Open XR Optics Transceiver Optical and Client Interface Specification

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ABSTRACT:

This document provides specifications for Open XR Optics compliant coherent transceiver modules that can transmit/receive up to 400Gbps. It provides optical and electrical interfaces with the objective of enabling the development of multi-vendor interoperability of Open XR pluggable transceivers.

The Open XR Optics Forum
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Open XR Optics Forum

The Open XR Optics Forum is the multi-source agreement (MSA) working group for XR optics, the industry's first point-to-multipoint coherent pluggable transceiver technology. The Open XR Optics Forum's mission is to foster collaboration that will advance development of XR optics-enabled products and services, accelerate adoption of intelligent coherent transceivers ,coherent point-to-multipoint network architectures, and drive standardization of networking interfaces to ensure ease of multi-vendor interoperability and an open, multi-source solution ecosystem.

For additional information contact:

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1. Scope

This document provides specifications for Open XR compliant coherent transceiver modules. It focusses on optical and electrical interfaces with the objective of enabling the development of multi-vendor interoperability of Open XR pluggable transceivers.

This document provides specifications for 400G modules that can transmit/receive up to 400Gbps. Specifications of 100G modules that can transmit/receive up to 100Gbps will be added in a revision of this specification.

The Open XR coherent subcarrier DSP specification is not within the scope of this document. Also, the control and software features to enable various applications is not covered in this document. This optical and interface specification provides the hardware building block requirements to support those applications.

2. Introduction

Open XR optical modules are intelligent pluggable coherent transceivers with the following optical and management features:

- Open XR optical features:
    - Full C-Band tunability
    - 16QAM, 8QAM and QPSK modulation formats
    - Support for 25GE, 50GE, 100GE, 200GE, 400GE, (and optionally OTU4) client services
    - Variable data throughput 12.5G, 18.75G, or 25G per subcarrier, with up to 16 subcarriers (400G module) on a single wavelength
    - Dual fiber or Single Fiber operating modes
    - Automatic Tx power adjustment for point to multipoint applications
- Management related features:
    - I2C/CMIS or MDIO/MIS host interface based on MSA requirements.
    - Remote in-band management with Management VLANs (MVLANs)
    - An optical in-band management channel (the Open XR Supervisory Channel (XSC))
    - Serial Gigabit Media Independent Interface (SGMII) host interface for management

Open XR optical modules are largely compliant to the following MSAs and Standards:

- Industry-standard module MSAs (Form Factor dependent)
- IEEE802.3 interface protocol standards
- OIF Common Electrical Interface (CEI) implementation

Exceptions to these MSAs and Standards are explicitly documented in the Open XR Optics specifications.

3. Open XR Applications

Open XR optical transceiver utilizes digital signal processing to subdivide the transmission and reception of a given wavelength into a series of smaller-frequency channels called digital subcarriers. These digital subcarriers can be independently modulated, managed, and assigned to different destinations, enabling Point-to-MultiPoint (P2MP), direct low-speed to high-speed optical transceiver connectivity, as shown in Figure 1. A single 400G XR optics hub module generates 16 digital subcarriers with up to 25Gbps per subcarrier. One or more digital subcarriers can be assigned to a specific destination to provide the required bandwidth. Open XR optical transceiver modules are designed for use in a wide variety of networking equipment, including Ethernet switches, routers, servers, wireless baseband processing systems, and passive optical network (PON) headend aggregation systems.

An Open XR coherent pluggable module can be software-configured to operate in Point-to-Point (P2P) or Point-to-MultiPoint applications. On the host side, Open XR optical modules are generally compatible with common standards for other coherent optical pluggable modules like those supporting 400ZR [1], including physical form factor (e.g., CFP2, QSFP-28, QSFP56-DD, OSFP), electrical interface, network protocol, and network management.

In addition to dual fiber (one for transmit, one for receive) applications, XR optics enhances deployment flexibility through the support of bidirectional (Bi-Di) transmission on a single fiber.

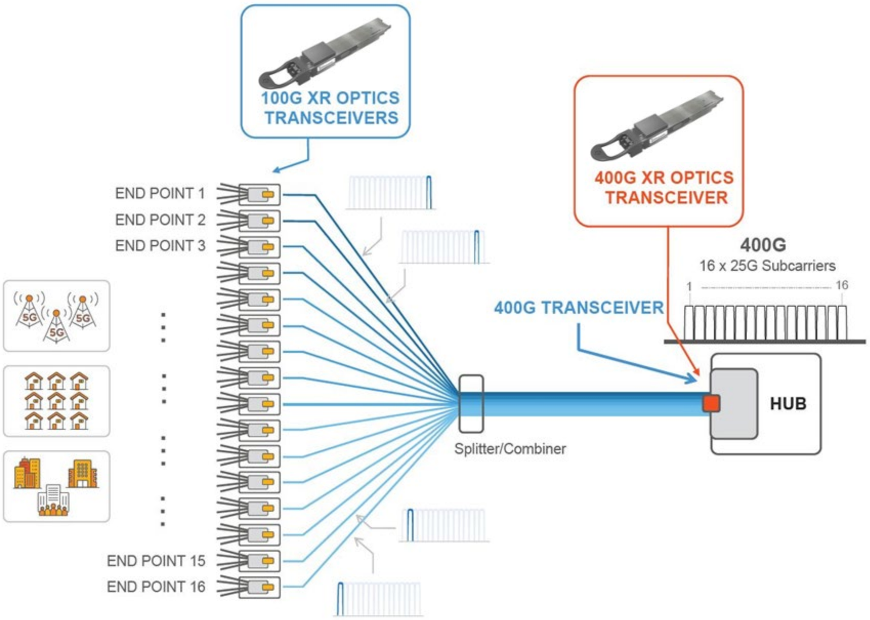

Figure 1. Open XR Optics Point-to-MultiPoint Connectivity.

The applications addressed in the present document include the following:

- Application I: Point-to-Point Single Span. This is a point-to-point application with no optical amplifiers other than possibly at either end of the link.
- Application II: Point to Point over ROADM link. This is an application with at least one ROADM[1] in the link. It allows for in-line optical amplifiers in the link.
- Application III: Point to Multi-Point PON Overlay. This is a point-to-multipoint application over a bi-directional (Bi-Di) single-fiber PON distribution network, which may need to coexist with a traditional PON deployment.
- Application IV: Point to Multi-Point Edge Aggregation. This is a point-to-multipoint application over a dual-fiber distribution network that may include optical amplifiers in the link.

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[1] The term "ROADM" is used generically to include any optical add/drop multiplexer, including a fixed optical add/drop multiplexer.

4. Optical Performance Specifications

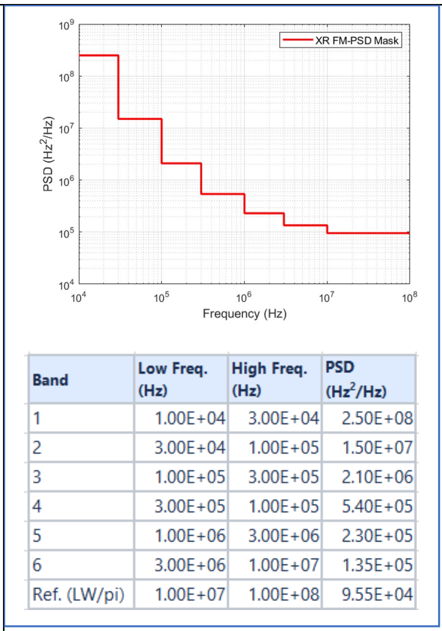
Requirements in this section are end-of-life specifications under all specified operating environmental conditions and cover all specified ranges (such as operating wavelength) unless otherwise noted. For definition of parameters, see Section 4.3.

