Baseline proposal for 100GBASE-BR10

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Supporter

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Current status overview

The TF have adopted the wavelength selection of 100GBASE-BR10 and 100GBASE-BR20

Motion #3: Specify 100 Gb/s PAM4 modulation using wavelengths 1304.5 +/- 1 nm upstream and 1309.1 +/- 1 nm downstream for 10 km and 20 km PMDs.
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Motion passes without objection.

- For 100GBASE-BR10, baseline specification seems low hanging fruit.
  - 100G-LR1 and some proprietary products such as 400G-DR4++, have been deployed in the market for 10km ethernet applications. Both uses Transmitter of nominal wavelength at 1311nm+/-6.5nm.
  - IEEE has defined 100GBASE-LR1 specification, at the wavelength range of 1310+/-6.5nm, inclusive of the two adopted wavelengths.
- We propose a set of baseline for 100GBASE-BR10, while showing some measurement data using current LR optics, to show feasibility of fulfilling the bidi link budget and proposed baseline.

Link budget depends on use case

- Anticipated use cases of 100GBASE-BR10
  - Backhaul and metro network
  - Upgrade of precedent generations of xxGBASE-BR10
  - Save fiber resources by replacing 100G-LR1
- Up to four connectors, 10km of worst case fiber.
- Maintain the link budget of 10km ethernet application as is.

Reviewing link budget and link cabling model in IEEE 10km PMDs

- 10km ethernet P2P application has been well defined in IEEE, for both duplex and bidi optics.
- Channel insertion loss has been consistent through multiple generations of ethernet optical PMD

Link power budgets of 10 km Ethernet application

Parameter	100GBASE-LR4	50GBASE-LR	100G-LR1	Unit
Power budget (for maximum TDECQ)	—	10.1	10.6	dB
Power budget (for maximum TDP)	8.5	—	—	dB
Power budget	—	—	—	dB
Operating distance	10	10	10	km
Channel insertion loss	**6.3**	**6.3**	**6.3**	dB
Maximum discrete reflectance	**-26**	**See 139.10.2.2**	**-35**	dB
Allocation for penalties (for maximum TDECQ)	—	3.8	4.3	dB
Allocation for penalties (for maximum TDP)	2.2	—	—	dB
Allocation for penalties	—	—	—	dB

Link power budget of xxGBASE-BR10

Parameter	10GBASE-BR10	25GBASE-BR10	50GBASE-BR10	Unit
Power budget (for maximum TDECQ)	—	—	10.1	dB
Power budget (for maximum TDP)	—	9	—	dB
Power budget	9.4	—	—	dB
Operating distance	10	10	10	km
Channel insertion loss	**6.2**	**6.3**	**6.3**	dB
Maximum discrete reflectance	**-26**	**See 159.10**	**-26**	dB
Allocation for penalties (for maximum TDECQ)	—	—	3.8	dB
Allocation for penalties (for maximum TDP)	—	2.7	—	dB
Allocation for penalties	3.2	—	—	dB

Cabling characteristics of 10 km Ethernet application

Description	100GBASE-LR4	50GBASE-LR	100G-LR1	Unit
Operating distance (max)	10	10	10	km
Channel insertion loss (max)	6.3	6.3	6.3	dB
Channel insertion loss (min)	0	0	0	dB
Positive dispersion (max)	9.5	16	16	ps/nm
Negative dispersion (min)	-28.5	-18.6	-18.6	ps/nm
DGD_max	8	8	5	ps
Optical return loss (min)	21	22	22	dB

Cabling characteristics of xxGBASE-BR10

Description	10GBASE-BR10	25GBASE-BR10	50GBASE-BR10	Unit
Operating distance (max)	10	10	10	km
Channel insertion loss (max)	6.2	6.2	6.2	dB
Channel insertion loss (min)	0	0	0	dB
Positive dispersion (max)	35	35	35	ps/nm
Negative dispersion (min)	-64	-64	-64	ps/nm
DGD_max	10	8	8	ps
Optical return loss (min)	21	21	21	dB

Proposal of link budget

- 100G Bidi optics will be used in the same link as 50G Bidi, and its duplex peers
- Therefore, we propose to align the link characteristic as that of 100G-LR1 and the associated link budget
- Regarding the CD range, with the on going discussion of incorporation of CD_Q methodology, we propose two possible ways for this TF's consideration
  - We could put TBD in the rows of max and min dispersion
  - We could adopt for now a tentative value, max = 3.3, min = -12.4, assuming M=4 Q = 1e-4, and update as necessary to align with further consensus built among the standardization organizations.

