# 802.3dj SMF Channel Definition
# $CD_Q$ approach utilizing $PMD_Q$ methodology

IEEE 802.3dj Joint Optics/Logic ad hoc

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# Supporters

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# Background

Single-Mode Fiber Requirements for Calculating 800GBASE-LR4 PMD (Physical Medium Dependent)

- Chromatic Dispersion introduces ISI with penalty increasing by a factor of four with every doubling of baud rate
    - https://www.ieee802.org/3/dj/public/23_05/rodes_3dj_01_2305.pdf
- Four-wave mixing introduces power penalty depending on fiber ZDW
    - https://www.ieee802.org/3/df/public/22_03/rodes_3df_01a_220329.pdf
    - https://www.ieee802.org/3/dj/public/23_01/23_0206/johnson_3dj_01a_230206.pdf
- Request to adopt tighter ZDW (aka lambda zero) limits for calculating penalties in transceiver design and manufacture
    - ITU G.652.D spec: 1300 nm to 1324 nm to remain unchanged
    - Various proposals for models to tighten ZDW
        - https://www.ieee802.org/3/dj/public/23_05/cole_3dj_01b_2305.pdf
        - https://www.ieee802.org/3/dj/public/adhoc/optics/0423_OPTX/liu_3dj_optx_01_230427.pdf

# Background

ITU-T Q2/15, Q5/15, and Q6/15 agreed to start discussion on the applicability of statistical dispersion design approach and on the applicability of $PMD_Q$ in a short link

IEC 86A WG1 fiber manufacturers agreed to examine lambda-zero and zero-dispersion-slope statistics for each manufacturer to support the above discussion, utilizing the statistical link design methodology as described in Appendix I of Recommendation ITU-T G.652 to analyze chromatic dispersion of their G.652 and G.657 products

- Calculated chromatic dispersion distributions consider not only zero dispersion wavelength but the associated dispersion slope as well
- After confirmation of the validity of this statistical approach, fiber manufacturers and/or network operators will plan to perform the analysis and share the results among the IEC SC86A WG1 and ITU-T SG15
- After completion, IEC SC86A WG1 and ITU-T SG15 will decide how to provide an industry consented statistical range of probable dispersion values at the low and high wavelengths called out in 802.3dj for the 10km 800G LR4 application
- Expectation is that this analysis will tighten the total channel chromatic dispersion range to a more realistic value versus the worse-case assumptions currently used

# Current Chromatic Dispersion methodology only assumes using the worse-case design which is conservative

- The worst-case design is a deterministic methodology utilizing minimum and maximum values for a transmission system with a small number of components and lengths of optical fibre cables

From ITU-T Recommendation G.652/G.657

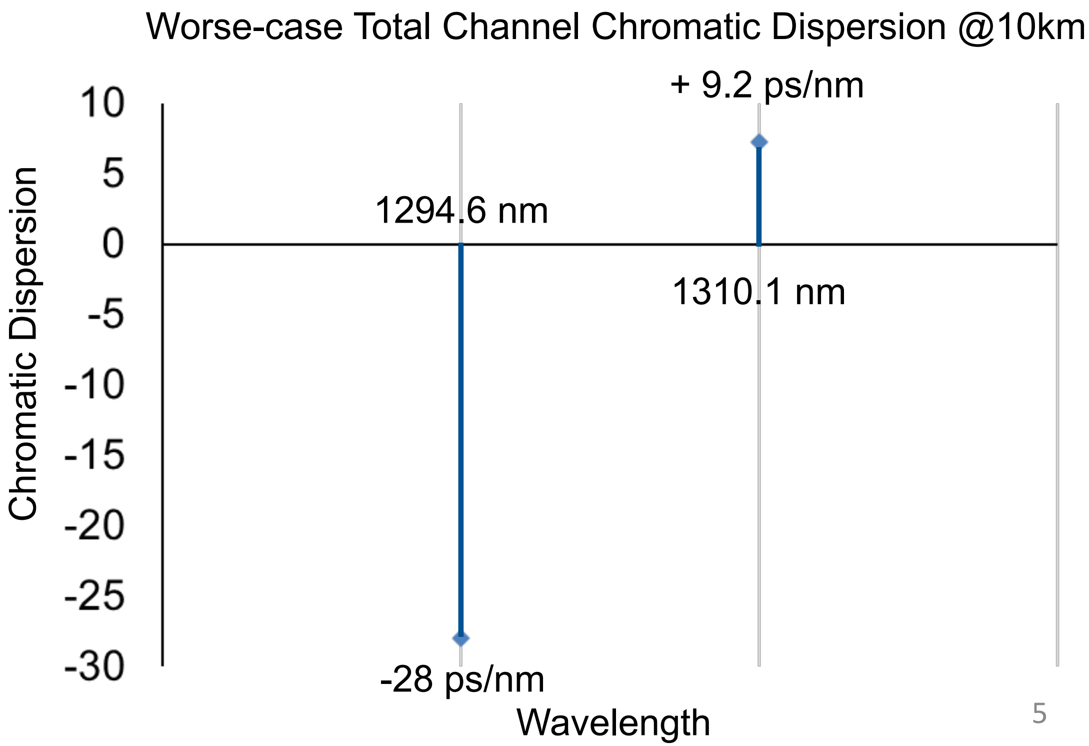
| Attribute | Detail | Value | Unit |
|---|---|---|---|
| Chromatic dispersion parameter | $\lambda_{0min}$ | 1300 | nm |
| 3-term Sellmeier fitting (1260 nm to 1460 nm) | $\lambda_{0max}$ | 1324 | nm |
| | $S_{0min}$ | 0.073 | ps/(nm$^2$ × km) |
| | $S_{0max}$ | 0.092 | ps/(nm$^2$ × km) |

