IEEE Standards

IEEE Std 802.3ak™-2004
(Amendment to IEEE Std 802.3™-2002
as amended by
IEEE Stds 802.3ae™-2002,
802.3af™-2003,
and 802.3aj™-2003)

802.3ak™

IEEE Standard for Information technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements

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

Amendment: Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE

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Approved 12 May 2004

American National Standards Institute

Approved 9 February 2004

IEEE-SA Standards Board

Abstract: This amendment to IEEE Std 802.3-2002 as amended by IEEE Std 802.3ae-2002, IEEE Std 802.3af-2003 and IEEE Std 802.3aj-2003 specifies a new physical layer medium dependent sublayer interface for 10Gb/s Ethernet. 10GBASE-CX4 specifies an equipment interconnect based on the 10 Gigabit Attachment Unit Interface (XAUI) for up to 15m of balanced shielded cabling.

Keywords: 802.3ak, 10GBASE-CX4,10 Gigabit Ethernet, cable assembly, physical medium dependent (PMD) sublayer, XAUI

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Introduction to IEEE Std 802.3ak-2004

(This introduction is not part of IEEE Std 802.3ak-2004, IEEE Standard for Information technology— Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements CSMA/CD Access Method and Physical Layer Specifications Amendment: Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4.)

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 802.3ae™). A historical listing of all projects that have added to or modified IEEE Std 802.3 follows as a part of this introductory material. The listing is in chronological order of project initiation and for each project describes: subject, clauses added (if any), approval dates, and committee officers.

The media access control (MAC) protocol specified in IEEE Std 802.3 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was included in the experimental Ethernet developed at Xerox Palo Alto Research Center. While the experimental Ethernet had a 2.94 Mb/s data rate, IEEE Std 802.3-1985 specified operation at 10 Mb/s. Since 1985 new media options, new speeds of operation, and new protocol capabilities have been added to IEEE Std 802.3.

Some of the major additions to IEEE Std 802.3 are identified 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 802.3x™ specified full duplex operation and a flow control protocol, IEEE Std 802.3z™ added 1000 Mb/s operation (also called Gigabit Ethernet) and IEEE Std 802.3ad specified link aggregation. These major additions are all now included in IEEE Std 802.3-2002 and are not available as separate documents.

Recent additions such as IEEE Std 802.3ae (also called 10 Gigabit Ethernet) and IEEE Std 802.3af™ (also called Power over Ethernet) are currently published as separate documents. These recent amendments are part of IEEE Std 802.3 and they are dependent on and reference information published in IEEE Std 802.3-2002.

At the date of IEEE Std 802.3ak publication, IEEE Std 802.3 is comprised of the following documents:

IEEE Std 802.3-2002

Section One—Includes Clause 1 through Clause 20 and Annexes A through H. 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 Clause32 and Annexes 22A through 32A. Section Two includes the specifications for 100 Mb/s operation and management attributes for multiple protocols and operational speeds.

Section Three—Includes Clause 34 through Clause 43 and Annexes 36A through 43C. Section Three includes the specifications for 1000 Mb/s operation.

IEEE Std 802.3ae-2002

Includes changes to IEEE Std 802.3-2002, and adds Clauses 44 through 53 and Annexes 44A through 50A. This amendment includes specifications for 10 Gb/s operation.

IEEE Std 802.3af-2003

Includes changes to IEEE Std 802.3-2002, and adds Clause 33 and Annexes 33A through 33E. This amendment includes specifications for the provision of power over 10BASE-T, 100BASE-TX and 1000BASE-T cabling.

IEEE Std 802.3aj™-2003

Includes changes to IEEE Std 802.3-2002 and IEEE Std 802.3ae-2002.

IEEE Std 802.3ak-2004

Includes changes to IEEE Std 802.3-2002, and IEEE Std 802.3ae-2002, and adds Clause 54. This amendment adds 10GBASE-CX4 specifications for 10 Gb/s operation over balanced shielded cabling.

IEEE 802.3 will continue to evolve. Revisions are anticipated to the above standards within the next few years to integrate approved changes into IEEE 802.3, to clarify existing material, to correct possible errors, and to incorporate new related material.

Conformance test methodology

An additional standard, IEEE Std 1802.3™ provides conformance test information for 10BASE-T.

IEEE Std 802.3ak-2004

IEEE Std 802.3ak-2004, Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4 is an amendment to IEEE Std 802.3. It includes changes to both IEEE Std 802.3-2002 and IEEE Std 802.3ae-2002. In a few cases, text published in IEEE Std 802.3-2002 is modified by IEEE Std 802.3ae-2002 and is subsequently modified by IEEE Std 802.3ak-2004. IEEE Std 802.3ak-2004 does not include any modifications to the text of IEEE Std 802.3af-2003 and IEEE Std 802.3aj-2003.

Historical listing of IEEE Std 802.3 projects

Included in IEEE Std 802.3-2002

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
802.3-1985, Original 10 Mb/s standard, MAC, PLS, AUI, 10BASE5	23 June 1983 (IEEE) 31 December 1984 (ANSI)	**Donald C. Loughry,** *Working Group Chair*
802.3a-1988 (Clause 10), 10 Mb/s MAU 10BASE2	15 November 1985 (IEEE) 28 December 1987 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Alan Flatman,** *Task Force Chair*
802.3b-1985 (Clause 11), 10 Mb/s Broadband MAU, 10BROAD36	19 September 1985 (IEEE) 28 February 1986 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Menachem Abraham,** *Task Force Chair*
802.3c-1985 (9.1–9.8), 10 Mb/s Baseband Repeater	12 December 1985 (IEEE) 4 June 1986 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Geoffrey O. Thompson,** *Task Force Chair*
802.3d-1987 (9.9), 10 Mb/s Fiber MAU, FOIRL	10 December 1987 (IEEE) 9 February 1989 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Steven Moustakas,** *Task Force Chair*
802.3e-1987 (Clause 12), 1 Mb/s MAU and Hub 1BASE5	11 June 1987 (IEEE) 15 December 1987 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Robert Galin,** *Task Force Chair*
802.3h-1990 (Clause 5), 10 Mb/s Layer Management, DTEs	28 September 1990 (IEEE) 11 March 1991 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Andy J. Luque,** *Task Force Chair*
802.3i-1990 (Clauses 13 and 14), 10 Mb/s UTP MAU, 10 BASE-T	28 September 1990 (IEEE) 11 March 1991 (ANSI)	**Donald C. Loughry**, *Working Group Chair* **Patricia Thaler,** *Task Force Chair (initial)* **Richard Anderson,** *Task Force Chair (final)*

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
802.3j-1993 (Clauses 15–18), 10 Mb/s Fiber MAUs 10BASE-FP, FB, and FL	15 September 1993 (IEEE) 15 March 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Keith Amundsen,** *Task Force Chair (initial)* **Frederick Scholl,** *Task Force Chair (final)* **Michael E. Lee,** *Technical Editor*
802.3k-1993 (Clause 19), 10 Mb/s Layer Management, Repeaters	17 September 1992 (IEEE) 8 March 1993 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*
802.3*l*-1992 (14.10), 10 Mb/s PICS Proforma 10BASE-T MAU	17 September 1992 (IEEE) 23 February 1993 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Mike Armstrong,** *Task Force Chair and Editor* **Paul Nikolich,** *Vice Chair* **William Randle,** *Editorial Coordinator*
802.3m-1995, Maintenance 2	21 September 1995 (IEEE) 16 July 1996 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
802.3n-1995, Maintenance 3	21 September 1995 (IEEE) 4 April 1996 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
802.3p-1993™ (Clause 20), Management, 10 Mb/s Integrated MAUs	17 June 1993 (IEEE) 4 January 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*
802.3q-1993™ (Clause 5), 10 Mb/s Layer Management, GDMO Format	17 June 1993 (IEEE) 4 January 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*
802.3r-1996 (8.8), Type 10BASE5 Medium Attachment Unit PICS proforma	29 July 1996 (IEEE) 6 January 1997 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Imre Juhász**, *Task Force Chair* **William Randle,** *Task Force Editor*
802.3s-1995, Maintenance 4	21 September 1995 (IEEE) 8 April 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
802.3t-1995, 120 Ω informative annex to 10BASE-T	14 June 1995 (IEEE) 12 January 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Jacques Christ,** *Task Force Chair*
802.3u-1995 (Clauses 21–30), Type 100BASE-T MAC parameters, Physical Layer, MAUs, and Repeater for 100 Mb/s Operation	14 June 1995 (IEEE) 4 April 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Peter Tarrant,** *Task Force Chair (Phase 1)* **Howard Frazier,** *Task Force Chair (Phase 2)* **Paul Sherer,** *Editor-in-Chief (Phase 1)* **Howard Johnson,** *Editor-in-Chief (Phase 2)* **Colin Mick,** *Comment Editor*
802.3v-1995, 150 Ω informative annex to 10BASE-T	12 December 1995 (IEEE) 16 July 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Larry Nicholson,** *Task Force Chair*
802.3x-1997 and 802.3y-1997 (Revisions to 802.3, Clauses 31 and 32), Full Duplex Operation and Type 100BASE-T2	20 March 1997 (IEEE) 5 September 1997 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Rich Seifert,** *Task Force Chair and Editor (802.3x)* **J. Scott Carter,** *Task Force Chair (802.3y)* **Colin Mick**, *Task Force Editor (802.3y)*
802.3z-1998™ (Clauses 34–39, 41–42), Type 1000BASE-X MAC Parameters, Physical Layer, Repeater, and Management Parameters for 1000 Mb/s Operation	25 June 1998 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Howard M. Frazier, Jr.,** *Task Force Chair and Editor* **Howard W. Johnson,** *Task Force Editor*

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
802.3aa-1998, Maintenance 5	25 June 1998 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **Colin Mick**, *Task Force Editor (100BASE-T Maintenance)*
802.3ab-1999 (Clause 40), Physical Layer Parameters and Specifications for 1000 Mb/s Operation Over 4 Pair of Category 5 Balanced Copper Cabling, Type 1000BASE-T	26 June 1999 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary* **George Eisler**, *Task Force Chair* **Colin Mick**, *Task Force Editor*
802.3ac-1998, Frame Extensions for Virtual Bridged Local Area Network (VLAN) Tagging on 802.3 Networks	16 September 1998 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Andy J. Luque,** *Working Group Secretary* **Ian Crayford,** *Task Force Chair* **Rich Seifert,** *Task Force Editor*
802.3ad-2000 (Clause 43), Aggregation of Multiple Link Segments	30 March 2000 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary* **Steven Haddock,** *Task Force Chair* **Tony Jeffree,** *Co-Editor* **Rich Seifert,** *CoEditor*
802.3-2002 (802.3ag, Maintenance 6, Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and physical layer specifications	14 January 2002 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary*

Temporarily published as separate documents

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
802.3ae-2002,(Clauses 44–53) Media Access Control (MAC) Parameters, Physical Layers, and Management Parameters for 10 Gb/s Operation	13 June 2002 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary* **R. Jonathan Thatcher,** *Task Force Chair* **Stephen Haddock,** *Task Force Vice Chair* **Bradley J. Booth,** *Task Force Editor* **Lacreshia Laningham,** *Task Force Assistant Editor* **Benjamin Brown,** *Logic Track Chair* **Walter Thirion,** *Optical Track Chair*
802.3af-2003, (Clause 33) Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)	12 June 2003 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair—Phase 1* **Robert M. Grow,** *Working Group Chair—Phase 2* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Secretary—Phase 1* **Steven B. Carlson,** *Secretary—Phase 2* **Steven B. Carlson,** *Task Force Chair* **Michael S. McCormack,** *Editor—Phase 1* **John J. Jetzt,** *Editor—Phase 2* **Chad M. Jones,** *Comment Editor*

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
802.3aj-2003, Maintenance 7	11 September 2003 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Chair* **Steven B. Carlson,** *Working Group Secretary* **Catherine K. N. Berger,** *Task Force Editor*
802.3ak-2004, Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4	9 February 2004 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Steven B. Carlson,** *Working Group Secretary* **Daniel J. Dove,** *Task Force Chair* **Howard A. Baumer,** *Task Force Editor*

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The following is a list of chairs and editors during the development of this standard:

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Steven B. Carlson, *Working Group Secretary*
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Also included are the following nonvoting IEEE-SA Standards Board liaisons:

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Richard DeBlasio, DOE Representative
Alan Cookson, NIST Representative

Michelle D. Turner
IEEE Standards Project Editor

Contents

List of special symbols

For the benefit of those who have received this document by electronic means, what follows is a list of special symbols and operators. If any of these symbols or operators fail to display or print out correctly, the editors hope that this table will aid in interpreting any funny blobs and strokes appearing in the body of the document.

