Benefit of Adding DFE to TDECQ

(Comments 381, 382, 383, 384)

Ali Ghiasi - Ghiasi Quantum/Marvell

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Supporter

- **Marco Mazzini – Cisco**
- **Roberto Rodes – Coherent**
- **Chris Cole – Coherent**
- **Ahmad El-Chayeb – Keysight Technologies**
- **Mike Dudek – Marvell**

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Overview

- **Background**
- **TECQ correlation with receiver sensitivity**
- **200G TDECQ with addition of 1T DFE**
- **Summary.**

Background

- **Most optical DSP implementations include a 1T DFE and optional MLSE**
  - To save power MLSE by default will be off to save power
- **The benefit of enabling 1T DFE in TDECQ**
  - Reduces reliance on transmitter overshoot to reduce TDECQ where it may degrade link BER as TDECQ doesn't incorporate any compression or ADC ENOB penalties
  - Enabling 1T DFE reduces TDECQ ~0.5 dB on complaint TDECQ transmitter
    - For transmitter with low overshoot and high TDECQ >5 dB there is ~1.5 dB reduction
  - Allow passing slower more linear waveforms with better link BER
  - Improved correlation of TDECQ penalty with receive sensitivity
  - Scope supplier already have implemented 1T DFE to EECQ which is based on TDECQ for electrical penalty
- **The drawback of enabling 1T DFE in TDECQ**
  - Burst error will be the main drawback but we do have ILT for optics and DFE Bmax can be limited to 0.4
  - Shift some margin from receiver to transmitter.

Receiver Sensitivity

- **Assumed receiver sensitivity as shown in Figure 180-4 show 1:1 relationship between TDECQ and receive sensitivity but actual data from he_3dj_01_2505 1:0.4 relationship**
  - The reason for shallow slope is that the HW receiver is that hardware receiver is more capable compared to TDECQ equalizer
  - Adding 1T DFE to the TDECQ equalizer will improve TECQ penalty with receive sensitivity penalty.

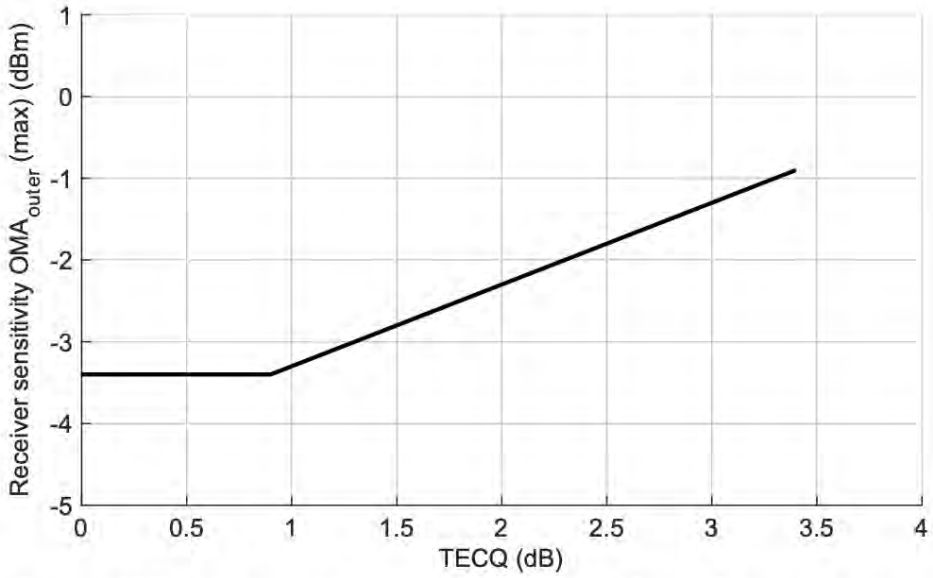
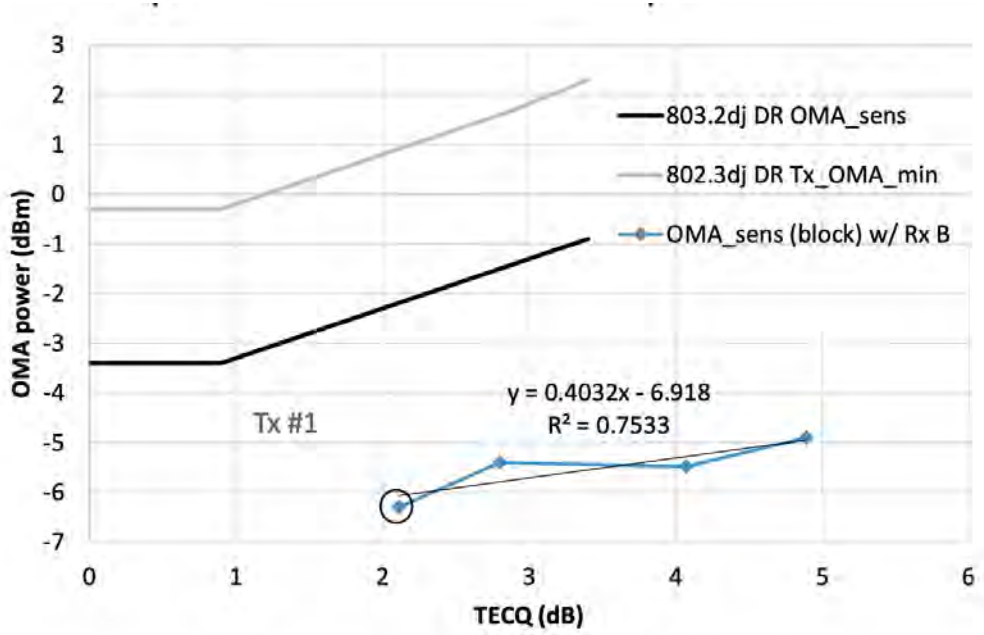


