P802.3cu DGD penalty

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Introduction

A baseline was proposed for 100GBASE-LR in welch_3cu_adhoc_050119 and a set of possible values for 400GBASE-LR4 was presented in lewis_optx_01a_0319.

In both of these power budgets, an allowance of 0.5 dB or 0.6 dB has been made for MPI penalty (depending on ER value) in accordance with the budgets for 50GBASE-LR, 200GBASE-LR4, and 400GBASE-LR8.

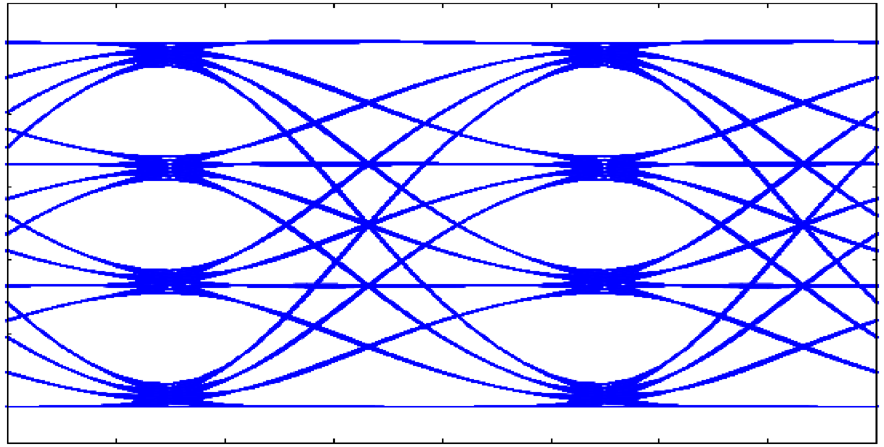
However, no additional allocation has been made for DGD penalty. This issue was raised in shuai_3cu_adhoc_050119.

The DGD_max value for 25GBASE-LR, 50GBASE-LR, 100GBASE-LR4, 200GBASE-LR4, and 400GBASE-LR8 is 8 ps.

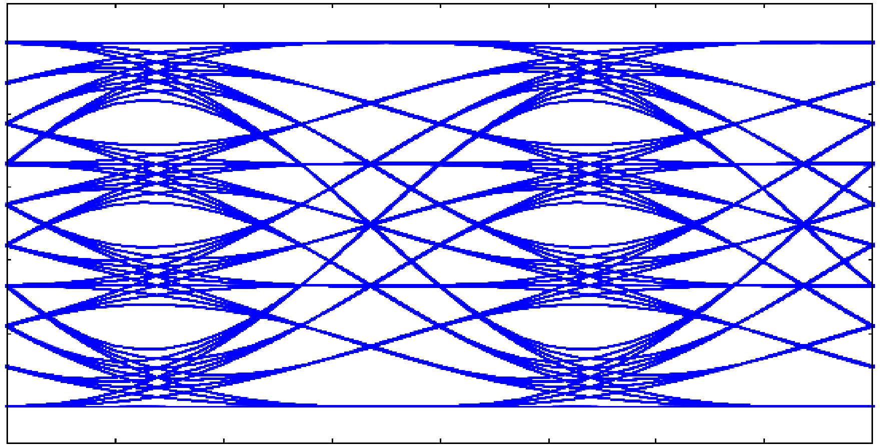
This presentation uses simulations to further investigate the DGD penalty that 100GBASE-LR and 400GBASE-LR4 could have.