Special symbols and operators

Printed Character	Meaning	Font
∗	Boolean AND	Symbol
+	Boolean OR, Arithmetic addition	Symbol
^	Boolean XOR	Times
!	Boolean NOT	Symbol
<	Less than	Symbol
≤	Less than or equal to	Symbol
=	Equal to	Symbol
≠	Not equal to	Symbol
≥	Greater than or equal to	Symbol
>	Greater than	Symbol
⇐	Assignment operator	Symbol
∈	Indicates membership	Symbol
∉	Indicates nonmembership	Symbol
±	Plus or minus (a tolerance)	Symbol
°	Degrees (as in degrees Celsius)	Symbol
∑	Summation	Symbol
—	Big dash (Em dash)	Times
–	Little dash (En dash)	Times
†	Dagger	Times
‡	Double dagger	Times

IEEE Standard for Information technology—
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Local and metropolitan area networks—
Specific requirements—

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

Amendment: Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4

[These changes are part of IEEE Std 802.3™-2002.]

EDITORIAL NOTE—This amendment is based on the current edition of IEEE Std 802.3-2002 as amended by IEEE Std 802.3ae™-2002, IEEE Std 802.3af™-2003, and IEEE Std 802.3aj™-2003. The editing instructions define how to merge the material contained here into this base document set to form the new comprehensive standard as created by the addition of IEEE Std 802.3ak™-2004.

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

1. Introduction

1.3 Normative references

Insert the following alphabetically into 1.3.

IEC 61076-3-113, Ed. 1.0 (draft, 48B/1327/NP, 14 March 2003.) [48B Secretariat 1327][1] Connectors for electronic equipment—Part 3-113: Screened, serial multi-conductor cable to board connectors suitable for 10 Gbit/sec data rates.

1.4 Definitions

Insert each of the following alphabetically into 1.4. Renumber as required.

1.4.xxx cable assembly: An assembly containing one or more insulated conductors, terminated in a connector at each end, for use as a link segment between MDIs.

1.4.xxx twinaxial cable: A cable similar to coaxial cable in construction but containing two insulated inner conductors rather than one.

1.4.xxx twinaxial cable assembly: An assembly containing multiple twinaxial cables, terminated in a connector at each end, for use as a link segment between MDIs, such as that used in 10GBASE-CX4.

30. 10 Mb/s, 100 Mb/s, 1000 Mb/s, and 10 Gb/s Management

30.5.1.1.2 aMAUType

Change 30.5.1.1.2 (as modified by IEEE 802.3ae-2002) as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

A GET-SET ENUMERATION that meets the requirements of the description below:

global	undefined
other	See 30.2.5
unknown	Initializing, true state or type not yet known
AUI	no internal MAU, view from AUI
10BASE5	Thick coax MAU as specified in Clause 8
FOIRL	FOIRL MAU as specified in 9.9
10BASE2	Thin coax MAU as specified in Clause 10
10BROAD36	Broadband DTE MAU as specified in Clause 11
10BASE-T	UTP MAU as specified in Clause 14, duplex mode unknown
10BASE-THD	UTP MAU as specified in Clause 14, half duplex mode
10BASE-TFD	UTP MAU as specified in Clause 14, full duplex mode
10BASE-FP	Passive fiber MAU as specified in Clause 16
10BASE-FB	Synchronous fiber MAU as specified in Clause 17
10BASE-FL	Asynchronous fiber MAU as specified in Clause 18, duplex mode unknown
10BASE-FLHD	Asynchronous fiber MAU as specified in Clause 18, half duplex mode
10BASE-FLFD	Asynchronous fiber MAU as specified in Clause 18, full duplex mode

[1]Presently, IEC 61076-3-113 is a committee draft.

100BASE-T4	Four-pair Category 3 UTP as specified in Clause 23
100BASE-TX	Two-pair Category 5 UTP as specified in Clause 25, duplex mode unknown
100BASE-TXHD	Two-pair Category 5 UTP as specified in Clause 25, half duplex mode
100BASE-TXFD	Two-pair Category 5 UTP as specified in Clause 25, full duplex mode
100BASE-FX	X fiber over PMD as specified in Clause 26, duplex mode unknown
100BASE-FXHD	X fiber over PMD as specified in Clause 26, half duplex mode
100BASE-FXFD	X fiber over PMD as specified in Clause 26, full duplex mode
100BASE-T2	Two-pair Category 3 UTP as specified in Clause 32, duplex mode unknown
100BASE-T2HD	Two-pair Category 3 UTP as specified in Clause 32, half duplex mode
100BASE-T2FD	Two-pair Category 3 UTP as specified in Clause 32, full duplex mode
1000BASE-X	X PCS/PMA as specified in Clause 36 over undefined PMD, duplex mode unknown
1000BASE-XHD	X PCS/PMA as specified in Clause 36 over undefined PMD, half duplex mode
1000BASE-XFD	X PCS/PMA as specified in Clause 36 over undefined PMD, full duplex mode
1000BASE-LX	X fiber over long-wavelength laser PMD as specified in Clause 38, duplex mode unknown
1000BASE-LXHD	X fiber over long-wavelength laser PMD as specified in Clause 38, half duplex mode
1000BASE-LXFD	X fiber over long-wavelength laser PMD as specified in Clause 38, full duplex mode
1000BASE-SX	X fiber over short-wavelength laser PMD as specified in Clause 38, duplex mode unknown
1000BASE-SXHD	X fiber over short-wavelength laser PMD as specified in Clause 38, half duplex mode
1000BASE-SXFD	X fiber over short-wavelength laser PMD as specified in Clause 38, full duplex mode
1000BASE-CX	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, duplex mode unknown
1000BASE-CXHD	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, half duplex mode
1000BASE-CXFD	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, full duplex mode
1000BASE-T	Four-pair Category 5 UTP PHY to be specified in Clause 40, duplex mode unknown
1000BASE-THD	Four-pair Category 5 UTP PHY to be specified in Clause 40, half duplex mode
1000BASE-TFD	Four-pair Category 5 UTP PHY to be specified in Clause 40, full duplex mode
10GBASE-X	X PCS/PMA as specified in Clause 48 over undefined PMD
10GBASE-LX4	X fibre over 4 lane 1310nm optics as specified in Clause 53
10GBASE-CX4	X copper over 8 pair 100-Ohm balanced cable as specified in Clause 54
10GBASE-R	R PCS/PMA as specified in Clause 49 over undefined PMD
10GBASE-ER	R fibre over 1550nm optics as specified in Clause 52
10GBASE-LR	R fibre over 1310nm optics as specified in Clause 52
10GBASE-SR	R fibre over 850nm optics as specified in Clause 52
10GBASE-W	W PCS/PMA as specified in Clauses 49 and 50 over undefined PMD
10GBASE-EW	W fibre over 1550nm optics as specified in Clause 52
10GBASE-LW	W fibre over 1310nm optics as specified in Clause 52
10GBASE-SW	W fibre over 850nm optics as specified in Clause 52
802.9a	Integrated services MAU as specified in IEEE Std 802.9 ISLAN-16T

44. Introduction to 10 Gb/s baseband network

44.1.1 Scope

Change the first paragraph in 44.1.1 (inserted by IEEE Std 802.3ae-2002) to read as follows:

10 Gigabit Ethernet uses the IEEE 802.3 MAC sublayer, connected through a 10 Gigabit Media Independent Interface (XGMII) to Physical Layer entities such as 10GBASE-SR, 10GBASE-LX4, 10GBASE-CX4, 10GBASE-LR, 10GBASE-ER, 10GBASE-SW, 10GBASE-LW, and 10GBASE-EW.

44.1.2 Objectives

Change 44.1.2 (inserted by IEEE Std 802.3ae-2002) to read as follows:

The following are the objectives of 10 Gigabit Ethernet:

f) Support operation over a twinaxial cable assembly for wiring closet and data center applications.
g) Support a BER objective of 10^{-12}.

44.1.3 Relationship of 10 Gigabit Ethernet to the ISO OSI reference model

Change item d) in 44.1.3 (inserted by IEEE Std 802.3ae-2002) to read as follows:

d) The MDI as specified in Clause 53 for 10GBASE-LX4, in Clause 54 for 10GBASE-CX4, and in Clause 52 for other PMD types.

44.1.4.4 Physical Layer signaling systems

Change the second paragraph in 44.1.4.4 (inserted by IEEE Std 802.3ae-2002) to read as follows:

The term 10GBASE-X, specified in Clause 48, ~~and~~ Clause 53, and Clause 54, refer to a specific family of physical layer implementations based upon 8B/10B data coding method. The 10GBASE-X family of physical layer implementations is composed of 10GBASE-LX4 and 10GBASE-CX4.

Change Table 44–1 (inserted by IEEE Std 802.3ae-2002) by inserting a new row and a new column as follows:

Table 44–1—Nomenclature and clause correlation

Nomenclature	Clause								
	48	49	50	51	52			53	54
	8B/10B PCS & PMA	64B/66B PCS	WIS	Serial PMA	850 nm Serial PMD	1310 nm Serial PMD	1550 nm Serial PMD	1310 nm WDM PMD	4-Lane electrical PMD
10GBASE-SR		M[a]		M	M				
10GBASE-SW		M	M	M	M				
10GBASE-LX4	M							M	
10GBASE-CX4	M								M
10GBASE-LR		M		M		M			
10GBASE-LW		M	M	M		M			
10GBASE-ER		M		M			M		
10GBASE-EW		M	M	M			M		

[a]M = Mandatory

Change the fourth paragraph in 44.1.4.4 (inserted by IEEE Std 802.3ae-2002) to read as follows:

Specifications of each physical layer device are contained in Clause 52 ~~and Clause 53~~through Clause 54 inclusive.

44.3 Delay constraints

Change the second paragraph in 44.3 (inserted by IEEE Std 802.3ae-2002) to read as follows:

Equation (44-1) specifies the calculation of bit time per meter of fiber or electrical cable based upon the parameter n, which represents the ratio of the speed of ~~light~~ electromagnetic propagation in the fiber or electrical cable to the speed of light in a vacuum. The value of n should be available from the fiber or electrical cable manufacturer, but if no value is known then a conservative delay estimate can be calculated using a default value of $n = 0.66$. The speed of light in a vacuum is $c = 3 \times 10^8$ m/s. Table 44–3 can be used to convert fiber or electrical cable delay values specified relative to the speed of light or in nanoseconds per meter.

Change Table 44-2 (inserted by IEEE Std 802.3ae-2002) by inserting a new row as follows:

Table 44–2—Round-trip delay constraints (informative)

Sublayer	Maximum (bit time)	Maximum (pause_quanta)	Notes
MAC, RS and MAC Control	8192	16	See 46.1.4.
XGXS and XAUI	4096	8	Round-trip of 2 XGXS and trace for both directions. See 47.2.2.
10GBASE-X PCS and PMA	2048	4	See 48.5.
10GBASE-R PCS	3584	7	See 49.2.15.
WIS	14336	28	See 50.3.7.
LX4 PMD	512	1	Includes 2 meters of fiber. See 53.2.
CX4 PMD	512	1	See 54.3
Serial PMA and PMD	512	1	Includes 2 meters of fiber. See 52.2.

44.4 Protocol Implementation Conformance Statement (PICS) proforma

Change the first paragraph in 44.4 (as inserted by IEEE Std 802.3ae-2002) to read as follows:

The supplier of a protocol implementation that is claimed to conform to any part of IEEE 802.3, Clause 45 through Clause ~~53~~54, demonstrates compliance by completing a Protocol Implementation Conformance Statement (PICS) proforma.

45. Management Data Input/Output (MDIO) Interface

45.2.1 PMA/PMD registers

Change Table 45–2 (inserted by IEEE Std 802.3ae-2002) by inserting a new row and changing a previously existing row as follows:

Table 45–2—PMA/PMD registers

Register address	Register name
1.0	PMA/PMD control 1
1.1	PMA/PMD status 1
1.2, 1.3	PMA/PMD device identifier
1.4	PMA/PMD speed ability
1.5, 1.6	PMA/PMD devices in package
1.7	10G PMA/PMD control 2
1.8	10G PMA/PMD status 2
1.9	10G PMD transmit disable
1.10	10G PMD receive signal detect
<u>1.11</u>	<u>10G PMA/PMD extended ability register</u>
1.1~~1~~<u>2,</u>~~ through~~ 1.13	Reserved
1.14, 1.15	PMA/PMD package identifier
1.16 through 1.32 767	Reserved
1.32 768 through 1.65 535	Vendor specific

45.2.1.6.1 PMA/PMD type selection (1.7.2:0)

Change the first paragraph in 45.2.1.6.1 (inserted by IEEE Std 802.3ae-2002) to read as follows:

The PMA/PMD type of the 10G PMA/PMD shall be selected using bits 2 through 0. The PMA/PMD type abilities of the 10G PMA/PMD are advertised in bits <u>9 and </u>7 through 0 of the 10G PMA/PMD status 2 register<u> and bit 0 of the 10G PMA/PMD extended ability register</u>. A 10G PMA/PMD shall ignore writes to the PMA/PMD type selection bits that select PMA/PMD types it has not advertised in the status register. It is the responsibility of the STA entity to ensure that mutually acceptable MMD types are applied consistently across all the MMDs on a particular PHY.