4.1 Optical Specifications for a 400G Module

4.1.1 Application I: Point-to-Point Single Span

4.1.1.1 400G Module P2P Single Span Optical Transmit Characteristics

ID	Parameter	Condition	Min	Typical	Max	Unit	Comments
4.1.1.1.10	Laser Center Frequency Range		191.300		196.100	THz	
4.1.1.1.20	Modulation Formats		**16QAM**: up to 400G with 16 SCs, 25Gbps per SC. **8QAM**: 300G with 16 SCs, 18.75Gbps per SC. **QPSK**: up to 200G with 16 SCs, 12.5Gbps per SC.				16QAM and QPSK can be used in P2P and P2MP applications. 8QAM is for P2P applications only, using all 16 SCs.
4.1.1.1.30	Total Subcarriers Spectral Width (with consecutive SCs)	 16 Subcarriers 8 Subcarriers 4 Subcarriers 2 Subcarriers	Ethernet 64.205 32.063 15.992 7.957		OTU4 67.351 33.634 16.776 8.347	GHz	
4.1.1.1.40	Channel Frequency setting Grid support		6.25			GHz	
4.1.1.1.50	Frequency Fine Tuning Range		-6.25		+6.25	GHz	
4.1.1.1.60	Frequency Fine Tuning Resolution				150	MHz	
4.1.1.1.70	Frequency Setting Accuracy		-1.5		+1.5	GHz	

4.1.1.1.100	Tx Noise Power Frequency Spectral Density Mask						

Band	Low Freq. (Hz)	High Freq. (Hz)	PSD (Hz^2/Hz)
1	1.00E+04	3.00E+04	2.50E+08
2	3.00E+04	1.00E+05	1.50E+07
3	1.00E+05	3.00E+05	2.10E+06
4	3.00E+05	1.00E+05	5.40E+05
5	1.00E+06	3.00E+06	2.30E+05
6	3.00E+06	1.00E+07	1.35E+05
Ref. (LW/pi)	1.00E+07	1.00E+08	9.55E+04

4.1.1.1.130	Laser Linewidth				300	kHz	
4.1.1.1.140	Laser Side Mode Suppression Ratio		40			dB	
4.1.1.1.160	Tx Optical Output Power		-1			dBm	Tx optical output power shall meet at least this minimum value at maximum power setting.
4.1.1.1.180	Tx Power Control Dynamic Range		6			dB	
4.1.1.1.200	Tx Output Power Monitor Range		-7		+2	dBm	
4.1.1.1.220	Tx Output Power Monitor Absolute Accuracy		-1.5		+1.5	dB	
4.1.1.1.221	Tx Output Power Stability		-1.0		+1.0	dB	
4.1.1.1.230	Tx Output Power During Tuning or When Tx Is Disabled				-35	dBm	
4.1.1.1.240	Tx In-Band Optical Signal to Noise Ratio		37			dB	Up to maximum power specified in 4.1.1.1.160 and full dynamic range 4.1.1.1.180. (Noise power is measured in a 12.5GHz band, see 4.3.14)
4.1.1.1.250	Tx Out-of-Band Optical Signal to Noise Ratio		36			dB	Up to maximum power specified in 4.1.1.1.160 and full dynamic range 4.1.1.1.180. (Noise power is measured in a 12.5GHz band, see 4.3.15) With 15 other wavelengths colorlessly dropped at Rx without filter, the worst

							combined total out-of-band OSNR contribution from other channels could be 12 dB worse than this value.
4.1.1.1.260	Transmitter Optical Return Loss		24			dB	
4.1.1.1.270	Transmitter Back Reflection Tolerance				-24	dB	
4.1.1.1.340	Tx Output Power Imbalance Between X- and Y-Polarizations				1.0	dB	
4.1.1.1.350	Tx DC IQ Offset, per Polarization				For future study	dB	
4.1.1.1.360	Tx IQ Amplitude Imbalance				1.0	dB	
4.1.1.1.370	Tx Quadrature Error		-5.0		5.0	Degree	
4.1.1.1.380	Tx Residual IQ Skew		-0.4		0.4	ps	
4.1.1.1.400	Tx Residual X-Y Skew		-5		5	ps	

Table 1. 400G Module P2P Single Span Optical Transmit Characteristics

4.1.1.2 400G Module P2P Single Span Optical Receive Characteristics

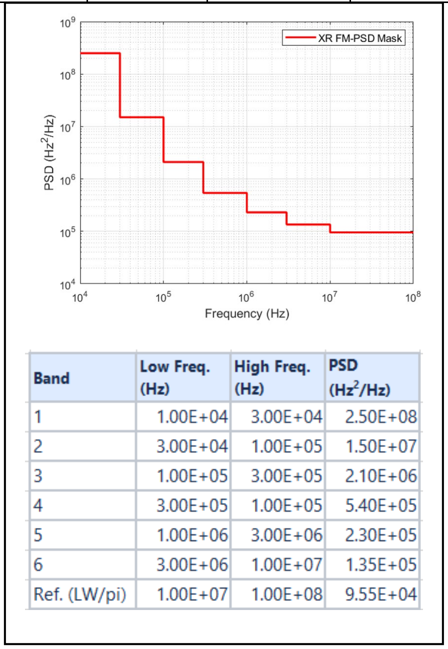
ID	Parameter	Condition	Min	Typical	Max	Unit	Comments
4.1.1.2.10	Rx Signal Input Power Range	400G, 16QAM 300G, 8QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK	-12 -16 -17 -15 -17 -20		0	dBm	Coherent signal, with Rx OSNR Tolerance specified below in 4.1.1.2.20. Note: The modulation formats supported by an XR module design depend on the intended applications. An XR module may choose to support only selected modulation formats. This table is intended to give interop guidelines when any of these modulation formats are selected.
4.1.1.2.20	Rx OSNR Tolerance at Defined Rx Input Power Range	400G, 16QAM 300G, 8QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK			24 20 15 20 17 12	dB	For post FEC BER less than or equal to 10^{-15}.
4.1.1.2.30	Rx Total Input Power				13	dBm	
4.1.1.2.40	Rx Max Absolute Power without Damage				17	dBm	
4.1.1.2.70	CD Tolerance	400G, 16QAM	37			nsec /nm	Less than 0.1dB OSNR penalty at minimum CD tolerance.

		300G, 8QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK	37 80 37 37 80				
4.1.1.2.80	DGD Tolerance		100			psec	Less than 0.1dB OSNR penalty at minimum DGD tolerance.
4.1.1.2.90	PMD Tolerance		33			psec	Less than 0.1dB OSNR penalty at minimum PMD tolerance.
4.1.1.2.100	Polarization Tracking Rate		90			krad/ sec	Less than 0.5dB OSNR penalty at minimum Polarization Tracking Rate.
4.1.1.2.110	PDL Tolerance	SOP change rate < =1 krad/sec.	2			dB	Less than 0.5dB OSNR penalty.
4.1.1.2.120	Rx In-Band Signal Input Power Transient Tolerance		-2		2	dB	Less than 0.5dB OSNR penalty
4.1.1.2.130	Rx In-Band Signal Power Sensitivity	400G, 16QAM 300G, 8QAM 200G, 16QAM 200G, QPSK 100G, 16QAM 100G, QPSK			-22 -25 -25 -28 -28 -31	dBm	OSNR > 35dB (Noise power is measured in a 12.5GHz band)
4.1.1.2.140	Rx In-Band Signal Input Power Monitor Range		-24		+1	dBm	
4.1.1.2.150	Rx In-Band Signal Input Power Monitor Accuracy	Input Power: -24dBm to -18dBm	-2.5		+2.5	dBm	
		Input Power: -18dBm to +1dBm	-2.0		2.0	dBm	
4.1.1.2.160	Rx Total Input Power Monitor Range		-24		+4	dBm	
4.1.1.2.170	Rx Total Input Power Monitor Accuracy	Input Power: -24dBm to -18dBm	-2.5		+2.5	dBm	
		Input Power: -18dBm to +4 dBm	-2.0		+2.0	dBm	
4.1.1.2.180	Rx Total Power to In-Band Power Ratio				15	dB	Less than 0.5dB OSNR penalty
4.1.1.2.230	Rx Optical Return Loss		24			dB	
4.1.1.2.270	Rx IQ Residual Skew Variation		-0.5		0.5	ps	
4.1.1.2.280	Rx XY Residual Skew Variation		-5		5	ps	

