1 1 1 x x x x = reserved 1 1 0 1 x x x = reserved 1 1 0 0 1 x x = reserved 1 1 0 0 0 1 1 = 400GBASE-ER8 PMA/PMD 1 1 0 0 0 1 0 = reserved 1 1 0 0 0 0 x = reserved … 1 0 1 1 0 0 0 = 200GBASE-ER4 PMA/PMD~~reserved~~ … 1 0 0 0 1 0 1 = 50GBASE-ER PMA/PMD~~reserved~~ …	R/W

[a] R/W = Read/Write, RO = Read only

45.2.1.7 PMA/PMD status 2 register (Register 1.8)

45.2.1.7.4 Transmit fault (1.8.11)

Change Table 45–9 (as modified by IEEE Std 802.3cd-2018) as follows (unchanged rows not shown):

Table 45–9—Transmit fault description location

PMA/PMD	Description location
…	
50GBASE-FR, 50GBASE-LR, 50GBASE-ER	139.5.8
…	
200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, 400GBASE-LR8, 400GBASE-ER8	122.5.10
…	

45.2.1.7.5 Receive fault (1.8.10)

Change Table 45–10 (as modified by IEEE Std 802.3cd-2018) as follows (unchanged rows not shown):

Table 45–10—Receive fault description location

PMA/PMD	Description location
…	
50GBASE-FR, 50GBASE-LR, 50GBASE-ER	139.5.9
…	
200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, 400GBASE-LR8, 400GBASE-ER8	122.5.11
…	

45.2.1.8 PMD transmit disable register (Register 1.9)

Change Table 45–12 (as modified by IEEE Std 802.3cd-2018) as follows (unchanged rows not shown):

Table 45–12—Transmit disable description location

PMA/PMD	Description location
…	
50GBASE-FR, ~~and~~ 50GBASE-LR, and 50GBASE-ER	139.5.6
…	
200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8	122.5.7
…	

45.2.1.17a 50G PMA/PMD extended ability register (Register 1.20)

Change Table 45–20a (as inserted by IEEE Std 802.3cd-2018) as follows (unchanged rows not shown):

Table 45–20a—50G PMA/PMD extended ability register bit definitions

Bit(s)	Name	Description	R/W[a]
…			
1.20.14:6~~5~~	Reserved	Value always 0	RO
1.20.5	50GBASE-ER ability	1 = PMA/PMD is able to perform 50GBASE-ER 0 = PMA/PMD is not able to perform 50GBASE-ER	RO
…			

[a] RO = Read only

Insert the following new subclause (45.2.1.17a.1a) after 45.2.1.17a.1 (as inserted by IEEE Std 802.3cd-2018):

45.2.1.17a.1a 50GBASE-ER ability (1.20.5)

When read as a one, bit 1.20.5 indicates that the PMA/PMD is able to operate as a 50GBASE-ER PMA/PMD type. When read as a zero, bit 1.20.5 indicates that the PMA/PMD is not able to operate as a 50GBASE-ER PMA/PMD type.

45.2.1.20 200G PMA/PMD extended ability register (Register 1.23)

Change Table 45–23 as follows (unchanged rows not shown):

Table 45–23—200G PMA/PMD extended ability register bit definitions

Bit(s)	Name	Description	R/W[a]
…			
1.23.14:7~~6~~	Reserved	Value always 0	RO
1.23.6	200GBASE-ER4 ability	1 = PMA/PMD is able to perform 200GBASE-ER4 0 = PMA/PMD is not able to perform 200GBASE-ER4	RO
…			
~~1.23.2:0~~	~~Reserved~~	~~Value always 0~~	~~RO~~
1.23.2	200GBASE-SR4 ability	1 = PMA/PMD is able to perform 200GBASE-SR4 0 = PMA/PMD is not able to perform 200GBASE-SR4	RO
1.23.1	200GBASE-CR4 ability	1 = PMA/PMD is able to perform 200GBASE-CR4 0 = PMA/PMD is not able to perform 200GBASE-CR4	RO
1.23.0	200GBASE-KR4 ability	1 = PMA/PMD is able to perform 200GBASE-KR4 0 = PMA/PMD is not able to perform 200GBASE-KR4	RO

[a] RO = Read only

Insert the following new subclause (45.2.1.20.1a) after 45.2.1.20.1:

45.2.1.20.1a 200GBASE-ER4 ability (1.23.6)

When read as a one, bit 1.23.6 indicates that the PMA/PMD is able to operate as a 200GBASE-ER4 PMA/PMD type. When read as a zero, bit 1.23.6 indicates that the PMA/PMD is not able to operate as a 200GBASE-ER4 PMA/PMD type.

Insert the following new subclauses (45.2.1.20.5, 45.2.1.20.6, and 45.2.1.20.7) after 45.2.1.20.4:

45.2.1.20.5 200GBASE-SR4 ability (1.23.2)

When read as a one, bit 1.23.2 indicates that the PMA/PMD is able to operate as a 200GBASE-SR4 PMA/PMD type. When read as a zero, bit 1.23.2 indicates that the PMA/PMD is not able to operate as a 200GBASE-SR4 PMA/PMD type.

45.2.1.20.6 200GBASE-CR4 ability (1.23.1)

When read as a one, bit 1.23.1 indicates that the PMA/PMD is able to operate as a 200GBASE-CR4 PMA/PMD type. When read as a zero, bit 1.23.1 indicates that the PMA/PMD is not able to operate as a 200GBASE-CR4 PMA/PMD type.

45.2.1.20.7 200GBASE-KR4 ability (1.23.0)

When read as a one, bit 1.23.0 indicates that the PMA/PMD is able to operate as a 200GBASE-KR4 PMA/PMD type. When read as a zero, bit 1.23.0 indicates that the PMA/PMD is not able to operate as a 200GBASE-KR4 PMA/PMD type.

45.2.1.21 400G PMA/PMD extended ability register (Register 1.24)

Change Table 45–24 as follows (unchanged rows not shown):

Table 45–24—400G PMA/PMD extended ability register bit definitions

Bit(s)	Name	Description	R/W[a]
…			
1.24.14:11 ~~6~~	Reserved	Value always 0	RO
1.24.10	400GBASE-ER8 ability	1 = PMA/PMD is able to perform 400GBASE-ER8 0 = PMA/PMD is not able to perform 400GBASE-ER8	RO
1.24.9:6	Reserved	Value always 0	RO
…			

[a] RO = Read only

Insert the following new subclause (45.2.1.21.1a) after 45.2.1.21.1:

45.2.1.21.1a 400GBASE-ER8 ability (1.24.10)

When read as a one, bit 1.24.10 indicates that the PMA/PMD is able to operate as a 400GBASE-ER8 PMA/PMD type. When read as a zero, bit 1.24.10 indicates that the PMA/PMD is not able to operate as a 400GBASE-ER8 PMA/PMD type.

Insert the following new subclauses (45.2.1.21b through 45.2.1.21b.4) after 45.2.1.21a (as inserted by IEEE Std 802.3cd-2018):

45.2.1.21b 40G/100G PMA/PMD extended ability 2 (Register 1.26)

The assignment of bits in the 40G/100G PMA/PMD extended ability 2 register is shown in Table 45–24b.

Table 45–24b—40G/100G PMA/PMD extended ability 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.26.15:10	Reserved	Value always 0	RO
1.26.9	100GBASE-SR2 ability	1 = PMA/PMD is able to perform 100GBASE-SR2 0 = PMA/PMD is not able to perform 100GBASE-SR2	RO
1.26.8	100GBASE-CR2 ability	1 = PMA/PMD is able to perform 100GBASE-CR2 0 = PMA/PMD is not able to perform 100GBASE-CR2	RO
1.26.7	100GBASE-KR2 ability	1 = PMA/PMD is able to perform 100GBASE-KR2 0 = PMA/PMD is not able to perform 100GBASE-KR2	RO
1.26.6:4	Reserved	Value always 0	RO
1.26.3	100GBASE-DR ability	1 = PMA/PMD is able to perform 100GBASE-DR 0 = PMA/PMD is not able to perform 100GBASE-DR	RO
1.26.2:0	Reserved	Value always 0	RO

[a] RO = Read only

45.2.1.21b.1 100GBASE-SR2 ability (1.26.9)

When read as a one, bit 1.26.9 indicates that the PMA/PMD is able to operate as a 100GBASE-SR2 PMA/PMD type. When read as a zero, bit 1.26.9 indicates that the PMA/PMD is not able to operate as a 100GBASE-SR2 PMA/PMD type.

45.2.1.21b.2 100GBASE-CR2 ability (1.26.8)

When read as a one, bit 1.26.8 indicates that the PMA/PMD is able to operate as a 100GBASE-CR2 PMA/PMD type. When read as a zero, bit 1.26.8 indicates that the PMA/PMD is not able to operate as a 100GBASE-CR2 PMA/PMD type.

45.2.1.21b.3 100GBASE-KR2 ability (1.26.7)

When read as a one, bit 1.26.7 indicates that the PMA/PMD is able to operate as a 100GBASE-KR2 PMA/PMD type. When read as a zero, bit 1.26.7 indicates that the PMA/PMD is not able to operate as a 100GBASE-KR2 PMA/PMD type.

45.2.1.21b.4 100GBASE-DR ability (1.26.3)

When read as a one, bit 1.26.3 indicates that the PMA/PMD is able to operate as a 100GBASE-DR PMA/PMD type. When read as a zero, bit 1.26.3 indicates that the PMA/PMD is not able to operate as a 100GBASE-DR PMA/PMD type.

78. Energy-Efficient Ethernet (EEE)

78.1 Overview

78.1.4 PHY types optionally supporting EEE

Change Table 78–1 (as modified by IEEE Std 802.3cd-2018) as follows (most unchanged rows not shown):

Table 78–1—Clauses associated with each PHY or interface type

PHY or interface type	Clause
…	
50GBASE-LR	133, 134, 139
50GBASE-ER[b]	133, 134, 139
…	
200GBASE-LR4	119, 120, 122
200GBASE-ER4[b]	119, 120, 122
…	
400GBASE-LR8	119, 120, 122
400GBASE-ER8[b]	119, 120, 122

[b] The deep sleep mode of EEE is not supported for this PHY.

116. Introduction to 200 Gb/s and 400 Gb/s networks

116.1 Overview

116.1.2 Relationship of 200 Gigabit and 400 Gigabit Ethernet to the ISO OSI reference model

Change items g) and h) in 116.1.2 (as modified by IEEE Std 802.3cd-2018) as follows:

g) The MDI as specified in Clause 122 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 uses an 8-lane data path.

h) The MDIs as specified in Clause 121 for 200GBASE-DR4, in Clause 122 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4, and in Clause 124 for 400GBASE-DR4, Clause 136 for 200GBASE-CR4, Clause 137 for 200GBASE-KR4, and Clause for 200GBASE-SR4, all use a 4-lane data path.

