53 Gbaud VCSEL MMF System Measurements

Ali Ghiasi – Ghiasi Quantum/Marvell
Ariel Nachum – Marvell
Ravi Bemra – Marvell

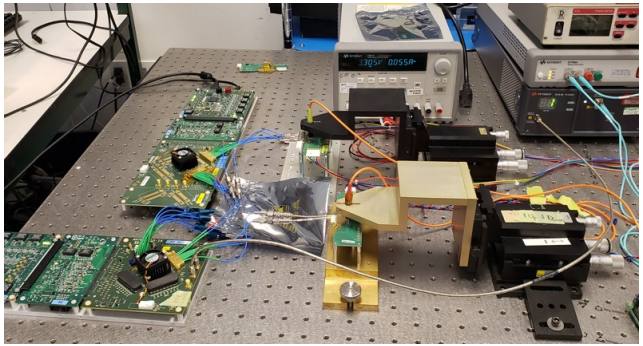
IEEE 802.3db Interim Meeting
Sept 24, 2021

Overview

- Setup
- Example of 53 GBd VCSEL eyes
- Hit ratio
- TDECQ distribution
- Iterative vs MMSE optimization of TDECQ
- TDECQ as function of FIR taps
- TDECQ as function of overshoot
- BER penalty due to excess overshoot.

Special Thanks to Greg Le Cheminant of Keysight Technology for providing updated TDECQ and support for these measurements.

53Gbaud VCSEL Experimental Setup



Rx Electrical Loss at 26.5 GHz (including pkg):

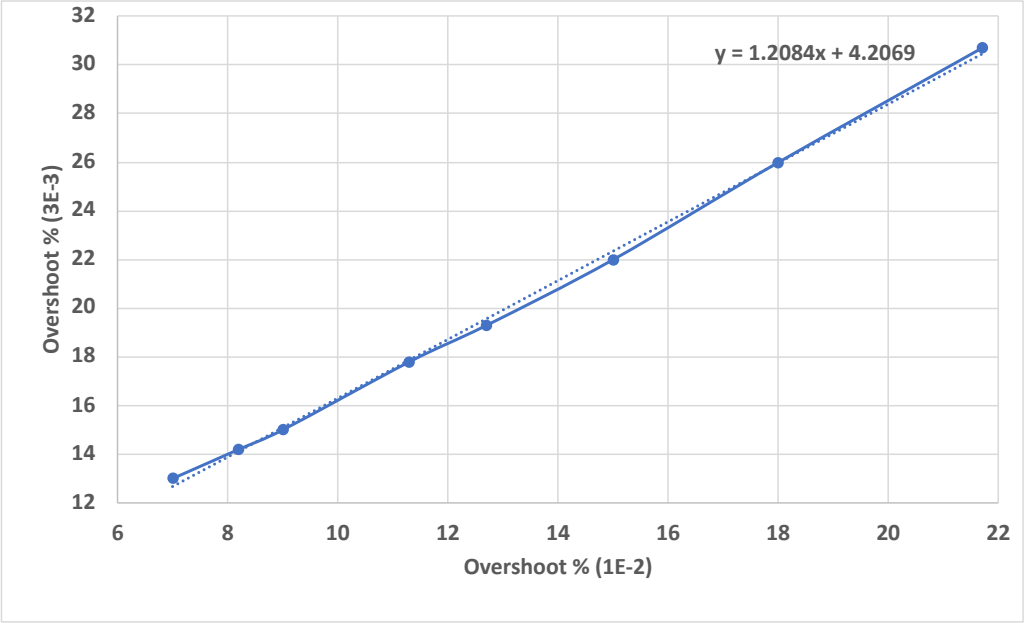
TIA EVB	+	cable + EVB + PKG
1 dB		4.25 dB

