Concerning Comments r03-21, -22, -42, -43 On TDECQ

20180709

P802.3cd

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In Support Of Comments r03-21, r03-43 Against 50GBASE-FR/LR In P802.3cd D3.3

Cl **139** *SC* **139.6** *P* **293** *L* **43** # r03-21

Tamura, Kohichi — Oclaro

Comment Type **TR** *Comment Status* **X**

In D3.2, 1% OMA threshold adjustment was introduced to the TDECQ algorithm in order to improve the yields of transmitters with slightly unequal eye levels and to improve correlation between changes in TDECQ and receiver sensitivity. Real receivers have threshold adjustment capability exceeding 1%, so the changes will mainly benefit transmitters with some nonlinearity, such as DML, but not adversely impact receivers. However, in D3.3, TDECQ (max) of 50GBASE-FR and 50GBASE-LR were reduced from 3.2 dB to 2.8 dB and from 3.4 dB to 3 dB, respectively, which negated the improvement gained with threshold adjustment. Furthermore, highly linear transmitters, for which TDECQ is the same with or without threshold adjustment, were penalized by a reduction in TDECQ (max) by 0.4 dB.

SuggestedRemedy

In Table 139-6, change TDECQ (max) of 50GBASE-FR from 2.8 dB to 3.2 dB.
In Table 139-6, change TDECQ (max) of 50GBASE-LR from 3 dB to 3.4 dB.

These changes will require additional changes as described below in other parts of the draft.
In Table 139-7, change "Stressed receiver sensitivity ... (max)" of 50GBASE-FR from -5.5 dB to -5.1 dB.
In Table 139-7, change "Stressed receiver sensitivity ... (max)" of 50GBASE-LR from -6.8 dB to -6.4 dB.
In Table 139-7, change foot note "c" from "... SECQ up to 2.8 dB for 50GBASE-FR and 3 dB for 50GBASE-LR." to "... SECQ up to 3.2 dB for 50GBASE-FR and 3.4 dB for 50GBASE-LR."
In Table 139-8, change "Power budget" of 50GBASE-FR from 7.2 dB to 7.6 dB.
In Table 139-8, change "Power budget" of 50GBASE-LR from 9.9 dB to 10.3 dB.
In Table 139-8, change "Allocation for penalties" of 50GBASE-FR from 3.2 dB to 3.6 dB.
In Table 139-8, change "Allocation for penalties" of 50GBASE-LR from 3.6 dB to 4 dB.
In 139.7.9, change "... SECQ up to 2.8 dB" to "... SECQ up to 3.2 dB" for 50GBASE-FR
In 139.7.9, change "... SECQ up to 3 dB" to "... SECQ up to 3.4 dB" for 50GBASE-LR.
In 139.7.9, change Figure 139-6 so that curves include SECQ of 3.2 dB and 3.4 dB for 50GBASE-FR and 50GBASE-LR, respectively.

Proposed Response *Response Status* **O**

Cl **139** *SC* **139.6** *P* **293** *L* **43** # r03-43

Liu, Hai-Feng — Intel Corporation

Comment Type **TR** *Comment Status* **X**

The primary benefit of introducing threshold adjustment in D3.2 was to improve the TDECQ and link BER penalty correlation. This change would also relax the TDECQ for those Tx with unequal sub-eyes. In D3.3, TDECQmax was reduced to keep the maximum sub-eye inequality no greater than before threshold adjustment was added. However, the proposed 0.4 dB reduction from 3.4 dB to 3 dB was based on the simulation/measurement for the worst symmetric eye compression case under 1% threshold adjustment. Applying the same 0.4 dB reduction in TDECQ max across the board will unnecessarily penalize a large portion of good Tx that would have nearly equal sub-eyes. These Tx will gain little in terms of TDECQ from the threshold adjustment, but the 0.4 dB reduction in TDECQmax will result in significant loss. In addition, the worst symmetric eye compression case is far from practical as it can be avoided at least for MZI and EML based Tx.

SuggestedRemedy

In Table 139-6, change TDECQ (max) of 50GBASE-FR from 2.8 dB to 3.2 dB.
In Table 139-6, change TDECQ (max) of 50GBASE-LR from 3 dB to 3.4 dB.
In Table 139-7, change "Stressed receiver sensitivity ... (max)" of 50GBASE-FR from -5.5 dB to -5.1 dB.
In Table 139-7, change "Stressed receiver sensitivity ... (max)" of 50GBASE-LR from -6.8 dB to -6.4 dB.
In Table 139-7, change "Stress eye closure for PAM4 (SECQ) of 50GBASE-FR from 2.8 dB to 3.2 dB
In Table 139-7, change "Stress eye closure for PAM4 (SECQ) of 50GBASE-LR from 3 dB to 3.4 dB
In Table 139-7, change foot note "c" from "... SECQ up to 2.8 dB for 50GBASE-FR and 3 dB for 50GBASE-LR." to "... SECQ up to 3.2 dB for 50GBASE-FR and 3.4 dB for 50GBASE-LR."
In Table 139-8, change "Power budget" of 50GBASE-FR from 7.2 dB to 7.6 dB.
In Table 139-8, change "Power budget" of 50GBASE-LR from 9.9 dB to 10.3 dB.
In Table 139-8, change "Allocation for penalties" of 50GBASE-FR from 3.2 dB to 3.6 dB.
In Table 139-8, change "Allocation for penalties" of 50GBASE-LR from 3.6 dB to 4 dB.
In 139.7.9, change "... SECQ up to 2.8 dB" to "... SECQ up to 3.2 dB" for 50GBASE-FR
In 139.7.9, change "... SECQ up to 3 dB" to "... SECQ up to 3.4 dB" for 50GBASE-LR.