116.1.3 Nomenclature

Insert the following new row at the end of Table 116–1 (as modified by IEEE Std 802.3cd-2018):

Table 116–1—200 Gb/s PHYs

Name	Description
200GBASE-ER4	200 Gb/s PHY using 200GBASE-R encoding over four WDM lanes on single-mode fiber, with reach up to at least 40 km (see Clause 122)

Insert the following new row at the end of Table 116–2:

Table 116–2—400 Gb/s PHYs

Name	Description
400GBASE-ER8	400 Gb/s PHY using 400GBASE-R encoding over eight WDM lanes on single-mode fiber, with reach up to at least 40 km (see Clause 122)

116.1.4 Physical Layer signaling systems

Change Table 116–3 (as modified by IEEE Std 802.3cd-2018) as follows:

Table 116–3—PHY type and clause correlation (200GBASE optical)

PHY type	Clause[a]														
	78	117		118	119	120	120B	120C	120D	120E	121	122			
	EEE	RS	200GMII	200GMII Extender	200GBASE-R PCS	200GBASE-R PMA	200GAUI-8 C2C	200GAUI-8 C2M	200GAUI-4 C2C	200GAUI-4 C2M	200GBASE-DR4 PMD	200GBASE-FR4 PMD	200GBASE-LR4 PMD	200GBASE-ER4 PMD	200GBASE-SR4 PMD
200GBASE-SR4	O	M	O	O	M	M	O	O	O	O					M
200GBASE-DR4	O	M	O	O	M	M	O	O	O	O	M				
200GBASE-FR4	O	M	O	O	M	M	O	O	O	O		M			
200GBASE-LR4	O	M	O	O	M	M	O	O	O	O			M		
200GBASE-ER4	O	M	O	O	M	M	O	O	O	O				M	

[a] O = Optional, M = Mandatory.

Change Table 116–4 as follows:

Table 116–4—PHY type and clause correlation (400GBASE optical)

PHY type	Clause[a]														
	78	117		118	119	120	120B	120C	120D	120E	123	124	122		
	EEE	RS	400GMII	400GMII Extender	400GBASE-R PCS	400GBASE-R PMA	400GAUI-16 C2C	400GAUI-16 C2M	400GAUI-8 C2C	400GAUI-8 C2M	400GBASE-SR16 PMD	400GBASE-DR4 PMD	400GBASE-FR8 PMD	400GBASE-LR8 PMD	400GBASE-ER8 PMD
400GBASE-SR16	O	M	O	O	M	M	O	O	O	O	M				
400GBASE-DR4	O	M	O	O	M	M	O	O	O	O		M			
400GBASE-FR8	O	M	O	O	M	M	O	O	O	O			M		
400GBASE-LR8	O	M	O	O	M	M	O	O	O	O				M	
400GBASE-ER8	O	M	O	O	M	M	O	O	O	O					M

[a] O = Optional, M = Mandatory.

116.4 Delay constraints

Insert the following new row at the end of Table 116–5 (as modified by IEEE Std 802.3cd-2018):

Table 116–5—Sublayer delay constraints (200GBASE)

Sublayer	Maximum (bit time)[a]	Maximum (pause_quanta)[b]	Maximum (ns)	Notes[c]
200GBASE-ER4 PMD	4 096	8	20.48	Includes 2 m of fiber. See 122.3.1.

[a] For 200GBASE-R, 1 bit time (BT) is equal to 5 ps. (See 1.4.160 for the definition of bit time.)
[b] For 200GBASE-R, 1 pause_quantum is equal to 2.56 ns. (See 31B.2 for the definition of pause_quanta.)
[c] Should there be a discrepancy between this table and the delay requirements of the relevant sublayer clause, the sublayer clause prevails.

Insert the following new row at the end of Table 116–6:

Table 116–6—Sublayer delay constraints (400GBASE)

Sublayer	Maximum (bit time)[a]	Maximum (pause_quanta)[b]	Maximum (ns)	Notes[c]
400GBASE-ER8 PMD	8 192	16	20.48	Includes 2 m of fiber. See 122.3.1.

[a] For 400GBASE-R, 1 bit time (BT) is equal to 2.5 ps. (See 1.4.160 for the definition of bit time.)
[b] For 400GBASE-R, 1 pause_quantum is equal to 1.28 ns. (See 31B.2 for the definition of pause_quanta.)
[c] Should there be a discrepancy between this table and the delay requirements of the relevant sublayer clause, the sublayer clause prevails.

121. Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-DR4

121.7 PMD to MDI optical specifications for 200GBASE-DR4

121.7.1 200GBASE-DR4 transmitter optical specifications

Change Table 121–6 as follows:

Table 121–6—200GBASE-DR4 transmit characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Modulation format	PAM4	—
Lane wavelength (range)	1304.5 to 1317.5	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Average launch power, each lane (max)	3	dBm
Average launch power, each lane[a] (min)	–5.1	dBm
Outer Optical Modulation Amplitude (OMA$_{outer}$), each lane (max)	2.8	dBm
Outer Optical Modulation Amplitude (OMA$_{outer}$), each lane (min)[b]	–3	dBm
Launch power in OMA$_{outer}$ minus TDECQ, each lane (min)	–4.4	dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	~~3.4~~3.2	dB
TDECQ – $10\log_{10}(C_{eq})$[c] (max)	3.2	dB
Average launch power of OFF transmitter, each lane (max)	–16	dBm
Extinction ratio, each lane (min)	3.5	dB
Transmitter transition time (max)	34	ps
RIN$_{21.4}$OMA (max)	–132	dB/Hz
Optical return loss tolerance (max)	21.4	dB
Transmitter reflectance[d] (max)	–26	dB

[a] Average launch power, each lane (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] Even if the TDECQ < 1.4 dB, the OMA$_{outer}$ (min) must exceed this value.
[c] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.
[d] Transmitter reflectance is defined looking into the transmitter.

121.7.2 200GBASE-DR4 receive optical specifications

Change Table 121–7 as follows:

Table 121–7—200GBASE-DR4 receive characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625± 100 ppm	GBd
Modulation format	PAM4	—
Lane wavelengths (range)	1304.5 to 1317.5	nm
Damage threshold[a], each lane	4	dBm
Average receive power, each lane (max)	3	dBm
Average receive power, each lane[b] (min)	–8.1	dBm
Receive power (OMA_{outer}), each lane (max)	2.8	dBm
Receiver reflectance (max)	–26	dB
Receiver sensitivity (OMA_{outer}), each lane[c] (max)	Equation (121–13)	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane[d] (max)	~~–4.1~~4.3	dBm
Conditions of stressed receiver sensitivity test:[e]		
Stressed eye closure for PAM4 (SECQ), lane under test	~~3.4~~3.2	dB
SECQ – $10\log_{10}(C_{eq})$[f] (max), lane under test	3.2	dB
OMA_{outer} of each aggressor lane	2.8	dBm

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level. The receiver does not have to operate correctly at this input power.
[b] Average receive power, each lane (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 (OMA_{outer}), each lane (max) is informative and is defined for a transmitter with a value of SECQ up to ~~3.4~~3.2 dB.
[d] Measured with conformance test signal at TP3 (see 121.8.9) for the BER specified in 121.1.1.
[e] These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.
[f] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.

121.7.3 200GBASE-DR4 illustrative link power budget

Change Table 121–8 as follows:

Table 121–8—200GBASE-DR4 illustrative link power budget

Parameter	Value	Unit
Power budget (for max TDECQ)	~~6.5~~6.3	dB
Operating distance	500	m
Channel insertion loss[a]	3	dB
Maximum discrete reflectance	See 121.11.2.2	dB
Allocation for penalties[b] (for max TDECQ)	~~3.5~~3.3	dB
Additional insertion loss allowed	0	dB

[a] The channel insertion loss is calculated using the maximum distance specified in Table 121–5 and cabled optical fiber attenuation of 0.5 dB/km at 1304.5 nm plus an allocation for connection and splice loss given in 121.11.2.1.
[b] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

121.8 Definition of optical parameters and measurement methods

121.8.1 Test patterns for optical parameters

Change Table 121–10 as follows:

Table 121–10—Test-pattern definitions and related subclauses

Parameter	Pattern	Related subclause
Wavelength	Square wave, 3, 4, 5, 6 or valid 200GBASE-R signal	121.8.2
Side mode suppression ratio	3, 5, 6 or valid 200GBASE-R signal	121.8.2
Average optical power	3, 5, 6 or valid 200GBASE-R signal	121.8.3
Outer Optical Modulation Amplitude (OMA_{outer})	4 or 6	121.8.4
Transmitter and dispersion eye closure for PAM4 (TDECQ)	6	121.8.5
Extinction ratio	4 or 6	121.8.6
Transmitter transition time	Square wave or 6	121.8.6a
$RIN_{21.4}OMA$	Square wave	121.8.7
Stressed receiver conformance test signal calibration	6	121.8.9.2
Stressed receiver sensitivity	3 or 5	121.8.9

121.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

Change the first paragraph of the introductory text of 121.8.5 as follows:

The TDECQ and TDECQ – $10\log_{10}(C_{eq})$ of each lane shall be within the limits given in Table 121–6 if measured using the methods specified in 121.8.5.1, 121.8.5.2, and 121.8.5.3.

121.8.5.1 TDECQ conformance test setup

Change the second paragraph of 121.8.5.1 as follows:

Each optical lane is tested individually with all other lanes in operation and all lanes using the same test pattern. There shall be at least 31 UI delay between the test pattern on one lane and the pattern on any other lane, so that the symbols on each lane are not correlated within the PMD. The optical splitter and variable reflector are adjusted so that each transmitter is tested with the optical return loss specified in Table 121–11. The state of polarization of the back reflection is adjusted to create the greatest RIN. Each optical lane is tested with the optical channel described in 121.8.5.2. The combination of the O/E converter and the oscilloscope has a 3 dB bandwidth of approximately 13.28125 GHz with a fourth-order Bessel-Thomson ~~filter~~ response to at least 1.5 × 26.5625 GHz, and at frequencies above 1.5 × 26.5625 GHz, the response should not exceed –24 dB ~~with a bandwidth of approximately 13.28125 GHz~~. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

121.8.5.3 TDECQ measurement method

Insert the following new paragraph into 121.8.5.3 before the 20th paragraph ("When the larger of SER_L and SER_R ...") and change the 20th paragraph as follows:

P_{th1}, P_{th2}, and P_{th3} are varied from their nominal values by up to ±1% of OMA_{outer} in order to optimize TDECQ. The same three thresholds are used for both the left and the right histogram.

When the larger of SER_L and SER_R is equal to the target SER of 4.8×10^{-4}, and the value of σ_G cannot be increased by further optimization of the equalizer tap coefficients or the sub-eye threshold levels, then TDECQ is calculated.

121.8.5.4 TDECQ reference equalizer

Change the first paragraph of 121.8.5.4 as follows:

The reference equalizer for 200GBASE-DR4 is a 5 tap, T spaced, feed-forward equalizer (FFE), where T is the symbol period. A functional model of the reference equalizer is shown in Figure 121–4. The sum of the equalizer tap coefficients is equal to 1. Tap 1, tap 2, or tap 3, has the largest magnitude tap coefficient, which is constrained to be at least 0.8.

Insert the following new subclause (121.8.6a) after 121.8.6:

121.8.6a Transmitter transition time

The transmitter transition time of each lane shall be within the limits given in Table 121–6 if measured using a test pattern specified for transmitter transition time in Table 121–10.

Transmitter transition time is defined as the slower of the time interval of the transition from 20% of OMA_{outer} to 80% of OMA_{outer}, or from 80% of OMA_{outer} to 20% of OMA_{outer}, for the rising and falling edges respectively, as measured through an O/E converter and oscilloscope with response defined as follows. The combined response of the O/E converter and oscilloscope has a 3 dB bandwidth of approximately 13.28125 GHz with a fourth-order Bessel-Thomson response to at least 1.5 × 26.5625 GHz. At frequencies above 1.5 × 26.5625 GHz, the response should not exceed –24 dB. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

The 0% level and the 100% level are P_0 and P_3 as defined by the OMA_{outer} measurement procedure (see 121.8.4), with the exception that the square wave test pattern can be used. When the SSPRQ pattern is used, the rising edge used for the measurement is that within the 00000333333 symbol sequence, and the falling edge is that within the 33333000000 symbol sequence.