Link power budgets of 50GBASE-BR10,100GBASE-LR1, 100GBASE-BR10

Parameter	50GBASE-BR10	100GBASE-LR1	100GBASE-BR10	Unit
Power budget (for maximum TDECQ)	10.1	10.6	10.6	dB
Operating distance	10	10	10	km
Channel insertion loss	6.3	6.3	6.3	dB
Maximum discrete reflectance	-26	-35	-35	dB
Allocation for penalties (for maximum TDECQ)	3.8	4.3	4.3	dB

Cabling characteristics of 50GBASE-BR10,100GBASE-LR1, 100GBASE-BR10

Description	50GBASE-BR10	100GBASE-LR1	100GBASE-BR10	Unit
Operating distance (max)	10	10	10	km
Channel insertion loss (max)	6.2	6.3	6.3	dB
Channel insertion loss (min)	0	0	0	dB
Positive dispersion (max)	35	16	TBD/3.3*	ps/nm
Negative dispersion (min)	-64	-18.6	TBD/-12.1*	ps/nm
DGD_max	8	5	5	ps
Optical return loss (min)	21	22	22	dB

*: Simulation followed method of johnson_3dj_01a_2307, details in backup page

Baseline proposal for 100GBASE-BR10

Description	**100GBASE-BR10**	Unit
Signaling rate (range)	53.125 ± 100 ppm	GBd
Modulation format	PAM4	
Downstream center wavelength (range)	1308.1 to1310.1	nm
Upstream center wavelength (range)	1303.5 to 1305.5	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Average launch power (max)	4.8	dBm
Average launch power (min)	-1.9	dBm
Outer Optical Modulation Amplitude (OMAouter) (max)	5	dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max))	3.4	dB
TECQ(max)	3.4	dB
|TDECQ-TECQ|(max)	2.5	dB
Transmitter over/under-shoot (max)	22	%
Outer Optical Modulation Amplitude(OMAouter) (min): for TDECQ < 1.4 dB for 1.4 dB ⩽TDECQ ⩽ 3.4 dB	 1.1 -0.3+TDECQ	 dBm dBm
Transmitter power excursion (max)	2.8	dBm
Average launch power of OFF transmitter (max)	-15	dBm
Extinction ratio (min)	3.5	dB
Transmitter transition time (max)	17	ps
RIN_xOMA (max)	-136	dB/Hz
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance (max)	-26	dB

Description	**100GBASE-BR10**	Unit
Signaling rate (range)	53.125 ± 100 ppm	GBd
Modulation format	PAM4	
Downstream center wavelength (range)	1303.5 to 1305.5	nm
Upstream center wavelength (range)	1308.1 to1310.1	nm
Damage threshold	5.8	dBm
Average receive power (max)	4.8	dBm
Average receive power (min)	-8.2	dBm
Receive power (OMAouter) (max)	5	dBm
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMAouter) (max) for TDECQ < 1.4 dB for 1.4 dB ⩽TDECQ ⩽ 3.4 dB	 -6.1 -7.5+TDECQ	 dBm dBm
Stressed receiver sensitivity (OMAouter) (max)	-4.1	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ)	3.4	dB

