400GBASE-SR4.2 optical penalties

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Introduction

- 400GBASE-SR4.2 is proposed to go 50% further on OM5 than 50GBASE-SR / 100GBASE-SR2 / 200GBASE-SR4 / 400GBASE-SR8
  - 150 m vs. 100 m on OM5, 100 m vs. 100 m on OM4
- With more chromatic dispersion caused by the extra distance, we need to revisit the mode partition noise penalty
- When the combination of all the other impairments is too high, modal noise becomes significant too

Method of estimating penalties

- The next slide starts with the well-researched 10GBASE-SR specification and model
- Scales for spectral width, frequency, FEC, PAM4 and reach
- Recognises recent investigations into mode partition noise k factor
- Shows example ways of bringing the total penalties back to a very high but plausible level
- Unlike dawe_3cd_01b_0918 this calculation fully includes the Pcross effect
- Unlike dawe_3cm_adhoc_01_092718 this calculation follows the Ogawa-Agrawal equations as in the 10 Gigabit Ethernet link model spreadsheet for scaling modal noise, and it includes recent small improvements in the fibre's specified chromatic dispersion
  - (~-108 ps/nm/km instead of ~-118 ps/nm/km)
- Like the draft, it assumes faster lasers for > 100 m

Estimates of budget with minor noise penalties

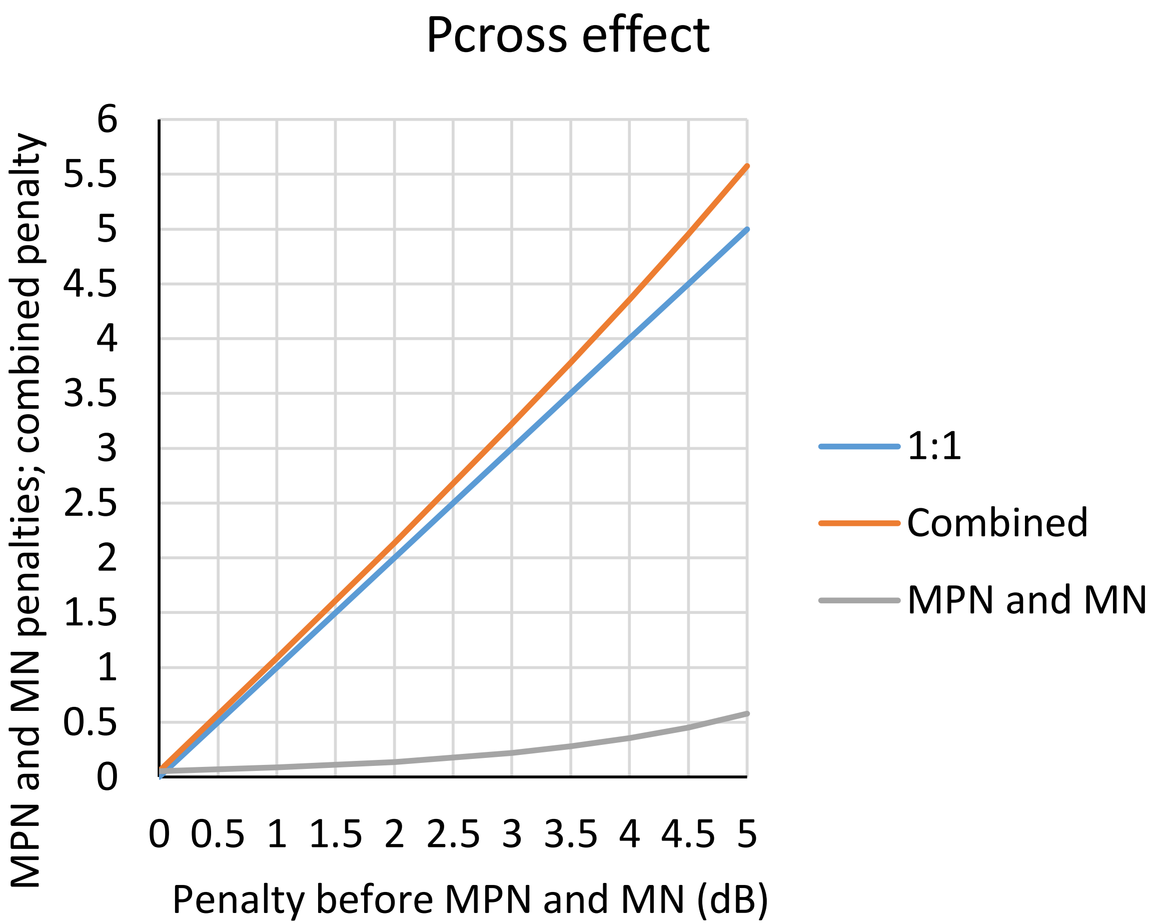
		10GBASE-SR	100GBASE-SR4		400GBASE-SR8			400G-4.2 D1.0		400G-4.2 better Tx		400G-4.2 125 m	
		Spreadsheet example	Estimates for two k values		As in P802.3cd	Pessi-mistic	Opti-mistic	Pessi-mistic	Opti-mistic	Pessi-mistic	Opti-mistic	Pessi-mistic	Opti-mistic
PAM- (no. levels)		2			4								
No. eyes		1			3								
Qmin		7.0345	3.8906		3.414								
TDP, TDEC or TDECQ	dBo	3.9	4.3		4.5	4.5		4.5		3.84	4.06	4.00	4.16
Total penalty	dBo	4.2	4.3	4.11	4.60	4.95	4.80	5.41	5.05	4.50	4.50	4.50	4.50
Signalling rate	GBd	10.3125	25.78125		26.5625								
Reach	m	300	100		100			150		150		125	
Spectral width	nm	0.29	0.6		0.6	0.6		0.6		0.6		0.6	
MPN penalty	dBo	0.1	0.14	0.02	0.02	0.15	0.09	0.55	0.31	0.41	0.25	0.25	0.15
MN penalty	dBo	0.3	0.11	0.03	0.08	0.30	0.22	0.36	0.24	0.25	0.19	0.25	0.19
Combined	dBo	0.4	0.24	0.05	0.10	0.45	0.30	0.91	0.55	0.66	0.44	0.50	0.35
MPN k, also used for MN		0.3	0.3	0.1	0.0296	0.1	0.075	0.1	0.075	0.1	0.075	0.1	0.075
TDP, TDEC or TDECQ w/o Pmpn		3.8	3.92	4.04	4.5	4.5	4.5	4.5	4.5	3.84	4.06	4.00	4.16
Rate*reach*spectral width		897	1547		1594			2391	2391	2391	2391	1992	1992
MPN noise	rel. OMA outer	0.01247	0.0257	0.0086	0.0030	0.0090	0.0068	0.0171	0.0128	0.0171	0.0128	0.0130	0.0098

