Proposed changes to TDECQ measurement process in 802.3bs clause 121.8.5

October 25, 2016

David Leyba
Marlin Viss
Greg LeCheminant

KEYSIGHT TECHNOLOGIES

Proposed changes to TDECQ measurement process

– Several comments have been submitted for section 121.8.5:

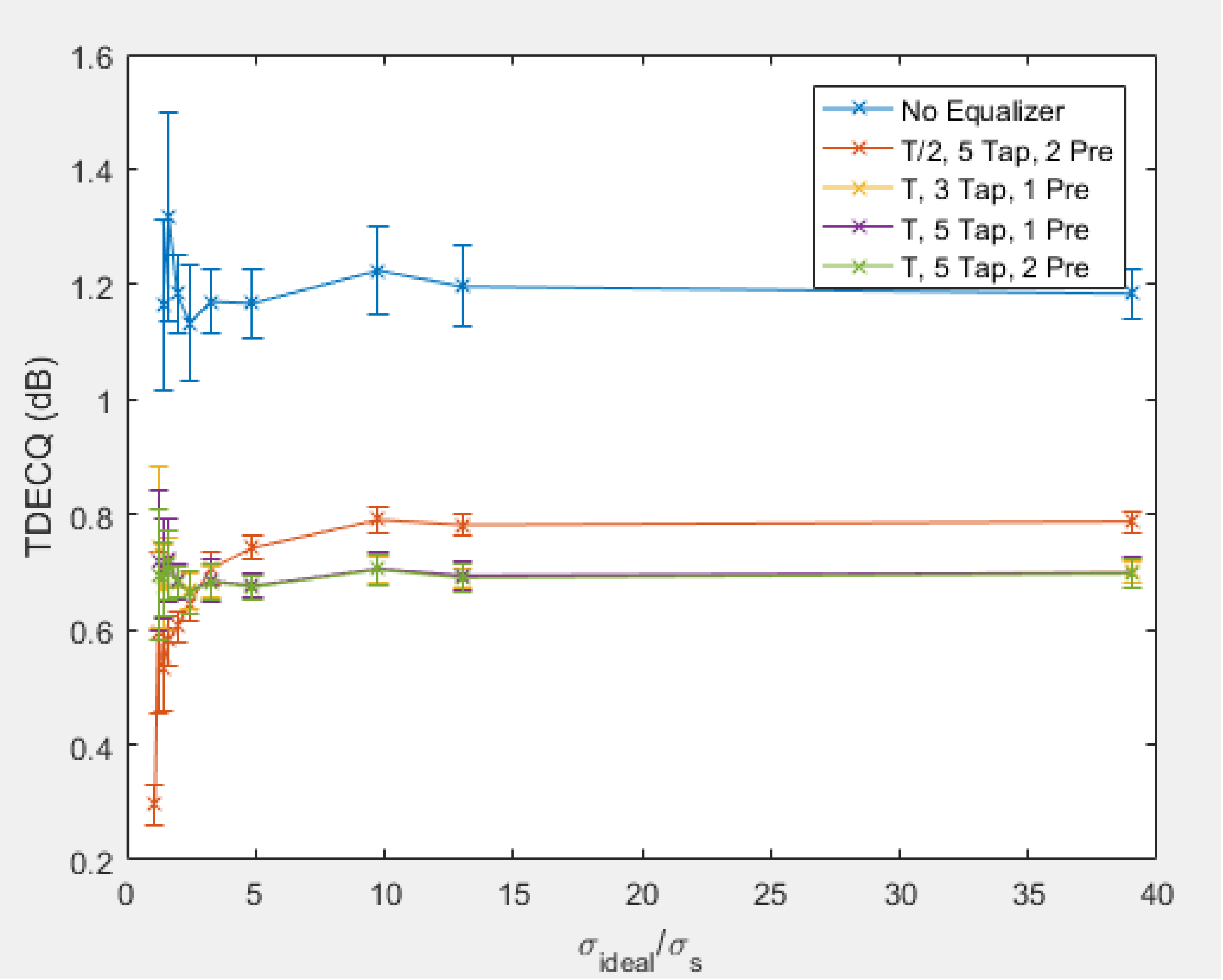
- A T spaced equalizer is recommended rather than the current T/2 approach
- Specifically document that OMA and Average power measured at the equalizer output (rather than the transmitter output)
- Modify equation 121-8 to reflect that the measurement is made using terms from the equalizer output
- A correction to equation 121-4
- Add a mathematical alternative to equation 121-5 (does not replace 121-5)
- Document a specific method for optimizing the TDECQ value