Table 2. 400G Module P2P Single Span Optical Receive Characteristics

4.1.2 Application II: Point to Point over ROADM

4.1.2.1 400G Module P2P over ROADM Optical Transmit Characteristics

ID	Parameter	Condition	Min	Typical	Max	Unit	Comments
4.1.2.1.10	Laser Center Frequency Range		191.300		196.100	THz	
4.1.2.1.20	Modulation Formats		**16QAM**: up to 400G with 16 SCs, 25Gbps per SC. **8QAM**: 300G with 16 SCs, 18.75Gbps per SC. **QPSK**: up to 200G with 16 SCs, 12.5Gbps per SC.				16QAM and QPSK can be used in P2P and P2MP applications. 8QAM is for P2P applications only, using all 16 SCs.
4.1.2.1.30	Total Subcarriers Spectral Width (with consecutive SCs)	 16 Subcarriers 8 Subcarriers 4 Subcarriers 2 Subcarriers	Ethernet 64.205 32.063 15.992 7.957		OTU4 67.351 33.634 16.776 8.347	GHz	
4.1.2.1.40	Channel Frequency setting Grid support		6.25			GHz	
4.1.2.1.50	Frequency Fine Tuning Range		-6.25		+6.25	GHz	
4.1.2.1.60	Frequency Fine Tuning Resolution				150	MHz	
4.1.2.1.70	Frequency Setting Accuracy		-1.5		+1.5	GHz	
4.1.2.1.100	Tx Noise Power Frequency Spectral Density Mask						
4.1.2.1.130	Laser Linewidth				300	kHz	

Band	Low Freq. (Hz)	High Freq. (Hz)	PSD (Hz^2/Hz)
1	1.00E+04	3.00E+04	2.50E+08
2	3.00E+04	1.00E+05	1.50E+07
3	1.00E+05	3.00E+05	2.10E+06
4	3.00E+05	1.00E+05	5.40E+05
5	1.00E+06	3.00E+06	2.30E+05
6	3.00E+06	1.00E+07	1.35E+05
Ref. (LW/pi)	1.00E+07	1.00E+08	9.55E+04

4.1.2.1.140	Laser Side Mode Suppression Ratio		40			dB	
4.1.2.1.160	Tx Optical Output Power		-1			dBm	Tx optical output power shall meet at least this minimum value at maximum setting.
4.1.2.1.180	Tx Power Control Dynamic Range		6			dB	
4.1.2.1.200	Tx Output Power Monitor Range		-7		+2	dBm	
4.1.2.1.220	Tx Output Power Monitor Accuracy		-1.5		+1.5	dB	
4.1.2.1.221	Tx Output Power Monitor Stability		-1.0		+1.0	dB	
4.1.2.1.230	Tx Output Power During Tuning or When Tx Is Disabled				-35	dBm	
4.1.2.1.240	Tx In-Band Optical Signal to Noise Ratio		42			dB	Up to maximum power specified in 4.1.2.1.160 and full dynamic range 4.1.2.1.180. (Noise power is measured in a 12.5GHz band, see 4.3.14)
4.1.2.1.250	Tx Out-of-Band Optical Signal to Noise Ratio		42			dB	Up to maximum power specified in 4.1.2.1.160 and full dynamic range 4.1.2.1.180. (Noise power is measured in a 12.5GHz band, see 4.3.15)
4.1.2.1.260	Transmitter Optical Return Loss		24			dB	
4.1.2.1.270	Transmitter Back Reflection Tolerance				-24	dB	
4.1.2.1.340	Tx Output Power Imbalance Between X- and Y-Polarizations				1.0	dB	
4.1.2.1.350	Tx DC IQ Offset, per Polarization				For future study	dB	
4.1.2.1.360	Tx IQ Amplitude Imbalance				1.0	dB	
4.1.2.1.370	Tx Quadrature Error		-5.0		5.0	Degree	
4.1.2.1.380	Tx Residual IQ Skew		-0.4		0.4	ps	
4.1.2.1.400	Tx Residual X-Y Skew		-5		5	ps	

Table 3. 400G Module P2P over ROADM Optical Transmit Characteristics

4.1.2.2 400G Module P2P over ROADM Optical Receive Characteristics

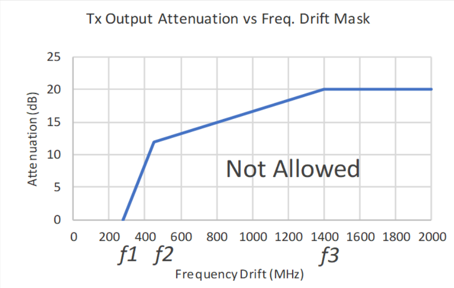
ID	Parameter	Condition	Min	Typical	Max	Unit	Comments
4.1.2.2.10	Rx Signal Input Power Range	400G, 16QAM 300G, 8QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK	-12 -16 -17 -15 -17 -20		0	dBm	Coherent signal, with Rx OSNR Tolerance specified below in 4.1.2.2.20. Note: The modulation formats supported by an XR module design depend on the intended applications. An XR module may choose to support only selected modulation formats. This table is intended to give interop guidelines when any of these modulation formats are selected.
4.1.2.2.20	Rx OSNR Tolerance at Defined Rx Input Power Range	400G, 16QAM 300G, 8QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK			23 20 15 20 17 12	dB	For post FEC BER less than or equal to 10^{-15}.
4.1.2.2.30	Rx Total Input Power				13	dBm	
4.1.2.2.40	Rx Max Absolute Power without Damage				17	dBm	
4.1.2.2.70	CD Tolerance	400G, 16QAM 300G, 8QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK	37 37 80 37 37 80			nsec /nm	Less than 0.1dB OSNR penalty at minimum CD tolerance.
4.1.2.2.80	DGD Tolerance		100			psec	Less than 0.1dB OSNR penalty at minimum DGD tolerance.
4.1.2.2.90	PMD Tolerance		33			psec	Less than 0.1dB OSNR penalty at minimum PMD tolerance.
4.1.2.2.100	Polarization Tracking Rate		90			krad/ sec	Less than 0.5dB OSNR penalty at minimum Polarization Tracking Rate.
4.1.2.2.110	PDL Tolerance	SOP change rate < =1 krad/sec.	2			dB	Less than 0.5dB OSNR penalty.
4.1.2.2.120	Rx In-Band Signal Input Power Transient Tolerance		-2		2	dB	Less than 0.5dB OSNR penalty
4.1.2.2.130	Rx In-Band Signal Power Sensitivity	400G, 16QAM 300G, 8QAM 200G, 16QAM			-22 -25 -25	dBm	OSNR > 35dB (Noise power is measured in a 12.5GHz band)

		200G, QPSK 100G, 16QAM 100G, QPSK			-28 -28 -31		
4.1.2.2.140	Rx In-Band Signal Input Power Monitor Range		-24		+1	dBm	
4.1.2.2.150	Rx In-Band Signal Input Power Monitor Accuracy	Input Power: -24dBm to -18dBm	-2.5		+2.5	dBm	
		Input Power: -18dBm to +1dBm	-2.0		2.0	dBm	
4.1.2.2.160	Rx Total Input Power Monitor Range		-24		+64	dBm	
4.1.2.2.170	Rx Total Input Power Monitor Accuracy	Input Power: -24dBm to -18dBm	-2.5		+2.5	dBm	
		Input Power: -18dBm to +4 dBm	-2.0		+2.0	dBm	
4.1.2.2.180	Rx Total Power to In-Band Power Ratio				15	dB	Less than 0.5dB OSNR penalty
4.1.2.2.230	Rx Optical Return Loss		24			dB	
4.1.2.2.270	Rx IQ Residual Skew Variation		-0.5		0.5	ps	
4.1.2.2.280	Rx XY Residual Skew Variation		-5		5	ps	

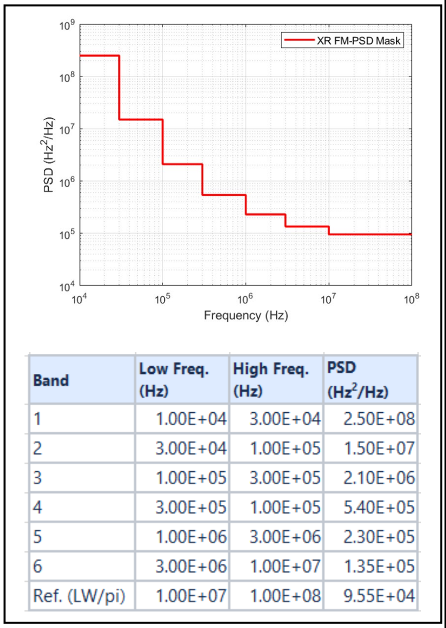
Table 4. 400G Module P2P over ROADM Optical Receive Characteristics