121.8.8 Receiver sensitivity

Change the first paragraph of 121.8.8 as follows:

Receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to ~~3.4~~3.2 dB. Receiver sensitivity should meet Equation (121–13), which is illustrated in Figure 121–7.

Replace Figure 121–7 with the following figure:

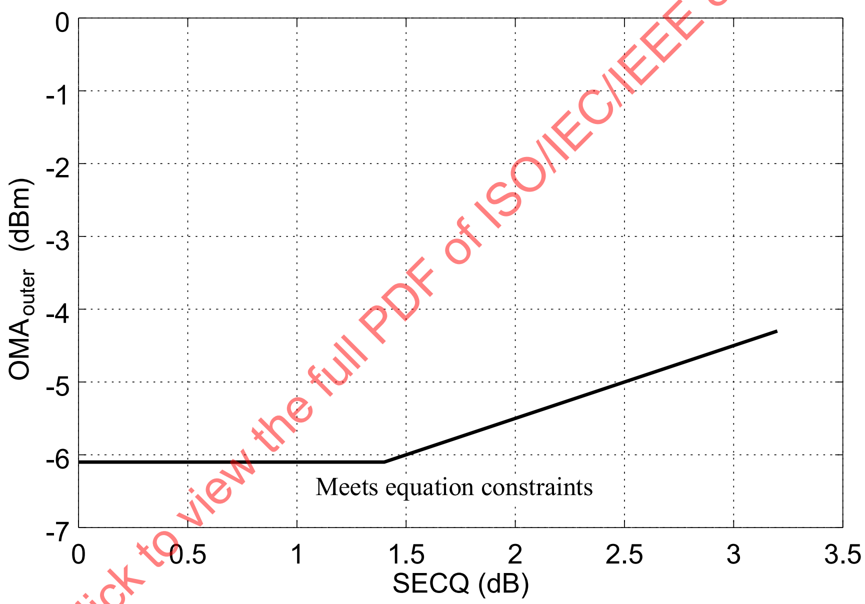


Figure 121–7—Illustration of receiver sensitivity

121.8.9 Stressed receiver sensitivity

121.8.9.1 Stressed receiver conformance test block diagram

Change the second paragraph of 121.8.9.1 as follows:

The low-pass filter is used to create ISI. ~~The combination of the low-pass filter and the E/O converter should have a frequency response that results in at least half of the dB value of the stressed eye closure (SECQ) specified in Table 121–7 before the sinusoidal and Gaussian noise terms are added, according to the methods specified in 121.8.9.2.~~ The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the finite edge rates, also causes some jitter.

121.8.9.2 Stressed receiver conformance test signal characteristics and calibration

Change the third paragraph of 121.8.9.2 as follows:

The following steps describe a possible method for setting up and calibrating a stressed receiver conformance test signal when using a stressed receiver conformance test setup as shown in Figure 121–8:

1) Set the signaling rate of the test pattern generator to meet the requirements in Table 121–6.
2) With the sinusoidal jitter, sinusoidal interferer, and the Gaussian noise generator turned off, set the extinction ratio of the E/O converter to approximately the minimum specified in Table 121–6.
3) The required value of SECQ is given in Table 121–7. ~~With the sinusoidal jitter, sinusoidal interferer, and Gaussian noise generator turned off, at least half of the dB value of SECQ should be created by the selection of the appropriate bandwidth for the combination of the low-pass filter and the E/O converter. Any remaining SECQ must be created with a combination of sinusoidal jitter, sinusoidal interference, and Gaussian noise.~~ Sinusoidal jitter is added as specified in Table 121–12.

Change the fifth paragraph of 121.8.9.2 as follows:

Iterate the adjustments of the sinusoidal interferer, the Gaussian noise generator, and extinction ratio, until the required value of SECQ is met, while also meeting the following conditions:

— The extinction ratio is approximately the minimum specified in Table 121–6;
— The transition time of the stressed receiver conformance test signal is no greater than the value specified in Table 121–6;
— With the Gaussian noise generator on and the sinusoidal jitter and sinusoidal interferer turned off, the $RIN_{21.4}OMA$ of the conformance test signal is no greater than the value specified in Table 121–6;
— The value of SECQ – $10\log_{10}(C_{eq})$ is less than the value specified in Table 121–7; and
— Sinusoidal jitter is as specified in Table 121–12.

Change the note at the end of 121.8.9.2 as follows:

NOTE—A compliant PMD receiver is expected to meet the stressed receiver sensitivity requirements with a calibrated conformance test signal regardless of the proportion ~~(as long as it is above half)~~ of the dB value of the SECQ that is due to the frequency response of the combination of the low-pass filter and the E/O converter.

121.12 Protocol implementation conformance statement (PICS) proforma for Clause 121, Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-DR4[2]

121.12.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-DR4

121.12.4.4 Optical measurement methods

Insert the following new item after item OM6 in the table in 121.12.4.4:

Item	Feature	Subclause	Value/Comment	Status	Support
OM6a	Transmitter transition time	121.8.6a	Each lane	M	Yes [ ]

[2] *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.

Change the title of Clause 122 as follows:

122. Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8

122.1 Overview

Change the first paragraph of the introductory text of 122.1 as follows:

This clause specifies the 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and the~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs together with the single-mode fiber medium. The optical signals generated by these ~~four~~six PMD types are modulated using a 4-level pulse amplitude modulation (PAM4) format. When forming a complete Physical Layer, a PMD shall be connected to the appropriate PMA as shown in Table 122–1, to the medium through the MDI and optionally with the management functions that may be accessible through the management interface defined in Clause 45, or equivalent.

Change Table 122–1 as follows:

Table 122–1—Physical Layer clauses associated with the 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs

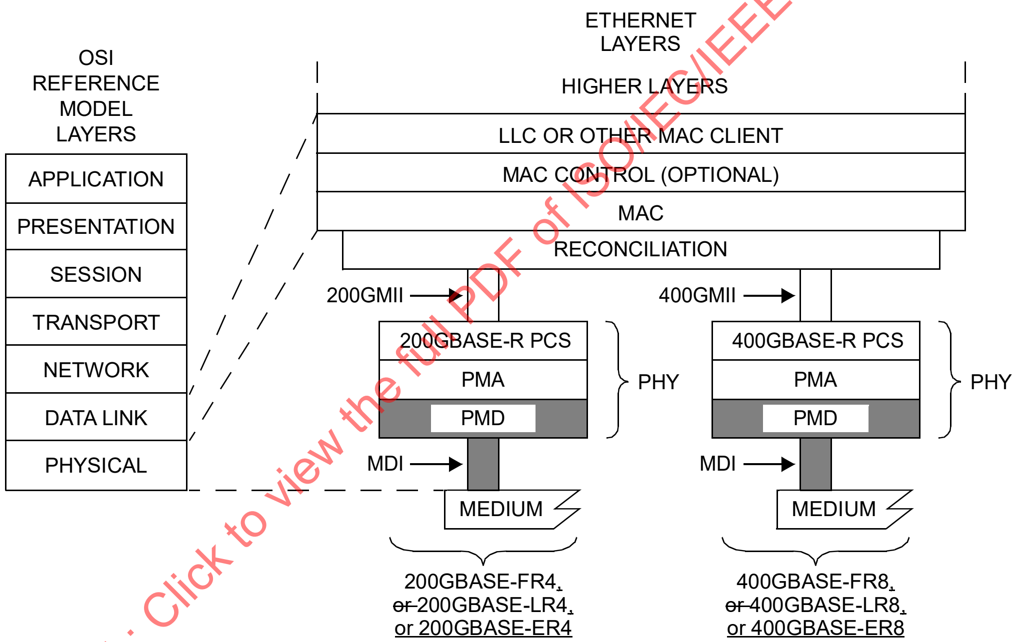
Associated clause	200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4	400GBASE-FR8, 400GBASE-LR8, 400GBASE-ER8
117—RS	Required	Required
117—200GMII[a]	Optional	Not applicable
117—400GMII[a]	Not applicable	Optional
118—200GMII Extender	Optional	Not applicable
118—400GMII Extender	Not applicable	Optional
119—PCS for 200GBASE-R	Required	Not applicable
119—PCS for 400GBASE-R	Not applicable	Required
120—PMA for 200GBASE-R	Required	Not applicable
120—PMA for 400GBASE-R	Not applicable	Required
120B—Chip-to-chip 200GAUI-8	Optional	Not applicable
120B—Chip-to-chip 400GAUI-16	Not applicable	Optional
120C—Chip-to-module 200GAUI-8	Optional	Not applicable
120C—Chip-to-module 400GAUI-16	Not applicable	Optional
120D—Chip-to-chip 200GAUI-4	Optional	Not applicable
120D—Chip-to-chip 400GAUI-8	Not applicable	Optional

Table 122–1—Physical Layer clauses associated with the 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs *(continued)*

Associated clause	200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4	400GBASE-FR8, 400GBASE-LR8, 400GBASE-ER8
120E—Chip-to-module 200GAUI-4	Optional	Not applicable
120E—Chip-to-module 400GAUI-8	Not applicable	Optional
78—Energy Efficient Ethernet	Optional	Optional

[a] 200GMII and 400GMII are optional interfaces. However, if the appropriate interface is not implemented, a conforming implementation must behave functionally as though the RS and 200GMII or 400GMII were present.

Change Figure 122-1 as follows:



400GMII = 400 Gb/s MEDIA INDEPENDENT INTERFACE
200GMII = 200 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
FR = PMD FOR SINGLE-MODE FIBER — 2 km
LR = PMD FOR SINGLE-MODE FIBER — 10 km
ER = PMD FOR SINGLE-MODE FIBER — 40 km

Figure 122–1—200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and IEEE 802.3 Ethernet model

Change the two final paragraphs of 122.1 as follows:

200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 use four lanes, while 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 use eight lanes. In this clause, where there are four or eight items (depending on PMD type) such as lanes, the items are numbered from 0 to $n - 1$, and an example item is numbered i. Thus n is 4 or 8.

200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PHYs with the optional Energy Efficient Ethernet (EEE) fast wake capability may enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization (see Clause 78). The deep sleep mode of EEE is not supported.

122.2 Physical Medium Dependent (PMD) service interface

Change the first paragraph of 122.2 as follows:

This subclause specifies the services provided by the 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs. The service interfaces for these PMDs are described in an abstract manner and do not imply any particular implementation. The PMD service interface supports the exchange of encoded data between the PMA entity that resides just above the PMD, and the PMD entity. The PMD translates the encoded data to and from signals suitable for the specified medium.

Change the third paragraph of 122.2 as follows:

The 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 PMDs have four parallel symbol streams, in which case $i = 0$ to 3, and the 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs have eight parallel symbol streams, in which case $i = 0$ to 7.

122.3 Delay and Skew

122.3.1 Delay constraints

Change 122.3.1 as follows:

The sum of the transmit and receive delays at one end of the link contributed by the 200GBASE-FR4, ~~or~~ 200GBASE-LR4, or 200GBASE-ER4 PMD including 2 m of fiber in one direction shall be no more than 4096 bit times (8 pause_quanta or 20.48 ns). The sum of the transmit and receive delays at one end of the link contributed by the 400GBASE-FR8, ~~or~~ 400GBASE-LR8, or 400GBASE-ER8 PMD including 2 m of fiber in one direction shall be no more than 8192 bit times (16 pause_quanta or 20.48 ns). A description of overall system delay constraints and the definitions for bit times and pause_quanta can be found in 116.4 and its references.

