Controlling the combination of all penalties for the MMF PMDs

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Introduction

- The draft allows TDECQ of 4.5 dB for MMF PMDs, much higher than any SMF PMD (3.4 dB)
- Modal noise (MN) and mode partition noise (MPN), which are higher with PAM4 than we previously thought, when combined with this high TDECQ, can cause an **excessive** total penalty, around 5 dB
  - Previous comments have pointed out the issue – also see dawe_3cd_01b_0918 slides 17 to 24 and 27-28, and dawe_3cm_adhoc_01_092718
- **Remember this is on top of 4.8 dB PAM4 penalty, so the eyes would be 9.8 dB closed after equalization**
- Comment 2 provides a simpler remedy that puts less burden on healthy transmitters

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
- Unlike dawe_3cd_01b_0918 this calculation fully includes the Pcross effect
- Unlike dawe_3cm_adhoc_01_092718, this scales the Ogawa-Agrawal method of calculating the MPN noise, and includes recent small improvements in the fibre's specified chromatic dispersion (~-108 ps/nm/km instead of ~-118 ps/nm/km)
- This is more optimistic than the calculation used for writing comment 2

Estimates of budget with minor noise penalties

		10GBASE-SR	100GBASE-SR4		50GBASE-SR		
Spreadsheet example			Estimates for two k values		As in P802.3cd D3.5	Pessimistic	Optimistic
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**	
Total penalty	dBo	**4.2**	**4.3**	**4.11**	**4.60**	**4.95**	**4.80**
Signalling rate	GBd	**10.3125**	**25.78125**				
Reach	m	**300**	**100**		**100**		
Spectral width	nm	**0.29**	**0.6**		**0.6**	**0.6**	
MPN penalty	dBo	**0.1**	0.14	0.02	0.02	0.15	0.09
MN penalty	dBo	**0.3**	0.11	0.03	0.08	0.30	0.22
Combined	dBo	0.4	0.24	0.05	**0.10**	**0.45**	**0.30**
MPN k, also used for MN		**0.3**	**0.3**	**0.1**	**0.0296**	**0.1**	**0.075**
TDP, TDEC or TDECQ w/o Pmpn		3.8	3.92	4.04	4.5	4.5	4.5
Rate*reach*spectral width		897	1547		1594		
MPN noise	rel. OMA outer	**0.01247**	0.0257	0.0086	0.0030	0.0090	0.0068

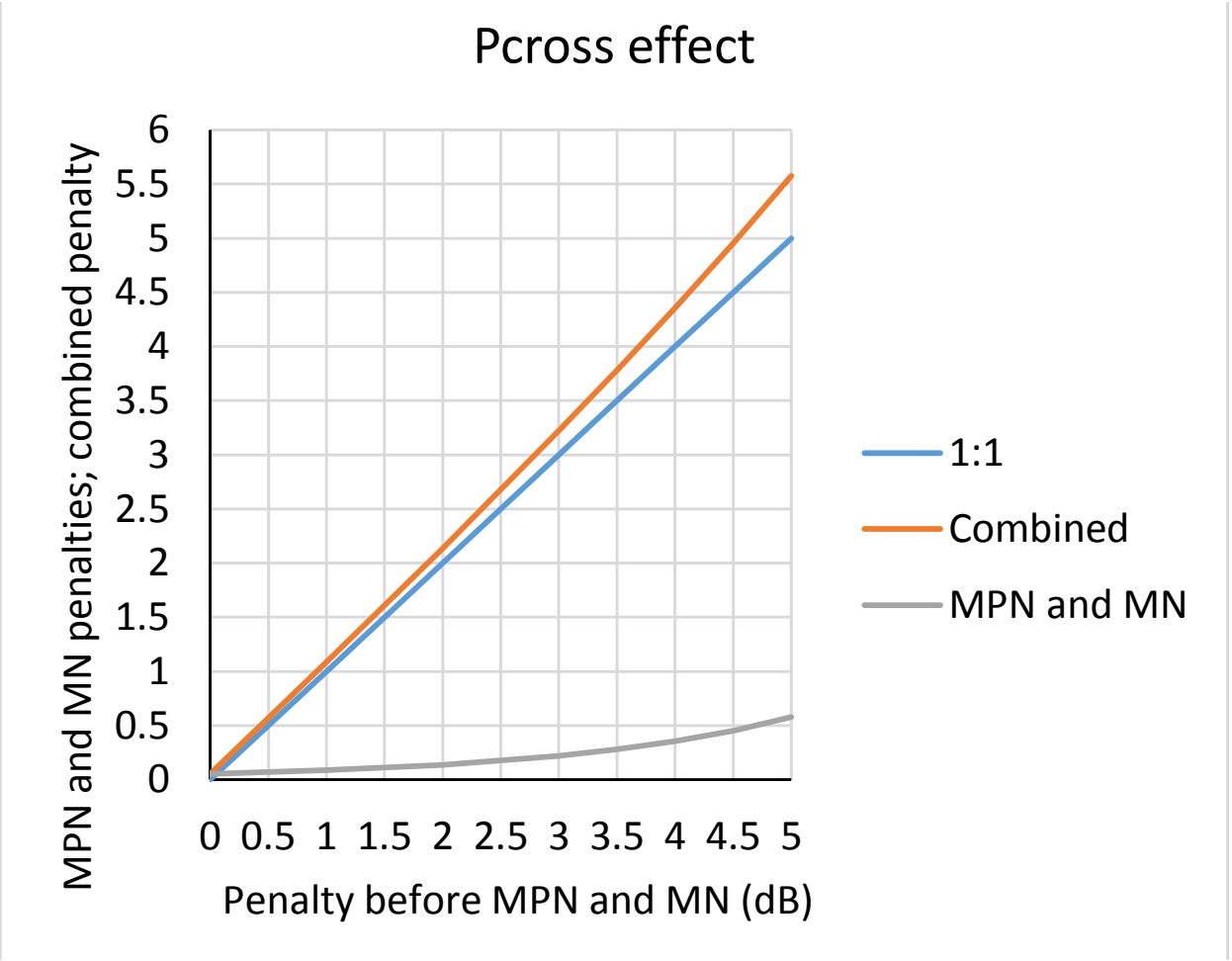
Start with the penalties and k factor in 10GBASE-SR

