800G-FR4
Technical Specification

800G Pluggable MSA

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The following companies were members of the 800G Pluggable MSA at the release of this Specification:

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	USCONEC
	Viavi
	ZTE
	II-VI

Revisions

Rev	Date	Description
1.0	08 June 2021	Initial Release

TABLES

FIGURES

1 GENERAL

1.1 SCOPE

This Multi-Source Agreement (MSA) defines 4x200 Gbps wavelength division-multiplex (WDM) optical interface for 800 Gbps optical transceivers for Ethernet applications. Forward error correction (FEC) is suggested to be implemented in the module to ensure reliable system operation. Two transceivers communicate over single mode fibers (SMF) of length from 2 meters to at least 2 kilo-meters. The transceiver electrical interface is not specified by this MSA but can have, for example, eight lanes or four lanes in each direction with a total signaling rate of 800 Gbps. A variety of form factors for the 4x200G-FR4 transceivers are possible and none are precluded by this MSA.

1.2 4x200G-FR4 MODULE BLOCK DIAGRAM

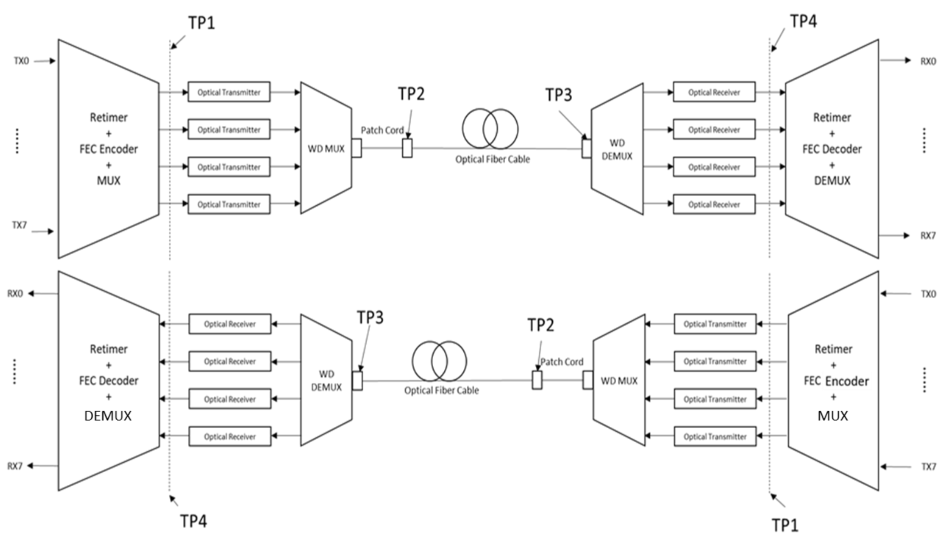

Figure 1-1: Block diagram for 4x200G-FR4 transmit/receive paths

1.3 FUNCTIONAL DESCRIPTION

4x200G-FR4 modules comply with the requirements of this document and have the following common features: four optical transmitters; wavelength multiplexer and de-multiplexer; four optical receivers with signal detection; Dual LC connectors for single-mode fiber.

1.4 HARDWARE SIGNALING PINS

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

1.5 MODULE MANAGEMENT INTERFACE

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

1.6 HIGH SPEED ELECTRICAL CHARACTERISTICS

The detailed high speed electrical characteristics are not defined by this MSA. 800G modules should be implemented in compliance with applicable electrical interface specifications. For example, it can have either 8 lanes of 100 Gbps or 4 lanes of 200 Gbps in each direction for electrical interface.

