Polarization Mode Dispersion (PMD) & 10GBE

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PMD & DGD

- The PMD value is the average of differential group delay (DGD) values
- DGD varies randomly with wavelength and time
  - Wavelength - could be fast
  - Time - generally on the order of hours
- System impairment also varies with State of Polarization

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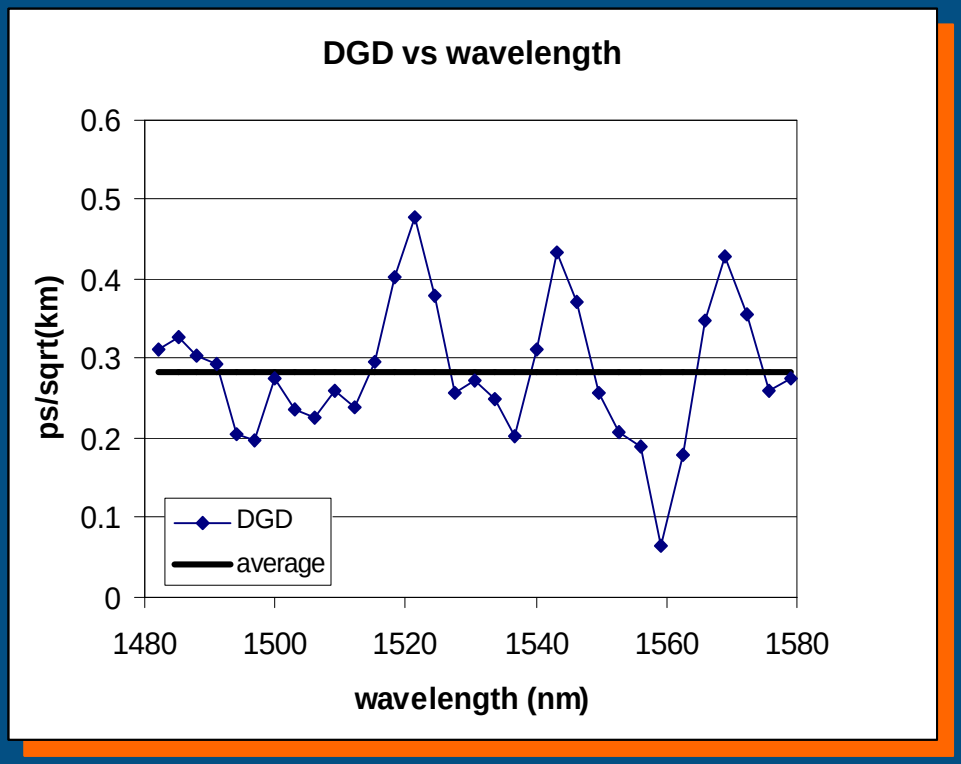
DGD plot



