Transmitter testing for MMF PMDs

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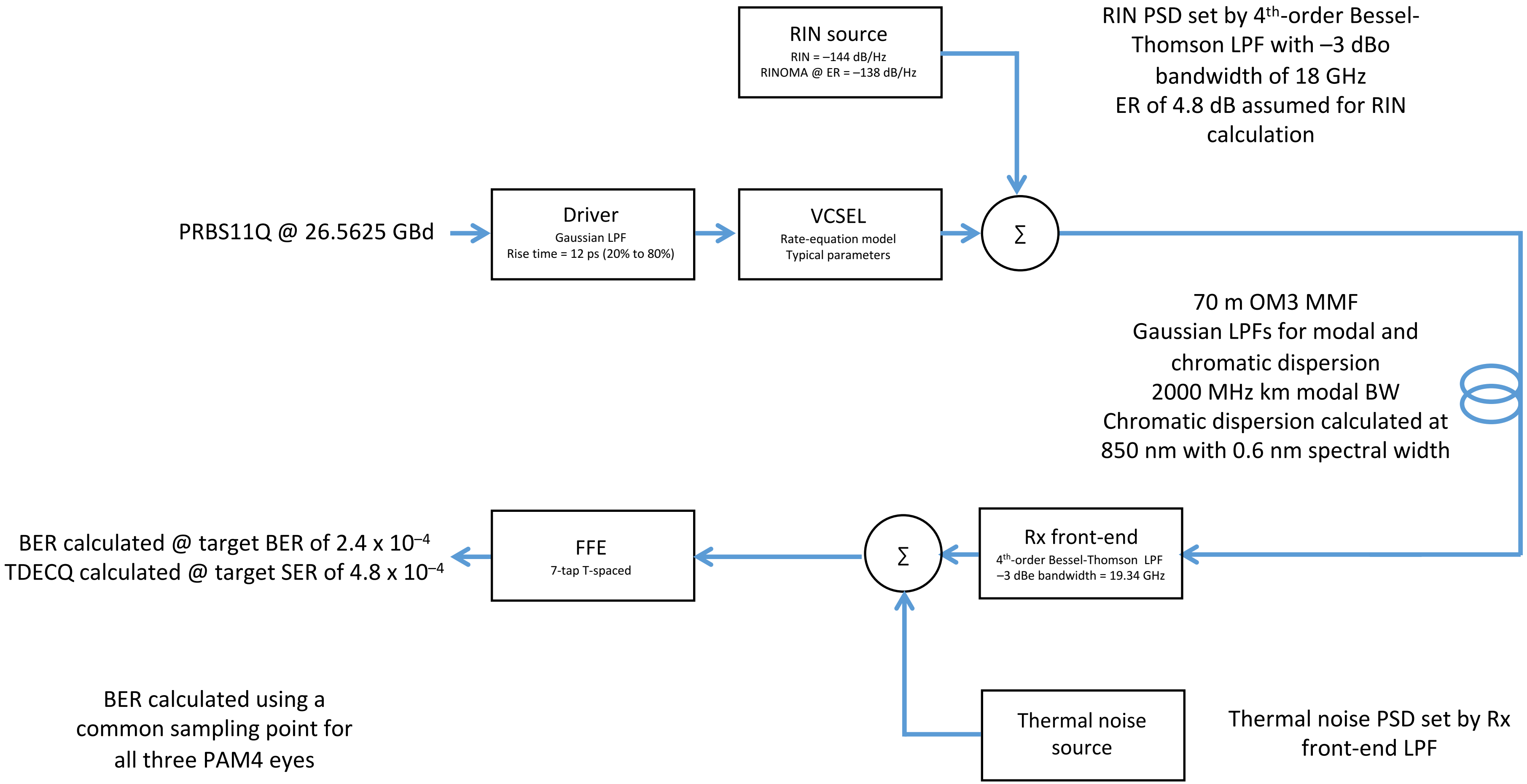
Introduction

