Relaxing TDECQ For SMF PMDs With PAM4

20170911

K. Tamura, M. Akashi

Supporters

- Frank Chang, Inphi
- Hai-Feng Liu, Intel
- Winston Way, Neophotonics
- Mark Kimber, Semtech

Introduction

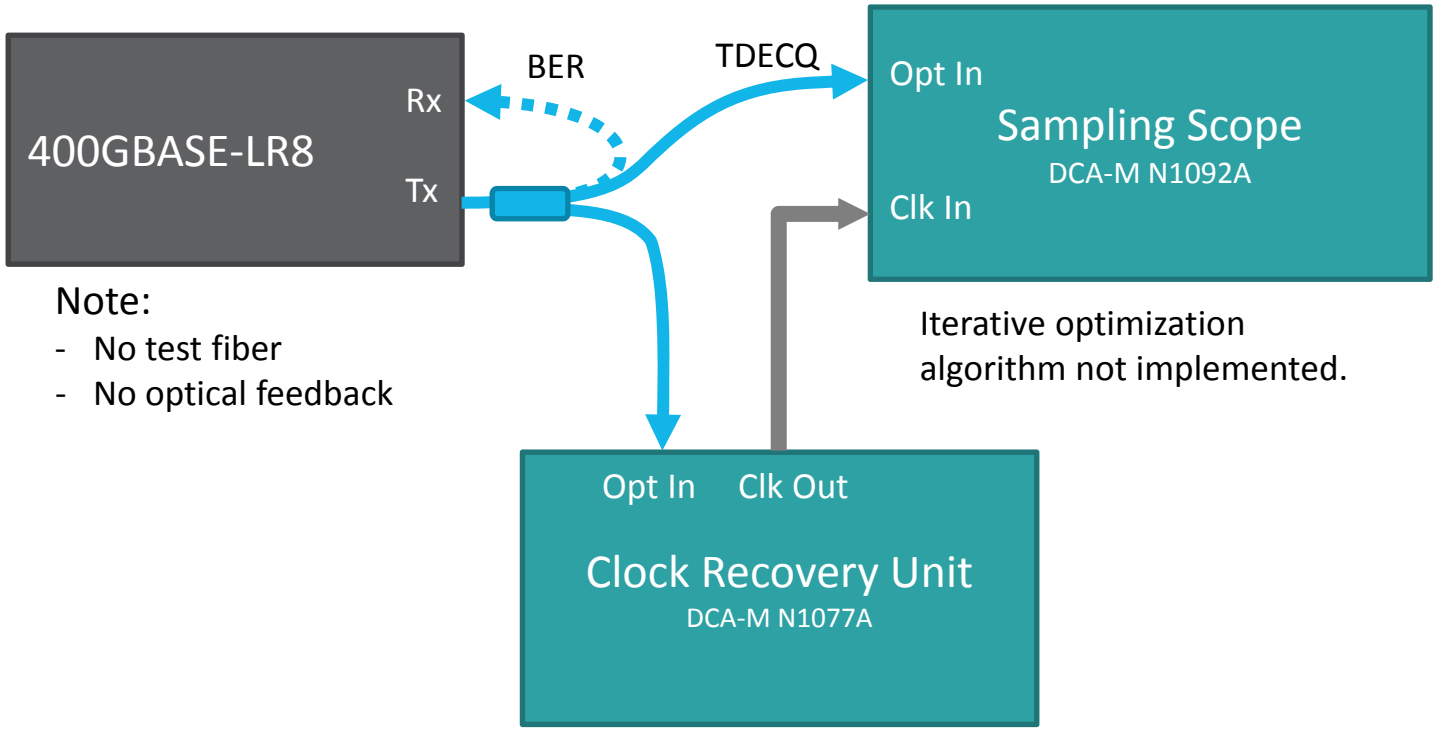
1. Recent contributions raised concern TDECQ (max) specification seems too difficult to meet for PAM4 transmitters (Tx).

