Implementation of changes to TDECQ and SRS

Pete Anslow, Ciena

IEEE P802.3cd Task Force, San Diego, CA, July 2018

TDECQ changes

Table 138-8

Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)§	4.5§	dB§
TDECQ – $10\log_{10}(C_{eq})$[c], each lane (max)§	4.5§	dB§
Average launch power of OFF transmitter, each lane (max)§	−30§	dBm§
Extinction ratio, each lane (min)§	3§	dB§
Transmitter transition time, each lane (max)§	34§	ps§
$RIN_{12}OMA$ (max)§	−128§	dB/Hz§
Optical return loss tolerance (max)§	12§	dB§
Encircled flux[d]§	≥ 86% at 19 µm¶ ≤ 30% at 4.5 µm§	§

[a]RMS spectral width is the standard deviation of the spectrum.§
[b]Even if the TDECQ < 1.4 dB, the OMA (min) must exceed this value.§
[c]C_{eq} is a coefficient defined in 121.8.5.8, which accounts for the reference equalizer noise enhancement.§
[d]If measured into type A1a.2 or type A1a.3, or A1a.4, 50 µm fiber, in accordance with IEC 61280-1-4.§

138.8.5

138.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

TDECQ is a measure of each optical transmitter's vertical eye closure as measured through an optical to electrical converter (O/E) with a bandwidth equivalent to a combined reference receiver and worst case optical channel, and equalized with the reference equalizer specified in 138.8.5.1. Table 138–9 specifies the test pattern to be used for measurement of TDECQ.

The TDECQ and TDECQ − $10\log_{10}(C_{eq})$ of each lane shall be within the limits given in Table 138–8 if measured using the methods specified in 121.8.5, with the following exceptions:

- The polarization rotator and test fiber shown in Figure 121–4 are not used
- The optical channel requirements in 121.8.5.2 do not apply
- The combination of the O/E and the oscilloscope used to measure the optical waveform has a fourth-order Bessel-Thomson filter response with a bandwidth of 11.2 GHz.
- The reference equalizer to be used for TDECQ for 50GBASE-SR, 100GBASE-SR2, and 200GBASE-SR4 is specified in 138.8.5.1.
- P_{th1}, P_{th2}, and P_{th3} are varied from their nominal values by up to ±1% of OMA_{outer} in order to optimize TDECQ. The same three thresholds are used for both the left and the right histogram.

Table 139-6

Launch power in OMA_{outer} minus TDECQ (min)§	−3.9§	−2.9§	dBm§
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)§	3§	3.2§	dB§
TDECQ − $10\log_{10}(C_{eq})^{c}$ (max)§	3§	3.2§	dB§
Average launch power of OFF transmitter (max)§	−16§		dBm§
Extinction ratio (min)§	3.5§		dB§
Transmitter transition time (max)§	34§		ps§
$RIN_{17.1}OMA$ (max)§	−132§	—§	dB/Hz§
$RIN_{15.6}OMA$ (max)§	—§	−132§	dB/Hz§
Optical return loss tolerance (max)§	17.1§	15.6§	dB§
Transmitter reflectance[d] (max)§	−26§		dB§

[a] Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.§

[b] Even if the TDECQ < 1.4 dB, the OMA_{outer} (min) must exceed this value.§

[c] C_{eq} is a coefficient defined in 121.8.5.8, which accounts for the reference equalizer noise enhancement.§

[d] Transmitter reflectance is defined looking into the transmitter.§

139.7.5

139.7.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

The TDECQ and TDECQ – $10\log_{10}(C_{eq})$ shall be within the limits given in Table 139–6 for 50GBASE-FR and 50GBASE-LR if measured using the methods specified in 139.7.5.1, 139.7.5.2, and 139.7.5.3.

TDECQ is a measure of each optical transmitter's vertical eye closure when transmitted through a worst case optical channel (specified in 139.7.5.2), as measured through an optical to electrical converter (O/E) with a bandwidth equivalent to a reference receiver, and equalized with the reference equalizer (as described in 139.7.5.4). The reference receiver and equalizer may be implemented in software or may be part of the oscilloscope.

