

Improving TDECQ Test Definition

(Addressing comments 236, 237, 238, 239, 240, 241, 242, 243)

Ali Ghiasi - Ghiasi Quantum/Marvell

Karl Muth – Broadcom

Pavel Zivny - Multilane

IEEE 802.3dj Interim Meeting

Phoenix

January 20, 2025

Supporters/Contributors

- ❑ **Chris Cole – Coherent**
- ❑ **Phil Sun – Credo**
- ❑ **Mike Dudek – Marvell**
- ❑ **Bill Simms – Nvidia.**

Overview

- ❑ **Concern about TDECQ test method not capturing jitter/block errors**
- ❑ **802.3 CL 121 TDECQ definition**
- ❑ **802.3dj supplemental TDECQ definition**
- ❑ **Mission mode testing**
- ❑ **Clause 86 precedence**
- ❑ **Enhancement to TDECQ test definition based on CL86 precedence**
- ❑ **Summary.**

Improving TDECQ Test Method

- ❑ **Concern raised that high phase noise in the 4-100 MHz may cause error floor, see [ran 3dj elec 01 240822](#)**
 - Ran suggest adding J3U test to TP2 to protect the receiver
- ❑ **[Ghiasi 3dJ 01 2409](#) investigated number of issues around TDECQ test method which may explain lack of correlation to receiver sensitivity**
 - The biggest issue maybe due to measuring TDECQ in non-mission mode where no jitter passes through the CDR – Testing in mission mode is a must to capture any form of jitter
 - Ghiasi showed that TDECQ does already capture correct J3U jitter only if the module is in the mission mode – Adding separate J3U test is redundant and not necessary
 - TDECQ with SSPRQ can capture jitter to ~1.6 MHz which is better the J3U based on PRBS13Q – If capturing jitter down 100's kHz become necessary then phase noise measurement with PRBS31Q would be needed
- ❑ **[Mi 3dJ 02a 2409](#) investigates possible method how to better define TECQ/TDECQ to capture effect of block errors – will improve TECQ/TDECQ correlation to post-FEC**
- ❑ **[ghiasi 3dj 02a 2411](#) investigates block TDECQ method to determine the worst TDECQ over ~ 10 SSPRQ waveforms – The current TDECQ provide average penalty.**

802.3bs TDECQ Method

□ 121.8.5.3 TDECQ measurement method

- The standard deviation of the noise of the O/E and oscilloscope combination, σ_s , is determined with no optical input signal and the same settings as used to capture the histograms described below.
- OMA_{outer} is measured according to 121.8.4 on the equalized signal.
- The test pattern specified for TDECQ (see Table 121–10) is transmitted repetitively by the optical lane under test and the oscilloscope is set up to capture samples from all symbols in the complete pattern without averaging

..... Detail on the scope processing of data

□ 121.8.5.4 TDECQ reference equalizer

- **No mention that AUI is active and module is in mission mode, and no mention of counter propagating traffic during TDECQ test in CL 121!**

Current TDECQ SER Calculation

□ Two normalized histogram created (Left and Right) are created and associated function $F(y_i)$ equal to the number of sample captured divided by number of sample in the histogram window

- The sum of all $F(y_i)=1$
- Three cumulative probability functions are created for left and right histogram $F(y_i)$
 - The three histograms are for level 1, 2, 3
- The left cumulative function given below:

$$CF_{Li}(y_i) = \begin{cases} \sum_{y=P_{th1}}^{y_i} F(y) \text{ for } y_i \geq P_{th1} \\ \sum_{y=y_i}^{P_{th1}} F(y) \text{ for } y_i < P_{th1} \end{cases}$$

- Each element of CF_{L1} , CF_{L2} , and CF_{L3} are multiplied with associated threshold to partial SER for each level, then the 3 left cumulative distribution summed to get SER(left)
- The larger of SER_L or SER_R is used for TDECQ calculation.