T/2 spaced equalizer can yield unanticipated results

- TDECQ is designed to back out the channel noise of the scope (σ_S). We would expect that for a fixed OMA and Tx signal noise, that TDECQ would be constant as σ_S is varied
- We can see that as the intrinsic noise begins to dominate the signal, the T/2 equalizer optimizes for noise reduction, which produces smaller TDECQ numbers. The TDECQ number is affected similarly when the scope noise is increased, but it serves to slow the increase in TDECQ that is expected

TDECQ as the ratio of OMA/TX noise to scope noise is diminished

When scope noise is proportionally large T/2 equalizer optimizes to diminish scope noise and yield a low TDECQ result. Not seen with T spaced implementation



KEYSIGHT TECHNOLOGIES

T spaced design edits

– **Section 121.8.5.4, pg227, line 27:**

– Change: …is a 5 tap, T/2 spaced, feed-forward equalizer (FFE), where T is the symbol period.

– To: is a 5 tap, 1 precursor, T spaced, feed-forward equalizer (FFE), where T is the symbol period.

OMA and Pave at equalizer output

- **Section 121.8.5.3, pg225, line 6. Change definition of Outer OMA to:**
- OMAouter is measured according to 121.8.4 on the equalized signal.
- **Section 121.8.5.3, pg225, line 21. Clarify, by adding the term “equalized”:**
- The average optical power (Pave) of the *equalized* eye diagram is determined…

Enhance flexibility of TDECQ

- **Section 121.8.5.3, pg227, line 16, equation 121-8:**
- $TDECQ = 10\log_{10}\left(\frac{C_{dc}OMA_{outer}}{6} \times \frac{1}{Q_t R}\right)$
- **And append at line 24:**
- C_{dc} is a coefficient which compensates for the reference equalizer DC gain when the equalizer has been optimized for minimum TDECQ.
- The value of C_{dc} can be calculated from the equalizer tap coefficients, A_i as shown in Equation (121-??)
- $\frac{1}{C_{dc}} = \sum_i A_i$ (121-??)

- Allow the TDECQ measurement to be more portable. Given the two gain terms of the equalizer, the measurement, as proposed, can be made entirely on the resulting waveform. This also allows the equalizer used for this measurement to be implemented in hardware

- As defined right now, the standard defines the decision thresholds based on Pave and OMAouter, where Pavg is defined after equalization and OMA outer is defined after equalization. This can only work with equalizers that have a DC gain of 1.0, or very close to it. By defining it as we have, the measurement can be used with other equalizers like CTLE, which likely does not have a DC gain of 1.0. This makes the measurement much more portable, and will not appreciably change the results when the DC gain is 1.0.

Correction

– **Section 121.8.5.3, pg226, line 25, equation 121-4:**

– Replace

$$Cf_1(y_i) = \sum_{y=P_{th1}}^{y_i} \left|(f(y_i) - f(P_{th1}))\right|$$

– With $C_1 f(y_i) = \begin{cases} \sum_{y=p_{th1}}^{y_i} f(y) \; for \; y_i \geq p_{th1} \\ \sum_{y=y_i}^{p_{th1}} f(y) \; for \; y_i \leq p_{th1} \end{cases}$

Call out the actual Gaussian histogram, and provide a method for estimation (use either the exact equation or the estimate)

- **Section 121.8.5.3, pg226, line 31-36, including equation 121-5:**
- Gth1(yi) is given by Equation (121–5) and can be estimated by (121-6).
- Replace Equation (121-5)

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

- with:
- $G_{th1}(y_i) = \int_{y_i-\frac{\Delta y}{2}}^{y_i-\frac{\Delta y}{2}} \frac{1}{\sigma_g\sqrt{2\pi}} \times e^{-\frac{1}{2}\left(\frac{y_i-P_{th1}}{\sigma_g}\right)^2} dy$
- And make equation (121-6) be what (121-5) was previously.

Specify the method of optimization

Section 121.8.5.3 currently has this statement:

– "The reference equalizer (specified in 121.8.5.4) is used to minimize the value of TDECQ derived from the captured waveform".

– Proposed change:

– The reference equalizer (specified in 121.8.5.4) is applied to the waveform. The equalizer taps are optimized for the minimum mean square error about the symbol levels (Pave – OMA/2), (Pave – OMA/6), (Pave+OMA/6), and (Pave+OMA/2), where the mean square error is calculated over the center 0.1 UI of the eye diagram.

– Reason: MMSE optimization is a standard technique that can be implemented by software algorithms or by actual receiver equalizers. By specifying the optimization criteria, it avoids multiple T&M vendors implementing different optimization techniques, or T&M vendors using optimization techniques that an actual receiver could not achieve.

–