Block TDECQ Test Method

(Addressing comments: 244, 245, 246, 247)

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Overview

- **Concern about TDECQ not capturing jitter**
- **Current TDECQ method**
- **Block processing**
- **TDECQ based on block processing**
- **Summary.**

Improving TDECQ Test Method

- **Ghiasi_3dJ_01_2501 proposes several enhancements to TDECQ method**
  - Testing TDECQ in mission mode
  - Adding counter propagating traffic during TDECQ test
- **Mi_3dJ_02a_2409 investigate possible method how to better define TECQ/TDECQ to capture effect of block errors – will improve TECQ/TDECQ correlation to post-FEC**
- **Current TDECQ test method provides average TDECQ over ~ 1 seconds assuming Oscope and all perturbation events gets averaged out**
  - This contribution leverages method of healey_3dj_02a_2409 to process SSPRQ waveforms as blocks with real time scope to determine the $TDECQ_{Max}$
  - $TDECQ_{Max}$ will also address concern raised by Mi_3dJ_02a_2409 on how to capture effect of block errors and concerns raised by ran_3dj_elec_01_240822 due to jitter
- **The advantage of measuring $TDECQ_{Max}$ by using Blocks is that there is no need for Golden hardware receiver which may introduce its own block errors and may not even be available commercially.**

Current TDECQ SER Calculation

- **Two normalized histogram created (Left and Right) are created and associated function F(yi) equal to the number of sample captured divided by number of sample in the histogram window**
  - The sum of all F(yi)=1
  - Three cumulative probability functions are created for left and right histogram F(yi)
    - The three histograms are for level 1, 2, 3
  - The left cumulative function given below:
    - $$CF_{Li}(y_i) = \begin{cases} \sum_{y=P_{th1}}^{y_i} F(y)\ for\ y_i \geq P_{th1} \\ \sum_{y=y_i}^{P_{th1}} F(y)\ for\ y_i < P_{th1} \end{cases}$$
    - 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
- **The current TDECQ calculate SER_L or SER_R (PAM4 symbols)**
  - Currently one full SPPRQ waveform is captured on the Oscope for SER_L or SER_R and TDECQ calculation which takes ~ 3 seconds.

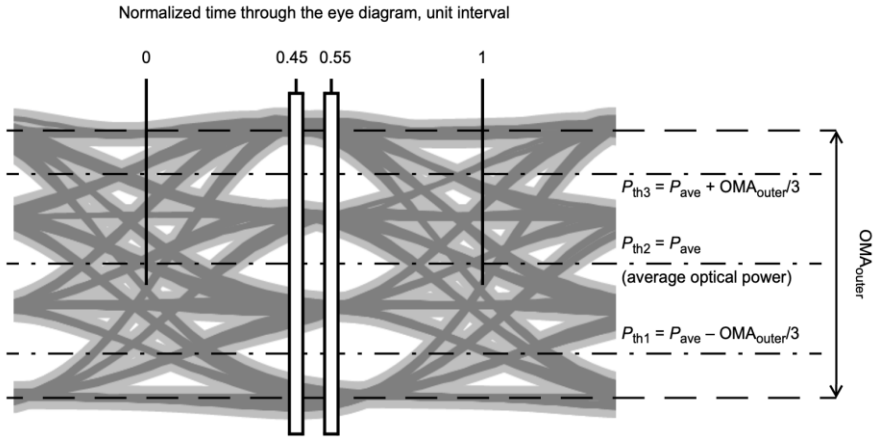
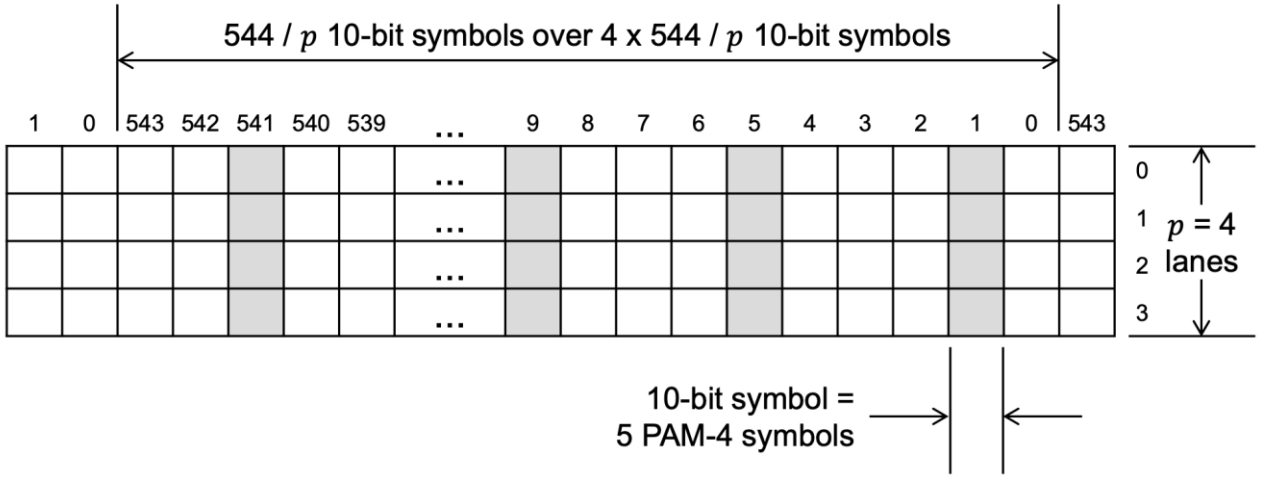
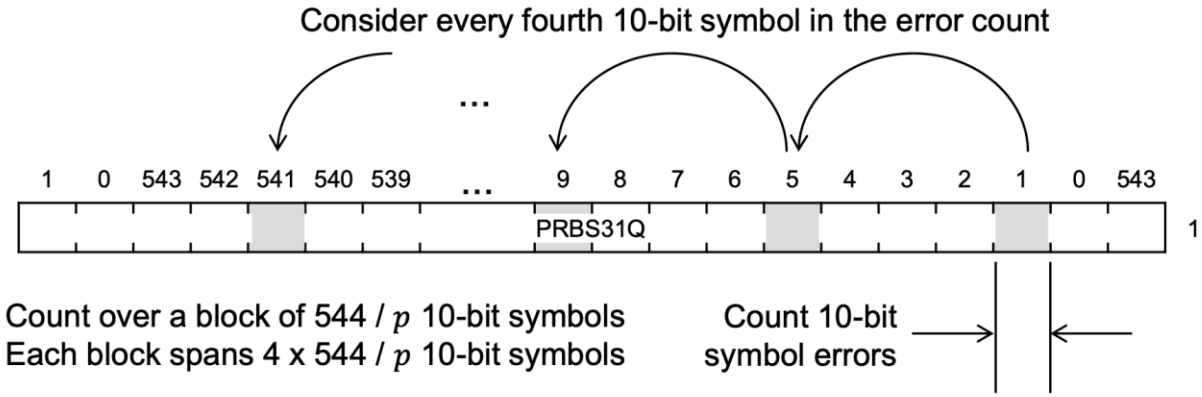


