Polarisation Mode Dispersion in 100GbE links

Pete Anslow, Nortel Networks

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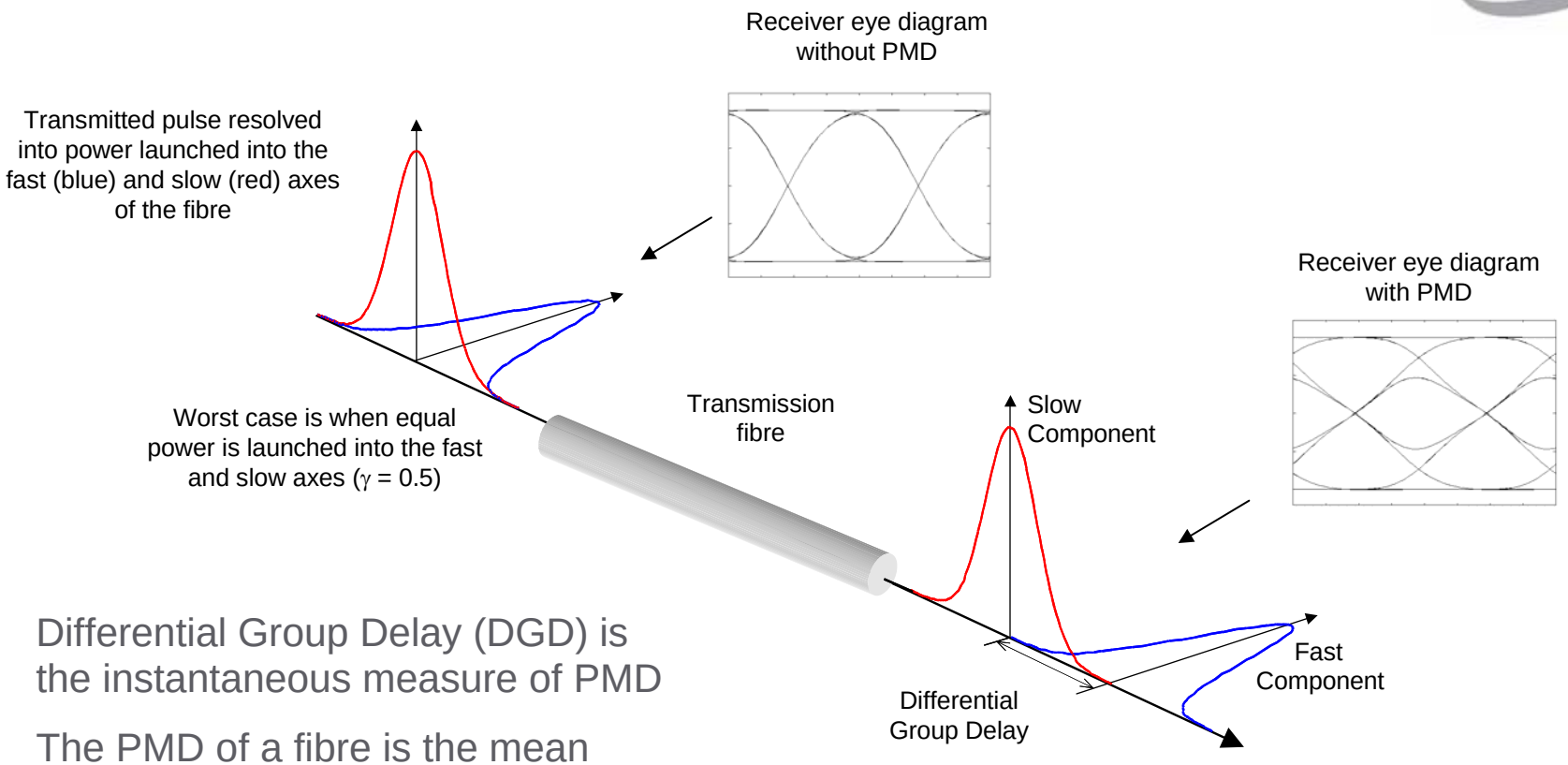
Introduction

During the discussion of cole_02_0108 in the Portland meeting the question of whether Polarisation Mode Dispersion (PMD) is an issue for the 40 km objective for 100 GbE was raised.

