TDECQ Updates with Threshold Adjustment (1): VCSEL Results*

Frank Chang, Inphi Tony Ambrose, Pavel Zivny, Tektronix David Leyba, David Weldon, Keysight

* With data to support comment resolution for adding Adaptive Threshold Adj in computing TDECQ (float slicing).

IEEE802.3cd ad hoc Conference Call, 10 January 2018



Problem Statements

- Adaptive slicing seems promising to resolve TDECQ specs dilemma
 - Consider Precise threshold is optimized to further minimize TDECQ (Cisco) (mazzini_120617_3cd_adhoc-v2)
 - □ TDECQ improvements have shown using DML (AOI).
- There exists 2 major concerns associated with TDECQ (SECQ)
 - □ Is TDECQ methodology robust from different testers?
 - How adaptive slicing (vertical threshold adj) work on non-DML transmitters: VCSEL, EML, and MZM (e.g. for SRS)?
- This will facilitate the PAM4 module compliance/manufacturability without throwing away any known good TXs (improve yield).
- □ This report:
 - Focus on looking into VCSEL TX, in some way similar to DFB for direct modulated type of lasers.
 - Test results for EML and MZM will follow up next.

💢 Inphi

TDECQ Test Configurations

Firstly test against 2 different testers under GOLDEN VCSEL TX

- Evaluation board mounted commercial PAM4 ASIC with direct drive test board mounted 50Gb/s VCSELs (Similar to <u>chang_3cd_01a_0917</u>)
 - Driverless
- TDECQ SR tests (no test fiber needed)
 - PRBS 2¹⁵-1
- Secondly apply threshold Adj.
- Reasonably open eyes with timing window to start with.
- 3 scenarios with Golden VCSELs
 - Varying filter BWs
 - Varying the number of taps
 - Test deviations of multiple tests



Raw eye with 19.3GHz RX

W.r.t 5T Equalizers, PRBS 2¹⁵-1 for one tester

11.2GHz, TDECQ=2.71dB

12.6GHz, TDECQ=2.32dB

13.28GHz, TDECQ=2.35dB



14.5GHz, TDECQ=2.09dB

15.9GHz, TDECQ=2.06dB

19.3GHz, TDECQ=2.02dB





W.r.t 5T Equalizers, PRBS 2¹⁵-1 for another tester



W.r.t 5T Equalizers with Threshold Adj (post-processed)

11.2GHz, TDECQ=2.09dB 12.6GHz, TDECQ=1.84dB 13.28GHz, TDECQ=1.80dB ence Equalizer Se) TDECO Reference Equalizer Set **v** + **v** + **v** + Custom Custom Custom Taps Tans 🖌 Automatic Taps 🖌 Iterative Optimization Recalculate 🖌 Automatic Taps 🖌 Iterative Optimization Recalculate 🖌 Automatic Taps 🖌 Iterative Opt Recalculate 1 ¥ 🔺 1 ¥ A Taps per UI: Taps per UI: 1 ¥ 👗 Taps per UI 5 ¥ 🔺 5 ¥ A 5 ¥ 🔺 Number of Taps Number of Taps Number of Taps: Tan Values Tan Values Number of Tans: 5 DC Gain: 1 0000 Number of Taps: 5 Number of Taps: 5 DC Gain: 1.0000 DC Gain* Precursors: 2 Advance Advancer Noise Processing Noise Processing Results Noise Processing Results V Preserve Nois V Preserve Noise Current Count V Preserve Noise Measuremen Curren Count easuremen werage Po F1 931.0 µ\ Average Powe F1 935.5 µW Input Noise Bandwidth Input Noise Bandwidth Average Power F1 932.0 µV Input Noise Bandwidth F1 925.0 µV Outer OMA F1 951.0 µW Outer OMA Outer OMA F1 922.5 µW 11.17 GHz 🖌 🔺 3.28 GHz 🗡 🔺 ✓ Track Input Bandwidth V Track Input Bandwidth F1 2.09 dB Track Input Bandwidth TDECQ F1 1.80 dB TDECC TDECQ F1 1.84 dB

