Consensus Results: Corrections Needed in Clause 180.9.6

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Rev B

Addresses Comments: R2-15, R2-16, R2-17, R2-18, R2-126, R2-141, R2-144, R2-188, R2-189, R2-206

Consensus

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Introduction

- With the changes introduced in 3.2, there are a few things that need cleaning up in clause 180.9.6
- The DFE is based on a balanced and scaled alphabet, {-1, -1/3, 1/3, 1}:
  - At the input to the feedback path
  - For the MMSE calculation
- SSPRQ is specified as a sequence from the unbalanced alphabet {0, 1, 2, 3}
- The method of estimating OMA is based on a continuous-time signal, and the output of the DFE is a discrete-time signal
- The following presentation corrects these inconsistencies and addresses other TDECQ-related comments against D3.2

Comments: R2-15, R2-141, R2-144, R2-188, R2-206

The reference equalizer is a T-spaced, discrete-time equalizer with 15 feed-forward taps and a single decision feedback tap, where T is the symbol period. Equalizer coefficient constraints are given in Table 180–16. The reference equalizer may be implemented in the oscilloscope.

The equalizer is modeled as shown in Figure 180–10, where

R2-206

R2-141

R2-15, R2-144

— $r(t)$ is the output of the reference receiver defined in 180.9.2
— $\eta(t)$ is colored Gaussian noise, generated from additive white Gaussian noise (AWGN) filtered by a Bessel-Thomson (BT) filter as defined in 180.9.2
— $z(t)$ is the input signal given by Equation (180–1)
— z_n is the sampled response of input signal $z(t)$, given by Equation (180–2)
— y_n is the equalizer output corresponding to x_n
— X_n is the nth symbol in the test pattern sequence, $X_n \in \{0, 1, 2, 3\}$, and x_n is given by Equation (180-3)
— ~~w is the set of feed-forward tap coefficients, given by Equation (180–3)~~
$\boldsymbol{w}$ is a vector of feed-forward tap coefficients, given by Equation (180-4)
— $b(1)$ is the feedback tap coefficient
— ~~the feedback is modeled as correct, i.e., x_n is the pattern used to generate the input $r(t)$~~
the decisions are modeled as being correct, i.e., the input to the decision feedback path is based on the sequence $\{x_n\}$ corresponding to the transmitted test pattern sequence without errors
— the received signal $r(t)$ is aligned with the test pattern such that $r(nT)$ corresponds to x_n
-- OMA_{TDECQ} is defined in 180.9.6.4

$$z(t) = r(t) + \eta(t) \qquad (180\text{–}1)$$

$$z_n = z(nT + \phi)\text{, where } 0 \le \phi < T \qquad (180\text{–}2)$$

$$x_n = 2/3\,X_n - 1, \qquad x_n \in \{-1, -1/3, 1/3, 1\} \qquad (180\text{-}3)$$

$$\cancel{w = \{w(a), w(a+1), \ldots, w(a+14)\}} \qquad \cancel{(180\text{–}3)}$$

$$\boldsymbol{w} = [w(a), w(a+1), \ldots, w(a+14)] \qquad (180\text{-}4)$$

Comments: R2-15, R2-144, R2-188

Feed-forward tap DC gain[a]	—	1	
Number of feedback taps	N_b	1	
Feedback tap coefficient limit[b]	$b(1)$	0	0.33

[a] The sum of all 15 feed-forward tap coefficients, $w(i)$.
[b] The feedback tap coefficient $b(1)$ is referenced to $OMA_{TDECQ}/2$ (see 180.9.6.4 for definition of OMA_{TDECQ}).

