Extinction ratio in DR links
(comment 298)

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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	100G-VR1, 100G-SR1 and similar	100G-DR	400G-DR4, 100G-FR1, 100G-LR1, 400G-FR4, 400G-LR4-6	50G-ER, 200G-ER4, 200G-ER8	200G-SR1, 200G-MR1 and similar	200G-DR1, 400G-DR2, 800G-DR4, 1.6T-DR8, 800G-FR4-500, 200G-DR1-2, 400G-DR2-2, 800G-DR4-2, 1.6T-DR8-2, 800G-FR4, 800G-LR4
Ext R (dB)	3	3.5	3.5, 4.5	2.5	3.5, 5	3.5	6	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
- We should continue the trend of relaxing the ER spec where it is feasible

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 looks tiny, but there are many MPI penalties depending on the discrete reflectances in a link

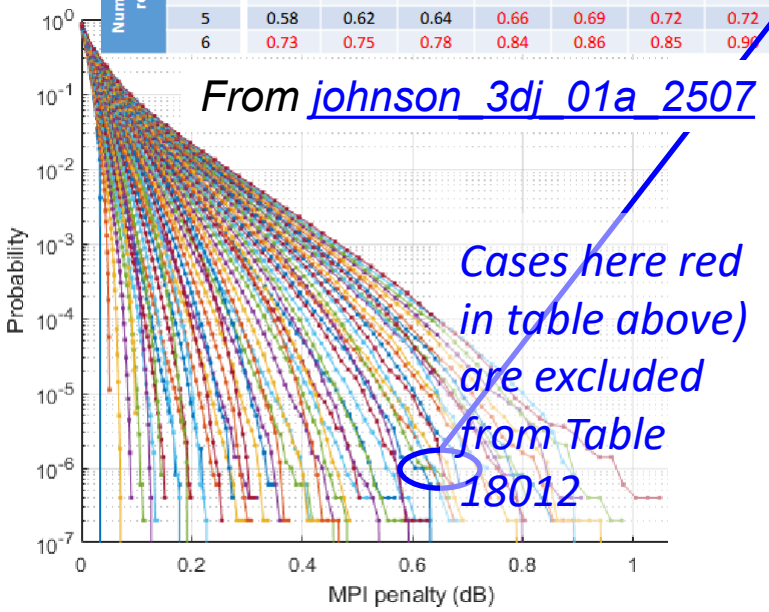
We trade off reflections and loss in the channel spec

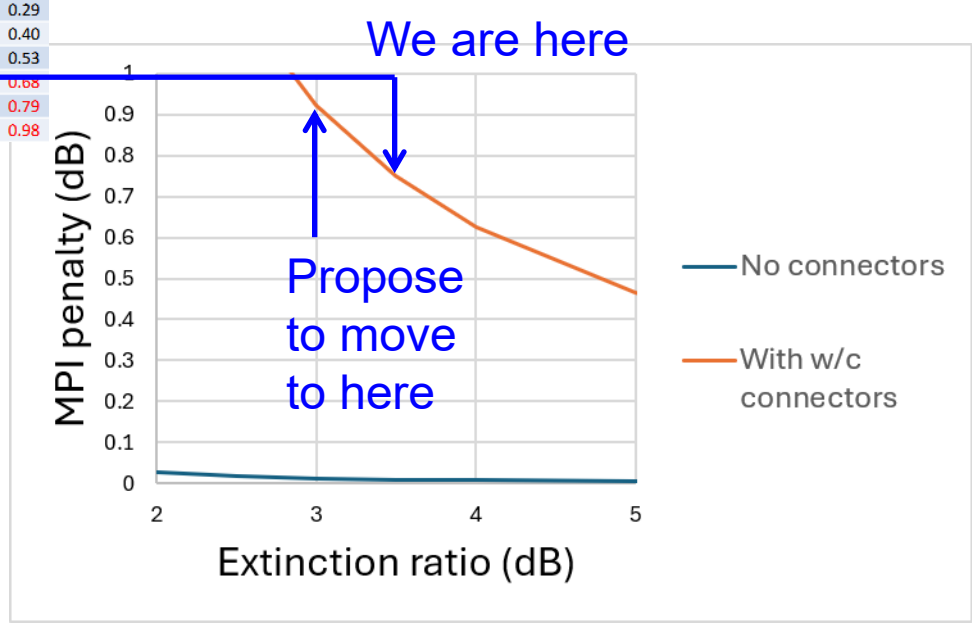
Table 180–12—Maximum channel insertion loss versus number of discrete reflectances										
Maximum channel insertion loss (dB)		Number of discrete reflectances > -55 dB and <= 45 dB								
		0	1	2	3	4	5	6	7	8
Number of discrete reflectances >-45 dB and <= -35 dB	0	3	3	3	3	3	3	2.9	2.9	2.9
	1	3	3	3	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
- The worst allowed cell at the bottom of the table represents an MPI penalty of 0.65 dB
- In the next slide it was assumed to be 0.75 dB (as in anslow_3cd_01_0517)

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	0.90	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
- For the receiver...

