Proposed reference equalizer change in Clause 124 (TDECQ/SECQ methodologies).

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P802.3bs SMF ad hoc

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Introduction

In mazzini_01a_0317_smf, some concerns about TDECQ/Sensitivity results consistency were shared.

In this updated work we'll:

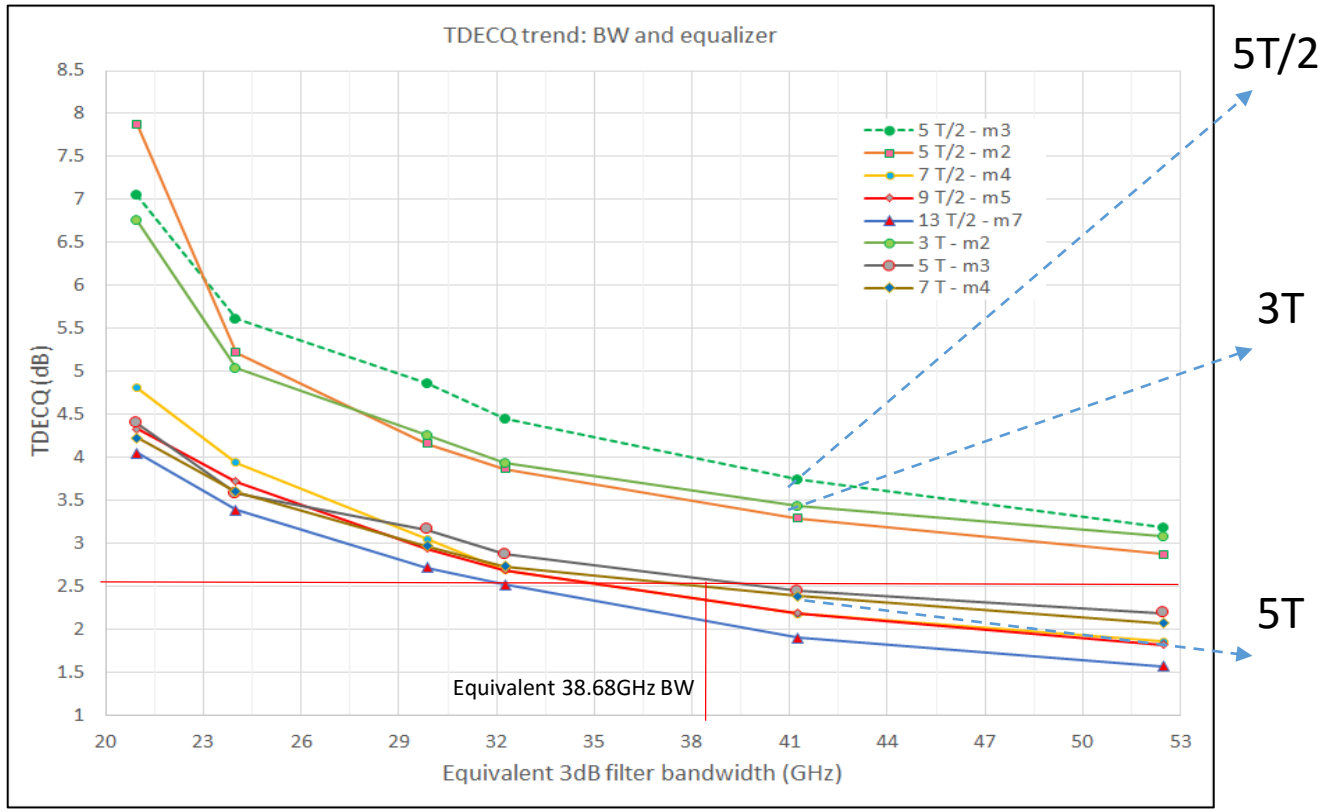
- Update TDECQ results (fixed noise BW into file's header) with Cisco Lab Tx.
- Provide feedback from different companies about:
  - TDECQ results with shared Cisco Lab Tx (PRBS11 waveforms).
  - TDECQ (max) challenges with current TX technologies, link consistency.
- Propose a change in the reference equalizer for TDECQ/SECQ methodologies of Clause 124.

