802.3cu D1p0
proposed editing to 100GBASE-FR1/LR1 and 400GBASE-FR4/LR4 PMDs.

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Background

- This presentation contains 802.3cu D1p0 considerations and proposed relative changes for 100GBASE-FR1/LR1 and 400GBASE-FR4/LR4 PMDs.
- Comments and proposed changes about:
  1. Delta between Average launch power (min), Outer Optical Modulation Amplitude (OMAouter) (min)
  2. Allocation for penalties (DGD penalties).
  3. Compatibility between 100GBASE-FR1 and 100GBASE-LR1.
  4. Average power of OFF transmitters.

1. Delta between Average launch power (min), Outer Optical Modulation Amplitude (OMAouter) (min)

Table 140–6—100GBASE-DR, 100GBASE-FR1, and 100GBASE-LR1 transmit characteristics

Description	~~Value~~ 100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Signaling rate (range)	53.125 ± 100 ppm			GBd
Modulation format	PAM4			—
Wavelength (range)	1304.5 to 1317.5			nm
Side-mode suppression ratio (SMSR), (min)	30			dB
Average launch power (max)	4	4	4.8	dBm
Average launch power[a] (min)	−2.9	−2.4	−1.1	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (max)	4.2	4.2	5	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (min)[b]	−0.8	−0.2	1	dBm
Launch power in OMA_{outer} minus TDECQ (min): for extinction ratio ≥ 5 dB for extinction ratio < 5 dB	 −2.2 −1.9	 — —	 — —	 dBm dBm
Launch power in OMA_{outer} minus TDECQ (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 — —	 −1.6 −1.5	 −0.4 −0.3	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)	3.4	3.4	3.4	dB
TDECQ − $10\log_{10}(C_{eq})$[c] (max)	3.4	3.4	3.4	dB
Average launch power of OFF transmitter (max)	−15	−15	−15	dBm
Extinction ratio (min)	3.5	3.5	3.5	dB
Transmitter transition time (max)	17	17	17	ps
~~$RIN_{15.5}$OMA (max)~~ $RIN_{xx.x}$OMA (max), where xx.x is the optical return loss tolerance (max)	−136	−136	−136	dB/Hz
Optical return loss tolerance (max)	15.5	17.1	15.6	dB
Transmitter reflectance[d] (max)	−26	−26	−26	dB

[a] Average launch power (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] For 100GBASE-DR, ~~E~~even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 5 dB or TDECQ < 1.1 dB for an extinction ratio of < 5 dB, the OMA_{outer} (min) must exceed this value. For 100GBASE-FR1, or 100GBASE-LR1, even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMA_{outer} (min) must exceed this value.
[c] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.
[d] Transmitter reflectance is defined looking into the transmitter.

The difference between Average launch power (min) and Outer Optical Modulation Amplitude (OMAouter) (min) has been set to 3dB for 400GBASE-FR4 and 400GBASE-LR4 transmitters (equal to the delta considering infinite ER of the transmitter).
This is in line with other adopted PAM-4 PMD in previous standards (e.g. 50G-based PMD (200GBASE-FR4/LR4, 400GBASE-FR8/LR8).

But this is not applied to 100GBASE-FR1 and 100GBASE-LR1, so in this way we unfairly penalize existing high ER (> 10dB) TXs.

Note: also 100GBASE-DR too is affected, but is outside the scope of this project.
So, to allow interoperability with 100GBASE-DR, 100GBASE-FR1 power should be reduced to its minimum launch power.

