Extinction ratio in DR links
(comment 199)

Piers Dawe

NVIDIA

Supporters

- Karl Muth Broadcom
- Bill Simms NVIDIA
- Steen Christensen NVIDIA

Introduction 1

- Extinction ratio limits were high for PAM2
  - Gigabit Ethernet: 9 dB
    - When there was only one eye, starving the zeros of light was a mitigation against reflection noise (multi-path interference, MPI)
    - It was achievable
- But were lowered for bandwidth and cost reasons:
  - 10 Gigabit Ethernet: 3, 3.5, 3 dB "SONET extinction ratio"
- For PAM4, that mitigation doesn't work well so the motivation for a high extinction ratio is weaker

Introduction 2

- MMF PMDs have continued to lower the extinction ratio limit, indicating what is desirable if MPI is not a consideration

	50G/lane				100G/lane				200G/lane (in draft)	
PMD	50G-SR, 100G-SR2, 200G-SR4, 400G-SR8	200G-DR4, 400G-DR4, 50G-FR, 50G-LR	200G-FR4, 400G-FR8, 200G-LR4, 400G-LR8	50G-ER, 200G-ER4, 200G-ER8	100G-VR1, 100G-SR1 and similar	100G-DR	400G-DR4, 100G-FR1, 100G-LR1, 400G-FR4, 400G-LR4-6	100G-DR-LPO	200G-SR1, 200G-MR1 and similar	200G-DR1, ..., 800G-FR4-500, 200G-DR1-2, ..., 800G-FR4, 800G-LR4
Ext R (dB)	3	3.5	3.5, 4.5	6	2.5	3.5, 5	3.5	2.5	2	**3.5**

- As frequencies increase, providing good modulation depth, output power, linearity, overshoot and bandwidth all at once for reasonable driver voltage and technology becomes more challenging. This is the case across transmitter technologies
  - Although transmitter implementers will not expose their pain points in detail
- We should continue the trend of relaxing the ER spec where it is feasible. Proposed in D3.0, D3.1 and D3.2

MPI allocations in the draft

PMD	Channel loss, no significant connectors (dB)	Allocation for MPI penalty (dB)
200GBASE-DR1 and similar	3	0.1
800GBASE-FR4-500	3.5	0.4
200GBASE-DR1-2 and similar	4	0.1
800GBASE-FR4	4	0.3
800GBASE-LR4	6.3	0.4

- Focus on the DR family which are expected to be used on modern cable plant with angled connectors
  - It looks like the spec for DR-2 could be improved similarly
- The allocation for MPI penalty in the table is tiny for links with few in-line reflections. There are many MPI penalties depending on the discrete reflectances in a link

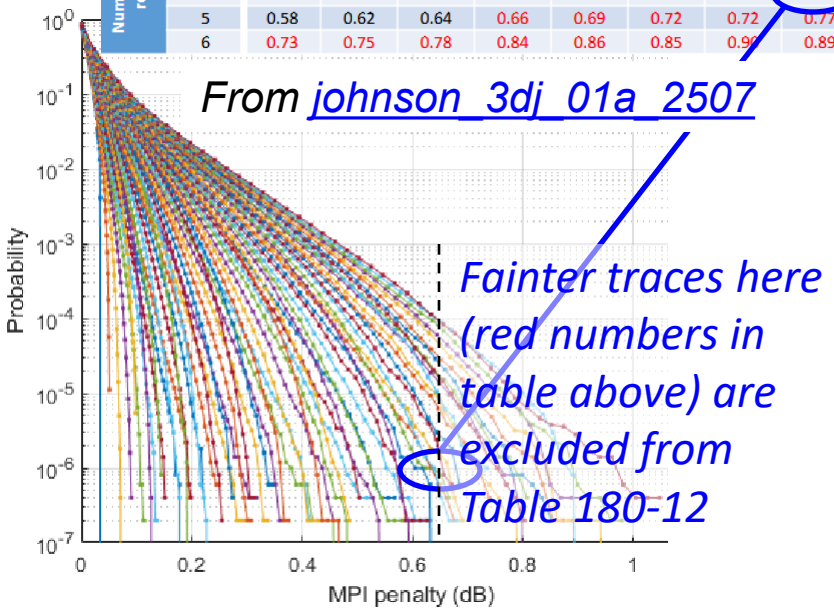
We trade off reflections and loss in the channel spec

