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Assessment of the PMD penalty in 800G-LR4 based on the updated ITU-T G.652 fiber PMD_Q model

(In correspondence to Comment 93)

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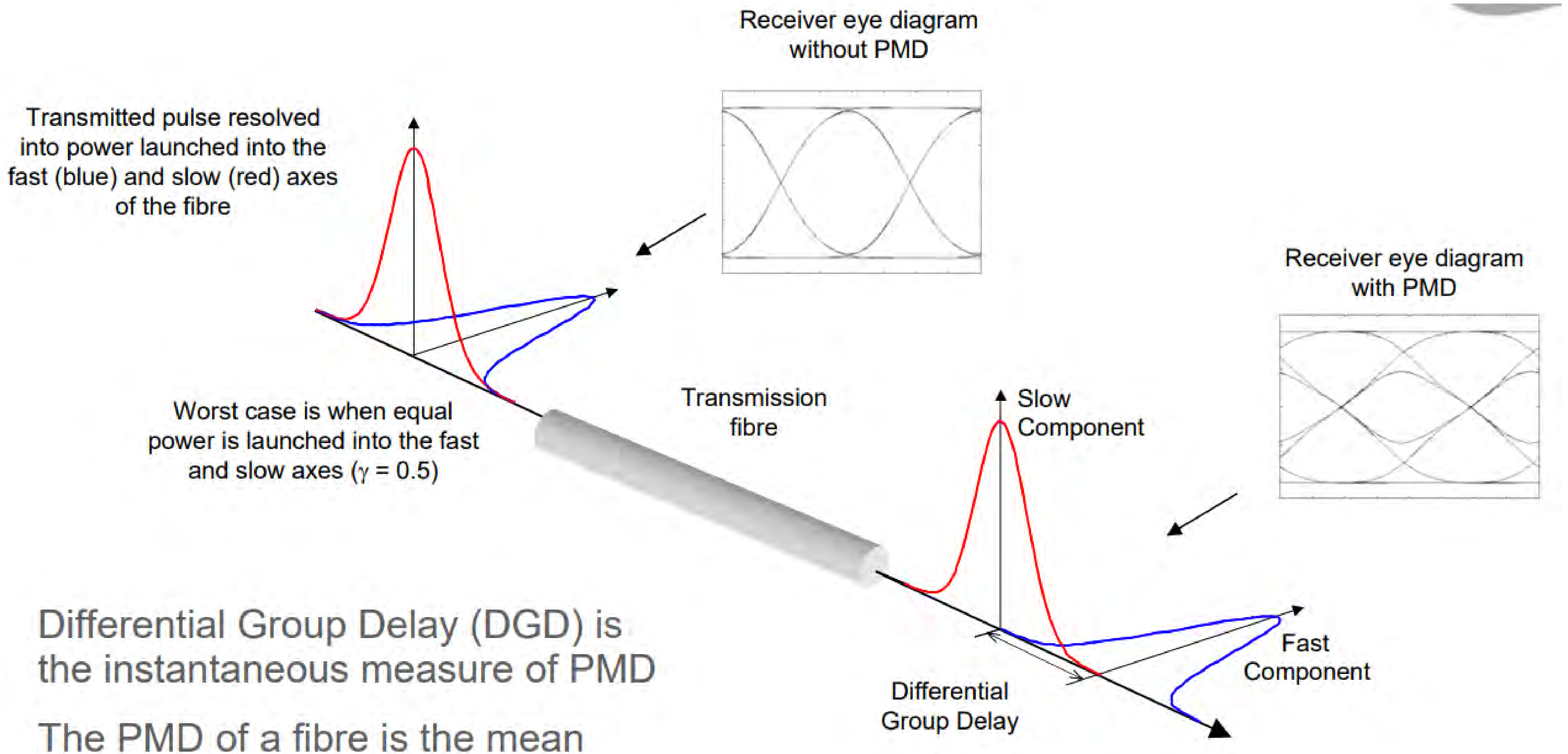
Introduction

- ITU-T has updated the G.652 fiber recommendations by adding the statistical link design methodology for chromatic dispersion (CD) and polarization-mode dispersion (PMD) for short-reach systems [1,2].
- With the new PMD model, the 800G-LR4 PMD penalty was found in ferretti_3dj_optx_01b_240829 [3] to be marginally acceptable when the DGD tolerance reported in ITU-T G.691 was assumed.
- Here, we quantify the PMD penalty when 800G-LR4 specific DGD tolerance is assumed, and verify that the PMD penalty is <0.7 dB.

