Proposed TDECQ Change in Clause 138.8.5*

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Supporters

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- Sudeep Bhoja, Inphi
- Ed Ulrichs, Source Photonics
- David Piehler, Dell EMC
- Kohichi Tamura, Oclaro
- Ali Ghiasi, Ghiasi Quantum
- Samuel Liu, Nokia
- Robert Lingle, Jr., OFS
- …… (TBD)

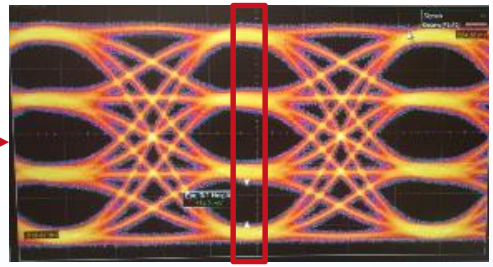
Problem statement (1)

- P802.3cd D2.1 Clause 138.8.5 and Table 138-8 define new TDECQ specs for SR1/2/4 but no actual tests under MMF reported so far.
  - All TDECQ tests posted are based on either LN MZM or EML for SMF.
- Currently defined 5 T-spaced equalizers are much simpler than actual chip implementations prevailing by industry, so making TDECQ specs still more stringent.
  - All 26.5GBd PAM4 DSP ASICs have implemented 9 or more T-spaced taps.
  - The situation with 53GBd PAM4 DSP ASICs could be only more complicated.
  - Unavoidably many “bad” TOSAs are still able to maintain the link closed.
- There are already efforts (e.g. way_3bs_01a_0517.pdf, way_3bs_01a_0717.pdf) to explore relaxing further TDECQ specs by:
  - Increase tap numbers, or,
  - Adjust filter BW, or,
  - Increase TDECQ value or,
  - Select different test pattern

Problem statement (2)

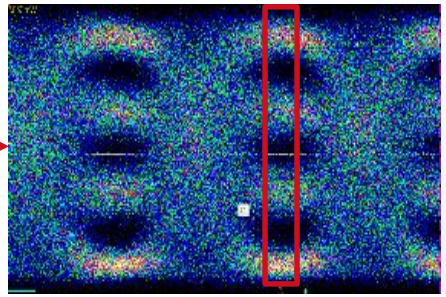
- Laser characteristics with direct modulation cause seriously skewed waveform.
  - Such non-linearity compensation can be readily implemented in PAM4 RX DSP and/or driver devices.
  - However, this is not defined in current TDECQ methodology possibly resulting in unrealistic & larger TDECQ values.

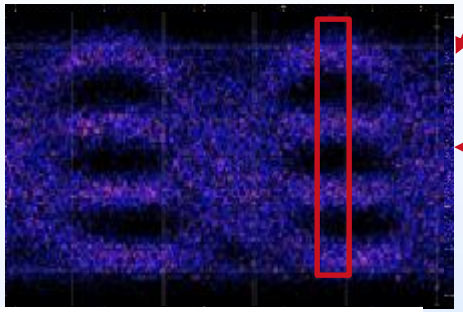
PAM4 output (elec)



One serious problem for directly modulated lasers: Amplitude-dependent skews with PAM4 eyes

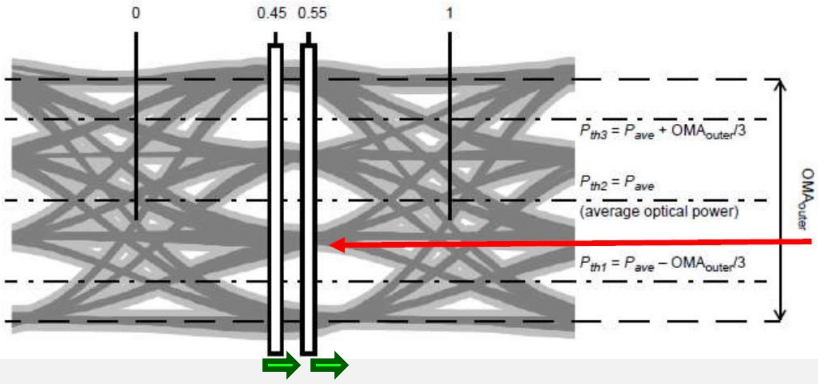
EML output (Optical)