Table 151–7—400GBASE-FR4 and 400GBASE-LR4 transmit characteristics

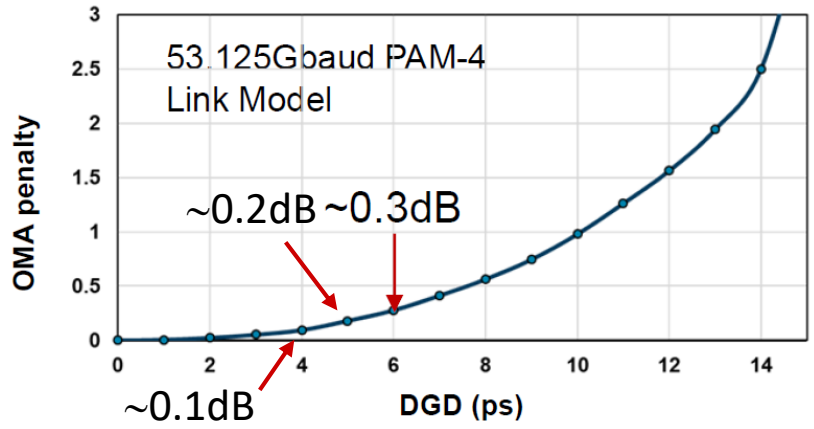
Description	400GBASE-FR4	400GBASE-LR4	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm		GBd
Modulation format	PAM4		—
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5		nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Total average launch power (max)	9.5	11.6	dBm
Average launch power, each lane (max)	3.5	5.6	dBm
Average launch power, each lane[a] (min)	−3.3	−2.8	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	3.7	4.4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[b]	−0.3	0.2	dBm
Difference in launch power between any two lanes (OMA_{outer}) (max)	4	4	dB
Launch power in OMA_{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 −1.7 −1.6	 −1.2 −1.1	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	3.4	3.5	dB
TDECQ − $10\log_{10}(C_{eq})$[c] (max)	3.4	3.5	dB
TDECQ − SECQ	—	TBD	dB
Average launch power of OFF transmitter, each lane (max)	−20	−20	dBm
Extinction ratio, each lane (min)	3.5	3.5	dB
Transmitter transition time (max)	17		ps
$RIN_{17.1}$OMA (max)	−136	—	dB/Hz
$RIN_{15.6}$OMA (max)	—	−136	dB/Hz
Optical return loss tolerance (max)	17.1	15.6	dB
Transmitter reflectance[d] (max)	−26		dB

[a] Average launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b] Even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMA_{outer} (min) must exceed this value.
[c] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for reference equalizer noise enhancement.
[d] Transmitter reflectance is defined looking into the transmitter.

2. Allocation for penalties: DGD penalty considerations

- DGD has been included for link >= 6kms in 802.3cu.
- Based on theoretical work reported in anslow_3cu_adhoc_051519 the corresponding DGD of 5ps corresponding to 10kms link will make a penalty of 0.25dB, which was rounded-up to 0.3dB by the adopted baseline.
- Further work (see castro_3cu_adhoc_070319) shown that the DGD penalty (max) to be considered is 0.2dB when DGD is 5ps.

From castro_3cu_adhoc_070319



	Lenght [km]	10	6	
Tail prob = 0.01	DGD_max [ps]	6.23	4.82	with S=3.75 (2.6s/year)
Tail prob = 0.01	DGD_max [ps]	5.48	4.24	with S=3.3 (2.5m/year)
Tail prob = 0.1	DGD_max [ps]	5.34	4.13	with S=3.75 (2.6s/year)
Tail prob = 0.1	DGD_max [ps]	4.70	3.64	with S=3.3 (2.5m/year)

DGD should be considered statistically when counted with other penalties like MPI.
To have the best fit with these simulations we should consider:

- 100GBASE-LR1 (10kms): DGD_max = 5ps, Penalty = 0.2dB
- 400GBASE-LR4 (6kms): DGD_max = 4ps, Penalty = 0.1dB

Currently D1p0 consider 0.3dB for 100GBASE-LR1 and 0.2dB for 400GBASE-LR4.

Note: Also no experimental work has been presented considering the DGD impairment when chromatic dispersion is present (the expectance is that its contribution will be ≤ than above numbers).

3. Compatibility between 100GBASE-FR1 and 100GBASE-LR1

Table 140–7—100GBASE-DR, 100GBASE-FR and 100GBASE-LR receive characteristics

D0p2

Description	~~Value~~ 100GBASE-DR	100GBASE-FR	100GBASE-LR	Unit
Signaling rate (range)	53.125 ± 100 ppm			GBd
Modulation format	PAM4			—
Wavelengths (range)	1304.5 to 1317.5			nm
Damage threshold[a]	5	5.5	5.5	dBm
Average receive power (max)	4	4.5	4.5	dBm
Average receive power[b] (min)	–5.9	–6.4	–7.7	dBm
Receive power (OMA_{outer}) (max)	4.2	4.7	4.7	dBm
Receiver reflectance (max)	–26	–26	–26	dB