Reference	PMD	Specification • Taps x Space • BW • TDECQ max	Pattern	Observation	Recommendation
way_3bs_01a_0517	400GBASE-LR8	• 5 x T/2 • 19.34GHz • 2.4 dB	PRBS15	• Links with sufficient margin can fail TDECQ.	• T-spaced reference EQ.
way_3bs_01a_0717	400GBASE-LR8	• 5 x T • 13.3GHz • 3.3 dB	PRBS15 SSPRQ	• TDECQ fails with 5 taps, but passes with >=7 taps. • TDECQ higher with SSPRQ than PRBS15.	• Change reference EQ and pattern: • 7-tap, T, 13.3GHz, PRBS15 • 9-tap, T, 13.3GHz, SSPRQ

2. Methods to relax TDECQ (see also king_02_0617_smf, mazzini_01_0817_smf).
   - Higher bandwidth in reference receiver (Rx)
   - More taps in reference equalizer
   - PRBS13Q or PRBS15 instead of SSPRQ

3. Purpose here is to share more TDECQ data and share comments.

Measurement Setup For TDECQ And BER



Note:
- No test fiber
- No optical feedback

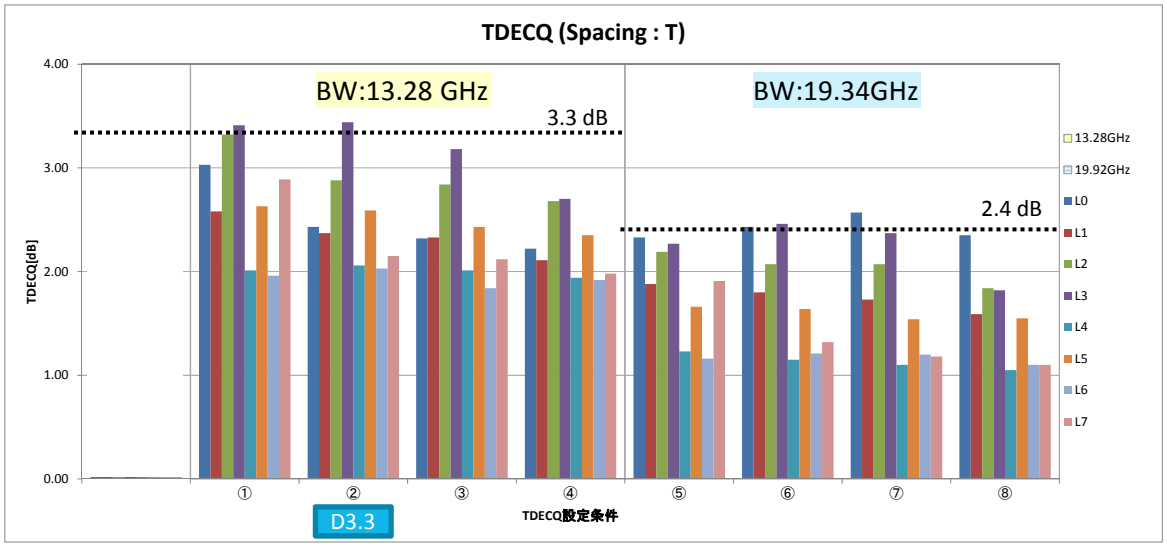
Iterative optimization algorithm not implemented.