Table 139–10 specifies the test patterns to be used for measurement of TDECQ.

Table 140-6

Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)§	3.4§	dB§
TDECQ – $10\log_{10}(C_{eq})$[c] (max)§	3.4§	dB§
Average launch power of OFF transmitter (max)§	–15§	dBm§
Extinction ratio (min)§	3.5§	dB§
Transmitter transition time (max)§	17§	ps§
$RIN_{15.5}OMA$ (max)§	–136§	dB/Hz§
Optical return loss tolerance (max)§	15.5§	dB§
Transmitter reflectance[d] (max)§	–26§	dB§

[a] Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.§

[b] Even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 5 dB or TDECQ < 1.1 dB for an extinction ratio of < 5 dB, the OMA_{outer} (min) must exceed this value.§

[c] C_{eq} is a coefficient defined in 121.8.5.8, which accounts for the reference equalizer noise enhancement.§

[d] Transmitter reflectance is defined looking into the transmitter.§

140.7.5

140.7.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

The TDECQ and TDECQ – $10\log_{10}(C_{eq})$ shall be within the limits given in Table 140–6 if measured using the methods specified in 121.8.5.1, 121.8.5.2, and 121.8.5.3 using a reference equalizer as described in 140.7.5.1, with the following exceptions:

- The optical return loss of the transmitter compliance channel is 15.5 dB.
- The signaling rate of the test pattern generator is as given in Table 140–6 and uses a test pattern specified for TDECQ in Table 140–10.
- There are no interfering optical lanes and therefore the delay requirement of at least 31 UI between test pattern on one lane and any other lane, as specified in 121.8.5.1, is redundant.
- The combination of the O/E converter and the oscilloscope has a fourth-order Bessel-Thomson filter response with a bandwidth of approximately 26.5625 GHz.
- The normalized noise power density spectrum, $N(f)$ in Equation (121–9), is equivalent to white noise filtered by a fourth-order Bessel-Thomson response filter with a bandwidth of 26.5625 GHz.
- P_{th1}, P_{th2}, and P_{th3} are varied from their nominal values by up to ±1% of OMA_{outer} in order to optimize TDECQ. The same three thresholds are used for both the left and the right histogram.

SRS changes

Table 138-9

Stressed receiver sensitivity (OMA_{outer}), each lane[c] (max)§	−3.4§	dBm§
Receiver sensitivity (OMA_{outer}), each lane[d] (max)§	Equation (138−1)§	dBm§
Conditions of stressed receiver sensitivity test:[e]§		
Stressed eye closure for PAM4 (SECQ), lane under test§	4.5§	dB§
SECQ − $10\log_{10}(C_{eq})$[f], (max) lane under test§	4.5§	dB§
OMA_{outer} of each aggressor lane[g]§	3§	dBm§

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level on one lane. The receiver does not have to operate correctly at this input power.§
[b]Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.§
[c]Measured with conformance test signal at TP3 (see 138.8.10) for the BER specified in 138.1.1.§
[d]Receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 4.5 dB.§
[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.§
[f]C_{eq} is a coefficient defined in 121.8.5.8, which accounts for the reference equalizer noise enhancement.§
[g]Only applies to 100GBASE-SR2 and 200GBASE-SR4.§

138.8.10

138.8.10 Stressed receiver sensitivity

Stressed receiver sensitivity shall be within the limits given in Table 138–9 if measured using the methodology defined in 121.8.9.1 and 121.8.9.3, with the conformance test signal at TP3 as described in 121.8.9.2, with the following exceptions:

- The SECQ of the stressed receiver conformance test signal is measured according to 138.8.5, except that the combination of the O/E and the oscilloscope has a bandwidth of approximately 13.28125 GHz and a fourth-order Bessel-Thomson filter response. This filter response should be followed to at least 0.9 × 26.5625 GHz and at frequencies between 0.9 × 26.5625 GHz and 1.5 × 26.5625 GHz the response should not exceed the Bessel-Thomson response. The optical splitter and variable reflector shown in Figure 121–4 are not used, and the transition time is no greater than the value specified in Table 138–8.
- With the Gaussian noise generator on and the sinusoidal jitter and sinusoidal interferer turned off, the $RIN_{12}OMA$ of the SRS test source should be no greater than the $RIN_{12}OMA$ (max) specified for the transmit characteristics in Table 138–8.
- The test patterns used for stressed receiver sensitivity are specified in Table 138–12.
- The signaling rate, ~~and~~ the required stressed eye closure (SECQ), and the maximum SECQ – $10\log_{10}(C_{eq})$ of the stressed receiver conformance test signal is as specified in Table 138–9.
- The restriction that at least half of the dB value of the SECQ is due to the frequency response of the combination of the low-pass filter and the E/O converter in 121.8.9.1 and 121.8.9.2 does not apply.
- The applied sinusoidal jitter is specified in 138.8.10.1.
- For 100GBASE-SR2 and 200GBASE-SR4, the OMA_{outer} of the aggressor lanes is specified in Table 138–9.

Table 139-7

Receiver reflectance (max)§	–26§		dB§
Receiver sensitivity (OMA_{outer})[c] (max)§	Equation (139–1)§	Equation (139–2)§	dBm§
Stressed receiver sensitivity (OMA_{outer})[d] (max)§	–5.5§	–6.8§	dBm§
Conditions of stressed receiver sensitivity test:[e]§			
Stressed eye closure for PAM4 (SECQ)§	3§	3.2§	dB§
SECQ – $10\log_{10}(C_{eq})$[f] (max)§	3§	3.2§	dB§

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.§

[b]Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.§

[c]Receiver sensitivity (OMA_{outer}) (max) is informative and is defined for a transmitter with a value of SECQ up to 2.8 dB for 50GBASE-FR and 3 dB for 50GBASE-LR.§

[d]Measured with conformance test signal at TP3 (see 139.7.10) for the BER specified in 139.1.1.§

[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.§

[f]C_{eq} is a coefficient defined in 121.8.5.8, which accounts for the reference equalizer noise enhancement.§

139.7.10.1

139.7.10.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 139–7. The patterns used for the received conformance signal are specified in Table 139–10. The optical test signal is conditioned (stressed) using the stressed receiver methodology defined in 139.7.10.2 and has sinusoidal jitter applied as specified in 121.8.9.4. A suitable test set is needed to characterize the signal used to test the receiver. Stressed receiver conformance test signal verification is described in 139.7.10.3.

The low-pass filter is used to create ISI. ~~The combination of the low-pass filter and the E/O converter should have a frequency response that results in at least half of the dB value of the stressed eye closure (SECQ) specified in Table 139–7 for 50GBASE-FR and 50GBASE-LR before the sinusoidal and Gaussian noise terms are added, according to the methods specified in 139.7.10.2.~~ The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the finite edge rates, also causes some jitter.

The sinusoidally jittered clock represents other forms of jitter and also verifies that the receiver under test can track low-frequency jitter. The sinusoidal amplitude interferer may be set at any frequency between 100 MHz and 2 GHz, although care should be taken to avoid harmonic relationships between the sinusoidal interferer, the sinusoidal jitter, the signaling rate, and the pattern repetition rate. The Gaussian noise generator, the amplitude of the sinusoidal interferer, and the low-pass filter are adjusted so that the SECQ specified in Table 139–7 is met, according to the methods specified in 139.7.10.2.

For improved visibility for calibration, all elements in the signal path (cables, DC blocks, E/O converter, etc.) should have wide and smooth frequency response, and linear phase response, throughout the spectrum of interest. Baseline wander and overshoot and undershoot should be negligible.