D1p0

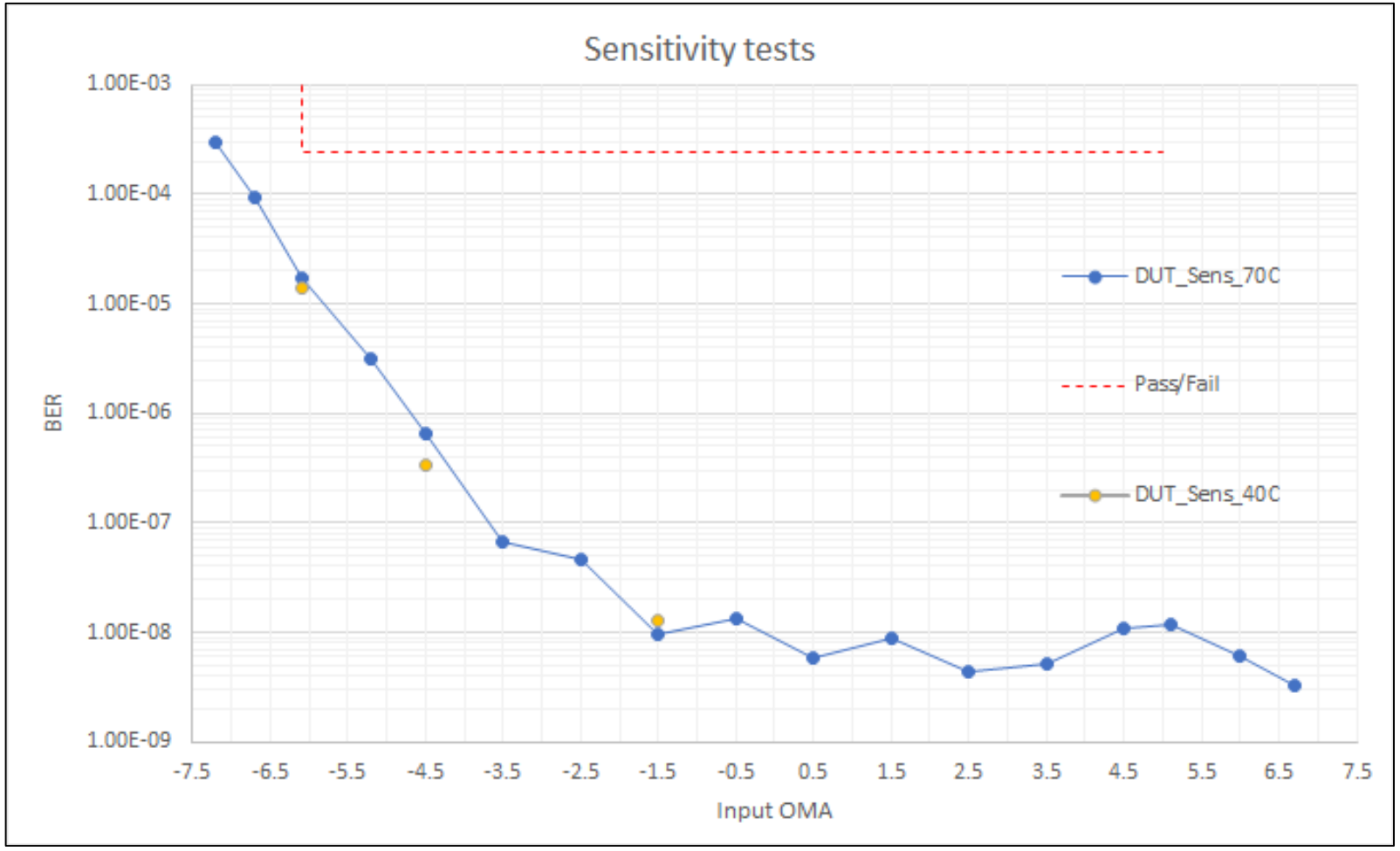
Description	~~Value~~ 100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Signaling rate (range)	53.125 ± 100 ppm			GBd
Modulation format	PAM4			—
Wavelengths (range)	1304.5 to 1317.5			nm
Damage threshold[a]	5	5.5	5.8	dBm
Average receive power (max)	4	4.5	4.8	dBm
Average receive power[b] (min)	–5.9	–6.4	–7.4	dBm
Receive power (OMA_{outer}) (max)	4.2	4.7	5	dBm
Receiver reflectance (max)	–26	–26	–26	dB

100GBASE-FR1 and 100GBASE-LR1 damage threshold and maximum average received power were kept aligned until draft D0p2, so to ensure compatibility between these two PMDs.

The option to use a 0.3dB attenuator as per Table 140–16 seems not practical because its too small value – minimum attenuator losses should be considered 0.5dB, with an added connection – some costs has to be considered too.

Since 100GBASE-LR1 maximum TX power has been increased into Table 140-6, we now need to align them back again into table 140-7, as well to update 140.10b and related Table 140-16.