Proposed Response *Response Status* **O**

In Support Of Comments r03-22, r03-42 Against 100GBASE-DR In P802.3cd D3.3

Cl **140** *SC* **140.6** *P* **318** *L* **42** # r03-22

Tamura, Kohichi — Oclaro

Comment Type **TR** *Comment Status* **X**

In D3.2, 1% OMA threshold adjustment was introduced to the TDECQ algorithm in order to improve the yields of transmitters with slightly unequal eye levels and to improve correlation between changes in TDECQ and receiver sensitivity. Real receivers have threshold adjustment capability exceeding 1%, so the changes will mainly benefit transmitters with some nonlinearity, such as DML, but not adversely impact receivers. However, in D3.3, TDECQ (max) of 100GBASE-DR reduced from 3.4 dB to 3 dB, which negated the improvement gained with threshold adjustment. Furthermore, highly linear transmitters, for which TDECQ is the same with or without threshold adjustment, were penalized by a reduction in TDECQ (max) by 0.4 dB.

SuggestedRemedy

In Table 140-6, change "TDECQ (max)" of 100GBASE-DR from 3 dB to 3.4 dB.
In Table 140-7, change "stressed receiver sensitivity ... (max)" of 100GBASE-DR from -2.3 dB to -1.9 dB.
In Table 140-7, change foot note "c" from "... SECQ up to 3 dB." to "... SECQ up to 3.4 dB."
In Table 140-7, change the "Stressed eye closure for PAM4 (SECQ)" from 3 dB to 3.4 dB
In Table 140-8, change "Power budget" of 100GBASE-DR for extinction ratio >= 5 dB from 6.1 dB to 6.5 dB.
In Table 140-8, change "Power budget" of 100GBASE-DR for extinction ratio < 5 dB from 6.4 dB to 6.8 dB.
In Table 140-8, change "Allocation for penalties" of 100GBASE-DR for extinction ratio >= 5 dB from 6.1 dB to 6.5 dB.
In Table 140-8, change "Allocation for penalties" of 100GBASE-DR for extinction ratio < 5 dB from 6.4 dB to 6.8 dB.
In 140.7.9, change "...SECQ up to 3 dB" to "...SECQ up to 3.4 dB"
In 140.7.9, change Figure 140-5 so curve includes up to SECQ of 3.4 dB.

Proposed Response *Response Status* **O**

Cl **140** *SC* **140.6** *P* **318** *L* **42** # r03-42

Liu, Hai-Feng — Intel Corporation

Comment Type **TR** *Comment Status* **X**

The primary benefit of introducing threshold adjustment in D3.2 was to improve the TDECQ and link BER penalty correlation. This change would also relax the TDECQ for those Tx with unequal sub-eyes. In D3.3, TDECQmax was reduced to keep the maximum sub-eye inequality no greater than before threshold adjustment was added. However, the proposed 0.4 dB reduction from 3.4 dB to 3 dB was based on the simulation/measurement for the worst symmetric eye compression case under 1% threshold adjustment. Applying the same 0.4 dB reduction in TDECQ max across the board will unnecessarily penalize a large portion of good Tx that would have nearly equal sub-eyes. These Tx will gain little in terms of TDECQ from the threshold adjustment, but the 0.4 dB reduction in TDECQmax will result in significant loss. In addition, the worst symmetric eye compression case is far from practical as it can be avoided at least for MZI and EML based Tx.

SuggestedRemedy

In Table 140-6, change "TDECQ (max)" of 100GBASE-DR from 3 dB to 3.4 dB.
In Table 140-7, change "stressed receiver sensitivity ... (max)" of 100GBASE-DR from -2.3 dB to -1.9 dB.
In Table 140-7, change foot note "c" from "... SECQ up to 3 dB." to "... SECQ up to 3.4 dB."
In Table 140-8, change "Power budget" of 100GBASE-DR for extinction ratio >= 5 dB from 6.1 dB to 6.5 dB.
In Table 140-7, change the Stressed eye closure for PAM4 (SECQ) from 3 dB to 3.4 dB
In Table 140-8, change "Power budget" of 100GBASE-DR for extinction ratio < 5 dB from 6.4 dB to 6.8 dB.
In Table 140-8, change "Allocation for penalties" of 100GBASE-DR for extinction ratio >= 5 dB from 6.1 dB to 6.5 dB.
In Table 140-8, change "Allocation for penalties" of 100GBASE-DR for extinction ratio < 5 dB from 6.4 dB to 6.8 dB.
In page 323, 140.7.9, Change "...SECQ up to 3 dB" to "...SECQ up to 3.4 dB"