Start with the penalties and k factor in 10GBASE-SR. Compare 100GBASE-SR4, where estimated Pmpn and Pmn are low because PAM2 and FEC

In right hand columns, assume k is 0.1 or 0.075. Scale the 10G/25G noises and predict the penalties for 802.3cm MMF: around 0.4 to 0.9 dB, bringing the total penalty to around **4.9 dB to 5.4 dB, which is too high.** There is only 0.1 dB in the budget for these penalties

The modal noise penalty could be higher or lower for all columns together – need new information

Pcross effect



MPN and MN penalties become bad only when TDECQ (without them) is bad

Discussion

- These links are dispersion-limited not power-limited
- It's about the penalties, not so much about the budget
- Mode partition noise is a concern and modal noise is a contributor
  - The classic theory of mode partition noise may not be accurate enough
  - Equations used here may under-estimate MPN for an equalised link and high total penalties
- Up-to-date information on modal noise is needed, e.g. from experiments
  - See also pepeljugoski_1_1104 pepeljugoski_01_12_12_mmf and dawe_04_0114_optx

Way forward for the spec

- We know how to account for mode partition noise and modal noise because we did it in 802.3bm (100GBASE-SR4)
- In 138.8.5, insert:
- Equation (138-1) is used in place of Equation (121-11).
- $R = \sqrt{(\sigma_G^2 + \sigma_S^2 - M^2)}$ (138-1)
- where $M = 0.0065P_{\text{ave}}$
- [Need to agree and/or refine the number 0.0065. P_{ave} is already defined in 121.8.5.3]

