Towards an 800G-LR4 IMDD Specification Consensus - September 2023 update

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Introduction

- This presentation is a status update on the 800GBASE-LR4 proposed specs in rodes_3dj_01_2307

- This presentation recaps the specs with work that is underway, and updates on the progress since the last meeting
  - CDq methodology with fiber segmentation
  - DGDmax clarification with fiber segmentation
  - Linear reference equalizer

- We propose this specification as a baseline for 800GBASE-LR4 with further refinements based on contributions from the Task Force

Recap of Specs with consensus

rodes_3dj_01_2307

Status Report

List of specs we have consensus on:

- Wavelength grid based on LWDM4
- Operating Distance 10km
- Use of Type 2 FEC based on patra_3dj_01b_2303
- Optical link budget= 6.3dB
- Tx and Rx specs achievable without APDs or SOAs:
  - Tx OMAmin @ maxTDECQ= 4.4dBm
  - SRS = -3dBm
- TDECQ max= 3.9dB
- Stronger receiver equalizer than 100G/Lane LR. rodes_3dj_01_2305
- Additional penalty allocations:
  - DGD=0.7 dB kuschnerov_3df_01b_221012
  - MPI = 0.4 dB kuschnerov_3df_02a_221012
  - FWM = 0 dB liu_3dj_01_2303, johnson_3dj_01a_230206
- Consider Statistical Approach for worst case chromatic dispersion (CDq) liu_3dj_optx_01_230427

Recap of Specs under investigation/discussion

Status Report

rodes_3dj_01_2307

Specs with work underway and more consensus is needed:

- Current effort in ITU-T SG15 Q5 and IEC 86A WG1 to gather data from fiber vendors to support statistical model of chromatic dispersion.
  - Interim values for CDq are proposed in liu_3dj_01_2307, pending more detailed calculation from ITU-T
  - Are CDq limits for power budget and TDECQ compliance testing the same? Or additional allocation is need?
- TDECQ reference equalizer
  - Is an FFE-only reference receiver enough to equalize CDq limits?
  - If not, should we include DFE or MLSE in the receiver? Stojanovic_3dj_01_2307
- Exact pre-FEC BER for optical PMD is pending further analysis from the task force

Even the specs with consensus are subject to change if needed based on new analysis and measurement data from the task force

In addition, during the last LR4 baseline update presentation, question about DGDmax spec was brought up. This was later clarified on kuschnerov_3dj_optx_01_230829

Updates during last 2 months related to CD and DGD specs

- Strong support of CDq methodology based on motions_3cwdfdj_2307
- liu_3dj_01a_2307 presented CDq values as a function of number of segments.
  - M=5 was suggested as reasonable assumption
- kuschnerov_3dj_optx_01_230829 presented an update on DGDmax accounting for fiber segmentation and assuming linear receiver equalizer.
  - M=4 was suggested as reasonable assumption
- During discussion during the Ad-hoc, fiber expert participating in ITU-T recommended a more conservative DGDmax specification until more data comes available from ITU-T

Straw Poll #15

I support the use of the CD_Q methodology (with values TBD) as described in johnson_3dj_01a_2307 and liu_3dj_01_2307 to specify chromatic dispersion (CD) for initial baseline specifications for 200G per lane PAM4 PMDs

A: Yes
B: No, wait for more accurate CD_Q values from ITU-T
C: No, continue to use traditional worst case CD values
D: Abstain
Results (all): A: 72, B: 8, C: 1, D: 33

Following that recommendation and after offline discussion, this baseline proposal assumes the same fiber segmentation of **M=4 for both CDq and DGDmax, with a +20% DGDmax for margin until more data is available**