- TDECQ has been introduced in P802.3bs as an extension of TDEC to PAM4
- It is reasonable to apply this approach to all MMF PMDs in P802.3cd
- However, it is important to address the question of an **appropriate reference equalizer**
- Here, initial modeling of a MMF link at 26.5625 GBd, relevant to all of the three MMF PMDs under standardization in P802.3cd, is considered
- In Part I, to introduce the modeling methodology, TDECQ is calculated for an example link. A comparison with penalty extracted from BER curves is performed as verification
- In Part II, TDECQ is calculated for a worst-case link for a range of equalizer lengths. Based upon the results, an appropriate reference equalizer is proposed

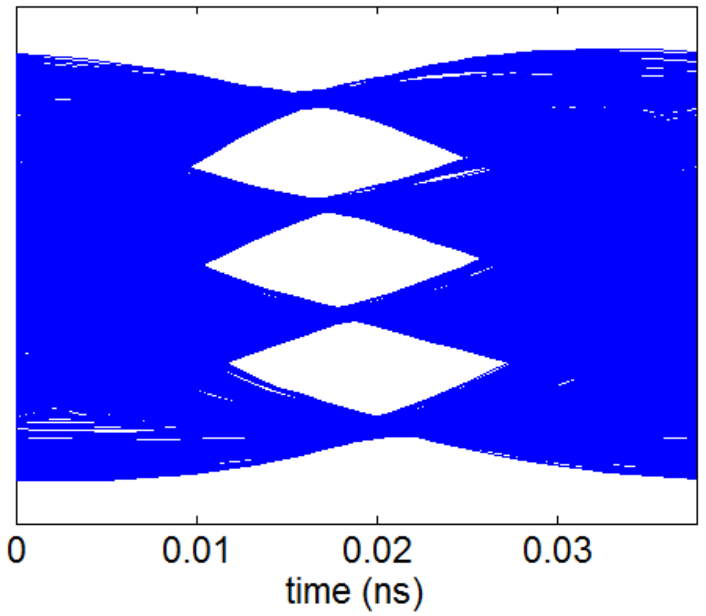
Part I: TDECQ and corresponding penalty for an example link