VCSEL output (Optical)

Current TDECQ Methodology



$$TDECQ = 10\log_{10}\left(\frac{OMA_{outer}}{6} \times \frac{1}{Q_t R}\right)$$

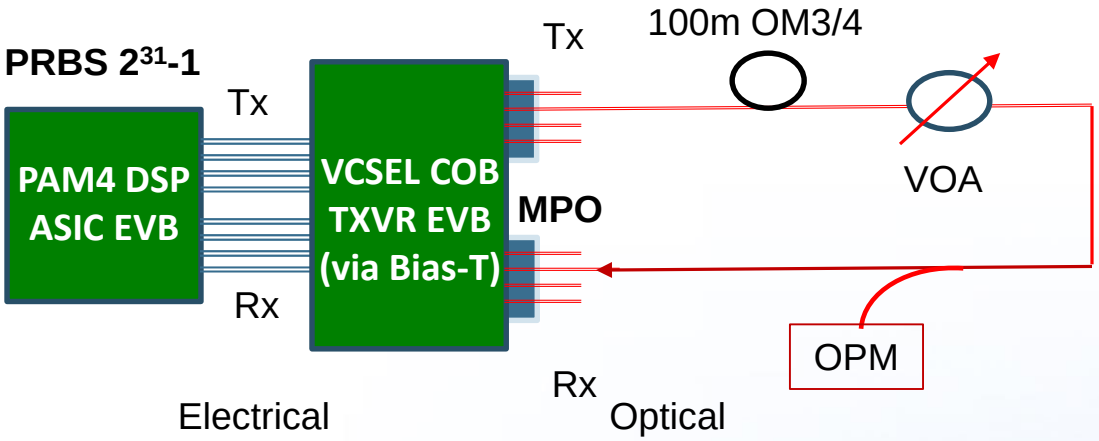
Where:
Qt = 3.414 (target SER)
R = noise term

Targeted samples on PAM-4 eye diagram.

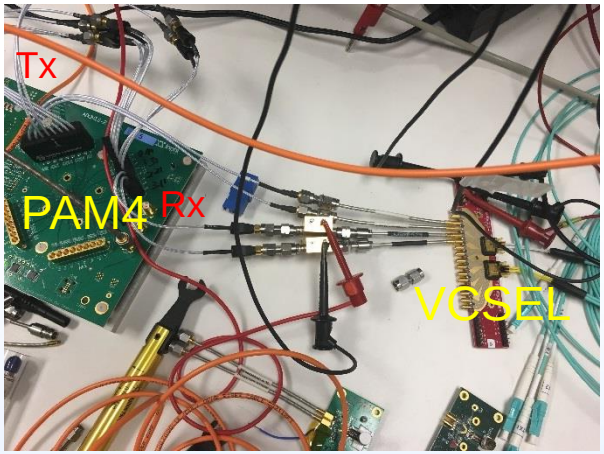
Note:
The proposal to allow the overall sampling timing to move may not align skews independently between 3 PAM4 eyes