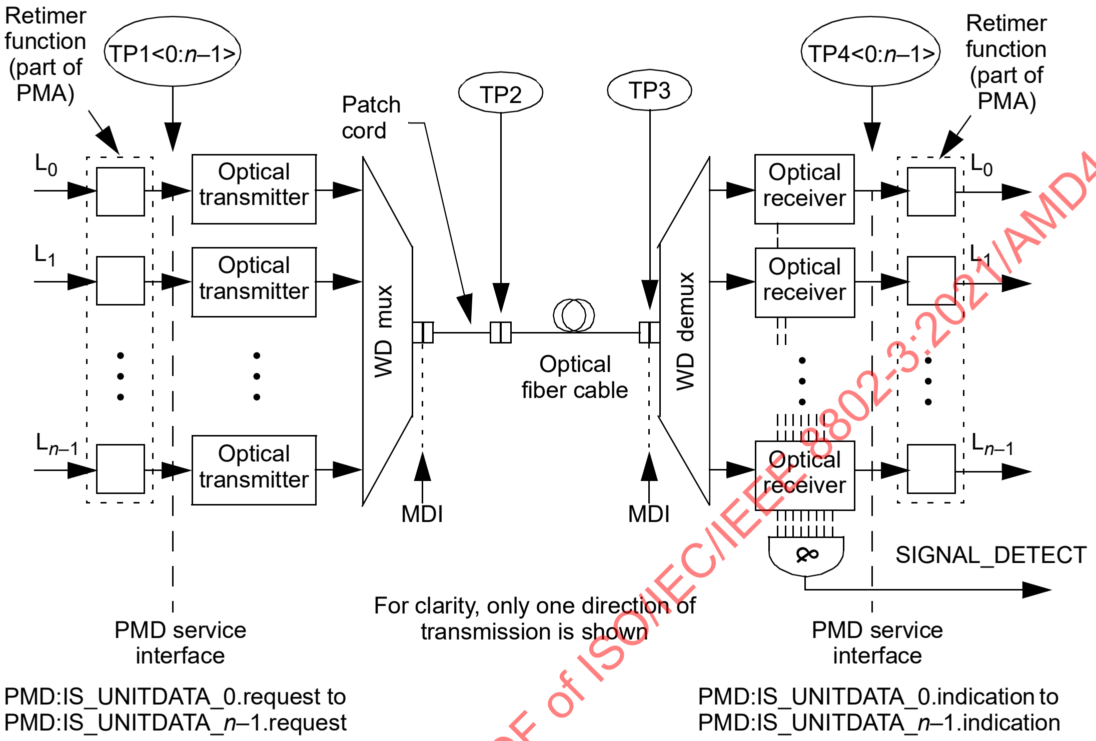
122.5 PMD functional specifications

Change the introductory text of 122.5 as follows:

The 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs perform the Transmit and Receive functions, which convey data between the PMD service interface and the MDI.

122.5.1 PMD block diagram

Change the title of Figure 122–2 as follows:



WD = Wavelength division

NOTE—Specification of the retimer function and the electrical implementation of the PMD service interface is beyond the scope of this standard.

Figure 122–2—Block diagram for 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 transmit/receive paths

122.5.4 PMD global signal detect function

Change Table 122–4 as follows:

Table 122–4—SIGNAL_DETECT value definition

Receive conditions	SIGNAL_DETECT value
For any lane; Average optical power at TP3 ≤ –30 dBm	FAIL
For all lanes; [(Optical power at TP3 ≥ average receive power, each lane (min) in Table 122–11 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 or Table 122–12 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8) AND (compliant 200GBASE-R or 400GBASE–R signal input)]	OK
All other conditions	Unspecified

122.5.7 PMD global transmit disable function (optional)

Change 122.5.7 as follows:

The PMD global transmit disable function is optional and allows all of the optical transmitters to be disabled.

a) When the PMD_global_transmit_disable variable is set to one, this function shall turn off all of the optical transmitters so that each transmitter meets the requirements of the average launch power of the OFF transmitter in Table 122–9 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and Table 122–10 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8.

b) If a PMD_fault is detected, then the PMD may set the PMD_global_transmit_disable variable to one, turning off the optical transmitter in each lane.

122.5.8 PMD lane-by-lane transmit disable function

Change the first paragraph of 122.5.8 as follows:

The PMD lane-by-lane transmit disable function allows the optical transmitters in each lane to be selectively disabled.

a) When a PMD_transmit_disable_*i* variable (where *i* represents the lane number in the range 0:3 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and 0:7 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8) is set to one, this function shall turn off the optical transmitter associated with that variable so that the transmitter meets the requirements of the average launch power of the OFF transmitter in Table 122–9 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and Table 122–10 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8 and 400GBASE-ER8.

b) If a PMD_fault is detected, then the PMD may set each PMD_transmit_disable_*i* variable to one, turning off the optical transmitter in each lane.

122.6 Wavelength-division-multiplexed lane assignments

Change the second paragraph of 122.6 as follows:

The wavelength range for each lane of the 200GBASE-LR4 and 200GBASE-ER4 PMDs is defined in Table 122–6. The wavelength range for each lane of the 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs is defined in Table 122–7. The 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 center frequencies are members of the frequency grid for 100 GHz spacing and above defined in ITU-T G.694.1 and are spaced at multiples of 800 GHz.

Change the titles of Table 122–6 and Table 122–7 as follows:

Table 122–6—200GBASE-LR4 and 200GBASE-ER4 wavelength-division-multiplexed lane assignments

Lane	Center frequency	Center wavelength	Wavelength range
L_0	231.4 THz	1295.56 nm	1294.53 to 1296.59 nm
L_1	230.6 THz	1300.05 nm	1299.02 to 1301.09 nm
L_2	229.8 THz	1304.58 nm	1303.54 to 1305.63 nm
L_3	229 THz	1309.14 nm	1308.09 to 1310.19 nm

Table 122–7—400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 wavelength-division-multiplexed lane assignments

Lane	Center frequency	Center wavelength	Wavelength range
L_0	235.4 THz	1273.54 nm	1272.55 to 1274.54 nm
L_1	234.6 THz	1277.89 nm	1276.89 to 1278.89 nm
L_2	233.8 THz	1282.26 nm	1281.25 to 1283.27 nm
L_3	233 THz	1286.66 nm	1285.65 to 1287.68 nm
L_4	231.4 THz	1295.56 nm	1294.53 to 1296.59 nm
L_5	230.6 THz	1300.05 nm	1299.02 to 1301.09 nm
L_6	229.8 THz	1304.58 nm	1303.54 to 1305.63 nm
L_7	229 THz	1309.14 nm	1308.09 to 1310.19 nm

Change the title and contents of 122.7 and its subclauses as follows:

122.7 PMD to MDI optical specifications for 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8

The operating ranges for the 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 PMDs are defined in Table 122–8. A 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~or~~ 400GBASE-LR8, or 400GBASE-ER8 compliant PMD operates on type B1.1, B1.3, or B6_a single-mode fibers according to the specifications defined in Table 122–18. A PMD that exceeds the operating range requirement while meeting all other optical specifications is considered compliant (e.g., a 400GBASE-FR8 PMD operating at 2.5 km meets the operating range requirement of 2 m to 2 km).

The 200GBASE-ER4 PMD interoperates with the 200GBASE-LR4 PMD provided that the channel requirements defined in 122.11a are met.

The 400GBASE-LR8 PMD interoperates with the 400GBASE-FR8 PMD provided that the channel requirements for 400GBASE-FR8 are met.

The 400GBASE-ER8 PMD interoperates with the 400GBASE-FR8 PMD provided that the channel requirements defined in 122.11b are met.

The 400GBASE-ER8 PMD interoperates with the 400GBASE-LR8 PMD provided that the channel requirements defined in 122.11c are met.

Table 122–8—200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 operating ranges

PMD type	Required operating range
200GBASE-FR4 and 400GBASE-FR8	2 m to 2 km
200GBASE-LR4 and 400GBASE-LR8	2 m to 10 km
200GBASE-ER4 and 400GBASE-ER8	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 worst case specified for IEC 60793-2-50 type B1.1, type B1.3, or type B6_a single-mode fiber.

122.7.1 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 transmitter optical specifications

The 200GBASE-FR4 transmitter shall meet the specifications defined in Table 122–9 per the definitions in 122.8. The 200GBASE-LR4 transmitter shall meet the specifications defined in Table 122–9 per the definitions in 122.8. The 200GBASE-ER4 transmitter shall meet the specifications defined in Table 122–9 per the definitions in 122.8. The 400GBASE-FR8 transmitter shall meet the specifications defined in Table 122–10 per the definitions in 122.8. The 400GBASE-LR8 transmitter shall meet the specifications defined in Table 122–10 per the definitions in 122.8. The 400GBASE-ER8 transmitter shall meet the specifications defined in Table 122–10 per the definitions in 122.8.

Table 122–9—200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 transmit characteristics

Description	200GBASE-FR4	200GBASE-LR4	200GBASE-ER4	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm			GBd
Modulation format	PAM4			—
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19		nm
Side-mode suppression ratio (SMSR), (min)	30			dB
Total average launch power (max)	10.7	11.3	12.6	dBm
Average launch power, each lane (max)	4.7	5.3	6.6	dBm
Average launch power, each lane[a] (min)	–4.2	–3.4	0.4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	4.5	5.1	7.4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[b]	–1.2	–0.4	3.4	dBm
Difference in launch power between any two lanes (OMA_{outer}) (max)	4			dB
Launch power in OMA_{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 –2.6 –2.5	 –1.8 –1.7	 2 —	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	~~3.3~~3.1	~~3.4~~3.2	3.2	dB
TDECQ $-10\log_{10}(C_{eq})$[c] (max)	3.1	3.2	3.2	dB
Average launch power of OFF transmitter, each lane (max)	–30			dBm
Extinction ratio, each lane (min)	3.5		6	dB
Transmitter transition time (max)	34			ps
$RIN_{17.1}OMA$ (max)	–132	—	—	dB/Hz
$RIN_{15.6}OMA$ (max)	—	–132	—	dB/Hz
$RIN_{15}OMA$ (max)	—	—	–132	dB/Hz
Optical return loss tolerance (max)	17.1	15.6	15	dB
Transmitter reflectance[d] (max)	–26			dB

[a] Average launch power, each lane (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] Even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMA_{outer} (min) must exceed this value.
[c] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.
[d] Transmitter reflectance is defined looking into the transmitter.