4.1.3 Application III: Point to Multi-Point PON Overlay

4.1.3.1 400G Module P2MP PON Overlay Optical Transmit Characteristics

<table>
<tr><th>ID</th><th>Parameter</th><th>Condition</th><th>Min</th><th>Typical</th><th>Max</th><th>Unit</th><th>Comments</th></tr>
<tr><td>4.1.3.1.10</td><td>Laser Center Frequency Range</td><td></td><td>191.300</td><td></td><td>196.100</td><td>THz</td><td></td></tr>
<tr><td>4.1.3.1.20</td><td>Modulation Formats</td><td></td><td colspan="3">16QAM: up to 400G with 16 SCs, 25Gbps per SC.
QPSK: up to 200G with 16 SCs, 12.5Gbps per SC.</td><td></td><td></td></tr>
<tr><td>4.1.3.1.30</td><td>Total Subcarriers Spectral Width (with consecutive SCs)</td><td>
16 Subcarriers
8 Subcarriers
4 Subcarriers
2 Subcarriers</td><td>Ethernet
67.750
33.717
16.701
8.193</td><td></td><td>OTU4
71.070
35.370
17.520
8.595</td><td>GHz</td><td></td></tr>
<tr><td>4.1.3.1.40</td><td>Channel Frequency setting Grid support</td><td></td><td>6.25</td><td></td><td></td><td>GHz</td><td></td></tr>
<tr><td>4.1.3.1.50</td><td>Frequency Fine Tuning Range</td><td></td><td>-6.25</td><td></td><td>+6.25</td><td>GHz</td><td></td></tr>
<tr><td>4.1.3.1.60</td><td>Frequency Fine Tuning Resolution</td><td></td><td></td><td></td><td>30</td><td>MHz</td><td></td></tr>
<tr><td>4.1.3.1.70</td><td>Frequency Setting Accuracy</td><td></td><td>-1.5</td><td></td><td>+1.5</td><td>GHz</td><td></td></tr>
<tr><td>4.1.3.1.90</td><td>Minimum Tx Output Attenuation vs Freq. Mask During Power Shutdown</td><td></td><td colspan="4">


<table>
<tr><th></th><th>Frequency (MHz)</th><th>Attenuation (dB)</th></tr>
<tr><td><i>f1</i></td><td>280</td><td>0</td></tr>
<tr><td><i>f2</i></td><td>450</td><td>12</td></tr>
<tr><td><i>f3</i></td><td>1400</td><td>20</td></tr>
</table>
</td><td>Mask is applicable to Tx output power from requirement in 4.1.3.1.160 (+2dBm) to minimum power setting of 4.1.3.1.200 (-20dBm)</td></tr>
</table>

<table>
<tr><td>4.1.3.1.100</td><td>Tx Noise Power Frequency Spectral Density Mask</td><td></td><td colspan="4">

<table>
<tr><th>Band</th><th>Low Freq. (Hz)</th><th>High Freq. (Hz)</th><th>PSD (Hz^2/Hz)</th></tr>
<tr><td>1</td><td>1.00E+04</td><td>3.00E+04</td><td>2.50E+08</td></tr>
<tr><td>2</td><td>3.00E+04</td><td>1.00E+05</td><td>1.50E+07</td></tr>
<tr><td>3</td><td>1.00E+05</td><td>3.00E+05</td><td>2.10E+06</td></tr>
<tr><td>4</td><td>3.00E+05</td><td>1.00E+05</td><td>5.40E+05</td></tr>
<tr><td>5</td><td>1.00E+06</td><td>3.00E+06</td><td>2.30E+05</td></tr>
<tr><td>6</td><td>3.00E+06</td><td>1.00E+07</td><td>1.35E+05</td></tr>
<tr><td>Ref. (LW/pi)</td><td>1.00E+07</td><td>1.00E+08</td><td>9.55E+04</td></tr>
</table></td><td></td></tr>
<tr><td>4.1.3.1.110</td><td>Frequency Deviation During Warm Boot</td><td></td><td>-200</td><td></td><td>200</td><td>MHz</td><td></td></tr>
<tr><td>4.1.3.1.111</td><td>Maximum Frequency Deviation of Leaf Tx Laser from DSP-Locked Rx frequency</td><td>1 sigma statistical distribution value</td><td>-25</td><td></td><td>25</td><td>MHz</td><td></td></tr>
<tr><td>4.1.3.1.120</td><td>Hub Laser Frequency Wander/Jitter When locked to Wavelength Locker</td><td></td><td></td><td></td><td>280</td><td>MHz</td><td></td></tr>
<tr><td>4.1.3.1.130</td><td>Laser Linewidth</td><td></td><td></td><td></td><td>300</td><td>kHz</td><td></td></tr>
<tr><td>4.1.3.1.140</td><td>Laser Side Mode Suppression Ratio</td><td></td><td>40</td><td></td><td></td><td>dB</td><td></td></tr>
<tr><td>4.1.3.1.160</td><td>Tx Optical Output Power</td><td></td><td>+2</td><td></td><td></td><td>dBm</td><td>Tx optical output power shall meet at least this minimum value at maximum setting.</td></tr>
<tr><td>4.1.3.1.180</td><td>Tx Power Control Dynamic Range</td><td></td><td>10</td><td></td><td></td><td>dB</td><td></td></tr>
<tr><td>4.1.3.1.200</td><td>Tx Output Power Monitor Range</td><td></td><td>-20</td><td></td><td>+3</td><td>dBm</td><td></td></tr>
<tr><td>4.1.3.1.220</td><td>Tx Output Power Monitor Accuracy</td><td></td><td>-1.5</td><td></td><td>+1.5</td><td>dB</td><td></td></tr>
</table>

4.1.3.1.221	Tx Output Power Monitor Stability		-1.0		+1.0	dB	
4.1.3.1.230	Tx Output Power During Tuning or When Tx Is Disabled				-40	dBm	
4.1.3.1.240	Tx In-Band Optical Signal to Noise Ratio		42			dB	Up to maximum power specified in 4.1.3.1.160 and full dynamic range 4.1.3.1.180. (Noise power is measured in a 12.5GHz band, see 4.3.14)
4.1.3.1.250	Tx Out-of-Band Optical Signal to Noise Ratio		42			dB	Up to maximum power specified in 4.1.3.1.160 and full dynamic range 4.1.3.1.180. (Noise power is measured in a 12.5GHz band, see 4.3.15)
4.1.3.1.260	Transmitter Optical Return Loss		24			dB	
4.1.3.1.270	Transmitter Back Reflection Tolerance				-24	dB	
4.1.3.1.340	Tx Output Power Imbalance Between X- and Y-Polarizations				1.0	dB	
4.1.3.1.350	Tx DC IQ Offset, per Polarization				For future study	dB	
4.1.3.1.360	Tx IQ Amplitude Imbalance				1.0	dB	
4.1.3.1.370	Tx Quadrature Error		-5.0		5.0	Degree	
4.1.3.1.380	Tx Residual IQ Skew		-0.4		0.4	ps	
4.1.3.1.400	Tx Residual X-Y Skew		-5		5	ps	