[1] LS on revision of Recommendation G.652, https://www.ieee802.org/3/minutes/jul24/incoming/SG15-LS121_Redacted.pdf
[2] Draft revised Recommendation G.652 (for consent), https://www.itu.int/md/T22-SG15-240701-TD-PLEN-0375/en
[3] Vince Ferretti, "An in-depth look at PMD and DGD scenarios for 50 Gbaud, 100 Gbaud and 200 Gbaud IMDD links," https://www.ieee802.org/3/dj/public/adhoc/optics/0824_OPTX/ferretti_3dj_optx_01b_240829.pdf

Introduction on PMD

Reference: https://www.ieee802.org/3/ba/public/mar08/anslow_01_0308.pdf



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

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

Background on PMD_Q

- Due to the fact that fibers used in cable manufacturing have different polarization mode dispersion (PMD) coefficients, PMD requirements for fiber are expressed in terms of PMD_Q in modern ITU standards such as G.652, G.653, G.654, G.655 and G.656.

- The definition of PMD_Q is based on a statistical approach where an imaginary reference link consisting of M equal length fiber cable sections is considered.

- The value of PMD_Q for a transmission link depends on M and Q, where Q is the probability of the link PMD being exceeding PMD_Q, which is chosen to be acceptably small.

- In G.652-656, M=20 and Q=1E-4 (or 0.01%) are chosen.

PMD_Q in the updated ITU-T G.652 (1)

- Statistical link design values for PMD in a link composed of 4, 10, 20, and 40 cable pieces are also included.

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

- Here, $DGD_{mean, normalized}(M) = PMD_{Q, mean, normalized}(M) * sqrt(M/20)$

(Note: this is a very conservative estimation of DGD because the “worst-case” PMD at Q=1E-4 is used)

PMD_Q in the updated ITU-T G.652 (2)

- G.652 specifies the following "Cable attributes"

PMD coefficient	M	20	cables
	Q	0.01	%
	Maximum PMD_Q	**0.20**	$ps/\sqrt{km}$

which means $PMD_Q(M=20)=0.2$ ps/sqrt(km).

- For M=4, the PMD coefficient becomes:

$PMD_Q(M=4) = PMD_{Q,\ mean,\ normalized}(M=4)$ * 0.2 ps/sqrt(km)
=1.32 * 0.2 ps/sqrt(km) =0.264 ps/sqrt(km)

- For LR (10km) and M=4, the mean differential group delay is:

$<DGD_Q(M=4,10km)> = PMD_Q(M=4)$ *sqrt(10km)
=0.264*sqrt(10) ps = 0.835 ps

So the maximum DGD is: DGD_{max}=3.75 * $<DGD_Q(M=4,10km)>$ =3.13 ps

(Here the ratio 3.75 is the S factor according to anslow_01_0308, which corresponds to an outage probability of 8.21e-8)

PMD penalty allocation in IEEE 800GBASE-LR4
(According to 8023dj_D1p1)