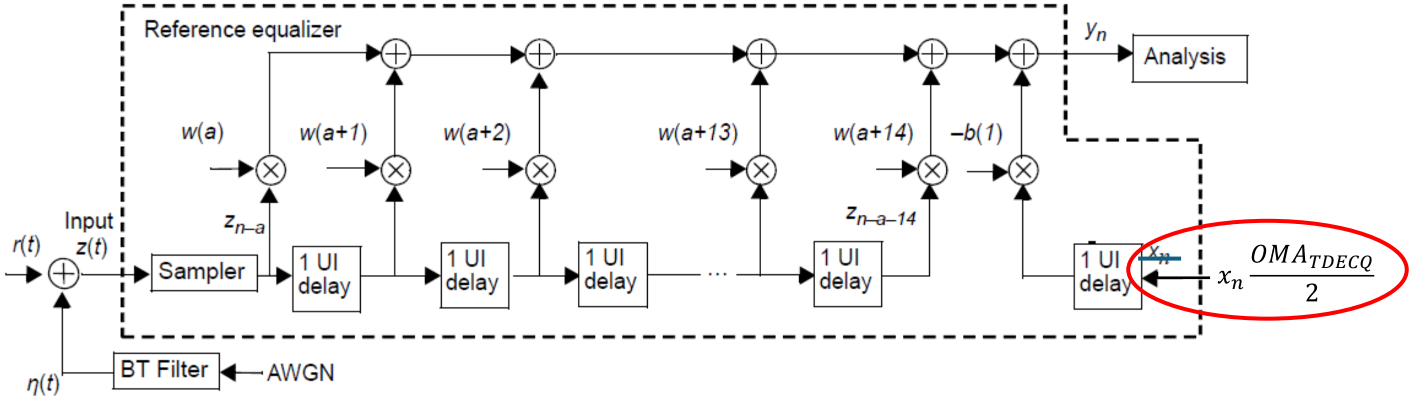

Figure 180–10—TDECQ reference equalizer functional model

Footnote b on Table 180-16 is now consistent with Figure 180-10

Comment: R2-188

For a given sampling phase ϕ_0 and assumed RMS value σ_G for the colored Gaussian noise $\eta(t)$, determine the equalizer coefficients $\boldsymbol{w}$ and $b(1)$, subject to the limits in Table 180–16, that result in the minimum mean squared error (MMSE) between ~~y_n and x_n~~. Alternative optimization methods may be used to determine equalizer tap weights if they report comparable values of TDECQ.

Replace here

$\overline{y}_n$ and a scaled version of x_n, where $\overline{y}_n = y_n - \text{mean}(y_n)$ and the scaling is such that the sum of the feedforward tap coefficients is 1.

Explanation (not to be included in the standard):

- Using $\overline{y}_n$ instead of y_n in the MMSE description obviates the need to subtract the mean from the received signal $r(t)$ out of the reference receiver. This minimizes changes required elsewhere.
- Because we require that sum($\boldsymbol{w}$) = 1, the MSE references a scaled version of x_n.
- The scaling factor is approximately but not exactly $OMA_{TDECQ}/2$ due to nonlinearities and our method of measuring OMA

Comments: R2-18, R2-188

Use X_n instead of x_n

y_n is implicitly a function of X_n

$$P(y_{n,\mathrm{L}}, \sigma_\mathrm{G}) = \frac{1}{2}\begin{cases} \operatorname{erfc}\left(\dfrac{P_{\mathrm{th1}} - y_{n,\mathrm{L}}}{\sqrt{2}C_{\mathrm{eq}}\sigma_\mathrm{G}}\right) & X_n = 0 \\ \operatorname{erfc}\left(\dfrac{y_{n,\mathrm{L}} - P_{\mathrm{th1}}}{\sqrt{2}C_{\mathrm{eq}}\sigma_\mathrm{G}}\right) + \operatorname{erfc}\left(\dfrac{P_{\mathrm{th2}} - y_{n,\mathrm{L}}}{\sqrt{2}C_{\mathrm{eq}}\sigma_\mathrm{G}}\right) & X_n = 1 \\ \operatorname{erfc}\left(\dfrac{y_{n,\mathrm{L}} - P_{\mathrm{th2}}}{\sqrt{2}C_{\mathrm{eq}}\sigma_\mathrm{G}}\right) + \operatorname{erfc}\left(\dfrac{P_{\mathrm{th3}} - y_{n,\mathrm{L}}}{\sqrt{2}C_{\mathrm{eq}}\sigma_\mathrm{G}}\right) & X_n = 2 \\ \operatorname{erfc}\left(\dfrac{y_{n,\mathrm{L}} - P_{\mathrm{th3}}}{\sqrt{2}C_{\mathrm{eq}}\sigma_\mathrm{G}}\right) & X_n = 3 \end{cases} \qquad (180\text{–}7)$$

where

C_{eq} is a coefficient which accounts for the reference equalizer noise enhancement

R2-18

$P_{th1}, P_{th2}, P_{th3}$ are thresholds adjusted from $P_{0,th1}, P_{0,th2}, P_{0,th3}$ within limits described below

Comments: R2-16, R2-17, R2-189 (background)

In D3.2, we do not mention at all how the values of y_n are determined away from $\phi = \phi_0$. We need those values for two reasons:

- We need the values in the regions defined at $\phi = \phi_0 \pm .05T$ to estimate symbol error rate, and
- The method defined in 180.9.5 to measure OMA_{TDECQ} is for a continuous-time (or over-sampled) signal with runs of threes and runs of zeros.

We can introduce the notion easily by talking about it when we introduce the eye diagram without being prescriptive.

The nominal threshold levels $P_{0,\text{th1}}$, $P_{0,\text{th2}}$, and $P_{0,\text{th3}}$, are determined from the $\text{OMA}_{\text{TDECQ}}$ and the average optical power P_{ave} as defined in Equation (180–4), Equation (180–5), and Equation (180–6), and illustrated in Figure 180–11.

$$P_{0,\,th1} = \text{P}_{\text{ave}} - \frac{\text{OMA}_{\text{TDECQ}}}{3} \qquad (180\text{–}4)$$

$$P_{0,\,\text{th2}} = \text{P}_{\text{ave}} \qquad (180\text{–}5)$$

$$P_{0,\,\text{th3}} = \text{P}_{\text{ave}} + \frac{\text{OMA}_{\text{TDECQ}}}{3} \qquad (180\text{–}6)$$

where $\text{OMA}_{\text{TDECQ}}$ is measured on the equalized captured waveform y_n using the method defined in 180.9.5.