Reference: Table for 100GBASE-LR1 Transmitter and Receiver Spec

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

Description	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	–3.1	–1.9	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (max)	4.2	4.2	5	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (min)[b] for TDECQ < 1.4 dB for 1.4 dB ≤ TDECQ ≤ 3.4 dB	–0.8 — —	— –0.1 –1.5 + TDECQ	— 1.1 –0.3 + TDECQ	dBm dBm 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
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	—	—	dB
Transmitter eye closure for PAM4 (TECQ) (max)	—	3.4	3.4	dB
| TDECQ – TECQ | (max)	—	2.5	2.5	dB
Over/under-shoot (max)	—	22	22	%
Transmitter power excursion (max)	—	2	2.8	dBm
Extinction ratio (min)	3.5	3.5	3.5	dB
Transmitter transition time (max)	17	17	17	ps
Average launch power of OFF transmitter (max)	–15	–15	–15	dBm
$RIN_x OMA$ (max), where 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

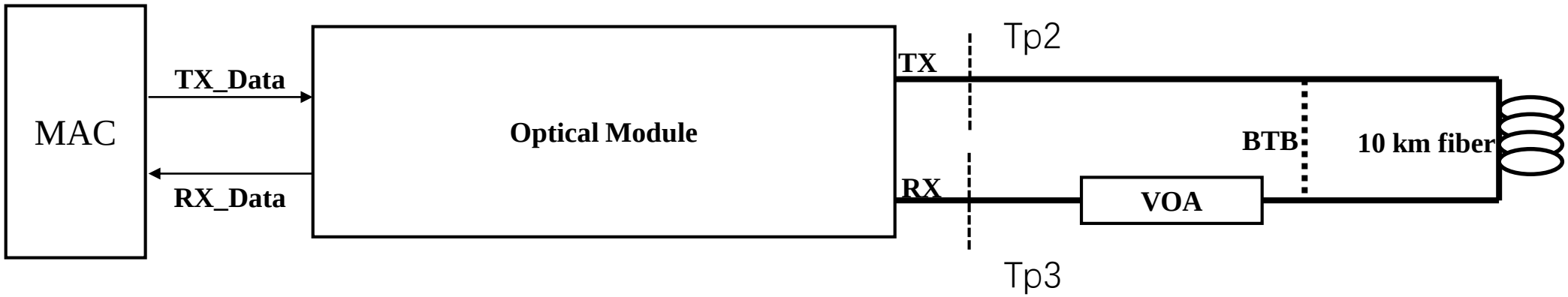
Table 140–7—100GBASE-DR, 100GBASE-FR1, and 100GBASE-LR1 receive characteristics

Description	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	5.8	dBm
Average receive power (max)	4	4	4.8	dBm
Average receive power[b] (min)	–5.9	–7.1	–8.2	dBm
Receive power (OMA_{outer}) (max)	4.2	4.2	5	dBm
Receiver reflectance (max)	–26	–26	–26	dB
Receiver sensitivity (OMA_{outer}) (max) for TECQ < 1.4 dB for 1.4 dB ≤ TECQ ≤ 3.4 dB	Equation (140–1)[c] — —	— –4.5 –5.9 + TECQ	— –6.1 –7.5 + TECQ	dBm dBm dBm