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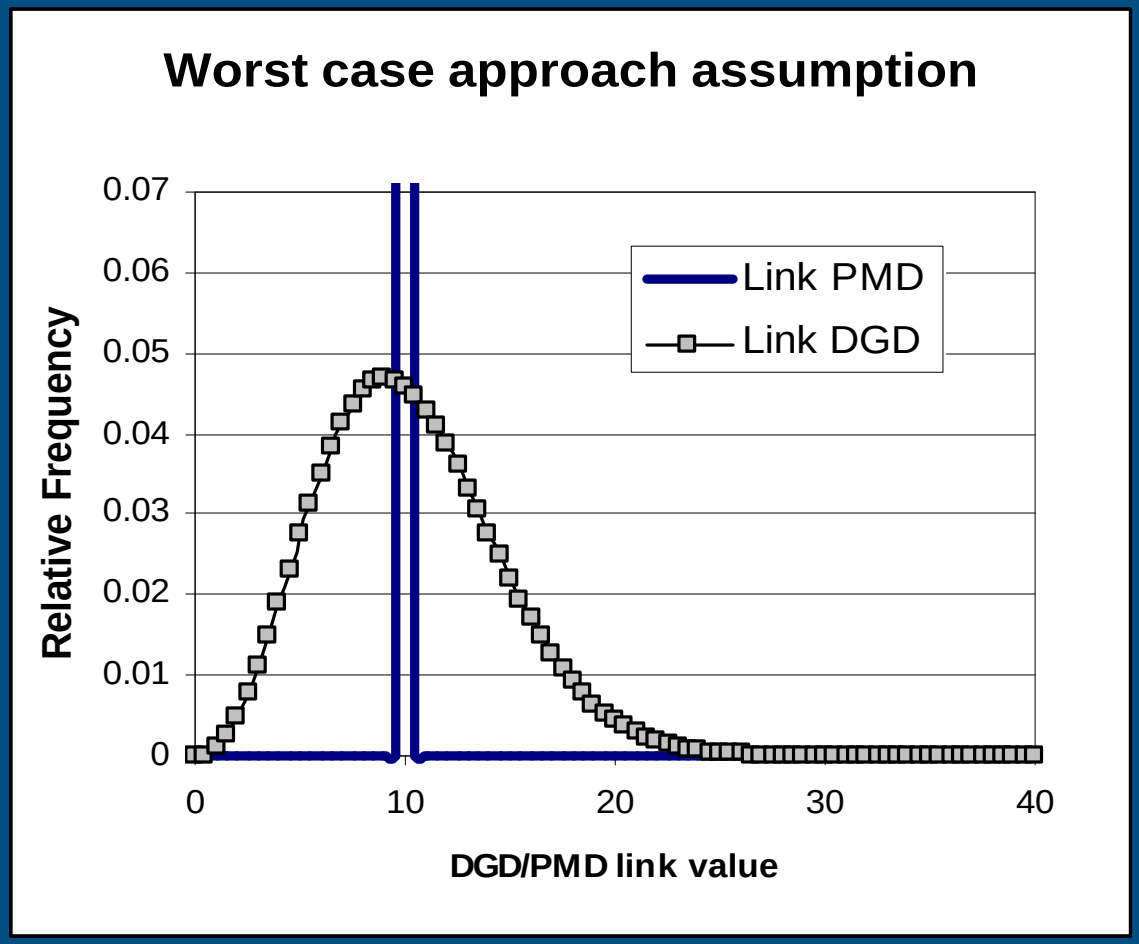
Maxwell DGD distribution



