TDECQ Reference FFE Constraints Regarding Comment r03-47 and r03-37

Phil Sun, Credo

IEEE 802.3cd Task Force, San Diego, July 2018

Supporters

- Piers Dawe, Mellanox
- Johan Jacob Mohr, Mellanox

Introduction

- Limiting the number of receiver precursors helps to reduce module power and improve link performance given power constraint [sun_3cd_01a_0518]. This contribution discusses precursor 2 constraint for 50GBASE-FR (some analysis also covers 50GBASE-LR).

- Changing TDECQ EQ from 5-tap T/2-spaced to T-spaced FFE, and adding threshold adjustment are good for transmitter yield. As a consequence, it also requires more complicated receivers to cover more ISI and nonlinearity. Removing precursor2 relieves complexity pressure of receivers to some extent.

- For the same transmitter, over boosting TX FIR reduces TDECQ value at a cost of signal DC swing and may cause link margin issue for receivers. This contribution explores whether a TDECQ EQ constraint can solve this issue.

Fiber Dispersion Spec

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 Chromatic Dispersion Impact

- DML output spectral width of a DML is measured to be about 0.3nm at -3dB and 0.6nm at -20dB including chirp.

- As a first-order estimation, 0.3nm spectral width results in 0.3*3.2=0.96ps pulse widening for 50GBASE-FR, and 4.8ps for 50GBASE-LR. Roughly 0.48ps and 2.4ps for leading edge. Even if taking 5 times of these pulse widening numbers as worst case, chromatic dispersion impact on precursor is 2.4ps for 50GBASE-FR, and 12.8ps for 50GBASE-LR, which are small compared to one UI (37.6ps).

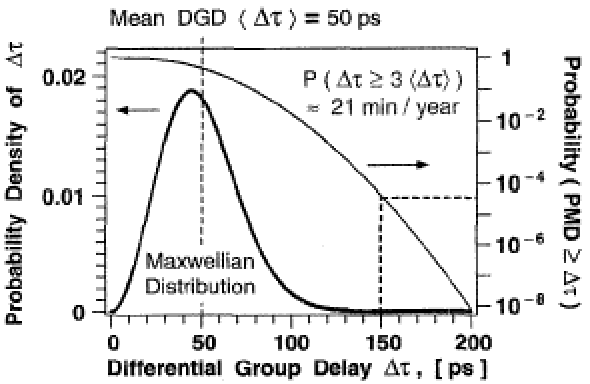
- Optical waveforms of DML are also being collected to study the impact of chirp and dispersion.

Chromatic dispersion impact on precursor 2 is minimal for 50GBASE-FR, and small for 50GBASE-LR.

Polarization Mode Dispersion (PMD) Impact

- A question was raised in ad hoc meeting that polarization mode dispersion may impact precursors.
- For “modern fibers” in the last century, mean differential group delay (DGD) for 2km and 10km fiber is 0.14 and 0.32 ps. Actual DGD may vary, and 4*sigma is within about 0.56 and 1.28ps. [1]

Fiber Type	Mean DGD Coefficient $\langle \Delta\tau \rangle / \sqrt{L}$	Average DGD for $L = 625$ km
Modern Low PMD	≤ 0.1 ps / √ km	2.5 ps
Older High PMD	~ 2 ps / √ km	50 ps

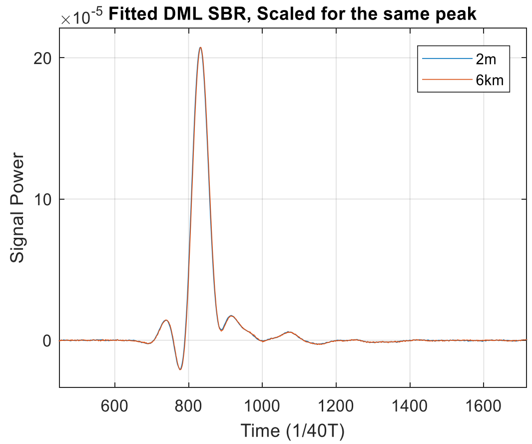


- PMD spec can also be found in public fiber product information. For example, PMD is specified as less than 0.06ps/sqrt(km) for a widely used SMF28.
- 802.3cd specifies DGD_max as 3ps for 50GBASE-FR, and 8ps for 50GBASE-LR. Suppose half will be on precursors, These numbers are small compared to 1 UI especially for 50GBASE-FR.

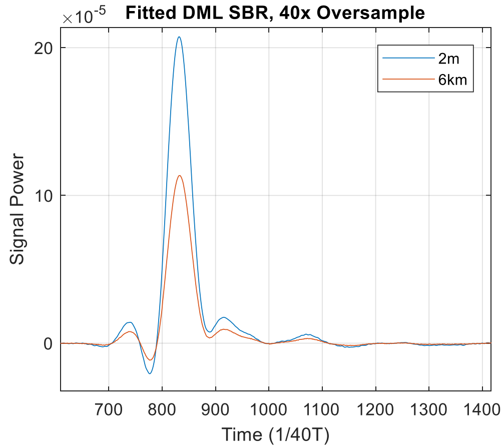
Polarization mode dispersion impact on precursor 2 is minimal for 50GBASE-FR and small for 50GBASE-LR.

[1] Fred Heismann, “Tutorial: Polarization mode dispersion_ Fundamentals and impact on optical communication systems,” *ECOC*, 1998.