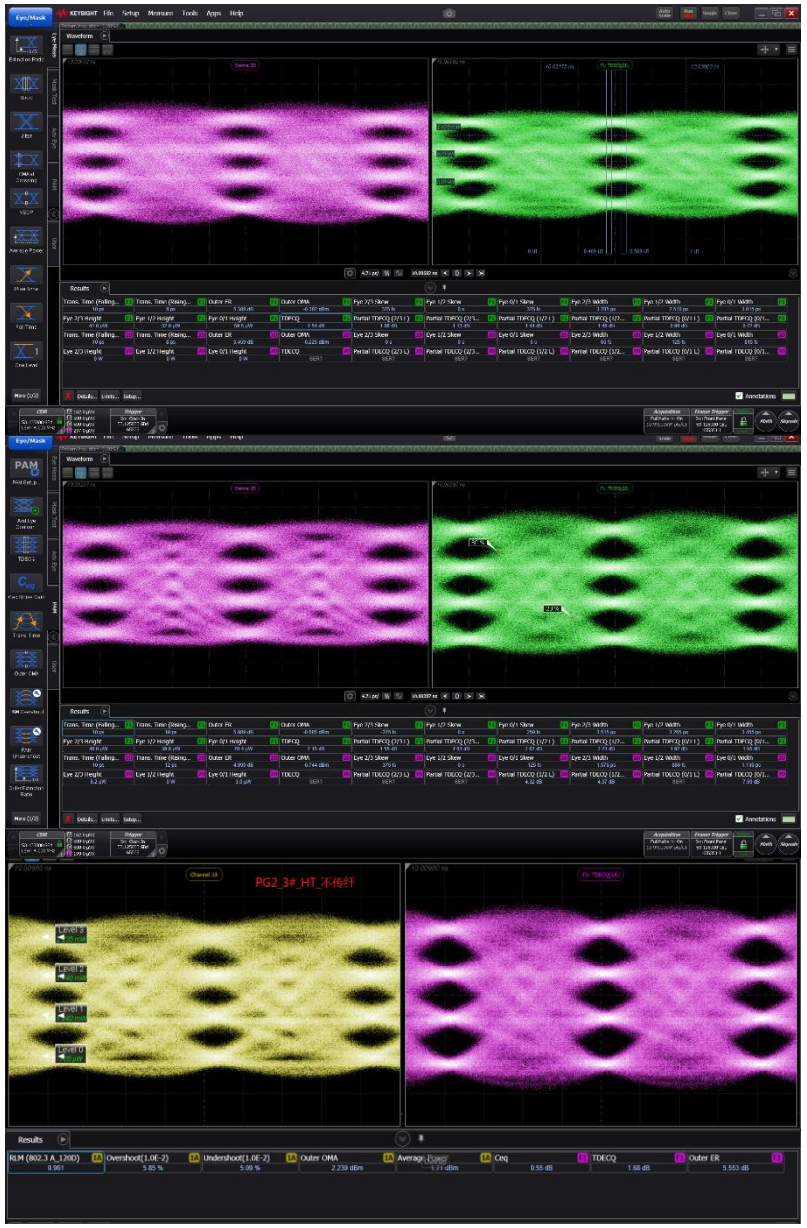
Description	100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Stressed receiver sensitivity (OMA_{outer})[d] (max)	–1.9	–2.5	–4.1	dBm
Conditions of stressed receiver sensitivity test:[e]				
Stressed eye closure for PAM4 (SECQ)	3.4	3.4	3.4	dB
SECQ – $10\log_{10}(C_{eq})$[f] (max)	3.4	—	—	dB

Some updated data of 100G/lane technology

- Experimental Setup
  - We used LR optics from 3 vendors, measured at room temperature
  - Though these modules are not 100G-Bidi modules but rather 400G-LR4-6/400GDR4++, the measurement result may serve as reference of the capability of 100G/lane optics in mass production



Some updated data of 100G/lane optics



- Vendor A

  TECQ=1.54 dB , ER=5.39 dB , Wavelength=1314 nm

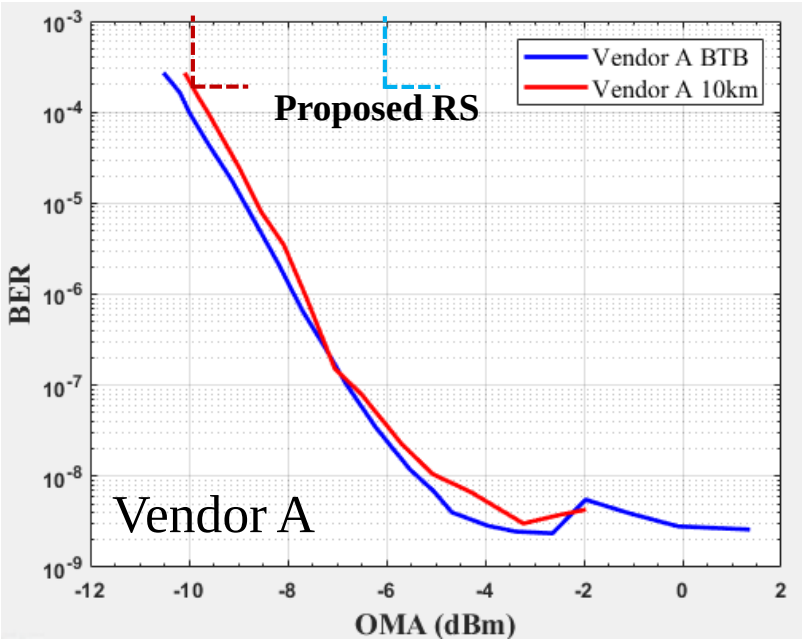
- Vendor B (with mux)