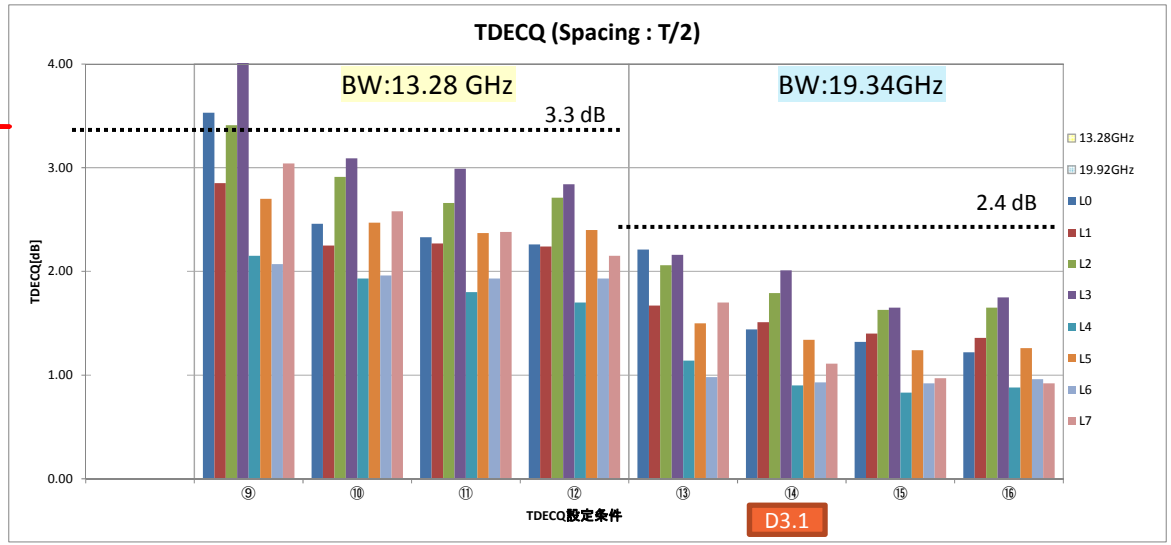
TDECQ From 400GBASE-LR8 Module

Test conditions:

1. PRBS15
2. Ref Rx as in table below

No.	Rate (GBd)	Spacing	Taps	Precursors	Bandwidth (GHz)
①	26.5625	T	3	1	13.28
②	26.5625	T	5	2	13.28
③	26.5625	T	7	3	13.28
④	26.5625	T	9	4	13.28
⑤	26.5625	T	3	1	19.34
⑥	26.5625	T	5	2	19.34
⑦	26.5625	T	7	3	19.34
⑧	26.5625	T	9	4	19.34
⑨	26.5625	T/2	5	2	13.28
⑩	26.5625	T/2	9	4	13.28
⑪	26.5625	T/2	13	6	13.28
⑫	26.5625	T/2	17	8	13.28
⑬	26.5625	T/2	5	2	19.34
⑭	26.5625	T/2	9	4	19.34
⑮	26.5625	T/2	13	6	19.34
⑯	26.5625	T/2	17	8	19.34



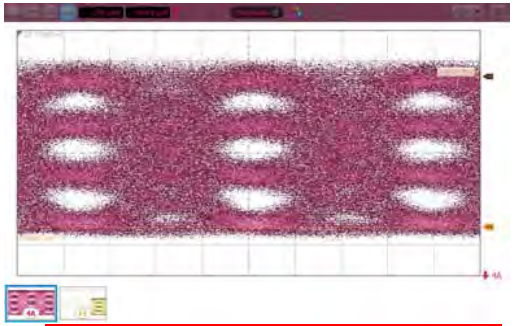


Consistent with other reports i.e. TDECQ is lower for:

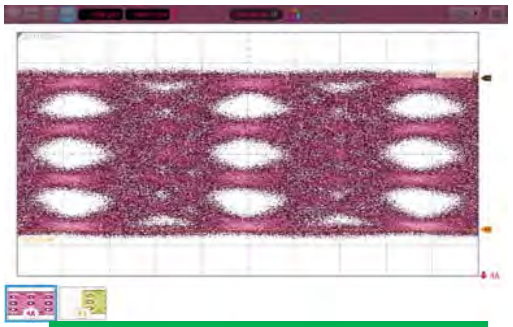
1. Higher bandwidth
2. More taps
3. T/2 space if total time interval fixed (i.e. two T/2 taps per one T tap)

BER Comparison For High & Low TDECQ Tx

Sample #1 (Tx Eye)