- In 138.8.10 Stressed receiver sensitivity, insert:
- the value of M in Equation (138-1) is set to zero, and

Discussion 1

- This addresses modal noise
- This is simpler than 95.8.5.2 which uses two terms
- Also more optimistic than 95.8.5.2 which uses a much higher value
- Mode partition noise could be handled as in 95.8.5.2 or with a fixed allocation in the budget

Discussion 2

- This would be appropriate if modal noise is not significantly affected by the equalizer
  - The mode partition noise theory already assumes an equalized signal
  - However, it seems probable that modal noise can have a similar or wider spectrum as RIN, so undergoes noise enhancement like receiver noise or RIN
  - The next slide shows a simple alternative fix to take noise enhancement into account

Alternative way forward

- In 138.8.5, insert:
- Equation (138-1) is used in place of Equation (121-11).
- $R = \sqrt{(\sigma_G{}^2 + \sigma_S{}^2 - (M/C_{\mathrm{eq}})^2)}$ (138-1)
- where $M = 0.0065P_{\mathrm{ave}}$
- [Need to agree and/or refine the number 0.0065. P_{ave} is already defined in 121.8.5.3]

- In 138.8.10 Stressed receiver sensitivity, insert:
- the value of M in Equation (138-1) is set to zero, and

Alternative in context

138.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

...

... Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

— Equation (138-1) is used in place of Equation (121-11).

$$R = \sqrt{(\sigma_G^2 + \sigma_S^2 - (M/C_{eq})^2)} \quad (138\text{-}1)$$

where $M = 0.0065P_{ave}$

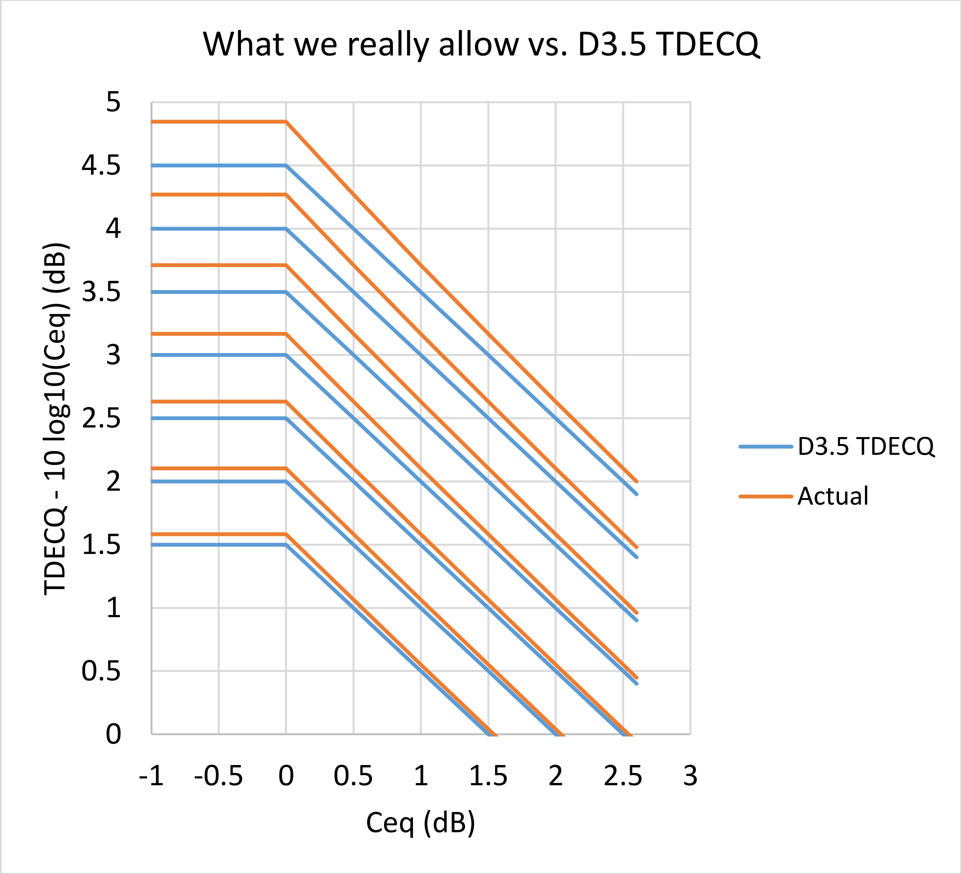
— The reference equalizer to be used for TDECQ for 50GBASE-SR, 100GBASE-SR2, and 200GBASE-SR4 is specified in 138.8.5.1.