Test Setup and Measurement Configuration

- A 100G SR capable VCSEL die mounted on the same substrate as VCSEL driver
  - The same VCSEL is used to study both SR and VR, but expectation is that VR VCSELs will be lower cost/slower
  - The VCSEL driver is driven from a SerDes with 3 taps [C_{-1}, C_0, C_1] TX FIR
  - TX FIR and VCSEL driver are optimized to produce best TDECQ for given overshoot
  - TDECQ penalty is studied for overshoot from 13% to 30.7% with SSPRQ pattern
    - Baseline TDECQ is measured with 26.55 GHz filter front end BW
    - TDECQ are reported with fiber emulation FA BW of (18, 20.7, and 33.6 GHz) as given in table 167-12
  - For the same pre-emphasis producing 13% to 30.7% overshoot receive BERs are measured with PRBS31Q

Overshoot at 1E-2/3E-3 Hit Ratio

- 802.3cu uses overshoot/undershoot is based on 1E-2 hit ratio
- Proposed overshoot for 802.3db overshoot/undershoot hit ratio is 3e-3
  - A hit ratio of 3e-3 is less sensitive to DML ROF (Relaxation oscillation Frequency) and may provide more stable measurement.

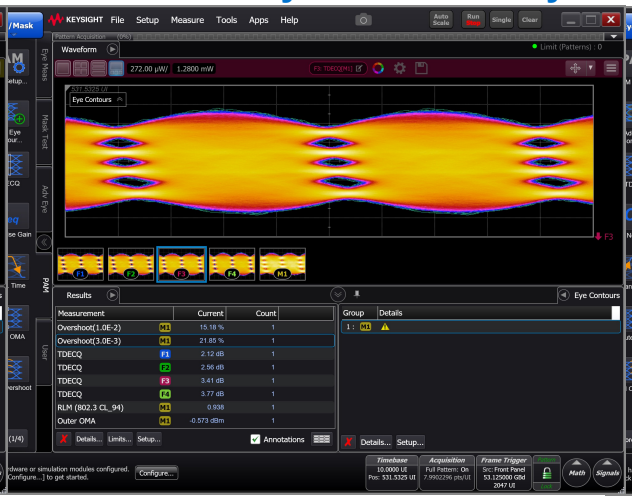


Example Eye Diagram and TDECQ

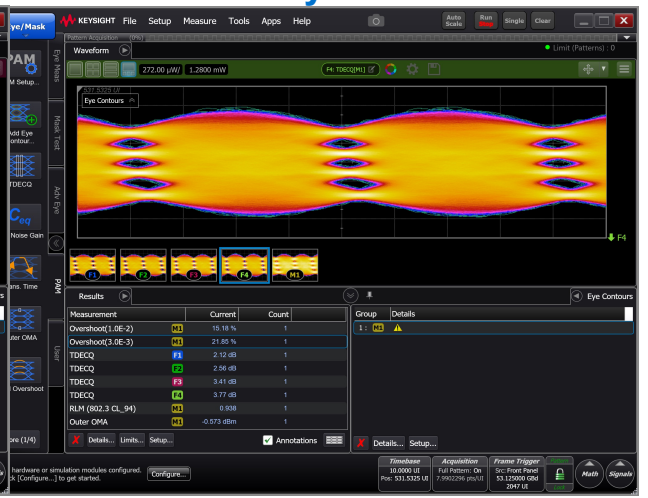
- Eye diagrams for 22% overshoot @ 3e-3 hit ratio with 9T FFE
  - F2 TDECQ 50 m SR, Taps= [-1%, 11%, -6%, 1.09, 0.6%, -8%, -2%, -2.1%, -1.4%]
  - F3 TDECQ 50 m ~VR@940 nm, Taps= [-2.6%, 15.6%, -15.7%, 1.28, -14.4%, -4.4%, -3.1, -1.8%, -1.6%]
  - F4 TDECQ 100 m SR, Taps= [-3.4%, 18.1%, -21%, 1.4, -25%, -0.18%, -4.6%, -1.1%, -1.7%].