Table 5. 400G Module P2MP PON Overlay Optical Transmit Characteristics

4.1.3.2 400G Module P2MP PON Overlay Optical Receive Characteristics

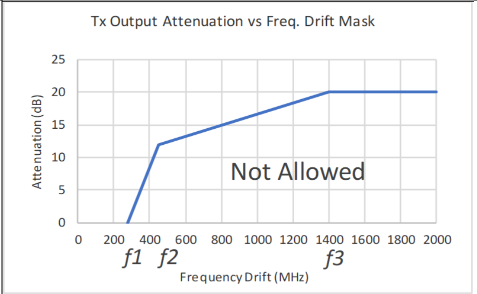
ID	Parameter	Condition	Min	Typical	Max	Unit	Comments
4.1.3.2.10	Rx Signal Input Power Range	400G, 16QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK	-12 -17 -15 -17 -20		0	dBm	Coherent signal, with Rx OSNR Tolerance specified below in 4.1.3.2.20. Note: The modulation formats supported by an XR module design depend on the intended applications. An XR module may choose to support only selected modulation formats. This table is intended to give interop guidelines when any of these modulation formats are selected.
4.1.3.2.20	Rx OSNR Tolerance at Defined Rx Input Power Range	400G, 16QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK			24 15 20 17 12	dB	For post FEC BER less than or equal to 10^{-15}.
4.1.3.2.30	Rx Total Input Power				13	dBm	
4.1.3.2.40	Rx Max Absolute Power without Damage				17	dBm	
4.1.3.2.70	CD Tolerance	400G, 16QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK	37 80 37 37 80			nsec /nm	Less than 0.1dB OSNR penalty at minimum CD tolerance.
4.1.3.2.80	DGD Tolerance		100			psec	Less than 0.1dB OSNR penalty at minimum DGD tolerance.
4.1.3.2.90	PMD Tolerance		33			psec	Less than 0.1dB OSNR penalty at minimum PMD tolerance.
4.1.3.2.100	Polarization Tracking Rate		90			krad/ sec	Less than 0.5dB OSNR penalty at minimum Polarization Tracking Rate.
4.1.3.2.110	PDL Tolerance	SOP change rate < =1 krad/sec.	2			dB	Less than 0.5dB OSNR penalty.
4.1.3.2.120	Rx In-Band Signal Input Power Transient Tolerance		-2		2	dB	Less than 0.5dB OSNR penalty
4.1.3.2.130	Rx In-Band Signal Power Sensitivity	400G, 16QAM 200G, 16QAM 200G, QPSK 100G, 16QAM 100G, QPSK			-22 -25 -28 -28 -31	dBm	OSNR > 35dB (Noise power is measured in a 12.5GHz band)

4.1.3.2.140	Rx In-Band Signal Input Power Monitor Range		-24		+1	dBm	
4.1.3.2.150	Rx In-Band Signal Input Power Monitor Accuracy	Input Power: -24dBm to -18dBm	-2.5		+2.5	dBm	
		Input Power: -18dBm to +1dBm	-2.0		2.0	dBm	
4.1.3.2.160	Rx Total Input Power Monitor Range		-24		+4	dBm	
4.1.3.2.170	Rx Total Input Power Monitor Accuracy	Input Power: -24dBm to -18dBm	-2.5		+2.5	dBm	
		Input Power: -18dBm to +4 dBm	-2.0		+2.0	dBm	
4.1.3.2.180	Rx Total Power to In-Band Power Ratio				15	dB	Less than 0.5dB OSNR penalty
4.1.3.2.230	Rx Optical Return Loss		24			dB	
4.1.3.2.270	Rx IQ Residual Skew Variation		-0.5		0.5	ps	
4.1.3.2.280	Rx XY Residual Skew Variation		-5		5	ps	

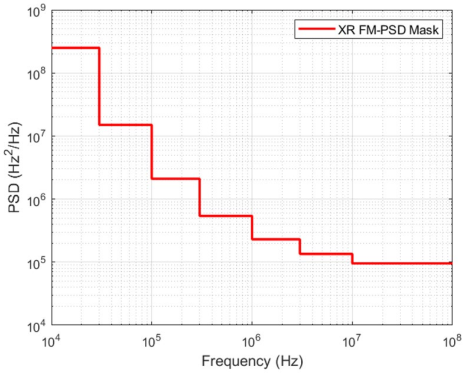
Table 6. 400G Module P2MP PON Overlay Optical Receive Characteristics

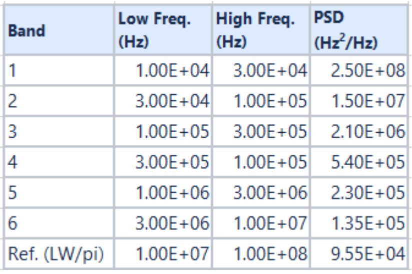
4.1.4 P2MP Edge Application IV: Point to Multi-Point Edge Aggregation

4.1.4.1 400G Module P2MP Edge Aggregation Optical Transmit Characteristics

<table>
<tr><th>ID</th><th>Parameter</th><th>Condition</th><th>Min</th><th>Typical</th><th>Max</th><th>Unit</th><th>Comments</th></tr>
<tr><td>4.1.4.1.10</td><td>Laser Center Frequency Range</td><td></td><td>191.300</td><td></td><td>196.100</td><td>THz</td><td></td></tr>
<tr><td>4.1.4.1.20</td><td>Modulation Formats</td><td></td><td colspan="3">16QAM: up to 400G with 16 SCs, 25Gbps per SC.
QPSK: up to 200G with 16 SCs, 12.5Gbps per SC.</td><td></td><td></td></tr>
<tr><td>4.1.4.1.30</td><td>Total Subcarriers Spectral Width (with consecutive SCs)</td><td>
16 Subcarriers
8 Subcarriers
4 Subcarriers
2 Subcarriers</td><td>Ethernet
67.750
33.717
16.701
8.193</td><td></td><td>OTU4
71.070
35.370
17.520
8.595</td><td>GHz</td><td></td></tr>
<tr><td>4.1.4.1.40</td><td>Channel Frequency setting Grid support</td><td></td><td>6.25</td><td></td><td></td><td>GHz</td><td></td></tr>
<tr><td>4.1.4.1.50</td><td>Frequency Fine Tuning Range</td><td></td><td>-6.25</td><td></td><td>+6.25</td><td>GHz</td><td></td></tr>
<tr><td>4.1.4.1.60</td><td>Frequency Fine Tuning Resolution</td><td></td><td></td><td></td><td>30</td><td>MHz</td><td></td></tr>
<tr><td>4.1.4.1.70</td><td>Frequency Setting Accuracy</td><td></td><td>-1.5</td><td></td><td>+1.5</td><td>GHz</td><td></td></tr>
<tr><td>4.1.4.1.90</td><td>Minimum Tx Output Attenuation vs Freq. Deviation Mask During Power Shutdown</td><td></td><td colspan="4">

<table>
<tr><th></th><th>Frequency (MHz)</th><th>Attenuation (dB)</th></tr>
<tr><td><i>f1</i></td><td>280</td><td>0</td></tr>
<tr><td><i>f2</i></td><td>450</td><td>12</td></tr>
<tr><td><i>f3</i></td><td>1400</td><td>20</td></tr>
</table></td><td>Mask is applicable to Tx output power from requirement in 4.1.4.1.160 (-2dBm) to minimum power setting of 4.1.4.1.200 (-24dBm)</td></tr>
</table>

<table>
<tr><td>4.1.4.1.100</td><td>Tx Noise Power Frequency Spectral Density Mask</td><td></td><td colspan="4">


<table>
<tr><th>Band</th><th>Low Freq. (Hz)</th><th>High Freq. (Hz)</th><th>PSD (Hz^2/Hz)</th></tr>
<tr><td>1</td><td>1.00E+04</td><td>3.00E+04</td><td>2.50E+08</td></tr>
<tr><td>2</td><td>3.00E+04</td><td>1.00E+05</td><td>1.50E+07</td></tr>
<tr><td>3</td><td>1.00E+05</td><td>3.00E+05</td><td>2.10E+06</td></tr>
<tr><td>4</td><td>3.00E+05</td><td>1.00E+05</td><td>5.40E+05</td></tr>
<tr><td>5</td><td>1.00E+06</td><td>3.00E+06</td><td>2.30E+05</td></tr>
<tr><td>6</td><td>3.00E+06</td><td>1.00E+07</td><td>1.35E+05</td></tr>
<tr><td>Ref. (LW/pi)</td><td>1.00E+07</td><td>1.00E+08</td><td>9.55E+04</td></tr>
</table></td><td></td></tr>
<tr><td>4.1.4.1.110</td><td>Frequency Deviation During Warm Boot</td><td></td><td>-200</td><td></td><td>200</td><td>MHz</td><td></td></tr>
<tr><td>4.1.4.1.111</td><td>Maximum Frequency Deviation of Leaf Tx Laser from DSP-Locked Rx frequency</td><td>1 sigma statistical distribution value</td><td>-25</td><td></td><td>25</td><td>MHz</td><td></td></tr>
<tr><td>4.1.4.1.120</td><td>Hub Laser Frequency Wander/Jitter When locked to Wavelength Locker</td><td></td><td></td><td></td><td>280</td><td>MHz</td><td></td></tr>
<tr><td>4.1.4.1.130</td><td>Laser Linewidth</td><td></td><td></td><td></td><td>300</td><td>kHz</td><td></td></tr>
<tr><td>4.1.4.1.140</td><td>Laser Side Mode Suppression Ratio</td><td></td><td>40</td><td></td><td></td><td>dB</td><td></td></tr>
<tr><td>4.1.4.1.160</td><td>Tx Optical Output Power</td><td></td><td>-2</td><td></td><td></td><td>dBm</td><td>Tx optical output power shall meet at least this minimum value at maximum setting.</td></tr>
<tr><td>4.1.4.1.180</td><td>Tx Power Control Dynamic Range</td><td></td><td>10</td><td></td><td></td><td>dB</td><td></td></tr>
<tr><td>4.1.4.1.200</td><td>Tx Output Power Monitor Range</td><td></td><td>-24</td><td></td><td>+1</td><td>dBm</td><td></td></tr>
<tr><td>4.1.4.1.220</td><td>Tx Output Power Monitor Accuracy</td><td></td><td>-1.5</td><td></td><td>+1.5</td><td>dB</td><td></td></tr>
</table>