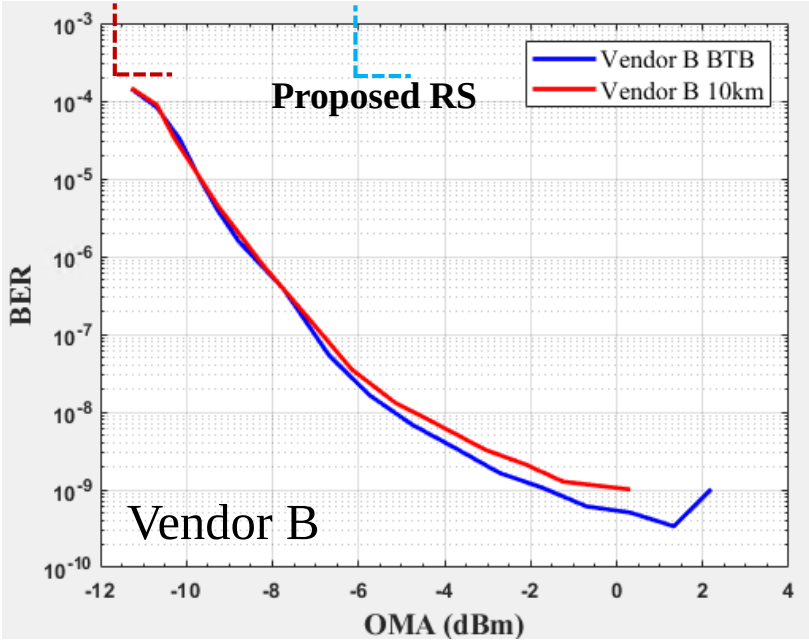
  TECQ=2.15 dB , ER=5.09 dB , Wavelength=1311 nm

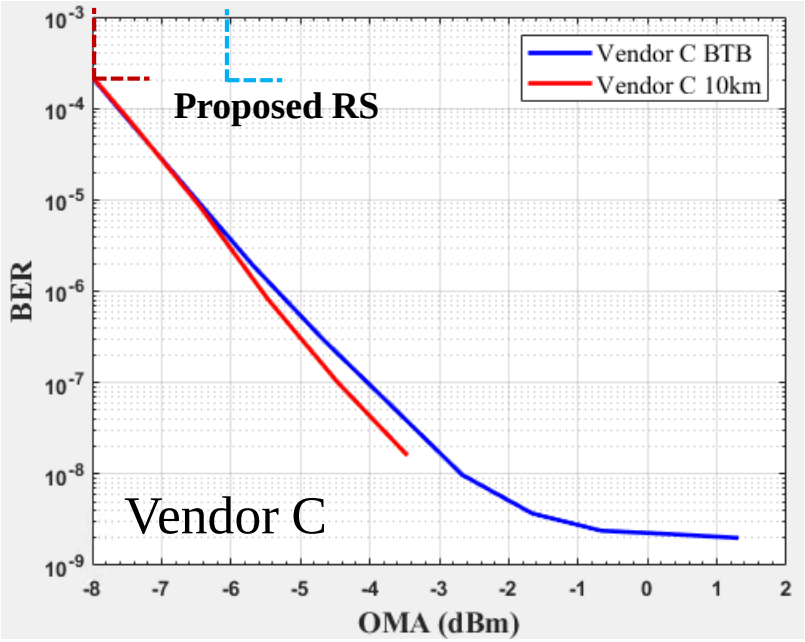
- Vendor C (with mux)