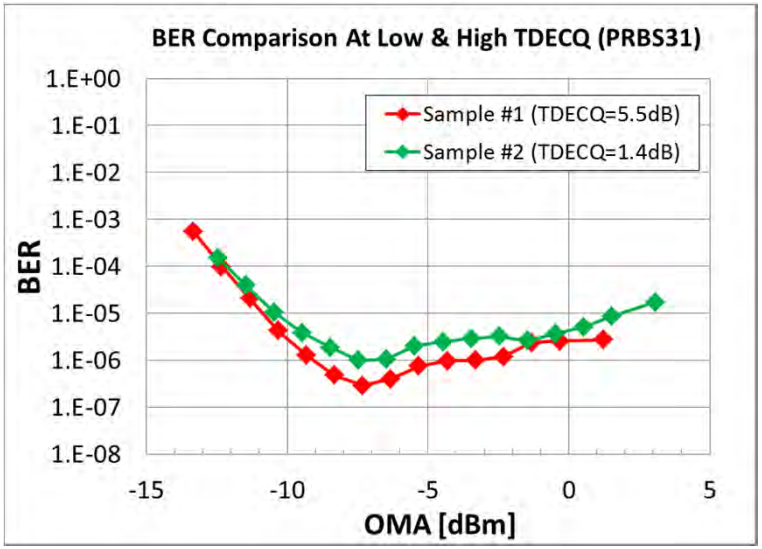


Sample #2 (Tx Eye)



Sample #1 (TDECQ = 5.5dB)

Sample #2 (TDECQ=1.4dB)



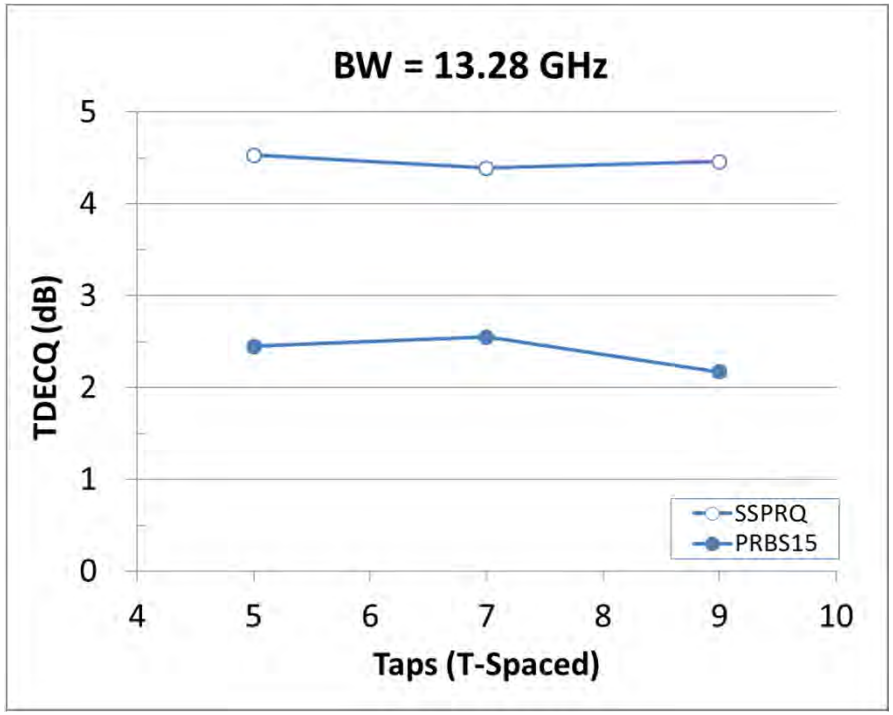
TDECQ Test Conditions:

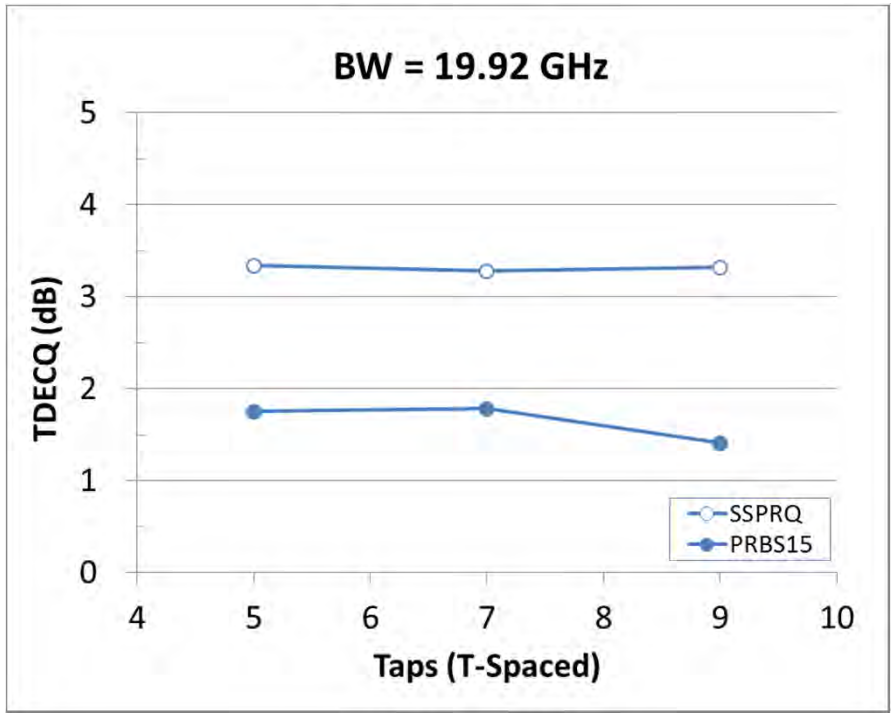
Pattern: PRBS15

Ref Rx: 5-tap, T/2, 19.34 GHz

- Despite large difference in TDECQ, BER still acceptable. (Note: Rx were different, so)
- Rx is DSP with “typical” level of signal processing (i.e. T-space, practical tap count, etc).
- Over 80 samples tested:
  - TDECQ range: 1dB to 5.5 dB
  - BER floor range: 1E-8 to 5E-6
  - Weak BER-TDECQ correlation

SSPRQ vs PRBS15





Δ = 1.8 - 2.3 dB

Δ = 1.5 – 1.9 dB

$$\Delta = TDECQ_{SSPRQ} - TDECQ_{PRBS15}$$

- TDECQ expected to increase when SSPRQ implemented.
- If Δ is as above, large percentage of 80 lanes would fail.
- Δ not reduced to <0.5 dB with 9 taps (see way_3bs_01a_0717).