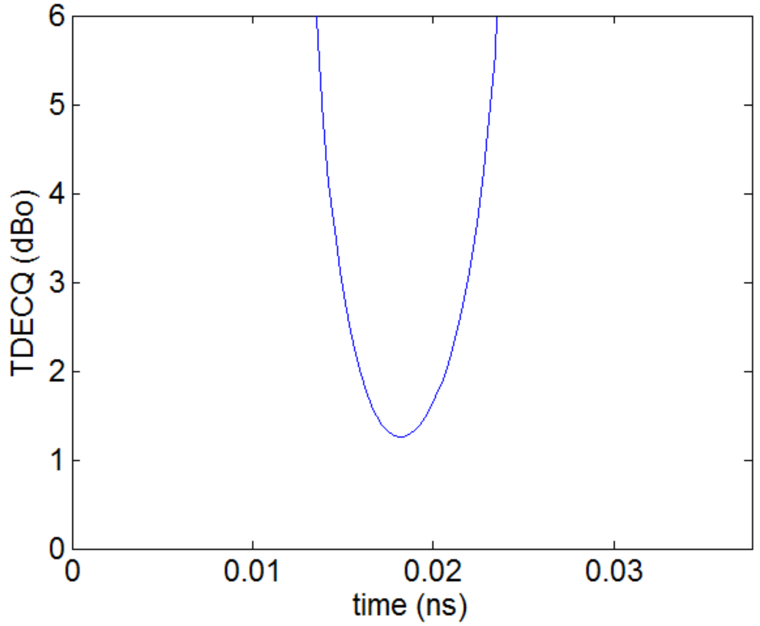
Simulated link



Equalized eye diagram and TDECQ

Noise-free eye diagram

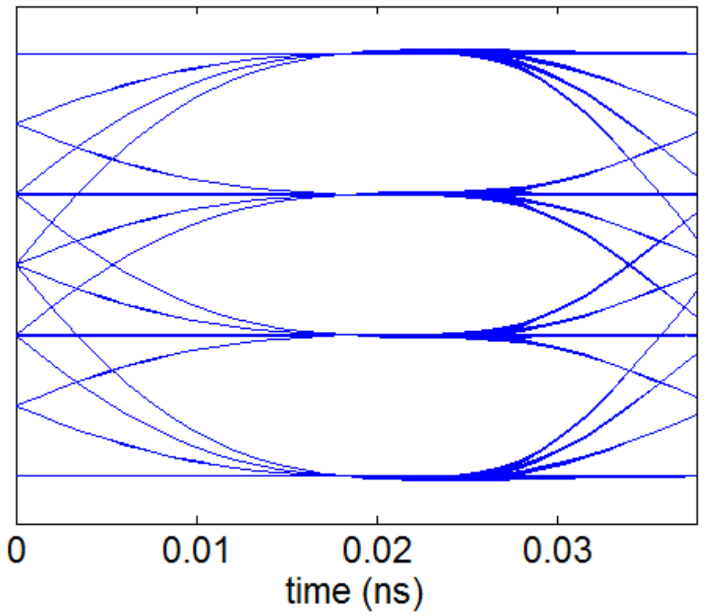


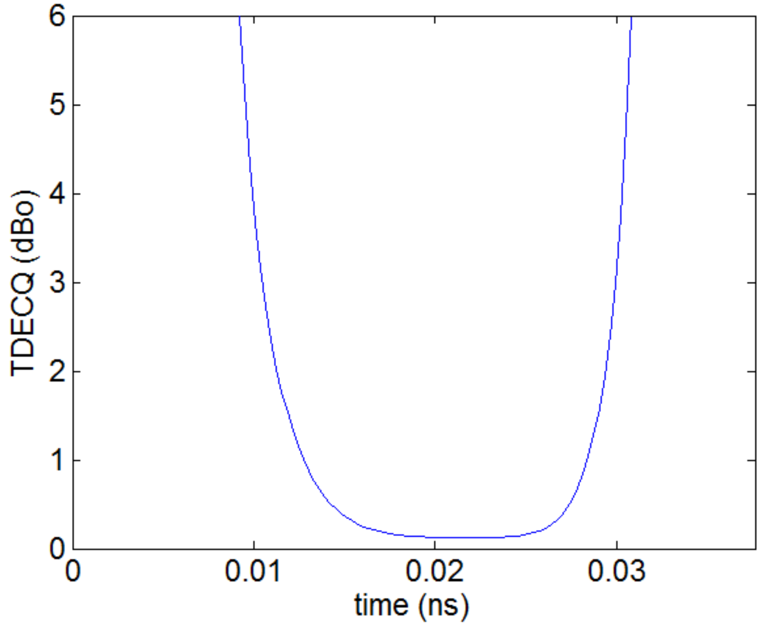


- Minimum TDECQ at a single sampling point: 1.2 dBo
- TDECQ in 0.04-UI-wide windows at 0.5 ± 0.05 UI: 2.0 dBo