1.7 FEC REQUIREMENTS

1.7.1 Concatenated FEC framework

As shown in Fig 1-2, the 4×200G-FR4 Forward Error Correction (FEC) scheme is the concatenation of the outer Reed-Solomon (RS) FEC implemented in host system and an inner hard decision (HD) FEC implemented in 800G pluggable optical module with the chip-to-module (C2M) interfaces connecting them. In accordance with Annex 120G, IEEE P802.3ck™/D1.3, a BER_{C2M} which is less than 1.0E-5 is introduced for each interface. The RS codewords are not terminated in the optical module and they are appropriately distributed to the inner HD FEC encoder. The RS FEC is transparent to the optical module. The 4×200G-FR4 link relies on the host system to implement the legacy 400GBASE-R PCS layer in accordance with Clause 119 of IEEE Std 802.3-2018™. The PCS layer includes implementation of RS (544,514) FEC encoding and decoding functions. With FEC defined for 800GE in the future, the FEC implementation will be updated correspondingly.

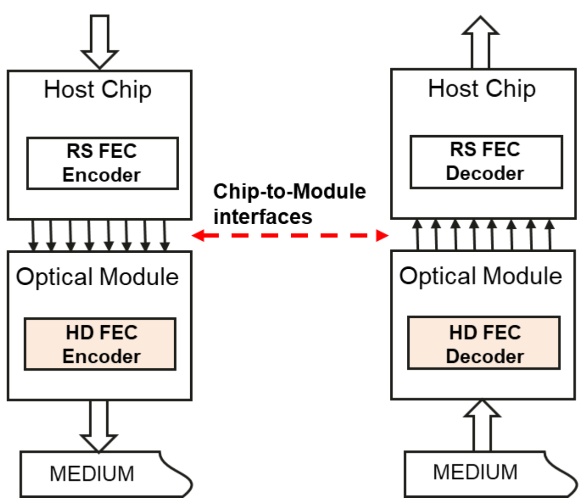

Figure 1-2 Concatenated FEC framework for 4×200G-FR4

1.7.2 Inner HD FEC

The inner HD FEC is a spatially coupled code constructed by serially concatenating a series of Bose-Chaudhuri-Hocquengham (BCH) component codes together in a single coupled chain. The spatially coupled structure guarantees a good performance of the concatenated FEC scheme. A simple BCH component code with correcting capability of t=2 ensures the hard-in-hard-out iteratively decoder can be implemented in a low complexity. The spatially coupled code with overhead less than 6% is enough to correct the bit error rate (BER) from 2.0E-3 to a BER region better than 1.0E-5. Then the outer RS FEC is capable to correct this residue error together with the errors introduced in the C2M interface to achieve a BER better than 1.0E-15. The latency of the inner HD FEC is less than 150 ns to meet the requirement of the 800G-FR4 application.

1.8 MECHANICAL DIMENSIONS

Mechanical dimensions are defined in module form factor MSA specifications.

2 4x200G FR4 OPTICAL SPECIFICATIONS

2.1 WAVELENGTH DIVISION MULTIPLEXED LANE ASSIGNMENTS

The wavelength range for the 4x200G-FR4 Physical Medium Dependent (PMD) is defined in Table 2-1.

Table 2-1: Wavelength lane assignments

Lane	Center wavelength	Wavelength range
L_0	1271 nm	1264.5 to 1277.5 nm
L_1	1291 nm	1284.5 to 1297.5 nm
L_2	1311 nm	1304.5 to 1317.5 nm
L_3	1331 nm	1324.5 to 1337.5 nm

2.2 OPTICAL SPECIFICATIONS

The operating range for 4x200G-FR4 PMD is defined in Table 2-2. A compliant PMD operates on single mode fibers according to the specifications defined in Table 4-1 and characteristics in Table 5.1.

Table 2-2: 4x200G-FR4 operating range

PMD type	Required operating range
4x200G-FR4	2 m to 2 km

2.2.1 4x200G-FR4 transmitter optical specifications

The 4x200G-FR4 transmitter shall meet the specifications defined in Table 2-3.