We'll also address some of the questions about experiments from the previous ad-hoc.

- Effects of Phase shift on sensitivity results.
- TX impulse response.
- Sensitivity results (shared PRBS20 waveforms).

Cisco Lab Tx: TDECQ versus equalizer and bandwidth.

All TDECQ plots show similar trends for varying RX BW (see mazzini_01a_0317_smf and back-up slide 12).
Cisco Lab Tx is not compliant to TDECQ with the 5xT/2 equalizer, but is compliant with a 5xT (same complexity) equalizer.
Longer equalizers give smaller improvements (<0.5dB) in TDECQ.



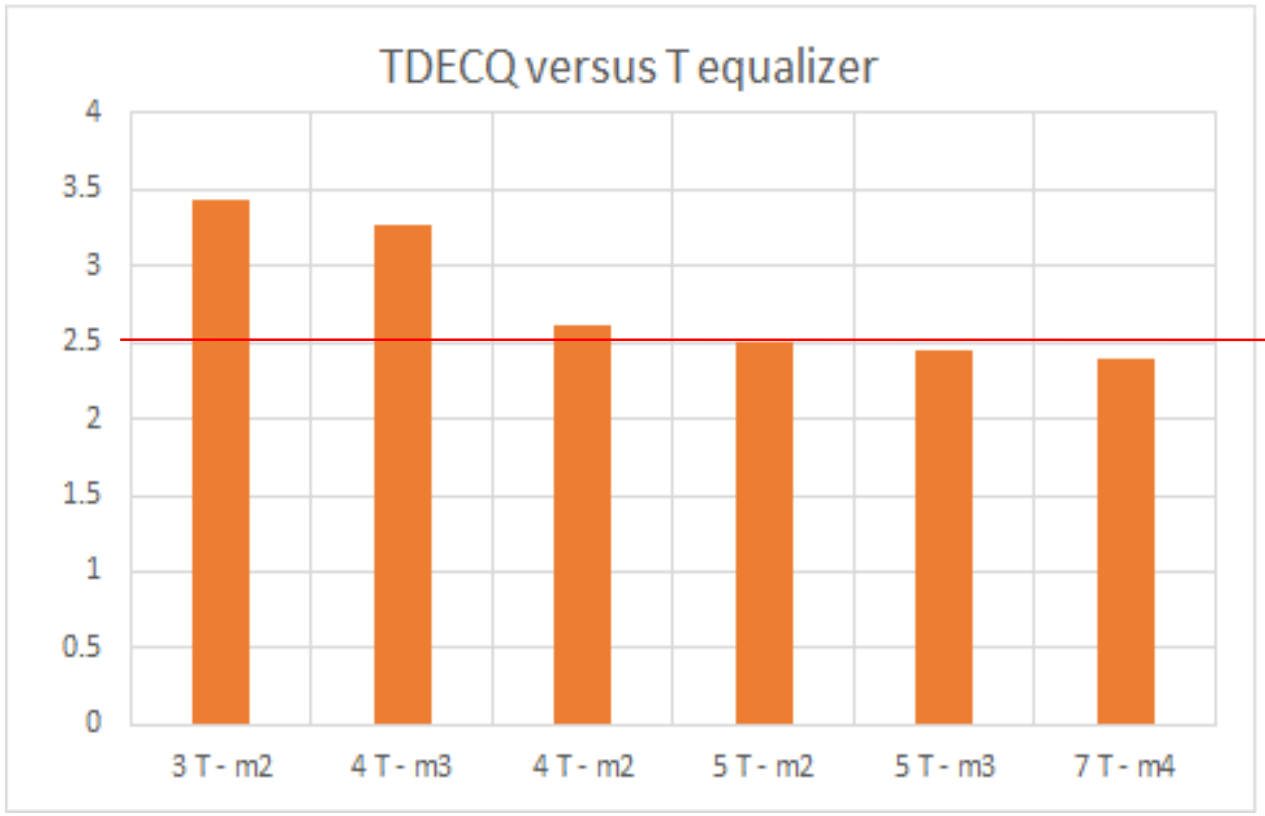
'm' is the relative main tap position (e.g. 5 T/2 – m2 is 1pre and 3post)