Reference case

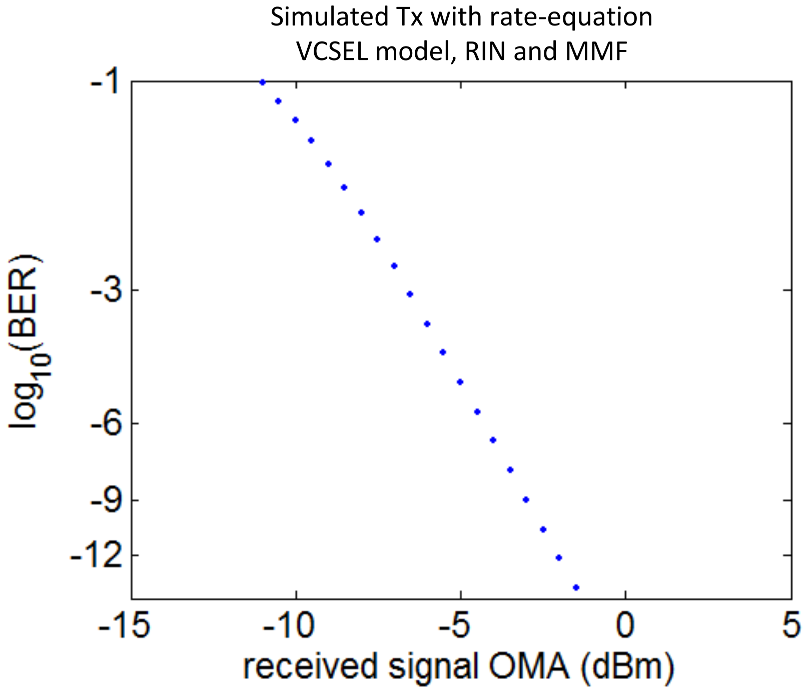
Noise-free eye diagram

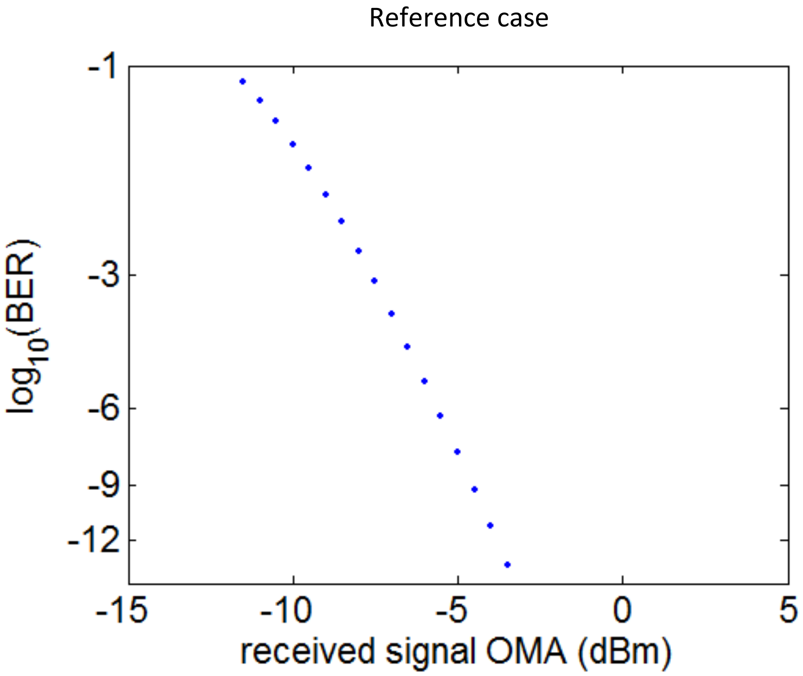




- Reference case: 0 ps Tx rise time, –∞ dB/Hz RIN, 0 m MMF
- Minimum TDECQ at a single sampling point: 0.1 dBo
- TDECQ in 0.04-UI-wide windows at 0.5 ± 0.05 UI: 0.1 dBo

BER curves





- At BER = 2.4×10^{-4} ($\log_{10}$ (BER) = –3.6): simulated Tx sensitivity: –5.9 dBm
- At BER = 2.4×10^{-4} ($\log_{10}$ (BER) = –3.6): reference case sensitivity: –7.0 dBm
- Penalty of 1.1 dBo matches TDECQ difference of 1.1 dBo

Part II: TDECQ for a worst-case link

Approach

- The overall philosophy of the TDECQ methodology is “worst-case”. For example:

  (i) Rx is assumed to sample all three PAM4 eyes at a common time, *although Rx do exist with greater capability*

  (ii) Rx is assumed to have “simple” thresholds at mean level and mean level ± OMA/3, *although Rx do exist with greater capability*

- To continue this philosophy and to maximize interoperability it is sensible to:

  (i) Assume Tx does not have pre-emphasis, *although Tx do exist with this capability*

  (ii) Assume Rx FFE has a T-spaced FFE only, *although Rx do exist with fractionally-spaced FFE and/or DFE*

Approach (cont.)