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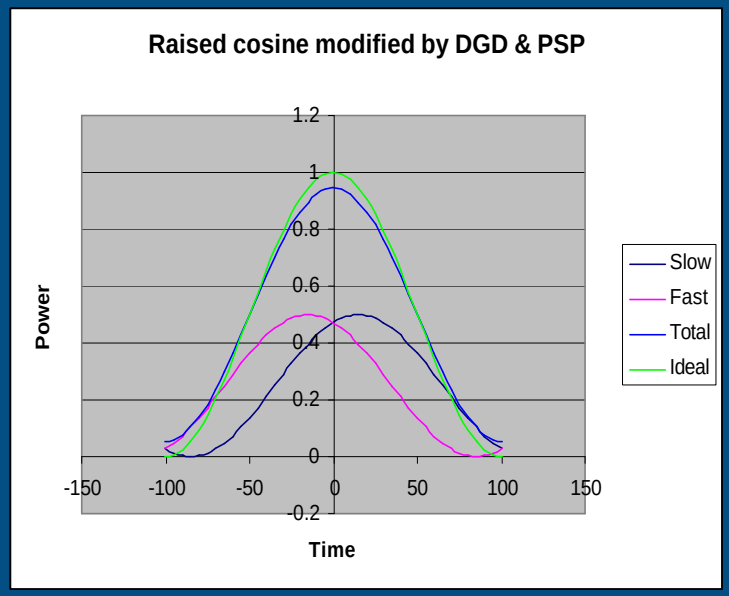
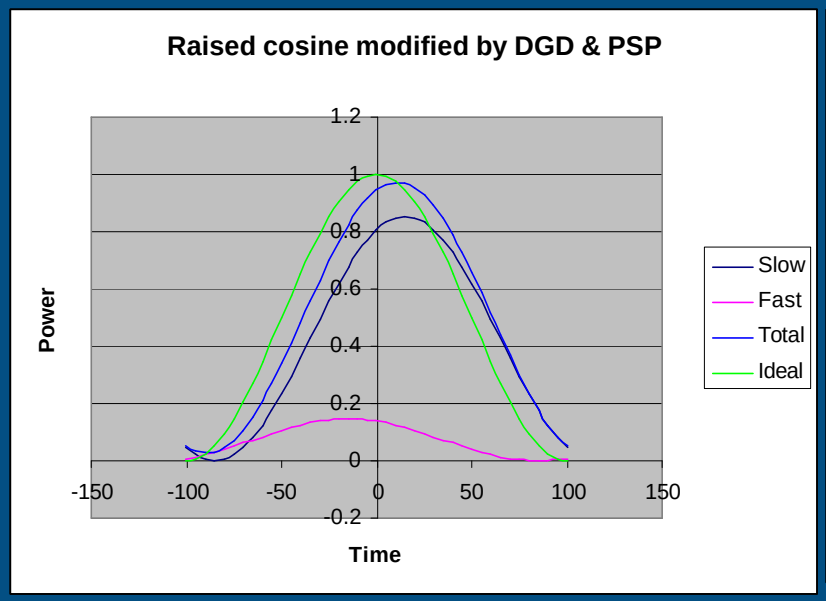
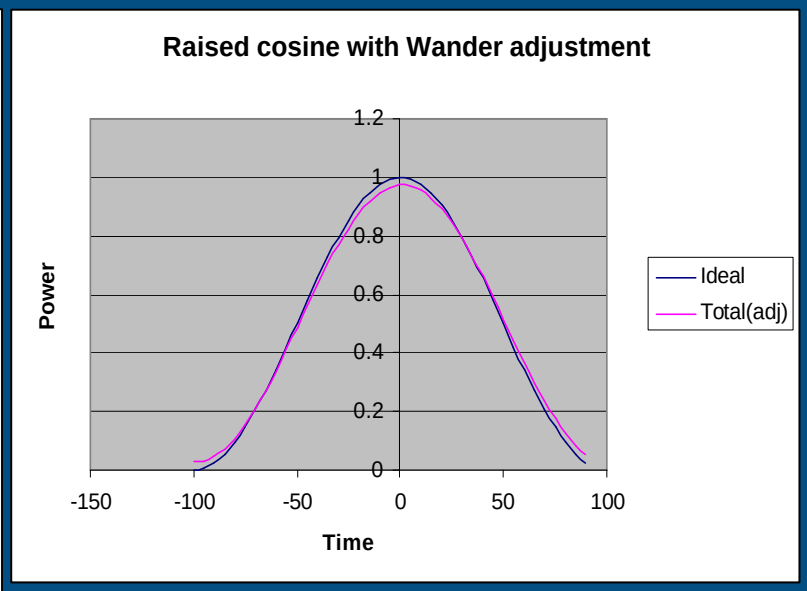
Pulse arrival







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Power penalty (Raised Cos)

$$e = 44\left(\frac{\Delta t}{T}\right)^2 g(1-g)$$

- ε Receiver sensitivity penalty (dB)
- $\Delta\tau$ DGD (ps)
- T Bit period (ps)
- γ Power splitting ratio with values from 0 to 1

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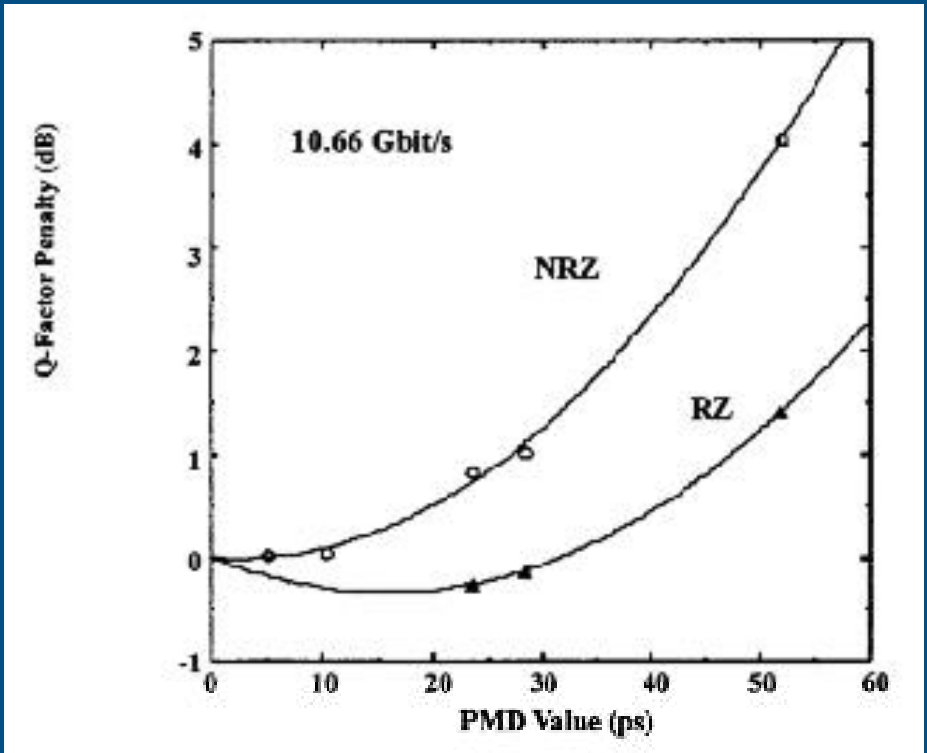
Namihira (ITU SG 15 D454)