Table 2-3: 4x200G-FR4 transmit characteristics

Description	Value	Unit
PAM4 Signaling rate, each lane (range)	112.5	GBd
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Total average launch power (max)	10	dBm
Average launch power, each lane (max)	4.0	dBm
Average launch power, each lane[a] (min)	-2.8	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	4.2	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane[b] (min)	0.2	dBm
Launch power in OMA_{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	-1.2 -1.1	dBm
Transmitter and dispersion penalty eye closure for PAM4 (TDECQ), each lane (max)	3.9	dB
Transmitter penalty eye closure for PAM4 (TECQ), each lane (max)	3.9	dB
|TDECQ-TECQ|, each lane (max)	TBD	dB
Average launch power of OFF transmitter, each lane (max)	-20	dBm
Difference in launch power between any two lanes (OMA_{outer}) (max)	4	dB
Transmitter overshoot/undershoot as a fraction of OMA_{outer}(max)	TBD	-
Extinction ratio (min)	3.5	dB
$RIN_{17.1}$ OMA (max)	-139	dB/Hz
Optical return loss tolerance (max)	17.1	dB
Transmitter reflectance[c] (max)	-26	dB

[a] Average launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.

[b] Even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMA_{outer} (min) must exceed this value.

[c] Transmitter reflectance is defined looking into the transmitter.

[d] C_{eq} is a coefficient defined in IEEE Std 802.3-2018 clause 121.8.5.3 which accounts for reference equalizer noise enhancement.

2.2.2 4x200G-FR4 receive optical specifications

The 4x200G-FR4 receiver shall meet the specifications defined in Table 2-4.

Table 2-4: 4x200G-FR4 receive characteristics

Description	Value	Unit
PAM4 Signaling rate, each lane (range)	112.5	GBd
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm
Damage threshold, each lane (min)[a]	5	dBm
Average receive power, each lane (max)	4	dBm
Average receive power, each lane[b] (min)	-6.8	dBm
Receive power, each lane (OMA_{outer}) (max)	4.2	dBm
Difference in receive power between any two lanes (OMA_{outer}) (max)	4.1	dB
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMA_{outer}), each lane[c] (max)	max(-4.6, -6+SECQ)	
Stressed receiver sensitivity (OMA_{outer}), each lane[d] (max)	-2.1	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ), lane under test	3.9	dB
SECQ – $10*\log_{10}(C_{eq})$, lane under test (max) [e]	3.9	dB
OMA_{outer} of each aggressor lane	1.5	dBm

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical signal having this average power level. The receiver does not have to operate correctly at this input power.

[b] Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.

[c] Receiver sensitivity (OMA_{outer}), each lane (max) is informative and is defined for a transmitter with a value of SECQ up to 4.5 dB.

[d] Measured with conformance test signal at TP3 (see 3.11) for the BER specified in IEEE Std 802.3-2018 clause 124.1.1.

[e] C_{eq} is a coefficient defined in IEEE Std 802.3-2018 clause 121.8.5.3 which accounts for reference equalizer noise enhancement.

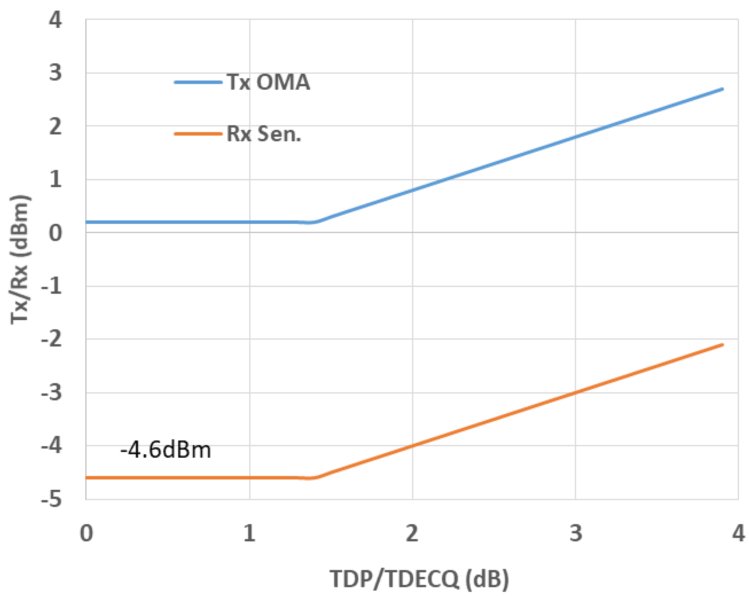

Figure 2-1 Illustration of receiver sensitivity mask for 4x200G-FR4

2.2.3 4x200G-FR4 illustrative link power budget

An illustrative power budget and penalties for 4x200G-FR4 are shown in Table 2-5.