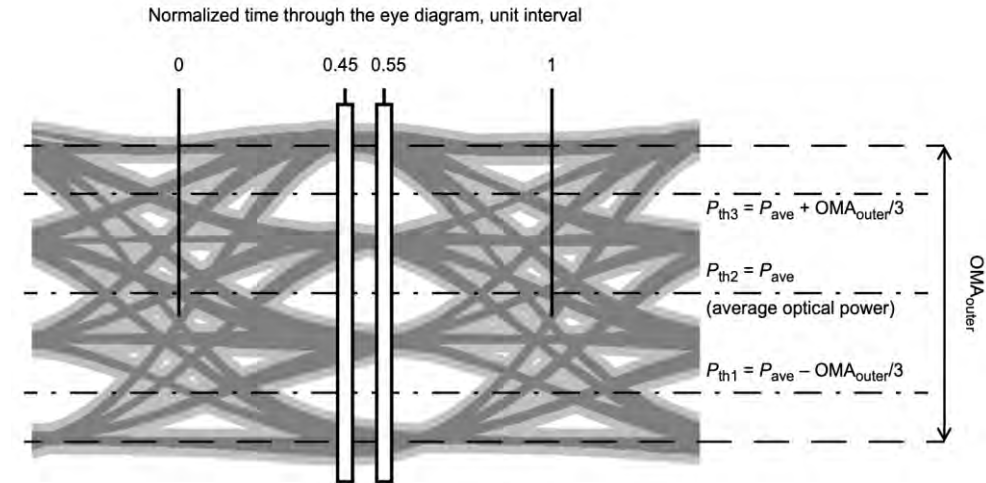


Figure 121-5—Illustration of the TDECQ measurement

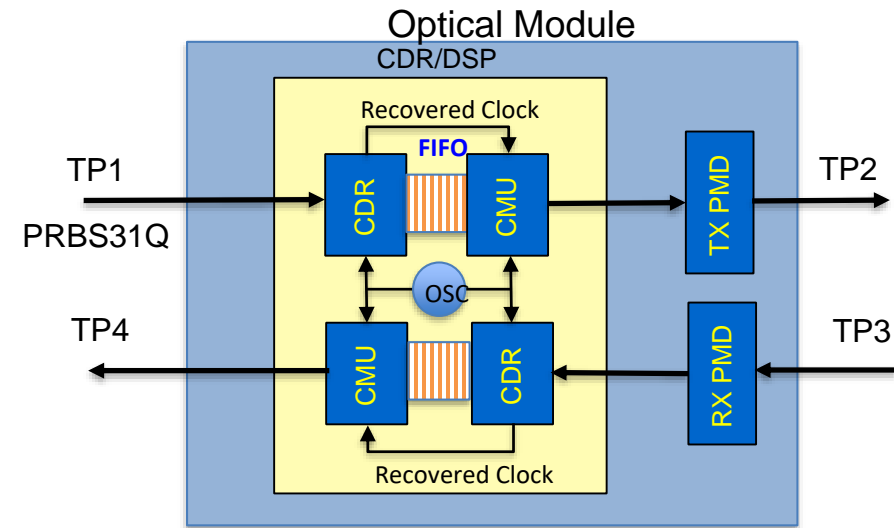
802.3dj TDECQ Supplement

□ 180.9.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

- The signaling rate of the test pattern generator is as given in Table 180–7 and uses the test pattern specified for TDECQ in Table 180–17.
 - The reference equalizer is a 15-tap, T-spaced, feed-forward equalizer (FFE), where T is the symbol period, with equalizer coefficient constraints as shown in Table 180–18.
 - The combination of the O/E converter and the oscilloscope has a 3 dB bandwidth of approximately 53.125 GHz with a fourth-order Bessel-Thomson response to at least 1.3×106.25 GHz, and at frequencies above 1.3×106.25 GHz, the response should not exceed –20 dB. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.
 - The normalized noise power density spectrum $N(f)$ is equivalent to white noise filtered by a fourth-order Bessel-Thomson response filter with a 3 dB bandwidth of 53.125 GHz.
 - The optical return loss is as given in Table 180–7.
 - The lowest measured TDECQ values are achieved with the equalizer optimization method described in 121.8.5. Alternative optimization methods such as minimum mean squared error (MMSE) may be used to determine equalizer tap weights to reduce test time, and are expected to report equal or higher values of TDECQ. These alternative methods should not be used for receiver sensitivity and stressed receiver sensitivity calibration.
- **No mention that AUI is active and module is in mission mode, and no mention of counter propagating traffic during TDECQ test in CL 180!**