Figure 180–4—Receiver sensitivity (OMA$_{outer}$), each lane (max)



Adding 1T DFE to the TDECQ Equalizer

- **Add 1T DFE to the TDECQ equalizer**
  - Table 180-15, 181-15, 182-15, and 183-15.

Table 180–15—Reference equalizer tap coefficients

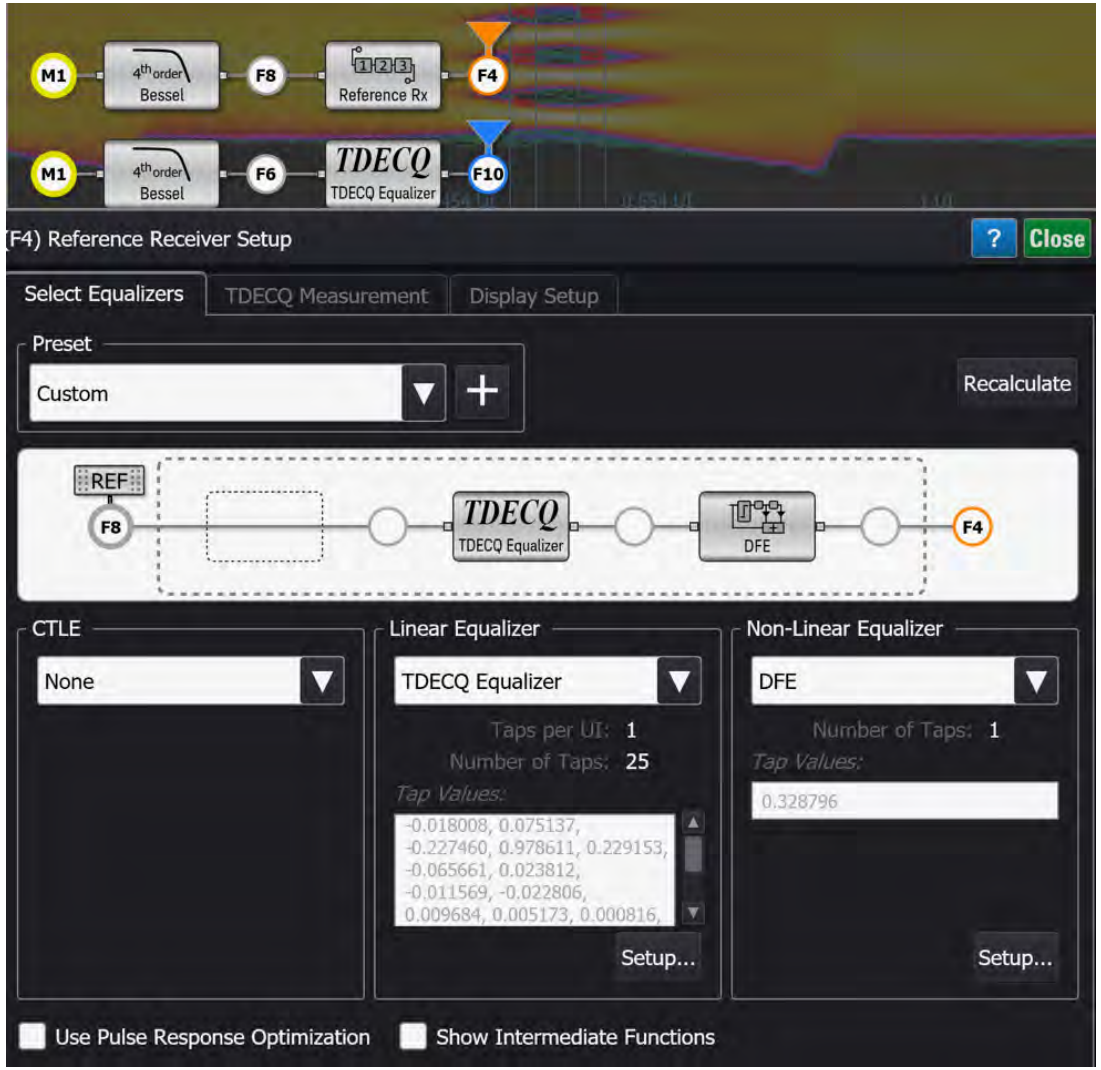
Parameter	Symbol	Value	
		Minimum	Maximum
Feed-forward equalizer (FFE) length	N_b	15	
Number of equalizer pre-cursor taps	—	0	3
Main tap coefficient limit	$c(0)$	0.9	2.5
Normalized equalizer coefficient limits:[a]	$c(i)$		
$i = -3$		–0.15	0.1
$i = -2$		–0.1	0.25
$i = -1$		–0.5	0.1
$i = 1$		–0.6	0.2
$i = 2$		–0.2	0.3
$i = 3$		–0.15	0.15
$i = 4$		–0.15	0.15
$i = 5$		–0.15	0.15
$i = 6$		–0.15	0.15
$i \geq 7$		–0.1	0.1
Equalizer gain[b]	—	1	