Table 122–10—400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 transmit characteristics

Description	400GBASE-FR8	400GBASE-LR8	400GBASE-ER8	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm			GBd
Modulation format	PAM4			—
Lane wavelengths (range)	1272.55 to 1274.54 1276.89 to 1278.89 1281.25 to 1283.27 1285.65 to 1287.68 1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19			nm
Side-mode suppression ratio (SMSR), (min)	30			dB
Total average launch power (max)	13.2		14.6	dBm
Average launch power, each lane[a] (max)	5.3		5.6	dBm
Average launch power, each lane[b] (min)	–3.5	–2.8	–0.6	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	5.5	5.7	6.4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[c]	–0.5	0.2	2.4	dBm
Difference in launch power between any two lanes (OMA_{outer}) (max)	4			dB
Launch power in OMA_{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 –1.9 –1.8	 –1.2 –1.1	 1 —	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	~~3.1~~2.9	~~3.3~~3.1	3.4	dB
TDECQ $-10\log_{10}(C_{eq})$[d] (max)	2.9	3.1	3.4	dB
Average launch power of OFF transmitter, each lane (max)	–30			dBm
Extinction ratio, each lane (min)	3.5		6	dB
Transmitter transition time (max)	34			ps
$RIN_{17.1}OMA$ (max)	–132	—	—	dB/Hz
$RIN_{15.6}OMA$ (max)	—	–132	—	dB/Hz
$RIN_{15}OMA$ (max)	—	—	–132	dB/Hz
Optical return loss tolerance (max)	17.1	15.6	15	dB
Transmitter reflectance[e] (max)	–26			dB

[a] As the total average launch power limit has to be met, not all of the lanes can operate at the maximum average launch power, each lane.
[b] Average launch power, each lane (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.
[c] Even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMA_{outer} (min) must exceed this value.
[d] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.
[e] Transmitter reflectance is defined looking into the transmitter.

122.7.2 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 receive optical specifications

The 200GBASE-FR4 receiver shall meet the specifications defined in Table 122–11 per the definitions in 122.8. The 200GBASE-LR4 receiver shall meet the specifications defined in Table 122–11 per the definitions in 122.8. The 200GBASE-ER4 receiver shall meet the specifications defined in Table 122–11 per the definitions in 122.8. The 400GBASE-FR8 receiver shall meet the specifications defined in Table 122–12 per the definitions in 122.8. The 400GBASE-LR8 receiver shall meet the specifications defined in Table 122–12 per the definitions in 122.8. The 400GBASE-ER8 receiver shall meet the specifications defined in Table 122–12 per the definitions in 122.8.

Table 122–11—200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 receive characteristics

Description	200GBASE-FR4	200GBASE-LR4	200GBASE-ER4	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm			GBd
Modulation format	PAM4			—
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19		nm
Damage threshold[a], each lane	5.7	6.3	–2.4	dBm
Average receive power, each lane (max)	4.7	5.3	–3.4	dBm
Average receive power, each lane[b] (min)	–8.2	–9.7	–17.6	dBm
Receive power (OMA_{outer}), each lane (max)	4.5	5.1	–2.6	dBm
Difference in receive power between any two lanes (OMA_{outer}) (max)	4.1	4.2	4.6	dB
Receiver reflectance (max)	–26			dB
Receiver sensitivity (OMA_{outer}), each lane[c] (max)	Equation (122–1)	Equation (122–2)	Equation (122–2a)	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane[d] (max)	~~–3.6~~ –3.8	~~–5.2~~ –5.4	–13.3	dBm
Conditions of stressed receiver sensitivity test:[e]				
Stressed eye closure for PAM4 (SECQ), lane under test	~~3.3~~3.1	~~3.4~~3.2	3.2	dB
SECQ – $10\log_{10}(C_{eq})$[f] (max), lane under test	3.1	3.2	3.2	dB
OMA_{outer} of each aggressor lane	~~0.5~~0.3	~~–1~~ –1.2	–8.7	dBm

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.
[b] Average receive power, each lane (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 (OMA_{outer}), each lane (max) is informative and is defined for a transmitter with a value of SECQ up to ~~3.3~~3.1 dB for 200GBASE-FR4, ~~and~~ ~~3.4~~3.2 dB for 200GBASE-LR4, and 3.2 dB for 200GBASE-ER4.
[d] Measured with conformance test signal at TP3 (see 122.8.9) for the BER specified in 122.1.1.
[e] These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.
[f] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.

Table 122–12—400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 receive characteristics

Description	400GBASE-FR8	400GBASE-LR8	400GBASE-ER8	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm			GBd
Modulation format	PAM4			—
Lane wavelengths (range)	1272.55 to 1274.54 1276.89 to 1278.89 1281.25 to 1283.27 1285.65 to 1287.68 1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19			nm
Damage threshold[a], each lane	6.3		–3.4	dBm
Average receive power, each lane (max)	5.3		–4.4	dBm
Average receive power, each lane[b] (min)	–7.5	–9.1	–18.6	dBm
Receive power (OMA_{outer}), each lane (max)	5.7		–3.6	dBm
Difference in receive power between any two lanes (OMA_{outer}) (max)	4.1	4.5	5.8	dB
Receiver reflectance (max)	–26			dB
Receiver sensitivity (OMA_{outer}), each lane[c] (max)	Equation (122–3)	Equation (122–4)	Equation (122–5)	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane[d] (max)	~~–3.1~~ –3.3	~~–4.7~~ –4.9	–14.1	dBm
Conditions of stressed receiver sensitivity test:[e]				
Stressed eye closure for PAM4 (SECQ), lane under test	~~3.1~~2.9	~~3.3~~3.1	3.4	dB
SECQ – $10\log_{10}(C_{eq})$[f] (max), lane under test	2.9	3.1	3.4	dB
OMA_{outer} of each aggressor lane	~~1~~0.8	~~–0.2~~ –0.4	–8.3	dBm

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.
[b] Average receive power, each lane (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 (OMA_{outer}), each lane (max) is informative and is defined for a transmitter with a value of SECQ up to ~~3.1~~2.9 dB for 400GBASE-FR8, ~~and~~ ~~3.3~~3.1 dB for 400GBASE-LR8, and 3.4 dB for 400GBASE-ER8.
[d] Measured with conformance test signal at TP3 (see 122.8.9) for the BER specified in 122.1.1.
[e] These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.
[f] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.

122.7.3 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 illustrative link power budgets

Illustrative power budgets and penalties for 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 channels are shown in Table 122–13.

Table 122–13—200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 illustrative link power budgets

Parameter	200GBASE-FR4	400GBASE-FR8	200GBASE-LR4	400GBASE-LR8	200GBASE-ER4		400GBASE-ER8		Unit
Power budget (for maximum TDECQ): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 ~~7.6~~7.4 ~~7.7~~7.5	 ~~7.4~~7.2 ~~7.5~~7.3	 ~~10.2~~10 ~~10.3~~10.1	 ~~10.1~~9.9 ~~10.2~~10	 21.7 —		 21.9 —		 dB dB
Operating distance	2		10		30	40[a]	30	40[a]	km
Channel insertion loss (max)	4[b]		6.3		15	18	15	18	dB
Channel insertion loss (min)	0				10		10		dB
Maximum discrete reflectance	See 122.11.2.2								dB
Allocation for penalties[c] (for maximum TDECQ): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 ~~3.6~~3.4 ~~3.7~~3.5	 ~~3.4~~3.2 ~~3.5~~3.3	 ~~3.9~~3.7 ~~4~~3.8	 ~~3.8~~3.6 ~~3.9~~3.7	 3.7 —		 3.9 —		 dB dB
Additional insertion loss allowed	0		0		3	0	3	0	dB

[a] Links longer than 30 km are considered engineered links. Attenuation for such links needs to be less than the worst case for cables containing IEC 60793-2-50 type B1.1, type B1.3, or type B6_a single-mode cabled optical fiber.
[b] The channel insertion loss is calculated using the maximum distance specified in Table 122–8 for 200GBASE-FR4 and 400GBASE-FR8 and fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 122.11.2.1.
[c] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

122.8 Definition of optical parameters and measurement methods

122.8.1 Test patterns for optical parameters

Change Table 122-15 as follows:

Table 122–15—Test-pattern definitions and related subclauses

Parameter	Pattern	Related subclause
Wavelength	Square wave, 3, 4, 5, 6 or valid 200GBASE-R or 400GBASE-R signal	122.8.2
Side mode suppression ratio	3, 5, 6 or valid 200GBASE-R or 400GBASE-R signal	122.8.2
Average optical power	3, 5, 6 or valid 200GBASE-R or 400GBASE-R signal	122.8.3
Outer Optical Modulation Amplitude (OMA_{outer})	4 or 6	122.8.4
Transmitter and dispersion eye closure for PAM4 (TDECQ)	6	122.8.5
Extinction ratio	4 or 6	122.8.6
Transmitter transition time	Square wave or 6	122.8.6a
$RIN_{15.1}OMA$, ~~and~~ $RIN_{16.5}OMA$, and $RIN_{15}OMA$	Square wave	122.8.7
Stressed receiver conformance test signal calibration	6	122.8.9.2
Stressed receiver sensitivity	3 or 5	122.8.9

122.8.2 Wavelength and side mode suppression ratio (SMSR)

Change 122.8.2 as follows:

The wavelength and SMSR of each optical lane shall be within the ranges given in Table 122–5 for 200GBASE-FR4, in Table 122–6 for 200GBASE-LR4 and 200GBASE-ER4 and in Table 122–7 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8, if measured per IEC 61280-1-3. The lane under test is modulated using the test pattern defined in Table 122–15.

122.8.3 Average optical power

Change 122.8.3 as follows:

The average optical power of each lane shall be within the limits given in Table 122–9 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–10 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 if measured using the methods given in IEC 61280-1-1, with the sum of the optical power from all of the lanes not under test below –30 dBm, per the test setup in Figure 53–6.

122.8.4 Outer Optical Modulation Amplitude (OMA_{outer})

Change the text of 122.8.4 as follows (Figure 122-3 remains unchanged):

The OMA_{outer} of each lane shall be within the limits given in Table 122–9 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–10 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8. The OMA_{outer} is measured using a test pattern specified for OMA_{outer} in Table 122–15. It is the difference between the average optical launch power level P_3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P_0, measured over the central 2 UI of a run of 6 zeros, as shown in Figure 122–3. For this measurement the sum of the optical power from all of the lanes not under test is below –30 dBm, or if other lanes are operating, a suitable optical filter may be used to separate the lane under test.

122.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

Change the first paragraph of 122.8.5 as follows:

The TDECQ and TDECQ – $10\log_{10}(C_{eq})$ of each lane shall be within the limits given in Table 122–9 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–10 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 if measured using the methods specified in 122.8.5.1, 122.8.5.2, and 122.8.5.3.

122.8.5.1 TDECQ conformance test setup

Change the second paragraph of 122.8.5.1 as follows:

Each optical lane is tested individually with all other lanes in operation and all lanes using the same test pattern. There shall be at least 31 UI delay between the test pattern on one lane and the pattern on any other lane, so that the symbols on each lane are not correlated within the PMD. The optical splitter and variable reflector are adjusted so that each transmitter is tested with the optical return loss specified in Table 122–16. The state of polarization of the back reflection is adjusted to create the greatest RIN. The optical filter is used to separate the lane under test from the others. Each optical lane is tested with the optical channel described in 122.8.5.2. The combination of the O/E converter and the oscilloscope has a 3 dB bandwidth of approximately 13.28125 GHz with a fourth-order Bessel-Thomson ~~filter~~ response to at least 1.5 × 26.5625 GHz, and at frequencies above 1.5 × 26.5625 GHz, the response should not exceed –24 dB ~~with a bandwidth of approximately 13.28125 GHz~~. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

122.8.5.2 Channel requirements

Change Table 122–16 as follows:

Table 122–16—Transmitter compliance channel specifications

PMD type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
200GBASE-FR4 or 400GBASE-FR8	$0.0465 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.0465 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	17.1 dB	0.8 ps
200GBASE-LR4 or 400GBASE-LR8	$0.2325 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.2325 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	15.6 dB	0.8 ps
200GBASE-ER4 or 400GBASE-ER8	$0.93 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.93 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	15 dB	0.8 ps

[a] The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 2 km for 200GBASE-FR4 and 400GBASE-FR8, ~~and~~ 10 km for 200GBASE-LR4 and 400GBASE-LR8, and 40 km for 200GBASE-ER4 and 400GBASE-ER8.
[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.