~26.56 GHz bandwidth Tx eyes, 8 ps DGD

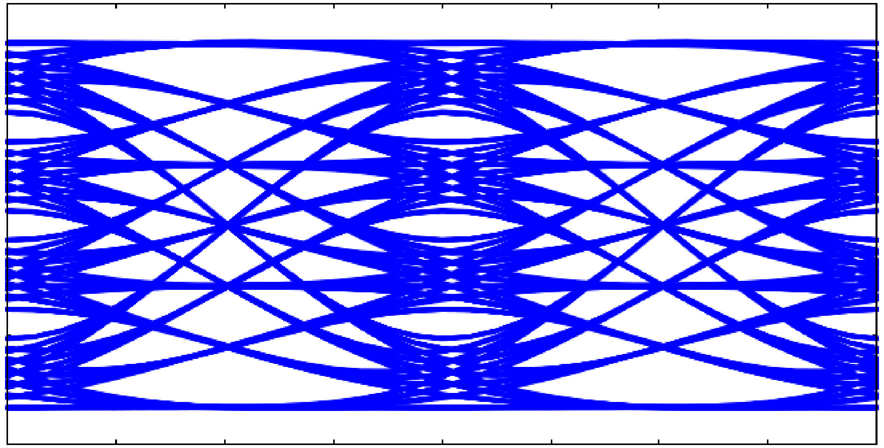
Tx eye 0 ps DGD



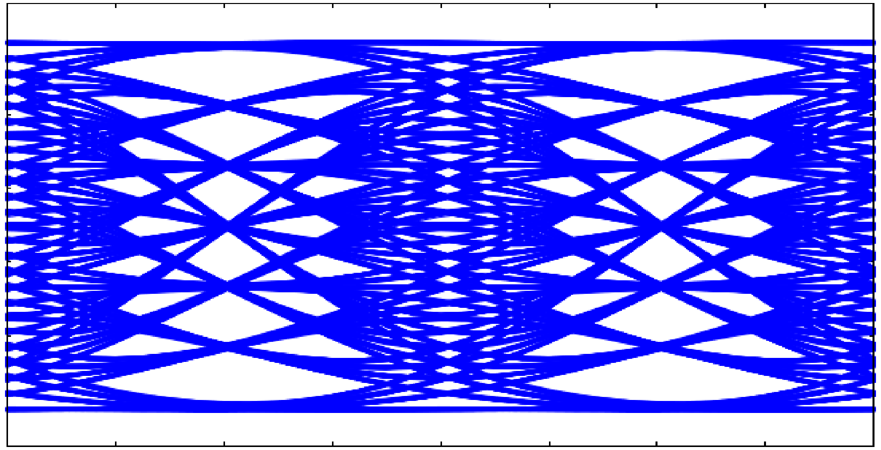
Tx eye 8 ps DGD



Eye as seen via a 26.56 GHz Rx 0 ps DGD

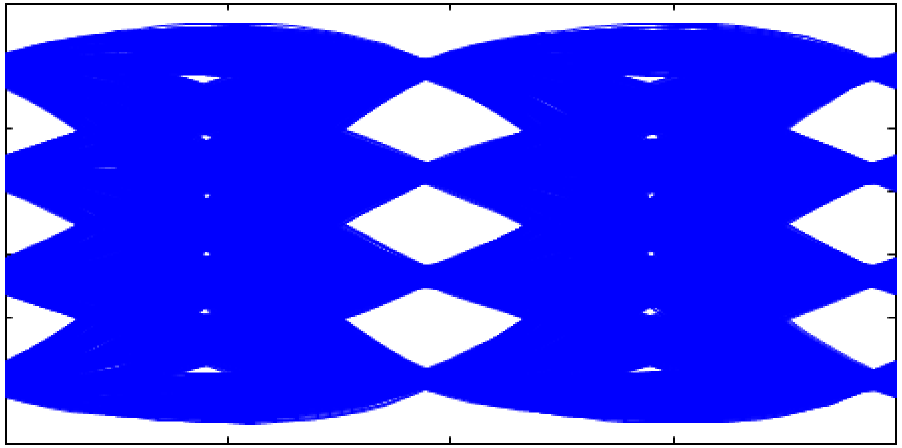


Eye as seen via a 26.56 GHz Rx 8 ps DGD



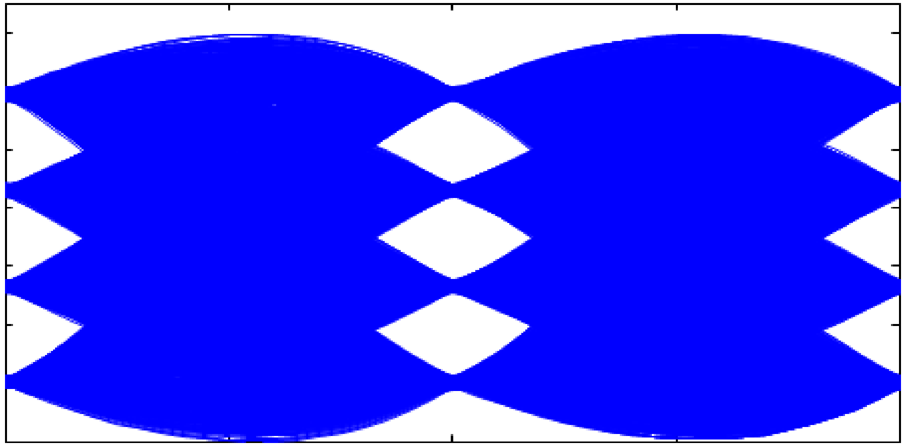
SECQ for ~26.56 GHz bandwidth Tx , 8 ps DGD