Table 2-5: 4x200G-FR4 illustrative power budget

Description	Value	Unit
Power budget (for max TDECQ)		
for extinction ratio ≥ 4.5 dB	8.6	dB
for extinction ratio < 4.5 dB	8.7	
Operating distance	2	km
Channel insertion loss[a]	4	dB
Maximum discrete reflectance	See Table 2-6	dB
Allocation for penalties[b] (for max TDECQ)		
for extinction ratio ≥ 4.5 dB	4.6	
for extinction ratio < 4.5 dB	4.7	dB
Additional insertion loss allowed	0	dB

[a] The channel insertion loss is calculated using the maximum distance specified in Table 2-2 and cabled optical fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 5.2.1.

[b] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Table 2-6: 4x200G-FR4 Maximum value for each discrete reflectance

Number of discrete reflectance above -55dB	Maximum value for each discrete reflectance	Unit
1	-25	dB
2	-31	dB
4	-35	dB
6	-38	dB
8	-40	dB
10	-41	dB

3 DEFINITION OF OPTICAL PARAMETERS AND MEASUREMENT METHODS

All optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

Table 3- 1: Test patterns

Pattern	Pattern Description	Defined in[a]
Square wave	Square wave (8 threes, 8 zeroes)	120.5.11.2.4
3	PRBS31Q	120.5.11.2.2
4	PRBS13Q	120.5.11.2.1
5	Scrambled idle	119.2.4.9
6	SSPRQ	120.5.11.2.3

[a] These sub-clauses make reference to relevant clauses of IEEE Std 802.3-2018.

3.1 TEST PATTERNS FOR OPTICAL PARAMETERS

Table 3- 2: Test pattern definitions and related subclauses

Parameter	*Pattern*	*Reference*
Wavelength	Square wave, 3, 4, 5, 6 or valid 400GBASE-R signal	3.3
Side mode suppression ratio	3, 5, 6 or valid 400GBASE-R signal	122.8.2[a]
Average optical power	3, 5, 6 or valid 400GBASE-R signal	3.4
Optical modulation amplitude (OMA_{outer})	4 or 6	3.5
Transmitter and dispersion eye closure for PAM4 (TDECQ)	6	3.6
Extinction ratio	4 or 6	3.7
$RIN_{17.1}$ OMA	Square wave	3.9
Stressed receiver conformance test signal calibration	6	3.11
Stressed receiver sensitivity	3 or 5	3.11

[a] IEEE Std 802.3-2018.

3.2 SKEW AND SKEW VARIATION

The skew and skew variation is specified in IEEE Std 802.3-2018 clause 124.3.

3.3 WAVELENGTH

The wavelength of each optical lane shall be within the range given in Table 2-3 if measured per TIA/EIA-455-127-A or IEC 61280-1-3. The lane under test is modulated using the test pattern defined in Table 3-2.

3.4 AVERAGE OPTICAL POWER

The average optical power of each lane shall be within the limits given in Table 2-3 if measured using the methods given in IEC 61280-1-1. The average optical power is measured using the test pattern defined in Table 3-2, with the test setup in IEEE Std 802.3-2018 Figure 53-6.

3.5 OPTICAL MODULATION AMPLITUDE (OMA_{outer})

The OMA_{outer} of each lane shall be within the limits given in Table 2-3. The OMA_{outer} is measured using a test pattern specified for OMA_{outer} in Table 3-2 as the difference between the average optical launch power level P3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P0, measured over the central 2 UI of a run of 6 zeros, as shown in IEEE Std 802.3-2018 Figure 124–3. Each lane may be tested individually with all other lanes turned off, or by using an optical filter if the other lanes are active.

