Optical Link Test Results and Refinement

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Introduction

- Limiting the number of receiver precursors helps to reduce module power and improve link performance given power constraint [sun_3cd_01a_0518]. Precursor constraint for 100GBASE-DR was added in May meeting. This contribution is for 50GBASE-FR and 50GBASE-LR.

- TDECQ and corresponding receiver BER are measured on a test bench. Preliminary results on link performance and receiver complexity are presented.

Fiber Dispersion Spec for 50G

Table 139–12—Fiber optic cabling (channel) characteristics

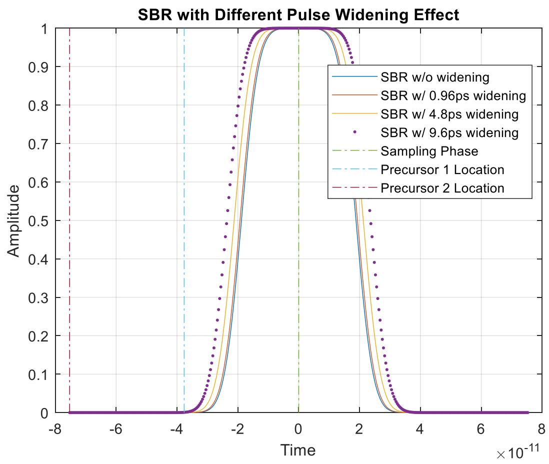
Description	50GBASE-FR	50GBASE-LR	Unit
Operating distance (max)	2	10	km
Channel insertion loss[a, b] (max)	4	6.3	dB
Channel insertion loss (min)	0	0	dB
Positive dispersion[b] (max)	3.2	16	ps/nm
Negative dispersion[b] (min)	–3.7	–18.6	ps/nm
DGD_max[c]	3	8	ps
Optical return loss (min)	25	22	dB

[a]These channel insertion loss values include cable, connectors, and splices.
[b]Over the wavelength range 1304.5 nm to 1317.5 nm for 50GBASE-FR and 50GBASE-LR.
[c]Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

Fiber Dispersion Impact on Precursor

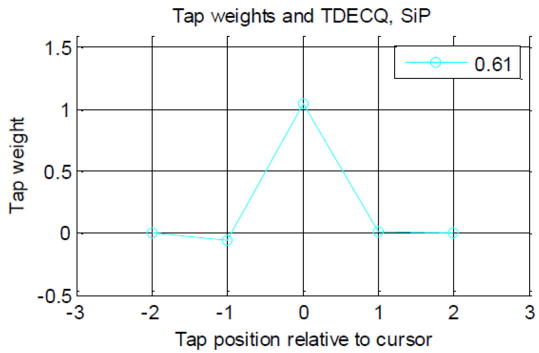
- Side band for 50G PAM4 is about 0.14nm. Total spectral width of DML is measured to be about 0.3nm at -3dB including chirp, worst case pulse widening is 0.96ps for 50GBASE-FR, and 4.8ps for 50GBASE-LR.

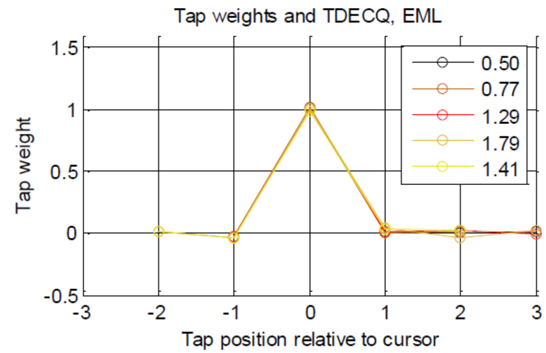
- For a Gaussian shape single bit response (SBR) with Nyquist Bandwidth, pulse widening effect is negligible for 50GBASE-FR and very small for 50GBASE-LR. Even assuming a 9.6ps widening (0.6 nm spectral width), widening effect is still small compared to 1 UI.

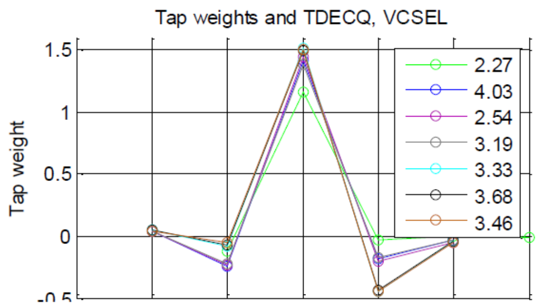


Dispersion impact on precursor 2 is minimal for 50GBASE-FR and 50GBASE-LR.