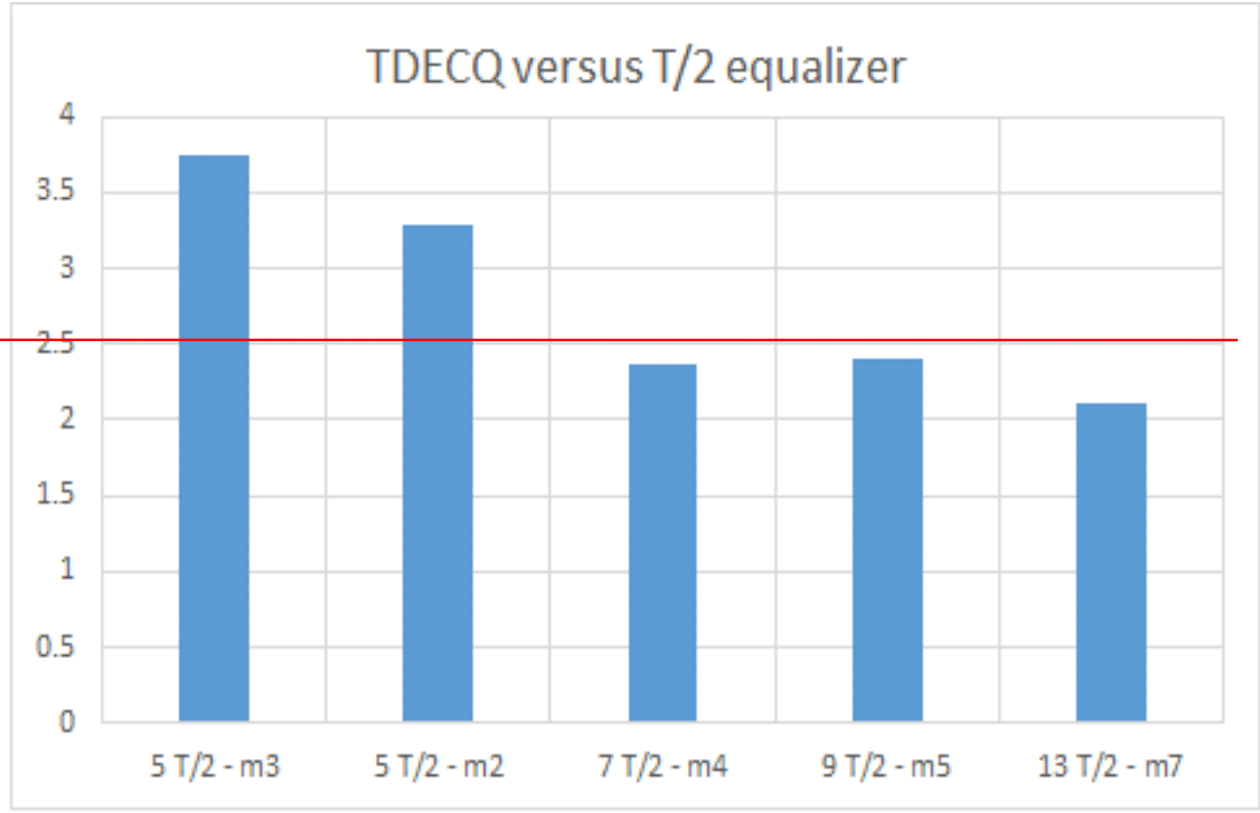
2.5dB TDECQ seems challenging to be achieved by 53GBaud transmitters.

These results have been also confirmed by other companies by using FlexDCA. When using their homemade methods to calculate TDECQ , some differences with respect FlexDCA were observed, especially for low BW/short equalizer conditions.

Cisco Lab Tx: TDECQ versus equalizer type and length

Cisco Lab Tx not compliant to TDECQ considering 5xT/2 equalizer, but is compliant for a 5xT equalizer, which is same complexity for DSP developers.
Longer equalizers than 5xT give smaller improvements (<0.5dB) on TDECQ.





'm' is the relative main tap position (e.g. 5 T/2 – m2 is 1pre and 3post)

(41.25GHz BW = 55GHz*0.75 case results)

Comments.