Receiver's view

- The MPI combines with the impairments captured by ECQ (TECQ and TDECQ)
- The ECQ limits of 3.4 dB for DR allow the residual penalty K (without MPI) to be up to about 3.9 dB
- 800GBASE-LR4 has a TDECQ limit of 3.9 dB with a higher headline MPI penalty than DR, showing what is possible
- Receivers have improved since Ethernet's early years with PAM4
- However, the residual penalty K should still be limited, one way or another (e.g. a direct K limit as is well known, or comment 237 proposes Ceq_TXBW)
  - With an extinction ratio limit of 3 dB and either a K limit of 3.4 or a Ceq_TXBW, the total residual penalty will be lower than is allowed in this draft

Clause 140 shows how to make such a change while leaving the receiver and channel specs unaffected

Table 140–6—100GBASE-DR, 100GBASE-FR1, and 100GBASE-LR1 transmit characteristics *(continued)*

Description	100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Outer Optical Modulation Amplitude (OMA_{outer}) (min)[b]	–0.8	—	—	dBm
for TDECQ < 1.4 dB	—	–0.1	1.1	dBm
for 1.4 dB ≤ TDECQ ≤ 3.4 dB	—	–1.5 + TDECQ	–0.3 + TDECQ	dBm
Launch power in OMA_{outer} minus TDECQ (min):				
for extinction ratio ≥ 5 dB	–2.2	—	—	dBm
for extinction ratio < 5 dB	–1.9	—	—	dBm
Extinction ratio (min)	3.5	3.5	3.5	dB

Table 180-7 does this differently: see next slide

Would become 3 in Table 180-7

[b] For 100GBASE-DR, the requirement on the OMA_{outer} (min) applies even in the cases where TDECQ < 1.4 dB for an extinction ratio of ≥ 5 dB or where TDECQ < 1.1 dB for an extinction ratio of < 5 dB.

There is no equivalent note in Table 180-7 anyway: no change needed

180.7.2 Receive optical specifications Table 180-8 and text beneath

Description	Reference	200GBASE-DR1	200GBASE-DR1 400GBASE-DR2 800GBASE-DR4 1.6TBASE-DR8	Unit
...				
Outer optical modulation amplitude (OMA_{outer}), each lane (min) for max(TECQ, TDECQ) < 0.9 dB for 0.9 dB <= max(TECQ, TDECQ) <= 3.4 dB	180.9.5	*Table 180-7 can be modified the same way* –0.1 or 0.1[c] –1 + max(TECQ, TDECQ) or –0.8 + max(TECQ, TDECQ)[c]		dBm dBm
...				
Extinction ratio, each lane (min)	180.9.11	3.5		dB

[c] For extinction ratio >= 3.5 dB, and <3.5 dB, respectively

The values for OMA_{outer} each lane (min) in Table 180–8 vary with max(TECQ, TDECQ) and extinction ratio. The relationships are illustrated in Figure 180–3 for an extinction ratio >=3.5 dB along with the values for OMA_{outer} each lane (max).

Clause 140 shows how to make the change while leaving the receiver and channel specs unaffected

Table 140–8—100GBASE-DR, 100GBASE-FR1, and 100GBASE-LR1 illustrative link power budgets

Parameter	100GBASE-DR	100GBASE-FR1	100GBASE-LR1	Unit
Power budget (for max TDECQ): for extinction ratio ≥ 5 dB for extinction ratio < 5 dB	— 6.5 6.8	7.8 — —	10.6 — —	dB dB dB
Operating distance	500	2 000	10 000	m
Channel insertion loss	See 140.9[a]	4[a]	6.3[b]	dB
Maximum discrete reflectance	–35	–35[c, d]	–35[c, e]	dB
Allocation for penalties[f] (for max TDECQ): for extinction ratio ≥ 5 dB for extinction ratio < 5 dB	— 6.5 minus max channel insertion loss per Table 140–13 6.8 minus max channel insertion loss per Table 140–13	3.8 — —	4.3 — —	dB dB dB
Additional insertion loss allowed	0	0	0	dB

Table 180-9 has only one column and doesn't give an MPI penalty

One could present two columns (6.7 and 6.9 dB) or, as it is only an illustration, give the budget for just one case

- No change needed for Table 180–12, Maximum channel insertion loss versus number of discrete reflectances
  - The cells at the margin stay the same; links to the lower extinction ratio spec have a little more hidden margin at top left of the table (few or no significant reflections)
- Note: Comment 208 proposes changes to the extinction ratio range in Table 180-18, Presently the limits there do not extend to the limit in Table 180-7 anyway.

Simpler alternative if acceptable to receivers

- 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
  - 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—Transmitter OMA_{outer} each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA_{outer}) each lane versus TECQ, to reflect this change
- If appropriate, in Table 180-9 (budget), 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 c, change the allocation of 0.1 dB for MPI penalty to 0.3 dB, change "6.7 – channel insertion loss" to "6.9 – channel insertion loss".
- Bear the changed extinction ratio in mind when considering the limits in Table 180-18, LRS conformance test signal exceptions to transmit characteristics

References

- 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
  http://ieee802.org/3/bs/public/adhoc/smf/17_05_16/anslow_01_0517_smf.pdf
  http://ieee802.org/3/cd/public/May17/king_3cd_01_0517.pdf
  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