- Actually DGD on hi-bi fiber

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Statistical specifications

- Based on concatenated links
- Method 1: 99.99%-tile of the link < 0.5 ps/sqrt(km)
  - 20 cable sections/link
- Method 2: DGDmax<25 ps
  - Convolution of link PMD & Maxwell variation
  - Probability < $6.5 \bullet 10^{-8}$
  - 400 km (of 10 km cables)
  - Allows for components (amps & DCs)
- Methods statistically equivalent

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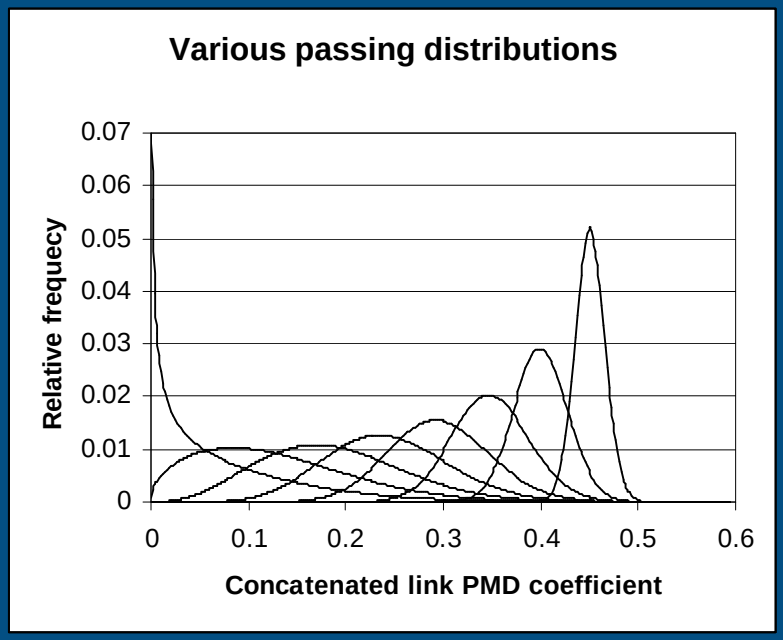
Why Method 2?

- Hard to determine DGDmax & probability otherwise



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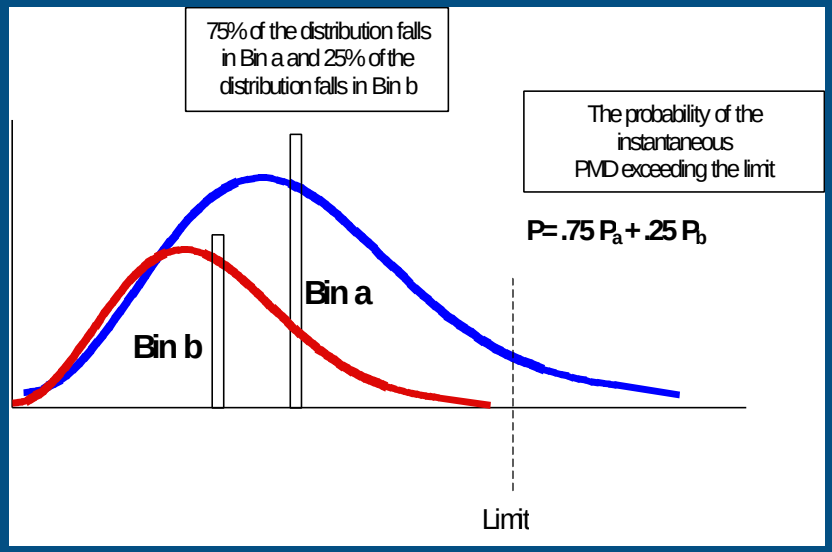
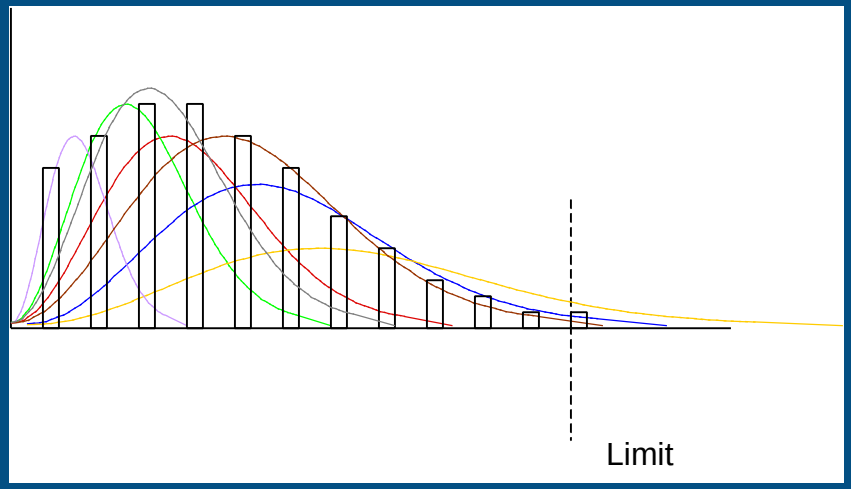
Convolution