Change Bit 1.7.2:0 in Table 45–7 (inserted by IEEE Std 802.3ae-2002) to read as follows:

Table 45–7—10G PMA/PMD control 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.7.15:3	Reserved	Value always 0, writes ignored	R/W
1.7.2:0	PMA/PMD type selection	2 1 0 1 1 1= 10GBASE-SR PMA/PMD type 1 1 0= 10GBASE-LR PMA/PMD type 1 0 1= 10GBASE-ER PMA/PMD type 1 0 0= 10GBASE-LX4 PMA/PMD type 0 1 1= 10GBASE-SW PMA/PMD type 0 1 0= 10GBASE-LW PMA/PMD type 0 0 1= 10GBASE-EW PMA/PMD type 0 0 0= ~~Reserved~~ 10GBASE-CX4 PMA/PMD type	R/W

[a]R/W = Read/Write

45.2.1.7 10G PMA/PMD status 2 register (Register 1.8)

Change Bit 1.8.9 in Table 45–8 (inserted by IEEE Std 802.3ae-2002) to read as follows:

Table 45–8—10G PMA/PMD status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.8.15:14	Device present	15 14 1 0 = Device responding at this address 1 1 = No device responding at this address 0 1 = No device responding at this address 0 0 = No device responding at this address	RO
1.8.13	Transmit fault ability	1 = PMA/PMD has the ability to detect a fault condition on the transmit path 0 = PMA/PMD does not have the ability to detect a fault condition on the transmit path	RO
1.8.12	Receive fault ability	1 = PMA/PMD has the ability to detect a fault condition on the receive path 0 = PMA/PMD does not have the ability to detect a fault condition on the receive path	RO
1.8.11	Transmit fault	1 = Fault condition on transmit path 0 = No fault condition on transmit path	RO/LH
1.8.10	Receive fault	1 = Fault condition on receive path 0 = No fault condition on receive path	RO/LH
1.8.9	~~Reserved~~ Extended abilities	~~Ignore on read~~ 1 = PMA/PMD has extended abilities listed in register 1.11 0 = PMA/PMD does not have extended abilities	RO

Table 45–8—10G PMA/PMD status 2 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.8.8	PMD transmit disable ability	1 = PMD has the ability to disable the transmit path 0 = PMD does not have the ability to disable the transmit path	RO
1.8.7	10GBASE-SR ability	1 = PMA/PMD is able to perform 10GBASE-SR 0 = PMA/PMD is not able to perform 10GBASE-SR	RO
1.8.6	10GBASE-LR ability	1 = PMA/PMD is able to perform 10GBASE-LR 0 = PMA/PMD is not able to perform 10GBASE-LR	RO
1.8.5	10GBASE-ER ability	1 = PMA/PMD is able to perform 10GBASE-ER 0 = PMA/PMD is not able to perform 10GBASE-ER	RO
1.8.4	10GBASE-LX4 ability	1 = PMA/PMD is able to perform 10GBASE-LX4 0 = PMA/PMD is not able to perform 10GBASE-LX4	RO
1.8.3	10GBASE-SW ability	1 = PMA/PMD is able to perform 10GBASE-SW 0 = PMA/PMD is not able to perform 10GBASE-SW	RO
1.8.2	10GBASE-LW ability	1 = PMA/PMD is able to perform 10GBASE-LW 0 = PMA/PMD is not able to perform 10GBASE-LW	RO
1.8.1	10GBASE-EW ability	1 = PMA/PMD is able to perform 10GBASE-EW 0 = PMA/PMD is not able to perform 10GBASE-EW	RO
1.8.0	PMA loopback ability	1 = PMA has the ability to perform a loopback function 0 = PMA does not have the ability to perform a loopback function	RO

[a]RO = Read Only, LH = Latching High

45.2.1.7.4 Transmit fault (1.8.11)

Change the first paragraph of 45.2.1.7.4 (inserted by IEEE Std 802.3ae-2002) to read as follows:

When read as a one, bit 1.8.11 indicates that the PMA/PMD has detected a fault condition on the transmit path. When read as a zero, bit 1.8.11 indicates that the PMA/PMD has not detected a fault condition on the transmit path. Detection of a fault condition on the transmit path is optional and the ability to detect such a condition is advertised by bit 1.8.13. A PMA/PMD that is unable to detect a fault condition on the transmit path shall return a value of zero for this bit. The description of the transmit fault function for serial PMDs is given in 52.4.8. The description of the transmit fault function for WWDM PMDs is given in 53.4.10. <u>The description of the transmit fault function for the 10GBASE-CX4 PMD is given in 54.5.10.</u> The transmit fault bit shall be implemented with latching high behavior.

45.2.1.7.5 Receive fault (1.8.10)

Change the first paragraph of 45.2.1.7.5 (inserted by IEEE Std 802.3ae-2002) to read as follows:

When read as a one, bit 1.8.10 indicates that the PMA/PMD has detected a fault condition on the receive path. When read as a zero, bit 1.8.10 indicates that the PMA/PMD has not detected a fault condition on the receive path. Detection of a fault condition on the receive path is optional and the ability to detect such a condition is advertised by bit 1.8.12. A PMA/PMD that is unable to detect a fault condition on the receive path shall return a value of zero for this bit. The description of the receive fault function for serial PMDs is given in 52.4.9. The description of the receive fault function for WWDM PMDs is given in 53.4.11. The description of the receive fault function for the 10GBASE-CX4 PMD is given in 54.5.11. The receive fault bit shall be implemented with latching high behavior.

Insert the following subclause before 45.2.1.7.6 (inserted by IEEE Std 802.3ae-2002). Renumber current 45.2.17.6 through 45.2.1.7.14.

45.2.1.7.6 PMA/PMD extended abilities (1.8.9)

When read as a one, bit 1.8.9 indicates that the PMA/PMD has extended abilities listed in register 1.11. When read as a zero, bit 1.8.9 indicates that the PMA/PMD does not have extended abilities.

45.2.1.8 10G PMD transmit disable register (Register 1.9)

Change the first paragraph in 45.2.1.8 (inserted by IEEE Std 802.3ae-2002) to read as follows:

The assignment of bits in the 10G PMD transmit disable register is shown in Table 45–9. The transmit disable functionality is optional and a PMD's ability to perform the transmit disable functionality is advertised in the PMD transmit disable ability bit 1.8.8. A PMD that does not implement the transmit disable functionality shall ignore writes to the 10G PMD transmit disable register and may return a value of zero for all bits. A PMD device that operates using a single wavelength and has implemented the transmit disable function shall use bit 1.9.0 to control the function. Such devices shall ignore writes to bits 1.9.4:1 and return a value of zero for those bits when they are read. The transmit disable function for serial PMDs is described in 52.4.7. The transmit disable function for wide wavelength division multiplexing (WWDM) PMDs is described in 53.4.7. The transmit disable function for four-lane electrical PMDs is described in 54.5.6.

45.2.1.8.5 Global PMD transmit disable (1.9.0)

Change the third paragraph in 45.2.1.8.5 (inserted by IEEE Std 802.3ae-2002) to read as follows:

For multiple wavelength or lane PMD types, transmission will be disabled on all lanes when this bit is set to one. When this bit is set to zero, the lanes are individually controlled by their corresponding transmit disable bits 1.9.4:1.

45.2.1.9 10G PMD receive signal detect register (Register 1.10)

Change the first paragraph in 45.2.1.9 (inserted by IEEE Std 802.3ae-2002) to read as follows:

The assignment of bits in the 10G PMD receive signal detect register is shown in Table 45–10. The 10G PMD receive signal detect register is mandatory. PMD types that use only a single wavelength indicate the status of the receive signal detect using bit 1.10.0 and return a value of zero for bits 1.10.4:1. PMD types that use multiple wavelengths or lanes indicate the status of each lane in bits 1.10.4:1 and the logical AND of those bits in bit 1.10.0

45.2.1.9.5 Global PMD receive signal detect (1.10.0)

Change the third paragraph in 45.2.1.9.5 (inserted by IEEE Std 802.3ae-2002) to read as follows:

Multiple wavelength or multiple lane PMD types indicate the global status of the lane-by-lane signal detect indications using this bit. This bit is read as a one when all the lane signal detect indications are one; otherwise, this bit is read as a zero.

Insert the following subclause before 45.2.1.10 (inserted by IEEE Std 802.3ae-2002). Renumber current 45.2.1.10 to 45.2.1.11, and renumber current Table 45–11 through Table 45–65

45.2.1.10 10G PMA/PMD extended ability register (Register 1.11)

The assignment of bits in the 10G PMA/PMD extended ability register is shown in Table 45–11. All of the bits in the 10G PMA/PMD extended ability register are read only; a write to the 10G PMA/PMD extended ability register shall have no effect.

Table 45–11—10G PMA/PMD Extended Ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.11.15:1	Reserved	Ignore on read	RO
1.11.0	10GBASE-CX4 ability	1 = PMA/PMD is able to perform 10GBASE-CX4 0 = PMA/PMD is not able to perform 10GBASE-CX4	RO

[a]RO = Read Only

Change PICS item MM43 in 45.5.5.3 (inserted by IEEE Std 802.3-2002) as follows:

45.5.5.3 PMA/PMD management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MM43a	Writes to the extended ability register have no effect	45.2.1.10		PMA:M	Yes [ ] N/A [ ]
MM43b	Unique identifier is composed of OUI, model number and revision	45.2.1.1~~0~~1		PMA:M	Yes [ ] N/A [ ]

46. Reconciliation Sublayer (RS) and 10 Gigabit Media Independent Interface (XGMII)

46.1.2 Application

Change the last paragraph in 46.1.2 (inserted by IEEE Std 802.3ae-2002) to read as follows:

This interface is used to provide media independence so that an identical media access controller may be used with all 10GBASE PHY types~~ using either serial or wavelength division multiplexed optics~~.

48. Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 10GBASE-X

48.1 Overview

Change the first paragraph in 48.1 (inserted by IEEE Std 802.3ae-2002) to read as follows:

This clause specifies the Physical Coding Sublayer (PCS) and the Physical Medium Attachment (PMA) sublayer that are common to a family of 10 Gb/s Physical Layer implementations, collectively known as 10GBASE-X. The 10GBASE-LX4 PMD described in Clause 53 ~~is a member~~ and 10GBASE-CX4 PMD described in Clause 54 are members of the 10GBASE-X PHY family. The term 10GBASE-X is used when referring to issues common to any of the variants within this family.