CDq min/max proposal

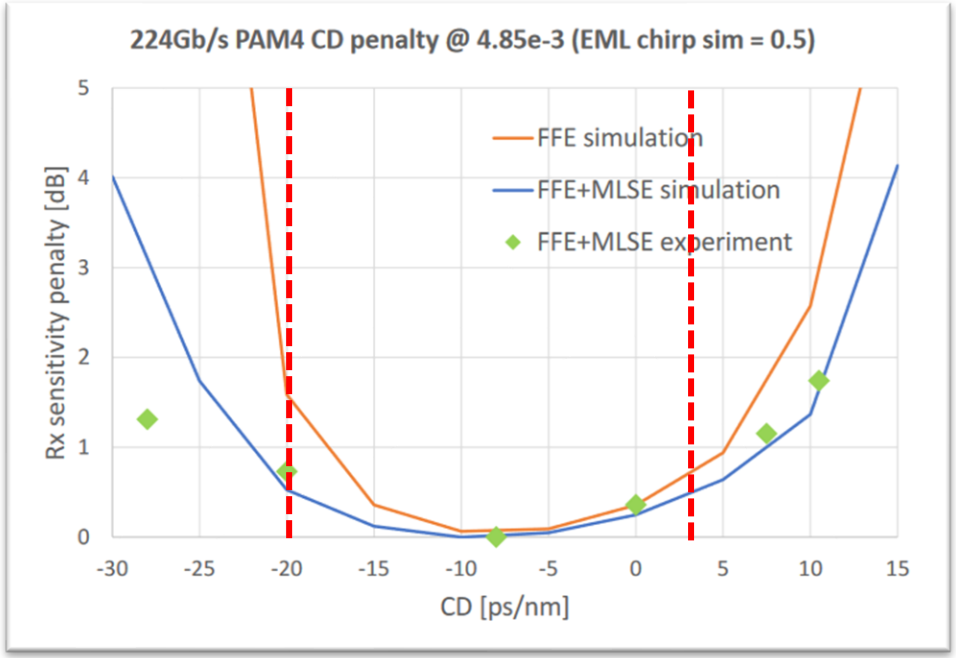
liu_3dj_01a_2307

Case 1: CD_{min} and CD_{max} at Q=1E-4

M	CD_{min}
1	-22.90
2	-21.09
3	-20.33
4	-19.88
5	-19.58
6	-19.36
7	-19.18
8	-19.05
9	-18.94
10	-18.85

M	CD_{max}
1	5.99
2	4.40
3	3.71
4	3.32
5	3.04
6	2.84
7	2.69
8	2.56
9	2.46
10	2.38

kuschnerov_3df_02_221012

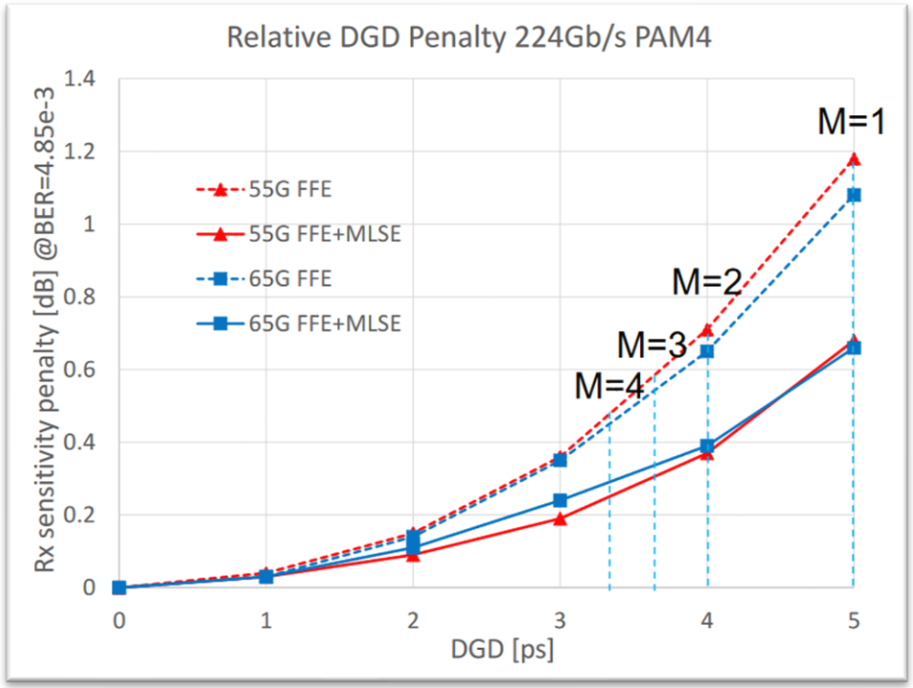


- We propose to use CDqmin= -19.88ps/nm and CDqmax = 3.32ps/nm.
- This corresponds to fiber segmentation M=4 and correlation between the different segment. liu_3dj_01a_2307
- This CDq range is expected to have < 2dB penalty in Rx Sensitivity even with a linear receiver kuschnerov_3df_02_221012