Compare 100GBASE-SR4
Estimated Pmpn and Pmn are very low because PAM2 and FEC

Compare P802.3cd D3.5: implied k of 0.03 is too optimistic

In right hand columns, assume k is 0.1 or 0.075. Scale the 10G/25G noises and predict the penalties for 802.3cd MMF: around 0.4 dB, bringing the total penalty to around **4.9 dB**, vs. P802.3cd D3.5 statement of 4.6 dB
4.9 dB is too high.

Pcross effect



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

Remedy

- We know how to fix this issue because we did it in 802.3bm (100GBASE-SR4)
- Here's the remedy, modified from comment 2
- 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 $M = 0.0065P_{\text{ave}}$
  - (Comment 2 has $0.0075P_{\text{ave}}$)
- [Note to reader: P_{ave} is already defined in 121.8.5.3]

- In 138.8.10 Stressed receiver sensitivity, e.g. at page 275 line 46, insert:
- the value of M in Equation (138-1) is set to zero, and

Discussion 1

- 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
- This remedy does not need any changes to the budget or any spec limit numbers
  - It brings an actual worst-case budget of 4.95 dB back to 4.6 dB

Discussion 2

- The remedy in comment 2 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, which assumes that noise causing 0.35 dB undergoes noise enhancement and noise causing 0.1 dB (the fixed additional penalty in the budget) doesn't

Alternative remedy

- This assumes that 3/4 of the penalty caused by MN and MPN undergoes noise enhancement
- Insert:
- Equation (138-1) is used in place of Equation (121-11).
- $R = \sqrt{(\sigma_G^2 + \sigma_S^2 - (M/C_{eq})^2)}$ (138-1)
- where $M = 0.0065 P_{ave}$
- [Note to reader: P_{ave} is already defined in 121.8.5.3]

- In 138.8.10 Stressed receiver sensitivity, e.g. at page 275 line 46, insert:
- the value of M in Equation (138-1) is set to zero, and

Alternative remedy 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).