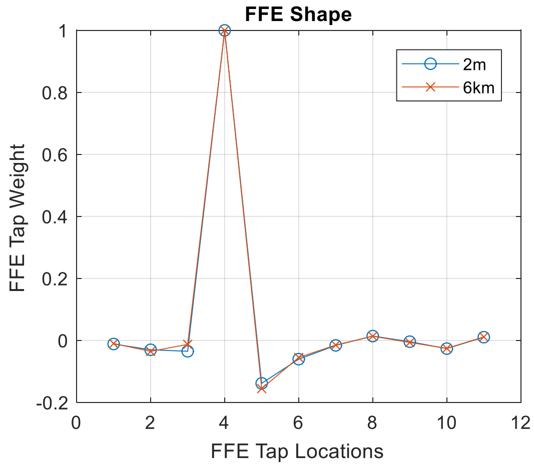
Dispersion on Pulse Response



Scaled Single Bit Response



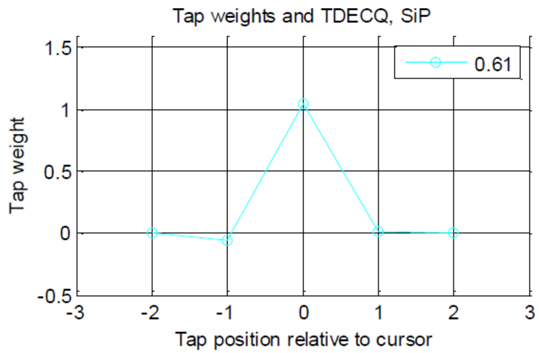
Single Bit Response

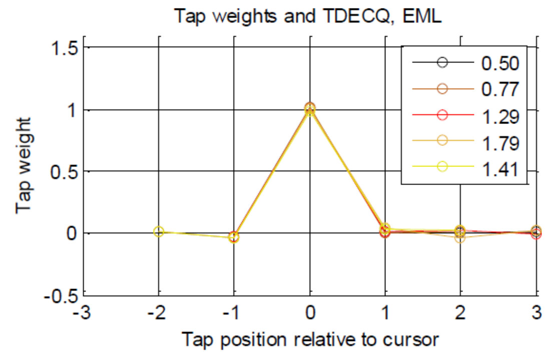


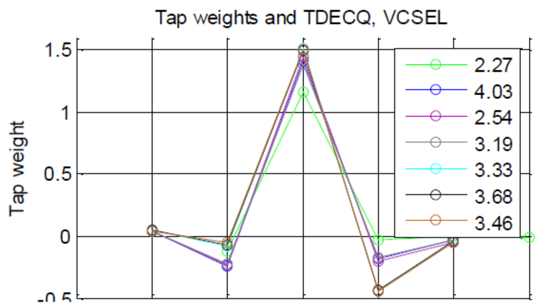
FFE Shape

- A test bench is built to spot check dispersion impact.
- Sigle bit responses are extracted for DML. A 6km fiber is used to stress dispersion.
- SBR curves show some loss of 6km cable box. After scaling to the same peak, two SBR are very close.
- FFE precursor 1 and postcursor 1 has some difference. Difference of precursor 2 is only about 0.5%.

More 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.

Conclusions

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

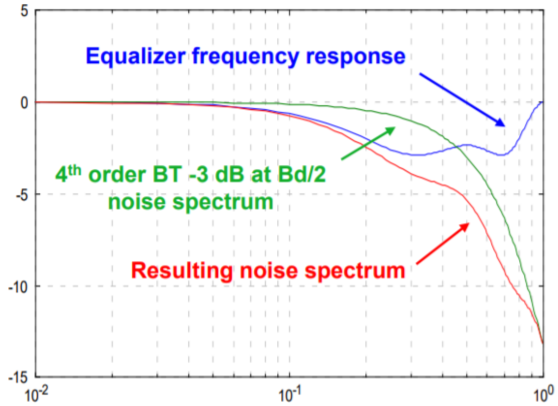
- To allocate receiver power more efficiently for better equalization and enable broader implementations, we propose:

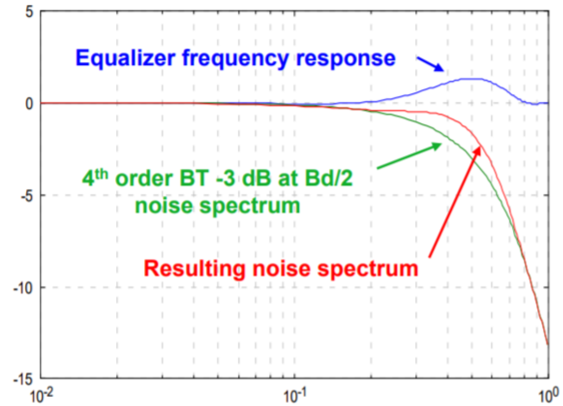
Limit the number of TDECQ FFE precursors to one for 50GBASE-FR

Thanks!

TDECQ ISSUE with TX FIR Over Boost

- For the same transmitter, lower TDECQ can be achieved at cost of lower signal DC swing by over boosting TX FIR [dawe_3cd_01a_0518]. The reason is TDECQ reference FFE will be low pass and suppresses noise.





[Noise spectrum w/ different TDECQ FFE Shaping [anslow_062718_3cd_adhoc]

- TIA response may have a dip at location post 1 as a result of bandwidth enhancement. On receiver side over boosted signal will worsen this dip of TIA response and cause equalization difficulty of some receivers.

- As the problem is caused by a low-pass reference FFE, limiting TDECQ reference FFE to high pass seems a solution for this problem.

- For FFE tap weights on page 7, none of them is really low pass. This constraint should be safe.