Eye after equalizer 0 ps DGD



SECQ = 1.52 dB

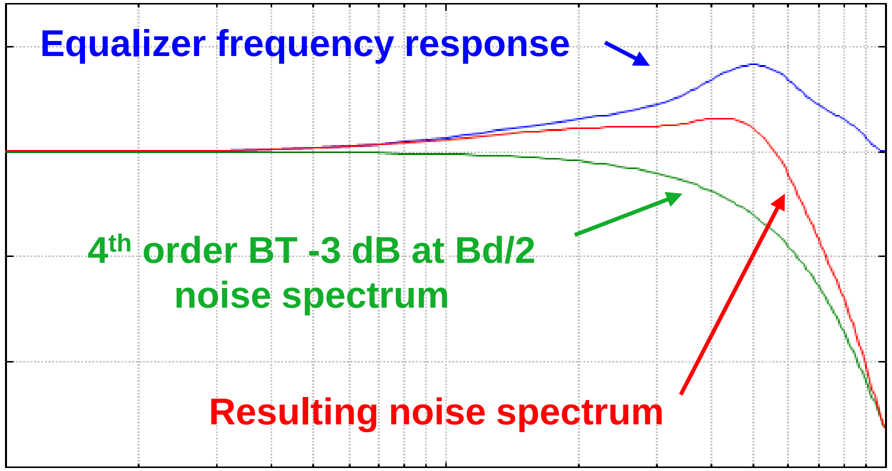
Eye after equalizer 8 ps DGD



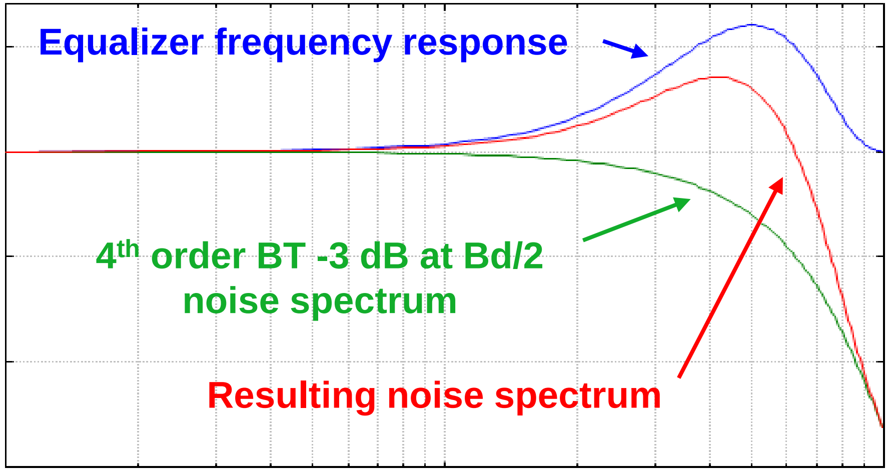
SECQ = 2.07 dB

0.55 dB DGD penalty

Equalizer frequency response 0 ps DGD



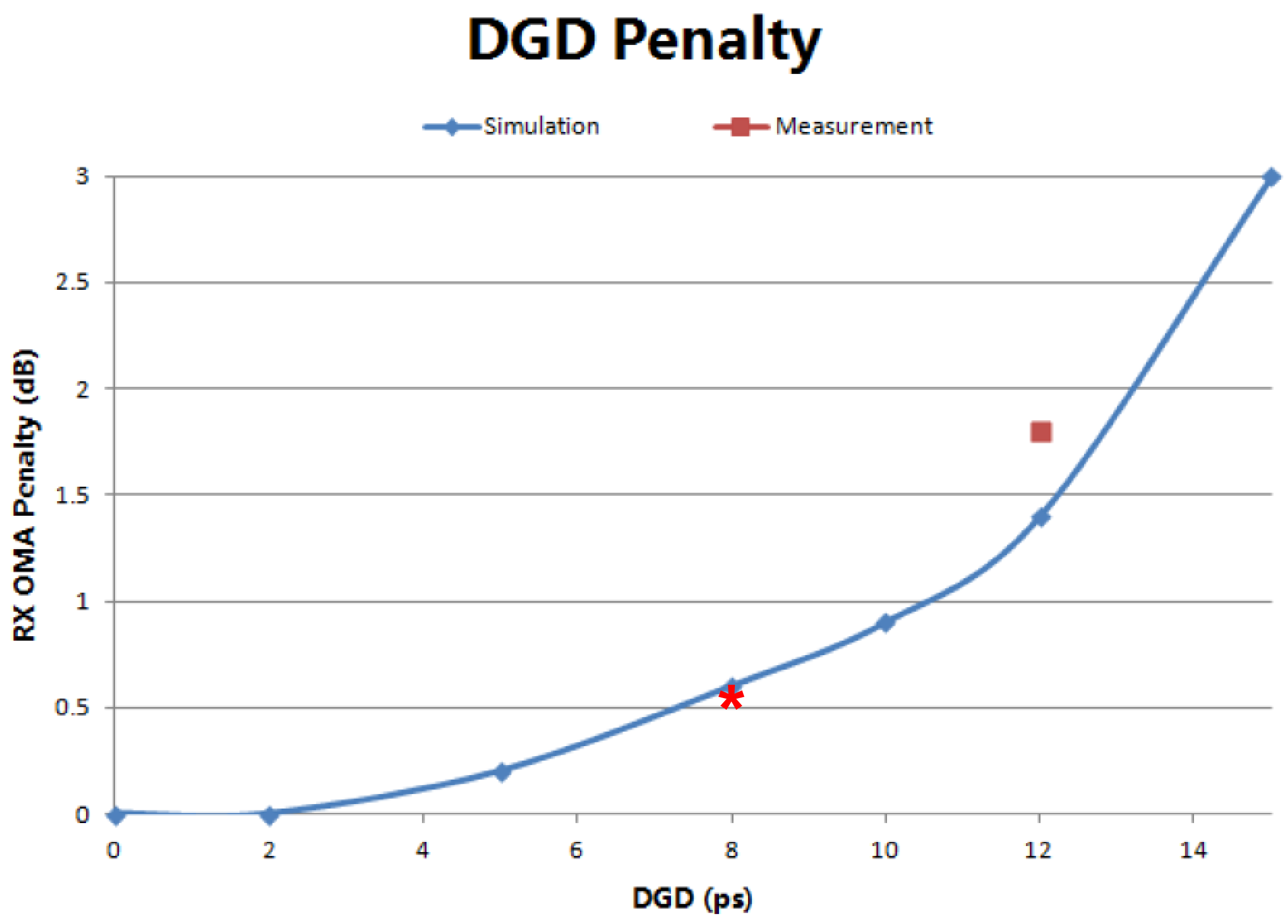
Equalizer frequency response 8 ps DGD



DGD penalty for 8 ps

The value of 0.55 dB obtained on the previous page ("*" right) agrees very closely with the predicted penalty for 8 ps of DGD in shuai_3cu_adhoc_050119.

However, it would be difficult to find an extra ~0.6 dB in the optical power budget for this (particularly for 400GBASE-LR4).