4.1.4.1.221	Tx Output Power Monitor Stability		-1.0		+1.0	dB	
4.1.4.1.230	Tx Output Power During Tuning or When Tx Is Disabled				-40	dBm	
4.1.4.1.240	Tx In-Band Optical Signal to Noise Ratio		42			dB	Up to maximum power specified in 4.1.4.1.160 and full dynamic range 4.1.4.1.180. (Noise power is measured in a 12.5GHz band, see 4.3.14)
4.1.4.1.250	Tx Out-of-Band Optical Signal to Noise Ratio		42			dB	Up to maximum power specified in 4.1.4.1.160 and full dynamic range 4.1.4.1.180. (Noise power is measured in a 12.5GHz band, see 4.3.15)
4.1.4.1.260	Transmitter Optical Return Loss		24			dB	
4.1.4.1.270	Transmitter Back Reflection Tolerance				-24	dB	
4.1.4.1.340	Tx Output Power Imbalance Between X- and Y-Polarizations				1.0	dB	
4.1.4.1.350	Tx DC IQ Offset, per Polarization				For future study	dB	
4.1.4.1.360	Tx IQ Amplitude Imbalance				1.0	dB	
4.1.4.1.370	Tx Quadrature Error		-5.0		5.0	Degree	
4.1.4.1.380	Tx Residual IQ Skew		-0.4		0.4	ps	
4.1.4.1.400	Tx Residual X-Y Skew		-5		5	ps	

Table 7. 400G Module P2MP Edge Aggregation Optical Transmit Characteristics

4.1.4.2 400G Module P2MP Edge Aggregation Optical Receive Characteristics

ID	Parameter	Condition	Min	Typical	Max	Unit	Comments
4.1.4.2.10	Rx Signal Input Power Range	400G, 16QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK	-12 -17 -15 -17 -20		0	dBm	Coherent signal, with Rx OSNR Tolerance specified below in 4.1.4.2.20. Note: The modulation formats supported by an XR module design depend on the intended applications. An XR module may choose to support only selected modulation formats. This table is intended to give interop guidelines when any of these modulation formats are selected.
4.1.4.2.20	Rx OSNR Tolerance at Defined Rx Input Power Range	400G, 16QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK			24 15 20 17 12	dB	For post FEC BER less than or equal to 10^{-15}.
4.1.4.2.30	Rx Total Input Power				13	dBm	
4.1.4.2.40	Rx Max Absolute Power without Damage				17	dBm	
4.1.4.2.70	CD Tolerance	400G, 16QAM 200G, QPSK 200G, 16QAM 100G, 16QAM 100G, QPSK	37 80 37 37 80			nsec /nm	Less than 0.1dB OSNR penalty at minimum CD tolerance.
4.1.4.2.80	DGD Tolerance		100			psec	Less than 0.1dB OSNR penalty at minimum DGD tolerance.
4.1.4.2.90	PMD Tolerance		33			psec	Less than 0.1dB OSNR penalty at minimum PMD tolerance.
4.1.4.2.100	Polarization Tracking Rate		90			krad/ sec	Less than 0.5dB OSNR penalty at minimum Polarization Tracking Rate.
4.1.4.2.110	PDL Tolerance	SOP change rate < =1 krad/sec.	2			dB	Less than 0.5dB OSNR penalty
4.1.4.2.120	Rx In-Band Signal Input Power Transient Tolerance		-2		2	dB	Less than 0.5dB OSNR penalty
4.1.4.2.130	Rx In-Band Signal Power Sensitivity	400G, 16QAM 200G, 16QAM 200G, QPSK 100G, 16QAM 100G, QPSK			-22 -25 -28 -28 -31	dBm	OSNR > 35dB (Noise power is measured in a 12.5GHz band)

4.1.4.2.140	Rx In-Band Signal Input Power Monitor Range		-24		+1	dBm	
4.1.4.2.150	Rx In-Band Signal Input Power Monitor Accuracy	Input Power: -24dBm to -18dBm	-2.5		+2.5	dBm	
		Input Power: -18dBm to +1dBm	-2.0		2.0	dBm	
4.1.4.2.160	Rx Total Input Power Monitor Range		-24		+4	dBm	
4.1.4.2.170	Rx Total Input Power Monitor Accuracy	Input Power: -24dBm to -18dBm	-2.5		+2.5	dBm	
		Input Power: -18dBm to +4 dBm	-2.0		+2.0	dBm	
4.1.4.2.180	Rx Total Power to In-Band Power Ratio				15	dB	Less than 0.5dB OSNR penalty
4.1.4.2.230	Rx Optical Return Loss		24			dB	
4.1.4.2.270	Rx IQ Residual Skew Variation		-0.5		0.5	ps	
4.1.4.2.280	Rx XY Residual Skew Variation		-5		5	ps	

Table 8. 400G Module P2MP Edge Aggregation Optical Receive Characteristics

4.2 Optical Specifications for a 100G Module

To Be Provided

4.3 Optical Parameter Definitions

Definitions in this specification appear in the following format. N.B. only the definition is normative and indented explanatory material is just that – explanatory.

x.y.z Term being defined

Definition of term being defined.

> Indented – all text - explanatory material.

4.3.1 Laser Center Frequency Range

Tx output laser operating center frequency set range, applicable to all data rates with different Total Subcarrier Spectral Width.

4.3.2 Total Subcarriers Spectral Width (with consecutive SCs)

Optical spectral width of the combined SCs from XR transceiver.

> This total Subcarrier Spectral Width depends on 1) numbers of SCs, 2) per SC Baud rates, 3) width of guard band between SCs, 4) the SC roll off factor. Detail requirement is covered in DSP requirement document.

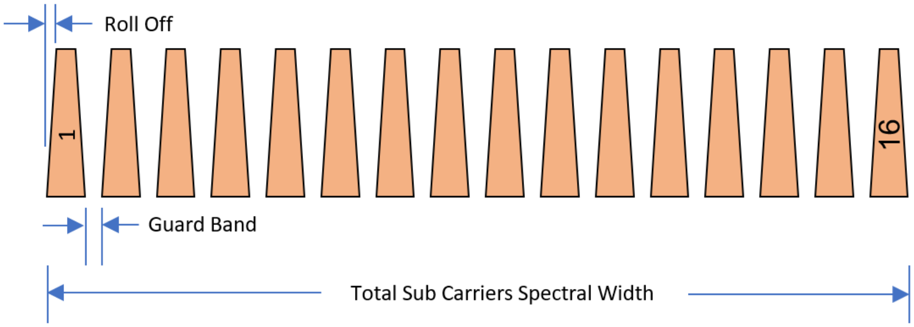


Figure 2. Subcarriers Total Spectral Width

> Module electrical circuitry design needs to be able to handle sufficient RF signal frequency bandwidth based on applications. And it is also important to determine the required optical filtering passband.
>
> Total Subcarriers Spectral Width can be viewed as a specification to be verified when the XR subcarrier settings are correctly configured in DSP.

4.3.3 Frequency Fine Tuning Range

The continuous frequency tuning range while Tx output is enabled.

> Running traffic shall not be interrupted.

4.3.4 Frequency Setting Accuracy

Accuracy with which the Tx Laser Frequency is set.

> Typically measured against an external calibrated frequency reference.

4.3.5 Minimum Tx Output Attenuation vs Freq. Drift Mask during Power Shutdown.

Tx output power attenuation vs frequency drift mask during power shutdown.