[a] The main tap is marked by $i = 0$. The minimum and maximum values are relative to this tap's coefficient.
[b] The sum of the equalizer coefficients.

Parameter	Symbol	Minimum	Maximum
Number of feedback taps	**B(1)**	**0**	**0.35**

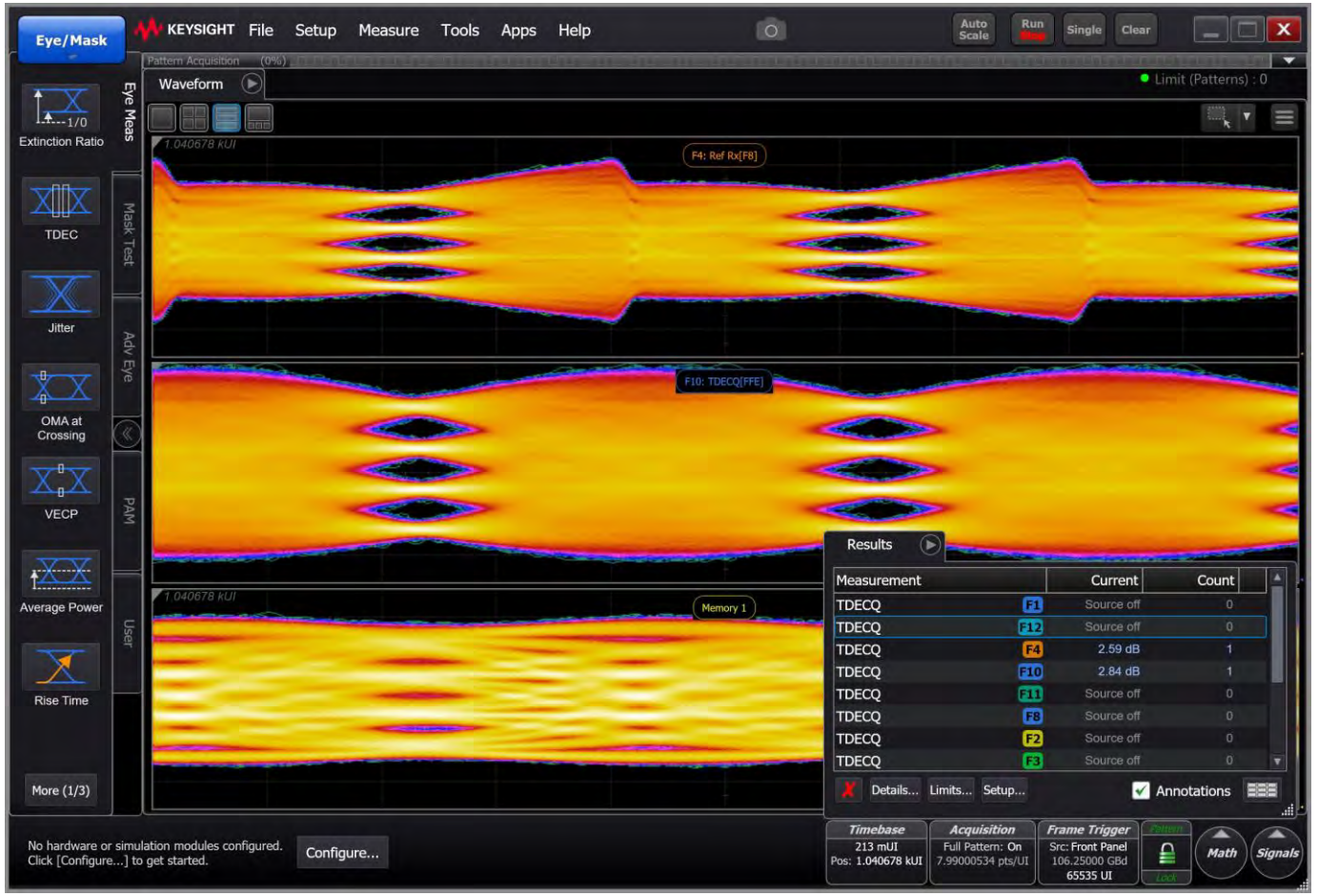
Configuring TDECQ with DFE

- **Keysight Scope FlexDCA A.07.81.6 already supports TDECQ with 1T DFE**
  - Instead of using TDECQ equalizer generic Reference Rx is selected
  - Then under Linear Equalizer TDECQ Equalizer is selected
    - Then set SER and other TDECQ parameters.



