Tektronix

Repeatability of TDECQ results when the FFE equalization taps are optimized using MMSE

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Supporters

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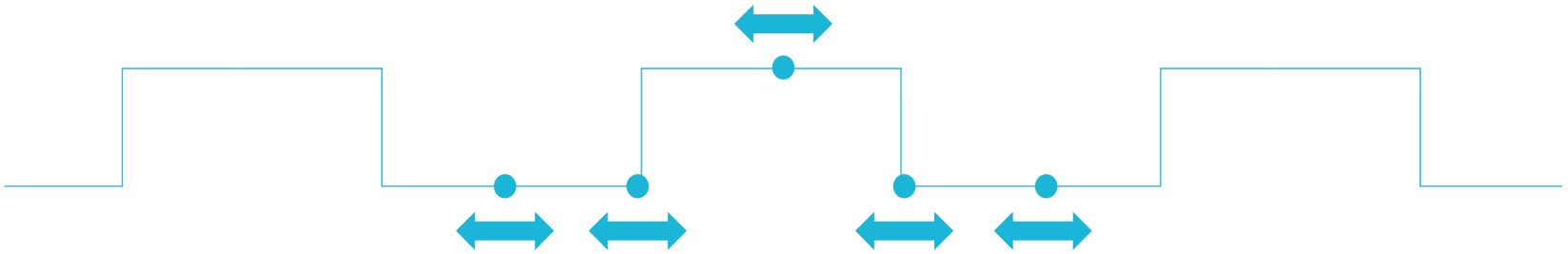
Introduction

- The calculation of TDECQ requires a set of FFE tap coefficients. The method for determining the taps is (as of D2.1) to minimize the mean square error (MMSE) of the equalized waveform.
  - Unfortunately, sets of taps with relatively small differences in MSE can have relatively large differences in TDECQ. Also, the MMSE optimized taps do not necessarily produce the minimum TDECQ. Both of these problems causes a repeatability issues with TDECQ.
- In a November SMF ad-hoc it was proposed that adding uncorrelated Gaussian noise to the waveform before tap optimization limits the problems listed above.
  - We have found that the addition of noise does indeed improve repeatability (reduces the variance) of TDECQ for sets of taps optimized using MMSE. However, it tends to also provide taps sets that increase the TDECQ values, i.e. they introduce undesirable bias to the measurement.
  - This is true even while the noise is *not* included in the TDECQ calculations, through the following course:
    adding uncorrelated Gaussian noise is equivalent to l_2 norm regularization, and regularization produces the so-called bias-variance tradeoff.

FFE taps optimization using MMSE: 1: recap

- For TDECQ, the equalizer has 5 taps with half UI spacing. Design freedom consists of the placement of the taps within the UI (phase) as well as the position of the cursor.



- For a chosen placement within the UI (phase) and the cursor position it is then straightforward to use MMSE to get an optimized set of tap coefficients. This method is then repeated for a number of combinations (of phase and cursor position) to get many sets of optimized taps.

FFE taps optimization using MMSE: 2

- Having found many sets of optimized taps, where each set was optimized using MMSE, the next task is to find the overall optimal set of taps. The most obvious method would be to pick the set with the smallest MSE.
- Unfortunately, plotting the TDECQ and MSE for many sets of taps shows (see next page) that small changes in MSE can produce large changes in TDECQ and that the minimal MSE point doesn't always correspond to the minimal TDECQ.
- This sensitivity and the difference in minimal points is one of the reasons for the repeatability issues seen in the TDECQ measurements.