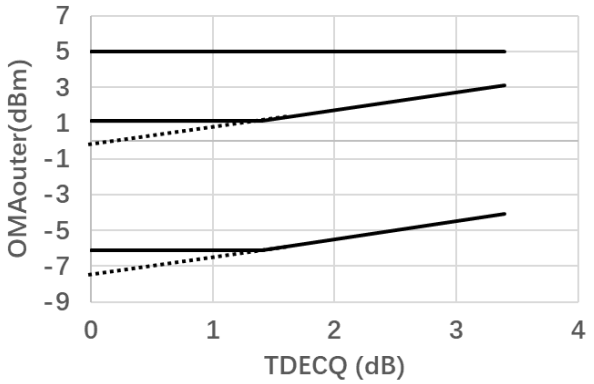
  TECQ=1.68 dB , ER=5.55 dB , Wavelength=1290 nm

Some updated data of 100G/lane optics









	100GBASE-BR10
OMAmax(dBm)	5
OMA-TDECQ(dBm)	-0.3
OMAmin@TDECQmax(dBm)	3.1
SRS(dBm)	-4.1
Rx Sens (TDECQ<=1.4dB)	-6.1
RSnominal(dBm)	-7.5
Optical Loss Budget	6.3
Additional Penalties	0.9
TDECQmax	3.4
Power Budget	10.6

The measured receiver sensitivity is well below the proposed RS

- Rx OMA are all measured at Tp3,
  - Vendor B and C has CWDM4 Demux in the module
- The result showed good link budget margin with respect to the proposed baseline

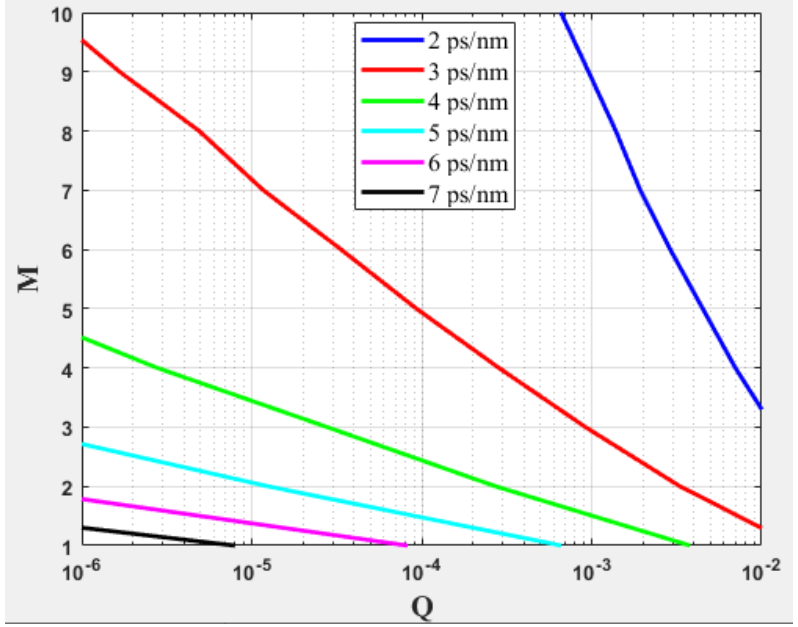
Summary

- Propose to maintain the same link budget methodology as 50G bidi and 100G-LR1, and to make appropriate changes according to the adopted wavelength and recent discussion
- Proposal of link budget summarized in P6
- Propose to adopt baseline of 100G bidi 10km objective as listed in slide 7