Change the second paragraph of 122.8.5.2 as follows:

A 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~or~~ 400GBASE-LR8, or 400GBASE-ER8 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 122–16 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.

122.8.5.3 TDECQ measurement method

Change 122.8.5.3 as follows:

TDECQ for 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 is measured as described in 121.8.5.3 with the exception that the reference equalizer is as specified in 122.8.5.4.

122.8.5.4 TDECQ reference equalizer

Change the first paragraph of 122.8.5.4 as follows:

The reference equalizer for 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 is a 5 tap, T spaced, feed-forward equalizer (FFE), where T is the symbol period. A functional model of the reference equalizer is shown in Figure 122–5. The sum of the equalizer tap coefficients is equal to 1. Tap 1, tap 2, or tap 3 has the largest magnitude tap coefficient, which is constrained to be at least 0.8.

122.8.6 Extinction ratio

Change 122.8.6 as follows:

The extinction ratio of each lane shall be within the limits given in Table 122–9 for 200GBASE-FR4<u>,</u>~~ and~~ 200GBASE-LR4<u>, and 200GBASE-ER4</u> and in Table 122–10 for 400GBASE-FR8<u>,</u>~~ and~~ 400GBASE-LR8<u>, and 400GBASE-ER8</u> if measured using a test pattern specified for extinction ratio in Table 122–15 with the sum of the optical power from all of the lanes not under test being below –30 dBm, or if other lanes are operating, a suitable optical filter may be used to separate the lane under test. The extinction ratio of a PAM4 optical signal is defined as the ratio of the average optical launch power level P_3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P_0, measured over the central 2 UI of a run of 6 zeros, as shown in Figure 122–3.

Insert the following new subclause (122.8.6a) after 122.8.6:

122.8.6a Transmitter transition time

The transmitter transition time of each lane shall be within the limits given in Table 122–9 for 200GBASE-FR4, 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–10 for 400GBASE-FR8, 400GBASE-LR8, and 400GBASE-ER8, if measured using a test pattern specified for transmitter transition time in Table 122–15.

Transmitter transition time is defined as the slower of the time interval of the transition from 20% of OMA_{outer} to 80% of OMA_{outer}, or from 80% of OMA_{outer} to 20% of OMA_{outer}, for the rising and falling edges respectively, as measured through an O/E converter and oscilloscope with response defined as follows. The combined response of the O/E converter and oscilloscope has a 3 dB bandwidth of approximately 13.28125 GHz with a fourth-order Bessel-Thomson response to at least 1.5 × 26.5625 GHz. At frequencies above 1.5 × 26.5625 GHz, the response should not exceed –24 dB. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

The 0% level and the 100% level are P_0 and P_3 as defined by the OMA_{outer} measurement procedure (see 121.8.4), with the exception that the square wave test pattern can be used. When the SSPRQ pattern is used, the rising edge used for the measurement is that within the 00000333333 symbol sequence, and the falling edge is that within the 33333000000 symbol sequence.

Change the title of 122.8.7 as follows:

122.8.7 Relative intensity noise ($RIN_{17.1}OMA$<u>,</u> ~~and~~ $RIN_{15.6}OMA$<u>, and $RIN_{15}OMA$</u>)

Change item a) in 122.8.7 as follows:

a) The optical return loss is 17.1 dB for 200GBASE-FR4 and 400GBASE-FR8<u>,</u>~~ and~~ 15.6 dB for 200GBASE-LR4 and 400GBASE-LR8<u>, and 15 dB for 200GBASE-ER4 and 400GBASE-ER8</u>.

122.8.8 Receiver sensitivity

Change the text of 122.8.8 as follows:

For 200GBASE-FR4, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to ~~3.3~~<u>3.1</u> dB. Receiver sensitivity should meet Equation (122–1), which is illustrated in Figure 122–6.

For 200GBASE-LR4, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to ~~3.4~~3.2 dB. Receiver sensitivity should meet Equation (122–2), which is illustrated in Figure 122–6.

For 200GBASE-ER4, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 3.2 dB. Receiver sensitivity should meet Equation (122–2a), which is illustrated in Figure 122–6.

$$RS = \max(-5.5, SECQ - 6.9)$$ (~~dB~~dBm) (122–1)

$$RS = \max(-7.2, SECQ - 8.6)$$ (~~dB~~dBm) (122–2)

$$RS = \max(-15.1, SECQ - 16.5)$$ (dBm) (122–2a)

where

RS	is the receiver sensitivity
SECQ	is the SECQ of the transmitter used to measure the receiver sensitivity

Replace Figure 122-6 with the following figure:

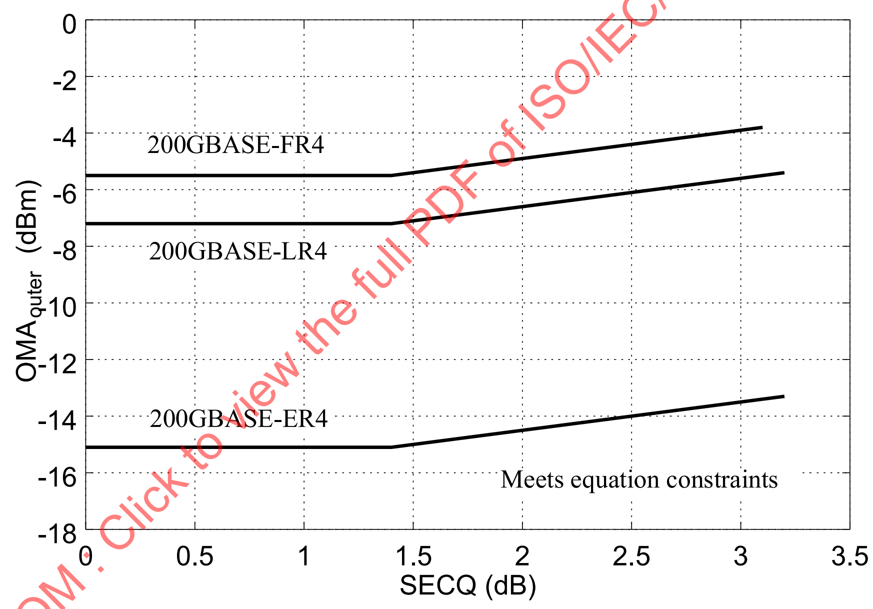


Figure 122–6—Illustration of receiver sensitivity for 200GBASE-FR4,~~ and~~ 200GBASE-LR4, and 200GBASE-ER4

For 400GBASE-FR8, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to ~~3.1~~2.9 dB. Receiver sensitivity should meet Equation (122–3), which is illustrated in Figure 122–7.

For 400GBASE-LR8, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to ~~3.3~~3.1 dB. Receiver sensitivity should meet Equation (122–4), which is illustrated in Figure 122–7.

For 400GBASE-ER8, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 3.4 dB. Receiver sensitivity should meet Equation (122–5), which is illustrated in Figure 122–7.

$$RS = \max(-4.8, SECQ - 6.2) \quad (~~dB~~dBm) \qquad (122\text{–}3)$$

$$RS = \max(-6.6, SECQ - 8) \quad (~~dB~~dBm) \qquad (122\text{–}4)$$

$$RS = \max(-16.1, SECQ - 17.5) \quad (dBm) \qquad (122\text{–}5)$$

where

RS	is the receiver sensitivity
SECQ	is the SECQ of the transmitter used to measure the receiver sensitivity

Replace Figure 122-7 with the following figure:

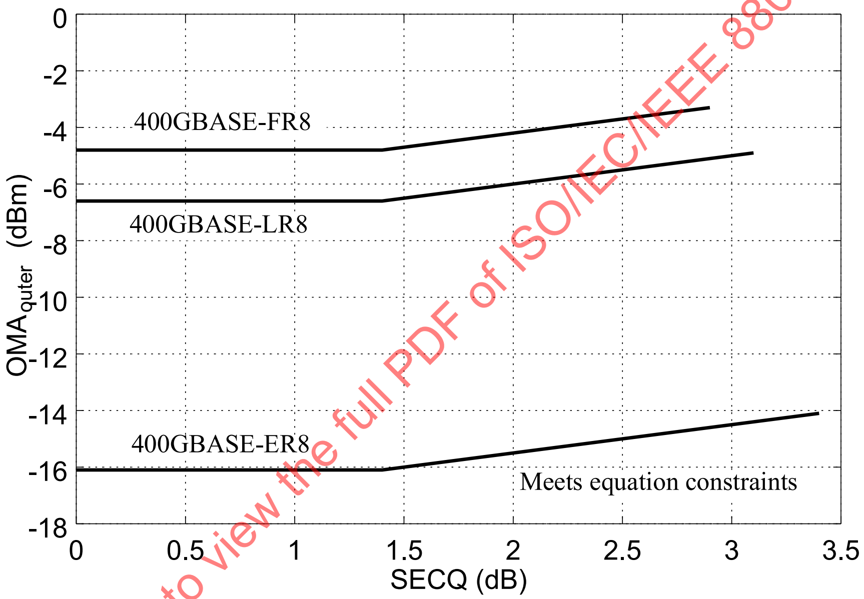


Figure 122–7—Illustration of receiver sensitivity for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8

The normative requirement for receivers is stressed receiver sensitivity.

122.8.9 Stressed receiver sensitivity

Change the first paragraph of 122.8.9 as follows:

Stressed receiver sensitivity shall be within the limits given in Table 122–11 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–12 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 if measured using the method defined in 122.8.9.1 and 122.8.9.3, with the conformance test signal at TP3 as described in 122.8.9.2, using the test pattern specified for SRS in Table 122–15. The BER is required to be met for the lane under test on its own.

122.8.9.1 Stressed receiver conformance test block diagram

Change second paragraph of 122.8.9.1 as follows:

The low-pass filter is used to create ISI. ~~The combination of the low-pass filter and the E/O converter should have a frequency response that results in at least half of the dB value of the stressed eye closure (SECQ) specified in Table 122–11 for 200GBASE-FR4 and 200GBASE-LR4 and in Table 122–12 for 400GBASE-FR8 and 400GBASE-LR8 before the sinusoidal and Gaussian noise terms are added, according to the methods specified in 122.8.9.2.~~ The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the finite edge rates, also causes some jitter.

122.8.9.2 Stressed receiver conformance test signal characteristics and calibration

Change 122.8.9.2 as follows:

The stressed receiver conformance test signal characteristics and calibration methods are as described in 121.8.9.2 with the following exceptions:

— The SECQ of the stressed receiver conformance test signal is measured according to 122.8.5, except that the test fiber is not used. The transition time of the stressed receiver conformance test signal is no greater than the value specified in Table 122–9 for 200GBASE-FR4, 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–10 for 400GBASE-FR8, 400GBASE-LR8, and 400GBASE-ER8.

— An example stressed receiver conformance test setup is shown in Figure 122–8; however, alternative test setups that generate equivalent stress conditions may be used.

— With the Gaussian noise generator on and the sinusoidal jitter and sinusoidal interferer turned off, the $RIN_{xx.x}OMA$ of the SRS test source should be no greater than the value specified in Table 122–9 for 200GBASE-FR4, 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–10 for 400GBASE-FR8, 400GBASE-LR8, and 400GBASE-ER8.

