Tektronix

TDECQ results is function of the 4th-order B-T filter roll-off stop frequency. We are proposing to mandate the minimum roll-off stop frequency.

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Supporters

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Abstract

- In 802.3cd, the measurement and the calculation of TDECQ require a waveform acquisition by an oscilloscope system with a 4th order Bessel-Thomson roll off compliant to infinity
- A realistic Bessel-Thomson is not compliant to infinity, rather its compliance is truncated at some realistic frequency (end-of-compliance)
- We show that the TDECQ result can be significantly impacted by the frequency at which the Bessel-Thomson filter reaches end-of-compliance
- We show that a reasonable requirement on the B-T compliance frequency reach renders this impact negligible
- We propose that in order to limit the variability of the TDECQ result between different measurement tools, the Bessel-Thomson compliance should be mandated up to at least a certain frequency
- Ditto for SECQ

Specifically: (next page)

Current instances of Bessel-Thomson in 802.3cd

- The calculation of TDECQ requires that:

  1. "The combination of the O/E and the oscilloscope used to measure the optical waveform has a fourth-order Bessel-Thomson filter response with a bandwidth of 11.2 GHz"
     [*138.8.5 Transmitter and dispersion eye closure - quaternary (TDECQ)*, line 43, 8023cd_D3p0]

  2. "The combination of the O/E and the oscilloscope has a fourth-order Bessel-Thomson filter response with a bandwidth of approximately 13.28125 GHz."
     [*139.7.5.1 TDECQ conformance test setup,* line 40, 8023cd_D3p0]

  3. "The combination of the O/E converter and the oscilloscope has a fourth-order Bessel-Thomson filter response with a bandwidth of approximately 26.5625 GHz"
     [*140.7.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)*, line 30, 8023cd_D3p0]

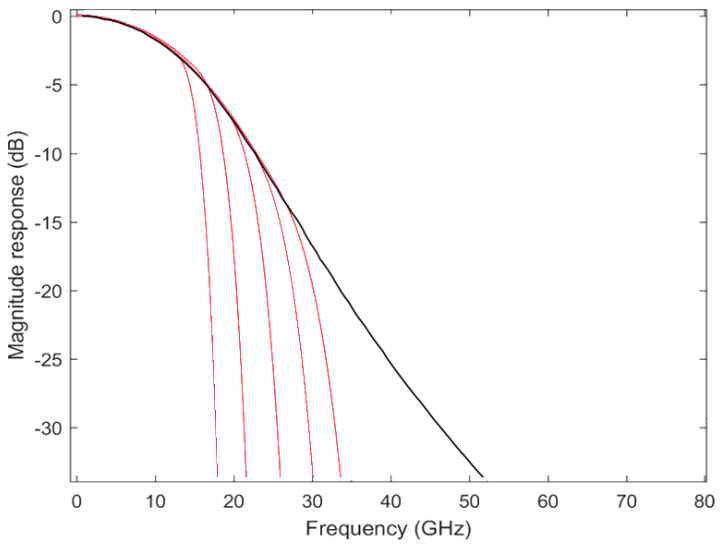
- And the calculation of SECQ requires that:

  1. "…and the oscilloscope has a fourth-order Bessel-Thomson filter response with a bandwidth of approximately 13.28125 GHz"
     [*138.8.8 Stressed receiver sensitivity*, line 26, 8023cd_D3p0]

Terms in this paper:
symbol rate: f_{Bd};
B-T: Bessel-Thomson 4^{th} order filter.

The question of end-of-compliance of the B-T

- How far (to how high a frequency) does the Bessel-Thomson filter need to comply ?
- We generated a set of B-T end-of-compliance experiments by convolving the B-T with a flat pass-band, higher order filter that was set to different increasing frequencies. The bandwidth of this flat pass-band filters is quoted below.
- Plotted below is: the nominal B-T response (of a 13.28 GHz B-T ; shown in black); and several examples of full system response of the limited B-T;



these responses with limited compliance (here showing B-T convolved with a 15, 18, 22, 26 and 30 GHz roll-off function, resp.) are plotted in red.