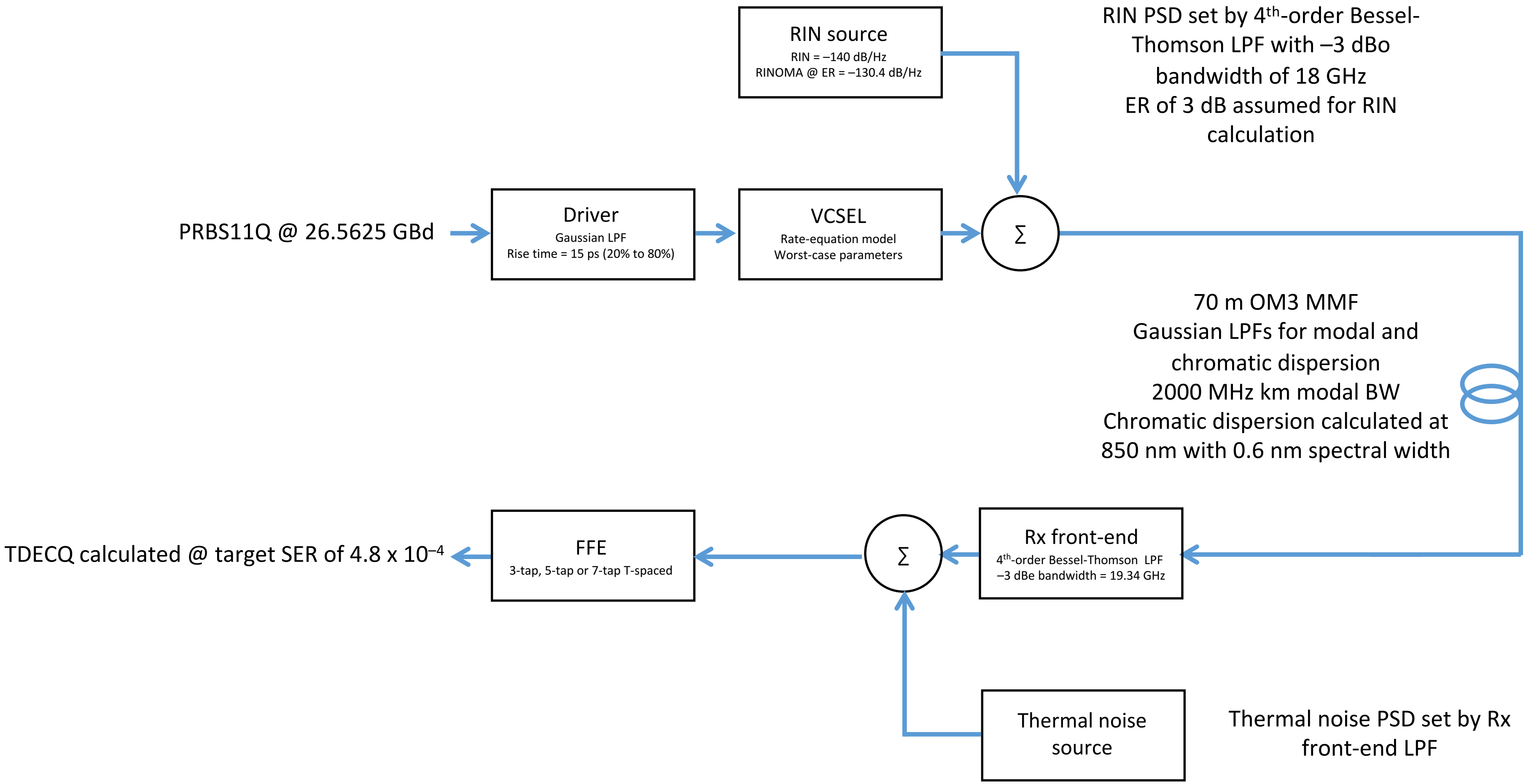
- Therefore, in this work we calculate TDECQ for worst-case Tx and MMF parameters with a T-spaced FFE as the reference equalizer