48.1.2 Relationship of 10GBASE-X to other standards

Change Figure 48–1 (inserted by IEEE Std 802.3ae-2002) by inserting 10GBASE-CX4 below 10GBASE-LX4 as follows:

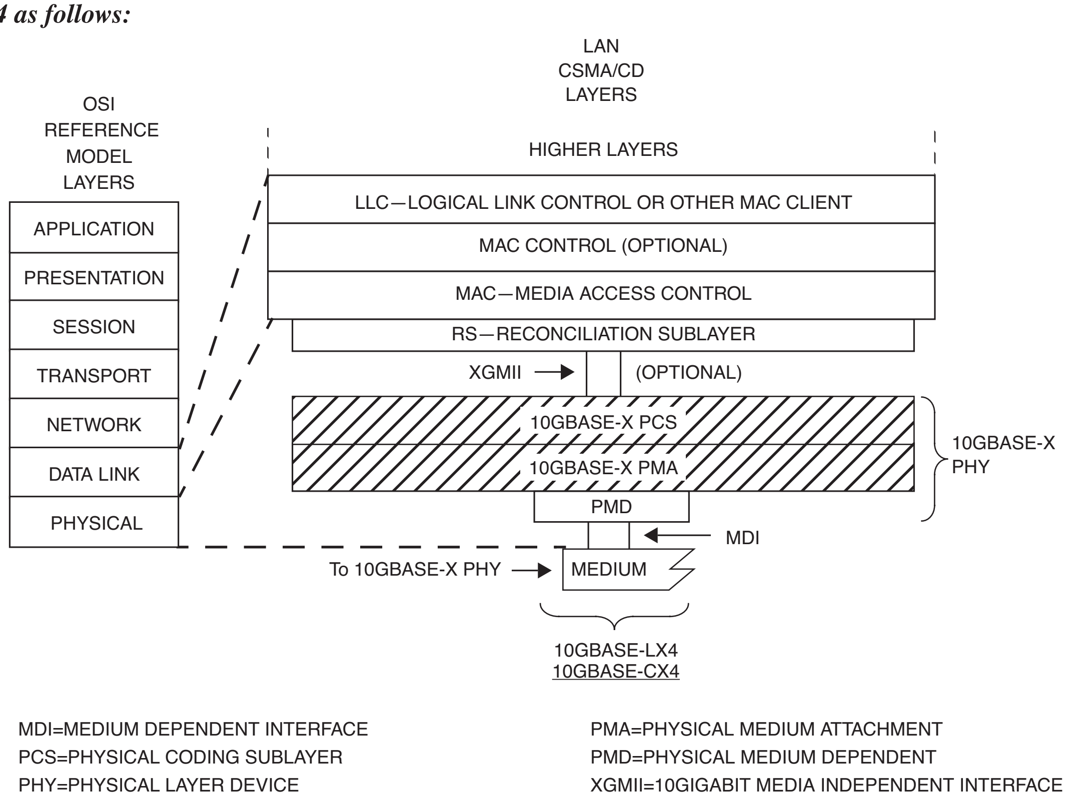

Figure 48–1—10GBASE-X PCS and PMA relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE CSMA/CD LAN Model

48.1.3.3 Physical Medium Dependent (PMD) sublayer

Change the first paragraph in 48.1.3.3 (inserted by IEEE Std 802.3ae-2002) to read as follows:

10GBASE-X supports the PMD sublayer and MDI specified in Clause 53 and Clause 54. The 10GBASE-LX4 ~~PMD performs~~ and 10GBASE-CX4 PMDs perform the following functions:

48.2.6.1.3 Variables

Change the variable descriptions for rx_lane <3:0> and tx_lane <3:0> in 48.2.6.1.3 (inserted by IEEE Std 802.3ae-2002) to read as follows:

rx_lane <3:0>
A vector of bits representing the serial lanes used to convey data from the PMD to the PMA via the PMD_UNITDATA.indicate service primitive as specified in Clause 53 or Clause 54.

tx_lane <3:0>
A vector of bits representing the serial lanes used to convey data from the PMA to the PMD via the PMD_UNITDATA.request service primitive as specified in Clause 53 or Clause 54.

48.2.6.1.6 Messages

Change the message description for PMD_SIGNAL.indicate(signal_detect<3:0>) in 48.2.6.1.6 (inserted by IEEE Std 802.3ae-2002) to read as follows:

PMD_SIGNAL.indicate(signal_detect <3:0>)
Indicates the status of the incoming link signal. A signal mapped to the PMD_SIGNAL.indicate(SIGNAL_DETECT) service primitive specified in Clause 53 or Clause 54. signal_detect <n> is set to the same value for all lanes n where n=0:3.

48.3.1 Functions within the PMA

Change the note in 48.3.1 (inserted by IEEE Std 802.3ae-2002) to read as follows:

NOTE—Strict adherence to manufacturer-supplied guidelines for the operation and use of PMA serializer components is required to meet the jitter specifications of Clause 47, ~~and~~ Clause 53 and Clause 54. The supplied guidelines should address the quality of power supply filtering associated with the transmit clock generator, and also the purity of the reference clock fed to the transmit clock generator.

48.7.3 Major capabilities/options

Change the unnumbered table in 48.7.3 (inserted by IEEE Std 802.3ae-2002) by inserting a row as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
MD	MDIO	45, 48.1.3.1	Registers and interface supported	O	Yes [ ] No [ ]
XGXS	Support of XAUI/XGXS	47, 48.1.5		O	Yes [ ] No [ ]
XGE	XGMII compatibility interface	46, 48.1.3.1	Compatibility interface is supported	O	Yes [ ] No [ ]
LX4	Support of 10GBASE-LX4 PMD	53, 48.1.3.3		O	Yes [ ] No [ ]
CX4	Support of 10GBASE-CX4 PMD	54, 48.1.3.3		O	Yes [ ] No [ ]

Annex 30B

(normative)

GDMO and ASN.1 definitions for management

30B.2 ASN.1 module for CSMA/CD managed objects

Change 30B.2 (as modified by IEEE Std 802.3ae-2002) as follows:

```
TypeValue::= ENUMERATED {
        global                  (0),     --undefined
        other                   (1),     --undefined
        unknown                 (2),     --initializing, true state not yet known
        AUI                     (7),     --no internal MAU, view from AUI
        10BASE5                 (8),     --Thick coax MAU as specified in Clause 8
        FOIRL                   (9),     --FOIRL MAU as specified in 9.9
        10BASE2                 (10),    --Thin coax MAU as specified in Clause 10
        10BROAD36               (11),    --Broadband DTE MAU as specified in Clause 11
        10BASE-T                (14),    --UTP MAU as specified in Clause 14, duplex mode
                                           unknown
        10BASE-THD              (141),   --UTP MAU as specified in Clause 14, half duplex mode
        10BASE-TFD              (142),   --UTP MAU as specified in Clause 14, full duplex mode
        10BASE-FP               (16),    --Passive fiber MAU as specified in Clause 16
        10BASE-FB               (17),    --Synchronous fiber MAU as specified in Clause 17
        10BASE-FL               (18),    --Asynchronous fiber MAU as specified in Clause 18, duplex
                                           mode unknown
        10BASE-FLHD             (181),   --Asynchronous fiber MAU as specified in Clause 18, half
                                           duplex mode
        10BASE-FLFD             (182),   --Asynchronous fiber MAU as specified in Clause 18, full
                                           duplex mode
        100BASE-T4              (23),    --Four-pair Category 3 UTP as specified in Clause 23
        100BASE-TX              (25),    --Two-pair Category 5 UTP as specified in Clause 25, duplex
                                           mode unknown
        100BASE-TXHD            (251),   --Two-pair Category 5 UTP as specified in Clause 25, half
                                           duplex mode
        100BASE-TXFD            (252),   --Two-pair Category 5 UTP as specified in Clause 25, full
                                           duplex mode
        100BASE-FX              (26),    --X fiber over PMD as specified in Clause 26, duplex mode
                                           unknown
        100BASE-FXHD            (261),   --X fiber over PMD as specified in Clause 26, half duplex mode
        100BASE-FXFD            (262),   --X fiber over PMD as specified in Clause 26, full duplex mode
        100BASE-T2              (32),    --Two-pair Category 3 UTP as specified in Clause 32, duplex
                                           mode unknown
        100BASE-T2HD            (321),   --Two-pair Category 3 UTP as specified in Clause 32, half
                                           duplex mode
        100BASE-T2FD            (322),   --Two-pair Category 3 UTP as specified in Clause 32, full
                                           duplex mode
        1000BASE-X              (36),    --X PCS/PMA as specified in Clause 36 over unknown PMD,
                                         duplex mode unknown
        1000BASE-XHD            (361),   --X  PCS/PMA as specified in Clause 36 over unknown PMD,
                                         half duplex mode
        1000BASE-XFD            (362),   --X PCS/PMA as specified in Clause 36 over unknown PMD,
                                          full duplex mode
        1000BASE-LX             (381),   --X fiber over long-wavelength laser PMD as specified in
                                         Clause 38, duplex mode unknown
        1000BASE-LXHD           (382),   --X fiber over long-wavelength laser PMD as specified in
                                         Clause 38, half duplex mode
        1000BASE-LXFD           (383),   --X fiber over long-wavelength laser PMD as specified in
                                         Clause 38, full duplex mode
```

1000BASE-SX	(384),	--X fiber over short-wavelength laser PMD as specified in Clause 38, duplex mode unknown
1000BASE-SXHD	(385),	--X fiber over short-wavelength laser PMD as specified in Clause 38, half duplex mode
1000BASE-SXFD	(386),	--X fiber over short-wavelength laser PMD as specified in Clause 38, full duplex mode
1000BASE-CX	(39),	--X copper over 150-Ohm balanced cable PMD as specified in Clause 39, duplex mode unknown
1000BASE-CXHD	(391),	--X copper over 150-Ohm balanced cable PMD as specified in Clause 39, half duplex mode
1000BASE-CXFD	(392),	--X copper over 150-Ohm balanced cable PMD as specified in Clause 39, full duplex mode
1000BASE-T	(40),	--Four-pair Category 5 UTP PHY as specified in Clause 40, duplex mode unknown
1000BASE-THD	(401),	--Four-pair Category 5 UTP PHY as specified in Clause 40, half duplex mode
1000BASE-TFD	(402),	--Four-pair Category 5 UTP PHY as specified in Clause 40, full duplex mode
10GBASE-X	(48)	--X PCS/PMA as specified in Clause 48 over undefined PMD
10GBASE-LX4	(481)	--X fibre over WWDM optics as specified in Clause 53
10GBASE-CX4	(482)	--X copper over 8 pair 100-Ohm balanced cable as specified in Clause 54
10GBASE-R	(49)	--R PCS/PMA as specified in Clause 49 over undefined PMD
10GBASE-ER	(491)	--R fibre over 1550nm optics as specified in Clause 52
10GBASE-LR	(492)	--R fibre over 1310nm optics as specified in Clause 52
10GBASE-SR	(493)	--R fibre over 850nm optics as specified in Clause 52
10GBASE-W	(50)	--W PCS/PMA as specified in Clauses 49 and 50 over undefined PMD
10GBASE-EW	(501)	--W fibre over 1550nm optics as specified in Clause 52
10GBASE-LW	(502)	--W fibre over 1310nm optics as specified in Clause 52
10GBASE-SW	(503)	--W fibre over 850nm optics as specified in Clause 52
802.9a	(99)	--Integrated services MAU as specified in IEEE Std 802.9 ISLAN-16T

}

Annex 48B

(informative)

Jitter test methods

Change the first paragraph of Annex 48B (inserted by IEEE Std 802.3ae-2002) to read as follows:

This annex specifies the definitions and measurement requirements for the jitter specification of the XGXS and XAUI described in Clause 47, ~~and~~ the 10GBASE-LX4 PMD described in Clause 53 and the 10GBASE-CX4 PMD described in Clause 54. These measurement methods and specifications are intended to be used for jitter and wander compliance testing, but are not definitive.

54. Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-CX4

54.1 Overview

This clause specifies the 10GBASE-CX4 PMD (including MDI) and the baseband medium. In order to form a complete PHY (physical layer device), a PMD is combined with the appropriate sublayers (see Table 54–1) and with the management functions, which are optionally accessible through the management interface defined in Clause 45, or equivalent.

Table 54–1—PHY (physical layer) clauses associated with the 10GBASE-CX4 PMD

Associated clause	10GBASE-CX4
46—XGMII[a]	Optional
47—XGXS and XAUI	Optional
48—10GBASE-X PCS/PMA	Required

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

Figure 54–1 shows the relationship of the 10GBASE-CX4 PMD sublayers and MDI to the ISO/IEC Open System Interconnection (OSI) reference model.

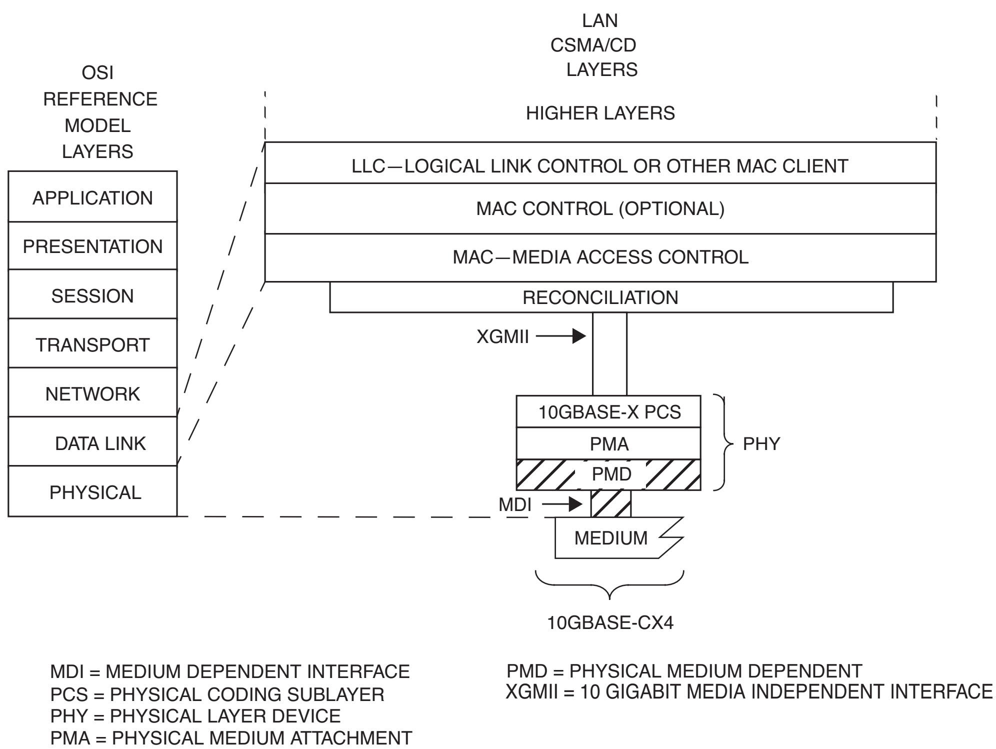

Figure 54–1—10GBASE-CX4 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

54.2 Physical Medium Dependent (PMD) service interface

The 10GBASE-CX4 PMD utilizes the PMD service interface defined in 53.1.1. The PMD service interface is summarized below:

PMD_UNITDATA.request
PMD_UNITDATA.indicate
PMD_SIGNAL.indicate

54.3 Delay constraints

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

The sum of the transmit and the receive delays contributed by the 10GBASE-CX4 PMD shall be no more than 512 BT or 1 pause_quantum.

