Proposed TDECQ Change in Clause 138.8.5*

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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. <u>way 3bs_01a_0517.pdf</u>, <u>way_3bs_01a_0717.pdf</u>) 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.



VCSEL/MMF Measurement Setup

Setup for BER test after 100m OM3 and OM4





Setup for TDECQ (no test fiber needed)



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BER versus OMA

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



TP3 OMA (dBm)



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

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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

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| | | Outer OMA | 2A | 1.1805 mW | 1.1805 mW | 1.1805 mW | 1 | * | | | | | | | | |
| More (1/2) | | X Details Limits | Setup | | | | ~ | Annotations | | | | | | Bet | a | |
| 317.5 | μW/ | Trigger | 275.0 µW/ | Trigger | | | | | | | Timebase | Acquisition | Frame Trigger | Pattern | | |
| 382.1 | μW | Src: Clock In 26,562500 GBd | 466.1 µW | Src: Clock 1 26,562500 (| In SBd Jack | | | | | | 9.41 ps/ Pos: 10.00163 ns | Full Pattern: On 12.98998993 pts/UI | Src: Front Panel 26.562500 GBd | | Math) (Signa | als |
| | | 26,562500 GBd 32767 | | 26,562500 G 32767 | Bd 2 | | | | | | Pos: 10.00163 ns | 12.98998993 pts/UI | 26.562500 GBd 32767 UI | Lock | |) |



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 | <4.0dB | Keysight |
| 7 taps | 5.12 | 4.90 | 4.71 | 4.65 | 4.65 | (each lane) | Scope |
| 9 taps | 4.52 | 4.23 | 4.11 | 4.12 | 4.12 | | (beta version) |

Comments:

- Much larger TDECQ variation (\sim 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.

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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.