3.6 TRANSMITTER AND DISPERSION EYE CLOSURE PENALTY (TDECQ)

The TDECQ and TDECQ – 10*log10(C_{eq}) of each lane shall be within the limits given in Table 2-3 if measured using the methods specified in IEEE Std 802.3-2018 clauses 121.8.5.1, 121.8.5.2, and 121.8.5.3 using a reference equalizer as described in section 3.6.1, with the following exceptions:

a. The transmitter is tested using an optical channel that meets the requirements listed in Table 3-3.
b. Q_t in TDECQ calculation is 2.785 consistent with the BER and target symbol ratio（2.0E-3）for Gray coded PAM4.
c. The signaling rate of the test pattern generator is as given in Table 2-3 and uses the test pattern specified for TDECQ in Table 3-2.
d. The normalized power density spectrum, N(f), is equivalent to white noise filtered by a fourth-order Bessel-Thompson filter response with a bandwidth to be determined.
e. The combination of the O/E converter and the oscilloscope has a fourth-order Bessel-Thompson filter response with a bandwidth to be determined.
f. Pth1, Pth2, and Pth3 are varied from their nominal values by up to +/-1% of OMA_{outer} in order to optimize TDECQ. The same three thresholds are used for both the left and the right histogram

Table 3- 3: Transmitter compliance channel specifications

Type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
4x200G-FR4	0.0465*λ*[1-(1324/λ)4]	0.0465*λ*[1-(1300/λ)4]	Minimum	17.1 dB	ps

a. The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes for 800G-FR4.
b. There is no intent to stress the sensitivity of the O/E converter associated with the oscilloscope.
c. The optical return loss is applied at TP2, i.e. after a 2 m patch cord.

3.6.1 TDECQ reference equalizer

The reference equalizer for 4x200G-FR4 is similar to that specified in IEEE Std 802.3cd clause 140.7.5.1 with the following exceptions:
The reference equalizer for 800GBASE-FR4 is a 21 tap, T spaced, feed-forward equalizer (FFE), where T is the symbol period. The sum of the equalizer tap coefficients is equal to 1 and the main tap is to be determined
NOTE—This reference equalizer is part of the TDECQ test and does not imply any particular receiver equalizer implementation.

3.7 EXTINCTION RATIO

Extinction ratio is measured using the methods specified in IEEE Std 802.3-2018 clause 124.8.6

3.8 RELATIVE INTENSITY NOISE ($RIN_{17.1}OMA$)

RIN shall be as defined by the measurement methodology of IEEE Std 802.3-2018 clause 52.9.6 with the following exceptions:

a. The optical return loss is 17.1 dB.
b. Each lane may be tested individually with the sum of the optical power from all of the lanes not under test being below –30 dBm.
c. The upper –3 dB limit of the measurement apparatus is to be approximately equal to the signaling rate.
d. The test pattern is according to Table 3-2.

3.9 RECEIVER SENSITIVITY

Receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 3.4 dB. Receiver sensitivity should meet Equation (1), which is illustrated in Figure 2-1.

$$= \max(-4.6, -6+SECQ) \qquad (1)$$

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

The normative requirement for receivers is stressed receiver sensitivity.

3.10 STRESSED RECEIVER SENSITIVITY

Stressed receiver sensitivity shall be within the limits given in Table 2-4 if measured using the method defined in IEEE Std 802.3cd clause 140.7.10 with the following exceptions:

a. The signaling rate of the test pattern generator, the extinction ratio of the E/O Converter, as well as the RIN_OMA of transmitter are as given in Table 2-3 and Table 2-4 using test patterns specified in Table 3-2.
b. The required values of the "Stressed receiver sensitivity (OMA_{outer}), each lane (max)","Stressed eye closure for PAM4 (SECQ), lane under test", "SECQ – 10*log10(C_{eq}), lane under test (max)" and "OMA_{outer} of each aggressor lane" are as given in Table 2-4.
c. The block diagram for the receiver conformance test is shown in IEEE Std 802.3-2018 Figure 122-8.

The BER is required to be met for the lane under test on its own.