Configuring DUT Module Test for Mission Mode

- ❑ **The module is configured into mission mode with worst case stress signal that include SJ applied to TP1**
 - The data pattern applied to TP1 are one of following PRBS31Q, valid FEC encoded data, or SSPRQ
 - When PRBS31Q or valid FEC encoded data are used the CDR recovered clock is used to drive the CMU with SSPRQ pattern
 - If the CDR can tolerate operating with SSPRQ then CDR-CMU are put in passthrough mode
- ❑ **Crosstalk optical source is active and applied at TP3 that passes to TP4 during TDECQ mission mode testing.**



Prior Precedence can Guide us to Enhanced TDECQ Definition

□ Clause 86 is PMD definition for 40GBASE-SR4 and 100GBASE-SR10

- Clause 86 PMD use nPPI (unretime) electrical interface
 - TP2 is dependent on TP1 input and TP4 dependent on TP3 input
- Below show the usual PMD block diagram where retime function is prior to TP1 and after TP4 given that clause 86 uses PPI interface

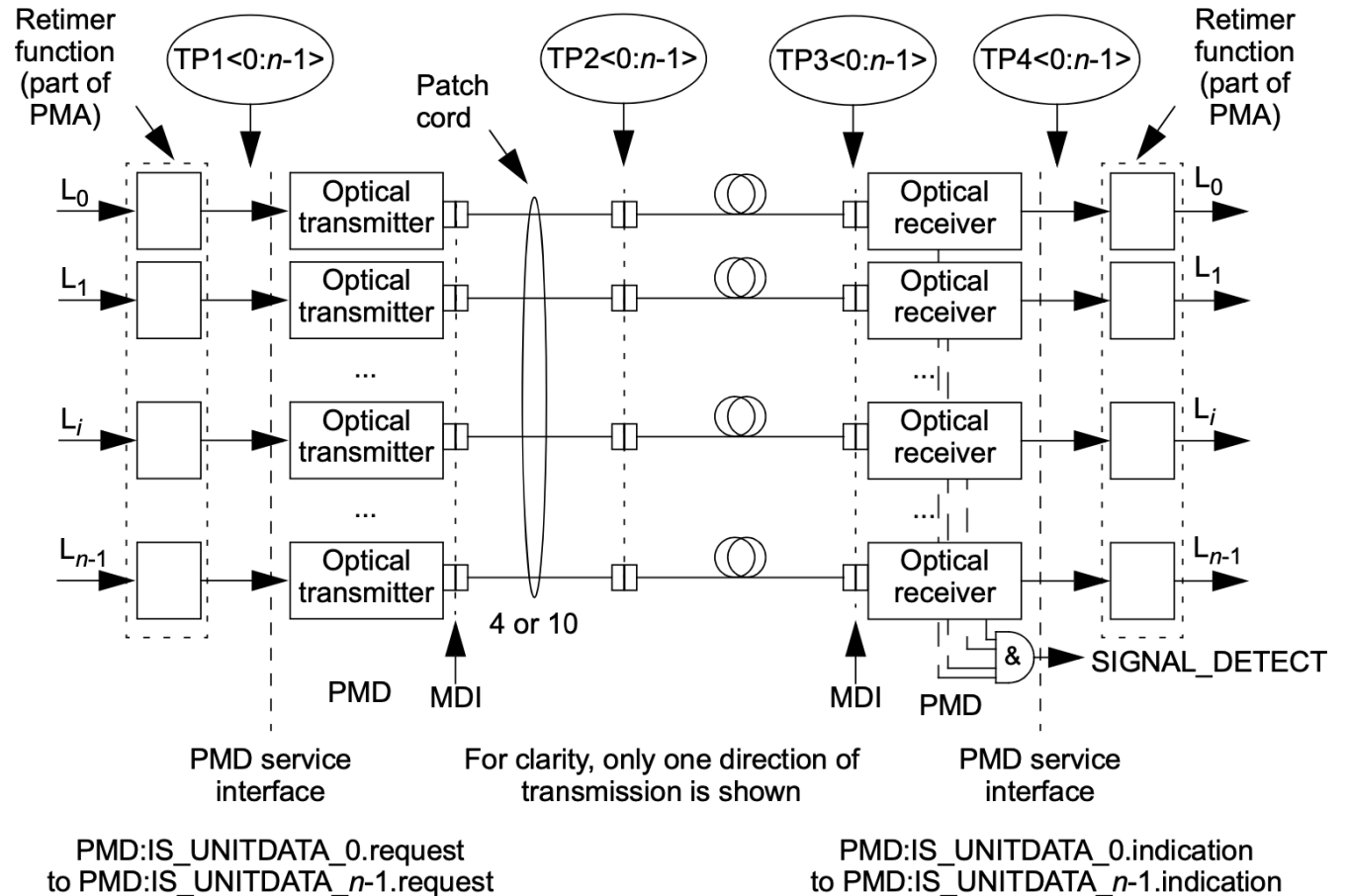


Figure 86–2—Block diagram for 40GBASE–SR4 and 100GBASE–SR10 transmit/receive paths

Prior Precedence can Guide Enhanced TDECQ Definition, cont.

□ **Clause 86.5.1 PMD block diagram and some of the associated text:**

- *The PMD block diagram is shown in Figure 86–2. Figure 86–3 shows the test points. It is not required that the PMD service interface be exposed or measurable (nPPI as defined in Annex 86A with compliance points TP1, TP1a, TP4, TP4a). However, if it is not, a conforming implementation must behave as though the interface were compliant Clause 86 PMD use nPPI (unretime) electrical interface.*

□ **Clause 86.8.4.7 Stressed receiver sensitivity and some of the associated text:**

- *H) Where nPPI or XLAUI/CAUI is exposed, a PMD receiver is considered compliant if it meets the module electrical output specifications at TP4 given in Table 86A–3 for nPPI, or the requirements in Table 83B–3 for XLAUI/CAUI.*