Presented updated TDECQ results.
From experiments, cross-verifications and discussions we can say:

1. At 53Gbaud, TDECQ < 2.5dB is hard to achieve with < 5xT equalizer.
   - Received same feedback from different sources during and after OFC.
     (Note: on Cisco's Lab TX, 7x does not provide strong TDECQ improvement).
   - Yet links can work with margin by using 7xT equalizers (see mazzini_01a_0317_smf and back-up).

2. Results using short equalizers (3xT, 5xT/2) are not a stable metric to correlate Rx BER with TDECQ: some convergence issues were exposed.
   - In line with other companies findings and with lecheminant_01_1016_smf (slides 4, 5).
   - As per mazzini_01a_0317_smf, this can cause issues for SECQ calibration.

3. 'Formally, TDECQ/SECQ signal processing should mimic what's expected for a real receiver' (king_04_0217_smf, 2), thus:
   - Multiple DSP-suppliers developing 53GBaud solutions were approached.
   - All of them confirmed that:
     a) That their ADC will sample at 1 sample per bit.
     b) That their RX equalizer will be equivalent to a 7xT (or more) T-spaced equalizer, not a T/2-spaced equalizer.

4. There's good correlation between worst case BER/TDECQ using a 5xT-spaced equalizer (mazzini_01a_0317_smf, 4).

Proposed changes for 802.3bs draft 3.2

Into 124.8.5, change:

124.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

The TDECQ of each lane shall be within the limits given in Table 124–6 if measured using the methods specified in 121.8.5.1, 121.8.5.2, and 121.8.5.3 using a reference equalizer as described in 121.8.5.4, with the following exceptions: — The signaling rate of the test pattern generator is as given in Table 124–6. — The combination of the O/E converter and the oscilloscope has a fourth-order Bessel-Thomson filter response with a bandwidth of 38.68 GHz.

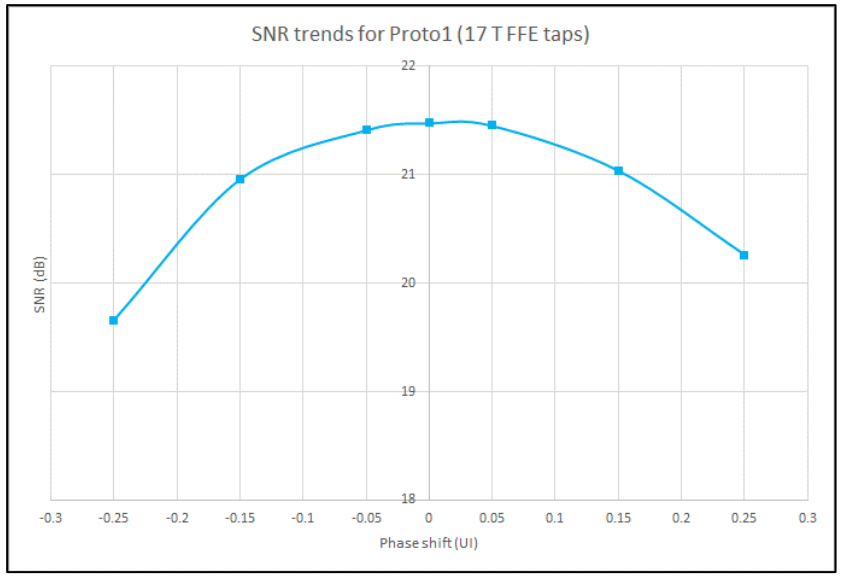
Into:

124.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

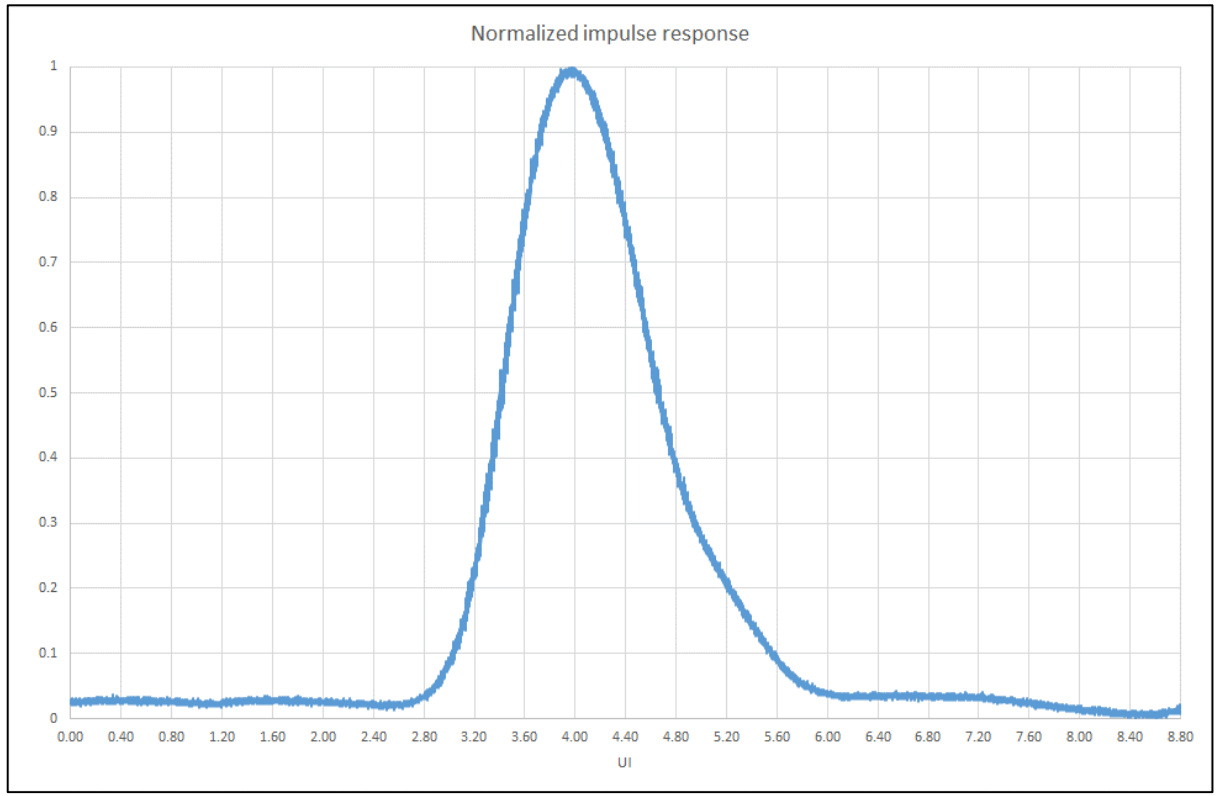
The TDECQ of each lane shall be within the limits given in Table 124–6 if measured using the methods specified in 121.8.5.1, 121.8.5.2, and 121.8.5.3 with the following exceptions: — The signaling rate of the test pattern generator is as given in Table 124–6. — The combination of the O/E converter and the oscilloscope has a fourth-order Bessel-Thomson filter response with a bandwidth of 38.68 GHz. — The reference equalizer is a 5 tap, T spaced, feed-forward equalizer (FFE), where T is the symbol period.

NOTE—This reference equalizer is part of the TDECQ test and does not imply any particular receiver equalizer implementation.

Cisco set-up: phase shift impairment and recorded TX IPR.