3. Compatibility between 100GBASE-FR1 and 100GBASE-LR1



Tested RX Cisco part (Ref TX input TDECQ=1.8dB and ER=8.6dB), showing no issues at overload, up to 6.7dBm OMA (4.9dBm power).

4. Average power of OFF transmitters

Table 140–6—100GBASE-DR, 100GBASE-FR1, and 100GBASE-LR1 transmit characteristics

Description	~~Value~~ 100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Signaling rate (range)	53.125 ± 100 ppm			GBd
Modulation format	PAM4			—
Wavelength (range)	1304.5 to 1317.5			nm
Side-mode suppression ratio (SMSR), (min)	30			dB
Average launch power (max)	4	4	4.8	dBm
Average launch power[a] (min)	−2.9	−2.4	−1.1	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (max)	4.2	4.2	5	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (min)[b]	−0.8	−0.2	1	dBm
Launch power in OMA_{outer} minus TDECQ (min): for extinction ratio ≥ 5 dB for extinction ratio < 5 dB	 −2.2 −1.9	 — —	 — —	 dBm dBm
Launch power in OMA_{outer} minus TDECQ (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 — —	 −1.6 −1.5	 −0.4 −0.3	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)	3.4	3.4	3.4	dB
TDECQ − $10\log_{10}(C_{eq})$[c] (max)	3.4	3.4	3.4	dB
Average launch power of OFF transmitter (max)	−15	−15	−15	dBm
Extinction ratio (min)	3.5	3.5	3.5	dB
Transmitter transition time (max)	17	17	17	ps
~~$RIN_{15.5}OMA$ (max)~~ $RIN_{xx.x}OMA$ (max), where xx.x is the optical return loss tolerance (max)	−136	−136	−136	dB/Hz
Optical return loss tolerance (max)	15.5	17.1	15.6	dB
Transmitter reflectance[d] (max)	−26	−26	−26	dB

[a] Average launch power (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] For 100GBASE-DR, ~~E~~even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 5 dB or TDECQ < 1.1 dB for an extinction ratio of < 5 dB, the OMA_{outer} (min) must exceed this value. For 100GBASE-FR1, or 100GBASE-LR1, even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMA_{outer} (min) must exceed this value.
[c] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.
[d] Transmitter reflectance is defined looking into the transmitter.

The average power of OFF transmitter can be implemented by laser shout down or by a SiP switch for this technology.

As already specified for 100GBASE PMDs, it would be good to relax this value to -15dBm too in consistency with 802.3bs and 802.3cd.

Table 151–7—400GBASE-FR4 and 400GBASE-LR4 transmit characteristics

Description	400GBASE-FR4	400GBASE-LR4	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm		GBd
Modulation format	PAM4		—
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5		nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Total average launch power (max)	9.5	11.6	dBm
Average launch power, each lane (max)	3.5	5.6	dBm
Average launch power, each lane[a] (min)	−3.3	−2.8	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	3.7	4.4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[b]	−0.3	0.2	dBm
Difference in launch power between any two lanes (OMA_{outer}) (max)	4	4	dB
Launch power in OMA_{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 −1.7 −1.6	 −1.2 −1.1	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	3.4	3.5	dB
TDECQ − $10\log_{10}(C_{eq})$[c] (max)	3.4	3.5	dB
TDECQ − SECQ	—	TBD	dB
Average launch power of OFF transmitter, each lane (max)	−20	−20	dBm
Extinction ratio, each lane (min)	3.5	3.5	dB
Transmitter transition time (max)	17		ps
$RIN_{17.1}OMA$ (max)	−136	—	dB/Hz
$RIN_{15.6}OMA$ (max)	—	−136	dB/Hz
Optical return loss tolerance (max)	17.1	15.6	dB
Transmitter reflectance[d] (max)	−26		dB

[a] Average launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b] Even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMA_{outer} (min) must exceed this value.
[c] C_{eq} is a coefficient defined in 121.8.5.3, which accounts for reference equalizer noise enhancement.
[d] Transmitter reflectance is defined looking into the transmitter.

Proposed changes to D1p0 draft

- All the changes from previous 4 points are summarized into proposed changes to table 140-6, 140-7, 140-8 and 140-16 for 100GBASE-FR1/LR1.
- All the changes from previous 4 points are summarized into proposed changes to table 151-7, 151-8, 151-9 for 400GBASE-FR4/LR4.
- Details are given in next slides.

802.3cu: transmit characteristics proposed changes.