□ **Clause 86 as an example provide us clear example that optical PMDs where there is an exposed nPPI or AUI then optical PMDs may need to meet additional requirements**

- There is no contradiction to state in the 802.3dj optical PMD the condition of TDECQ test or receive sensitivity test when there is an exposed AUI!

Counter Propagating Traffic

- ❑ **Current clause 180.9, 181.9, 182.9, and 183.9**
 - All transmitter optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.
- ❑ **Update above text to include counter propagating traffic**
 - All transmitter optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.
 - *Counter-propagating asynchronous optical signal (crosstalk) at maximum OMA applied to the module under test TP3. The crosstalk pattern can be PRBS31Q, or a valid 100GBASE-R, 200GBASE-R, or 400GBASE-R, or 800GBASE-R, or 1.6TBASE-R signal.*

Enhancement to TECQ/TDECQ Test Procedure

□ Additional verbiage to clause 180.9.5, 181.9.5, 182.9.5, and 183.9.5

- *Where AUI is exposed, a conforming implementation must meet TDECQ with the exposed AUI configured for applicable module stress input test as in 176C.4.4.5 Receiver jitter tolerance, 120G.3.4.3 Module stressed input tolerance, or 120E.3.4.1 Module stressed input test and the recovered AUI clock driving the TDECQ pattern.*
- *Where AUI is exposed, a conforming implementation must meet TDECQ with the module under test configured into mission mode where recovered AUI clock drives the SSPRQ test pattern.*

Summary

- ❑ **This contribution provide specific verbiage to be added to CL 180.9, 181.9, 182.9, and 183.9 by adding:**
 - Counter-propagating asynchronous optical crosstalk
 - Mission mode testing
 - Jitter tolerance applied to module AUI
- ❑ **This contribution doesn't capture following items that have been discussed in the task force:**
 - TDECQ block error contributions which is an ongoing effort
 - Phase noise measurement to capture low frequency jitter in sub 1 MHz
 - Maximum Jitter Transfer Function (JTF) corner frequency and maximum jitter peaking.

Thank You!