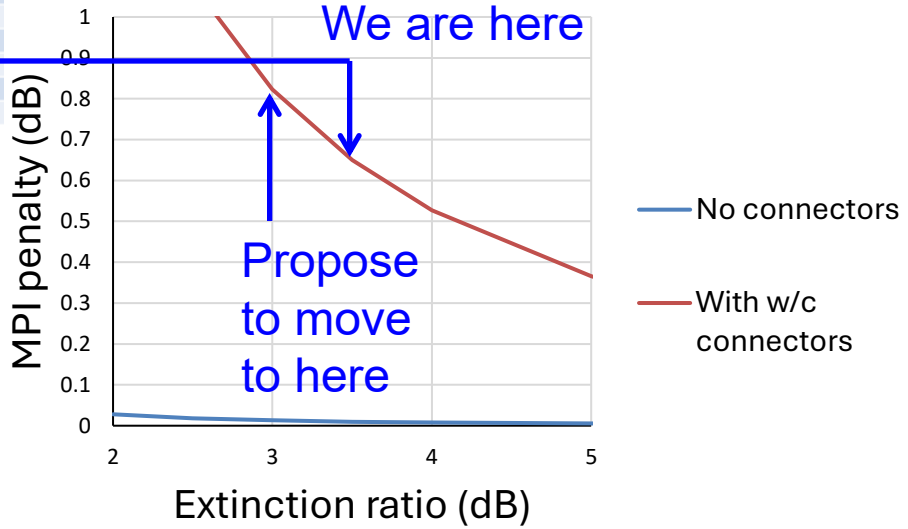
Table 180–12—Maximum channel insertion loss versus number of discrete reflectances										
Maximum channel insertion loss (dB)		**Number of discrete reflectances > -55 dB and <= 45 dB**								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Number of discrete reflectances >-45 dB and <= -35 dB	**0**	3	3	3	3	**3**	3	2.9	2.9	2.9
	1	3	3	3	2.9	2.9	2.9	2.9	2.8	2.8
	2	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7
	3	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.6
	4	2.7	2.6	2.6	2.6	2.5	2.5	2.5	**2.5**	—
	5	2.5	2.5	2.5	—	—	—	—	—	—
	6	—	—	—	—	—	—	—	—	—

- The 0.1 dB mentioned (actually 0.11 dB per johnson_3dj_01a_2507) applies to a cell where 3 dB loss is allowed
  - This is barely changed at 3 dB extinction ratio: it rounds to 0.1 dB
- The worst allowed cell at the bottom of the table represents an MPI penalty of 0.65 dB. "We are here" on next slide

Some scope for improvement

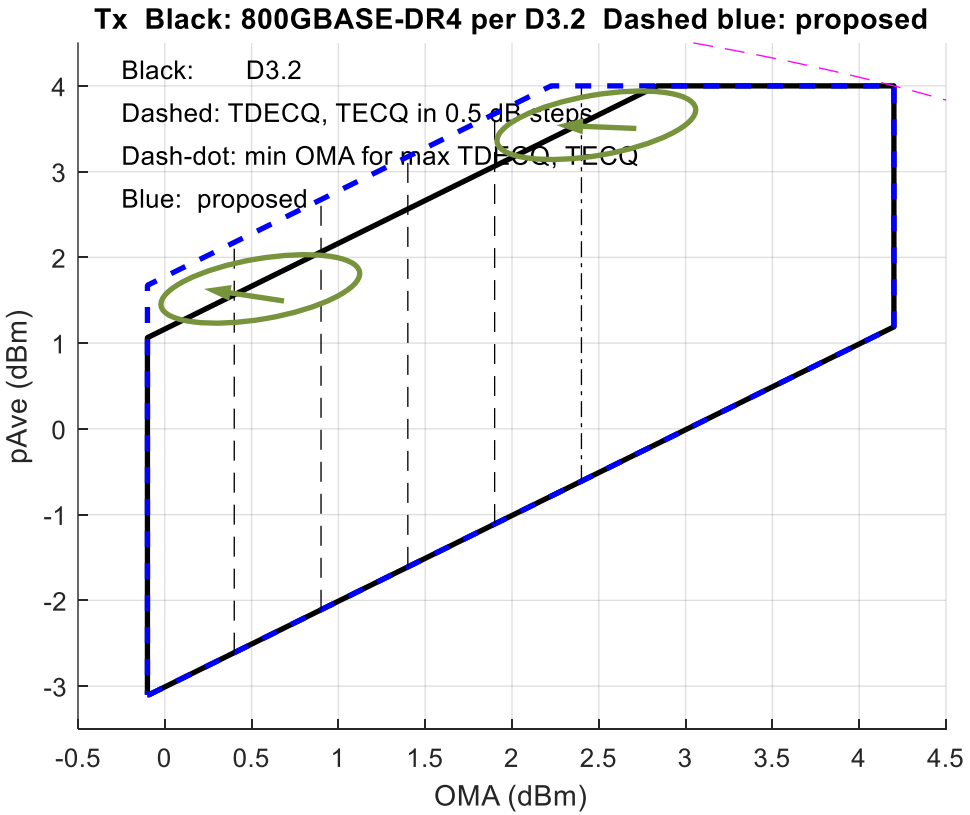
MPI Penalty (dB)	Number of -45dB reflections								
Number of -35dB reflections	0	1	2	3	4	5	6	7	8
0	0.04	0.05	0.07	0.09	0.11	0.13	0.15	0.17	0.20
1	0.10	0.13	0.14	0.17	0.20	0.22	0.24	0.28	0.29
2	0.20	0.22	0.25	0.27	0.29	0.32	0.35	0.39	0.40
3	0.31	0.34	0.37	0.40	0.42	0.45	0.48	0.49	0.53
4	0.43	0.47	0.51	0.53	0.57	0.58	0.63	0.65	0.68
5	0.58	0.62	0.64	0.66	0.69	0.72	0.72	0.77	0.79
6	0.73	0.75	0.78	0.84	0.86	0.85	0.91	0.89	0.98