54.4 PMD MDIO function mapping

The 10GBASE-CX4 PMD uses the same MDIO function mapping as 10GBASE-LX4, as defined in 53.3.

54.5 PMD functional specifications

The 10GBASE-CX4 PMD performs the transmit and receive functions (which convey data between the PMD service interface and the MDI), and provides various management functions if the optional MDIO is implemented.

54.5.1 Link block diagram

A 10GBASE-CX4 link is shown in Figure 54–2. For purposes of system conformance, the PMD sublayer is standardized at the points described in this subclause. The electrical transmit signal is defined at the output end of the mated connector (TP2). Unless specified otherwise, all transmitter measurements and tests defined in 54.6.3 are made at TP2. Unless specified otherwise, all receiver measurements and tests defined in 54.6.4 are made at the input end of the mated connector (TP3). A mated connector pair has been included in both the transmitter and receiver specifications defined in 54.6.3 and 54.6.4. Two mated connector pairs have been included in the cable assembly specifications defined in 54.7.

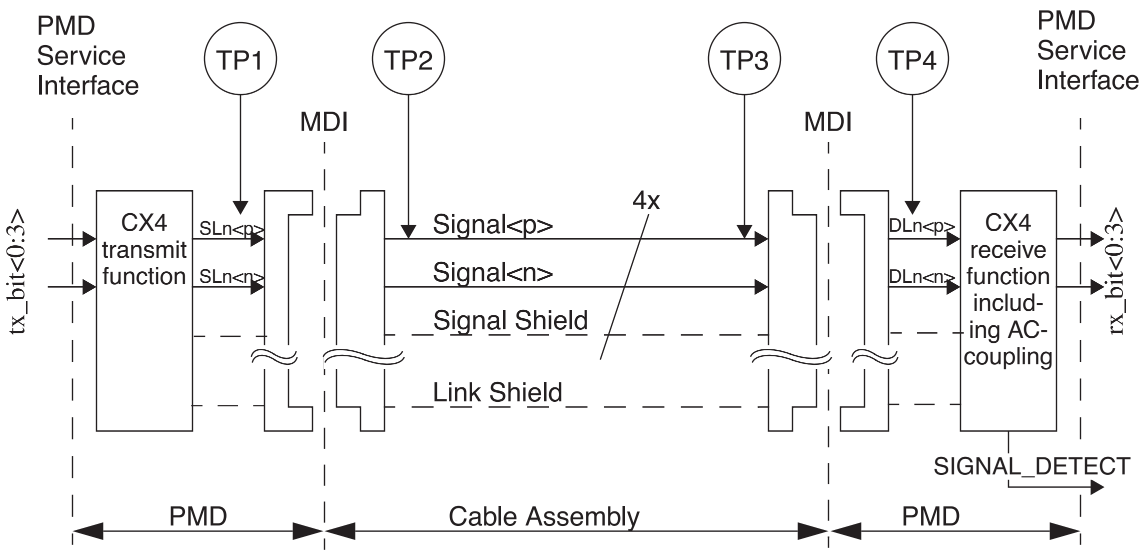

Figure 54–2—10GBASE-CX4 link (half link is shown)

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

54.5.2 PMD Transmit function

The PMD Transmit function shall convert the four logical bit streams requested by the PMD service interface message PMD_UNITDATA.request (tx_bit<0:3>) into four separate electrical signal streams. The four electrical signal streams shall then be delivered to the MDI, all according to the transmit electrical specifications in 54.6.3. A positive output voltage of SLn<p> minus SLn<n> (differential voltage) shall correspond to tx_bit = ONE.

The PMD shall convey the bits received from the PMD service interface using the message PMD_UNITDATA.request(tx_bit<0:3>) to the MDI lanes, where (SL0<p>/<n>, SL1<p>/<n>, SL2<p>/<n>, SL3<p>/<n>) = tx_bit<0:3>.

54.5.3 PMD Receive function

The PMD Receive function shall convert the four electrical signal streams from the MDI into four logical bit streams for delivery to the PMD service interface using the message PMD_UNITDATA.indicate (rx_bit<0:3>), all according to the receive electrical specifications in 54.6.4. A positive input voltage level in each signal stream of DLn<p> minus DLn<n> (differential voltage) shall correspond to a rx_bit = ONE.

The PMD shall convey the bits received from the MDI lanes to the PMD service interface using the message PMD_UNITDATA.indicate(rx_bit<0:3>), where rx_bit<0:3> = (DL0<p>/<n>, DL1<p>/<n>, DL2<p>/<n>, DL3<p>/<n>).

54.5.4 Global PMD signal detect function

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

SIGNAL_DETECT is a global indicator of the presence of electrical signals on all four lanes. The PMD receiver is not required to verify whether a compliant 10GBASE-CX4 signal is being received; however, it shall assert SIGNAL_DETECT = OK within 100 µs after the absolute differential peak-to-peak input voltage on each of the four lanes at the MDI has exceeded 175 mV for at least 1 UI (unit interval).

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

Table 54–2—SIGNAL_DETECT summary (informative)

Parameter	Value	Units
SIGNAL_DETECT = OK level (maximum differential peak-to-peak amplitude)	175	mV
SIGNAL_DETECT = OK width (minimum)	1	UI
SIGNAL_DETECT = OK assertion time (maximum)	100	µs
SIGNAL_DETECT = FAIL level (minimum differential peak-to-peak amplitude)	50	mV
SIGNAL_DETECT = FAIL de-assertion time maximum minimum	 500 250	 µs µs

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

54.5.5 PMD lane-by-lane signal detect function

When the MDIO is implemented, each PMD_signal_detect_n value, where n represents the lane number in the range 0:3, shall be continuously updated in response to the amplitude of the receive signal on its associated lane, according to the requirements of 54.5.4.

54.5.6 Global PMD transmit disable function

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

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

54.5.7 PMD lane-by-lane transmit disable function

The PMD_transmit_disable_n function is optional. It allows the electrical transmitters in each lane to be selectively disabled.

a) When a PMD_transmit_disable_n variable is set to ONE, this function shall turn off the transmitter associated with that variable such that the corresponding transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 54–3.

b) If a PMD_fault (54.5.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
c) Loopback, as defined in 54.5.8, shall not be affected by PMD_transmit_disable_n.

NOTE—Turning off a transmitter can be disruptive to a network.

54.5.8 Loopback mode

Loopback mode shall be provided for the 10GBASE-CX4 PMD by the transmitter and receiver of a device as a test function to the device. When loopback mode is selected, transmission requests passed to the transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. The transmitters shall not be disabled when loopback mode is enabled. A device must be explicitly placed in loopback mode because loopback mode is not the normal mode of operation of a device. Loopback applies to all lanes as a group (the lane 0 transmitter is directly connected to the lane 0 receiver, the lane 1 transmitter is directly connected to the lane 1 receiver, etc.). The method of implementing loopback mode is not defined by this standard.

Control of the loopback function is specified in 45.2.1.1.4.

NOTES

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

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

54.5.9 PMD fault function

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

54.5.10 PMD transmit fault function

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

54.5.11 PMD receive fault function

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

54.6 MDI Electrical specifications for 10GBASE-CX4

54.6.1 Signal levels

The 10GBASE-CX4 MDI is a low-swing AC-coupled differential interface. Transmitter to receiver path AC-coupling, as defined in 54.6.4.3, allows for interoperability between components operating from different supply voltages. Low-swing differential signaling provides noise immunity and improved electromagnetic interference (EMI).

54.6.2 Signal paths

The 10GBASE-CX4 MDI signal paths are point-to-point connections. Each path corresponds to a 10GBASE-CX4 MDI lane and comprises two complementary signals, which form a balanced differential pair. There are four differential paths in each direction for a total of eight pairs, or sixteen connections. The signal paths are intended to operate on twinaxial cable assemblies up to 15 m in length, as described in 54.7.

54.6.3 Transmitter characteristics

Transmitter characteristics shall meet specifications at TP2, unless otherwise noted. The specifications are summarized in Table 54–3 and detailed in 54.6.3.1 through 54.6.3.9.

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

Parameter	Subclause reference	Value	Units
Signaling speed, per lane	54.6.3.3	3.125 ± 100 ppm	GBd
Unit interval nominal	54.6.3.3	320	ps
Differential peak-to-peak output voltage maximum minimum	54.6.3.4	 1200 800	 mV mV
Differential peak-to-peak output voltage difference (maximum)	54.6.3.4	150	mV
Common mode voltage limits maximum minimum	54.6.3.4	 1.9 –0.4	 V V
Differential output return loss minimum	54.6.3.5	[See Equation (54–1) and Equation (54–2)]	dB
Differential output template	54.6.3.6	(See Figure 54–6 and Table 54–4)	V
Transition time maximum minimum	54.6.3.7	 130 60	 ps ps
Output jitter (peak-to-peak) Random jitter Deterministic jitter[a] Total jitter	54.6.3.8	 0.27 0.17 0.35	 UI UI UI

[a]Deterministic jitter is already incorporated into the differential output template.

54.6.3.1 Test fixtures

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

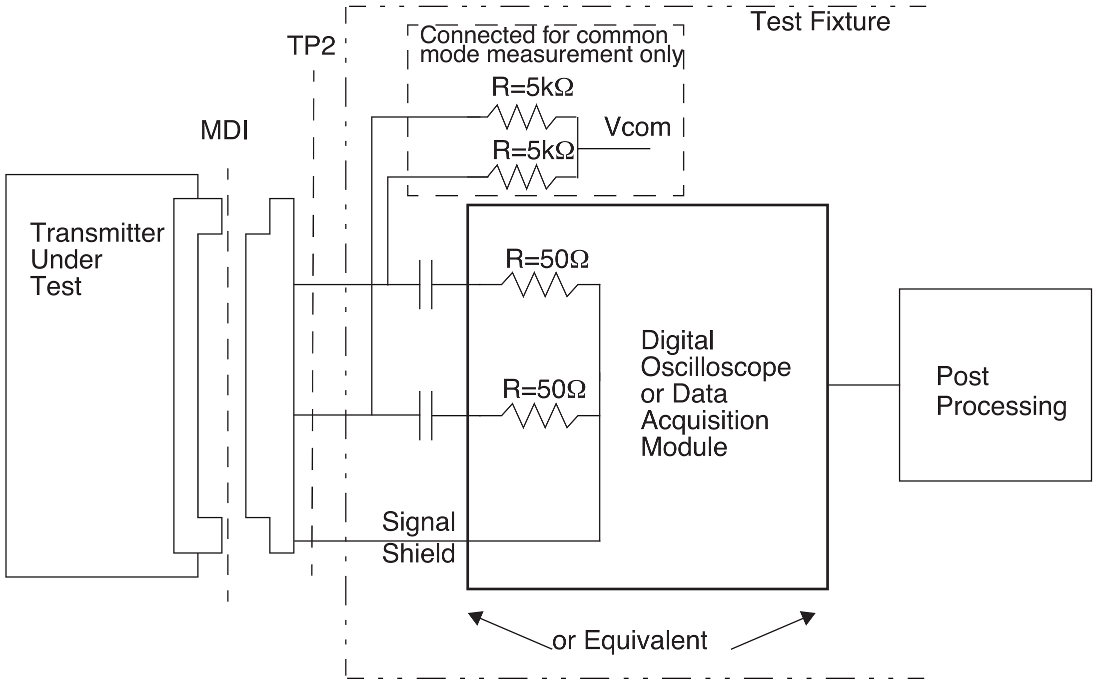

Figure 54–3—Transmit test fixture

54.6.3.2 Test-fixture impedance

The nominal differential impedance of the transmit test fixture depicted in Figure 54–3 shall be 100 Ω with a return loss greater than 20 dB from 100 MHz to 2000 MHz.

