Supporting information for D1.1 comments* on chromatic dispersion specifications

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* Reference D1.1 comments #18-29.

Supporters

- Peter Stassar, Huawei
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- Ryan Yu, Innolight
- Frank Effenberger, Futurewei
- Yu Xu, Huawei
- Earl Parsons, CommScope
- Chris Cole, Coherent
- Roberto Rodes, Coherent
- Jose Castro, Panduit
- Brian Welch, Cisco
- Mark Kimber, Semtech
- Vince Ferretti, Corning
- Mabud Choudhury, OFS

Introduction

- The specification methodology for chromatic dispersion specification was extensively discussed at the July Plenary.
  - ITU-T SG15 to IEEE 802.3: LS on revision of Recommendation G.652
  - Johnson_3dj_01a_2407: Baseline proposal for 800GBASE-FR4 chromatic dispersion specifications
  - Rodes_3dj_01a_2407: Baseline proposal for 800GBASE-LR4 chromatic dispersion specifications
- Strawpoll #O-1 was taken at the July meeting, showing strong support for adoption of the CD values documented in the Johnson and Rodes presentations for FR4 and LR4 PMDs (next slide).
- This presentation also proposes to apply the same CD methodology used for FR4, with suitable scaling, to the DRn, DRn-2 and FR4-500 PMDs.
- D1.1 Comments #18-29 are submitted to implement these changes in D1.2.
- This presentation provides detailed editorial input to support implementation of the comments.

Task force support

Straw Poll #O-1

I support a specification approach for 800GBASE-FR4 and 800GBASE-LR4 chromatic dispersion ranges by:

- referencing ITU-T Rec G.652 for fiber specs and the newly updated Appendix I for the CD values
- 800GBASE-FR4 cd range -11.26 to +6.02 ps/nm as proposed in johnson_3dj_01a_2407
- 800GBASE-LR4 cd range -24.6 to +2.8 ps/nm as proposed in rodes_3dj_01a_2407
- develop an Informative Annex to describe the background for these choices, explaining the statistical link design approach which factors in fiber, transceiver and length statistics

Results (all): Y:50 N:5 A:15

- The FR4 values are based on the G.652 data with M = 1 at Q = 99.9% for the upper boundary at 1337.5 nm, and Q = 99% for the lower boundary at 1264.5 nm.
- The LR4 values are based on the G.652 data with M = 4 at Q = 99.9% for the upper boundary at 1310.19 nm and the lower boundary at 1294.53 nm.
- These methodology details will be discussed in the new informative Annex, not in the PMD clauses.

Clause 183: 800GBASE-FR4/LR4

D1.1 comments #18, 19

Table 183–9—Optical channel characteristics

Table 183–9—Optical channel characteristics

Description	800GBASE-FR4	800GBASE-LR4	Unit
Operating distance (max)	2	10	km
Channel insertion loss[a, b] (max)	4	6.3	dB
Channel insertion loss (min)	0		dB
Positive dispersion[b] (max)	6.02	2.8	ps/nm
Negative dispersion[b] (min)	-11.26	-24.6	ps/nm
DGD_max[c]	TBD	4	ps
Optical return loss (min)	TBD	TBD	dB

[a] These channel insertion loss values include cable, connectors, and splices.

[b] Over the wavelength range 1264.5 nm to 1337.5 nm for 800GBASE-FR4, and 1294.53 nm to 1310.19 nm for 800GBASE-LR4.

[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 is required to tolerate.

The dispersion specifications are based on the statistical link design methodology documented in ITU-T REC G.652, Appendix I, and the optical channel characteristics methodology described in Annex-TBD.

