Baseline proposal for 800GBASE-FR4 chromatic dispersion specifications

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Introduction

- The optical channel model and transmitter compliance specifications for 800G-FR4 have been left incomplete pending conclusion of the statistical analysis of fiber CD data. D1.1 dispersion TBDs include:
  - Table 183–9—Optical channel characteristics
  - Table 183–14—Transmitter compliance channel specifications
- Statistical analysis of fiber CD data is being led by two groups:
  - ITU-T SG15 Q5 is drafting a new Appendix to G.652. See the Jan'24 liaison from ITU-T to P802.3. Recent discussions at the July'24 SG15 Plenary meeting have resolved outstanding questions about the analysis methodology.
  - Earl Parsons has analyzed a massive database of fiber from his affiliation, CommScope, and published the results in P802.3dj (parsons_3dj_01a_2405, parsons_optx_01_240627, and parsons_3dj_01_2407).
- To progress the P802.3dj draft standard, we need to make a decision on CD specs for 800G-FR4 in the D1.1 Task Force comment round.
- The analysis results of the CommScope dataset, which is an excellent model for what high-volume consumers of fiber experience, are proposed to be used for 800GBASE-FR4 CD specs.

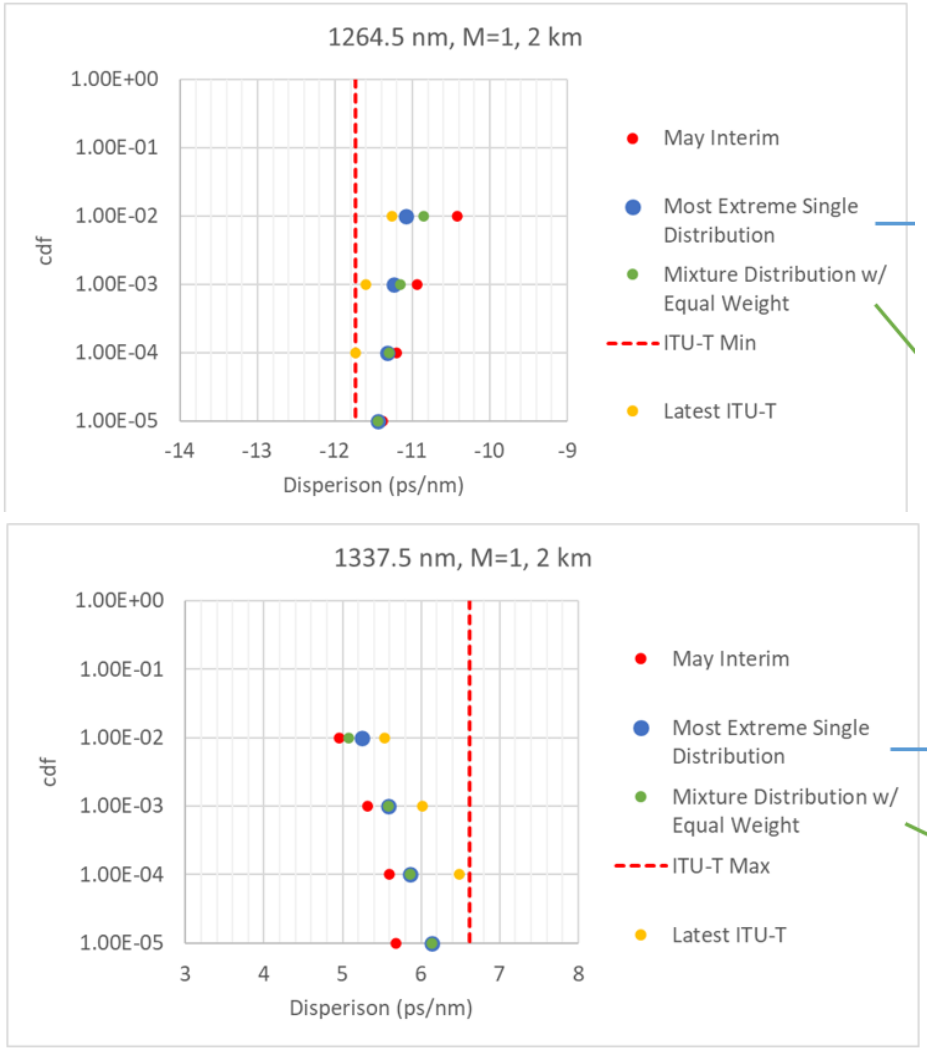
Statistical dispersion analysis summary

	800GBASE-FR4
Source data	CommScope, 6 fiber vendors, 2.5M fiber spools
Reference for channel model	802.3 Annex-TDB
Distribution type	Single extreme vendor for each tail
Distribution fitting	Direct from histograms
Number of cable segments	M = 1, no Monte Carlo
Confidence level	Q = 99.99%
TX Compliance formula	Linear fit per channel
Minimum dispersion	-11.32 ps/nm at 1264.5 nm
Maximum dispersion	+ 5.86 ps/nm at 1337.5 nm
Comments	• CommScope dataset is an excellent model for the CD distributions seen by high-volume fiber consumers. • Little difference between CommScope single extreme vendor and mixed vendor distributions. • M = 1 and Q = 99.99% are conservative assumptions.