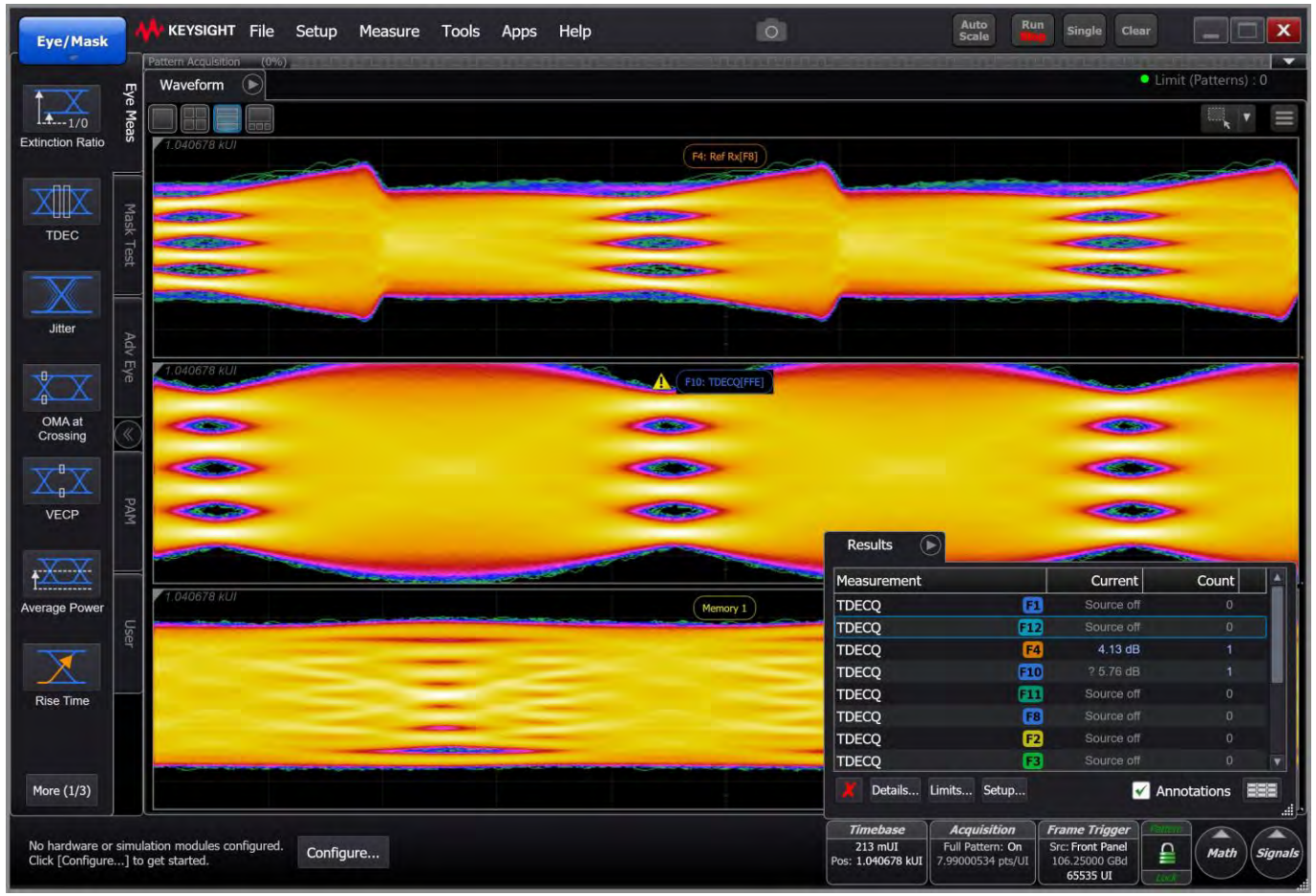
200G MZM TDECQ with Addition of DFE

- **TDECQ reduction with 1T DFE for TX with low TECQ**
  - TDECQ with 15T FFE is 2.84 dB
    - FFE Taps -0.017081, 0.078124, -0.275357, **1.490161**, -0.321593, 0.124306, -0.092210, 0.044500, -0.074899, 0.056275, -0.028502, 0.021386, -0.014024, 0.012652, -0.003738
  - TDECQ with 15T FFE + 1T DFE is 2.59 dB
    - FFE Tap -0.008442, 0.045556, -0.166764, **0.995970**, 0.181786, -0.000968, -0.031856, 0.005959, -0.042369, 0.019865, -0.005469, 0.007087, -0.004892, 0.005041, -0.000504
    - DFE Tap 0.283636.