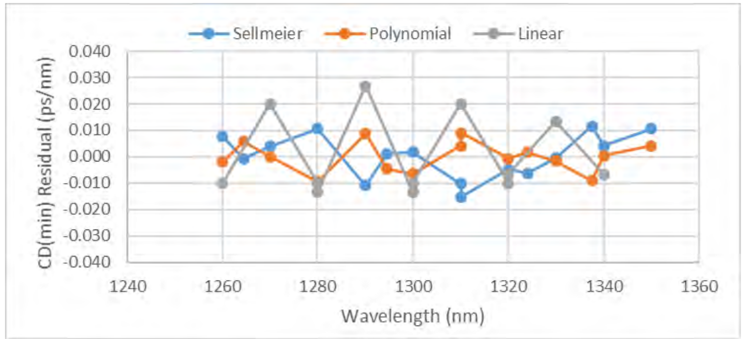
- The positive and negative dispersion limits per strawpoll #O-1 are added to Table 183-9.
- The FR4 limits correspond to CD values from G.652 Table I.3 for M = 1 at Q = 99.9% for the upper boundary at 1337.5 nm, and Q = 99% for the lower boundary at 1264.5 nm.
- The LR4 limits correspond to CD values from G.652 Table I.3 for M = 4 at Q = 99.9% for the upper boundary at 1310.19 nm and the lower boundary at 1294.53 nm.
- New text is added to footnote (b), pointing readers to the new informative Annex for additional information on the statistical CD methodology.

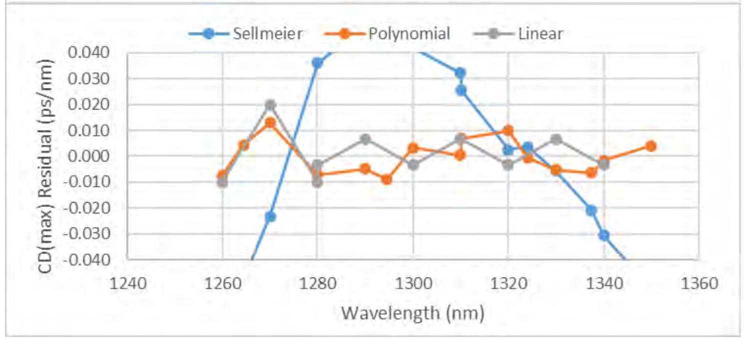
Fitting D(λ) for TX compliance channel specs

- Three possible empirical fitting methods for TX compliance were performed using G.652 data with M=1, at Q=99% for the lower limit and Q=99.9% for the upper limit for FR4.

1. Sellmeier function over entire wavelength range
   - Well-known form used previously with worst case S0 and ZDW values
   - Sellmeier coefficients are provided in G.652 for M≥4, but not for M=1 due to irregular CD distributions, as previously proposed in Rodes_3dj_01a_2407 for LR4
   - Sellmeier fits for FR4 data using Excel Solver:
     - Min: 0.1792*WL*[1-(1323.14/WL)^4]
     - Max: 0.1780*WL*[1-(1302.45/WL)^4]
2. Polynomial fit over entire wavelength range
   - Most general fit, but the resulting coefficients are not intuitive
   - A 3rd order polynomial is used to fit the data
     - Min: -247.0507 + 0.1867721*WL - 0.000226*(WL-1305.38)^2 + 1.5763e-7*(WL-1305.38)^3
     - Max: -232.1119 + 0.1781792*WL - 0.0001538*(WL-1305.38)^2 - 5.3872e-7*(WL-1305.38)^3
3. Linear fits over individual channels, of the form: $A(\lambda - \lambda_0) + B$
   - Simple, robust fit with intuitive coefficients (next slide)
   - Proposed in Johnson_3dj_01a_2407 for FR4 using Parsons data
   - Fit over 3 points per channel (tabulated data is on 10nm grid).

- The residual errors of the fits to the tabulated data points are compared below.
- The Sellmeier fit for CD(max) is poor due to irregular distributions for M = 1 with Q = 99.9%.
- The polynomial and linear fits both give low residual errors that are < ±0.03 ps/nm across the band.
- Propose using linear fits per channel for FR4, and Sellmeier fits for LR4





D1.1 comments #20, 21

Table 183–14—Transmitter compliance channel specifications

Table 183–14—Transmitter compliance channel specifications

PMD type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
800GBASE-FR4	TBD	TBD	Minimum	17.1 dB	0.8 ps
800GBASE-LR4	TBD	TBD	Minimum	15.6 dB	0.8 ps

[a] The dispersion is measured for the wavelength of the transmitter lane under test (λ in nm). The coefficient assumes 2 km for 800GBASE-FR4 and 10 km for 800GBASE-LR4.
[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.