Comparison Of Current TDECQ Specifications

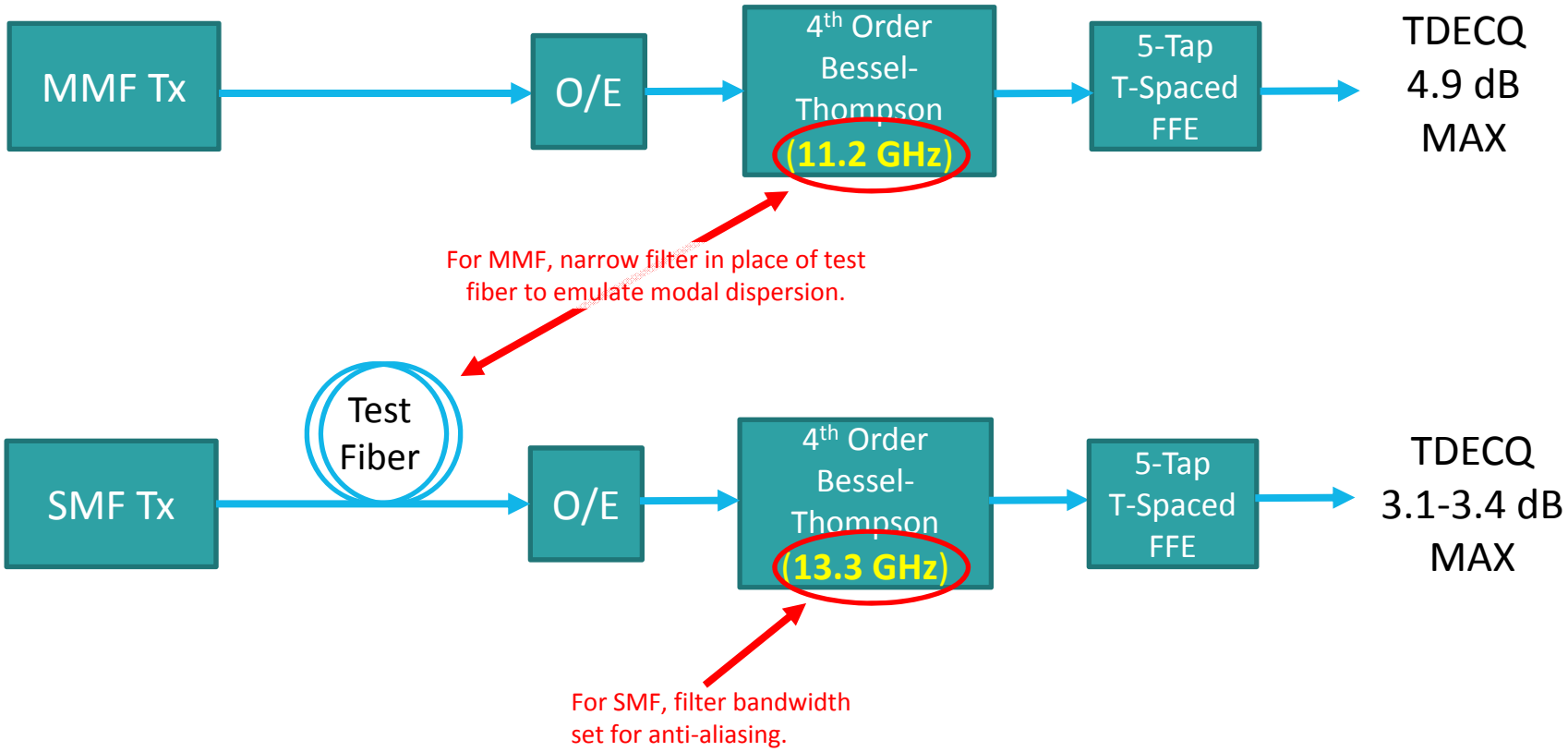
Parameter	Units	200GBASE-DR4	200GBASE-FR4	200GBASE-LR4	400GBASE-FR8	400GBASE-LR8	50GBASE-FR	50GBASE-LR	100GBASE-DR	400GBASE-DR4	50GBASE-SR 100GBASE-SR2 200GBASE-SR4
Baudrate	GBaud	26.5625	26.5625	26.5625	26.5625	26.5625	26.5625	26.5625	53.125	53.125	26.5625
Reference Rx bandwidth	GHz	13.28125	13.28125	13.28125	13.28125	13.28125	13.28125	13.28125	26.5625	26.5625	11.2
Reference Rx equalizer	Taps, Spacing	5, T	5, T	5, T	5, T	5, T	5, T	5, T	5, T	5, T	5, T
TDECQ (max)	dB	3.4	3.3	3.4	3.1	3.3	3.2	3.4	3.4	3.4	4.9
SRS	dBm	−4.1	−3.6	−5.2	−3.1	−4.7	−5.1	−6.4	−1.9	−1.9	−3
Dispersion (max)	ps/nm	0.8	6.7	9.5	1.9	9.5	3.2	16	0.8	0.8	–
Dispersion (min)	ps/nm	−0.93	−11.9	−28.4	−10.2	−50.8	−3.7	−18.6	−0.93	−0.93	–
|ΔTdisp / Tsymb| (dispersion max)	%	0.3%	2.7%	3.8%	0.8%	3.8%	1.3%	6.4%	1.3%	1.3%	–
|ΔTdisp / Tsymb| (dispersion min)	%	0.4%	4.7%	11.3%	4.1%	20.2%	1.5%	7.4%	1.5%	1.5%	–
Draft	–	P802.3cd D2.1	P802.3bs D3.3	P802.3bs D3.3	P802.3bs D3.3	P802.3bs D3.3	P802.3cd D2.1	P802.3cd D2.1	P802.3cd D2.1	P802.3bs D3.3	P802.3cd D2.1
Clause	–	121	122	122	122	122	139	139	140	124	138

Note: T_{disp} is approximate spread due to chromatic dispersion for transform-limited signals at the baud rate.. T_{symb} is symbol time.