M1 Eye – Equalized Eye

F3 Eye – 50 m VR Eye



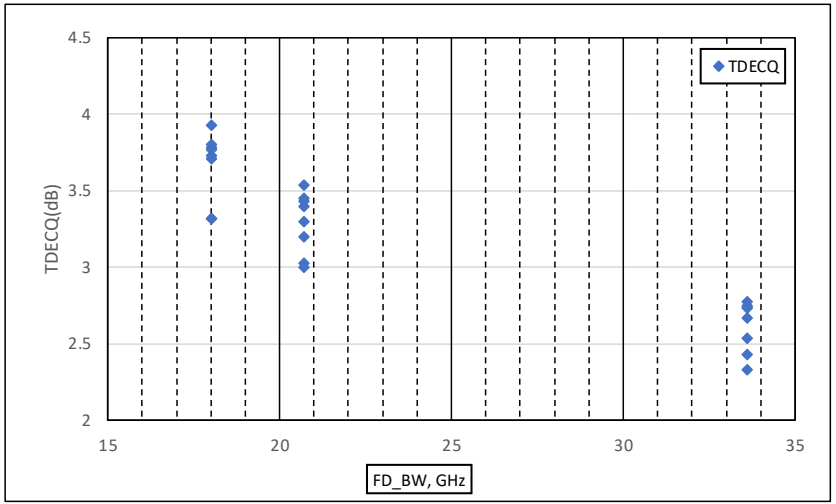
F4 Eye – 100 m SR



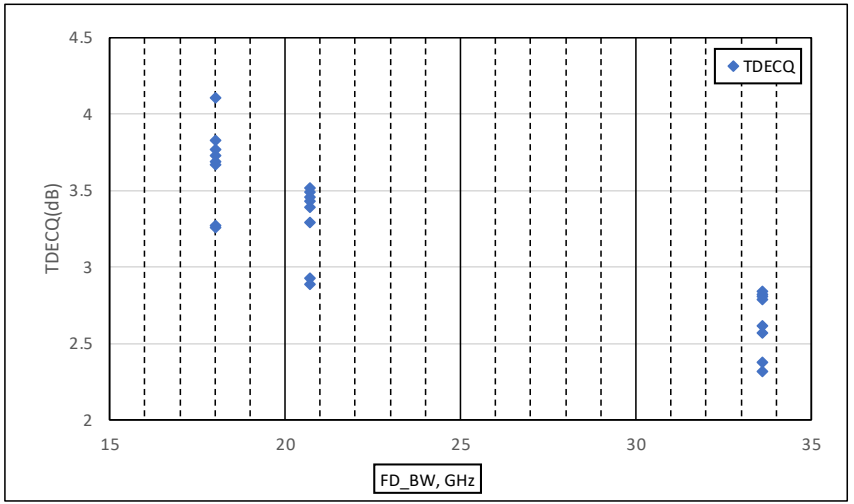
TDECQ Distribution as Function of BW for 9T FFE

- MMSE with 2% TH window and Iterative with 2% TH window for various overshoots (13% to 30.7%).