Back up slides

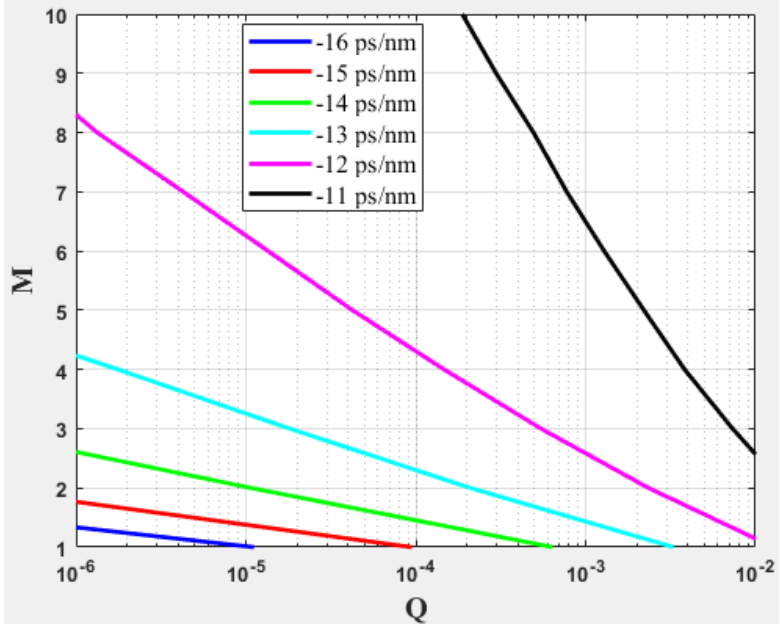
Simulation for determining the suggested CD range

- johnson_3dj_01a_2307 used a Monte Carlo model with statistical distributions for both ZDW and S_0 to calculate CD_Q, which avoids over-designing for statistically insignificant links.
- Here we employed the same modeling method to the adopted wavelength range of 100GBASE-BR10, reiterating the main assumptions
  - The fiber cable segments in a given 10-km link are correlated and have a fixed ZDW_{mean} that is inside [1309nm, 1315nm] when they happen to come from the same manufacturing batch.
  - The distribution of ZDW_{mean} inside [1309nm, 1315nm] is uniform.
  - S_0 follows a normal distribution with mean of 0.0825 and standard deviation of 0.002 truncated to [0.073, 0.092] based on six-sigma principles.
- The suggested CD range is [-12.1 ps/nm, 3.3 ps/nm] for M=4 and Q=1E-4.



For Q=1E-4, we have:

M	CDmax
1	5.9
2	4.4
3	3.7
4	**3.3**
5	3.0
6	2.8
7	2.6
8	2.5
9	2.4
10	2.3



For Q=1E-4, we have:

M	CDmin
1	-15.0
2	-13.3
3	-12.5
4	**-12.1**
5	-11.8
6	-11.6
7	-11.4
8	-11.3
9	-11.2
10	-11.1

50GBASE-BR10 Spec aligning to 50GBASE-LR1 Spec：Transmitter

Table 160–6—50GBASE-BRx transmit characteristics

Description	50GBASE-BR10	50GBASE-BR20	50GBASE-BR40	Unit
Signaling rate (range)	26.5625 ± 100 ppm			GBd
Modulation format	PAM4			—
50GBASE-BRx-D center wavelengths (range)	1320 to 1340	1306 to 1322		nm
50GBASE-BRx-U center wavelengths (range)	1260 to 1280	1281 to 1297		nm
Side-mode suppression ratio (SMSR), (min)	30			dB
Average launch power (max)	4.2	3.6	6.6	dBm
Average launch power[a] (min)	–4.5	–2.6	0.4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (max)	4	4.4	7.4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (min)[b]: for TDECQ < 1.4 dB for 1.4 dB ≤ TDECQ ≤ 3.2 dB	 –1.5 –2.9 + TDECQ	 0.4 –1 + TDECQ	 3.4 2 + TDECQ	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)	3.2			dB
TDECQ – $10\log_{10}(C_{eq})$[c] (max)	3.2			dB
TECQ (max)	3.2			dB
| TDECQ – TECQ | (max)	2.5			dB
Average launch power of OFF transmitter (max)	–16	–20	–15	dBm
Extinction ratio (min)	3.5	6		dB
Transmitter transition time (max)	34			ps
RIN_xOMA (max)[d]	–132			dB/Hz
Optical return loss tolerance (max)	15.6	15		dB
Transmitter reflectance[e] (max)	–26			dB