Stressed receiver sensitivity is defined with all transmit and receive lanes in operation. Any of the patterns specified for stressed receiver sensitivity in Table 3-2 is sent from the transmit section of the PMD under test. The signal being transmitted is asynchronous to the received signal.

4 FIBER OPTIC CABLING MODEL

The fiber optic cabling model is shown in Figure 4-1

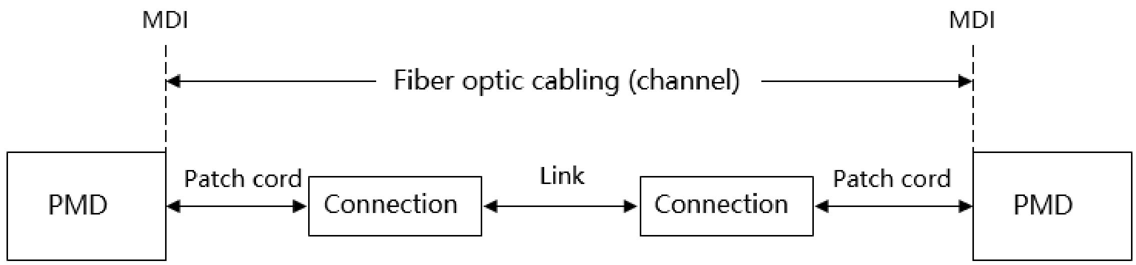

Figure 4-2: Fiber optic cabling model

The channel insertion loss is given in Table 4-1. A channel may contain additional connectors as long as the optical characteristics of the channel, such as attenuation, dispersion, reflections and polarization mode dispersion meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-7/method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

Table 4-1: Fiber optic cabling (channel) characteristics

Description	800G-FR4	Unit
Operating distance (max)	2	km
Channel insertion loss [a,b] (max)	4	dB
Channel insertion loss (min)	0.0	dB
Positive dispersion[b] (max)	6.7	ps/nm
Negative dispersion[b] (min)	-11.9	ps/nm
DGD_max[c]	2.3	ps
Optical return loss (min)	25	dB
[a] These channel loss values include cable, connectors and splices.		
[b] Over the wavelength range 1264.5 to 1337.5 nm.		
[c] Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.		

5 CHARACTERISTICS OF THE FIBER OPTIC CABLING (CHANNEL)

The 800G-FR4 fiber optic cabling shall meet the specifications defined in Table 4-1. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together.

5.1 OPTICAL FIBER CABLE

The fiber optic cable requirements are satisfied by cables containing IEC 60793-2-50 type B1.1 (dispersion un-shifted single-mode), type B1.3 (low water peak single-mode), or type B6_a (bend insensitive) fibers and the requirements in Table 5- 1 where they differ.

Table 5- 1: Optical fiber and cable characteristics

Description	Value	Unit
Nominal fiber specification wavelength	1311	nm
Cabled optical fiber attenuation (max)	0.47[a] or 0.5[b]	dB/km
Zero dispersion wavelength (λ_0)	$1300 \leq \lambda_0 \leq 1324$	nm
Dispersion slope (max) (S_0)	0.093	ps/nm^2km
a The 0.47 dB/km attenuation for optical fiber cables is derived from Appendix I of ITU-T G.695. b The 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3.		

5.2 OPTICAL FIBER CONNECTION

An optical fiber connection, as shown in Figure 4-2, consists of a mated pair of optical connectors.

5.2.1 Connection insertion loss

The maximum link distances for single-mode fiber are calculated based on an allocation of 3 dB total connection and splice loss. This allocation supports six connections with an average insertion loss per connection of 0.5dB.

5.2.2 Maximum discrete reflectance

The maximum discrete reflectance shall be less or equal to the value shown in Table 2-6.

5.3 MEDIUM DEPENDENT INTERFACE (MDI) REQUIREMENTS

The PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the “fiber optic cabling” (as shown in Figure 4-2). Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

When the MDI is a connector plug and receptacle connection, it shall meet the interface performance specifications of IEC 61753-1-1 and IEC 61753-021-2.

NOTE---Transmitter compliance testing is performed at TP2 i.e. after a 2 meter patch cord, not at the MDI.