MMSE with 2% TH



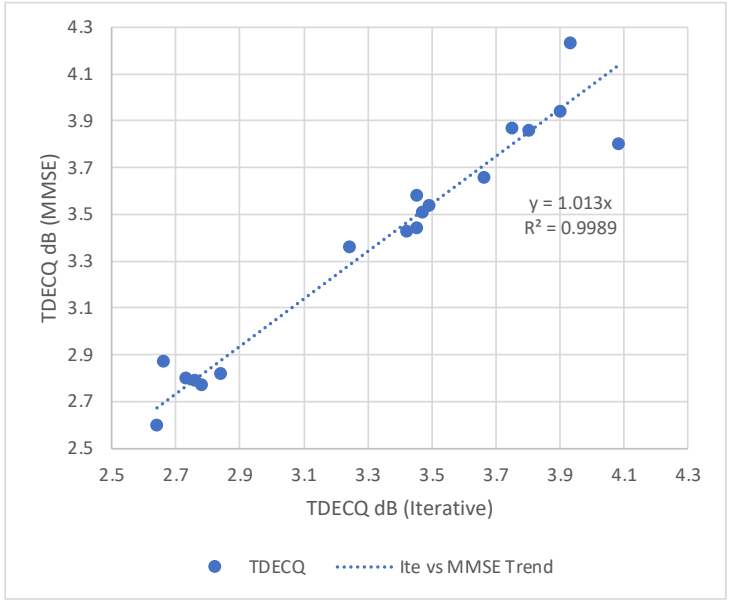
Iterative with 2% TH



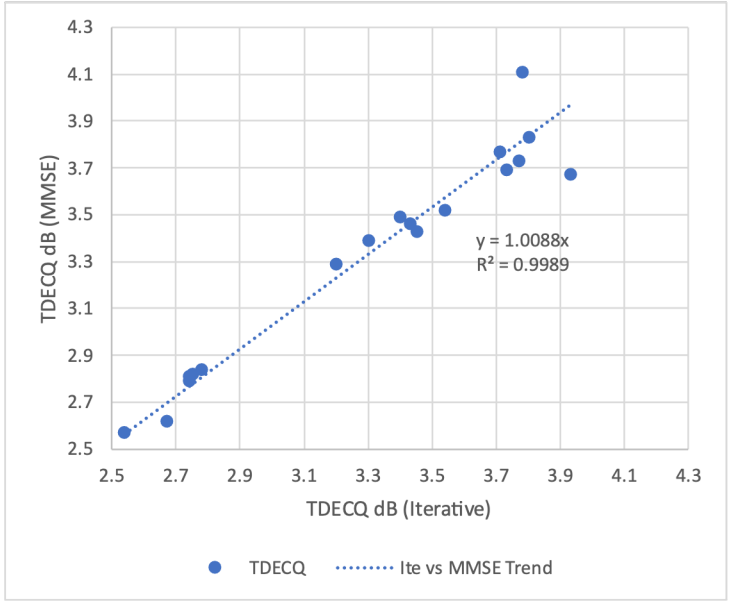
Correlation of Iterative vs MMSE TDECQ

- MMSE results correlation improves with 2% threshold window.