Table 183–8—800GBASE-FR4 and 800GBASE-LR4 illustrative link power budgets

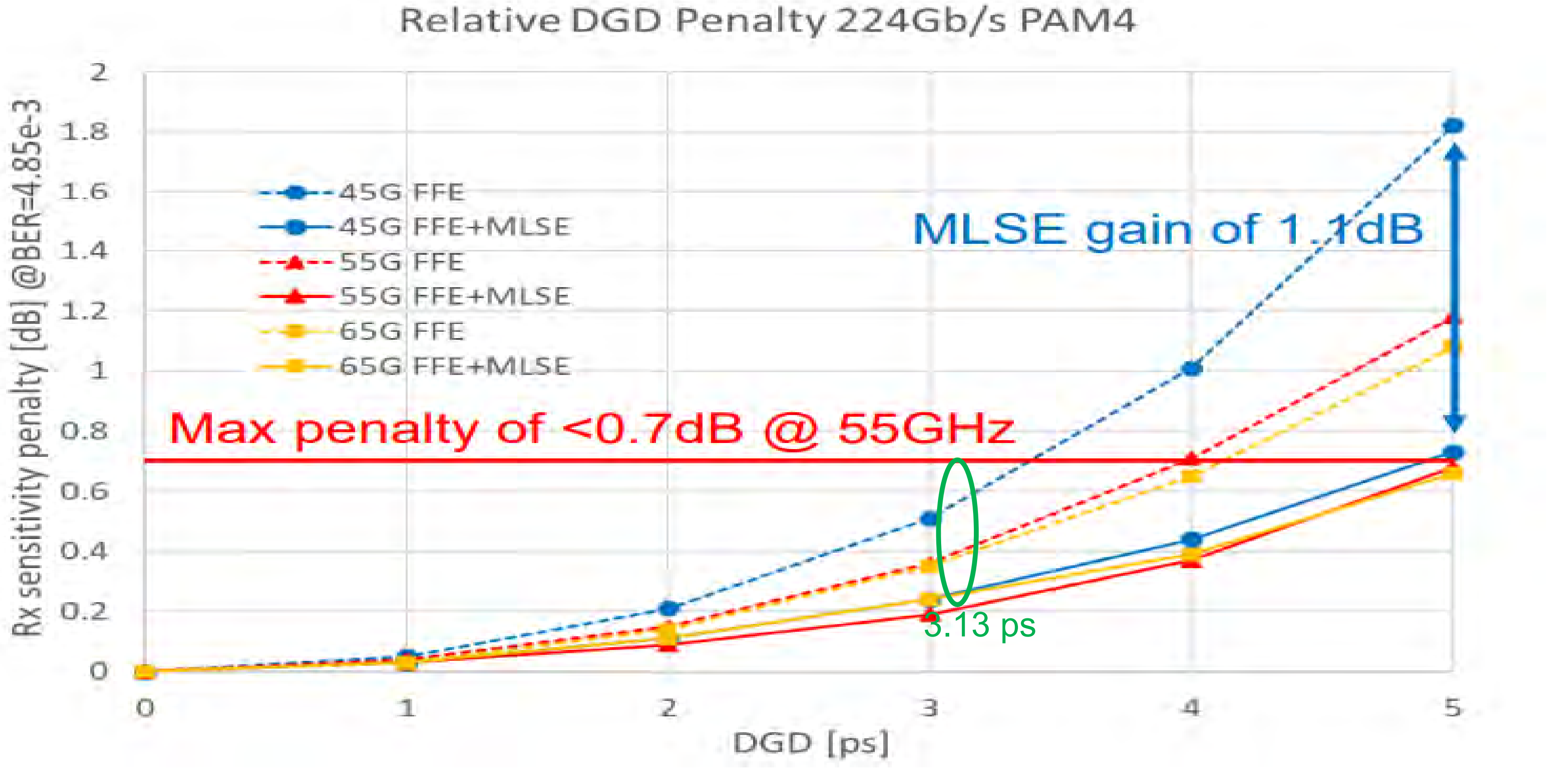
Parameter	800GBASE-FR4	800GBASE-LR4	Unit
Power budget (for maximum TDECQ)	TBD	11.3	dB
Operating distance	2	10	km
Channel insertion loss[a]	4	6.3	dB
Maximum discrete reflectance[b]	–35[c]	–35[d]	dB
Allocation for penalties[e] (for maximum TDECQ)	TBD[f]	5[g]	dB
Additional insertion loss allowed[h]	0		dB

[g] This value includes an allocation of 0.7dB for DGD penalties, and 0.4dB for MPI penalties.

Updated PMD penalty in 800G-LR4

Reference: kuschnerov_3dj_optx_01_230815

https://grouper.ieee.org/groups/802/3/dj/public/adhoc/optics/0823_OPTX/kuschnerov_3dj_optx_01_230815.pdf



✓ <0.7 dB penalty can be expected, even with the simple FFE.