VCSEL/MMF Measurement Setup

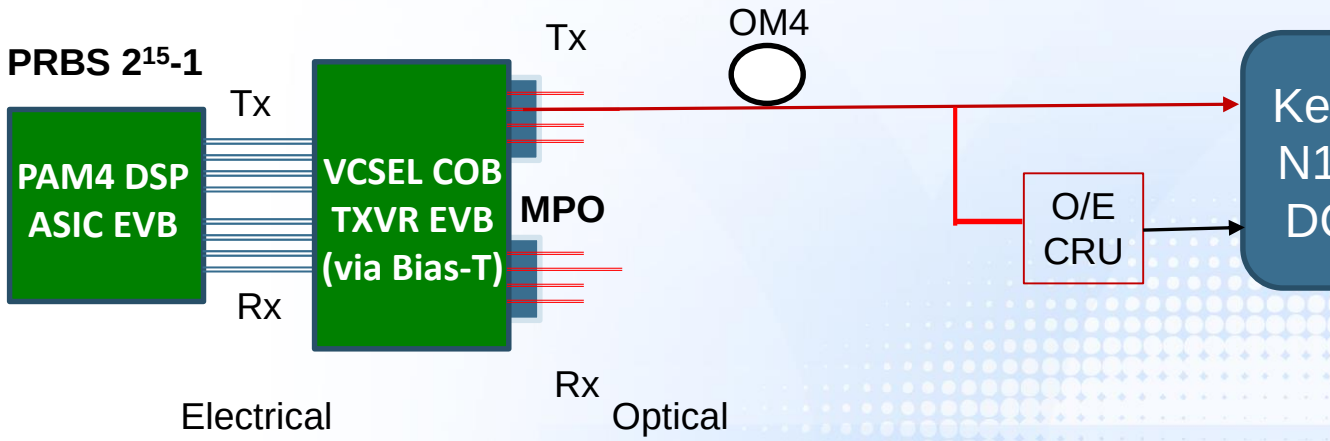
- Setup for BER test after 100m OM3 and OM4



Setup photo



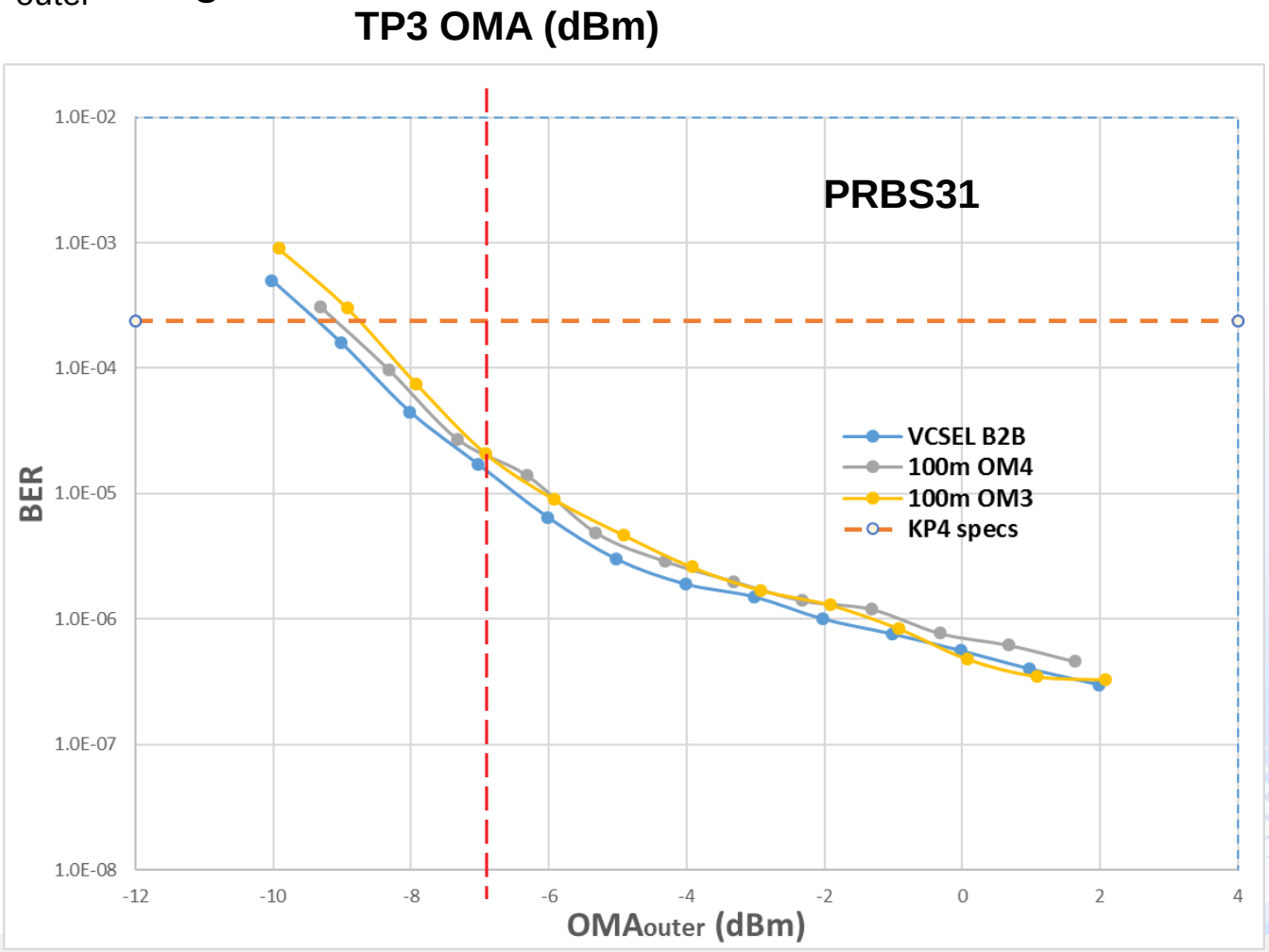
- Setup for TDECQ (no test fiber needed)