G.652 fiber specifications

The 2009 version of G.652 contained specifications for:

- G.652.A and G.652.C with a maximum PMD_Q of 0.5 ps/√km
- G.652.B and G.652.D with a maximum PMD_Q of 0.2 ps/√km

The 2016 version of G.652 contains only the newer G.652.B and G.652.D fibre types with a maximum PMD_Q of 0.2 ps/√km. It is believed that these fiber types represent the bulk of recently deployed fiber.

Note that 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.

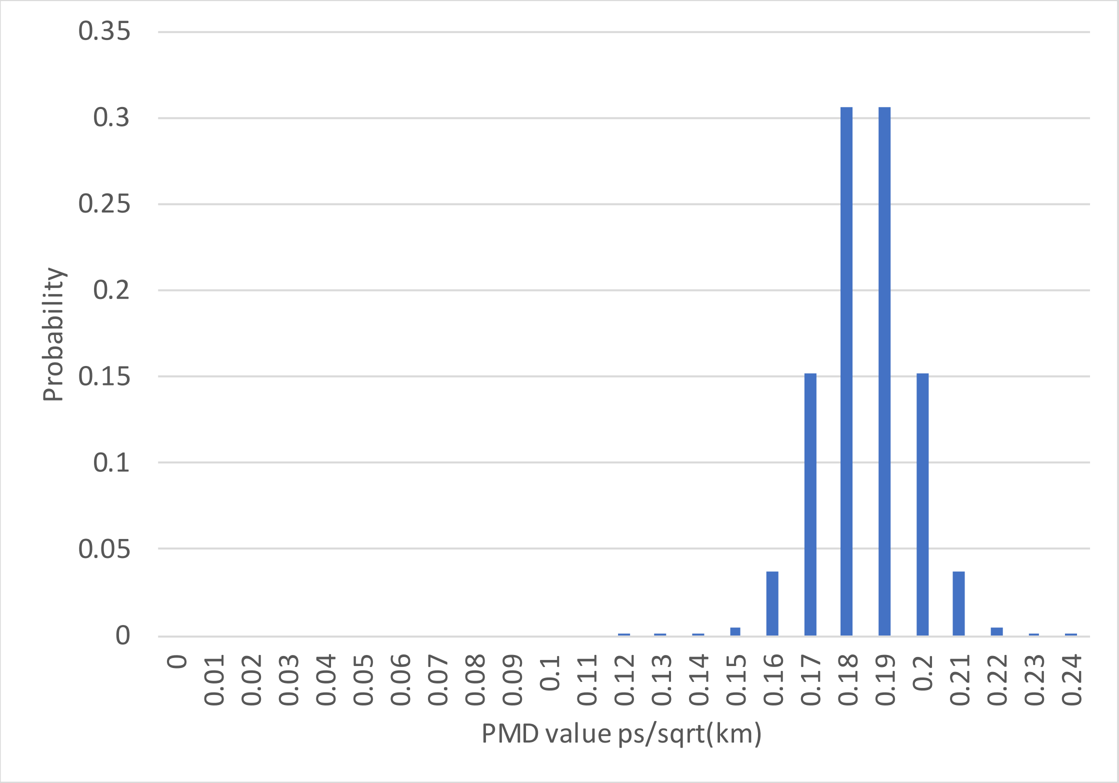
DGD_max 1

If the maximum PMD_Q is 0.2 ps/√km, what is the DGD_max for a 10 km link?