54.6.3.3 Signaling speed range

The 10GBASE-CX4 MDI signaling speed shall be 3.125 GBd ±100 ppm. The corresponding unit interval is nominally 320 ps.

54.6.3.4 Output amplitude

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

a) The transmitter maximum differential peak-to-peak output voltage shall be less than 1200 mV.
b) The minimum differential peak-to-peak output voltage shall be greater than 800 mV.
c) The maximum difference between any two lanes' differential peak-to-peak output voltage shall be less than or equal to 150 mV.

See Figure 54–4 for an illustration of the definition of differential peak-to-peak output voltage.

DC-referenced logic levels are not defined since the receiver is AC-coupled. The common-mode voltage of SLn<p> and SLn<n> shall be between –0.4 V and 1.9 V with respect to Signal Shield as measured at Vcom in Figure 54–3.

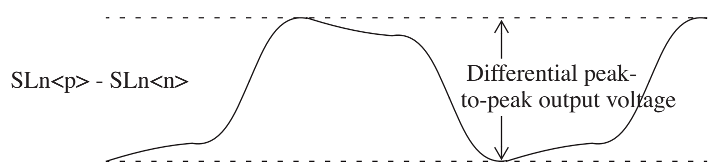

Figure 54–4—Transmitter differential peak-to-peak output voltage definition

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

54.6.3.5 Output return loss

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

$$\text{Return Loss}(f) \geq 10 \qquad (54\text{–}1)$$

for 100 MHz ≤ f < 625 MHz and

$$\text{Return Loss}(f) \geq 10 - 10 \times \log\left(\frac{f}{625}\right) \qquad (54\text{–}2)$$

for 625 MHz ≤ f ≤ 2000 MHz.

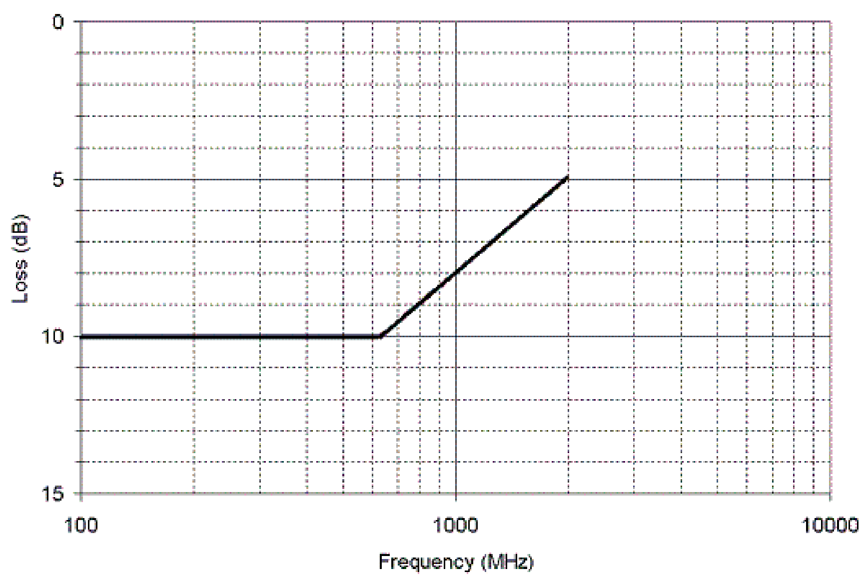

Figure 54–5—Minimum transmit differential output return loss (informative)

54.6.3.6 Differential output template

The transmitter differential output signal is defined at TP2, as shown in Figure 54–2. The transmitter shall provide equalization such that the output waveform falls within the template shown in Figure 54–6 for the test pattern specified in 48A.2, with all other transmitters active. Voltage and time coordinates for inflection points on Figure 54–6 are given in Table 54–4. The signals on each pair at TP2 shall meet the transmit template specifications when connected to the transmitter test fixture shown in Figure 54–3, with all other transmitters active. The waveform under test shall be normalized by using the following procedure:

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

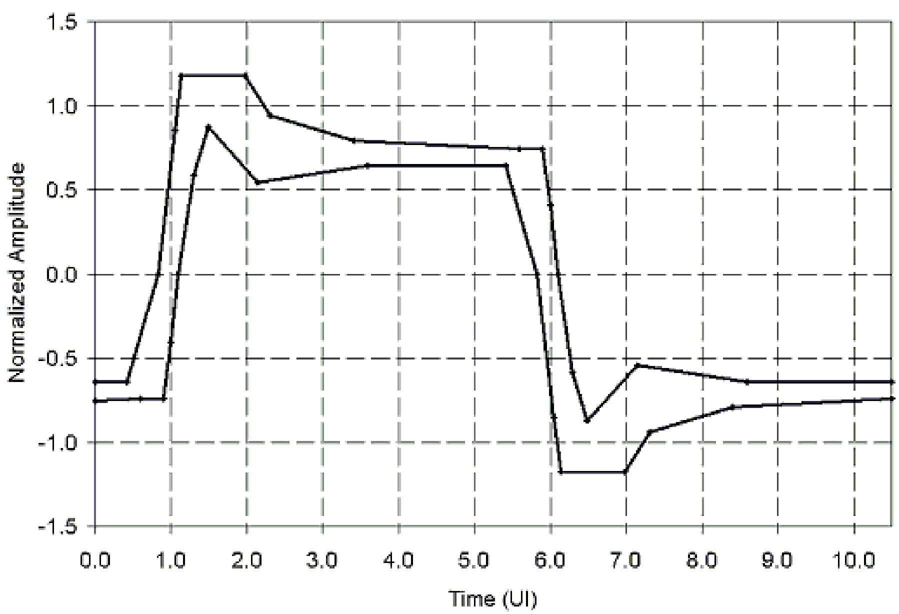

Figure 54–6—Normalized transmit template

Table 54–4—Normalized transmit time domain template

Upper limit				Lower limit			
Time (UI)	Amplitude	Time (UI)	Amplitude	Time (UI)	Amplitude	Time (UI)	Amplitude
0.000	–0.640	5.897	0.740	0.000	–0.754	5.409	0.640
0.409	–0.640	5.997	0.406	0.591	–0.740	5.828	0.000
0.828	0.000	6.094	0.000	0.897	–0.740	6.050	–0.856
1.050	0.856	6.294	–0.586	0.997	–0.406	6.134	–1.175
1.134	1.175	6.491	–0.870	1.094	0.000	6.975	–1.175
1.975	1.175	7.141	–0.546	1.294	0.586	7.309	–0.940
2.309	0.940	8.591	–0.640	1.491	0.870	8.500	–0.790
3.409	0.790	10.500	–0.640	2.141	0.546	10.500	–0.742
5.591	0.740	—	—	3.591	0.640	—	—

54.6.3.7 Transition time

The rising-edge transition time shall be between 60 ps and 130 ps as measured at the 20% and 80% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 48A.1. The falling edge transition time shall be between 60 ps and 130 ps as measured at the 80% and 20% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 48A.1.

54.6.3.8 Transmit jitter

The transmitter shall satisfy the jitter requirements of 54.6.3.9 with a maximum total jitter of 0.350 UI peak-to-peak, a maximum deterministic component of 0.170 UI peak-to-peak and a maximum random component of 0.270 UI peak-to-peak. Jitter specifications include all but 10^{-12} of the jitter population. Transmit jitter test requirements are specified in 54.6.3.9.

54.6.3.9 Transmit jitter test requirements

Transmit jitter is defined with respect to a test procedure resulting in a BER bathtub curve such as that described in Annex 48B. For the purpose of jitter measurement, the effect of a single-pole, high-pass filter with a 3 dB point at 1.875 MHz is applied to the jitter. The data pattern for jitter measurements shall be the CJPAT pattern defined in Annex 48A.5. All four lanes of the 10GBASE-CX4 transceiver are active in both directions, and opposite ends of the link use asynchronous clocks. Crossing times are defined with respect to the mid-point (0 V) of the AC-coupled differential signal.

54.6.4 Receiver characteristics

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

Table 54–5—Receiver characteristics' summary (informative)

Parameter	Subclause reference	Value	Units
Bit error ratio	54.6.4.1	10^{-12}	
Signaling speed, per lane	54.6.4.2	3.125 ± 100 ppm	GBd
Unit interval (UI) nominal	54.6.4.2	320	ps
Receiver coupling	54.6.4.3	AC	—
Differential input peak-to-peak amplitude (maximum)	54.6.4.4	1200	mV
Return loss[a] differential (minimum)	54.6.4.5	[See Equation (54–1) and Equation (54–2)]	dB

[a]Relative to 100 Ω differential.

54.6.4.1 Bit error ratio

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

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

54.6.4.2 Signaling speed range

A 10GBASE-CX4 receiver shall comply with the requirements of 54.6.4.1 for any signaling speed in the range 3.125 GBd ± 100 ppm. The corresponding unit interval is nominally 320 ps.

54.6.4.3 AC-coupling

The 10GBASE-CX4 receiver shall be AC-coupled to the cable assembly to allow for maximum interoperability between various 10 Gbps components. AC-coupling is considered to be part of the receiver for the purposes of this standard unless explicitly stated otherwise. It should be noted that there may be various methods for AC-coupling in actual implementations.

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

54.6.4.4 Input signal amplitude

10GBASE-CX4 receivers shall accept differential input signal peak-to-peak amplitudes produced by compliant transmitters connected without attenuation to the receiver, and still meet the BER requirement specified in 54.6.4.1. Note that this may be larger than the 1200 mV differential maximum of 54.6.3.4 due to the actual transmitter output and receiver input impedances. The input impedance of a receiver can cause the minimum signal into a receiver to differ from that measured when the receiver is replaced with a 100 Ω test load. Since the 10GBASE-CX4 receiver is AC-coupled, the absolute voltage levels with respect to the receiver ground are dependent on the receiver implementation.

54.6.4.5 Input return loss

For frequencies from 100 MHz to 2000 MHz, the differential return loss (in dB with *f* in MHz) of the receiver shall be greater than or equal to Equation (54–1) and Equation (54–2). This input impedance requirement applies to all valid input levels. The reference impedance for differential return loss measurements is 100 Ω.

54.7 Cable assembly characteristics

The 10GBASE-CX4 cable assembly is primarily intended as a point-to-point interface of up to 15 m between network ports using controlled impedance cables. All cable assembly measurements are to be made between TP1 and TP4 as shown in Figure 54–2. These cable assembly specifications are based upon twinaxial cable characteristics, but other cable types are acceptable if the specifications are met.

Table 54–6—Cable assembly differential characteristics' summary (informative)

Description	Reference	Value	Unit
Maximum Insertion loss at 1.5625 GHz	54.7.2 and 54.7.3	16	dB
Minimum Return loss at 1.5625 GHz	54.7.3	12.0	dB
Minimum NEXT loss at 1.5625 GHz	54.7.4.1	31.8	dB
Minimum MDNEXT loss at 1.5625 GHz	54.7.4.2	29.8	dB
Minimum ELFEXT loss at 1.5625 GHz	54.7.5.1	23.3	dB
Minimum MDELFEXT loss at 1.5625 GHz	54.7.5.2	21.1	dB

54.7.1 Characteristic impedance and reference impedance

The nominal differential characteristic impedance of the cable assembly is 100 Ω. The differential reference impedance for cable assembly specifications shall be 100 Ω.

54.7.2 Cable assembly insertion loss

The insertion loss (in dB with *f* in MHz) of each pair of the 10GBASE-CX4 cable assembly shall be:

$$\text{Insertion Loss }(f) \le (0.2629 \times \sqrt{f}) + (0.0034 \times f) + \left(\frac{12.76}{\sqrt{f}}\right) \qquad (54\text{–}3)$$

for all frequencies from 100 MHz to 2000 MHz. This includes the attenuation of the differential cabling pairs and the assembly connectors.