1% TH

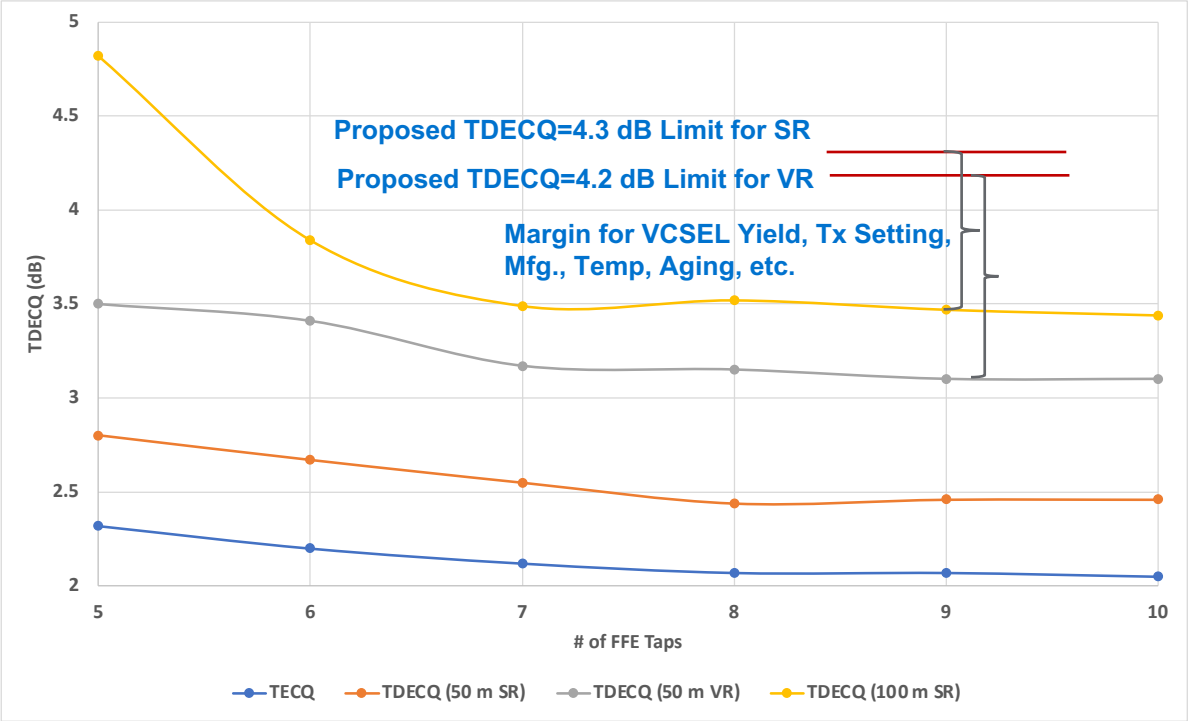


2% TH



TDECQ as Function of FIR Taps with 22% Overshoot

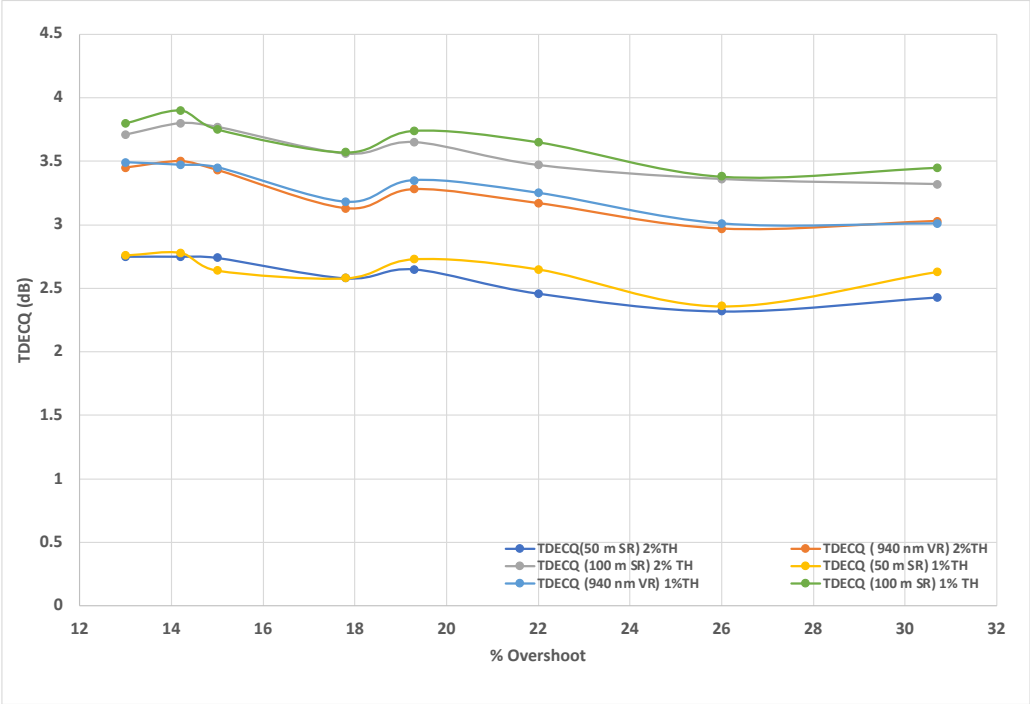
- For a well optimized transmitter with VCSEL die mounted on the VCSEL driver substrate an equalizer with at least 7 taps FFE with 3 pre-cursors is necessary
  - VR results shown are optimistic given that 100 m SR capable VCSEL was used with 20.7 GHz TDECQ filter
  - Consideration implementation flexibility and margins the current 9 taps FFE is an optimum solution for both SR/VR.



TDECQ results reported are with 2% TH and MMSE adaptation.