This depends on the statistical distribution of the cable sections that make up the link. At one extreme, the cable sections could all have a PMD coefficient that is close to 0.2 ps/√km with little scatter.

An example distribution with a mean of 0.19 ps/√km and a standard deviation of 0.0116 ps/√km is shown on the right. This meets the PMD_Q requirement as 20 cable sections taken at random from this distribution have a probability of the combined PMD coefficient exceeding 0.2 ps/√km of 0.008%.

If the 10 km link is only 1 cable section, the probability of the PMD coefficient exceeding 0.24 ps/√km is less than 0.01%



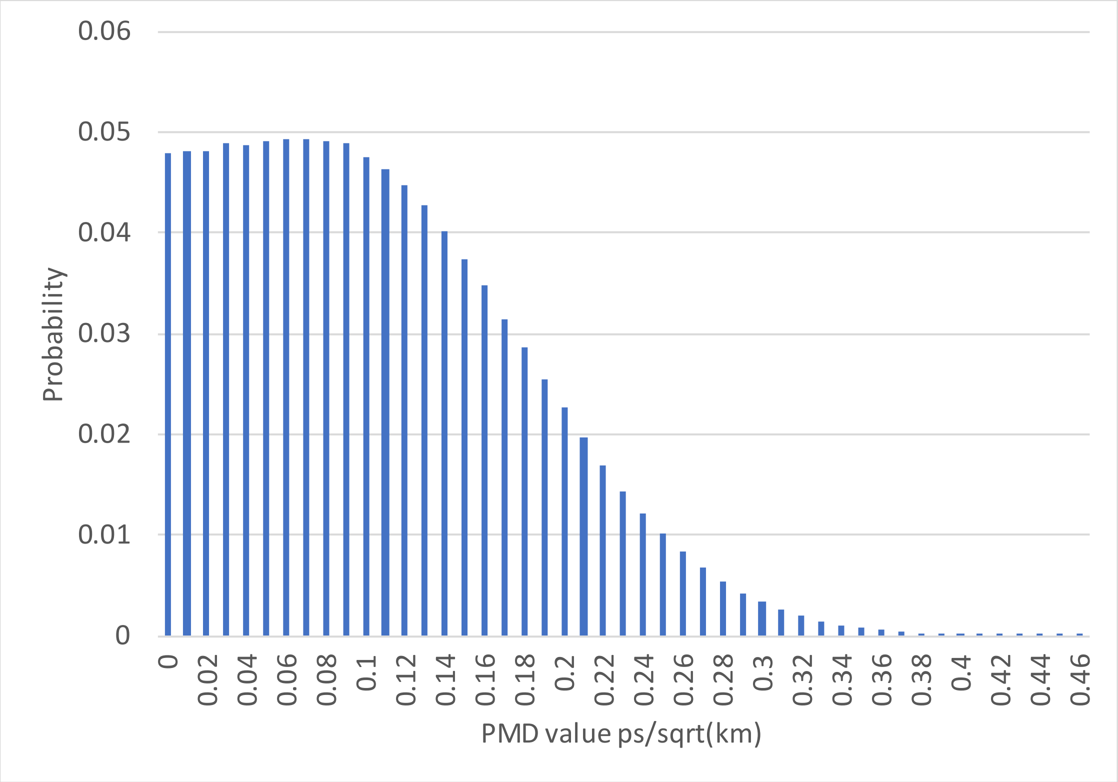
DGD_max 2

A more realistic statistical distribution of the cable sections that make up the link would be a mean of 0.1 ps/√km and a standard deviation of 0.09 ps/√km as shown below. This also meets the PMD_Q requirement as 20 cable sections taken at random from this distribution have a probability of the combined PMD coefficient exceeding 0.2 ps/√km of 0.009%.

If the 10 km link is only 1 cable section, the probability of the PMD coefficient exceeding 0.43 ps/√km is 0.012%.

0.43 ps/√km for a 10 km link corresponds to a mean DGD of 1.36 ps.

If the ratio of "Max" DGD to mean DGD is set to 3.75 (see page 8 anslow_01_0308), this corresponds to a DGD_max of 5 ps.



DGD_max 3

Vince Ferretti from Corning has helpfully pointed out a relevant publication:

JACOBS, S.A. et al., Statistical Estimation of PMD Coefficients for System Design. Electronics Letters, 1997, 33, pp. 619-621

This includes an analysis of 288 randomly selected scaled cabled fibers.