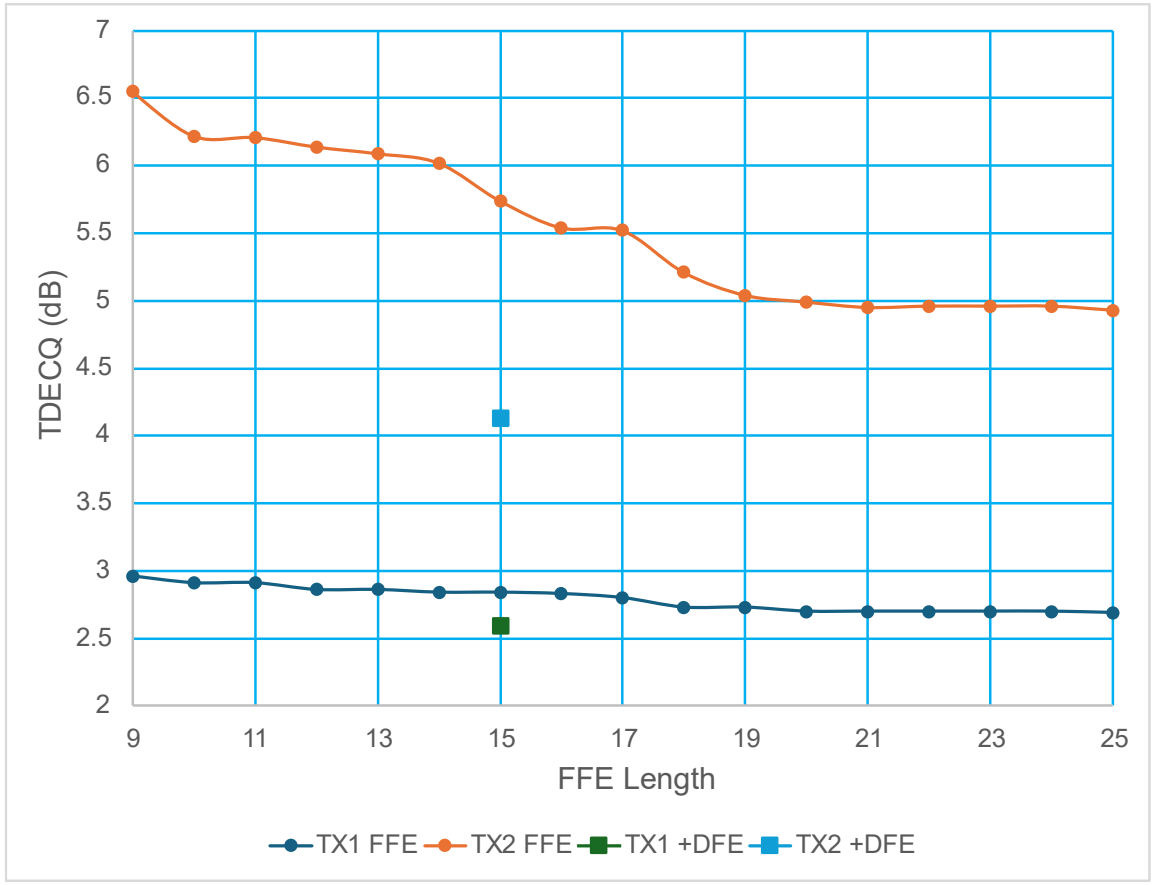
200G MZM TDECQ with Addition of DFE

- **TDECQ reduction with 1T DFE for TX with high TECQ**
  - TDECQ with 15T FFE is **5.76 dB**
    - FFE Taps -0.060232, 0.182759, -0.506969, **1.818684**, -0.532089, 0.157879, -0.044774, 0.005974, -0.044100, 0.035797, -0.010159, 0.003285, 0.018303, 0.004811, -0.029168
  - TDECQ with 15T FFE + 1T DFE is **4.13 dB**
    - FFE taps -0.017394, 0.073976, -0.226514, **0.979468**, 0.253183, -0.073706, 0.026715, -0.012512, -0.023035, 0.008908, 0.006088, -0.000323, 0.013989, 0.010717, -0.019560
    - DFE Tap 0.343287



Benefit of Adding DFE to TDECQ

- **Adding 1T DFE to current 15T FFE TDECQ offer more gain than even a 25T FFE**
- **Adding 1T DFE also improves TDECQ to Receiver sensitivity penalty**
  - Receive OMA sensitivity 2.4E-4 PreFEC are:
    - TX1 OMA Sensitivity -6.1 dB
    - TX2 OMA Sensitivity -4.6 dB
  - Delta sensitivity = **1.5 dB**
  - Delta TDECQ with 15T FFE = 2.92 dB
  - Delta TDECQ with 15T FFE + 1T DFE = **1.54 dB**
- **TDECQ with 15T FFE + 1T DFE the transmitter penalty matches receive sensitivity penalty 1:1!**



Summary

- **With FFE receiver transmitter are set with high overshoot in order to improve TDECQ which often results in inferior block BER**
  - Another issue with FFE only TDECQ given that receiver has a DFE the TECQ penalty doesn't correlate with receiver sensitivity
- **The current 15T FFE is a good compromise between complexity, power, and benefit**
  - Adding 1T DFE to the 15T FFE offer much better performance than even a 25T FFE
- **Adding 1T DFE to TDECQ/EECQ with Bmax≤0.35 penalty due to burst error is negligible and provide following benefits**
  - Reduces TDECQ by ~0.5 dB for compliant (≤3.4) transmitters
  - Reduces TDECQ by ~1.5 dB for slow high TDECQ (≥5.0) transmitters
- **Another key benefit of adding 1T DFE to the TDECQ equalize is the significant improvement of TDECQ penalty correlation with receive sensitivity penalty!**

Thank You!