FFE taps optimization using MMSE: 3

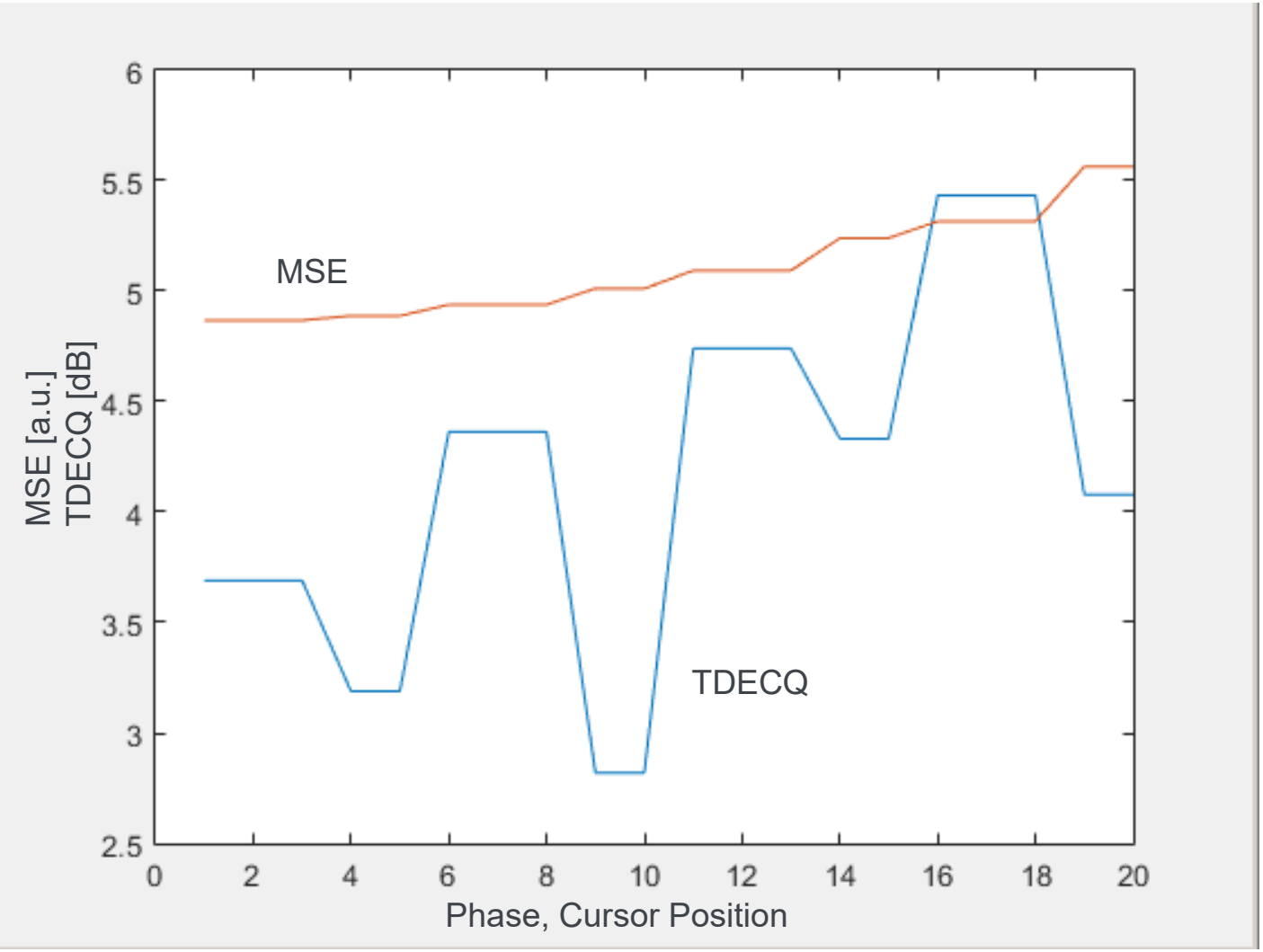


Figure 1: MSE, TDECQ with different phase and cursor positions

FFE tap optimization using MMSE with added noise

- The proposed improvement (adding uncorrelated Gaussian noise) does reduce the variance somewhat, but comes with the cost of higher TDECQ values. Again, the added noise is not included in the TDECQ calculations.