Proposed Response *Response Status* **O**

Background

- TDECQ may impact yield of SMF PMDs.
  - **P802.3bs**: way_3bs_01a_0517, way_3bs_01a_0717, tamura_3bs_01a_0917, tamura_01a_1017_smf (ad hoc)
  - **P802.3cd**: chang_3cd_01a_0917, baveja_3cd_01_1117, chang_3cd_01b_0318, chang_3cd_02_0318

- Link measurements show adequate margins for Rx Sensitivity, even when TDECQ (max) exceeded by wide margin.
  1. TDECQ too stringent.
  2. Rx Sensitivity has margin to spare.

- Threshold adjustment added to TDECQ algorithm (mazzini_120617_3cd_adhoc-v2, liu_3cd_01b_0118).
  1. Improve correlation between TDECQ and Rx Sensitivity.
  2. Improve yield of transmitters with some nonlinearity (i.e. EML, DML).

- Minimal impact on Rx assured by limiting threshold adjustment range to up to 1% OMA (confirmed by several IC vendors).

Background (Cont.)

- In D3.3, TDECQ (max) was reduced by 0.4 dB for all optical PMDs in P802.3cd (50GBASE-SR/FR/LR, 100GBASE-DR).

- Issues with reducing TDECQ (max) for SMF PMDs:
  1. Penalizes high linearity Tx, which do not benefit from threshold adjustment.
  2. Makes already tight Tx specs even tighter. 50GBASE-FR, 50GBASE-LR, or 100GBASE-DR had low values for TDECQ (max) i.e. 3.2 dB, 3.4 dB, and 3.4 dB in D3.2, respectively.

- This presentation:
  - New measurements on 50G-PAM4 DML and 100G-PAM4 EML to support higher TDECQ (max) values for SMF PMDs.
    - Recommend increase of TDECQ (max) by 0.2 dB for 50GBASE-FR/LR (i.e. mid way between D3.2 and D3.3 values).
    - Recommend increase of TDECQ (max) by 0.4 dB for 100GBASE-DR (i.e. restore D3.2 value).

(1) 50G-PAM4 DML Measurements

Description:

- DML at high temperature (CoC + GSG probe).
- Vary TDECQ with electrical signal noise.

Setup details:

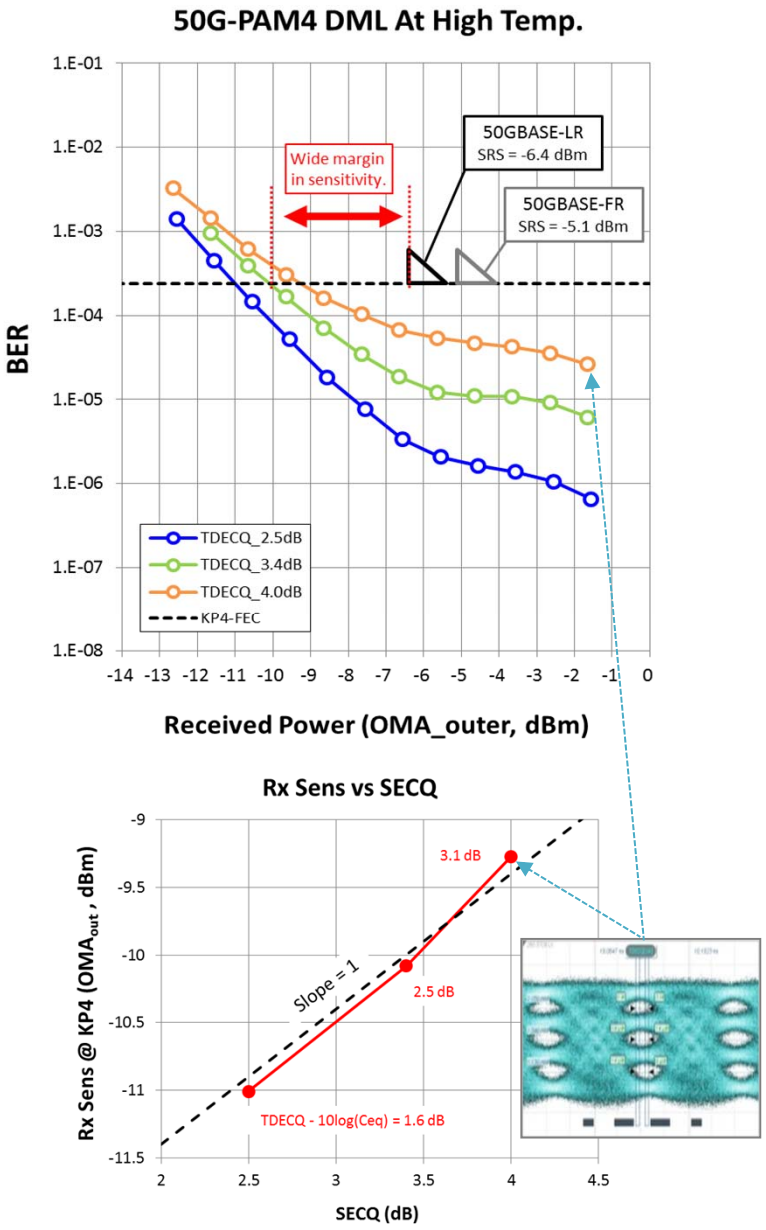
- Pattern Source: Keysight AWG
- Pattern (BER): PRBS15
- Baud rate: 26.5625 Gbaud
- Temperature: >75 degC
- SECQ: SSPRQ; 1% Thresh; No SMF
- Rx (BER): PIN ROSA + DSP w/ 6-Tap FFE