- We can reduce the limit from 3.5 dB to 3 dB for a cost of <0.2 dB
- This is a very good trade for the transmitter

Average power vs. OMA map



- Changing the min extinction ratio from 3.5 dB (black) to 3 dB (blue). Dashed and dash-dotted ECQ lines don't change
- Example areas of interest in green
- Thin magenta line is locus of constant power in 3s, showing that receiver is not exposed to more power in 3s by the change

Table 180–7—200GBASE-DR1, 400GBASE-DR2, 800GBASE-DR4, and 1.6TBASE-DR8 transmit characteristics *(continued)*

Description	Reference	200GBASE-DR1	400GBASE-DR2 800GBASE-DR4 1.6TBASE-DR8	Unit
Extinction ratio, each lane (min)	180.9.11	3.5 ~~3.5~~		dB

Table 180–8—200GBASE-DR1, 400GBASE-DR2, 800GBASE-DR4, and 1.6TBASE-DR8 receive characteristics

Description	Reference	Value	Unit
Receiver sensitivity (OMA_{outer}), each lane[c] (max) for TECQ < 0.9 dB for 0.9 dB ≤ TECQ ≤ SECQ	180.9.14	~~-3.4~~ -3.6 -4.5 ~~-4.3~~ + TECQ	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane[c] (max)	180.9.15	~~-0.9~~ -1.1	dBm

- Revise Figure 180–4, Receiver sensitivity (OMA_{outer}), each lane (max)
  - and
- Figure 180–5, Transmitter OMA_{outer} each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA_{outer}) each lane versus TECQ
- Rx lines move down by 0.2 dB
- Fig 180–3 does not change

Table 180–9—Illustrative link power budget

Parameter	Value	Unit
Power budget (for max TDECQ)	~~6.7~~ 6.9	dB
Operating distance	500	m
Channel insertion loss[a, b]	3	dB
Maximum discrete reflectance	–35	dB
Allocation for penalties[c] (for max TDECQ)	~~3.7~~ -3.9	dB
Additional insertion loss allowed	0	dB

a The channel insertion loss is calculated using the maximum distance specified in Table 180–6 and cabled optical fiber attenuation of 0.5 dB/km at 1304.5 nm plus an allocation for connection and splice loss given in 180.8.2.

b The channel insertion loss of 3 dB shown in this illustrative link power budget is valid for a maximum MPI penalty of ~~0.1~~ 0.3 dB, which . MPI penalty depends on the number and value of discrete reflectances present in the link. This channel insertion loss may be reduced by up to 0.5 dB depending on the discrete reflectances in the link as shown in Table 180–12.

c Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested. In this illustrative link power budget the value shown includes an allocation of 0.1 dB to 0.3 dB for MPI penalty and 0.2 dB for DGD penalty. For cases with a channel insertion loss less than 3 dB, as shown in Table 180–12, the allocation for penalties should be "~~6.7~~ 6.9 – channel insertion loss".