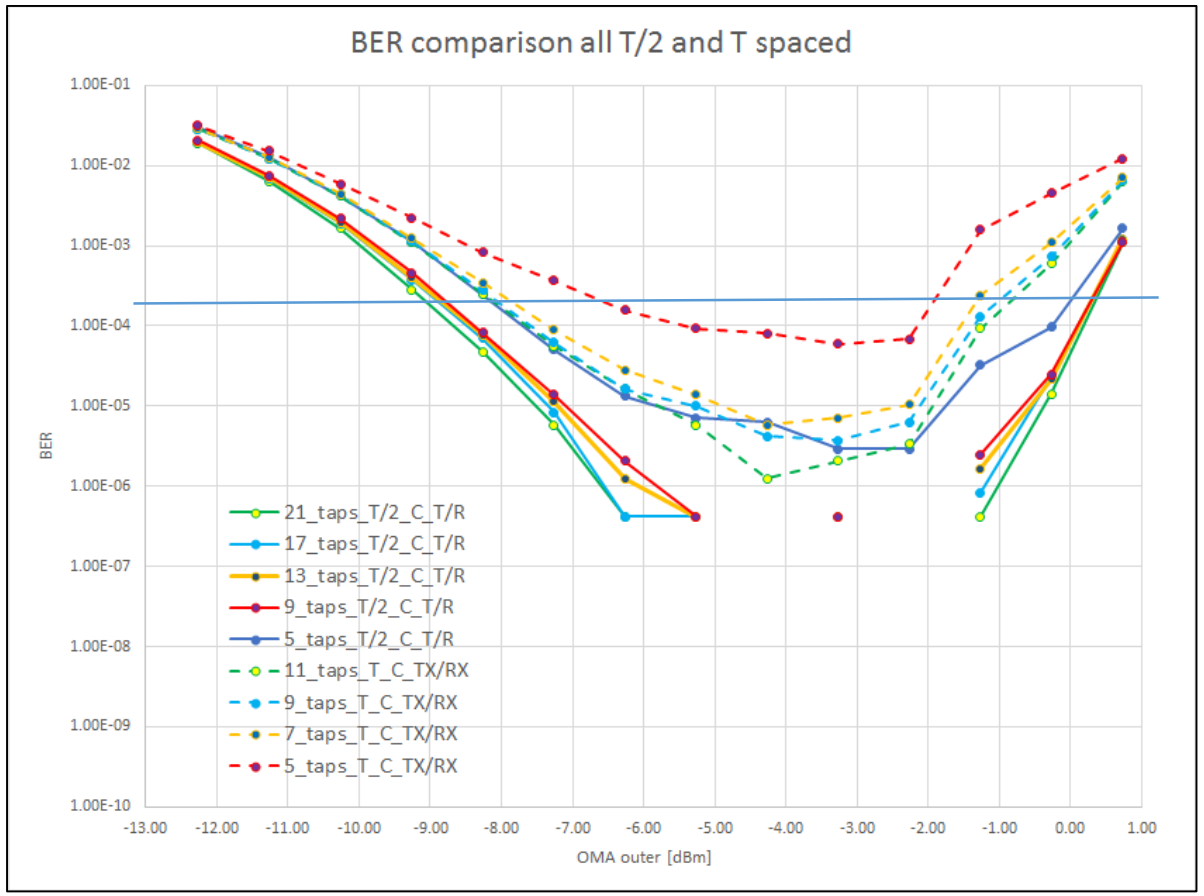


Small impact of the sampling phase over +/-0.05UI (confirmed with post-processing). For this TIA assembly case the optimal sampling phase is 0 UI.



Captured waveform can be made available upon request.

Recap of measured BERs with TIA assembly and various equalizers.



Left chart showing penalty versus long equalizer chain, as well indicates the equivalent T-spaced receiver that makes sensitivity as the 5 taps T/2 equalizer.