TX Optical PAM4 Eye diagram and TDECQ

BER versus OMA

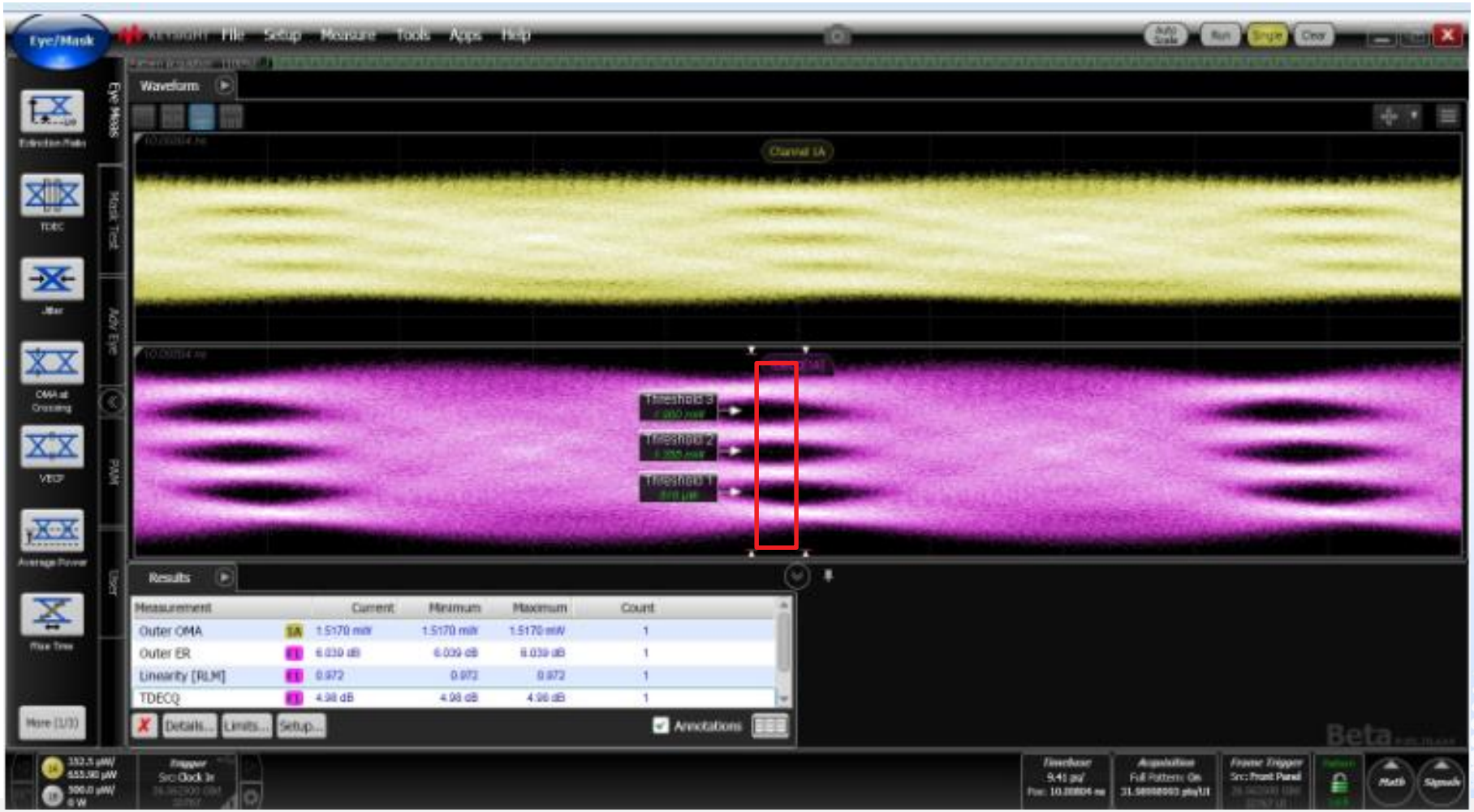
- Test results of directly modulated VCSELs – pass with sufficient BER and OMA_{outer} margin.