Observations on TDECQ (max):

1. For SMF PMDs, TDECQ (max) is as high as 3.4dB, even when dispersion negligible (200GBASE-DR4).
2. For MMF PMDs, TDECQ (max) is 4.9dB. Since similar DSPs will be used, if high TDECQ acceptable for interoperability in MMF PMDs, situation should be similar for SMF PMDs.

Comparing MMF And SMF TDECQ Measurement



For P802.3bs D3.3 and P802.3cd D2.1

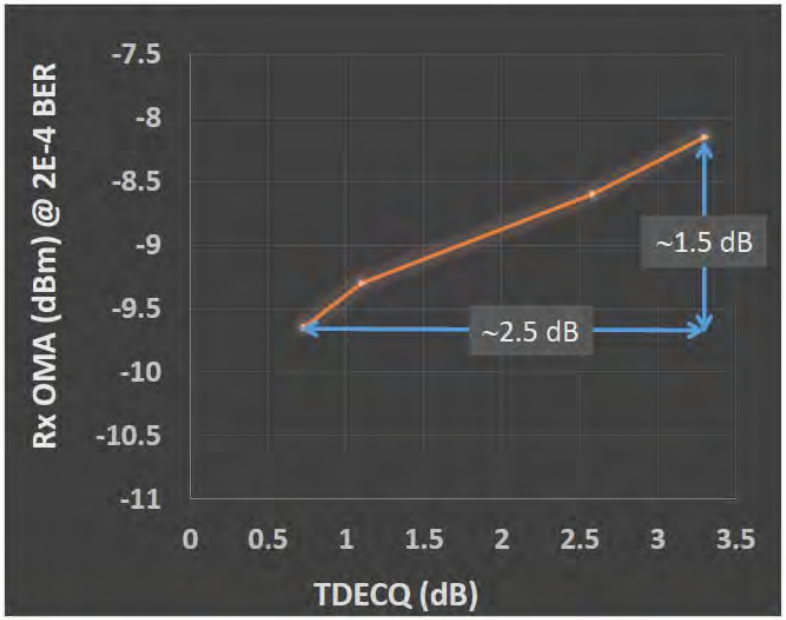
Conclusions / Recommendations

1. TDECQ max seems too stringent for SMF PMDs using PAM4 modulation. Support concerns expressed earlier on unnecessarily low Tx yield for SMF PMDs with current TDECQ max.

2. Comments:
   - Next steps:
     - Check improvements of (1) iterative optimization algorithm; (2) changing time of histograms.
   - Consider other possibilities beyond what has already been recommended:
     - Increase TDECQ (max)?
       - EX: 3.1dB → 4dB for 400GBASE-FR8; 3.3dB → 4.2 dB for 400GBASE-LR8.
       - Change will also affect Tx OMA and Rx Sensitivity.
     - Need for scaling factor?
       - If TDECQ overestimates penalty, renormalize TDECQ (see lecheminant_3cd_01_1116)
       - Can limit change to only TDECQ.

Scaling Factor

Correlation between BER Penalty and TDECQ



2.5 dB change in TDECQ vs.1.5 dB BER penalty
- Different optical Rx used
- Different EQ setting
- Rx with AGC used in BER testing

Consistent trend in measured TDECQ change and BER penalty

8

http://www.ieee802.org/3/cd/public/Nov16/lecheminant_3cd_01_1116.pdf

$$\frac{\Delta \text{Rx Sens OMA (dB)}}{\Delta \text{TDECQ (dB)}} \sim 0.6$$