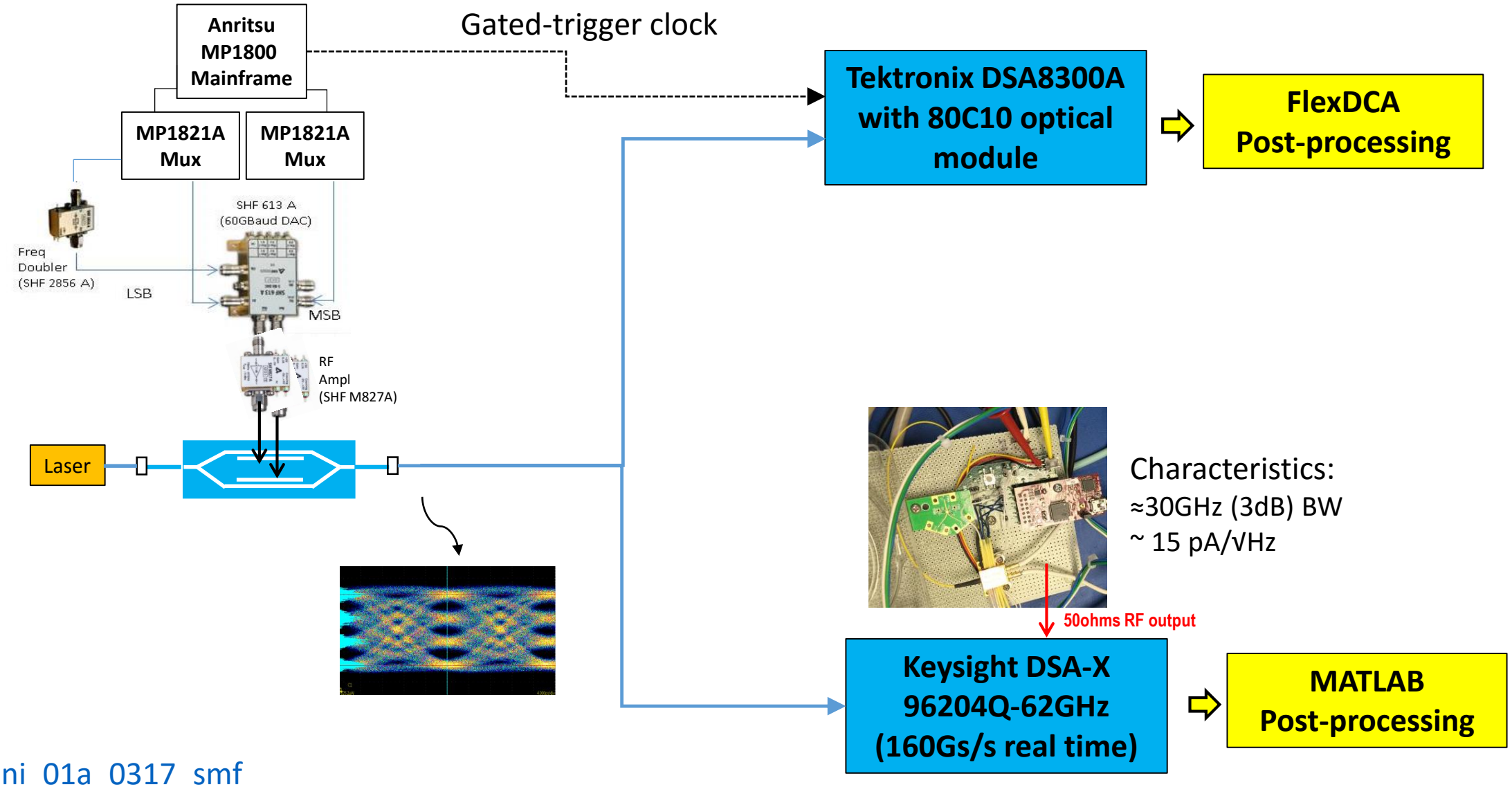
- T-spaced equalizer provides close to 1dB OMAouter penalty w/respect T/2 cases. **Not significant improvement increasing the T-spaced equalizer lenght from 7 to 9 or 11 taps**, 5 taps close to floor.
- 5T/2 is almost equivalent to 9 taps T in terms of sensitivity.

These results have been *verified independently* by others.
Depending on the different criterion to optimize the FFE taps, results can converge more towards long equalizer chain or not (we're also investigating sensitivity behavior versus criterion).
The usage of longer equalizer chain seems help normalizing results variability across companies, so reducing risks and debug time.

THANK YOU

Back-up

53GBaud PAM 4 TX/RX : sensitivity and TDECQ set-up.