139.7.10.2

139.7.10.2 Stressed receiver conformance test signal characteristics and calibration

The stressed receiver conformance test signal characteristics and calibration methods are as described in 121.8.9.2 with the following exceptions:

- The SECQ of the stressed receiver conformance test signal is measured according to 139.7.5, except that the test fiber is not used. The transition time of the stressed receiver conformance test signal is no greater than the value specified in Table 139–6. The filter response of the combination of the O/E and the oscilloscope used for the SECQ measurement should be a fourth-order Bessel-Thomson filter response with a bandwidth of approximately 13.28125 GHz to at least 0.9 × 26.5625 GHz and at frequencies between 0.9 × 26.5625 GHz and 1.5 × 26.5625 GHz the response should not exceed the Bessel-Thomson response.
- With the Gaussian noise generator on and the sinusoidal jitter and sinusoidal interferer turned off, the $RIN_{17.1}OMA$ and $RIN_{15.6}OMA$ of the SRS test source for 50GBASE-FR and 50GBASE-LR, respectively, should be no greater than the values specified in Table 139–6.
- An example stressed receiver conformance test setup is shown in Figure 139–7; however, alternative test setups that generate equivalent stress conditions may be used.
- The signaling rate of the test pattern generator and the extinction ratio of the E/O converter are as given in Table 139–6 for 50GBASE-FR and 50GBASE-LR.
- The required values of the "Stressed receiver sensitivity (OMA_{outer}) (max)", ~~and~~ "Stressed eye closure for PAM4 (SECQ)", and "SECQ – $10\log_{10}(C_{eq})$ (max)" are as given in Table 139–7 for 50GBASE-FR and 50GBASE-LR.
- The restriction that at least half of the dB value of the SECQ is due to the frequency response of the combination of the low-pass filter and the E/O converter does not apply.

Table 140-7

Receiver sensitivity (OMA_{outer})[c] (max) §	Equation (140–1)§	dBm§
Stressed receiver sensitivity (OMA_{outer})[d] (max)§	–2.3§	dBm§
Conditions of stressed receiver sensitivity test:[e]§		
Stressed eye closure for PAM4 (SECQ)§	3.4§	dB§
SECQ – $10\log_{10}(C_{eq})$[f] (max)§	3.4§	dB§

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level. The receiver does not have to operate correctly at this input power.§
[b]Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.§
[c]Receiver sensitivity (OMA_{outer}) (max) is informative and is defined for a transmitter with a value of SECQ up to 3 dB.§
[d]Measured with conformance test signal at TP3 (see 140.7.10) for the BER specified in 140.1.1.§
[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.§
[f]C_{eq} is a coefficient defined in 121.8.5.8, which accounts for the reference equalizer noise enhancement.§

140.7.10

140.7.10 Stressed receiver sensitivity

Stressed receiver sensitivity shall be within the limits given in Table 140–7 if measured using the method defined in 121.8.9 with the following exceptions:

- The SECQ of the stressed receiver conformance test signal is measured according to 140.7.5, except that the test fiber is not used. The transition time of the stressed receiver conformance test signal is no greater than the value specified in Table 140–6. The filter response of the combination of the O/E and the oscilloscope used for the SECQ measurement should be a fourth-order Bessel-Thomson filter response with a bandwidth of approximately 26.5625 GHz to at least 0.9 × 53.125 GHz and at frequencies between 0.9 × 53.125 GHz and 1.5 × 53.125 GHz the response should not exceed the Bessel-Thomson response.
- With the Gaussian noise generator on and the sinusoidal jitter and sinusoidal interferer turned off, the $RIN_{15.5}OMA$ of the SRS test source should be no greater than the value specified in Table 140–6.
- The signaling rate of the test pattern generator and the extinction ratio of the E/O converter are as given in Table 140–6 using test patterns specified in Table 140–10.
- The required values of the "Stressed receiver sensitivity (OMA_{outer}) (max)", ~~and~~ "Stressed eye closure for PAM4 (SECQ)" , and "SECQ – $10\log_{10}(C_{eq})$ (max)" are as given in Table 140–7.
- The restriction that at least half of the dB value of the SECQ is due to the frequency response of the combination of the low-pass filter and the E/O converter in 121.8.9.1 and 121.8.9.2 does not apply.

Thanks!