Figure 121–5—Illustration of the TDECQ measurement

Block Processing to Determine $TDECQ_{Max}$

- **Proposal from healey_3dj_02a_2409 show mechanisam to process PRBS data similar to FEC symbols block processing**
  - Exact same mechanisam can be used for optical signal at TP2 with real time scope and SSPRQ pattern
  - Block processing of SSPRQ waveform at TP2 will capture perturbations and jitter
  - TDECQ processed block waveform results in $TDECQ_{Max}$.
  - To capture blocks as shown below require real time scope but Equivalent Time Oscope (ETO) also captures periodic jitter/effects but the reported penalty/TDECQ maybe < $TDECQ_{Max}$
    - ETO's blocks are assembled from bits are from later samples but at the same exact location in the waveform.





$TDECQ_{Max}$ Based on Block Processing

- **Block processing of SSPRQ waveform (SSPRQ pattern length 65,535 PAM4 symbols)**
  - $TDECQ_{Max}$ ignores effect of averaging across lanes for simplicity
  - A FEC block would consist of 5 PAM4 symbols
  - Capture 10 SSPRQ waveform, each SSPRQ waveform forms 655,350 PAM4 symbols
  - KP4 FEC with 4-way interleaving creates 4*544 or 2176 FEC symbol blocks (10880 PAM4 symbols)
  - 10 repetition of SSPRQ forms ~60 4-way KP4 frames
  - Pick the worst 6 4-way KP4 frames to form the PDF
    - Calculate TDECQ on each of 60 blocks to determine the worst 6 blocks
  - From the PDF calculate SER_L or SER_R
  - Use existing TDECQ definition by using the larger of SER_L or SER_R to calculate $TDECQ_{Max}$
- **TDECQ based on 10 SSPRQ waveforms extend asynchronous jitter capture from ~810 kHz from ~81 kHz**
- **Number of errors per 4*544 FEC frame or 10880 PAM4 symbol**
  - FECo at target SER of 4.8e-4 has ~5 errored PAM4 symbols (or ~15 for 3 4-way KP4 frame)
  - FECi at target SER of 9.6e-3 has ~104 errored PAM4 symbols (or ~312 for 3 4-way KP4 frame).

Average TDECQ vs $TDECQ_{Max}$

- **What is in the draft today is average TDECQ**
  - Average TDECQ with current should stay in the draft
- **Proposed limit for $TDECQ_{Max}$ is +0.4 dB excursion above the current average TDECQ limit.**

Summary

- **There have been reports of compliant TDECQ transmitters resulting in high FEC codeword errors and we need to address these shortcoming in DJ taskforce**
  - TDECQ is measured in mission mode, see Ghiasi_3dj_01_2501
  - TDECQ is measured based on block processing to determine $TDECQ_{Max}$ (this contribution)
  - Functional test with a compliant receiver
- **Measuring $TDECQ_{Max}$ is the best way to determine transmitter/host/PLL/power supply are not causing any issue that may result in FEC tail without relying on hardware receiver where it may have its own FEC tail**
- **Both real time and Equivalent Time OScope (ETO) may be used to measure $TDECQ_{Max}$**
  - Real time scope offers block processing more like KP4 FEC block processing and 3 out of 30 worst blocks are used for TDECQ calculation – more exact solution
  - ETO constructs the block from non-consecutive samples in the waveform and expect to produce similar result for repetitive jitter/noise events – need confirmation
    - Statistically ETO expect to catch worst blocks, since 6 out of 60 worst blocks are used for $TDECQ_{Max}$ calculation.