This contribution discusses the limitations due to PMD assuming that the 40 km 100 GbE objective is realized using four 25.8 Gbaud lanes.

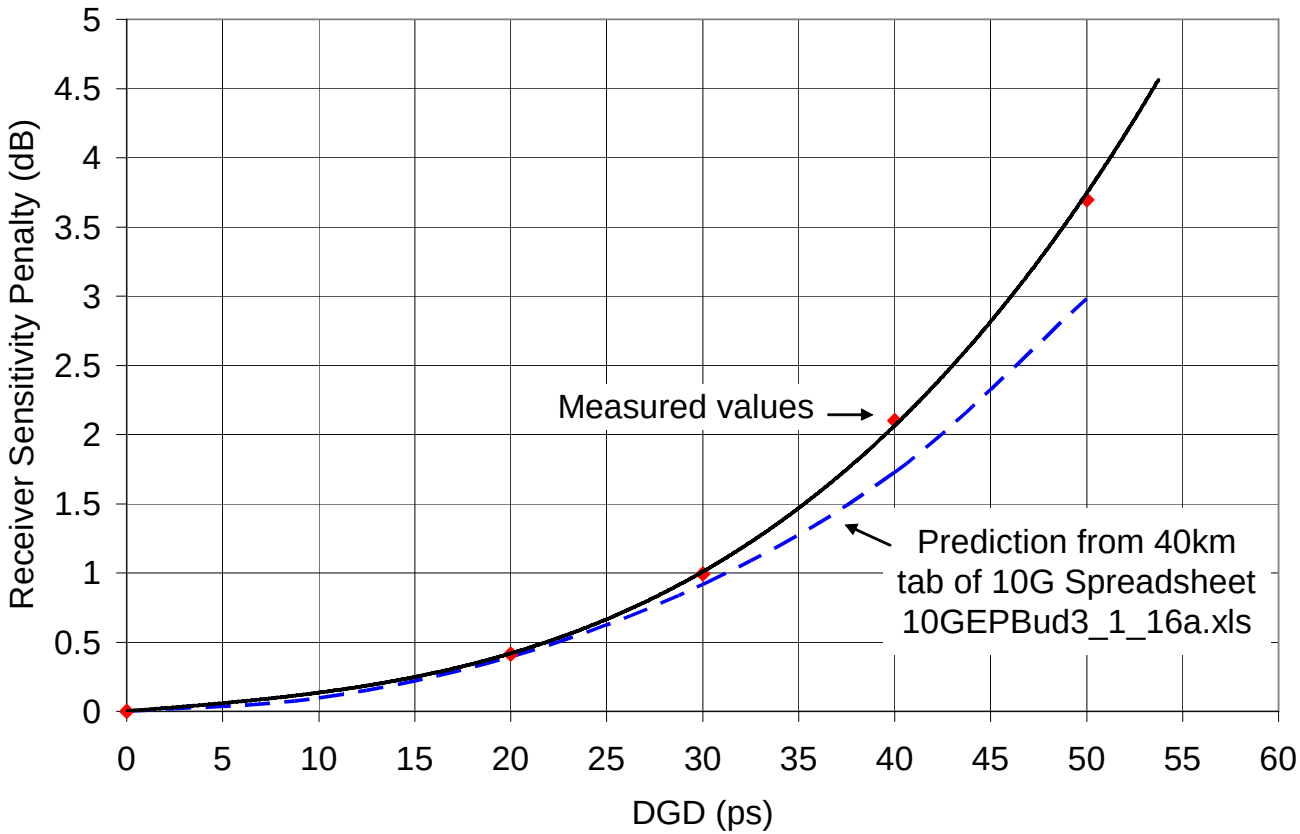
What is Polarisation Mode Dispersion?