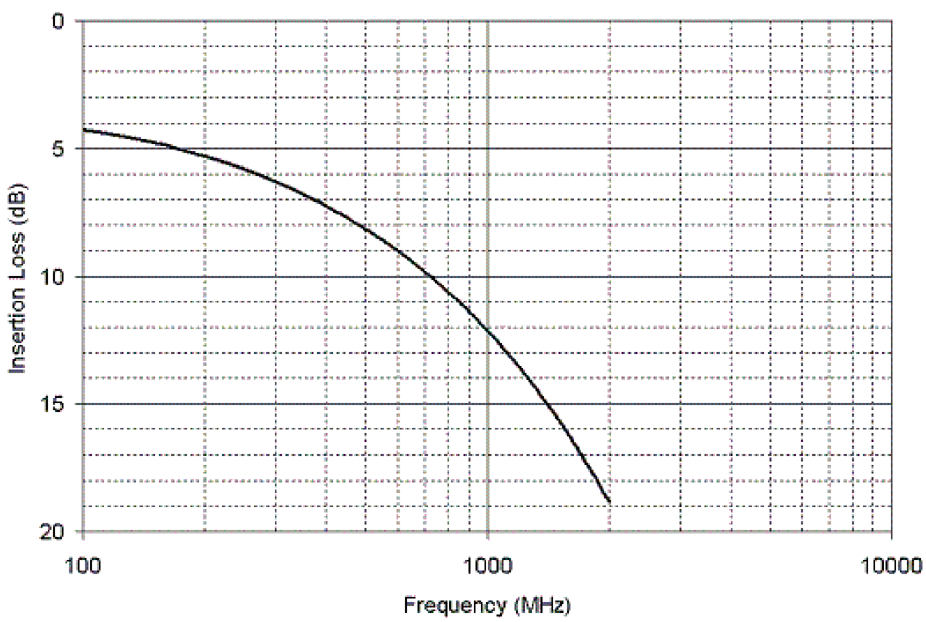

Figure 54–7—Maximum cable assembly insertion loss (informative)

54.7.3 Cable assembly return loss

The return loss (in dB with *f* in MHz) of each pair of the 10GBASE-CX4 cable assembly shall be:

$$\text{Return Loss } (f) \geq 22.35 - 17.19 \times \log\left(\frac{f}{100}\right) \quad (54\text{–}4)$$

for 100 MHz ≤ *f* < 400 MHz.

$$\text{Return Loss } (f) \geq 12 \quad (54\text{–}5)$$

for 400 MHz ≤ *f* ≤ 2000 MHz.

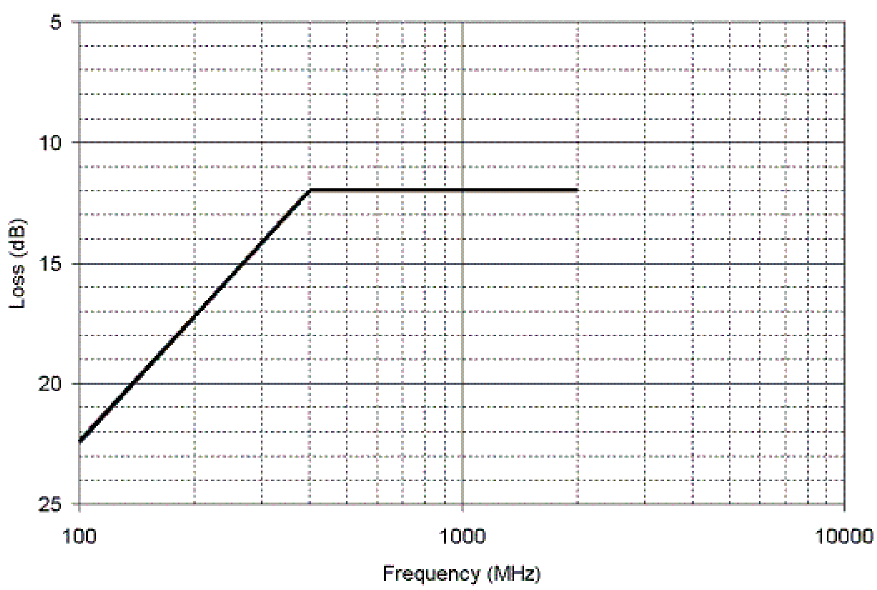

Figure 54–8—Minimum cable assembly return loss (informative)

54.7.4 Near-End Crosstalk (NEXT)

54.7.4.1 Differential Near-End Crosstalk

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

$$\text{NEXT } (f) \geq 30 - 17 \times \log\left(\frac{f}{2000}\right) \quad (54\text{–}6)$$

for all frequencies from 100 MHz to 2000 MHz.

54.7.4.2 Multiple Disturber Near-End Crosstalk (MDNEXT)

Since four transmit and four receive lanes are used to transfer data between PMDs, the NEXT that is coupled into a receive lane will be from the four transmit lanes. To ensure the total NEXT coupled into a receive lane is limited, multiple disturber NEXT loss is specified as the power sum of the individual NEXT losses.

The Power Sum loss between a receive lane and the four transmit lanes (in dB with f in MHz) shall be at least:

$$MDNEXT(f) \geq 28 - 17 \times \log\left(\frac{f}{2000}\right) \tag{54–7}$$

for all frequencies from 100 MHz to 2000 MHz.

MDNEXT loss is determined by summing the power of the four individual pair-to-pair differential NEXT loss values over the frequency range 100 MHz to 2000 MHz as follows:

$$MDNEXT_{loss}(f) = -10 \times \log\left(\sum_{i=0}^{i=3} 10^{-NL(f)_i / 10}\right) \tag{54–8}$$

where

$MDNEXT_{loss}(f)$	is the MDNEXT loss at frequency f,
$NL(f)_i$	is the power of the NEXT loss at frequency f of pair combination i, in dB,
f	is frequency ranging from 100 MHz to 2000 MHz,
i	is the 0, 1, 2, or 3 (pair-to-pair combination).

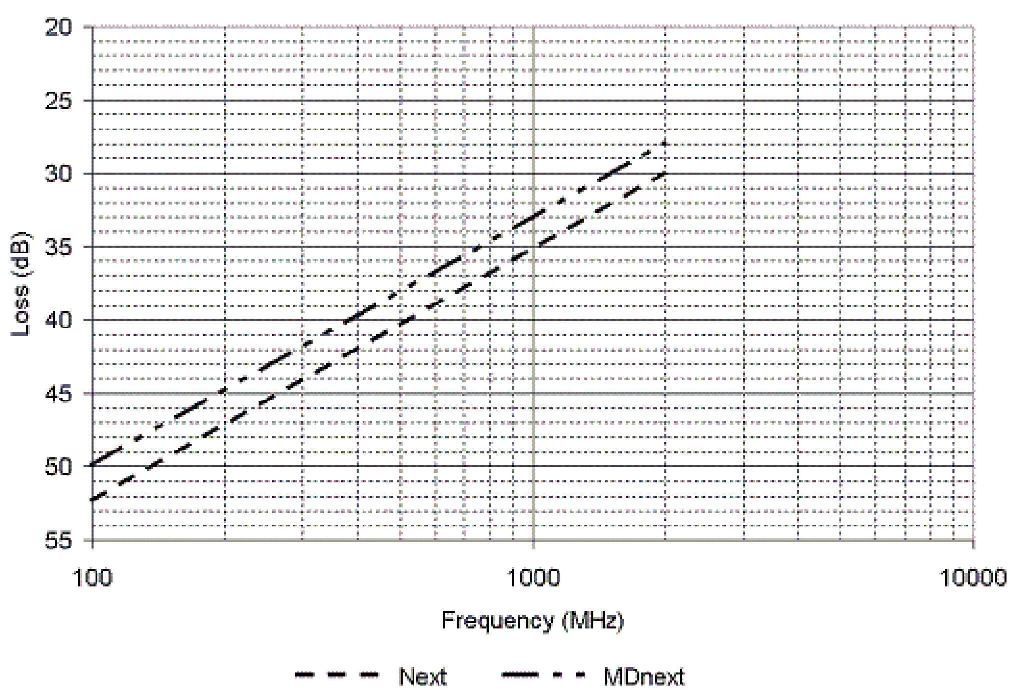

Figure 54–9—Minimum cable assembly NEXT / MDNEXT loss (informative)

54.7.5 Far-End Crosstalk (FEXT)

54.7.5.1 Equal Level Far-End Crosstalk (ELFEXT) loss

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

$$FEXT\_Loss(f) = 20 \times \log(Vpds(f)/Vpcn(f))$$

and ELFEXT Loss is defined as

$$ELFEXT\_Loss(f) = 20 \times \log(Vpds(f)/Vpcn(f)) - SLS\_Loss(f)$$

where

FEXT_Loss(f)	is the FEXT loss at frequency f,
ELFEXT_Loss(f)	is the ELFEXT loss at frequency f,
Vpds	is the peak voltage of the disturbing signal (near-end transmitter),
Vpcn	is the peak crosstalk noise at the far end of the disturbed lane,
SLS_Loss(f)	is the insertion loss of the disturbed lane in dB,
f	is frequency ranging from 100 MHz to 2000 MHz.

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

$$ELFEXT\ (f) \geq 21 - 20 \times \log\left(\frac{f}{2000}\right) \tag{54–9}$$

for all frequencies from 100 MHz to 2000 MHz.

54.7.5.2 Multiple Disturber Equal Level Far-End Crosstalk (MDELFEXT) loss

Since four lanes are used to transfer data between PMDs, the FEXT that is coupled into a data carrying lane will be from the three other lanes in the same direction. To ensure the total FEXT coupled into a lane is limited, multiple disturber ELFEXT loss is specified as the power sum of the individual ELFEXT losses.

The Power Sum loss (labeled as MDELFEXT) between a lane and the three adjacent disturbers shall be at least:

$$MDELFEXT(f) \geq 19 - 20 \times \log\left(\frac{f}{2000}\right) \tag{54–10}$$

for all frequencies from 100 MHz to 2000 MHz.

MDELFEXT loss is determined by summing the power of the three individual pair-to-pair differential ELFEXT loss values over the frequency range 100 MHz to 2000 MHz as follows:

$$\mathrm{MDELFEXT}_{\mathrm{loss}}(f) = -10 \times \log\left(\sum_{i=0}^{i=3} 10^{-NL(f)_i / 10}\right) \tag{54–11}$$

where

$\mathrm{MDELFEXT}_{\mathrm{loss}}(f)$	is the MDELFEXT loss at frequency f,
$\mathrm{NL}(f)_i$	is the power of ELFEXT loss at frequency f of pair combination i, in dB,
f	is frequency ranging from 100 MHz to 2000 MHz,
i	is the 1, 2, or 3 (pair-to-pair combination).

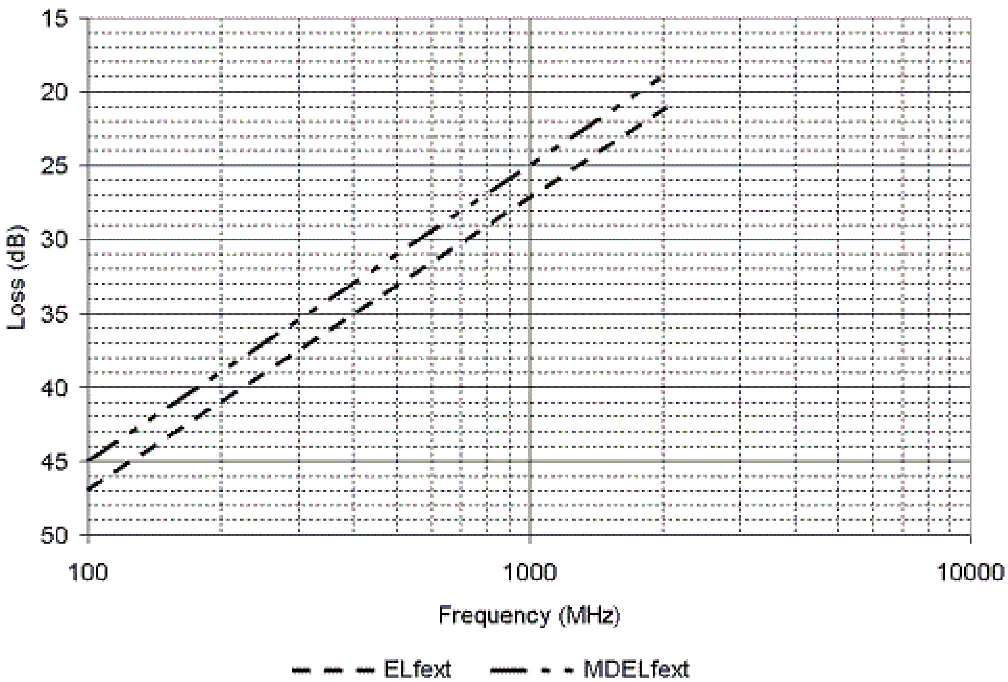

Figure 54–10—Minimum cable assembly ELFEXT / MDELFEXT loss (informative)

54.7.6 Shielding

The cable assembly shall provide Class 2 or better shielding in accordance with IEC 61196-1.

54.7.7 Crossover function

The cable assembly shall be wired in a crossover fashion as shown in Figure 54–11, with each of the four pairs being attached to the transmitter contacts at one end and the receiver contacts at the other end.