- The choice of a T-spaced FFE as the reference equalizer is **implementation agnostic** regarding the actual Rx. It can be implemented by analog or digital means

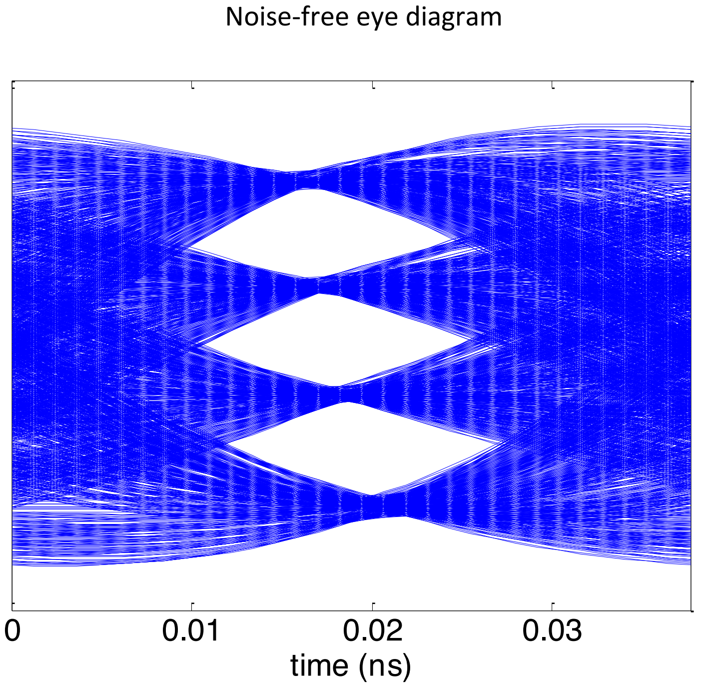
- By calculating TDECQ for different lengths of T-spaced FFE, we can determine the shortest possible equalizer that is capable of yielding a compliant link (TDECQ < 4.0 dBo) with worst-case Tx and MMF parameters

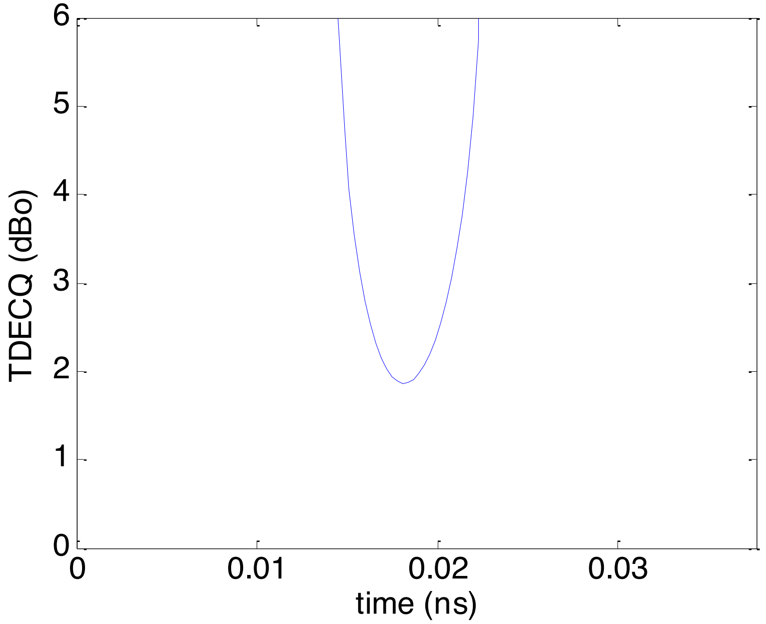
- This shortest possible equalizer is recommended as the TDECQ reference equalizer