Apply all these changes to clause 180 for DR and similar (0.2 dB) changes to Clause 182 for DR-2

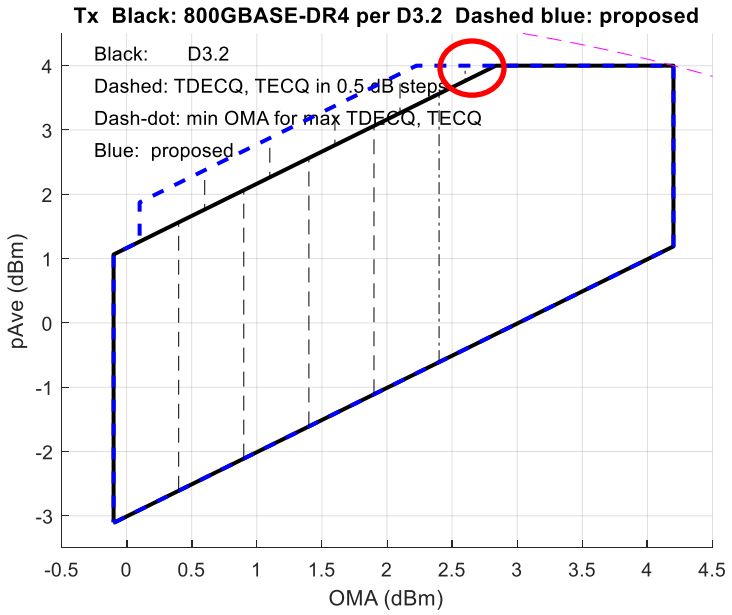
What does / doesn't change

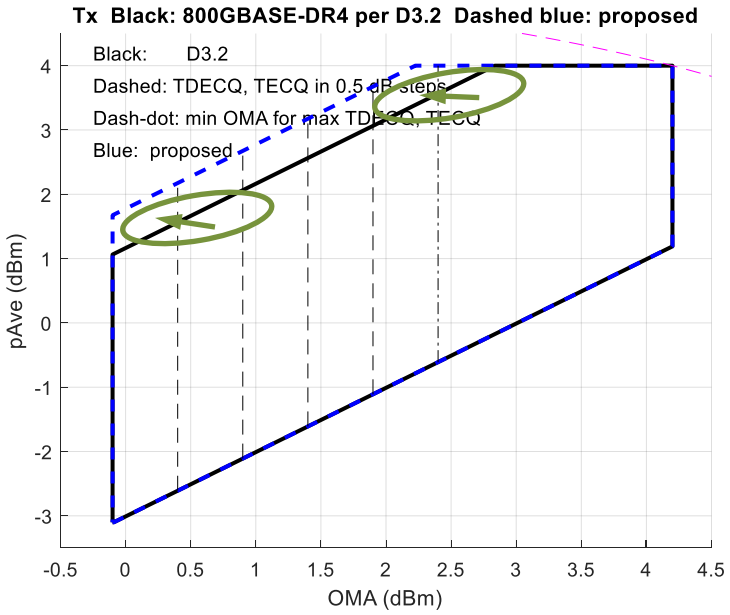
Table 180–12—Maximum channel insertion loss versus number of discrete reflectances

Maximum channel insertion loss (dB)	Number of discrete reflectances > –55 dB and ≤ –45 dB								
	0	1	2	3	4	5	6	7	8

- Table 180-12 (see slide 6) is not changed
- This means that for channels with few or good connectors, there is up to 0.2 dB margin
  - One could change Table 180-12 to be more restrictive at the bottom, and not change the receiver sensitivity and stressed sensitivity
  - Or, one could change the headline loss from 3 dB to 3.2 dB and change Table 180-12 to be more permissive at the top, keeping the bottom of the table, and change the receiver sensitivity and stressed sensitivity
  - This proposal does neither, but it changes the receiver sensitivity spec by 0.2 dB.

Why not like 100GBASE-DR and dawe_3dj_01_2607 option 1?