For 1294.6 nm,

$$D(\lambda) \geq \frac{\lambda S_{0\,max}}{4}\left[1 - \left(\frac{\lambda_{0max}}{\lambda}\right)^4\right]$$

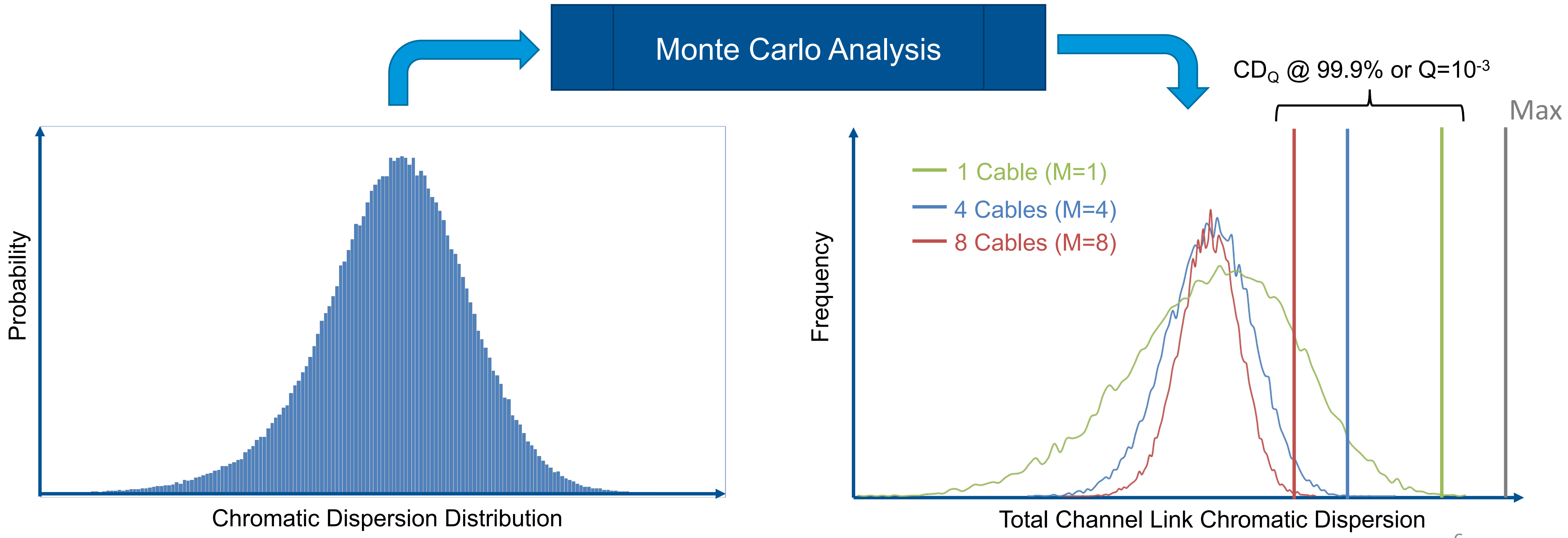
For 1310.1 nm,

$$D(\lambda) \leq \frac{\lambda S_{0\,max}}{4}\left[1 - \left(\frac{\lambda_{0min}}{\lambda}\right)^4\right]$$



# Link design methodology can be applied to evaluating Chromatic Dispersion providing a more realistic result

- For a concatenated link that includes several lengths of optical fibre cable, the transmission parameters for the concatenated link needs to consider not only the performance of the deterministic attributes of individual cable lengths but also the statistics of concatenation.



# Link design methodology can be applied to evaluating Chromatic Dispersion providing a more realistic result

- This method can be applied by following guidance in Appendix I of the ITU-T Recommendation G.652 (Transmission media and optical systems characteristics – Optical fibre cables)
- Using this method, each fiber manufacturer will collect a sufficient amount of data pairs for the zero dispersion wavelength, $\lambda_0$, and corresponding slope, $S_0$, to appropriately represent their distributions for G.652 and G.657 fibers
- Using the 3rd order Sellmeier equation, the chromatic dispersion coefficient can be calculated for each transmission wavelength, $\lambda$, of interest (1294.6 nm and 1310.1 nm for IEEE 800GBASE LR-4)

$$D(\lambda) = \frac{\lambda S_0}{4}\left[(1 - \frac{\lambda_0}{\lambda})^4\right]$$