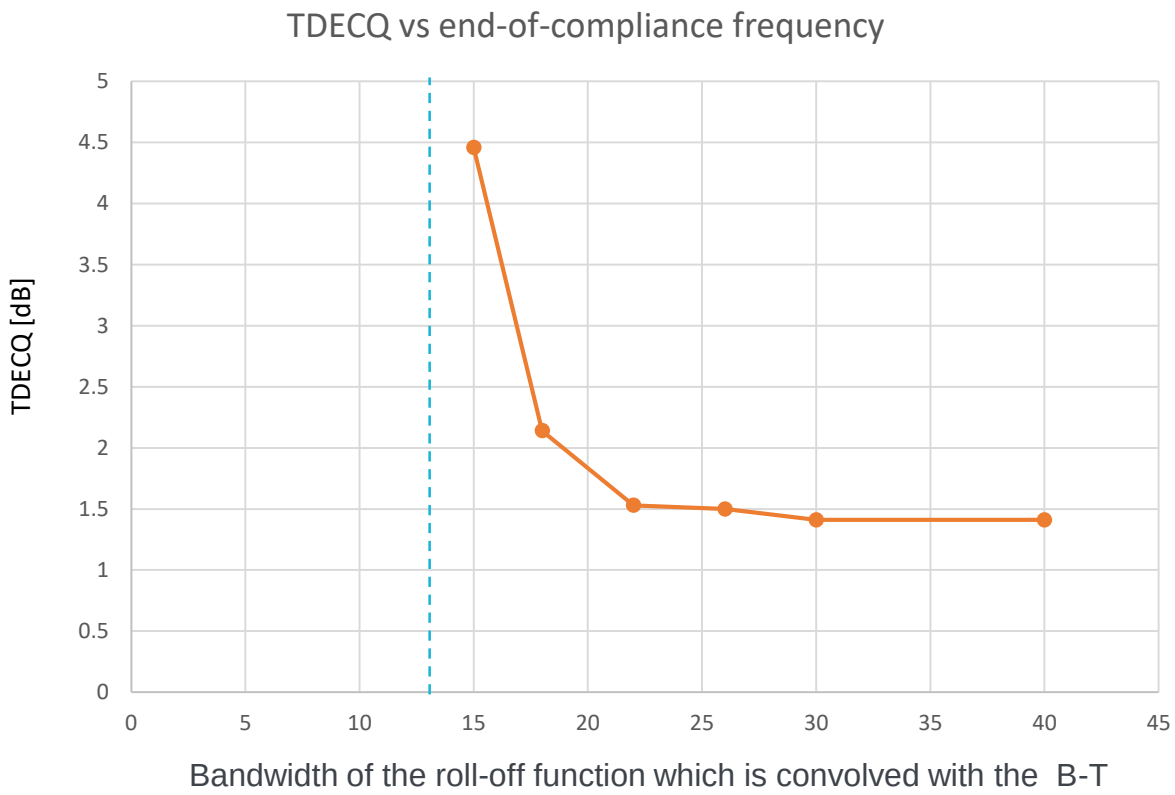
Note that the ‘end-of-compliance’ is here defined as meaning “error from compliance just reached 3 dB”.

Experiment setup

- PAM4 optical transmitter at 26.5625 GBd as signal source. SSPRQ pattern. 1310 nm.
- Signal bandwidth >> typical 26 GBd TX (we used a 53 GBd laboratory TX running at 26 GBd)
- TDECQ is using 802.3bs defined FFE (5 taps optimized for best TDECQ value with floating timing, fixed thresholds)
- No fiber, no reflective mirror
- End-of-compliance frequency of the B-T was swept from 15 GHz to 45 GHz (BW)
- All bandwidths [BW] mentioned in this document are in terms of electrical bandwidth, i.e. in the same terms as the B-T definition in 802.3*

Experiment results

Observe that the TDECQ result is nearly constant for B-T end-of-compliance frequency > 0.9 f_{Bd}



Symbol rate: f_{Bd} = 26.5625 GHz . B-T BW = 0.5 f_{Bd} (Blue dash)

Proposal

- Our experiments (see the graph on previous page) document that too low an end-of-compliance frequency of the B-T yields large penalty in TDECQ result
- It is apparent that for end-of-compliance f > 0.9 f_{Bd} there is negligible dependency of TDECQ on the end-of-compliance f of the B-T
- Based on the this we propose that the implemented B-T should be compliant to frequency equal to 1.0 f_{Bd}
  (i.e., for 26.5625 GBd the B-T should be compliant to 26.5625 GHz)
- This can be also said as
  “a B-T with bandwidth $f_{B\text{-}T}$ shall be compliant to at least 2*$f_{B\text{-}T}$.
  Such definition is similar to the requirement on B-T compliance in ITU for 10 Gb/s and faster, where B-T bandwidth is 0.75 f_{Bd} and compliance is mandated to 1.5 f_{Bd}