Table 140–6—100GBASE-DR, 100GBASE-FR1, and 100GBASE-LR1 transmit characteristics

Description	~~Value~~ 100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Signaling rate (range)	53.125 ± 100 ppm			GBd
Modulation format	PAM4			—
Wavelength (range)	1304.5 to 1317.5			nm
Side-mode suppression ratio (SMSR), (min)	30			dB
Average launch power (max)	4	4	4.8 **4.7**	dBm
Average launch power[a] (min)	–2.9	–2.4 **-2.9**	–1.1 **-2.1**	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (max)	4.2	4.2	5 **4.9**	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (min)[b]	–0.8	–0.2	1 **0.9**	dBm
Launch power in OMA_{outer} minus TDECQ (min): for extinction ratio ≥ 5 dB for extinction ratio < 5 dB	 –2.2 –1.9	 — —	 — —	 dBm dBm
Launch power in OMA_{outer} minus TDECQ (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 — —	 –1.6 –1.5	 –0.4 **-0.5** –0.3 **-0.4**	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)	3.4	3.4	3.4	dB
TDECQ – $10\log_{10}(C_{eq})$[c] (max)	3.4	3.4	3.4	dB
Average launch power of OFF transmitter (max)	–15	–15	–15	dBm
Extinction ratio (min)	3.5	3.5	3.5	dB
Transmitter transition time (max)	17	17	17	ps
~~$RIN_{15.5}$OMA (max)~~ $RIN_{xx.x}$OMA (max), where xx.x is the optical return loss tolerance (max)	–136	–136	–136	dB/Hz
Optical return loss tolerance (max)	15.5	17.1	15.6	dB
Transmitter reflectance[d] (max)	–26	–26	–26	dB

Table 151–7—400GBASE-FR4 and 400GBASE-LR4 transmit characteristics

Description	400GBASE-FR4	400GBASE-LR4	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm		GBd
Modulation format	PAM4		—
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5		nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Total average launch power (max)	9.5	11.6 **11.5**	dBm
Average launch power, each lane (max)	3.5	5.6 **5.5**	dBm
Average launch power, each lane[a] (min)	–3.3	–2.8 **-2.9**	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	3.7	4.4 **4.3**	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[b]	–0.3	0.2 **0.1**	dBm
Difference in launch power between any two lanes (OMA_{outer}) (max)	4	4	dB
Launch power in OMA_{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 –1.7 –1.6	 –1.2 **-1.3** –1.1 **-1.2**	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	3.4	3.5	dB
TDECQ – $10\log_{10}(C_{eq})$[c] (max)	3.4	3.5	dB
TDECQ – SECQ	—	TBD	dB
Average launch power of OFF transmitter, each lane (max)	–20 **-15**	–20 **-15**	dBm
Extinction ratio, each lane (min)	3.5	3.5	dB
Transmitter transition time (max)	17		ps
$RIN_{17.1}$OMA (max)	–136	—	dB/Hz
$RIN_{15.6}$OMA (max)	—	–136	dB/Hz
Optical return loss tolerance (max)	17.1	15.6	dB
Transmitter reflectance[d] (max)	–26		dB

802.3cu: 100GBASE-LR4 proposed changes.

Table 140–7—100GBASE-DR, 100GBASE-FR1, and 100GBASE-LR1 receive characteristics

Description	~~Value~~ 100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Signaling rate (range)	53.125 ± 100 ppm			GBd
Modulation format	PAM4			—
Wavelengths (range)	1304.5 to 1317.5			nm
Damage threshold[a]	5	5.5 **5.7**	5.8 **5.7**	dBm
Average receive power (max)	4	4.5 **4.7**	4.8 **4.7**	dBm
Average receive power[b] (min)	–5.9	–6.4 **-5.9**	–7.4 **-8.4**	dBm
Receive power (OMA_{outer}) (max)	4.2	4.7 **4.9**	5 **4.9**	dBm
Receiver reflectance (max)	–26	–26	–26	dB
Receiver sensitivity (OMA_{outer})[c] (max)	Equation (140–1)	Equation (140–2)	Equation (140–3)	dBm
Stressed receiver sensitivity (OMA_{outer})[d] (max)	–1.9	–2.5	–4.1	dBm
Conditions of stressed receiver sensitivity test:[e]				
Stressed eye closure for PAM4 (SECQ)	3.4	3.4	3.4	dB
SECQ – $10\log_{10}(C_{eq})$[f] (max)	3.4	3.4	3.4	dB

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level. The receiver does not have to operate correctly at this input power.
[b]Average receive power (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}) (max) is informative and is defined for a transmitter with a value of SECQ up to 3.4 dB.
[d]Measured with conformance test signal at TP3 (see 140.8) for the BER specified in 140.1.1.
[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.
[f]C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.