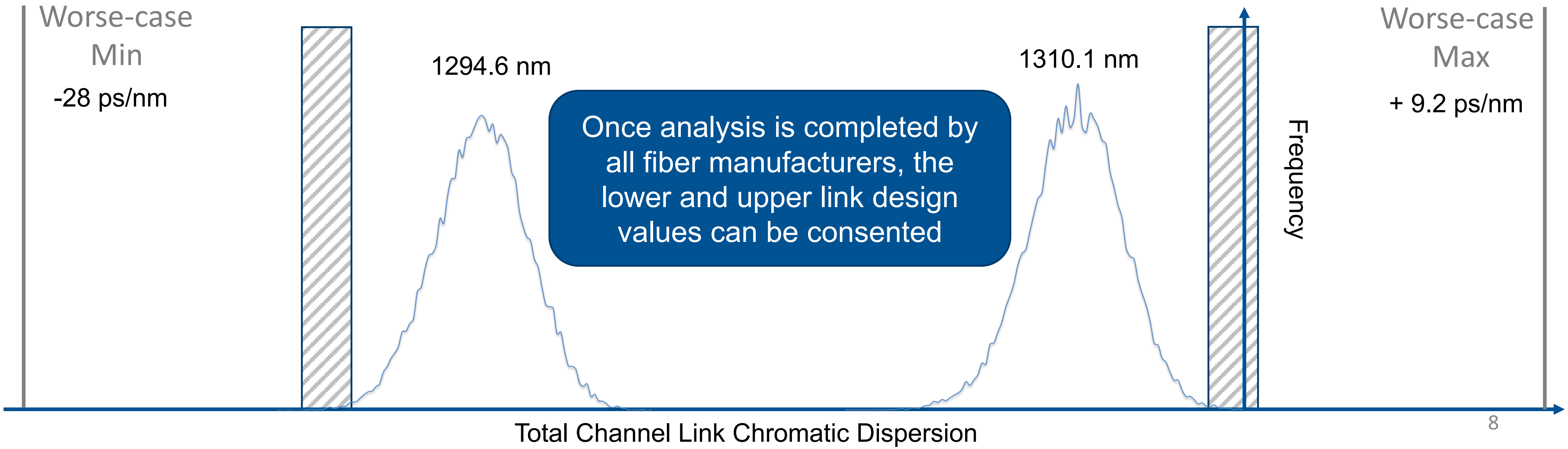
- The resulting dispersion coefficient data at each transmission wavelength is then curve fit to establish the probability distribution.
- Once the chromatic dispersion distribution has been established, the Monte Carlo method can be used to determine the probability density of the total chromatic dispersion of the concatenated link

# Analysis from all Fiber Manufacturers will Yield a Consented More Realistic Chromatic Dispersion range for a Given Link

- Monte Carlo computation is set up using M = 4 concatenations and cable length of $L_{Cab}$ = 2.5 km for a 10 km link, and a Q value of $10^{-3}$ which corresponds to a 99.9% confidence. (Refer to ITU-T G.652 Appendix I.6)

$$CD_M = \sum_{i=1}^{M} L_{Cab} CD_i$$

- The 99.9% chromatic dispersion of the lower end of the 1294.6 nm and the 99.9% chromatic dispersion of the upper end 1310.1 nm is selected for the link range.



# Analysis of a constrained Chromatic Zero Dispersion Range may be necessary when Four-wave mixing is of concern

- Because of four-wave mixing concerns in an 800GBASE LR-4 link, the same process can be followed by each vendor by collecting and using a constrained zero dispersion band of 1305 nm to 1324 nm for representative G.652 and G.657 fibers
- The results can be compared to the non-constrained band to evaluate any significant differences

# Proposed Transmitter Compliance Channel Specification Table

| PMD type | Dispersion (ps/nm) | | Insertion loss[b] | Optical return loss[c] | Max mean DGD |
|---|---|---|---|---|---|
| | Minimum [a] (CD$_Q$ at 1294.6 nm at 10 km) | Maximum[a] (CD$_Q$ at 1310.1 nm at 10 km) | | | |
| | TBD | TBD | | | |

[a] The minimum and maximum dispersion values have been calculated for the minimum and maximum link wavelengths at the link length using the link design method in Appendix I of ITU-T G.652 with M=4 and a Q value of $10^{-3}$ or 99.9%

# Conclusions &Next Steps

- The Link Design Method can be used by all Fiber Manufacturers to create a consented range of Chromatic Dispersion values for representative G.652 and G.657 fibers for a given link design
  - This not yet fully agreed to methodology will be shared across IEC SC86A and ITU-T SG15 and expedited analysis results will be requested
  - This methodology enables each fiber manufacturer to protect their proprietary data
- These values are expected to be more realistic than worse-case values used in past projects
- Four-wave mixing concerns in the O-band must also be taken into consideration
- A similar study for 10 km links needs to be conducted for $PMD_Q$
  - Current cabled $PMD_Q$ requirements are based on 20 concatenated lengths

# Thanks!