Justification for the proposed methodology

- The CommScope dataset
  - Is massive, encompassing > 2.5 million fiber spools from 6 vendors representing 64% of worldwide market.
  - Is user-centric, not vendor-centric: The dataset consists of a large sample of fibers procured by a single user from multiple vendors, rather than the total output of individual vendors into all users/applications.
  - Is an excellent model for actual CD distributions seen by high-volume, multi-sourced fiber consumers such as hyperscale datacenter operators.
  - Requires writing an informative P802.3 Annex rather than referencing an external standard. It's a new direction, but not a showstopper.
- Number of fiber cable segments, M = 1
  - Single fiber cable segment is the conservative, default assumption for links up to 2 km
  - There is some evidence that multiple segments are used in hyperscale intra-datacenter 2 km links, providing upside from additional CD averaging (ferretti_3dj_01_2405).
- Single extreme vendor distributions
  - This is a more conservative default assumption for users with a single cable supplier, although the analysis shows little difference at Q = 99.99% using a mixed-vendor distribution.
  - Hyperscale datacenters drive high fiber volume, requiring multiple sources.
- Confidence level, Q = 99.99%
  - The massive scale of hyperscale datacenter networks and AI clusters demands high confidence.
  - There is some anecdotal evidence that many hyperscale users require tighter CD than standard specs.
  - Only a small fraction of FR4 links in the datacenter may be the full 2 km length.
  - Only a small fraction of transmitters will operate some of the time at the extreme wavelength limits.

Comparison of CD analyses for M=1, 2 km



parsons_3dj_01a_2407

M = 1 L = 2 km	Parsons Single, Q = 99.99% (ps/nm)	ITU-T July Liaison, Q = 99.9% (ps/nm)	ITU-T July Liaison, Q = 99% (ps/nm)	G.652 Worst Case (ps/nm)
CD_min @ 1264.5 nm	-11.32	-11.6	-11.26	-11.7
CD_max @ 1337.5 nm	5.86	6.02	5.54	6.6

- The CommScope mixed distribution and single extreme vendor distributions give similar values at Q = 99.99%.
  - CD(max) at 1337.5 nm = 5.86 ps/nm
  - CD(min) at 1264.5 nm = -11.32 ps/nm
- The ITU-T July Liaison analysis gives similar values for CD_min at Q=99%, and for CD_max at Q = 99.9%. The asymmetry in Q values is caused by one vendor which has distribution that is truncated at ZDW = 1324 nm.

Table 183–9—Optical channel characteristics

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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)	5.86	TBD	ps/nm
Negative dispersion[b] (min)	-11.32	TBD	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.

- Based on the analysis of parsons_3dj_01_2407 with M=1 and Q = 99.99%, the optical channel CD limits for 800GBASE-FR4 are proposed to be:
  - CD(min) at 1264.5 nm = -11.32 ps/nm
  - CD(max) at 1337.5 nm = 5.86 ps/nm
- These are 0.42 and 0.76 ps/nm reductions with respect to historical G.652 worst-case CD values of -11.7 to +6.6 ps/nm.
- johnson_optx_01_240627 estimated a TDECQ improvement of ~0.5 dB per 1 ps/nm reduction in CD at the limit, so this represents real TX margin.

Table 183–14—Transmitter compliance channel specifications

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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	L_0	$0.2062(\lambda - 1271) - 9.98$	$0.1931(\lambda - 1271) - 6.06$
	L_1	$0.1900(\lambda - 1291) - 6.03$	$0.1842(\lambda - 1291) - 2.28$
	L_2	$0.1808(\lambda - 1311) - 2.32$	$0.1758(\lambda - 1311) + 1.32$
	L_3	$0.1548(\lambda - 1331) + 1.09$	$0.1681(\lambda - 1331) + 4.77$

Based upon further analysis of provided by Earl Parsons with M = 1 and Q = 99.99%, the transmitter compliance CD limits for 800GBASE-FR4 are proposed to be specified per-lane as a linear equation of the form: $A(\lambda - \lambda_0) + B$ where,

- λ_0 is the center wavelength of the lane
- A is the dispersion slope at λ_0
- B is the dispersion at λ_0.

Conclusions

- Chromatic dispersion specifications for the 800GBASE-FR4 optical channel characteristics and transmitter compliance specifications are proposed based on the analysis of CommScope fiber data contributed by Earl Parsons.
  - The dataset is user-centric, not vendor-centric, thus is an excellent model for actual CD distributions seen by hyperscale datacenter operators.
  - Conservative assumptions of single extreme fiber vendors, single 2 km fiber segments and 99.99% confidence level were used in the analysis.
  - The fiber cables themselves are still specified by ITU-T G.652 and G.657.
- There is an historical preference to continue referencing G.652 methods for P802.3 optical channel specifications
  - This may be possible by making appropriate corrections to translate the vendor-centric viewpoint to a user-centric viewpoint.
  - This could be accomplished by applying lower confidence levels to account for the possible dilution or uneven distribution of outlier fibers among multiple users and applications.
  - This approach will require additional discussion and contributions.
- We recommend that the Task Force adopt the baseline Optical Channel characteristics and Transmitter Compliance Channel specs given on slides 7 and 8 for 800GBASE-FR4 at this meeting in order to progress the P802.3dj draft.

Thank You