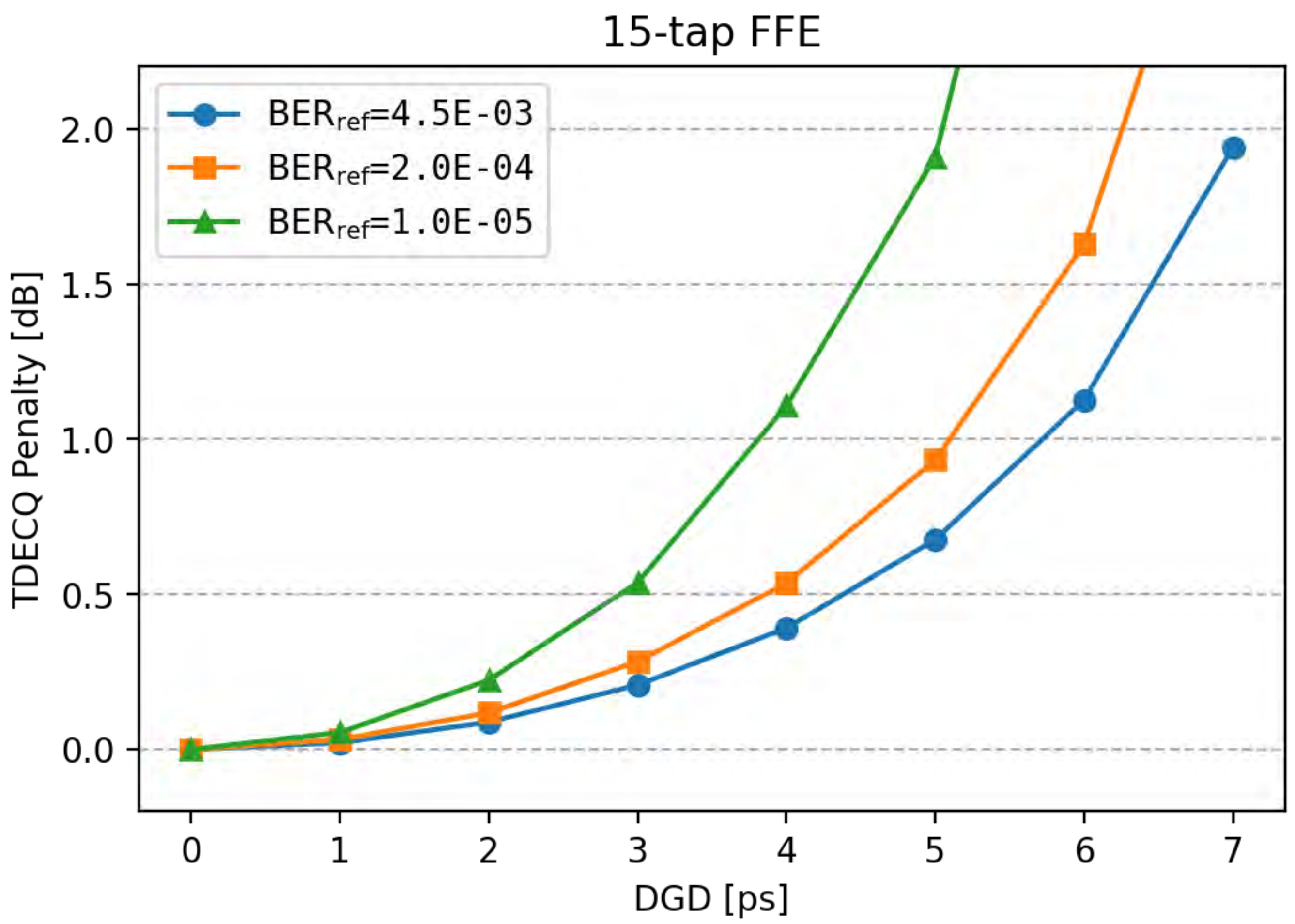
Discussion (1): Reasons for the reduced PMD penalty

- In ferretti_3dj_optx_01b_240829 [3], based on ITU-T G.691's DGD penalty curve, the DGD_{max} allowed for a penalty of 0.7dB is 0.26UI, or 2.3ps for 800GBASE-LR4 at 113Gbaud.

- However, the DGD_{max} from the updated ITU-T PMD model is 3.13ps (as shown in slide 6), which is more than the above tolerance of 2.3ps.