PMD type	Lane	Dispersion[a] (ps/nm)	
		Minimum	Maximum
800GBASE-FR4	L0	$0.203\times(\lambda - 1271) - 9.96$	$0.187\times(\lambda - 1271) - 5.81$
	L1	$0.194\times(\lambda - 1291) - 5.99$	$0.183\times(\lambda - 1291) - 2.12$
	L2	$0.185\times(\lambda - 1311) - 2.22$	$0.177\times(\lambda - 1311) + 1.47$
	L3	$0.176\times(\lambda - 1331) + 1.38$	$0.169\times(\lambda - 1331) + 4.92$
800GBASE-LR4	All	$0.225\times\lambda\times[1 - (1321.1 / \lambda)^4]$	$0.2175\times\lambda\times[1 - (1307 / \lambda)^4]$

- The FR4 equations are linear fits over the nearest 3 points from G.652 Table I.3 for M = 1, at Q = 99% for the minimum and Q = 99.9% for the maximum.
- The LR4 Sellmeier equations use the coefficients from G.652 Table I.4 for M = 4 and Q = 99.9%, as given previously in rodes_3dj_01a_2407.
- Table 183-14 is modified including a new column for the lane number, as shown at left.
- New text should be added to footnote (a):

The dispersion specifications are based on the statistical link design methodology documented in ITU-T REC G.652, Appendix I, and the optical channel characteristics methodology described in Annex-TBD.

Clauses 180/182: DRn and DRn-2

D1.1 comments #22, 23

Optical channel characteristics

Table 180–10—Optical channel characteristics

Description	200GBASE-DR1	400GBASE-DR2 800GBASE-DR4 1.6TBASE-DR8	Unit
Operating distance (max)	500		m
Channel insertion loss[a,b] (max)	3		dB
Channel insertion loss (min)	0		dB
Positive dispersion[b] (max)	~~0.79~~ 0.65		ps/nm
Negative dispersion[b] (min)	~~-0.92~~ -0.85		ps/nm
DGD_max[c]	2.24		ps
Optical return loss (min)	27	37	dB

[a] These channel insertion loss values include cable, connectors, and splices.
[b] Over the wavelength range 1304.5 nm to 1317.5 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 is required to tolerate.

Table 182–10—Optical channel characteristics

Description	200GBASE-DR1-2	400GBASE-DR2-2 800GBASE-DR4-2 1.6TBASE-DR8-2	Unit
Operating distance (max)	2000		m
Channel insertion loss[a,b] (max)	4		dB
Channel insertion loss (min)	0		dB
Positive dispersion[b] (max)	~~3.16~~ 2.62		ps/nm
Negative dispersion[b] (min)	~~-3.67~~ -3.41		ps/nm
DGD_max[c]	2.3		ps
Optical return loss (min)	25	37	dB

[a] These channel insertion loss values include cable, connectors, and splices.
[b] Over the wavelength range 1304.5 nm to 1317.5 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 is required to tolerate.

The dispersion specifications are based on the statistical link design methodology documented in ITU-T REC G.652, Appendix I, and the optical channel characteristics methodology described in Annex-TBD.

- The same CD methodology as 800GBASE-FR4 lane L2 is used here, with the dispersion values scaled for 500m for DRn.
- 3rd order polynomial fitting is used to interpolate the G.652 data at 1304.5 nm and 1317.5 nm as described on slide 7.
- The same new text is added to footnotes (b) as FR4.

D1.1 comments #24, 25, 26, 27

Transmitter compliance channel specifications

Table 180-TBD - Transmitter compliance channel specifications

PMD type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD (ps)
	Minimum	Maximum			
200GBASE-DR1, 400GBASE-DR2, 800GBASE-DR4, or 1.6TBASE-DR8	$0.0463(\lambda - 1311) - 0.55$	$0.0443(\lambda - 1311) + 0.37$	Minimum	see Table 180-7	0.5

[a] The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 500 m for all PMD types. The dispersion specifications are based on the statistical link design methodology documented in ITU-T REC G.652, Appendix I, and the optical channel characteristics methodology described in Annex-TBD.
[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.