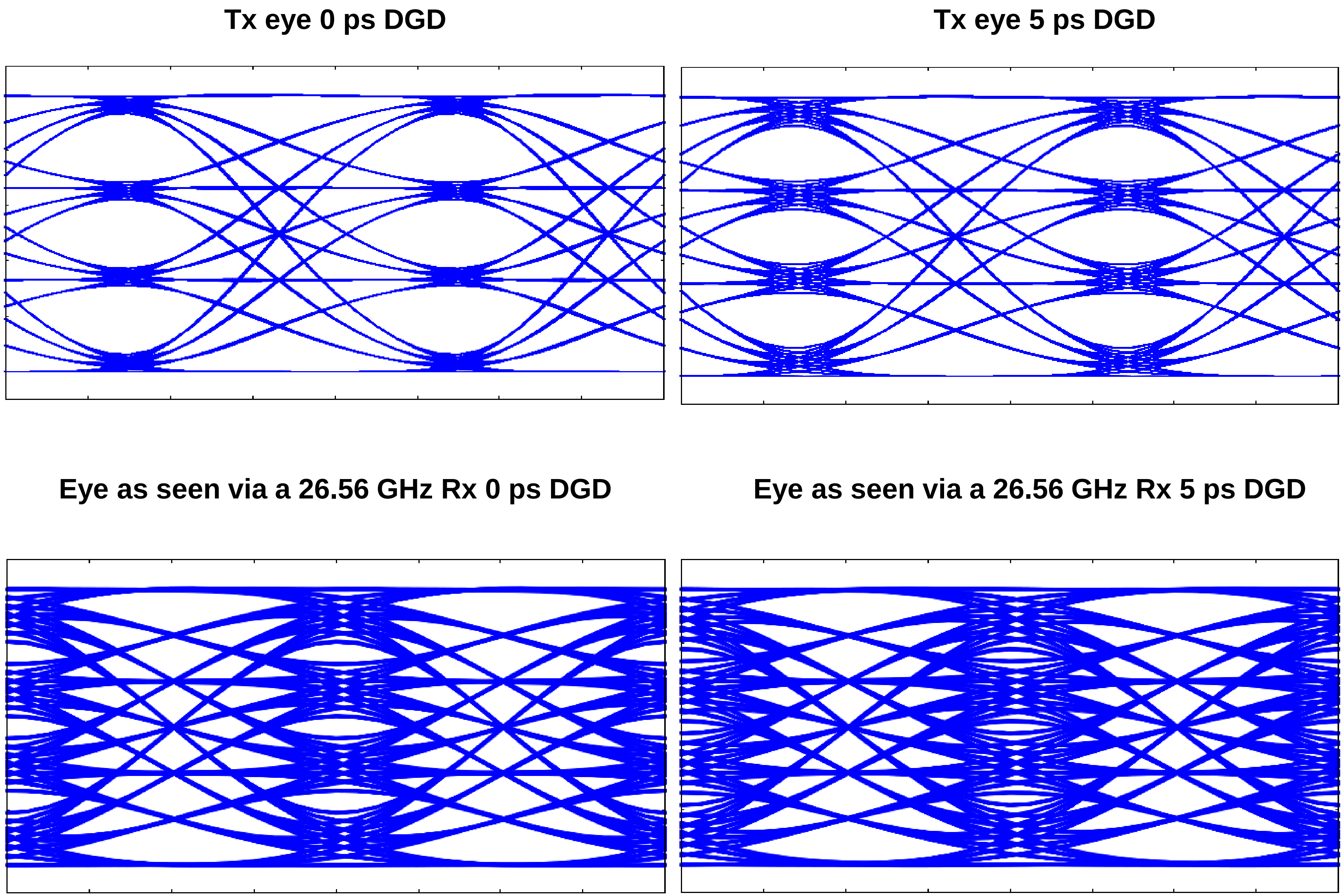
Equation 10 of this is:

$$X_Q = \frac{\left(2.004 + 0.975\sqrt{n \times 0.979}\right)}{\sqrt{n \times 48.6}}$$