138.8.10 Stressed receiver sensitivity

— The SECQ of the stressed receiver conformance test signal is measured according to 138.8.5, except that the value of M in Equation (138-1) is set to zero, and the combination of the O/E converter and the oscilloscope has

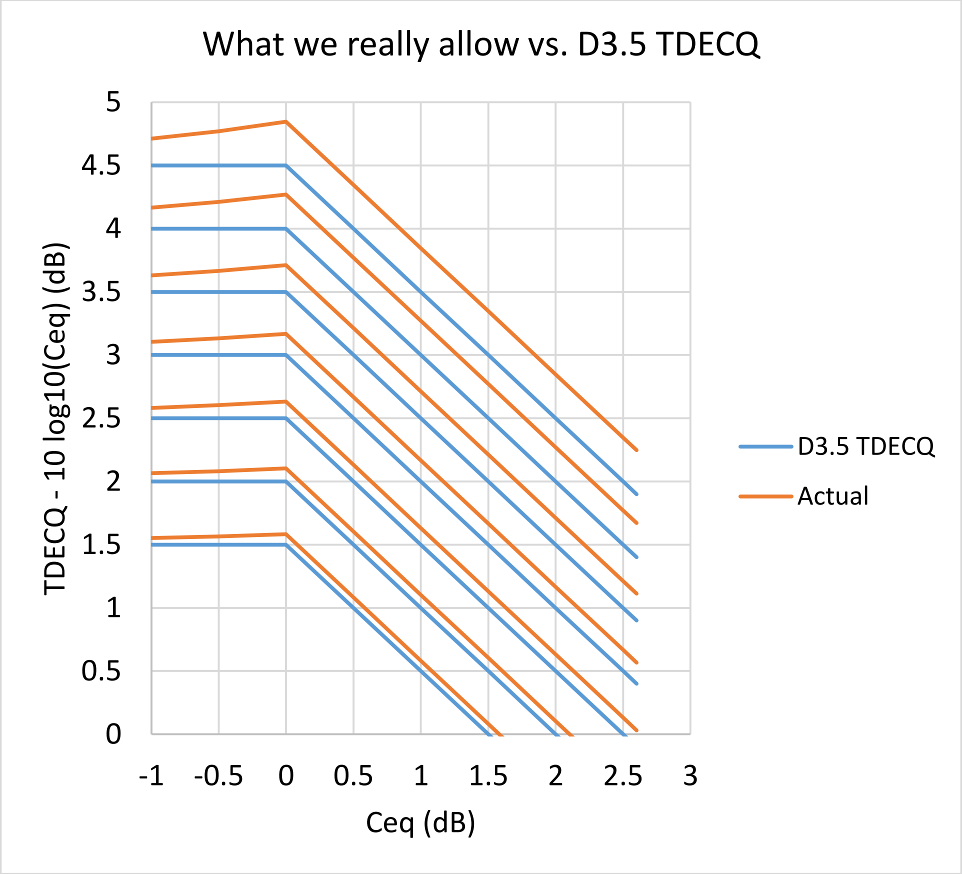
[In the first way forward, "/C_{eq}" would be omitted]

Effect of under-estimating MN and MPN in D3.5 – without their noise enhancement



D3.5 measures the blue lines
In service receiver may experience the orange lines
Significantly worse penalty when TDECQ is bad
This slide assumes these noises do not undergo noise enhancement

Effect of under-estimating MN and MPN in D3.5 – with full noise enhancement



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