Observations:

1. Rx Sensitivity vs SECQ has slope ~1.
2. Rx Sensitivity << SRS spec even for SECQ of 4 dB.

Conclusions:

1. **D3.2 values for TDECQ (max) of 3.2 dB/3.4 dB for 50GBASE-FR/LR are reasonable.**
2. **TDECQ (max) of 3 dB/3.2 dB acceptable.**



Contributed by Oclaro.

(2) 50G-PAM4 DML Measurements

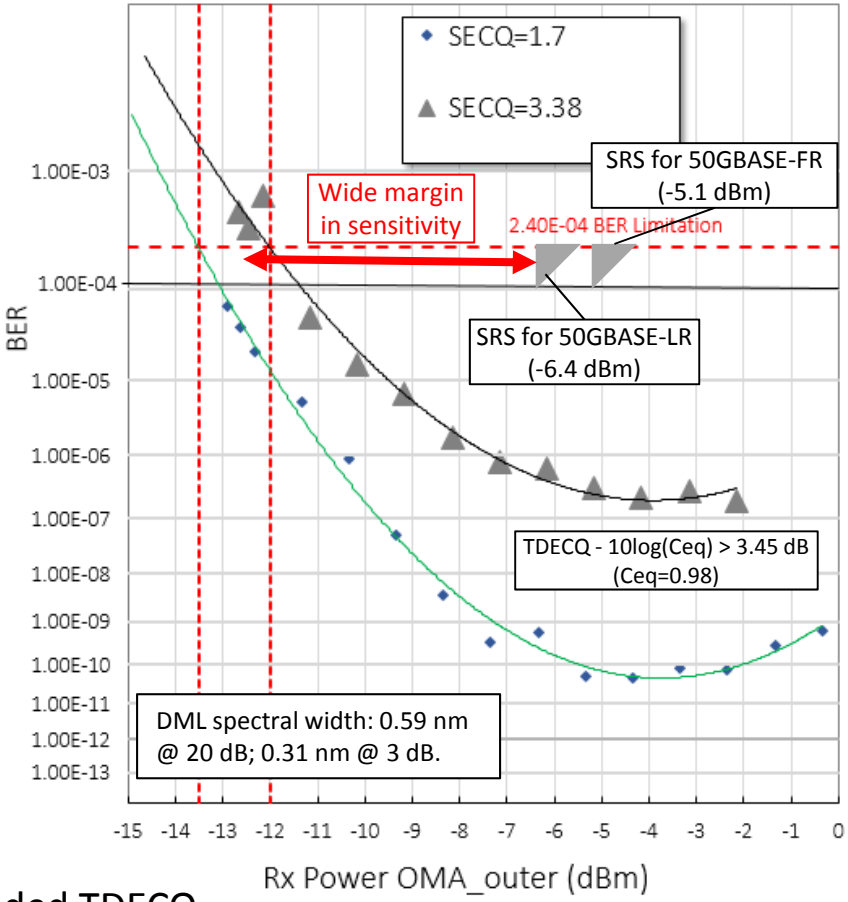
Description:

- DML sample measured at low and high temperature in transceiver
- Higher temperature results in TDECQ degradation

Setup details:

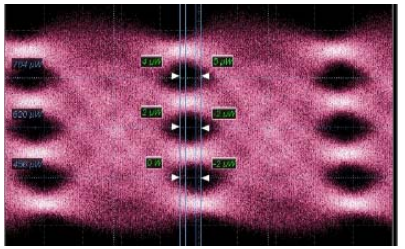
- Pattern Source: DSP
- Pattern (BER): PRBS31
- Baud rate: 26.5625 Gbaud PAM4
- SECQ (TDECQ): Keysight N1092A
  with 802.3cd Draft 3.2 (not 3.3).
  No SMF and with PRBS15, not SSPRQ.
  TDECQ will be > SECQ.
- Rx (BER): DSP w/ 6 TAP FFE + Pin ROSA

Data	TDECQ (dB)	Rx Sens (dBm)	BER floor
◆	>1.7	-13.5	1E-11
▲	*>3.4*	-12	3E-7



Observations:

1. BER floor and Rx Sens are good, despite skew-degraded TDECQ.
2. Rx Sensitivity << SRS requirement even for TDECQ > 3.4 dB.
3. BER floor << 2.4E-4 even for TDECQ > 3.4 dB.