— The signaling rate of the test pattern generator and the extinction ratio of the E/O converter are as given in Table 122–9 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–10 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8.

— The required values of the "Stressed receiver sensitivity (OMA_{outer}), each lane (max)", "Stressed eye closure for PAM4 (SECQ), lane under test", "SECQ – $10\log_{10}(C_{eq})$ (max), lane under test", and "OMA_{outer} of each aggressor lane" are as given in Table 122–11 for 200GBASE-FR4, ~~and~~ 200GBASE-LR4, and 200GBASE-ER4 and in Table 122–12 for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8.

122.9 Safety, installation, environment, and labeling

122.9.2 Laser safety

Change the first paragraph of 122.9.2 as follows:

200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, and 400GBASE-LR8 optical transceivers shall conform to Hazard Level 1 laser requirements and 400GBASE-ER8 optical transceivers shall conform to Hazard Level 1M 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.

122.9.4 Environment

Change the first paragraph of 122.9.4 as follows:

Normative specifications in this clause shall be met by a system integrating a 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~or~~ 400GBASE-LR8, or 400GBASE-ER8 PMD over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

122.9.5 Electromagnetic emission

Change 122.9.5 as follows:

A system integrating a 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~or~~ 400GBASE-LR8, or 400GBASE-ER8 PMD shall comply with applicable local and national codes for the limitation of electromagnetic interference.

122.9.7 PMD labeling requirements

Change the second paragraph of 122.9.7 as follows:

Labeling requirements for Hazard Level 1 and Hazard Level 1M lasers are given in the laser safety standards referenced in 122.9.2.

122.10 Fiber optic cabling model

Change Table 122-17 as follows:

Table 122–17—Fiber optic cabling (channel) characteristics

Description	200GBASE-FR4	400GBASE-FR8	200GBASE-LR4	400GBASE-LR8	200GBASE-ER4		400GBASE-ER8		Unit
Operating distance (max)	2		10		30	40	30	40	km
Channel insertion loss[a,b] (max)	4		6.3[c]		18		18		dB
Channel insertion loss (min)	0		0		10[d]				dB
Positive dispersion[b] (max)	6.7	1.9	9.5		28	37	28	37	ps/nm
Negative dispersion[b] (min)	−11.9	−10.2	−28.4	−50.8	−85	−114	−151	−201	ps/nm
DGD_max[e]	3		8		10.3				ps
Optical return loss (min)	25		22		19				dB

[a] These channel insertion loss values include cable, connectors, and splices.
[b] Over the wavelength range 1264.5 nm to 1337.5 nm for 200GBASE-FR4, 1294.53 nm to 1310.19 nm for 200GBASE-LR4 and 200GBASE-ER4, and 1272.55 nm to 1310.19 nm for 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8.
[c] Using 0.46 dB/km at 1272.55 nm attenuation for optical fiber cables derived from Appendix I of ITU-T G.695 may not support operation at 10 km for 400GBASE-LR8 under worst case conditions.
[d] Channel insertion loss (min) may be implemented with an optical attenuator.
[e] Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were 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.

122.11 Characteristics of the fiber optic cabling (channel)

Change the introductory text of 122.11 as follows:

The 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 fiber optic cabling shall meet the specifications defined in Table 122–17. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together.

122.11.1 Optical fiber cable

Change footnote b of Table 122-18 as follows:

Table 122–18—Optical fiber and cable characteristics

Description	Value	Unit
Nominal fiber specification wavelength	1310	nm
Cabled optical fiber attenuation (max)	0.47[a] or 0.5[b]	dB/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] The 0.47 dB/km at 1264.5 nm attenuation for optical fiber cables is derived from Appendix I of ITU-T G.695.
[b] 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 for 200GBASE-LR4 or 400GBASE-LR8 or at 40 km for 200GBASE-ER4 or 400GBASE-ER8.

122.11.2 Optical fiber connection

122.11.2.1 Connection insertion loss

Change 122.11.2.1 as follows:

The maximum link distance for 200GBASE-LR4, 200GBASE-ER4, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8 is based on an allocation of 2 dB total connection and splice loss. For example, this allocation supports four connections with an average insertion loss per connection of 0.5 dB. The maximum link distance for 200GBASE-FR4 and 400GBASE-FR8 is based on an allocation of 3 dB total connection and splice loss. Connections with different loss characteristics may be used provided the requirements of Table 122–17 are met.

122.11.2.2 Maximum discrete reflectance

Change Table 122-19 as follows:

Table 122–19—Maximum value of each discrete reflectance

Number of discrete reflectances above –55 dB	Maximum value for each discrete reflectance		
	200GBASE-FR4 or 400GBASE-FR8	200GBASE-LR4 or 400GBASE-LR8	200GBASE-ER4 or 400GBASE-ER8
1	–25 dB	–22 dB	–19 dB
2	–31 dB	–29 dB	–27 dB
4	–35 dB	–33 dB	–32 dB
6	–38 dB	–35 dB	–35 dB
8	–40 dB	–37 dB	–37 dB
10	–41 dB	–39 dB	–39 dB

122.11.3 Medium Dependent Interface (MDI) requirements

Change the first paragraph of 122.11.3 as follows:

The 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~or~~ 400GBASE-LR8, or 400GBASE-ER8 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 122–9). Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

Insert the following new subclauses (122.11a, 122.11b, and 122.11c) after 122.11's subclauses:

122.11a Requirements for interoperation between 200GBASE-ER4 and 200GBASE-LR4

The 200GBASE-ER4 and 200GBASE-LR4 PMDs can interoperate with each other (over an engineered link) provided that the fiber optic cabling (channel) characteristics for 200GBASE-LR4 are met, with the exception of the maximum and minimum channel insertion loss values, which are given in Table 122–20 for the two link directions separately. Attenuators may be used to achieve the required losses.

Table 122–20—Channel insertion loss requirements for interoperation between 200GBASE-ER4 and 200GBASE-LR4

Direction	Min loss	Max loss	Unit
200GBASE-ER4 transmitter to 200GBASE-LR4 receiver	2.3	10.1	dB
200GBASE-LR4 transmitter to 200GBASE-ER4 receiver	8.7	14.2	dB

122.11b Requirements for interoperation between 400GBASE-ER8 and 400GBASE-FR8

The 400GBASE-ER8 and 400GBASE-FR8 PMDs can interoperate with each other (over an engineered link) provided that the fiber optic cabling (channel) characteristics for 400GBASE-FR8 are met, with the exception of the maximum and minimum channel insertion loss values, which are given in Table 122–21 for the two link directions separately. Attenuators may be used to achieve the required losses.

Table 122–21—Channel insertion loss requirements for interoperation between 400GBASE-ER8 and 400GBASE-FR8

Direction	Min loss	Max loss	Unit
400GBASE-ER8 transmitter to 400GBASE-FR8 receiver	0.7	6.9	dB
400GBASE-FR8 transmitter to 400GBASE-ER8 receiver	9.7	15.1	dB

122.11c Requirements for interoperation between 400GBASE-ER8 and 400GBASE-LR8

The 400GBASE-ER8 and 400GBASE-LR8 PMDs can interoperate with each other (over an engineered link) provided that the fiber optic cabling (channel) characteristics for 400GBASE-LR8 are met, with the exception of the maximum and minimum channel insertion loss values, which are given in Table 122–22 for the two link directions separately. Attenuators may be used to achieve the required losses.

Table 122–22—Channel insertion loss requirements for interoperation between 400GBASE-ER8 and 400GBASE-LR8

Direction	Min loss	Max loss	Unit
400GBASE-ER8 transmitter to 400GBASE-LR8 receiver	0.7	8.5	dB
400GBASE-LR8 transmitter to 400GBASE-ER8 receiver	9.7	15.8	dB

Change the title of 122.12 as follows:

122.12 Protocol implementation conformance statement (PICS) proforma for Clause 122, Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8[3]

122.12.1 Introduction

Change the first paragraph of 122.12.1 as follows:

The supplier of a protocol implementation that is claimed to conform to Clause 122, Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8, shall complete the following protocol implementation conformance statement (PICS) proforma.

122.12.2 Identification

122.12.2.2 Protocol summary

Change the table in 122.12.2.2 as follows:

Identification of protocol standard	IEEE Std 802.3cn-2019, Clause 122, Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8
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 802.3cn-2019.)	

Date of Statement	

[3] *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.

122.12.3 Major capabilities/options

Change the table in 122.12.3 as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
*FR4	200GBASE-FR4 PMD	122.7	Device supports requirements for 200GBASE-FR4 PHY	O.1	Yes [ ] No [ ]
*LR4	200GBASE-LR4 PMD	122.7	Device supports requirements for 200GBASE-LR4 PHY	O.1	Yes [ ] No [ ]
*ER4	200GBASE-ER4 PMD	122.7	Device supports requirements for 200GBASE-ER4 PHY	O.1	Yes [ ] No [ ]
*FR8	400GBASE-FR8 PMD	122.7	Device supports requirements for 400GBASE-FR8 PHY	O.1	Yes [ ] No [ ]
*LR8	400GBASE-LR8 PMD	122.7	Device supports requirements for 400GBASE-LR8 PHY	O.1	Yes [ ] No [ ]
*ER8	400GBASE-ER8 PMD	122.7	Device supports requirements for 400GBASE-ER8 PHY	O.1	Yes [ ] No [ ]
*INS	Installation / cable	122.10	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]
TP1	Reference point TP1 exposed and available for testing	122.5.1	This point may be made available for use by implementers to certify component conformance	O	Yes [ ] No [ ]
TP4	Reference point TP4 exposed and available for testing	122.5.1	This point may be made available for use by implementers to certify component conformance	O	Yes [ ] No [ ]
DC	Delay constraints	122.5.1	Device conforms to delay constraints	M	Yes [ ]
SC	Skew constraints	122.5	Device conforms to Skew and Skew Variation constraints	M	Yes [ ]
*MD	MDIO capability	122.5	Registers and interface supported	O	Yes [ ] No [ ]

Change the title of 122.12.4 as follows:

122.12.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-FR4, 200GBASE-LR4, 200GBASE-ER4, 400GBASE-FR8, ~~and~~ 400GBASE-LR8, and 400GBASE-ER8

Insert the following new subclause (122.12.4.4a) after 122.12.4.4:

122.12.4.4a PMD to MDI optical specifications for 200GBASE-ER4

Item	Feature	Subclause	Value/Comment	Status	Support
ERF1	Transmitter meets specifications in Table 122–9	122.7.1	Per definitions in 122.8	ER4:M	Yes [ ] N/A [ ]
ERF2	Receiver meets specifications in Table 122–11	122.7.2	Per definitions in 122.8	ER4:M	Yes [ ] N/A [ ]

Insert the following new subclause (122.12.4.6a) after 122.12.4.6:

122.12.4.6a PMD to MDI optical specifications for 400GBASE-ER8

Item	Feature	Subclause	Value/Comment	Status	Support
ERE1	Transmitter meets specifications in Table 122–10	122.7.1	Per definitions in 122.8	ER8:M	Yes [ ] N/A [ ]
ERE2	Receiver meets specifications in Table 122–12	122.7.2	Per definitions in 122.8	ER8:M	Yes [ ] N/A [ ]

122.12.4.7 Optical measurement methods

Insert the following new item after item OM6 in the table in 122.12.4.7:

Item	Feature	Subclause	Value/Comment	Status	Support
OM6a	Transmitter transition time	122.8.6a	Each lane	M	Yes [ ]

122.12.4.8 Environmental specifications

Change the table in 122.12.4.8 as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	122.9.1	Conforms to IEC 60950-1	M	Yes [ ]
ES2	Laser safety—IEC Hazard Level 1	122.9.2	Conforms to Hazard Level 1 laser requirements defined in IEC 60825-1 and IEC 60825-2	!ER8:M	Yes [ ] N/A [ ]
ES2a	Laser safety—IEC Hazard Level 1M	122.9.2	Conforms to Hazard Level 1M laser requirements defined in IEC 60825-1 and IEC 60825-2	ER8:M	Yes [ ] N/A [ ]
ES3	Electromagnetic interference	122.9.5	Complies with applicable local and national codes for the limitation of electromagnetic interference	M	Yes [ ]

124. Physical Medium Dependent (PMD) sublayer and medium, type 400GBASE-DR4

124.7 PMD to MDI optical specifications for 400GBASE-DR4

124.7.1 400GBASE-DR4 transmitter optical specifications

Change Table 124–6 as follows:

Table 124–6—400GBASE-DR4 transmit characteristics

Description	Value	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Modulation format	PAM4	—
Lane wavelength (range)	1304.5 to 1317.5	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Average launch power, each lane (max)	4	dBm
Average launch power, each lane[a] (min)	–2.9	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	4.2	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[b]	–0.8	dBm
Launch power in OMA_{outer} minus TDECQ, each lane (min)	–2.2	dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	3.4	dB
TDECQ – $10\log_{10}(C_{eq})$[c] (max)	3.4	dB
Average launch power of OFF transmitter, each lane (max)	–15	dBm
Extinction ratio, each lane (min)	3.5	dB
Transmitter transition time (max)	17	ps
$RIN_{21.4}OMA$ (max)	–136	dB/Hz
Optical return loss tolerance (max)	21.4	dB
Transmitter reflectance[d] (max)	–26	dB

[a] Average launch power, each lane (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] Even if the TDECQ < 1.4 dB, the OMA_{outer} (min) must exceed these values.
[c] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.
[d] Transmitter reflectance is defined looking into the transmitter.

124.7.2 400GBASE-DR4 receive optical specifications

Change Table 124–7 as follows:

Table 124–7—400GBASE-DR4 receive characteristics

Description	Value	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Modulation format	PAM4	—
Lane wavelengths (range)	1304.5 to 1317.5	nm
Damage threshold[a], each lane	5	dBm
Average receive power, each lane (max)	4	dBm
Average receive power, each lane[b] (min)	–5.9	dBm
Receive power (OMA_{outer}), each lane (max)	4.2	dBm
Receiver reflectance (max)	–26	dB
Receiver sensitivity (OMA_{outer}), each lane[c] (max)	Equation (124–1)	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane[d] (max)	–1.9	dBm
Conditions of stressed receiver sensitivity test:[e]		
Stressed eye closure for PAM4 (SECQ), lane under test	3.4	dB
$SECQ - 10\log_{10}(C_{eq})$[f] (max), lane under test	3.4	dB
OMA_{outer} of each aggressor lane	4.2	dBm

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level. The receiver does not have to operate correctly at this input power.
[b] Average receive power, each lane (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 (OMA_{outer}), each lane (max) is informative and is defined for a transmitter with a value of SECQ up to 3.4 dB.
[d] Measured with conformance test signal at TP3 (see 124.8.9) for the BER specified in 124.1.1.
[e] These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.
[f] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.

124.8 Definition of optical parameters and measurement methods

124.8.1 Test patterns for optical parameters

Change Table 124–10 as follows:

Table 124–10—Test-pattern definitions and related subclauses

Parameter	Pattern	Related subclause
Wavelength	Square wave, 3, 4, 5, 6 or valid 400GBASE-R signal	124.8.2
Side mode suppression ratio	3, 5, 6 or valid 400GBASE-R signal	124.8.2
Average optical power	3, 5, 6 or valid 400GBASE-R signal	124.8.3

Table 124–10—Test-pattern definitions and related subclauses *(continued)*

Parameter	Pattern	Related subclause
Outer Optical Modulation Amplitude (OMA_{outer})	4 or 6	124.8.4
Transmitter and dispersion eye closure for PAM4 (TDECQ)	6	124.8.5
Extinction ratio	4 or 6	124.8.6
Transmitter transition time	Square wave or 6	124.8.6a
$RIN_{21.4}OMA$	Square wave	124.8.7
Stressed receiver conformance test signal calibration	6	124.8.9
Stressed receiver sensitivity	3 or 5	124.8.9

124.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

Change 124.8.5 as follows:

The TDECQ and TDECQ – $10\log_{10}(C_{eq})$ of each lane shall be within the limits given in Table 124–6 if measured using the methods specified in 121.8.5.1, 121.8.5.2, and 121.8.5.3 using a reference equalizer as described in 121.8.5.4 where T is the symbol period for 400GBASE-DR4, with the following exceptions:

— The signaling rate of the test pattern generator is as given in Table 124–6 and uses the test pattern specified for TDECQ in Table 124–10.

— The combination of the O/E converter and the oscilloscope has a 3 dB bandwidth of approximately 26.5625 GHz with a fourth-order Bessel-Thomson ~~filter~~ response to at least 1.3 × 53.125 GHz, and at frequencies above 1.3 × 53.125 GHz, the response should not exceed –20 dB~~with a bandwidth of approximately 26.5625 GHz~~. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

— The normalized noise power density spectrum *N*(*f*) is equivalent to white noise filtered by a fourth-order Bessel-Thomson response filter with a bandwidth of 26.5625 GHz.

Insert the following new subclause (124.8.6a) after 124.8.6:

124.8.6a Transmitter transition time

The transmitter transition time of each lane shall be within the limits given in Table 124–6 if measured using a test pattern specified for transmitter transition time in Table 124–10.

Transmitter transition time is defined as the slower of the time interval of the transition from 20% of OMA_{outer} to 80% of OMA_{outer}, or from 80% of OMA_{outer} to 20% of OMA_{outer}, for the rising and falling edges respectively, as measured through an O/E converter and oscilloscope with response defined as follows. The combined response of the O/E converter and oscilloscope has a 3 dB bandwidth of approximately 26.5625 GHz with a fourth-order Bessel-Thomson response to at least 1.3 × 53.125 GHz. At frequencies above 1.3 × 53.125 GHz, the response should not exceed –20 dB. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

The 0% level and the 100% level are P_0 and P_3 as defined by the OMA_{outer} measurement procedure (see 124.8.4), with the exception that the square wave test pattern can be used. When the SSPRQ pattern is used, the rising edge used for the measurement is that within the 00000333333 symbol sequence, and the falling edge is that within the 33333000000 symbol sequence.

124.8.9 Stressed receiver sensitivity

Change 124.8.9 as follows:

Stressed receiver sensitivity shall be within the limits given in Table 124–7 if measured using the method defined in 121.8.9 with the following exceptions:

— The SECQ of the stressed receiver conformance test signal is measured according to 124.8.5, except that the test fiber is not used. The transition time of the stressed receiver conformance test signal is no greater than the value specified in Table 124–6.

— With the Gaussian noise generator on and the sinusoidal jitter and sinusoidal interferer turned off, the $RIN_{21.4}OMA$ of the SRS test source should be no greater than the value specified in Table 124–6.

— The signaling rate of the test pattern generator and the extinction ratio of the E/O converter are as given in Table 124–6 using test patterns specified in Table 124–10.

— The required values of the “Stressed receiver sensitivity (OMA_{outer}), each lane (max)”, “Stressed eye closure for PAM4 (SECQ), lane under test”, “SECQ – $10\log_{10}(C_{eq})$ (max), lane under test”, and “OMA_{outer} of each aggressor lane” are as given in Table 124–7.

124.12 Protocol implementation conformance statement (PICS) proforma for Clause 124, Physical Medium Dependent (PMD) sublayer and medium, type 400GBASE-DR4[4]

124.12.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 400GBASE-DR4

124.12.4.4 Optical measurement methods

Insert the following new item after item OM6 in the table in 124.12.4.4:

Item	Feature	Subclause	Value/Comment	Status	Support
OM6a	Transmitter transition time	124.8.6a	Each lane	M	Yes [ ]

[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.

Clause 131 was added to IEEE Std 802.3-2018 by IEEE Std 803.3cd-2018.

131. Introduction to 50 Gb/s networks

131.1 Overview

131.1.2 Relationship of 50 Gigabit Ethernet to the ISO OSI reference model

Change item e) in 131.1.2 as follows:

e) The MDI as specified in Clause 136 for 50GBASE-CR, Clause 137 for 50GBASE-KR, Clause for 50GBASE-SR, and Clause 139 for 50GBASE-FR, ~~and~~ 50GBASE-LR, and 50GBASE-ER uses a one-lane data path.

131.1.3 Nomenclature

Insert the following new row at the end of Table 131–1:

Table 131–1—50 Gb/s PHYs

Name	Description
50GBASE-ER	50 Gb/s PHY using 50GBASE-R encoding over single-mode fiber, with reach up to at least 40 km (see Clause 139).

131.1.4 Physical Layer signaling systems

Change Table 131–3 as follows:

Table 131–3—PHY types and clause correlation (50GBASE optical)

PHY type	Clause[a]															
	78	132		133	134	135	135B	135C	135D	135E	135F	135G		139		
	EEE	RS	50GMII	50GBASE-R PCS	50GBASE-R RS-FEC	50GBASE-R PMA	LAUI-2 C2C	LAUI-2 C2M	50GAUI-2 C2C	50GAUI-2 C2M	50GAUI-1 C2C	50GAUI-1 C2M	50GBASE-SR PMD	50GBASE-FR PMD	50GBASE-LR PMD	50GBASE-ER PMD
50GBASE-SR	O	M	O	M	M	M	O	O	O	O	O	O	M			
50GBASE-FR	O	M	O	M	M	M	O	O	O	O	O	O		M		
50GBASE-LR	O	M	O	M	M	M	O	O	O	O	O	O			M	
50GBASE-ER	O	M	O	M	M	M	O	O	O	O	O	O				M

[a] O = Optional, M = Mandatory.

131.4 Delay constraints

Insert the following new row at the end of Table 131–4:

Table 131–4—Sublayer delay constraints (50GBASE)

Sublayer	Maximum (bit time)[a]	Maximum (pause_quanta)[b]	Maximum (ns)	Notes[c]
50GBASE-ER PMD	1 024	2	20.48	Includes 2 m of fiber. See 139.3.

[a] For 50GBASE-R, 1 bit time is equal to 20 ps. (See 1.4.160 for the definition of bit time.)
[b] For 50GBASE-R, 1 pause_quantum is equal to 10.24 ns. (See 31B.2 for the definition of pause_quanta.)
[c] Should there be a discrepancy between this table and the delay requirements of the relevant sublayer clause, the sublayer clause prevails.

Clause 138 was added to IEEE Std 802.3-2018 by IEEE Std 803.3cd-2018.

138. Physical Medium Dependent (PMD) sublayer and medium, type 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4

138.8 Definition of optical parameters and measurement methods

138.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

Delete the final item ("P_{th1}, P_{th2}, and P_{th3} are ... right histogram.") from the list of exceptions in 138.8.5.

138.8.10 Stressed receiver sensitivity

Delete the fifth item ("The restriction that ... does not apply.") from the list of exceptions in 138.8.10.