A Review of ITU-T SG15 Q5 July 2024 Liaison Response on Single Mode Fiber Properties and revised Appendix for ITU-T G.652

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Summary

- In response to several Liaisons from IEEE 802.3 on the subject of Chromatic Dispersion and PMD_Q, ITU-T SG15 Q5 has approved a revision on the ITU-T G.652 Recommendation (single mode fibers) to add more details in Appendix I on statistical Analysis of Chromatic dispersion and PMD_Q.
- Eight vendors contributed statistical link design data in the fall of 2023 and then again in the spring of 2024 when IEEE802.3 requested more information.
- Each fiber vendor confirmed that they had used raw data pairs (of the zero dispersion slope and wavelength) to conduct their chromatic dispersion analysis.
- ITU-T Question 5 also added a table exploring the statistical effects of M on PMD_Q to provide insights on how PMD_Q may change for M values less than 20.
- ITU-T remains open to further discussion with IEEE 802.3 on these topics.

New Chromatic Dispersion assumptions in ITU-T G.652 Appendix I

- A numerical case study for the statistical accumulated chromatic dispersion was conducted based on the actual products of 8 fibre manufacturers.
- This case study assumed a link which is composed of 1, 4, 8, 12, or 16 concatenated cable pieces.
- Existing products compliant with G.652.D and G.657.A fibres were considered.
- The wavelength dependence of maximum/minimum chromatic dispersion values with probability (of exceeding link design value, LDV) Q of 10^{-4}, 10^{-3}, and 10^{-2} were derived based on the actual zero-dispersion wavelength and zero-dispersion wavelength slope properties of each manufacturer in the anonymous way.
- The accumulated chromatic dispersion boundaries were established by using the maximum and minimum limit from all manufacturers' results.

Statistical accumulated chromatic dispersion table in ITU-T G.652 Appendix I

Number of concatenated cables *M*		*M* = 1			*M* = 4			*M* = 8			*M* = 12			*M* = 16		
Probability level *Q*		10^{-4}	10^{-3}	10^{-2}	10^{-4}	10^{-3}	10^{-2}	10^{-4}	10^{-3}	10^{-2}	10^{-4}	10^{-3}	10^{-2}	10^{-4}	10^{-3}	10^{-2}
Wavelength (nm)		Statistical chromatic dispersion coefficient (ps/(nm·km))														
Upper boundary	1260	-3.33	-3.94	-4.17	-4.21	-4.34	-4.45	-4.43	-4.48	-4.55	-4.46	-4.53	-4.58	-4.51	-4.56	-4.61
	1264.5	-2.95	-3.51	-3.73	-3.77	-3.90	-4.01	-3.99	-4.04	-4.11	-4.02	-4.09	-4.15	-4.08	-4.12	-4.17
	1270	-2.50	-2.99	-3.20	-3.23	-3.36	-3.48	-3.46	-3.51	-3.58	-3.49	-3.56	-3.62	-3.55	-3.59	-3.64
	1280	-1.68	-2.07	-2.25	-2.28	-2.42	-2.54	-2.52	-2.57	-2.64	-2.54	-2.62	-2.68	-2.61	-2.65	-2.70
	1290	-0.88	-1.15	-1.33	-1.35	-1.50	-1.63	-1.59	-1.65	-1.73	-1.63	-1.71	-1.77	-1.70	-1.74	-1.79
	1294.53	-0.49	-0.74	-0.92	-0.94	-1.10	-1.22	-1.18	-1.25	-1.33	-1.23	-1.30	-1.36	-1.30	-1.33	-1.39
	1300	-0.03	-0.24	-0.43	-0.44	-0.61	-0.74	-0.69	-0.76	-0.84	-0.74	-0.82	-0.88	-0.81	-0.85	-0.89
	1310	0.87	0.65	0.44	0.45	0.26	0.13	0.20	0.11	0.03	0.13	0.05	0.01	0.06	0.02	-0.01
	1310.19	0.89	0.67	0.46	0.47	0.28	0.15	0.22	0.12	0.05	0.14	0.06	0.02	0.07	0.04	0.01
	1320	1.75	1.53	1.30	1.32	1.11	0.98	1.07	0.95	0.90	0.97	0.91	0.88	0.91	0.89	0.86
	1324	2.10	1.87	1.63	1.66	1.44	1.31	1.42	1.29	1.24	1.31	1.25	1.22	1.25	1.23	1.20
	1330	2.62	2.38	2.13	2.17	1.94	1.81	1.92	1.79	1.75	1.81	1.76	1.72	1.76	1.74	1.71
	1337.5	3.24	3.01	2.77	2.79	2.55	2.44	2.54	2.42	2.37	2.43	2.38	2.35	2.39	2.36	2.33
	1340	3.45	3.22	2.98	3.00	2.75	2.65	2.75	2.64	2.58	2.64	2.59	2.55	2.60	2.57	2.54
	1350	4.28	4.04	3.82	3.81	3.59	3.48	3.56	3.47	3.41	3.47	3.42	3.37	3.43	3.40	3.35
Lower boundary	1260	-6.34	-6.27	-6.10	-5.98	-5.90	-5.81	-5.86	-5.80	-5.74	-5.79	-5.75	-5.70	-5.76	-5.72	-5.68
	1264.5	-5.87	-5.80	-5.63	-5.51	-5.44	-5.35	-5.39	-5.34	-5.28	-5.33	-5.29	-5.24	-5.30	-5.26	-5.22
	1270	-5.29	-5.22	-5.07	-4.95	-4.87	-4.79	-4.83	-4.77	-4.71	-4.76	-4.73	-4.68	-4.73	-4.70	-4.66
	1280	-4.25	-4.20	-4.07	-3.94	-3.87	-3.79	-3.83	-3.77	-3.71	-3.76	-3.73	-3.68	-3.73	-3.70	-3.66
	1290	-3.25	-3.20	-3.08	-3.02	-2.89	-2.81	-2.85	-2.80	-2.74	-2.79	-2.76	-2.71	-2.76	-2.73	-2.69
	1294.53	-2.81	-2.76	-2.65	-2.61	-2.46	-2.38	-2.41	-2.37	-2.31	-2.36	-2.32	-2.28	-2.33	-2.30	-2.26
	1300	-2.27	-2.23	-2.13	-2.11	-1.94	-1.86	-1.89	-1.84	-1.79	-1.84	-1.80	-1.76	-1.81	-1.78	-1.74
	1310	-1.31	-1.28	-1.19	-1.23	-1.01	-0.93	-0.98	-0.92	-0.86	-0.91	-0.88	-0.83	-0.88	-0.85	-0.81
	1310.19	-1.29	-1.26	-1.17	-1.21	-0.99	-0.91	-0.96	-0.90	-0.84	-0.89	-0.86	-0.81	-0.86	-0.83	-0.80
	1320	-0.37	-0.36	-0.28	-0.36	-0.10	-0.02	-0.12	-0.01	0.05	-0.01	0.03	0.07	0.03	0.06	0.09
	1324	0.00	0.00	0.08	0.00	0.26	0.33	0.21	0.35	0.40	0.35	0.39	0.43	0.38	0.41	0.45
	1330	0.44	0.54	0.61	0.48	0.79	0.86	0.73	0.88	0.93	0.84	0.92	0.96	0.90	0.94	0.98
	1337.5	0.97	1.17	1.26	1.10	1.44	1.51	1.35	1.53	1.58	1.46	1.56	1.61	1.52	1.59	1.63
	1340	1.15	1.39	1.48	1.31	1.65	1.73	1.55	1.74	1.80	1.67	1.78	1.83	1.73	1.81	1.84
	1350	1.85	2.23	2.33	2.11	2.50	2.57	2.36	2.58	2.62	2.47	2.61	2.65	2.54	2.63	2.66
	1260	-3.33	-3.94	-4.17	-4.21	-4.34	-4.45	-4.43	-4.48	-4.55	-4.46	-4.53	-4.58	-4.51	-4.56	-4.61