DGDmax proposal

- Adopt a DGDmax = 4ps for 10km Ethernet.
  - M=4 consistent with CDq results on DGDmax = 3.3ps based on kuschnerov_3dj_optx_01_230829
  - 3.3ps +20% (margin due to limited data)= **4ps DGDmax**
- Adopt PMD penalty in 800G LR4 baseline of 0.7dB based on linear receiver results in kuschnerov_3dj_optx_01_230829
- Adopt a Max DGDmean= 0.8ps for transmitter compliance testing

kuschnerov_3dj_optx_01_230829



Reference Receiver Equalizer

- In stojanovic_3dj_01_2307 presented a potential TDECQ metric based on FFE+MLSE.
- However, based on the strong support for CDq methodology shown in motions_3cwdfdj_2307, and the analysis shown in liu_3dj_01a_2307, the authors believe it is feasible to maintain a linear reference receiver equalizer without MLSE.
- As presented in rodes_3dj_01_2305, the reference receiver linear equalizer will need to have significantly larger number of taps.
- rodes_3dj_02b_2305 discussed additional reason to use reference receiver linear equalizer with ~17taps even for low CD

We propose to use 17-tap as initial value for reference receiver linear equalizer for 800G-LR4 baseline spec understanding that final value will be discussed when more experimental data is available

Transmit Characteristics

Description	800G-LR4 proposal	Unit
Signaling rate, each lane (range)	113.4375	GBd
Modulation format	PAM4	
Lane wavelengths (range)	1294.6 to 1296.6 1299.1 to 1301.1 1303.6 to 1305.6 1308.1 to 1310.1	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Total average launch power (max)	11.5	dBm
Average launch power, each lane (max)	5.5	dBm
Average launch power, each lane (min)	-0.9	dBm
Outer Optical Modulation Amplitude (OMAouter), each lane (max)	5.7	dBm
Outer Optical Modulation Amplitude (OMAouter), each lane (min) for TDECQ <1.4 dB for 1.4 dB ≤ TDECQ ≤ 3.9 dB	 1.9 0.5+TDECQ	 dBm dBm
Difference in launch power between any two lanes	3	dB
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max) *	3.9	dB
Transmitter eye closure for PAM4 (TECQ), each lane (max)	3.2	dB
|TDECQ-TECQ| (max)	2.5	dB
Over/under-shoot (max)	22	%
Transmitter power excursion (max)	3.1	
Extinction ratio, each lane (min)	3.5	dB
Transmitter transition time (max)	13	ps
Average launch power of OFF transmitter, each lane (max)	-16	dBm
$RIN_{15.6}OMA$ (max)	-139	dB/Hz
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance (max)	-26	dB