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Probability of Exceeding DGDmax

- Interpreted as potential unavailability
- Penalty, based on DGDmax, is allocated to system design
- If DGD<DGDmax, system is OK to the design
- If DGD>DGDmax, system could go down
  - If everything else is at the limit
- Minutes/year/circuit = 2 * minutes in year * Prob

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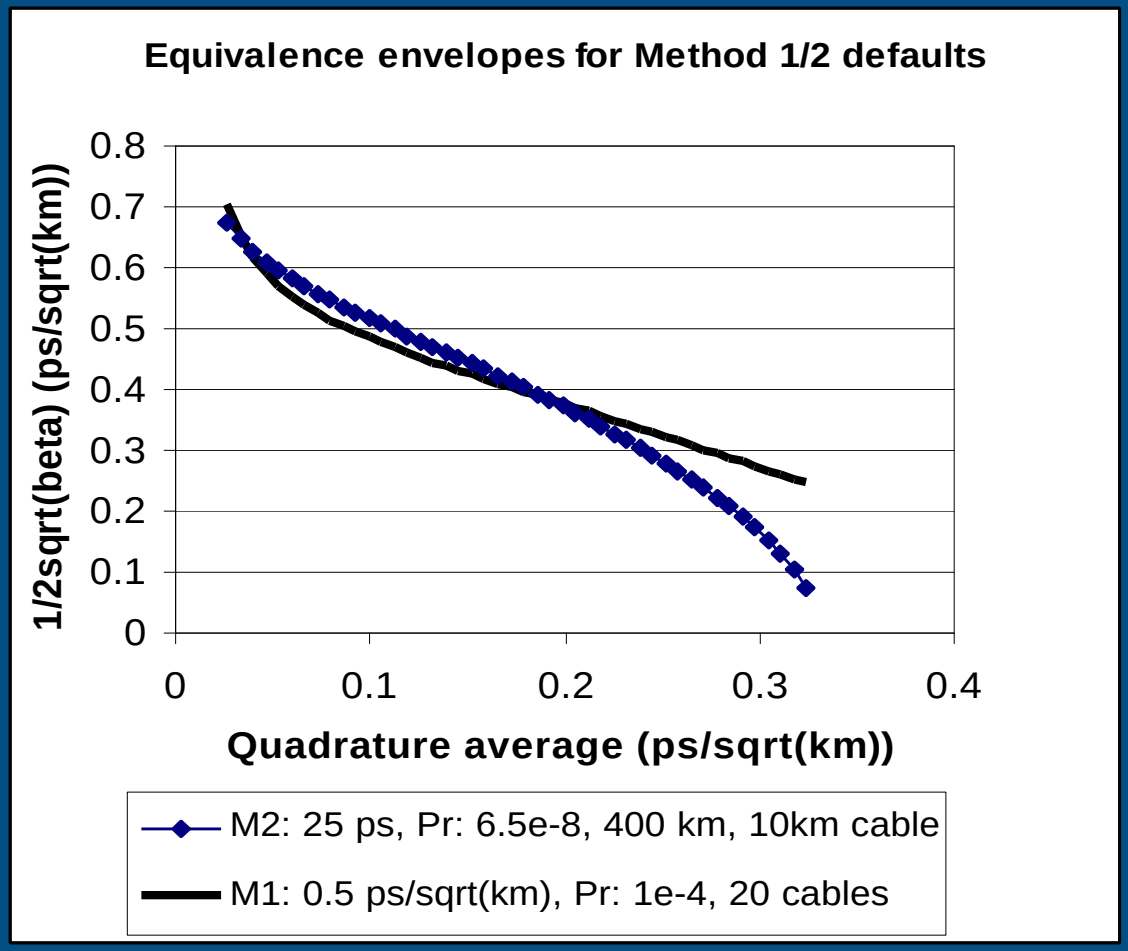
Equivalence for long length