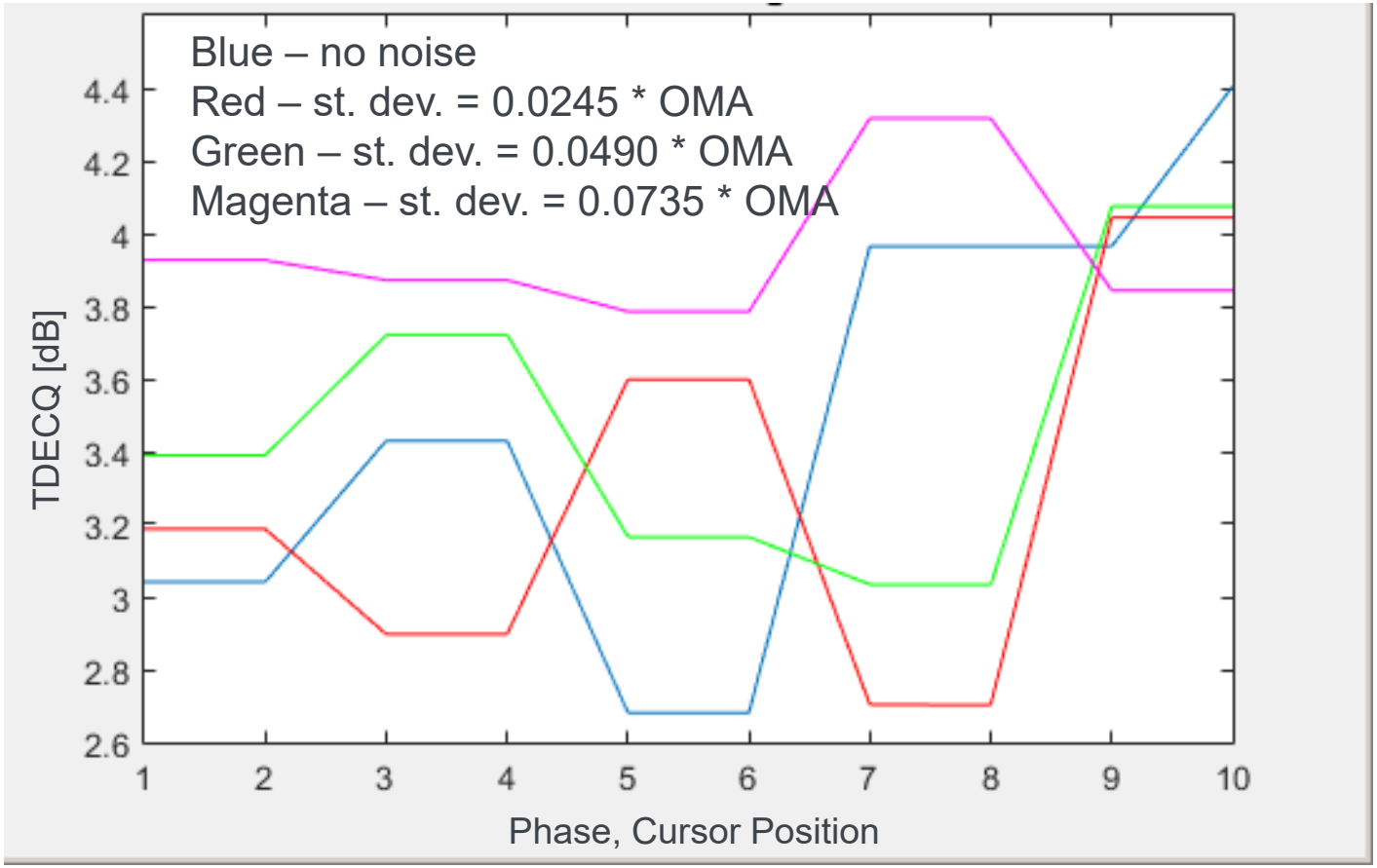


Figure 2: TDECQ with taps calculated with added noise

Proposed improvement

To-date we've found the following method to yield satisfactory results:

- Calculate the TDECQ value for the top *n* (based on MSE) sets of taps and choose the set with the smallest TDECQ.
- For the number of sets of taps, *n,* we suggest 20 based on experimentation (tradeoff between computation time and finding the minimum TDECQ).
- For further work: as the sets of taps are calculated using MMSE, they may also not be optimal in terms of TDECQ.

Conclusion

- We've analyzed a known concern with the TDECQ result.
- We identified the difference between the minima and the sensitivity of the TDECQ results as at least part of the problem.
- We suggest an improved solution search strategy that can be adopted by 802.3bs .

Thank you