Table 182–16—Transmitter compliance channel specifications

PMD type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c] ~~(dB)~~	Max mean DGD (ps)
	Minimum	Maximum			
200GBASE-DR1-2, 400GBASE-DR2-2, 800GBASE-DR4-2, or 1.6TBASE-DR8-2	~~$0.046 \times \lambda \times [1 - (1324 / \lambda)^4]$~~ $0.1850(\lambda - 1311) - 2.22$	~~$0.046 \times \lambda \times [1 - (1300 / \lambda)^4]$~~ $0.1770(\lambda - 1311) + 1.47$	Minimum	~~21.4~~ see Table 182-7	0.8

[a] The dispersion is measured for the wavelength of the transmitter lane under test (λ in nm). The coefficient assumes 2 km distance. Add text as above
[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.

- Clause 180:
  - The TDECQ test method for DRn points to 121.8.5.2 for the TX compliance channel, so a new TX compliance sub-clause 180.9.5.1 will need to be created, with editorial license.
  - The new TX compliance channel table is shown at left, using the same methodology as described for 800GBASE-FR4 channel L2, scaled for 500m.
  - New text should be added to footnote (a) as in the FR4 case.
- Clause 182:
  - Table 182-16 already exists in clause 182.9.5.1.
  - The new dispersion limits are the same as FR4 L2.
  - ORL limit of 21.4dB is not applicable for DR1-2, so update the table with a pointer to Table 182-7.
  - Update footnote (a) as above.

Clause 181: 800GBASE-FR4-500

D1.1 comment #28

Table 181–8—Optical channel characteristics

Table 181–8—Optical channel characteristics

Description	800GBASE-FR4-500	Unit
Operating distance (max)	500	m
Channel insertion loss[a, b] (max)	3.5	dB
Channel insertion loss (min)	0	dB
Positive dispersion[b] (max)	~~1.66~~ 1.50	ps/nm
Negative dispersion[b] (min)	~~-2.94~~ -2.82	ps/nm
DGD_max[c]	2.24	ps
Optical return loss (min)	17.1	dB

[a] These channel insertion loss values include cable, connectors, and splices.
[b] Over the wavelength range 1264.5 nm 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 is required to tolerate.

- The same CD methodology as 800GBASE-FR4 is used here, with the dispersion values scaled for 500m.
- The same new text is added to footnotes (b) as FR4.

The dispersion specifications are based on the statistical link design methodology documented in ITU-T REC G.652, Appendix I, and the optical channel characteristics methodology described in Annex-TBD.

D1.1 comment #29

Table 181–14—Transmitter compliance channel specifications

Table 181–14—Transmitter compliance channel specifications

PMD type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c] (dB)	Max mean DGD (ps)
	Minimum	Maximum			
800GBASE-FR4-500	$\cancel{0.0115 \times \lambda \times [1 - (1324 / \lambda)^4]}$	$\cancel{0.0115 \times \lambda \times [1 - (1300 / \lambda)^4]}$	Minimum	17.1	0.8

[a] The dispersion is measured for the wavelength of the transmitter lane under test (λ in nm). The coefficient assumes 500 m distance.
[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.

PMD type	Lane	Dispersion[a] (ps/nm)	
		Minimum	Maximum
800GBASE-FR4-500	L0	0.0508(λ – 1271) – 2.49	0.0468(λ – 1271) – 1.45
	L1	0.0485(λ – 1291) – 1.50	0.0458(λ – 1291) – 0.53
	L2	0.0463(λ – 1311) – 0.55	0.0443(λ – 1311) + 0.37
	L3	0.0440(λ – 1331) + 0.35	0.0423(λ – 1331) + 1.23

- The same CD methodology is used as for 800GBASE-FR4, with the length scaled to 500m.
- New text should be added to footnote (a):

The dispersion specifications are based on the statistical link design methodology documented in ITU-T REC G.652, Appendix I, and the optical channel characteristics methodology described in Annex-TBD.

Thank You