When module resets, loses power, or is unplugged, optical power shutting down of a Leaf module must not cause traffic issue of other Leaf modules. Thus, the frequency excursion must be limited. A leaf module frequency shall be kept within an allowed mask during power shutdown events.

Tx power must not be within the range indicated "Not Allowed" to avoid interfering with adjacent carrier. This is a requirement for XR Leaf units.

4.3.6 Tx Noise Power Frequency Spectral Density Mask

The frequency dependent power spectral density of the unmodulated laser source shall abide by this mask.

To obtain laser PSD, a CW laser beating method is used. Measurement is performed by beating the laser under test (all modulation off, DSP powered off) with a low-linewidth, low-noise local oscillator with a frequency offset and record beat signal over time using a sampling scope.

Typical Test Setup Parameters: Unmodulated low noise LO CW laser linewidth <=10kHz Number of samples > 4M Minimum Frequency resolution 1.5kHz

4.3.7 Frequency Deviation During Warm Boot

Permitted frequency deviation during warm boot, whenever active frequency locking is temporarily disabled.

A warm boot is a process of rebooting a transceiver module control processes will keep the data path running without interruption.

During warm boot, the active frequency control loop may be temporarily disabled and could cause Tx frequency to run unlocked to reference. During this warm boot, Tx frequency must not have a drift more than this defined frequency deviation before the frequency locking becomes active again when warm boot is completed.

4.3.8 Maximum Frequency Deviation of Leaf Tx Laser from DSP-Locked Rx frequency

Permitted frequency deviation of a Leaf Tx frequency from the Hub frequency at the Leaf Rx receiver.

The leaf transceiver module does not rely on internal Tx wavelength locker for frequency tracking. Leaf transceiver locks to the hub module frequency instead based on feedback from the Rx DSP.

In order to ensure the Leaf Tx signals do not interfere over operational lifetime , the laser frequency deviation histogram 1 sigma value must not be more than the value specified so over lifetime Leaf frequency deviation is not greater than 205MHz in 20years.

In case hub signal is lost and Leaf could not lock to the Hub frequency, Leaf XR must turn off Tx transmission to prevent possibly interference with another Leaf at the Hub Rx.

4.3.9 Hub Laser Frequency Wander/Jitter When Locked to Wavelength Locker

The Hub Laser Tx frequency jitter/wander while it is locked to the wavelength locker.

This Hub Tx laser Wander/Jitter tolerance is under the condition that Tx frequency is actively locked to Tx wavelength locker. Different Leaf units at different link distances locked to the same Hub frequency could be affected by Wander/Jitter and causes Leaf to Leaf frequencies spacing uncertainty. Thus, a maximum tolerable Wander/Jitter specification is required.

4.3.10 Tx Power Control Dynamic Range

Dynamic range by which the Tx output power can be changed without modifying the modulation signal.

For a fixed subcarriers Tx SCs MZM modulation profile, the module must have the capability of changing the transmitted optical power on all SCs in sync over this range by optical means, i.e. optical variable attenuator.

SCs profile can include how many SCs presented in the Tx spectrum or any optional emphasis on certain SC power over other SCs, and the modulation amplitude of each SC from modulator. Once the profile is set, the module shall have the capability of adjusting all SCs' power in sync over this Tx Power Control Dynamic Range.

This feature can be used to balancing the power of multiple Leaf modules at the Hub receiver.

4.3.11 Tx Output Power Monitor Range

This is the required measurement range of the TX output power monitor.

The TX output power monitor must cover full Tx power operating range. This includes the Tx Power Control Dynamic Range and, in case of P2MP application, the power changes resulting from changing the Tx subcarrier transmit profile. For example, changing from 16 subcarriers transmitting to a single subcarrier transmitting resulting in a 12 dB reduction if the per subcarrier power remains constant. A Leaf module in P2MP applications could operate with as little as 1 or 2 subcarriers, thus, a wide Tx output power monitor range is required for P2MP applications.

4.3.12 Tx Output Power Monitor Accuracy

Accuracy of Tx power reported by module against the Tx power measured with a calibrated external power meter.

4.3.13 Tx Output Power Monitor Stability

Stability of Tx reported output power monitor by module against an external reference power detector, over module lifetime operating at a fixed wavelength and temperature.

4.3.14 Tx In-Band Optical Signal to Noise Ratio

The ratio of the transmitted total coherent optical signal power to the optical power background noise integrated over a 12.5GHz band within the spectral range of the transmitted signal. Total coherent optical signal power is the coherent signal power summed over all SCs.

4.3.15 Tx Out-of-Band Optical Signal to Noise Ratio

The ratio of the transmitted total coherent optical signal power to the total optical background power integrated within any 12.5GHz band outside of the spectral range of the transmitted signal band. Total coherent optical signal power is the coherent signal power summed over all SCs.

4.3.16 Transmitter Optical Return Loss

The transmitter optical return loss is the ratio of the incident optical power into the transmitter port to the returned optical power at the same port while the module is inactive.

4.3.17 Transmitter Back Reflection Tolerance

Maximum light reflected back into the TX output port relative to Tx output power, while still meeting Tx optical performance requirements.

4.3.18 Tx Residual IQ Skew

Average differential delay between Q channel and I channel within a polarization after calibration.

4.3.19 Tx Residual X-Y Skew

Average differential delay between X and Y polarization after calibration.

Typically defined as (Delay_XI+Delay_XQ)/2 - (Delay_YI+Delay_YQ)/2, where the time delay for an individual I or Q channel is the mean of P trace and N trace. This is the residual X-Y skew variation after calibration.

4.3.20 Rx OSNR

Rx OSNR is the ratio of the received total coherent optical signal power to the background optical noise power in a 12.5GHz band within the spectral range of the received signal. Total coherent optical signal power is summed over all SCs. All SCs are at equal optical power for this Rx OSNR specification to be applicable.

4.3.21 Rx OSNR Tolerance at Defined Rx Input Power Range

The minimum required optical signal OSNR at the Rx to meet performance requirements within the specified optical input range for each modulation type.

4.3.22 Rx Total Input Power

Total optical input power, including in-band coherent signal power, other out-of-band optical channels, and ASE. This includes all optical power that is measurable by a broadband photo detector.

> Rx Total Input Power is measurable by a broadband photo detector.
>
> Below the maximum Rx total input power, performance is guaranteed. If input power is higher than this specified Rx Total Input Power, Rx may saturate, and performance cannot be guaranteed. Also, damage to the receiver may occur

4.3.23 CD Tolerance

Minimum supported chromatic dispersion that results in less than 0.1dB OSNR penalty.

4.3.24 DGD and PMD Tolerance

Minimum supported DGD or PMD tolerance that results in less than the specified 0.1dB OSNR penalty.

> Differential group delay (DGD) is the time difference between optical signal transmitted in the two principal states of polarization. Polarization Mode Dispersion (PMD) is the root-mean-square average of the DGD. Due to the polarization variation statistical nature, the instantaneous DGD is typically about 3.3 times the value of the PMD.

4.3.25 Polarization Tracking Rate

Minimum supported polarization change rate that results in less than 0.5dB OSNR penalty when system is operated within the specified PMD and PDL tolerance range.

4.3.26 PDL Tolerance

The minimum supported PDL that results in less than 0.5dB OSNR penalty.

> The polarization dependent loss (PDL) is the difference between the maximum and minimum values of the channel insertion loss (or gain) due to a variation of the State Of Polarization (SOP) over all state of polarizations.

4.3.27 Rx In-Band Signal Input Power Transient Tolerance

Acceptable receive signal power change with 50 µs rise/fall time (20%/80%), leading to less than 0.5 dB OSNR penalty.

> Tolerance for Rx input in-band optical power changes under the condition that the received power is within the range defined in "Rx Signal Input Power Range" during any time of the transition, and the rise/fall time, defined as between 20% and 80% of the transition power level, is 50µs or longer.

4.3.28 Rx In-Band Signal Input Power Monitor Range

The range within which the coherent Rx DSP of the module can detect and report the In-band signal power within Rx In-Band Signal Input Power Monitor Accuracy specification.

4.3.29 Rx Total Input Power Monitor Range

The range within which the module Rx broadband input power monitor can detect and report the total input power within Rx Total Input Power Monitor Accuracy specification. Rx Total Input Power includes in-band coherent signal power, other out-of-band optical channels, and ASE.