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

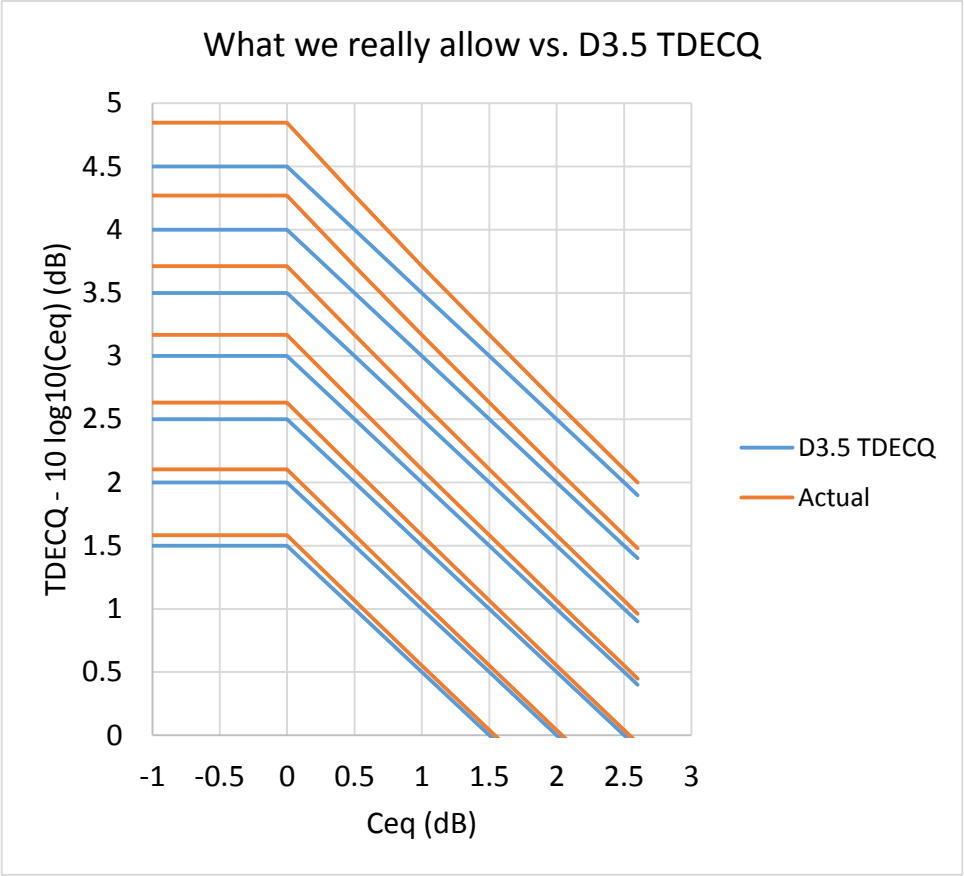
where $M = 0.0065P_{ave}$

— 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

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



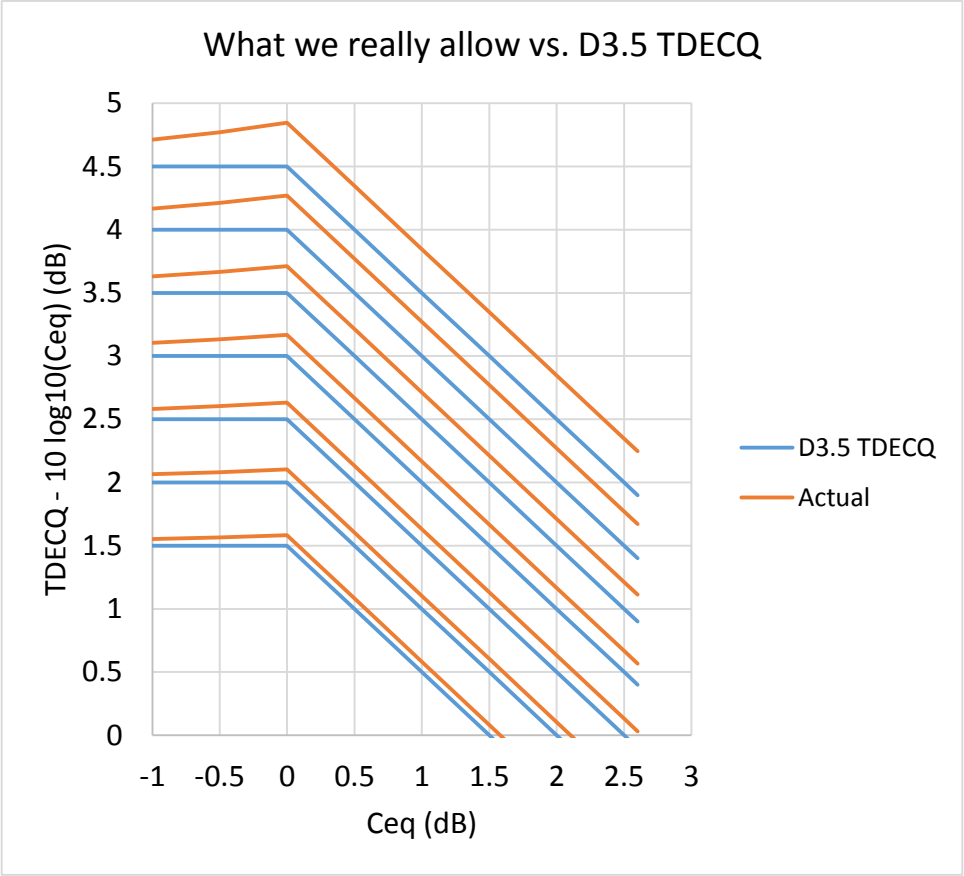
D3.5 measures the blue lines

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



D3.5 measures the blue lines

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Significantly worse penalty when TDECQ is bad

This slide assumes these noises undergo full noise enhancement