Conclusions:

1. **D3.2 values for TDECQ (max) desirable for DML for 50GBASE-FR/LR.**
2. **TDECQ (max) of 3 dB/3.2 dB acceptable.**

(1) 100G-PAM4 EML Measurements

Description:

- EML in GPPO test fixture.
- TDECQ changed by adjusting pre-emphasis

Setup details:

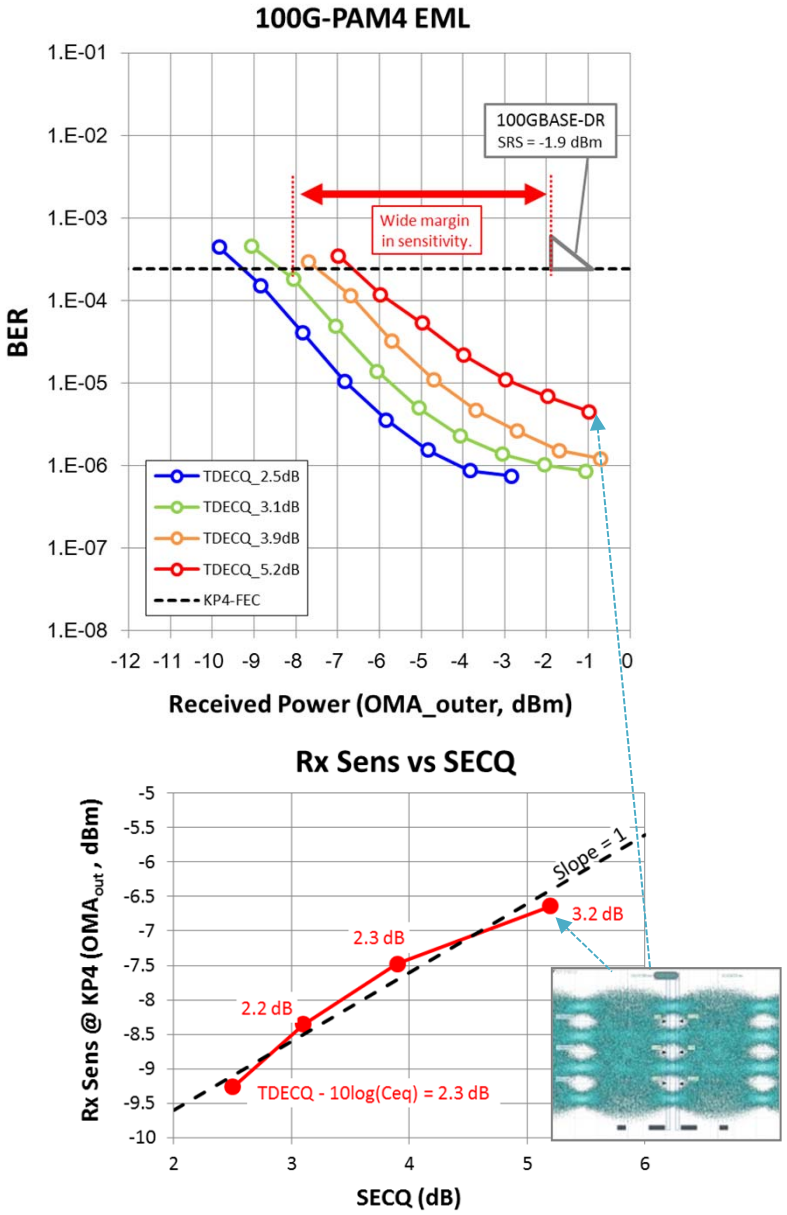
- Source: Keysight PPG
- Pattern (BER): PRBS15
- Baud rate: 53.125 Gbaud
- Temperature: Room
- SECQ: SSPRQ, 1% Threshold, No SMF.
- Rx (BER): PIN ROSA + DSP w/ FFE (7-9 effective taps)

Observations:

1. Rx Sensitivity vs SECQ has slope ~ 1.
2. Rx Sensitivity << SRS spec for SECQ of 5.2 dB.

Conclusions:

1. **D3.2 value of TDECQ (max) of 3.4 dB is reasonable for 100GBASE-DR.**



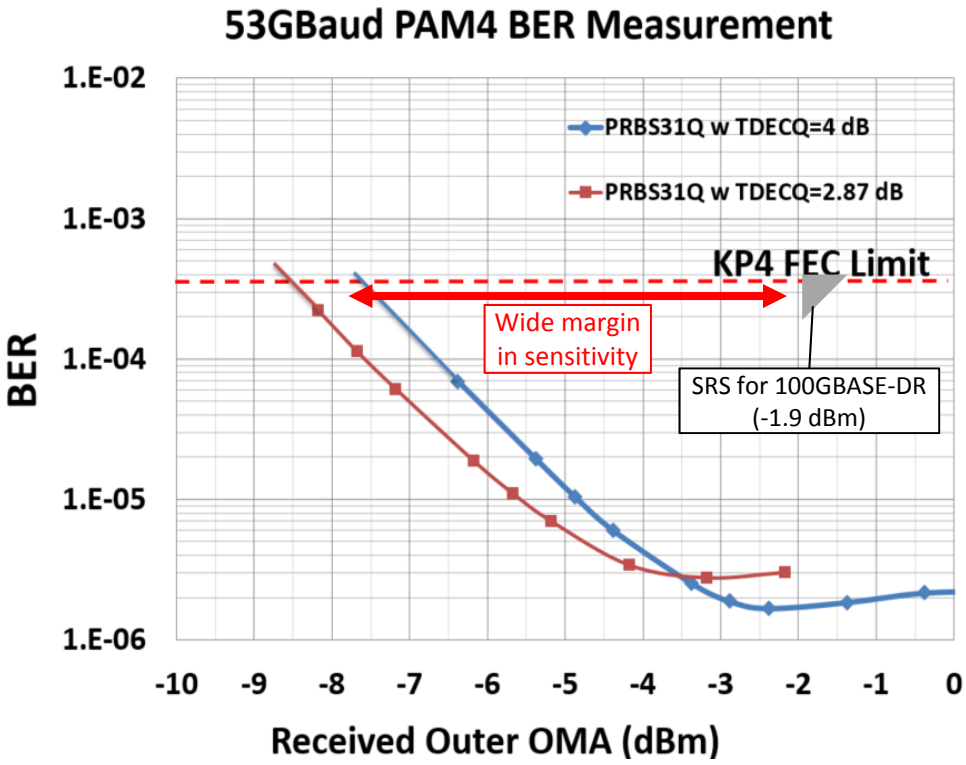
(2) 100G-PAM4 EML Measurements

Description:

- EML TOSA

Setup details:

- Source: DSP
- Pattern (BER): PRBS31
- Baud rate: 53.125 Gbaud
- Temperature: Room
- SECQ: Keysight 1092A
  802.3cd D3.2, SSPRQ, No SMF.
- Rx (BER): PIN ROSA +
  DSP w/ FFE (>5-Taps)



Observations:

1. Sensitivity correlates with TDECQ
2. Rx Sensitivity << SRS specification for TDECQ >3.4 dB.

Conclusions:

1. **D3.2 value for TDECQ (max) of 3.4 dB reasonable for 100GBASE-DR.**

Summary

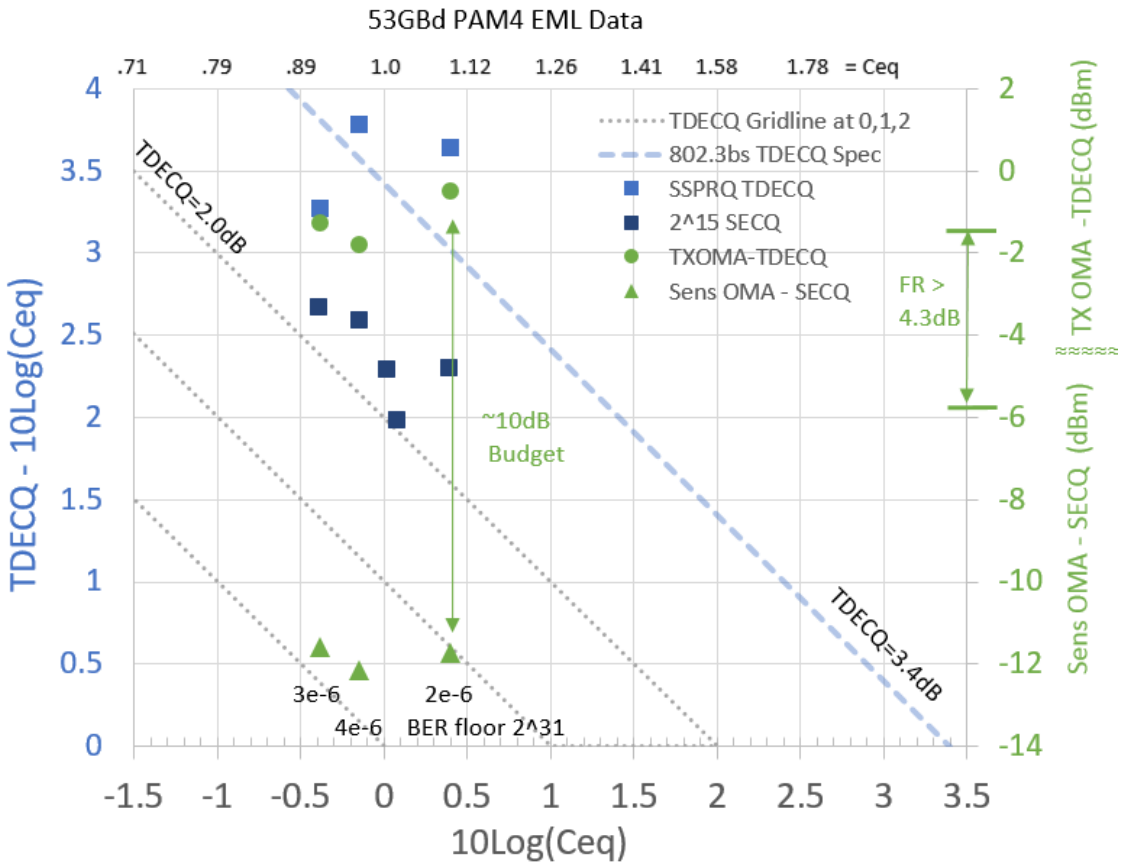
- Recommendation to accept in principle comments r03-21 and r03-43. Required changes in D3.3 are described below, where differences with the original comments are in red.
  - In Table 139-6, change TDECQ (max) of 50GBASE-FR from 2.8 dB to 3 dB.
  - In Table 139-6, change TDECQ (max) of 50GBASE-LR from 3 dB to 3.2 dB.
  - In Table 139-7, change "Stressed receiver sensitivity ... (max)" of 50GBASE-FR from -5.5 dB to -5.3 dB.
  - In Table 139-7, change "Stressed receiver sensitivity ... (max)" of 50GBASE-LR from -6.8 dB to -6.6 dB.
  - In Table 139-7, change " Stressed eye closure for PAM4 (SECQ)" of 50GBASE-FR from 2.8 dB to 3 dB.
  - In Table 139-7, change "Stressed eye closure for PAM4 (SECQ)" of 50GBASE-LR from 3 dB to 3.2 dB.
  - In Table 139-7, change foot note "c" from "... SECQ up to 2.8 dB for 50GBASE-FR and 3 dB for 50GBASE-LR." to "... SECQ up to 3 dB for 50GBASE-FR and 3.2 dB for 50GBASE-LR."
  - In Table 139-8, change "Power budget" of 50GBASE-FR from 7.2 dB to 7.4 dB.
  - In Table 139-8, change "Power budget" of 50GBASE-LR from 9.9 dB to 10.1 dB.
  - In Table 139-8, change "Allocation for penalties" of 50GBASE-FR from 3.2 dB to 3.4 dB.
  - In Table 139-8, change "Allocation for penalties" of 50GBASE-LR from 3.6 dB to 3.8 dB.
  - In 139.7.9, change "... SECQ up to 2.8 dB" to "... SECQ up to 3 dB" for 50GBASE-FR .
  - In 139.7.9, change "... SECQ up to 3 dB" to "... SECQ up to 3.2 dB" for 50GBASE-LR.
  - In 139.7.9, change Figure 139-6 so that curves include SECQ of 3 dB and 3.2 dB for 50GBASE-FR and 50GBASE-LR, respectively.

Summary

- Recommendation to accept in principle comments r03-22 and r03-42. Required changes in D3.3 are described below, where differences with the original comments are in red.
  - In Table 140-6, change "TDECQ (max)" of 100GBASE-DR from 3 dB to 3.4 dB.
  - In Table 140-7, change "stressed receiver sensitivity ... (max)" of 100GBASE-DR from -2.3 dB to -1.9 dB.
  - In Table 140-7, change foot note "c" from "... SECQ up to 3 dB." to "... SECQ up to 3.4 dB."
  - In Table 140-7, change the "Stressed eye closure for PAM4 (SECQ)" from 3 dB to 3.4 dB.
  - In Table 140-8, change "Power budget" of 100GBASE-DR for extinction ratio >= 5 dB from 6.1 dB to 6.5 dB.
  - In Table 140-8, change "Power budget" of 100GBASE-DR for extinction ratio < 5 dB from 6.4 dB to 6.8 dB.
  - In Table 140-8, change "Allocation for penalties" of 100GBASE-DR for extinction ratio >= 5 dB from “6.1 dB minus …” to “6.5 dB minus …”.
  - In Table 140-8, change "Allocation for penalties" of 100GBASE-DR for extinction ratio < 5 dB from “6.4 dB minus …” to “6.8 dB minus …”.
  - In 140.7.9, change "...SECQ up to 3 dB" to "...SECQ up to 3.4 dB“.
  - In 140.7.9, change Figure 140-5 so curve includes up to SECQ of 3.4 dB.

Additional 100G-PAM4 EML Measurements

- ~10dB link budget is obtainable with TDECQ - 10Log(Ceq) > 3.5dB.
- As MPI is added beyond the spec, Rx Sensitivity degrades only < 1.4dB as TDECQ degrades >>4dB.
- High TDECQ does not demonstrate a “cliff” in Rx Sensitivity as long as the SNR maintains a BER floor < 1E-4
- Requiring distributions at +-0.05 UI to support threshold offset inaccuracies is similar to creating a square, instead of a diamond, mask margin.