*Measured with a FFE 17-tap reference equalizer with SER=9.6e-3

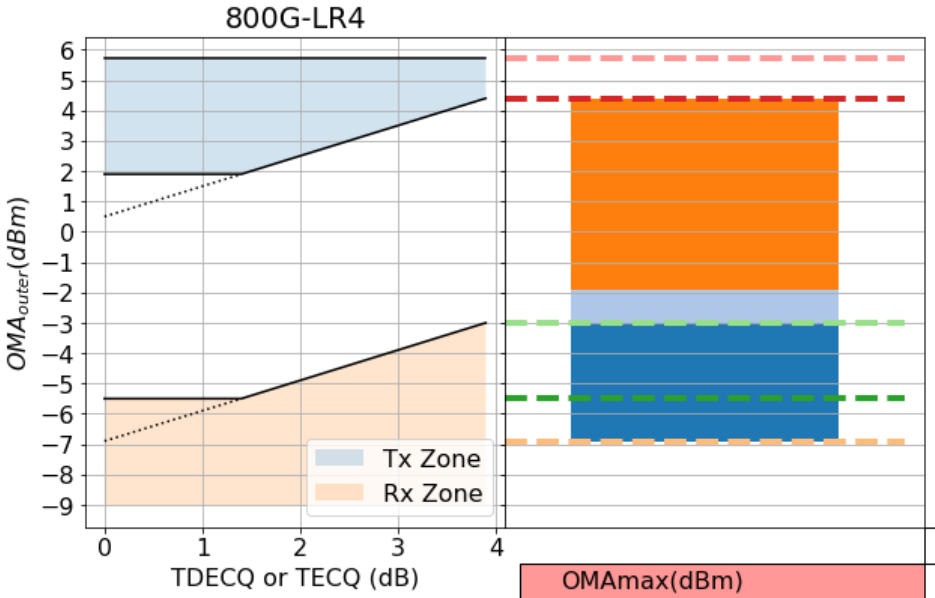
Receive Characteristics

Description	800G-LR4 proposal	Unit
Signaling rate, each lane (range)	113.4375	GBd
Modulation format	PAM4	
Lane wavelengths (range)	1294.6 to 1296.6 1299.1 to 1301.1 1303.6 to 1305.6 1308.1 to 1310.1	nm
Damage threshold, each lane	6.5	dBm
Average receive power, each lane (max)	5.5	dBm
Average receive power, each lane (min)	-8	dBm
Receive power (OMAouter), each lane (max)	5.7	dBm
Difference in receive power between any two lanes (OMAouter) (max)	3.3	dB
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMAouter), each lane (max) for TECQ <1.4 dB for 1.4 dB ≤ TECQ ≤ 3.9 dB	 -5.5 -6.9 + TECQ	 dBm dBm
Stressed receiver sensitivity (OMAouter), each lane (max)	-3	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ), lane under test *	3.9	dB
OMAouter of each aggressor lane	1.3	dBm

*Measured with a FFE 17-tap reference equalizer with SER=9.6e-3

FEC Type 2 based on patra_3dj_01b_2303

Tx & Rx specs



	800G-LR4
OMAmax(dBm)	5.7
OMA-TDECQ(dBm)	0.5
OMAmin@TDECQmax(dBm)	4.4
SRS(dBm)	-3.0
Rx Sens (TECQ <= 1.4dB)	-5.5
RSnominal(dBm)	-6.9
OpticalLossBudget	6.3
AdditionalPenalties	1.1
TDECQmax *	3.9
PowerBudget	11.3

*TDECQ and SECQ measured with a FFE 17-tap reference equalizer with SER=9.6e-3

Link Power Budget

Parameter	800G-LR4 proposal	Unit
Power budget (for maximum TDECQ)	11.3	dB
Operating Distance	10	km
Channel insertion loss	6.3	dB
Maximum discrete reflectance	-35	dB
Allocation for penalties (for maximum TDECQ) *	5	dB

*DGD=0.7dB and MPI= 0.4dB , kuschnerov_3dj_optx_01_230829 , kuschnerov_3df_02a_221012

Transmitter compliance channel specifications

Dispersion		Max mean DGD
Minimum*	Maximum*	
-19.88 ps/nm**	+3.22 ps/nm**	0.8 ps

*maximum and minimum wavelengths allowed by the wavelength plan.
**values are based on the CDq methodology with M=4 and Q=1e-4

Fiber optic cabling (channel) characteristics

Description	800GBASE-LR4	Unit
Channel insertion loss (max)	6.3	dB
Positive dispersion (max)	3.22	ps/nm
Negative dispersion (min)	-19.88	ps/nm
DGDmax	4	ps

Conclusion

We have presented a status report on the consensus effort to propose an 800GBASE-LR4 baseline.

The progress since last meeting includes updated values for the following parameters:

- Fiber segmentation M=4 consistent for CDq and DGDmax values
- CDq min= -19.88ps/nm and CDq max= 3.22ps/nm
- DGDmax of 4ps and DGD penalty of 0.7dB
- TDECQ reference equalizer of 17-tap FFE (no MLSE)

We expect further refinement as the task force progresses and more data comes available