For n = 1 (one cable segment), this evaluates to X_Q = 0.426 ps/√km

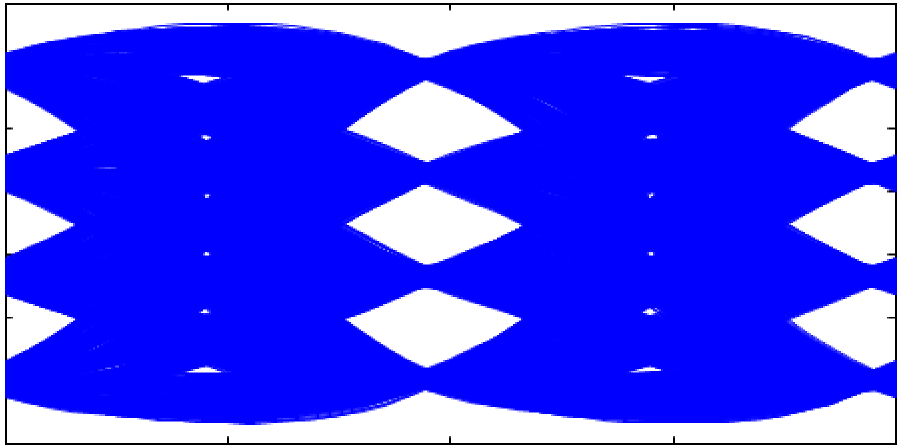
For a 10 km link and with a ratio of “Max” DGD to mean DGD of 3.75, this is also a DGD_max of 5 ps.

~26.56 GHz bandwidth Tx eyes, 5 ps DGD



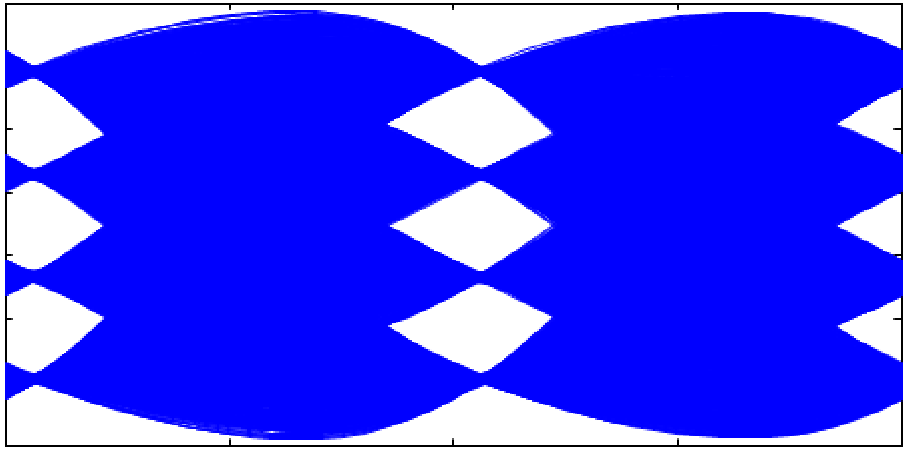
SECQ for ~26.56 GHz bandwidth Tx, 5 ps DGD