Example of VCSEL/OM4 TDECQ waveforms

VCSEL Transmitter (P802.3cd D2.1, 5 T-spaced at 11.2GHz)

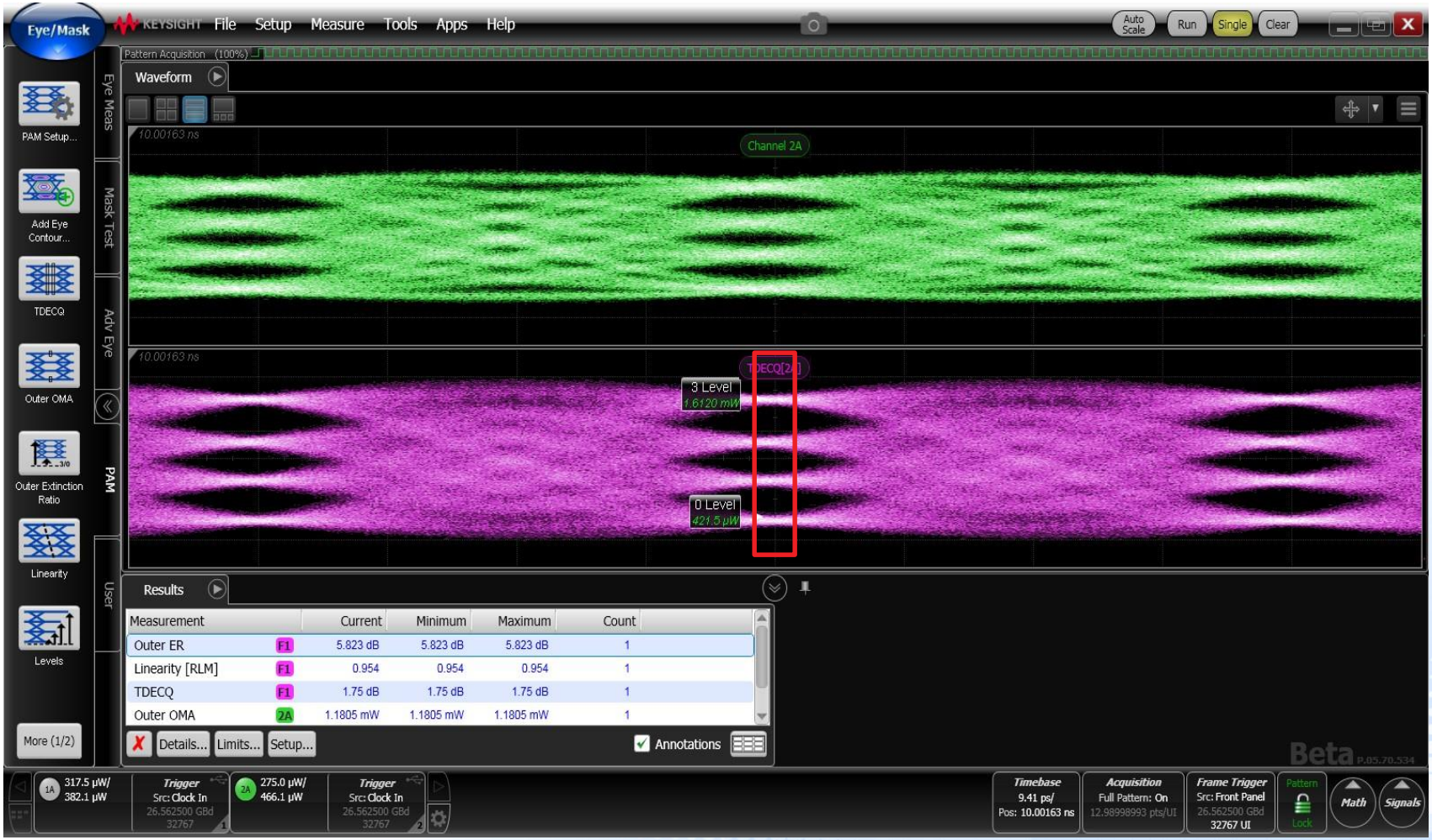
- Use PRBS15 pattern as SSPRQ is not available