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Problems for 10 GBE

- Links are short (40 km)
- Assuming 10 km cable
  - 4 cable sections, not 20
  - Statistical shrinkage not so great
- Method 2 is conservative for shorter links
  - Default values could be used
- How conservative?
  - Equivalence can used
  - Less conservative value

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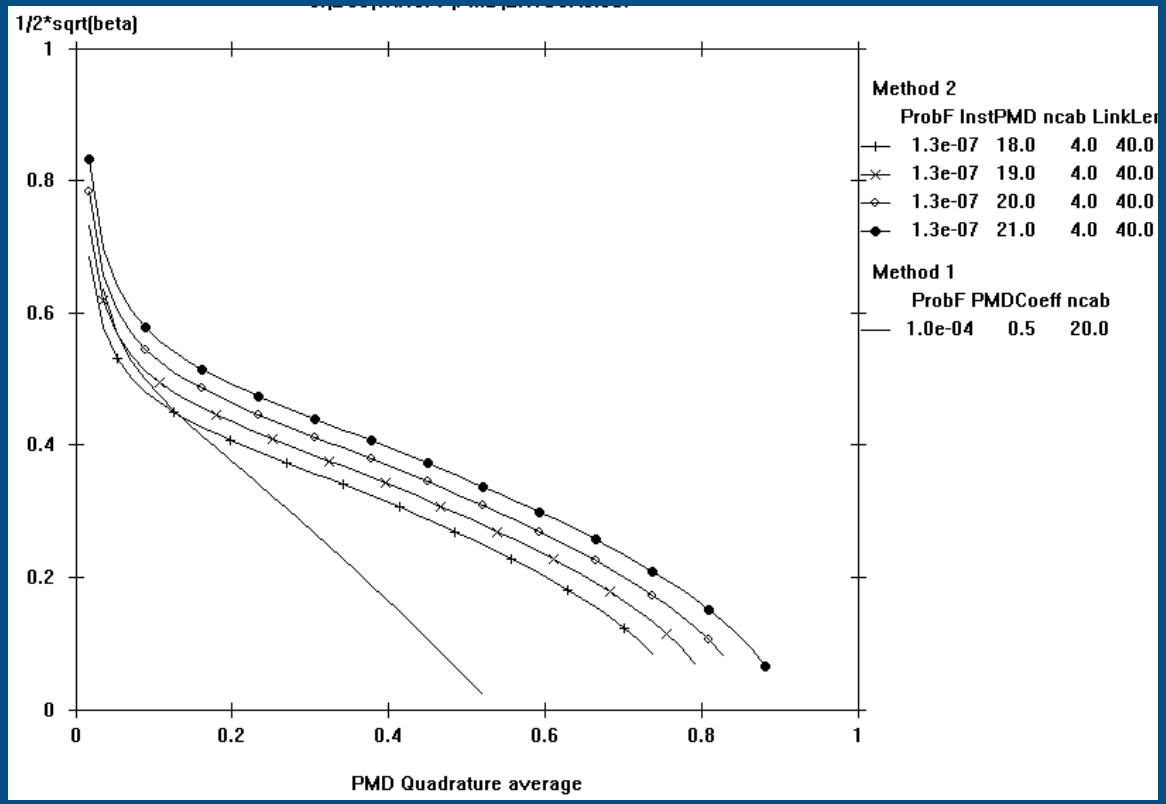
DGDmax for 10 GBE



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Values summary

- Link length: up to 40 km
- Cable section lengths: 10 km or less
  - 4 km is typical
- DGDmax: 19 ps
- Probability: $1.3*10^{-7}$
  - No need to allocate for components
- Min/yr/cir: 0.14 (8.2 s)

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What about varying polarization?