Table 151–8—400GBASE-FR4 and 400GBASE-LR4 receive characteristics

Description	400GBASE-FR4	400GBASE-LR4	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm		GBd
Modulation format	PAM4		—
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5		nm
Damage threshold[a], each lane	4.5	6.6 **6.5**	dBm
Average receive power, each lane (max)	3.5	5.6 **5.5**	dBm
Average receive power, each lane[b] (min)	–7.3	–9.1	dBm
Receive power (OMA_{outer}), each lane (max)	3.7	4.4	dBm
Difference in receive power between any two lanes (OMA_{outer}) (max)	4.1	4.3	dB
Receiver reflectance (max)	–26		dB
Receiver sensitivity (OMA_{outer}), each lane[c] (max)	Equation (151–1)	Equation (151–2)	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane[d] (max)	–2.6	–4.7	dBm
Conditions of stressed receiver sensitivity test:[e]			
Stressed eye closure for PAM4 (SECQ), lane under test	3.4	3.5	dB
SECQ – $10\log_{10}(C_{eq})$, lane under test (max)	3.4	3.5	dB
OMA_{outer} of each aggressor lane	1.5	–0.4 **-0.5**	dBm

802.3cu: proposed changes in power budgets.

Table 140–8—100GBASE-DR, 100GBASE-FR1, and 100GBASE-LR1 illustrative link power budgets

Parameter	~~Value~~ 100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Power budget (for max TDECQ): for extinction ratio ≥ 5 dB for extinction ratio < 5 dB	 6.5 6.8	 — —	 — —	 dB dB
Power budget (for max TDECQ): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 — —	 7.7 7.8	 10.5 **10.4** 10.6 **10.5**	 dB dB
Operating distance	500	2 000	10 000	m
Channel insertion loss[a,b]	See 140.10	4	6.3	dB
Maximum discrete reflectance	–35	See 140.10.3	See 140.10.3	dB
Allocation for penalties[c] (for max TDECQ): for extinction ratio ≥ 5 dB for extinction ratio < 5 dB	 6.5 minus max channel insertion loss per Table 140–12 6.8 minus max channel insertion loss per Table 140–12	 — —	 — —	 dB dB
Allocation for penalties[c] (for max TDECQ): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 — —	 3.7 3.8	 4.2 **4.1** 4.3 **4.2**	 dB dB
Additional insertion loss allowed	0	0	0	dB

Table 151–9—400GBASE-FR4 and 400GBASE-LR4 illustrative link power budgets

Parameter	400GBASE-FR4	400GBASE-LR4	Unit
Power budget (for maximum TDECQ): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 7.7 7.8	 10.5 **10.4** 10.6 **10.5**	 dB dB
Operating distance	2	6	km
Channel insertion loss	4[a]	5[b]	dB
Maximum discrete reflectance	See 151.11.2.2	See 151.11.2.2	dB
Allocation for penalties[c] (for maximum TDECQ): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 3.7 3.8	 4.2 **4.1** 4.3 **4.2**	 dB dB
Additional insertion loss allowed	0	1.3	dB

[a] The channel insertion loss is calculated using the maximum distance specified in Table 151–6 for 400GBASE-FR4 and fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 151.11.2.1.
[b] The channel insertion loss is calculated using the maximum distance specified in Table 151–6 for 400GBASE-LR4 and fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 151.11.2.1.
[c] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Proposed editorial changes into 802.3cu D1p0

140.10b Requirements for interoperation between 100GBASE-LR1 and 100GBASE-FR1

The 100GBASE-LR1 and 100GBASE-FR1 PMDs can interoperate with each other provided that the fiber optic cabling (channel) characteristics for 100GBASE-FR1 are met, with the exception of the maximum and minimum channel insertion loss values, which are given in Table 140–16 for the two link directions separately. ~~Attenuators may be used to achieve the required losses~~.

Table 140–16—Channel insertion loss requirements for interoperation between 100GBASE-LR1 and 100GBASE-FR1

Direction	Min loss	Max loss	Unit
100GBASE-LR1 transmitter to 100GBASE-FR1 receiver	0.3 **0**	4	dB
100GBASE-FR1 transmitter to 100GBASE-LR1 receiver	0	4	dB

THANK YOU