- Left: previous option 1
  - (Could be made to work with increased pAve)

Right: previous option 2 = this proposal

This proposal provides better relief for the transmitter with minimal impact on the receiver

Both proposals have no impact on the cabling

The comment

- R2-199 180 180.7.1 473 8 TR
- D3.0 comment 442 and D3.1 comment R1-298: as line rates are increased, maintaining a particular extinction ratio becomes increasingly challenging (this will be even worse at 400G). However, MPI can get worse at low extinction ratio, when it happens (rarely - fading) although for PAM4 this is a fairly weak function. On the other hand ECQ improves with low extinction ratio (linearity), differently for different technologies but it always happens (not fading). Also, RF power and supply voltage can be reduced at lower extinction ratio, and/or modulators can be made smaller or faster. We have addressed this before, in 100GBASE-DR where we reduced the minimum from 5 dB to 3.5 dB for a 0.3 increase in OMA-TDECQ (see https://ieee802.org/3/cd/public/July17/dawe_3cd_01_0717.pdf), then in 100GBASE-FR1, 100GBASE-LR1 and later PMDs when we specified 3.5 dB across the board.
  It is time to take the next step in this long-running secular trend.
  Notice D3.0 comment 72, proposing reducing the OMA for DR by 0.6 dB, had some support. So it is reasonable to take the simple approach of increasing the budget by 0.2 dB by improving the sensitivity by only 0.2 dB, not changing the max OMA and average power limits.
  By the way, if an additional 0.2 dB seems large when Table 190-9 says "includes an allocation of 0.1 dB for MPI penalty" some transmitter-related MPI penalty is measured in TDECQ, and some is needed to preserve the insertion loss vs. discrete reflectances trade-off in e.g. Table 180-12 and 182-12. The 0.1 dB in the draft for no additional reflectances is barely changed, but I am not proposing changing Table 180-12 or 182-12. In 2017 we estimated 0.3 dB extra for going from 5 dB to 3.5 dB extinction ratio, consistent with this proposal.
  https://ieee802.org/3/dj/public/26_07/dawe_3dj_01_2607.pdf provides background.
- In Table 180-7 (transmitter), change Extinction ratio, each lane (min) from 3.5 dB to 3 dB;
  In Table 180-8 (receiver), change Receiver sensitivity (OMAouter), each lane (max) from -3.4 to -3.6,
  and from -4.3 + TECQ to -4.5 + TECQ
  and change Stressed receiver sensitivity (OMAouter), each lane (max) from -0.9 dBm to -1.1 dBm;
  Revise Figure 180-4, Receiver sensitivity (OMAouter), each lane (max), and Figure 180-5 (Tx and Rx vs. ECQ), to reflect this change;
  In Table 180-9 (budget), change, change Power budget (for max TDECQ) from 6.7 dB to 6.9 dB, change Allocation for penalties (for max TDECQ) from 3.7 dB to 3.9 dB;
  In table footnote b, change "The channel insertion loss of 3 dB shown in this illustrative link power budget is valid for a maximum MPI penalty of 0.1 dB, which depends on the number and value of discrete reflectances present in the link." to "The channel insertion loss of 3 dB shown in this illustrative link power budget is valid for a maximum MPI penalty of 0.3 dB. MPI penalty depends on the number and value of discrete reflectances present in the link."; In table footnote c, change "an allocation of 0.1 dB for MPI penalty" to "an allocation of 0.1 dB to 0.3 dB for MPI penalty" and change "6.7 - channel insertion loss" to "6.9 - channel insertion loss".
  Apply this to clauses 180 for DR and 182 for DR-2.

References

- This presentation

  Under https://ieee802.org/3/dj/public/adhoc/optics/index.html
- July presentation with two options

  https://ieee802.org/3/dj/public/26_07/dawe_3dj_01_2607.pdf
- IEEE Std 802.3, Clause 140 for 100GBASE-DR
- Many presentations on MPI by Johnson, Ghiasi and King

  e.g. https://ieee802.org/3/dj/public/25_07/johnson_3dj_01a_2507.pdf and https://ieee802.org/3/dj/public/25_07/ghiasi_3dj_02_2507.pdf
- Here are are some older ones

  http://ieee802.org/3/bs/public/adhoc/smf/16_01_07/king_01a_0116_smf.pdf
  http://ieee802.org/3/bs/public/adhoc/smf/16_01_07/king_02a_0116_smf.7z
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  http://ieee802.org/3/cd/public/May17/anslow_3cd_01_0517.pdf
  http://ieee802.org/3/cd/public/May17/dawe_3cd_01_0517.pdf
- There are references to others within these