- Probability of exceeding the design penalty is decreased by variation of mode splitting ratio
- Depends on ratio of PMD to DGDmax
- Equivalence again:
  - 99.99%-tile on 4 section link: ~ 0.9 ps/sqrt(km)
- Probability is reduced by a factor of 0.23:
  - Leading to 1.9 s/yr/cir potential unavailability

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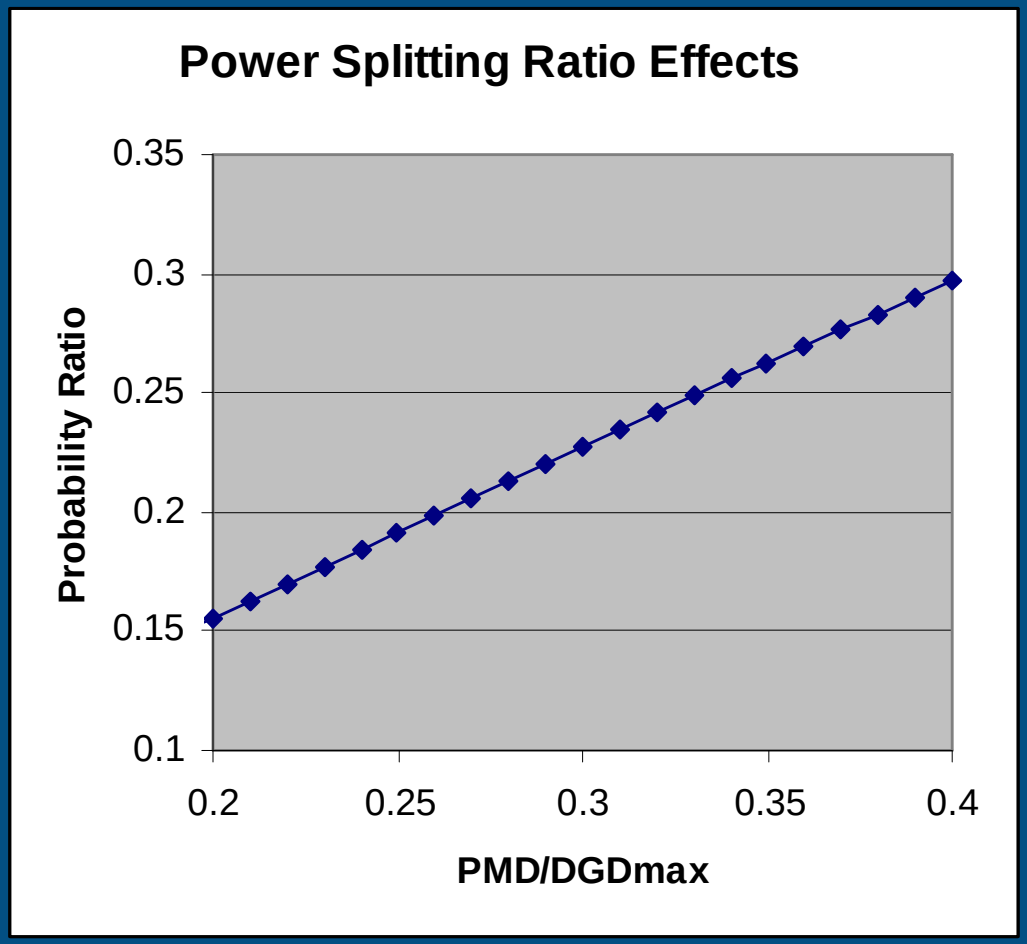
Power splitting ratio probability reduction factor



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Summary

- DGDmax:
  - 19 ps => 0.4 dB penalty
- Probability => potential unavailability
  - 1.9 seconds/year/circuit

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Relevant Standards (paraphrased titles)

- IEC 60794-3: Outdoor cable Sectional
- ITU G.652: Unshifted single-mode optical fibre and cable
- ITU G.691 High bit rate amplified single-channel SDH systems
- IEC 61282-3: Guide to PMD calculations for links
- TIA TSB-107: Guide to PMD calculations for cable links

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