Table 139–6—50GBASE-FR and 50GBASE-LR transmit characteristics

Description	50GBASE-FR	50GBASE-LR	Unit
Signaling rate (range)	26.5625 ± 100 ppm		GBd
Modulation format	PAM4		—
Wavelengths (range)	1304.5 to 1317.5		nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Average launch power (max)	3	4.2	dBm
Average launch power[a] (min)	–4.1	–4.5	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (max)	2.8	4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}) (min)[b]	–2.5	–1.5	dBm
Launch power in OMA_{outer} minus TDECQ (min)	–3.9	–2.9	dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)	3	3.2	dB
TDECQ – $10\log_{10}(C_{eq})$[c] (max)	3	3.2	dB
Average launch power of OFF transmitter (max)	–16		dBm
Extinction ratio (min)	3.5		dB
Transmitter transition time (max)	34		ps
Description	**50GBASE-FR**	**50GBASE-LR**	**Unit**
$RIN_{17.1}$OMA (max)	–132	—	dB/Hz
$RIN_{15.6}$OMA (max)	—	–132	dB/Hz
Optical return loss tolerance (max)	17.1	15.6	dB
Transmitter reflectance[d] (max)	–26		dB

50GBASE-BR10 Spec aligning to 50GBASE-LR1 Spec： Receiver

Table 160–7—50GBASE-BRx receive characteristics

Description	50GBASE-BR10	50GBASE-BR20	50GBASE-BR40	Unit
Signaling rate (range)	26.5625 ± 100 ppm			GBd
Modulation format	PAM4			—
50GBASE-BRx-D center wavelengths (range)	1260 to 1280	1281 to 1297		nm
50GBASE-BRx-U center wavelengths (range)	1320 to 1340	1306 to 1322		nm
Damage threshold[a]	5.2	4.6	–2.4	dBm
Average receive power (max)	4.2	3.6	–3.4	dBm
Average receive power[b] (min)	–10.8	–17.6		dBm
Receive power (OMA_{outer}) (max)	4	4.4	–2.6	dBm
Receiver reflectance (max)	–26			dB
Receiver sensitivity (OMA_{outer})[c] (max) for TECQ < 1.4 dB for 1.4 dB ≤ TECQ ≤ 3.2 dB	 –8.4 –9.8 + TECQ	 –15.1 –16.5 + TECQ		 dBm dBm
Stressed receiver sensitivity (OMA_{outer})[d] (max)	–6.6	–13.3		dBm
Conditions of stressed receiver sensitivity test:[e]				
Stressed eye closure for PAM4 (SECQ)		3.2		dB

Table 139–7—50GBASE-FR and 50GBASE-LR receive characteristics

Description	50GBASE-FR	50GBASE-LR	Unit
Signaling rate (range)	26.5625 ± 100 ppm		GBd
Modulation format	PAM4		—
Wavelengths (range)	1304.5 to 1317.5		nm
Damage threshold[a]	5.2	5.2	dBm
Average receive power (max)	3	4.2	dBm
Average receive power[b] (min)	–8.1	–10.8	dBm
Receive power (OMA_{outer}) (max)	2.8	4	dBm
Receiver reflectance (max)	–26		dB
Receiver sensitivity (OMA_{outer})[c] (max)	Equation (139–1)	Equation (139–2)	dBm
Stressed receiver sensitivity (OMA_{outer})[d] (max)	–5.3	–6.6	dBm
Conditions of stressed receiver sensitivity test:[e]			
Stressed eye closure for PAM4 (SECQ)	3	3.2	dB
SECQ – $10\log_{10}(C_{eq})$[f] (max)	3	3.2	dB