Differential Group Delay (DGD) is the instantaneous measure of PMD

The PMD of a fibre is the mean value of DGD (<DGD>)

Penalty due to Differential Group Delay (DGD) 10G



10 GbE DGD limit

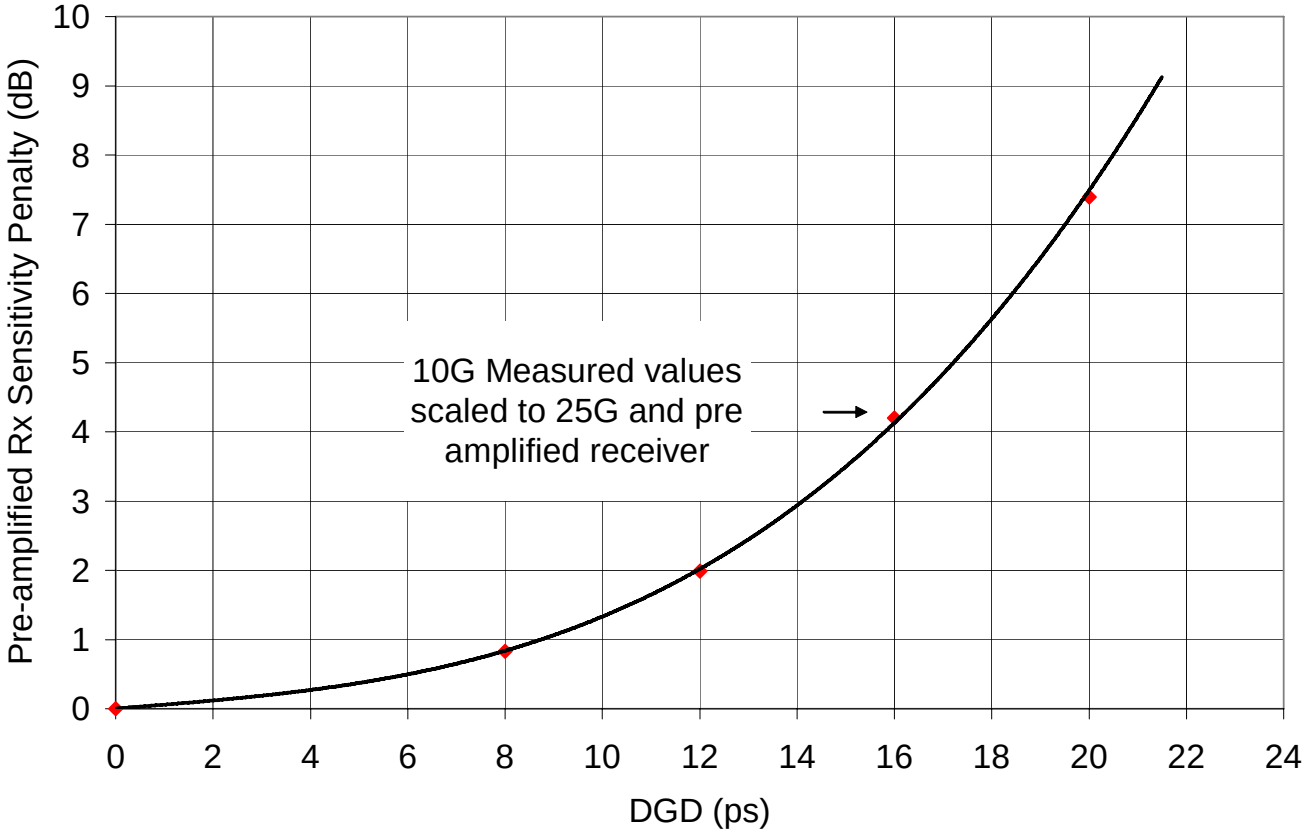
The DGD limit for 40km Single mode 10 GbE is a DGD_max of 19 ps from Table 52-24.

Both measurement and the 10G spreadsheet (previous chart) equate this to about 0.4 dB sensitivity penalty.

For operation at 25.8 GBd the DGD for a given penalty is expected to be 0.4 of the value at 10.3125 GBd. Also, for an OSNR limited pre-amplified receiver the sensitivity penalty due to eye-closure is roughly twice that for a non-amplified PIN receiver.

This results in a predicted penalty vs DGD curve as shown on the next chart.