Example Fitting Coefficients using Sellmeier Equations and Maximum Approximation Errors for the Statistical Chromatic Dispersion Coefficients in the O-band for M = 4, 8, 12, and 16

		Example fitting coefficients											
Number of concatenated cables *M*		*M* = 4			*M* = 8			*M* = 12			*M* = 16		
Probability level *Q*		10^{-4}	10^{-3}	10^{-2}	10^{-4}	10^{-3}	10^{-2}	10^{-4}	10^{-3}	10^{-2}	10^{-4}	10^{-3}	10^{-2}
Uppper boundary	l_0	1304.9	1307.0	1308.5	1307.7	1308.8	1309.7	1308.6	1309.4	1309.9	1309.4	1309.7	1310.1
	S_0 (l<l0)	0.089	0.087	0.086	0.088	0.086	0.086	0.086	0.086	0.087	0.086	0.086	0.087
	S_0 (l>l0)	0.089	0.087	0.087	0.088	0.087	0.088	0.087	0.088	0.088	0.088	0.088	0.088
Lower boundary	l_0	1324.0	1321.1	1320.3	1321.4	1320.1	1319.5	1320.1	1319.7	1319.2	1319.7	1319.4	1319.0
	S_0 (l<l0)	0.086	0.090	0.090	0.088	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090
	S_0 (l>l0)	0.083	0.089	0.089	0.085	0.089	0.089	0.086	0.089	0.089	0.087	0.089	0.089
Maximum approximation error (ps/(nm×km))		0.039	0.035	0.037	0.055	0.038	0.015	0.031	0.022	0.014	0.025	0.013	0.016

Note: l_0 in nm and S_0 in ps/(nm^2×km)

Alternate Chromatic Dispersion Estimation in ITU-T G.652 Appendix I

- An alternative method of estimating Link Design Values of chromatic dispersion was also introduced.
- Employing the central limit theorem (which allows the assumption of Gaussian distribution shapes as M >> 1), the LDV limits may be found by scaling from the Gaussian parameters
- Please reference the Liaison for more details

Influence of # of concatenated cable pieces M on PMD_Q and DGD

- IEEE 802.3 has also asked ITU-T SG15 to analyze cabled fiber PMD_Q for M values of less than 20.
- Because there is not sufficient recent data on cabled PMD_Q, ITU-T SG15 Q5 has addressed the issue theoretically to address PMD_Q for shorter links.
- PMDQ variation depends on the number of concatenated cable pieces M.
- A new table has been created to provide an example dependence of mean PMD_Q and mean DGD on the M value.
- The mean normalized PMD_Q or DGD denotes numerically expected PMD_Q or DGD values when M varies from 20, and these values are normalized with the PMD_Q or DGD values at M = 20.
- It is assumed that probability distribution of PMD_Q or DGD follows a Maxwellian distribution.

Hypothetical Influence of # of concatenated cable pieces M on PMD_Q and DGD

Number of concatenated cables *M*	Mean normalized PMD_Q	Mean normalized DGD
4	1.32	0.59
10	1.13	0.80
20	**1.00**	**1.00**
30	0.96	1.17

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