Conclusion

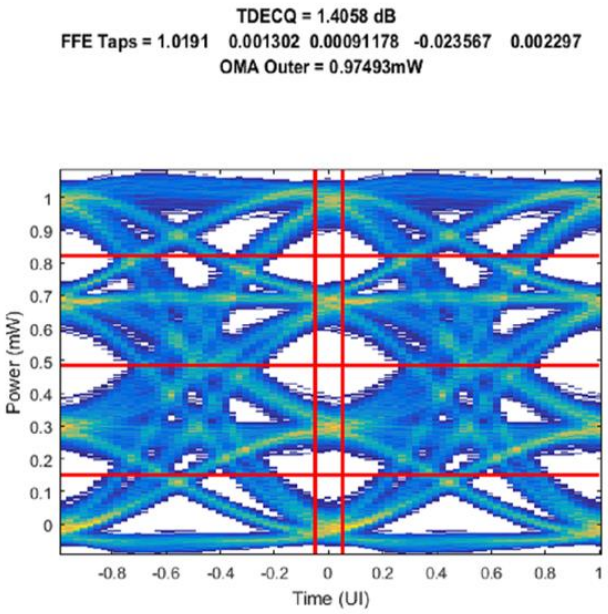
- We propose that the Bessel-Thomson reference receiver filter used in measurements of PAM4 signal should have a B-T compliant to 2x of its bandwidth.

Thank you

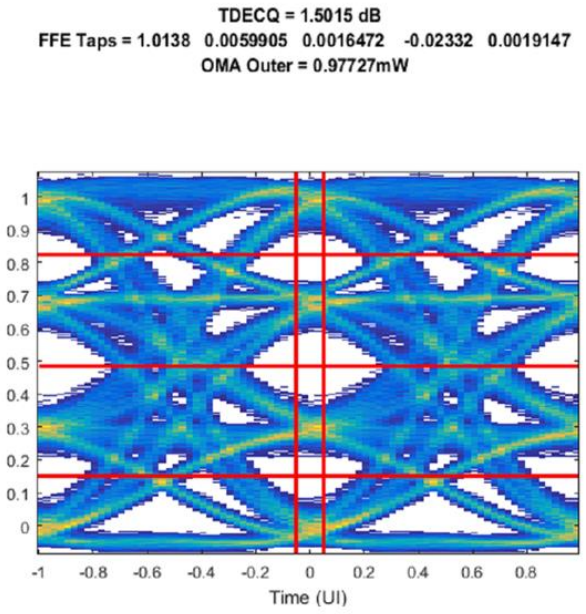
Pavel Zivny, Tek

Addendum 1: additional information: eye diagrams with limited compliance B-T after FFE

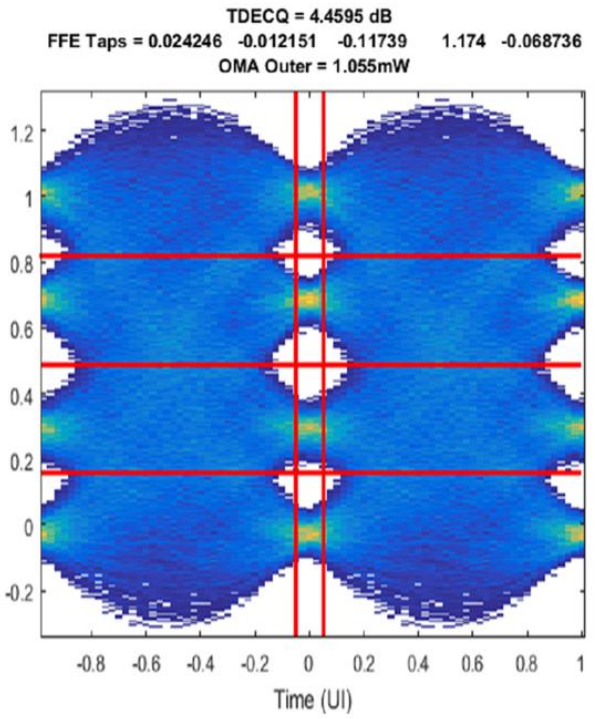
B-T end-of compliance 40 GHz



B-T end-of compliance 26 GHz



B-T end-of compliance 15 GHz



All diagrams the same input signa 26.5625 GBd. “end-of-compliance” meaning error from compliance just reached 3 dB.

Addendum 2: upper limit on filter behavior past its end-of-compliance

Some of the commenters on this proposal suggested an improvement as follows:

- This proposal, as it is, doesn’t specify what happens after the end-of-compliance frequency.
- To prevent pathological implementations it can be further proposed that the behavior after the end-of-compliance f should be controlled in this way:
- Past the end-of-compliance frequency the loss of the realized filter should be at least the larger of {the loss of an ideal B-T ; 20 dB}