Comments: R2-16, R2-189

An eye diagram to help illustrate TDECQ is shown in Figure 180–11. The eye diagram corresponds to the optimized equalizer setting at sampling phase ϕ_0. The feedback symbol x_n changes at phase $\phi = \phi_0 - T/2$.

Insert here

The eye diagram can be constructed, for example, by using the equalizer taps optimized at ϕ_0 and varying the phase ϕ in Eq. 180-2 to generate an oversampled equalized waveform.

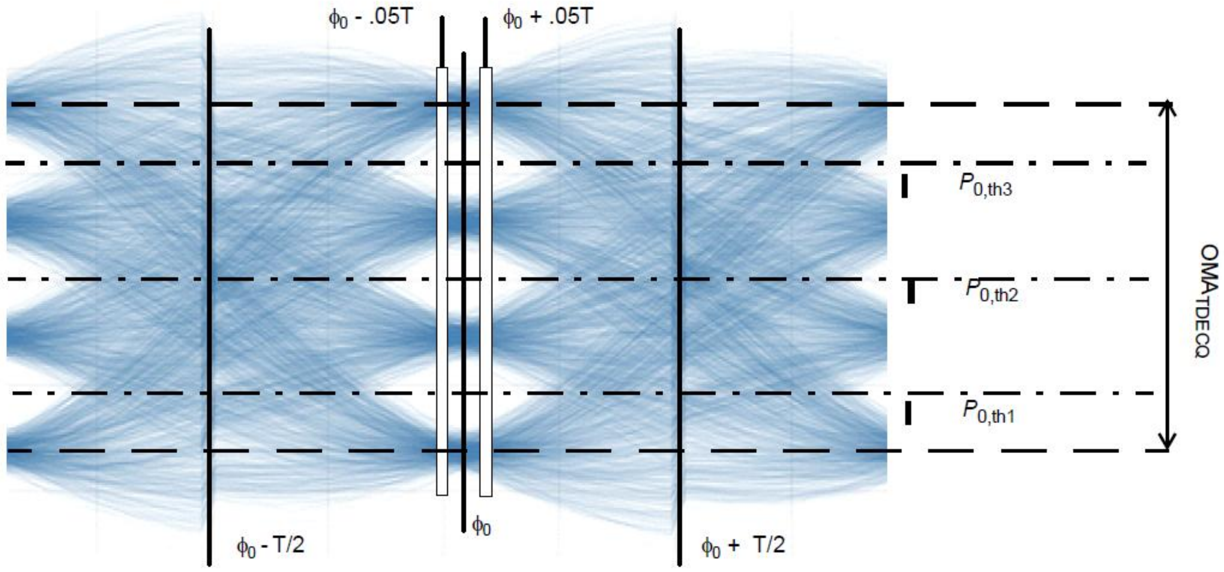

Figure 180–11—Illustration of the TDECQ measurement

Comments: R2-17, R2-189

The nominal threshold levels $P_{0,\text{th1}}$, $P_{0,\text{th2}}$, and $P_{0,\text{th3}}$, are determined from the $\text{OMA}_{\text{TDECQ}}$ and the average optical power P_{ave} as defined in Equation (180–4), Equation (180–5), and Equation (180–6), and illustrated in Figure 180–11.

$$P_{0,\,th1} = \text{P}_{\text{ave}} - \frac{\text{OMA}_{\text{TDECQ}}}{3} \quad (180\text{–}4)$$

$$P_{0,\,\text{th2}} = \text{P}_{\text{ave}} \quad (180\text{–}5)$$

$$P_{0,\,\text{th3}} = \text{P}_{\text{ave}} + \frac{\text{OMA}_{\text{TDECQ}}}{3} \quad (180\text{–}6)$$

~~where $\text{OMA}_{\text{TDECQ}}$ is measured on the equalized captured waveform y_n using the method defined in 180.9.5.~~ ,

where P_{ave} and OMA_{TDECQ} are measured on an oversampled equalized waveform, as illustrated in the eye diagram in Figure 180-11, using the method defined in 180.9.5 for OMA_{TDECQ}.

Comment: R2-126

initially

For a given sampling phase ϕ_0 two regions of a UI are measured, centered 0.05 UI before and after the sampling phase ϕ_0, each with a width of 0.04 UI. For the left region, all samples such that $\phi_0 - 0.07\mathrm{T} \le \phi \le \phi_0 - 0.03\mathrm{T}$ are included. For the right region, all samples such that $\phi_0 + 0.03\mathrm{T} \le \phi \le \phi_0 + 0.07\mathrm{T}$ are included. The precise time position of the pair of regions is adjusted to minimize TDECQ while keeping the regions spaced 0.1 UI apart. Let $y_{n,\mathrm{L}}$ and $y_{n,\mathrm{R}}$ be the equalized samples in the left region and the right region respectively.

Thank you