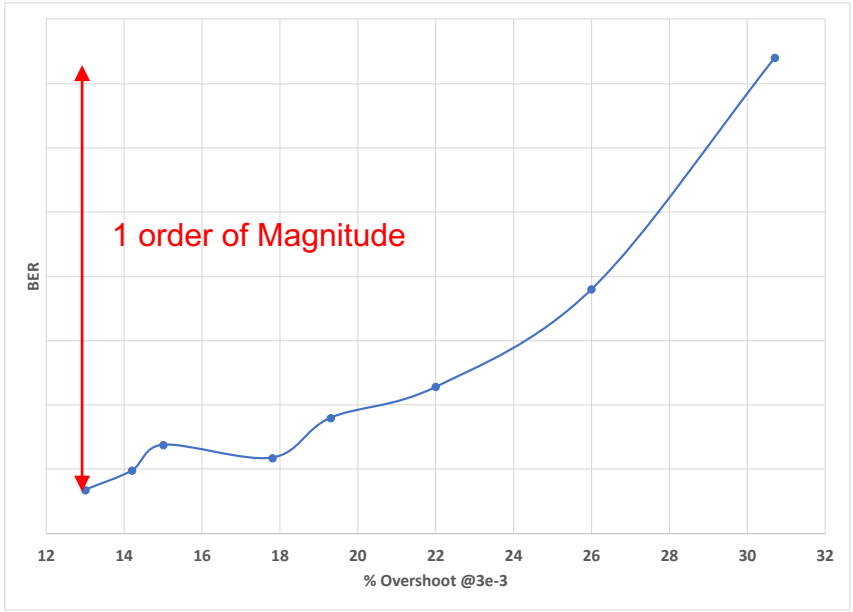
9T FFE TDECQ as Function of Overshoot

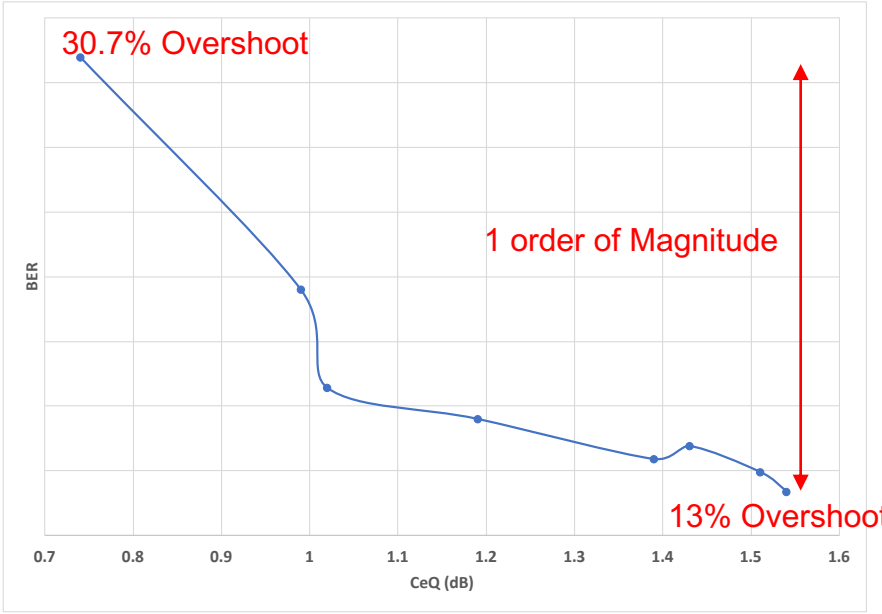
- TDECQ improves up to ~26% overshoot @ 3e-3 (equivalent to 18% @ 1E-2)
- VR TDECQ results are with faster 100 m SR VCSEL with FA BW of 20.7 GHz, therefore results shown would be optimistic
- Given that the test VCSEL is optimized with equal levels and RLM in 93-96% don't see substantial improvement with 2% threshold window
- In pathological TDECQ >4.5 dB 2%TH with MMSE produces substantially lower TDECQ and results more more similar to with 1% or 2% TH
- In real product 2% TH may allow reducing guard-band for Temp/aging.



Overshoot vs Ceq Protecting Receiver for Excess Overshoot

- Transmitter overshoot is a direct quantitative parameter protecting the receiver for excess pre-emphasis/overshoot
  - Ceq is insensitive to pre-emphasis and not as effective as overshoot to protect the receiver!





Summary

- MMSE with 2% threshold adjust produces better optimized TDECQ more inline with the 1% TH iterative optimization
  - 2% TH MMSE for the test setup only reduces TDECQ by ~ 0.05 dB but increased TH may offer additional gain by reducing product guard-band
  - Given that much faster MMSE with 2% TH correlates well with iterative recommend task force to consider MMSE
- Given that there is not a substantial reduction in TDECQ with 2% TH window proposed limits recommended are:
  - TDECQ for VR 4.2 dB
  - TDECQ for SR 4.3 dB
- At 30.7% overshoot BER increases by an order of magnitude and due to degradation of RLM there is no improvement in TDECQ
  - Recommend to limit maximum overshoot/undershoot to 26%.