Eye after equalizer 0 ps DGD



SECQ = 1.52 dB

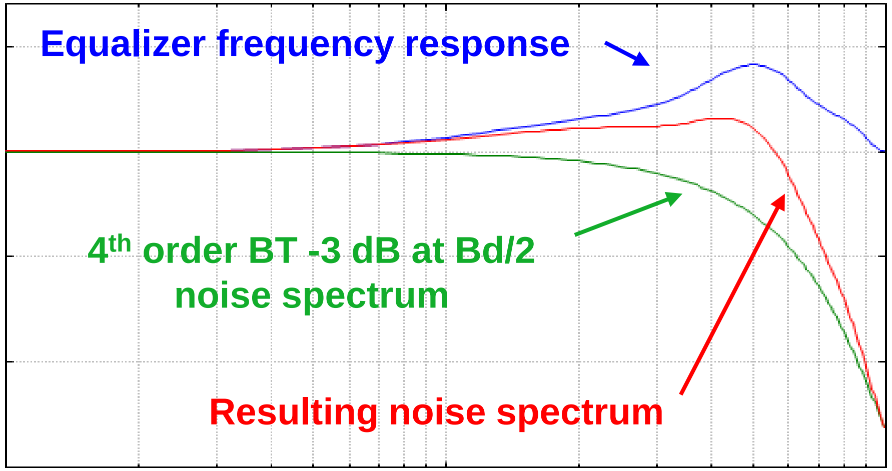
Eye after equalizer 5 ps DGD



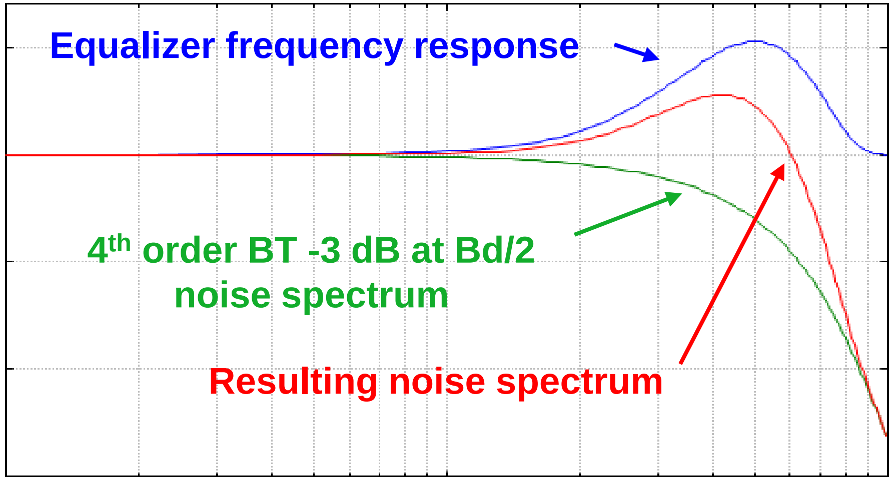
SECQ = 1.78 dB

0.26 dB DGD penalty

Equalizer frequency response 0ps DGD



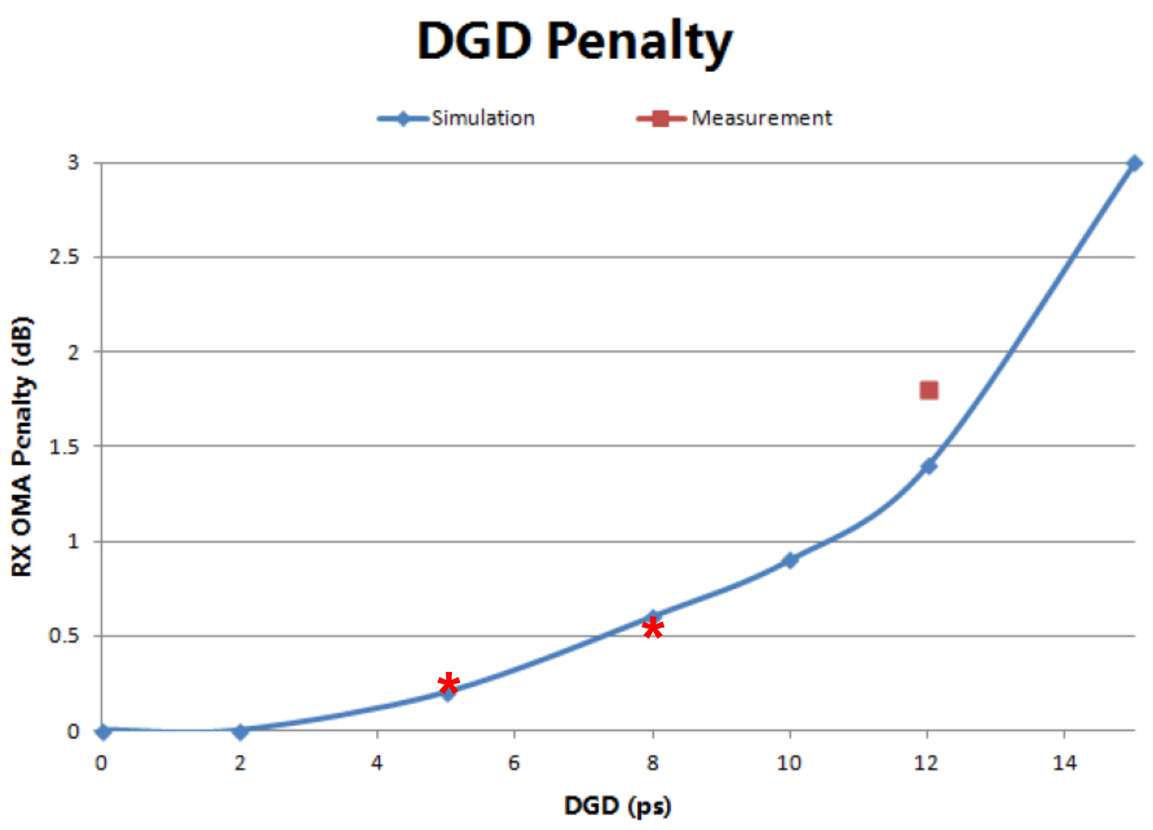
Equalizer frequency response 10.3ps DGD



DGD penalty for 5 ps

The value of 0.26 dB obtained on the previous page (second "*" right) agrees very closely with the predicted penalty for 5 ps of DGD in shuai_3cu_adhoc_050119.

It would be more feasible to find an extra ~0.25 dB in the optical power budget for this.



Conclusion

A specification of 8 ps for DGD_max for 100GBASE-LR and 400GBASE-LR4 would require an additional allowance of about 0.6 dB in the optical budget.

Based on the assumption that the newer G.652.B and G.652.D fibre types with a maximum PMD_Q of 0.2 ps/√km represent the bulk of recently deployed fiber, a value of around 5 ps for DGD_max seems possible.

A specification of 5 ps for DGD_max for 100GBASE-LR and 400GBASE-LR4 would require an additional allowance of about 0.25 dB in the optical budget.

Thanks!