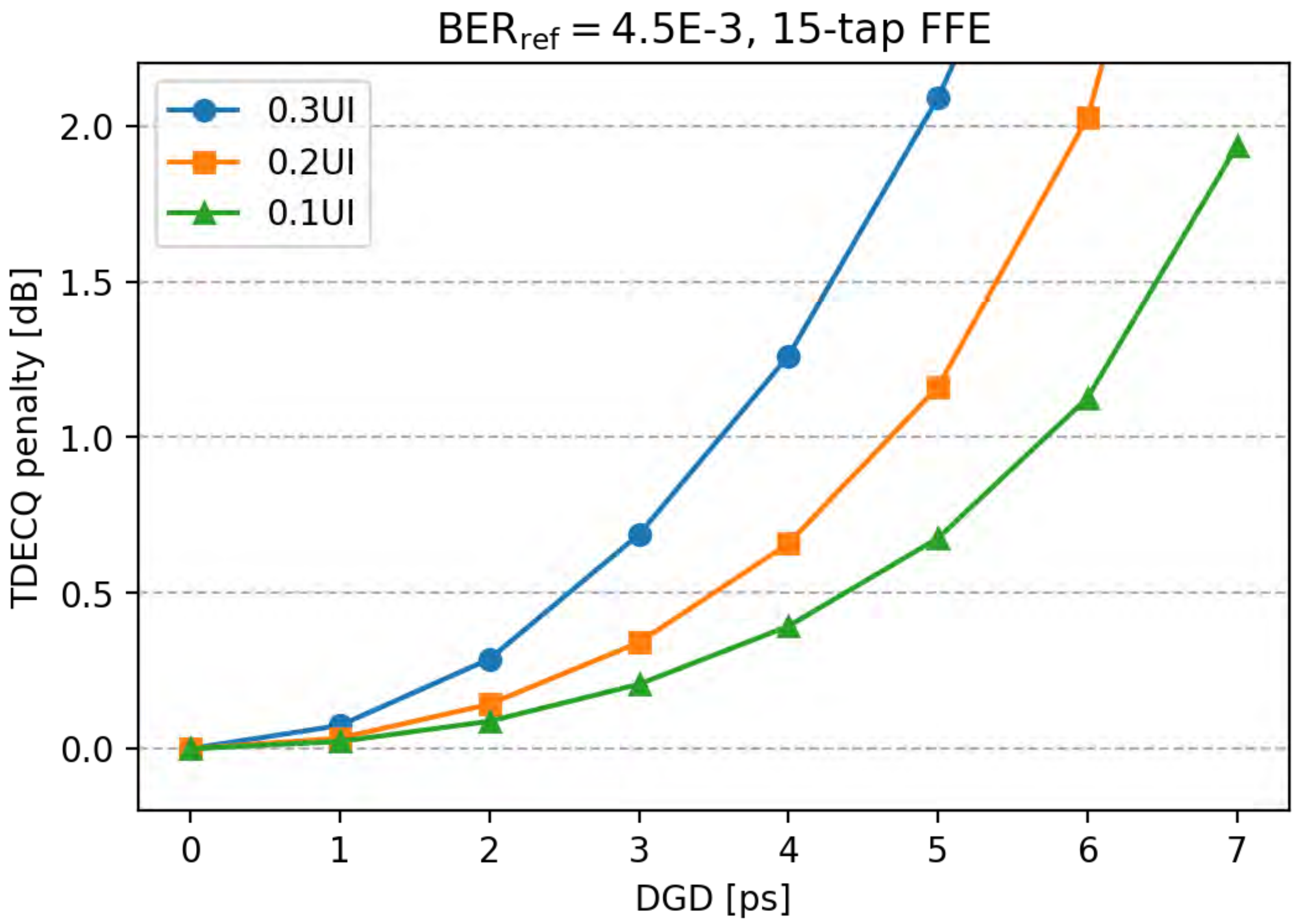
- Fortunately, IEEE 800GBASE-LR4 uses
  (i) higher reference BER (4.5E-3 instead of 1E-12 in G.691) and
  (ii) receiver-side equalization,
  so that even with DGD_{max}=3.13ps, the PMD penalty is well within 0.7dB (as shown in the last slide).

Discussion (2): Dependence of DGD tolerance on reference BER



✓ Higher reference BER leads to higher DGD tolerance.

Discussion (3): Dependence of DGD tolerance on decision window



✓ With receiver-side equalization, the decision window can be more precise (or narrower) and thus improves the DGD tolerance.

Concluding remarks

- The updated ITU-T G.652 fiber PMD spec is discussed
- The new PMD spec leads to a maximum DGD of 3.13 ps for LR4 with M=4, which causes a small penalty of <0.7 dB for IEEE 800GBASE-LR4.
- The updated ITU-T G.652 fiber PMD spec is thus very helpful to IEEE 800GBASE-LR4 to close the link.

Thank you!