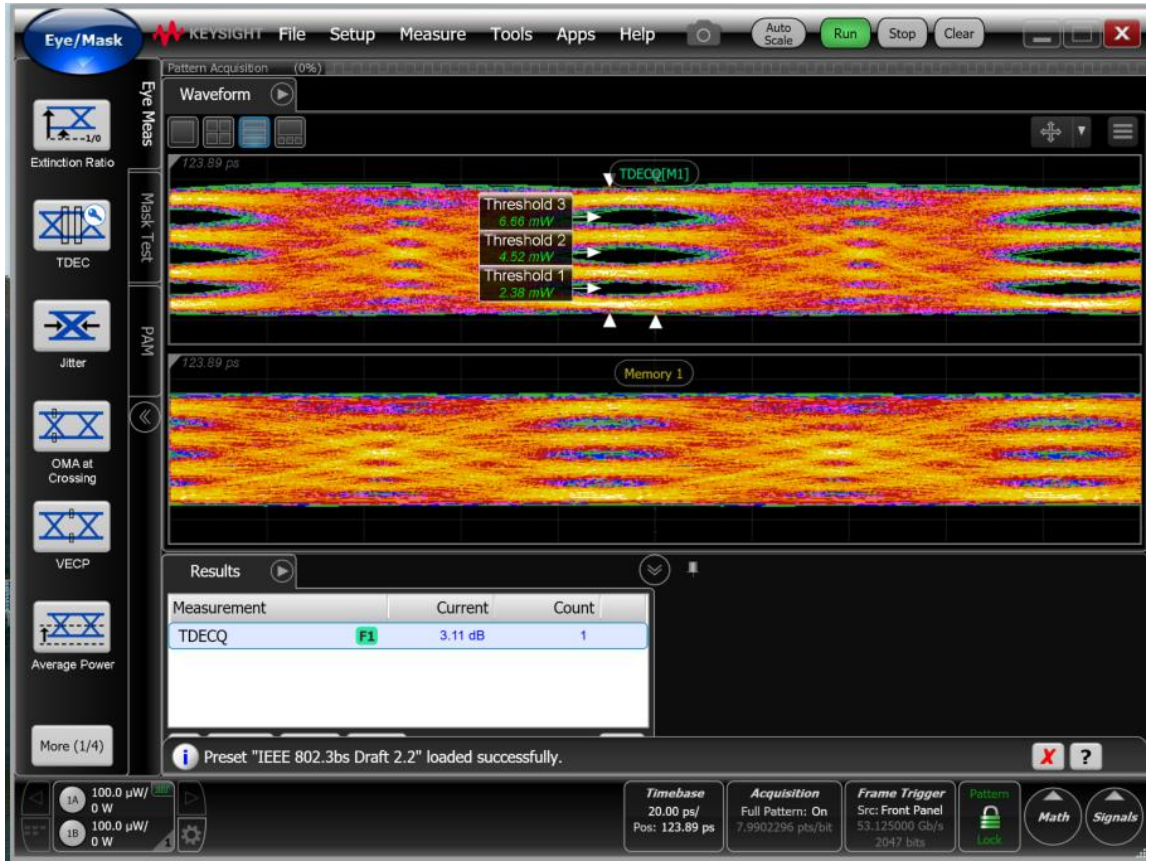


mazzini_01a_0317_smf

Cisco Lab Tx: TDECQ

TDECQ of Cisco Lab Tx measured by:

1. PRBS11 waveforms acquisitions with Tektronix sampling scope and 80C10 optical head.
    - Acquistion done using different reference filters (43, 39 and 28Gb/s) and head's optical bandwidth (70, 55 and 32GHz).
2. Acquired waveforms were post- processed using Keysight FlexDCA software and PAM4 analysis tool.



Left case showing FlexDCA TDECQ analysis with current IEEE reference equalizer and 70GHz BW on optical head (note: standard requires 38.68GHz, not yet available on scope).

About sampling scope reference RX filter and optical BW relationship.

- When applying a “Reference Receiver Filter" the electrical –3dB bandwidth is set to 0.75x of the bit rate.
- When selecting an unfiltered “Bandwidth” setting, the optical –3dB bandwidth is set to the listed number (acquisition done 32GHz, 55GHz, 70GHz).
- Since optical –3dB bandwidth is equal to the –6dB electrical bandwidth (due to 10*log versus 20*log calculations), and for a Gaussian or 4th-order Bessel-Thompson frequency response roll-off the –3dB frequency point is approximately ~0.75 of the –6dB frequency, this means that effectively an optical (e.g. “55GHz”) bandwidth selection has a –3dB optical (and –6dB electrical) bandwidth of 55GHz and a –3dB electrical bandwidth of roughly 0.75of the optical bandwidth (e.g. ~41.25GHz).
- In other words the “55GHz” bandwidth setting is essentially the same as a 55Gb/s reference receiver filter.