Comparing against EML TDECQ waveforms (example)

For reference to EML Transmitter (P802.3bs D3.3, 5 T-spaced at 13.28GHz)

- Use PRBS15 pattern as SSPRQ is not available



Corresponding TDECQ using PRBS15

Directly modulated VCSEL Transmitter

- Use PRBS15 pattern as SSPRQ is not available for now
- Future PAM4 TX could implement more stressed SSPRQ as user define pattern

- New 802.3cd D2.1 definitions (5 T-spaced at 11.2GHz)

TDECQ (dB)	Filter 11.2GHz	Filter 12.6GHz	Filter 13.28GHz (Nyquist)	Filter 15.5GHz	Filter 19.3GHz (75%)	802.3cd D2.1 specs
5 taps	5.60	5.29	4.92	4.44	5.12	<4.9dB (each lane)
7 taps	5.12	4.90	4.71	4.65	4.65	
9 taps	4.52	4.23	4.11	4.12	4.12	

Keysight Scope processing (beta version)

- Comments:
  - Much larger TDECQ variation (~1-1.5dB) for 5 taps, versus ≤ 0.5 dB for 7-9 taps.
  - PAM4 DSP ASICs have implemented 9 or more T-spaced taps
  - The modulation BW of directly modulated VCSELs normally limits to ~18GHz at optimum biasing current, and drops dramatically near threshold currents, resulting in seriously skewed PAM4 eyes (amplitude dependent).
  - PAM4 chip implementation may readily incorporate non-linear compensation for vertical eye skews.

Summary & recommendation

- Current TDECQ specs cause unnecessary yield loss of VCSEL-based transmitters, so is less practical.
- We propose to change Clause 138.8.5 for:
  - Reference equalizer from “5 tap, T spaced” to “7-9 tap, T-spaced”
    - Note tests with 7-9 tap also show much better TDECQ stability than 5 tap.
  - 4th-order Bessel-Thomson filter response from a bandwidth of “11.2GHz” to either “12.6GHz” or “13.28GHz”.
    - 13.28GHz (Nyquist) is more consistent with the filter definition for all other SMF PMDs.
- Amplitude-dependent skews in PAM4 eye openings call for the need of non-linear compensation.
  - This could apply to directly modulated VCSELs and DFBs.
  - The proposal to allow overall sampling timing window to move (but not independently between the 3 eyes) may help, but whether it will fully resolve the issue or not remain to be seen.