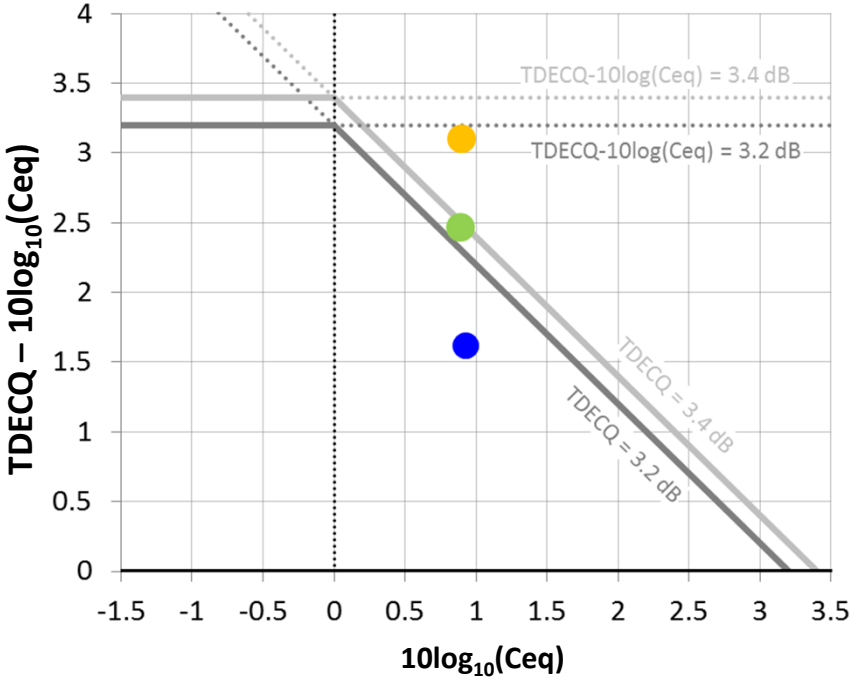


MPI (dB)	TDECQ w/ SSPRQ (dB)	10log(Ceq) (dB)	SECQ PRBS15 (dB)	Rx Sens OMA (dBm)	Rx Sens OMA - TDECQ (dBm)	BER Floor
NA	2.89	-0.39	2.28	-8.70	-11.59	3.6E-06
	4.04	0.40	2.70	-7.70	-11.74	1.7E-06
	5.50	0.00	3.15	-6.83	-12.33	3.0E-05
-29	6.68	0.00	3.50	-6.80	-13.48	5.0E-05
-23	13.00	0.00	7.60	-6.35	-19.35	7.2E-05

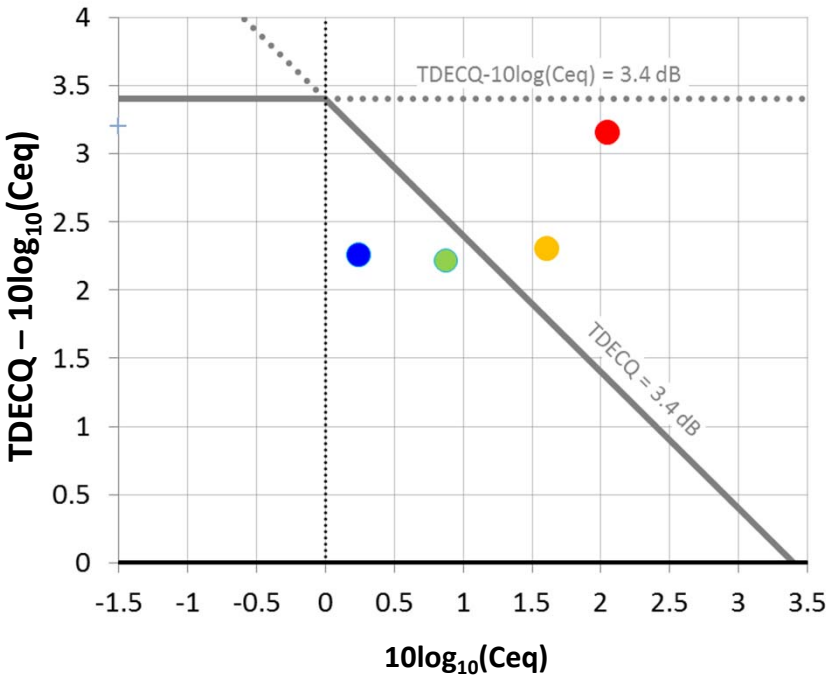
Contributed by Source Photonics.

Consideration Of TDECQ - $10\log_{10}$(Ceq)

For Oclaro 50G-PAM4 DML Data



For Oclaro 100G-PAM4 EML Data



Note: Marker colors correspond to curves on Slides 7 and 9.

Observations:

1. TDECQ – $10\log_{10}$(Ceq) < TDECQ (max) is one way to exclude cases where higher error floor was observed, though, for DML, case shown in green screened out by just TDECQ (max) of 3.2 dB.

Transition Time Of 50G-PAM4 DML

Observations:

1. Transmitter transition time of DML was much less than maximum specification of 34 ps for 50GBASE-FR/LR.

Contributed by Oclaro.