This is not the same as the "Rx Total Input Power" specification, which typically can be much higher. Module Rx Total Input Power Monitor has a finite range and is often optimized toward lower input power. When Rx Total Input Power (coherent signal power plus with aggressor channels power) is higher than the specified monitor range, the In-band signal power monitoring can be used to provide information of the coherent signal power.

4.3.30 Rx Total Power to In-Band Power Ratio

The maximum supported Power ratio between total received power, including out-of-band aggressors and ASE, to the received in-band signal power that results in less than 0.5dB OSNR penalty

For example, one in-band signal channel together with 15 out-of-band aggressor channels at Rx input with in-band signal 3dB less in per channel power compared to aggressors. This gives ~ 15dB total power to in-band power ratio. See Figure 3.

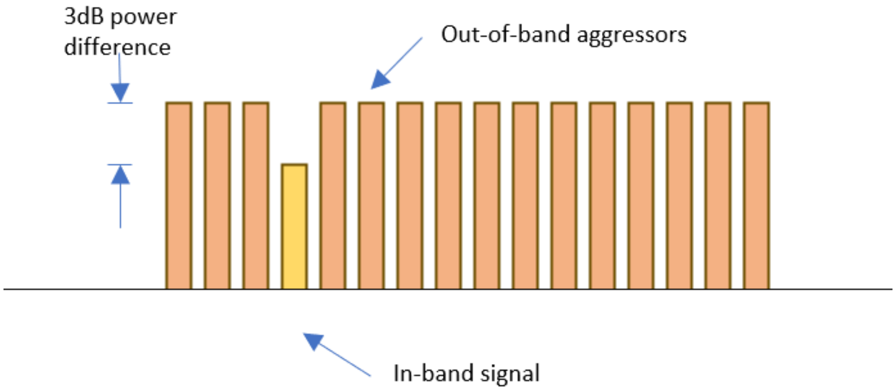


Figure 3. Rx Total Power vs. In-Band Power Illustration Diagram

Different numbers of aggressors at Rx can result in different tolerable maximum per channel power difference between signal and aggressors. This spec is based on assuming signal and aggressors are all using 400G 16QAM modulation. Other modulations, 8QAM or QPSK, could result in less OSNR penalty.

5. XR Host Client Interface support

5.1 Client Protocol Support

XR supports various types of Ethernet client services including 400GE, 200GE, 100GE, 50GE, and 25GE. And XR also supports OTN OTU4 clients. Table 9 lists the possible electrical interface protocol types [3] [5] that can be supported by 400G XR module. Which protocols to support of a given module is ASIC and application dependent.

XR module client SerDes lanes must be configured for 56Gbps or 28Gbps rates. Mixed SerDes rates (i.e., some lanes running 28 Gbps and other lanes running 56 Gbps) are not allowed. Also, the module does not support a mix of Ethernet & OTN clients; it must be configured either for Ethernet or for OTN service across all lanes in sync.

Port Speed and Types	Interface Protocol
25GE	25GAUI
50GE	50GAUI-1
100GE	100GAUI-2
	CAUI-4
200GE	200GAUI-4
400GE	400GAUI-8
OTU4	OTL4.2
	OTL4.4

Table 9. XR Module Supported Client Electrical Interfaces

5.2 Client-Side Lane Arrangement with 56G SerDes Configurations

At 50~56Gbps per lane, host electrical lanes can be combined to form higher bandwidth interfaces: 50GAUI-1, 100GAUI-2, 200GAUI-4 & 400GAUI-8 for Ethernet [3], and OTL4.2 for OTN [5]. Open XR allows mixed (non-homogeneous) combinations of 50GE, 100GE, 200GE among the 8 Serdes lanes. For example: "two 50GE streams on lane 1,2; one 100GE on lane 3and4; one 200GE on lane 5,6,7, and 8" can be a supported configuration. XR module advertises supported multiplexing modes following CMIS client encapsulation module multiplexing definition [2]. What client interfaces configurations to support is module design dependent.

Host Interface Lane	50GE	100GE	200GE	400GE	OTU4
Tx1, Rx1	50GAUI-1	100GAUI-2	200GAUI-4	400GAUI-8	OTL4.2
Tx2, Rx2	50GAUI-1				
Tx3, Rx3	50GAUI-1	100GAUI-2			OTL4.2
Tx4, Rx4	50GAUI-1				
Tx5, Rx5	50GAUI-1	100GAUI-2	200GAUI-4		OTL4.2
Tx6, Rx6	50GAUI-1				
Tx7, Rx7	50GAUI-1	100GAUI-2			OTL4.2
Tx8, Rx8	50GAUI-1				

Table 10. Allowed XR Module 50G/56G Serdes Client Lane Arrangement

5.3 Client-Side Lane Arrangement with 28G SerDes Configurations

At 25~28Gbps per lane, host electrical lanes can be combined to form higher bandwidth interfaces: 25GAUI, CAUI4 for Ethernet[3], and OTL4.4 for OTN [5]. Open XR allows mixed (non-homogeneous) combinations of 25GE, 100GE among the 8 Serdes lanes. For example: "four 25GE streams on lane 1,2,3,4; and one 100GE on lane 5,6,7, and 8" can be a supported configuration. XR module advertises supported multiplexing modes following CMIS client encapsulation module multiplexing definition [2]. What client interfaces configurations to support is module design dependent.

Host Interface Lane	25GE	100GE	OTU4
Tx1, Rx1	25GAUI	CAUI-4 (No FEC or with IEEE Clause91 RS FEC)	OTL4.4
Tx2, Rx2	25GAUI		
Tx3, Rx3	25GAUI		
Tx4, Rx4	25GAUI		

Tx5, Rx5	25GAUI	CAUI-4 (No FEC or with IEEE Clause91 RS FEC)	OTL4.4
Tx6, Rx6	25GAUI		
Tx7, Rx7	25GAUI		
Tx8, Rx8	25GAUI		

Table 11. XR Module 25G/28G Serdes Client Lane Arrangement

References

[1] OIF-400ZR-02.0 – Implementation Agreement 400ZR (November 2022)

[2] QSFP-DD Management Interface Specification Rev 5.1 (November 2021)

[3] IEEE 802.3-2022, Annex 120E specification for 400GAUI-8 and 200GAUI-4; 802.3cd Annex 135G specification for 100GAUI-2; IEEE 802.3-2022, Annex 83E specification for 100G CAUI-4; IEEE 802.3-2022, Annex 109B specification for 25GAUI.

[4] OIF-CEI-05.0 -- Common Electrical I/O (CEI) - Electrical and Jitter Interoperability agreements for 6G+ bps, 11G+ bps, 25G+ bps, 56G+ bps and 112G+ bps I/O (May 5, 2022)

[5] ITU-T G.709/Y.1331, Interfaces for the Optical Transport Network (June 2020)

[6] Open XR Forum documentation OXR2022.011.001 CMIS Modification Proposal (April 20, 2022)

6. Abbreviations

- List of abbreviations used in this document.

BER	Bit Error Ratio
CD	Chromatic Dispersion
CEI	Common Electrical Interface
CMIS	Common Management Interface Specification
CW	Continuous Wave
DGD	Differential Group Delay
DSC	Digital Subcarrier
DSP	Digital Signal Processing
GBPS	Gigabit per Second
GE	Gigabit Ethernet
I2C	Inter-Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineers
LO	Local Oscillator
MDIO	Management Data Input/Output
MVIO	Multi-Vendor Interoperable
MVLAN	Management Virtual Local Area Network
OIF	Optical Internetworking Forum
OSNR	Optical Signal to Noise Ratio

OTN	Optical Transport network
OTU	Optical Channel Transport Unit
OOF	Out Of Band
P2P	Point-to-Point
P2MP	Point-to-MultiPoint
PDL	Polarization Dependent Loss
PMD	Polarization Mode Dispersion
PSD	Power Spectral Density
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase shift Keying
ROADM	Reconfigurable Optical Add Drop Multiplexer
SGMII	Serial Gigabit Management Interface
SC	Subcarrier
SOP	State of Polarization
VOA	Variable Optical Attenuator
WDM	Wavelength Division Multiplexing
XSC	Open XR Supervisory Channel