TDECQ Measurement Results





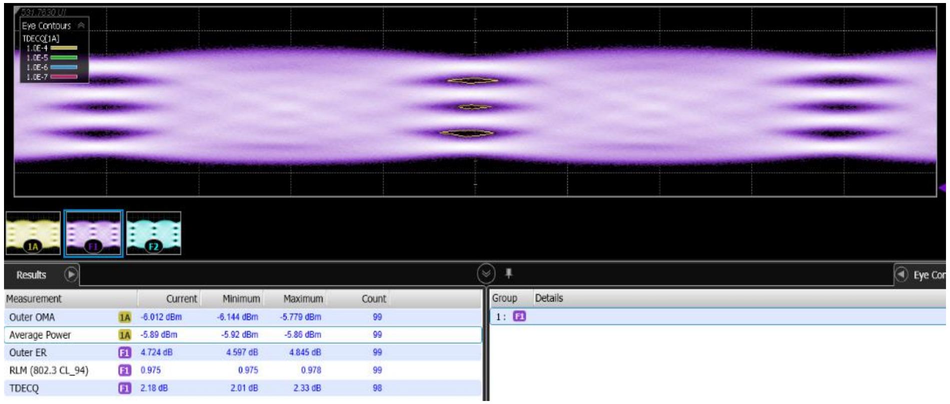


- Main tap is in position 2 or 3
- Not position 1
- Solid circle shows larger of the two end taps

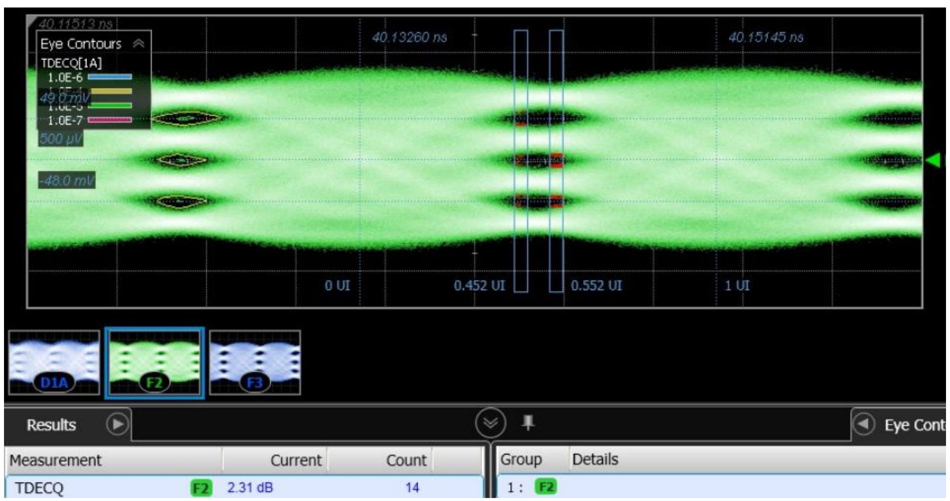
[dawe_3cd_01a_0518]

- More TDECQ measurement results for different transmitters have been reported recently.
- For SiPh, TDECQ is way below the threshold. Maximum weight of precursor 2 is only 0.5% of the main cursor.
- For EML, maximum precursor 2 weight is only 1% of main cursor.
- For VCSEL, TDECQ is on the high end. Maximum precursor 2 is 3.6% of main cursor. Postcursor 2 weight for the same transmitter is about 2.9%.
  - If TX FIR is applied to cover precursor 2, postcursor 3 will be covered and TDECQ should be lower. If 3.6% precursor 2 is not covered by FFE and postcursor 3 is assumed to be 1.9% (half of post 2) for the same transmitter, TDECQ will be about **0.1 dB** higher even if a VCSEL transmitter choose not to implement TX FIR and not to increase bandwidth in the future.