Penalty due to Differential Group Delay (DGD) 25G



25.8 GBd DGD limit

From this curve, we would expect:

Power Penalty	DGDmax	
0.5 dB	6 ps	
1.0 dB	8.7 ps	
2.0 dB	12 ps	
6.5dB	19 ps	(10GbE spec)

Fibre specifications, however, are normally given as a PMD coefficient in ps/√km which is the **mean** DGD value divided by the square root of the length. Since the distribution of instantaneous DGD with time for a fibre link is approximated by a Maxwell distribution, it is only possible to relate the DGDmax values to PMD coefficients by defining a probability that the DGDmax value is exceeded at any instant.

A table of ratios of DGDmax to DGDmean with associated probabilities is shown on the next slide.

Maxwell distribution “Max” to mean

S Ratio of “Max” to mean	Probability	Time above “Max” limit per year
3	4.2E-05	22 minutes
3.25	6.19E-06	3 minutes
3.5	7.74E-07	24 seconds
3.75	8.21E-08	2.6 seconds
4	7.41E-09	0.2 seconds

The above table needs to be corrected to take account of two factors:

- When the DGD is above the “Max” value, the penalty is only as high as shown on slide 6 when γ = 0.5 (equal power in the two axes). For S = 3 (see P802.3ae, Equalization Ad Hoc, T Hanson) the probability should be multiplied by a factor of 0.25.
- The 100GbE link is made up of 4 lanes so the time above the “Max” limit for the link is ~ 4 x the time above the “Max” limit for each lane.

These effects therefore almost cancel each other out.

25.8 GBd PMD limit

Using an S value of 3.75 (2.6 seconds / year) gives:

Power Penalty	DGDmax	Link PMD Coefficient
0.5 dB	6 ps	0.25 ps/√km
1.0 dB	8.7 ps	0.37 ps/√km
2.0 dB	12 ps	0.5 ps/√km

G.652 fibre has two categories of PMD limit:

- For G.652.A&C Max. PMD_Q = 0.5 ps/√km
- For G.652.B&D Max. PMD_Q = 0.2 ps/√km

Where PMD_Q is the PMD coefficient that will be exceeded by less than 0.01% of links made up of 20 cable sections in series.

Specification choice

- Using the DGD specification from 40km 10GbE of 19 ps leads to a penalty of 6.5 dB which is not viable.
- Allocating 0.5 dB sensitivity penalty to PMD as in 10GbE leads to a requirement of ~ 0.25 ps/√km for the link PMD coefficient which will rule out a lot of older fibre [3, 4].
- Operation over legacy fibre with a link PMD coefficient of ~ 0.5 ps/√km leads to ~ 2.0 dB sensitivity penalty due to PMD for a pre-amplified receiver which will make the power budget for this link more difficult to meet (see cole_02_0108) and therefore may increase the cost.
- A more balanced solution may therefore be to choose a DGD limit of ~ 8.7 ps which leads to a penalty of 1.0 dB and a link PMD coefficient of ~0.37 ps/√km

Conclusions

Assuming that the 100GbE 40km objective is met using 4 lanes at 25.8GBd:

- Operation with a maximum DGD of 19 ps (limit for 40km 10GbE) is not viable.
- Re-using the approach from 40km 10GbE of allocating 0.5 dB sensitivity penalty to PMD leads to a requirement of ~ 0.25 ps/√km for the link PMD coefficient which is too stringent.

- A DGD limit of ~ 8.7 ps seems a better compromise between cost and performance and leads to a link PMD coefficient of ~0.37 ps/√km

References

- [1] ITU-T G.652, "*Characteristics of a single-mode optical fibre and cable*"
- [2] Hanson T, "*Polarisation mode dispersion and related topics*", IEEE P802.3ae, Equalization Ad Hoc, October 2000.
- [3] Lord A, "*PMD from an operator's perspective*", ECOC, 2007, Workshop 9
- [4] Barcelos S, et al, "*Polarization Mode Dispersion (PMD) Field Measurements: Audit of Newly Installed Fiber Plants*", NFOEC, 2005, NThC3
- [5] Peters J, Dori A and Kapron F, "*Bellcore´s Fiber Measurement Audit of Existing Cable Plant for Use With High Bandwidth Systems*", NFOEC, 1997.

Thanks!

Pete Anslow,
Nortel Networks