Simulated link with worst-case parameters



7-tap FFE: equalized eye diagram and TDECQ

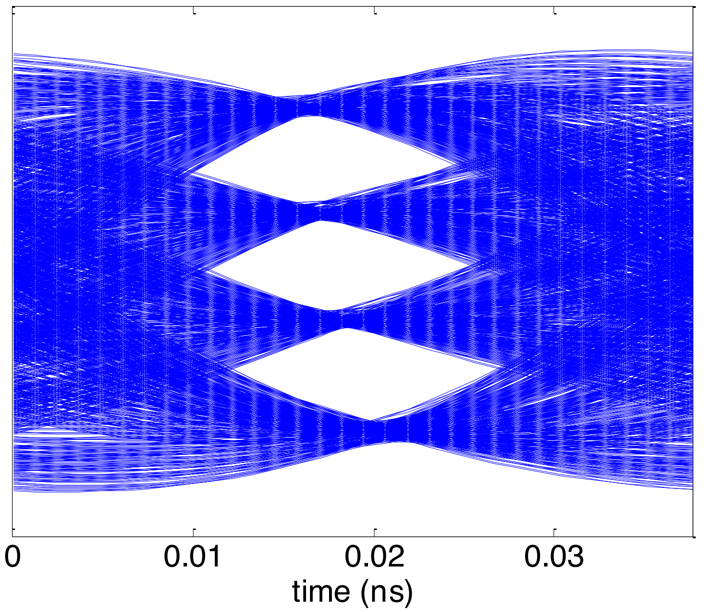


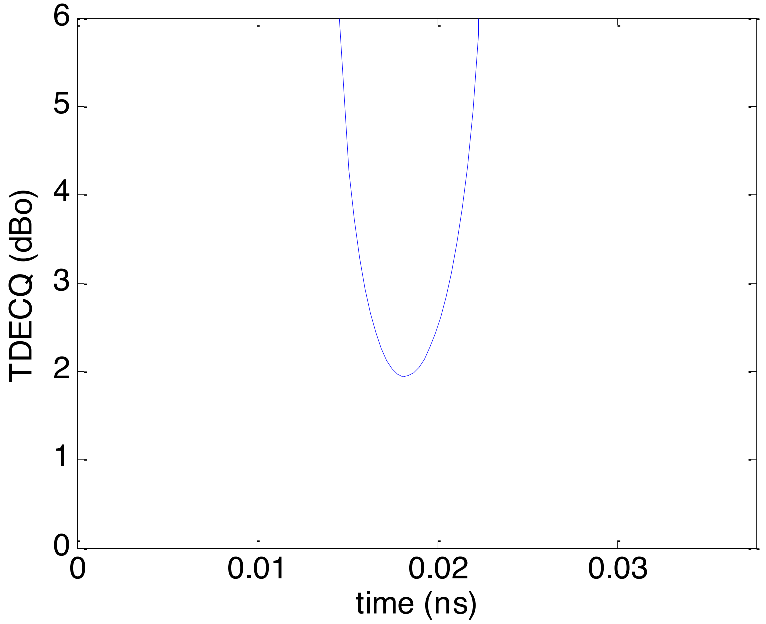


- TDECQ in 0.04-UI-wide windows at 0.5 ± 0.05 UI: 2.8 dBo

5-tap FFE: equalized eye diagram and TDECQ

Noise-free eye diagram

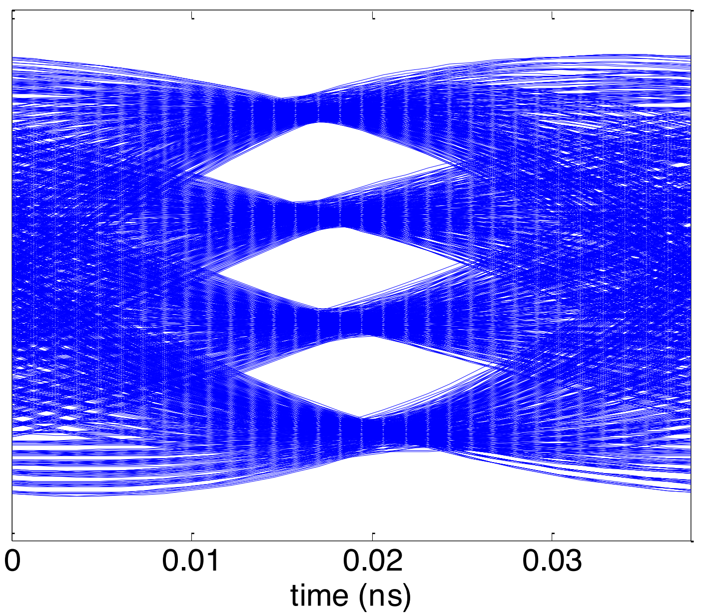


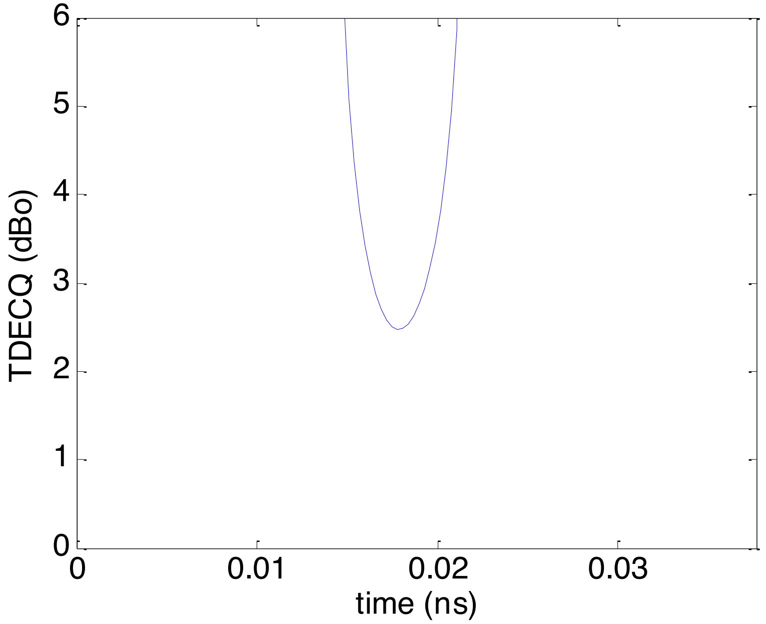


- TDECQ in 0.04-UI-wide windows at 0.5 ± 0.05 UI: 2.9 dBo

3-tap FFE: equalized eye diagram and TDECQ

Noise-free eye diagram





- TDECQ in 0.04-UI-wide windows at 0.5 ± 0.05 UI: 3.9 dBo

Summary of results

7-tap T-spaced FFE	TDECQ = 2.8 dBo
5-tap T-spaced FFE	TDECQ = 2.9 dBo
3-tap T-spaced FFE	TDECQ = 3.9 dBo

- These values do not include MPN. Separate calculations suggest a worst-case MPN penalty of 0.2 dBo
- Furthermore, there are additional impairments expected that are **not** captured in these simulations, e.g. electrical and optical reflections
- Since the TDECQ limit, i.e. maximum allocation for penalties, is 4.0 dBo, it is clear that a link with the worst-case Tx and MMF parameters is **not** compliant with a 3-tap T-spaced FFE
- The conclusion is that the reference equalizer for TDECQ for MMF PMDs must be at least a **5-tap T-spaced FFE**, since it is the shortest possible equalizer for a link with TDECQ below 4.0 dBo

Conclusions

- Initial modeling of a worst-case MMF link at 26.5625 GBd, relevant to all of the MMF PMDs in P802.3cd, is presented
- TDECQ is calculated in accordance with the methodology from P802.3bs
- **A T-spaced FFE is proposed as an implementation-agnostic reference equalizer**
- The results show that the reference equalizer must be at least a **5-tap T-spaced FFE**, since this is the shortest possible equalizer to allow the worst-case link to be compliant with the TDECQ limit of 4.0 dBo, allowing approximately 1 dBo allocation for other impairments
- The adoption of this reference equalizer does not constrain the implementation of an Rx to a T-spaced FFE. The necessary performance can also be achieved with a fractionally-spaced FFE