TDECQ review

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  - with sincere thanks for the insightful discussions with David Leyba, Marlin Viss and Greg LeCheminant of Keysight
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Re: Comment 570 on Clause 121, TDECQ

Cl **121** *SC* **121.8.3** *P* **225** *L* **5** # 570

King, Jonathan Finisar

Comment Type **T** *Comment Status* **D**

Equation 121-5 needs two corrections

SuggestedRemedy

The divisor sq_rt(2 pi) should be sigma_g x sq_rt(2 pi), and the divisor sigma_g in the exponent should be 2 sigma_g

Proposed Response *Response Status* **W**

[Editor's note: This comment was sent after the close of the comment period]

- Corrections to equation 121-5, $G_{th1}(y_i)$

$$G_{th1}(y_i) = \frac{2}{3} \times \frac{1}{\sqrt{2\pi}} \times \mathrm{e}^{-\left(\frac{y_i - P_{th1}}{\sigma_G}\right)^2} \times \Delta y$$

Corrections to equation 121-5, $G_{th1}(y_i)$

In draft 2.0, equation 121-5 should change from:

$$G_{th1}(y_i) = \frac{2}{3} \times \frac{1}{\sqrt{2\pi}} \times \mathrm{e}^{-\left(\frac{y_i - P_{th1}}{\sigma_G}\right)^2} \times \Delta y$$

to:

$$G_{th1}(y_i) = \frac{1}{\sigma_G \sqrt{2\pi}} \times e^{-\left(\frac{y_i - P_{th1}}{\sqrt{2}\sigma_G}\right)^2} \times \Delta y$$

(this makes the sum of $G_{th1}(y_i)$ over all y equal to 1).

TDECQ timing offset

- Draft 2.0 has +/-0.05 UI time interval between the two histograms used in the TDECQ measurement. The time interval is intended to ensure that TDECQ takes into account the PAM4 CDR timing window
- Contributions
  - JTOL test (at high frequency) +/-0.025 UI
  - VCO noise (e.g. 0.18 ps rms) +/-0.017 UI
  - Other ? +/-0.008 UI

Reference Equalizer for TDECQ -1

- Draft 2.0 reference equalizer is a 5 tap T/2 spaced FFE *
- The reference equalizer (EQ) does not define the implementation in a product – it's just for test and measurement purposes
- It does indicate a minimum EQ performance for reasonable transmitters to meet the TDECQ spec value
- The reference EQ definition shouldn't prevent the use of, or unduly favour, an otherwise functional equalizer technology
- Minimum complexity (number of taps) and max repeatability are desirable goals for test and measurement purposes

FFE – Feed Forward Equalizer

Reference Equalizer for TDECQ -2

- T spaced EQs fit nicely with digital implementations, e.g. where an analog-to-digital front end (for example, sampling once per symbol) feeds a relatively wide and slow bus to be processed.
  - There are relatively weak constraints on the maximum number of taps, there are commercial T spaced EQs with ~ two dozen taps or more.
  - Correct sampling point timing is critical,
- T/2 spaced EQs fit nicely with analogue implementations, e.g. where delay and tap weights are implemented in high speed linear electrical circuits.
  - The max number of taps that can be accommodated is limited by power burn and bandwidth constraints, to ~<10.
  - Sampling time isn't as critical
- The reference EQ should not prevent digital or analogue EQ implementations (it should allow, or be consistent with, both)

Reference Equalizer for TDECQ -3

- Based on modeling and off-line processing experiments on PAM4 links, T spaced tap based EQs seem to need about 1.5x to 2x as many active taps (3 to 4 times the time span) for equivalent equalization capabilities (i.e. for a particular transmitter to yield the same TDECQ value after equalization).
- *If a 10 tap T spaced FFE was used for the reference EQ, experience indicates a 5 tap T/2 FFE would be equivalently effective for most situations.*
- However, for some situations, e.g. a transmitter with a reflection that results in long post-curser type impulse responses), a long EQ will be much more effective than a shorter EQ just because it samples the incoming signal over a longer time span.
- *Unless long post-curser type impulse responses are otherwise excluded, a T/2 spaced EQ would be forced to have at least 19 T/2 taps to be able to cover the same time span as the 10 tap T spaced EQ; this would be severely challenging for an analog* implementation.
- *However, if a 5 tap T/2 spaced FFE is used as a reference, then a T spaced equivalent EQ isn't forced to be any longer than would otherwise be required to achieve a reasonable TDECQ value.*

Reference Equalizer for TDECQ -3

- Choosing a T/2 spaced FFE reference EQ
  - doesn't place any unnecessary requirements on the equivalent T spaced equalizer
  - whereas a T spaced reference EQ places onerous requirements on a T/2 spaced equivalent equalizer