14.5GHz, TDECQ=1.58dB

💢 Inphi

15.9GHz, TDECQ=1.54dB

19.3GHz, TDECQ=1.37dB

| (F1) TDECQ Reference Equalizer Setup | ? Close | Waveform 🕟 | (F1) TDECQ Reference Equalizer Setup ? Close | Waveform | (F1) TDECQ Reference Equalizer Setup ? Close |
|---|------------------|--|---|--|---|
| | | | Preset | | Preset |
| 237 25 ps 240.80 ps TDECOV Custom ¥ + | | 237.25 bs 240.35 ps | Custom Y + | 246.45 ps 250.30 ps | Custom Y + |
| | | | | 1240mW | |
| 240 Juli 245 Juli | Recalculate | | ✓ Automatic Taps ✓ Iterative Optimization Recalculate | | ✓ Automatic Taps ✓ Iterative Optimization Recalculate |
| | | | | | |
| | | 0 UI 0.55 U | | 0 UI 0.45 UI | |
| 7237.25 ps | | 237.25 ps | Number of Taps: 5 V A | 246.45.ps | Number of Taps: 5 ¥ A |
| Tap Values: | | | Tap Values: | | Tap Values: |
| 0.041414, -0.040721, 1.156823, -0.095063, -0.064433 | | And a second | 0.038667, -0.032808, 1.146812, -0.083089, -0.069582 | | 0.032285, -0.000006, 1.094549, -0.055345, -0.071483 |
| Number of Taps: 5 Precursors: 2 | DC Gain: 1.00000 | A REAL PROPERTY OF A REAL PROPER | Number of Taps: 5 Precursors: 2 DC Gain: 1.00000 | and the second sec | Number of Taps: 5 Precursors: 2 DC Gain: 1.00000 |
| | Advanced | | Advanced | | Advanced |
| | | | ۲ | | |
| Results Noise Processing |] | Results | Noise Processing | Results D | Noise Processing |
| Measurement Current Count Verserve Noise | | Measurement Count | Preserve Noise | Massurement Current Count | V Preserve Noise |
| Average Power F1 934.0 µW 1 Input Noise Bandwidth: | | Average Power EI 928.0 uW 1 | Terrat Maine Deschriftlich | Average Power FI 926.0 uW 1 | Input Noise Bandwidth: |
| Outer OMA EI 914.5 µW 1 I Track Input Bandwidth | | Outer OMA F1 916.0 µW 1 | | Outer OMA F1 972.0 µW 1 | |
| | | TDECQ F1 1.54 dB 1 | Track Input Bandwidth | TDECQ E1 1.37 dB 1 | |

W.r.t 5T Equalizers with Threshold Adj (post-processed)





7

W.r.t 11.2GHz filter BW for one tester

3 Taps, TDECQ=3.49dB

5 Taps, TDECQ=2.6dB



7 Taps. TDECQ=2.47dB

9 Taps, TDECQ=2.29dB



• W.r.t 11.2GHz filter BW for another tester

3 Taps, TDECQ=3.63dB

5 Taps, TDECQ=3.11dB

7 Taps, TDECQ=2.54dB







W.r.t 11.2GHz filter BW with Threshold Adj (post-processed) 5 Taps, TDECQ=2.16dB 7 Taps, TDECQ=2.13dB



9 Taps, TDECQ=2.06dB



Naveform 🕞 1) TDECQ Reference Equalizer Setup ? Close Preset **v** + Custom Taps 🖌 Automatic Taps 🖌 Iterative Optimization Recalculate 1 ¥ 🔺 Taps per UI: 5 ¥ 🔺 Number of Taps: Tap Values: Number of Taps: 5 Precursors: 2 DC Gain: 1.00000 Advanced (≫) Noise Processing Results 🖌 Preserve Noise Measurement Current Count Average Power F1 931.5 µW Input Noise Bandwidth: Outer OMA F1 934.5 µW 1 🖌 Track Input Bandwidth 🛛 11.17 GHz 💙 🔥 TDECQ F1 2.13 dB 1

Note: the post-processed data is actually done in 5 taps only using threshold adj. so somewhat pessimistic for larger number of taps. This has no impact to the conclusion we are making.

W.r.t 5T Equalizers with Threshold Adj (post-processed)





W.r.t 11.2GHz, 5T Equalizers with Threshold Adj (post-processed)





Concluding Remarks

We compared test results for two testers off-the-shelf. The discrepancy could be as high as 0.5-1dB between different testers w.r.t. VCSEL TX.

— There may be room to improve repeatability.

- Under golden TX configuration, It's consistently shown improvement by 0.4-0.5dB due to threshold adjustment.
 - The data support to implement threshold adjustment into TDECQ measurements.
- Under well-controlled lab environment, RLM is maintained higher than 0.95 for most cases. A limit should be set for RLM in actual manufacturing environment for TX, RX compliance.
 - RLM \geq 0.9 seems good strawman proposal to start with.