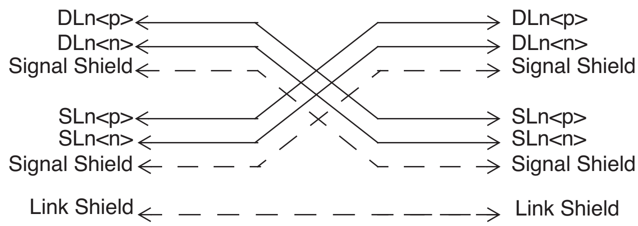

Figure 54–11—Cable wiring

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

54.8 MDI specification

This subclause defines the Media Dependent Interface (MDI). The 10GBASE-CX4 PMD, as per 54.6, is coupled to the cable assembly, as per 54.7, by the MDI.

54.8.1 MDI connectors

The connector for each end of the cable assembly shall be the latch-type plug with the mechanical mating interface defined by IEC 61076-3-113 and illustrated in Figure 54–12. The MDI connector shall be the latch-type receptacle with the mechanical mating interface defined by IEC 61076-3-113 and illustrated in Figure 54–13. These connectors have a pinout matching that in Table 54–7, and electrical performance consistent with the signal quality and electrical requirements of 54.6 and 54.7.

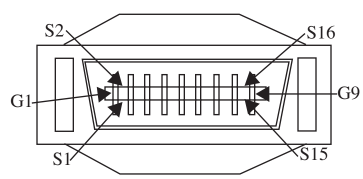

Figure 54–12—Example cable assembly plug (informative)

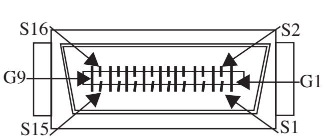

Figure 54–13—Example MDI board receptacle (informative)

54.8.2 Connector pin assignments

The MDI connector of the PMD comprises 16 signal connections, eight signal shield connections, and one link shield connection. The 10GBASE-CX4 PMD MDI connector pin assignments shall be as defined in Table 54–7.

Table 54–7—CX4 lane to MDI connector pin mapping

Rx lane	MDI Connector pin	Tx lane	MDI Connector pin
DL0<p>	S1	SL0<p>	S16
DL0<n>	S2	SL0<n>	S15
DL1<p>	S3	SL1<p>	S14
DL1<n>	S4	SL1<n>	S13
DL2<p>	S5	SL2<p>	S12
DL2<n>	S6	SL2<n>	S11
DL3<p>	S7	SL3<p>	S10
DL3<n>	S8	SL3<n>	S9
Signal Shield	G1	Signal Shield	G5
Signal Shield	G2	Signal Shield	G6
Signal Shield	G3	Signal Shield	G7
Signal Shield	G4	Signal Shield	G8
—	—	Link Shield	G9

54.9 Environmental specifications

All equipment subject to this clause shall conform to the applicable requirements of 14.7.

54.10 Protocol Implementation Conformance Statement (PICS) proforma for Clause 54, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-CX4[2]

54.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 54, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-CX4, shall complete the following Protocol Implementation Conformance Statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

54.10.2 Identification

54.10.2.1 Implementation identification

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

54.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3ak-2004, Clause 54, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-CX4
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 802.3ak-2004.)	

Date of Statement	

[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.

54.10.3 PICS proforma tables for 10GBASE-CX4 and baseband medium

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Environmental specifications	54.9		M	Yes [ ]

54.10.4 Major capabilities / options

Item[a]	Feature	Subclause	Value/Comment	Status	Support
XGE	XGMII interface	46, 54.1	Interface is supported	O	Yes [ ] No [ ]
XGXS	XGXS and XAUI	47, 54.1		O	Yes [ ] No [ ]
PCS	Support of 10GBASE-X PCS / PMA	48, 54.1		O	Yes [ ] No [ ]
DC	Delay constraints	54.3	Delay no more than 512 BT or 1 pause_quantum	M	Yes [ ]
*MD	MDIO capability	54.4	Registers and interface supported	O	Yes [ ] No [ ]

[a]A "*" preceding an "Item" identifier indicates there are other PICS that depend on whether or not this item is supported.

54.10.4.1 PMD Functional specifications

Item	Feature	Sub clause	Value/Comment	Status	Support
PF1	Transmit function	54.5.2	Convert the four logical signals requested by PMD_UNITDATA.request (tx_bit<0:3>) to 4 electrical signals	M	Yes [ ]
PF2	Delivery to the MDI	54.5.2	Supplies four electrical signal streams for delivery to the MDI	M	Yes [ ]
PF3	Mapping between logical signal and electrical signal for transmitter	54.5.2	A positive differential voltage is a one	M	Yes [ ]
PF4	Transmit Signal order	54.5.2	PMD_UNITDATA.request (tx_bit<0:3>) = (SL0<p>/<n>, SL1<p>/<n>, SL2<p>/<n>, SL3<p>/<n>)	M	Yes [ ]
PF5	Receive function	54.5.3	Convert the four electrical signals received from the MDI to 4 logical signals PMD_UNITDATA.indicate(rx_bit<0:3>) per 54.6.4	M	Yes [ ]
PF6	Mapping between electrical signal and logical signal for receiver	54.5.3	A positive differential voltage is a one	M	Yes [ ]
PF7	Receive Signal order	54.5.3	(DL0<p>/<n>, DL1<p>/<n>, DL2<p>/<n>, DL3<p>/<n>) = PMD_UNITDATA.indicate (rx_bit<0:3>)	M	Yes [ ]
PF8	Global PMD Signal Detect function	54.5.4	Report state via PMD_SIGNAL.indicate (SIGNAL_DETECT)	M	Yes [ ]
PF9	Global PMD Signal Detect OK threshold	54.5.4	SIGNAL_DETECT = OK for signal value >= 175 mV for at least 1 UI on each of the four lanes	M	Yes [ ]
PF10	Global PMD Signal Detect FAIL threshold, minimum	54.5.4	SIGNAL_DETECT = FAIL not asserted for signal level < 50 mV for < 250 µs on all four lanes	M	Yes [ ]
PF11	Global PMD Signal Detect FAIL threshold, maximum	54.5.4	SIGNAL_DETECT = FAIL asserted for signal level < 50 mV for > 500 µs on any of the four lanes	M	Yes [ ]
PF12	Global_PMD_transmit_disable	54.5.6	Disables all transmitters by forcing a constant output state	O	Yes [ ] No [ ]
PF13	PMD_fault disables transmitter	54.5.6	Disables all transmitters by forcing a constant output state when a fault is detected	O	Yes [ ] No [ ]
PF14	Effect on loopback of Global_PMD_transmit_disable	54.5.6	Global_PMD_transmit_disable does not affect loopback function	M	Yes [ ]

Item	Feature	Sub clause	Value/Comment	Status	Support
PF15	PMD_transmit_disable_n	54.5.7	Disables transmitter n (n=0:3) by forcing a constant output state	O	Yes [ ]
PF16	PMD_fault disables transmitter n	54.5.7	Disables transmitter n (n=0:3) by forcing a constant output state when a fault is detected	O	Yes [ ] No [ ]
PF17	Effect on loopback of PMD_transmit_disable_n	54.5.7	PMD_transmit_disable_n does not affect loopback function	M	Yes [ ]
PF18	Loop Back	54.5.8	Loopback function provided	M	Yes [ ]
PF19	Transmitters on during loopback	54.5.8	Loopback function does not disable the transmitters	M	Yes [ ]

54.10.4.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Lane-by-Lane Signal Detect function	54.5.5	Sets PMD_signal_detect_n values on a lane-by-lane basis per requirements of 54.5.4	MD:M	Yes [ ] N/A [ ]
MF2	PMD_fault function	54.5.9	Sets PMD_fault to a logical 1 if any local fault is detected otherwise set to 0	MD:M	Yes [ ] N/A [ ]
MF3	PMD_transmit_fault function	54.5.10	Sets PMD_transmit_fault to a logical 1 if a local fault is detected on the transmit path otherwise set to 0	MD:M	Yes [ ] N/A [ ]
MF4	PMD_receive_fault function	54.5.11	Sets PMD_receive_fault to a logical 1 if a local fault is detected on the receive path otherwise set to 0	MD:M	Yes [ ] N/A [ ]

54.10.4.3 Transmitter specifications

Item	Feature	Subclause	Value/Comment	Status	Support
DS1	Meets specifications at TP2	54.6.3		M	Yes [ ]
DS2	Test load	54.6.3.2	100 Ω differential load with return loss > 20 dB	M	Yes [ ]
DS3	Signaling speed	54.6.3.3	3.125 GBd ± 100 ppm	M	Yes [ ]
DS4	Maximum transmitter differential peak-to-peak output amplitude	54.6.3.4	Less than 1200 mV	M	Yes [ ]
DS5	Minimum transmitter differential peak-to-peak output amplitude	54.6.3.4	Greater than 800 mV	M	Yes [ ]
DS6	Maximum transmitter differential peak-to-peak amplitude difference	54.6.3.4	Less than 150 mV	M	Yes [ ]
DS7	Common mode output voltage	54.6.3.4	Between –0.4 V and +1.9 V	M	Yes [ ]
DS8	Transmitter output return loss	54.6.3.5	Per Equation (54–1) and Equation (54–2)	M	Yes [ ]
DS9	Transmitter output return loss reference impedance	54.6.3.5	100 Ω	M	Yes [ ]
DS10	Transmitter output template test pattern	54.6.3.6	Per 48A.2	M	Yes [ ]
DS11	Transmitter output template compliance	54.6.3.6	Met while connected to test fixture shown in Figure 54–3, with all outputs active	M	Yes [ ]
DS12	Transmitter output normalization	54.6.3.6	Per process defined in 54.6.3.6	M	Yes [ ]
DS13	Transmitter output template	54.6.3.6	Lies within template of Figure 54–6 and Table 54–4	M	Yes [ ]
DS14	Rising edge transition time	54.6.3.7	Between 60 ps and 130 ps as measured per 54.6.3.7	M	Yes [ ]
DS15	Falling edge transition time	54.6.3.7	Between 60 ps and 130 ps as measured per 54.6.3.7	M	Yes [ ]
DS16	Jitter requirements	54.6.3.8	Meet BER bathtub curve, See Annex 48B	M	Yes [ ]
DS17	Transmit jitter, peak-to-peak	54.6.3.8	Meet BER bathtub curve, See Annex 48B, with Total jitter < 0.35 UI Deterministic jitter < 0.17 UI Random jitter < 0.27 UI	M	Yes [ ]
DS18	Jitter test patterns	54.6.3.9	As per Annex 48A.5	M	Yes [ ]

54.10.4.4 Receiver specifications

Item	Feature	Subclause	Value/Comment	Status	Support
RS1	Bit Error Ratio	54.6.4.1	BER of better than 10^{-12}	M	Yes [ ]
RS2	Signaling speed	54.6.4.2	3.125 GBd ± 100 ppm	M	Yes [ ]
RS3	AC Coupling	54.6.4.3	—	M	Yes [ ]
RS4	Input peak-to-peak amplitude tolerance	54.6.4.4	Accepts signals compliant with 54.6.3, may be larger than 1200 mV	M	Yes [ ]
RS5	Receiver input return loss	54.6.4.5	Per Equation (54–1) and Equation (54–2)	M	Yes [ ]

54.10.4.5 Cable assembly specifications

Item	Feature	Subclause	Value/Comment	Status	Support
CA1	Differential reference impedance	54.7.1	100 Ω	M	Yes [ ]
CA2	Insertion loss	54.7.2	Per Equation (54–3)	M	Yes [ ]
CA3	Return loss	54.7.2	Per Equation (54–4), Equation (54–5), and Equation (54–6)	M	Yes [ ]
CA4	NEXT	54.7.4.1	Per Equation (54–6)	M	Yes [ ]
CA5	MDNEXT	54.7.4.2	Per Equation (54–7)	M	Yes [ ]
CA6	ELFEXT	54.7.5.1	Per Equation (54–9)	M	Yes [ ]
CA7	MDELFEXT	54.7.5.2	Per Equation (54–10)	M	Yes [ ]
CA8	Shielding	54.7.6	Class 2 or better in accordance with IEC 61196-1	M	Yes [ ]
CA9	Crossover function	54.7.7	Per Figure 54–11	M	Yes [ ]
CA10	Cable assembly connector type	54.8.1	IEC 61076-3-113 latch-type plug	M	Yes [ ]
CA11	MDI connector type	54.8.1	IEC 61076-3-113 latch-type receptacle	M	Yes [ ]
CA12	Pin assignments	54.8.2	Per Table 54–7	M	Yes [ ]