TDECQ and BER Measurement

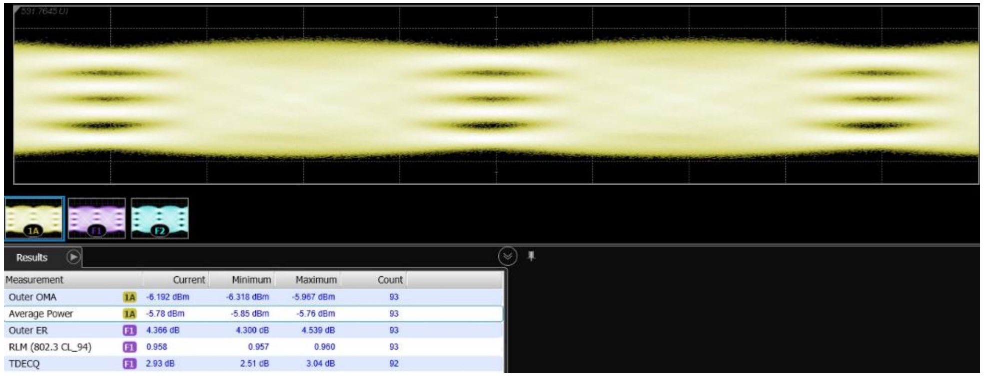


Baud Rate=53.125G, PRBS13Q Pattern
Transmitter TDECQ=2.18dB
FFE coefficients = [0.044 0.983, 0.008, -0.007, -0.028]

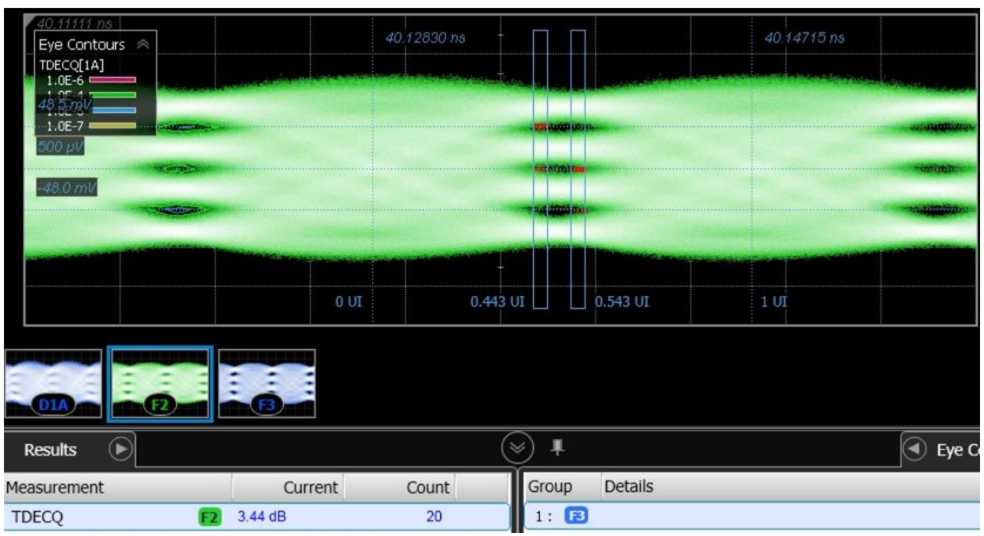


5-tap FFE is configured on scope as receiver.
BER contour shows slightly better than 1e-5. "TIA Output TDECQ" value is 2.31dB, corresponding to 9.21e-6 (assuming ideal slicer).
FFE coefficients = [-0.037, 0.993, 0.165, -0.0896, -0.030]

TDECQ and BER Measurement

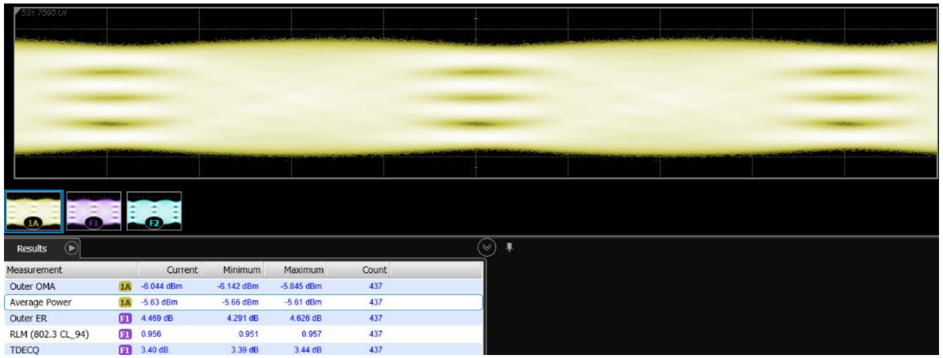


Baud Rate=53.125G, PRBS13Q
By adding post tap 6 on of TX FIR, Transmitter TDECQ is adjusted to 2.93dB.
FFE = [0.983, 0.026, 0.010, 0.004, -0.023]



BER contour shows around 1e-5. “TIA Output TDECQ” value is 3.44dB, corresponding to 4.8e-5 (assuming ideal slicer).

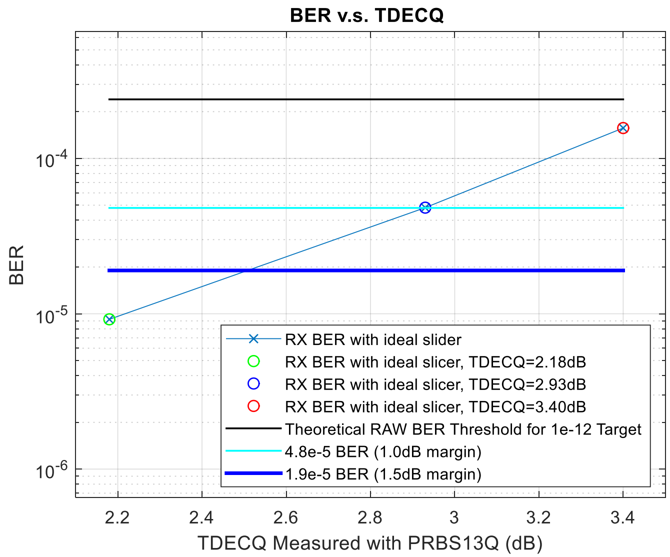
TDECQ and BER Measurement



By adding post tap 6 on of TX FIR, Transmitter TDECQ is adjusted to 3.40dB
FFE = [0.011, 0.981, 0.015, -0.001, -0.006]

BER contour shows around 1e-4. "TIA Output TDECQ" value is 5.98dB, corresponding to 1.60e-4 (assuming ideal slicer).

TDECQ and BER Measurement Results



- Theoretically BER needs to be better than 2.4e-4 to achieve 1e-12 target. Extra margin is needed for possible burst error penalty of KP4 FEC, CDR implementation noise, system imperfection/variation, and etc.

- As test pattern is PRBS13Q, TDECQ measured on SSPRQ will be worse (The difference seems to be around 0.5dB based on some 802.3bs presentations. Need measurement to confirm).

- For 2.5dB and 2.9dB TDECQ with PRBS13Q pattern (likely 3.0dB and 3.4dB TDECQ with SSPRQ), margin for CDR receiver is about 1.5dB (20log10) and 1.0dB. Receivers need to do better than 5-tap FFE for extra margin. Receiver complexity and power constraint will be a challenge.
  - Precursors are much more costly on RX than on TX. Taking care of precursors by TX side as much as possible helps receiver power, and better overall performance by allocating power more effectively.

  - A stronger FEC can help relax both transmitter and receiver.

Conclusions

- Receiver complexity and power is a challenge to achieve sufficient design margin and support transmitters with higher TDECQ. As FEC is unlikely to change at this stage of standard development, refinement to avoid unnecessarily forcing high power implementation is important. As a result, better equalization can be achieved.

- Dispersion impact on precursor 2 is minimal for 50GBASE-FR and 50GBASE-LR. Device bandwidth will improve and receiver will not need heavy precursor 2 for good links. But current standard allows transmitters to create precursor 2, forces real receivers to implement expensive multiple precursors to ensure interoperability (to be standard compliant), and causes module power to stay high forever.

- To allocate receiver power more efficiently for better equalization and enable broader implementations, we propose

  #1. Limit the number of TDECQ FFE precursors to one for 50GBASE-FR

  #2. Limit the number of TDECQ FFE precursors to one for 50GBASE-LR

  Potential extra stress on existing low-bandwidth transmitters without TX FIR is about 0.1dB. Therefore consider relax TDECQ by 0.1dB.

Thanks!