SECQ enhancement proposal

- Marco Mazzini -

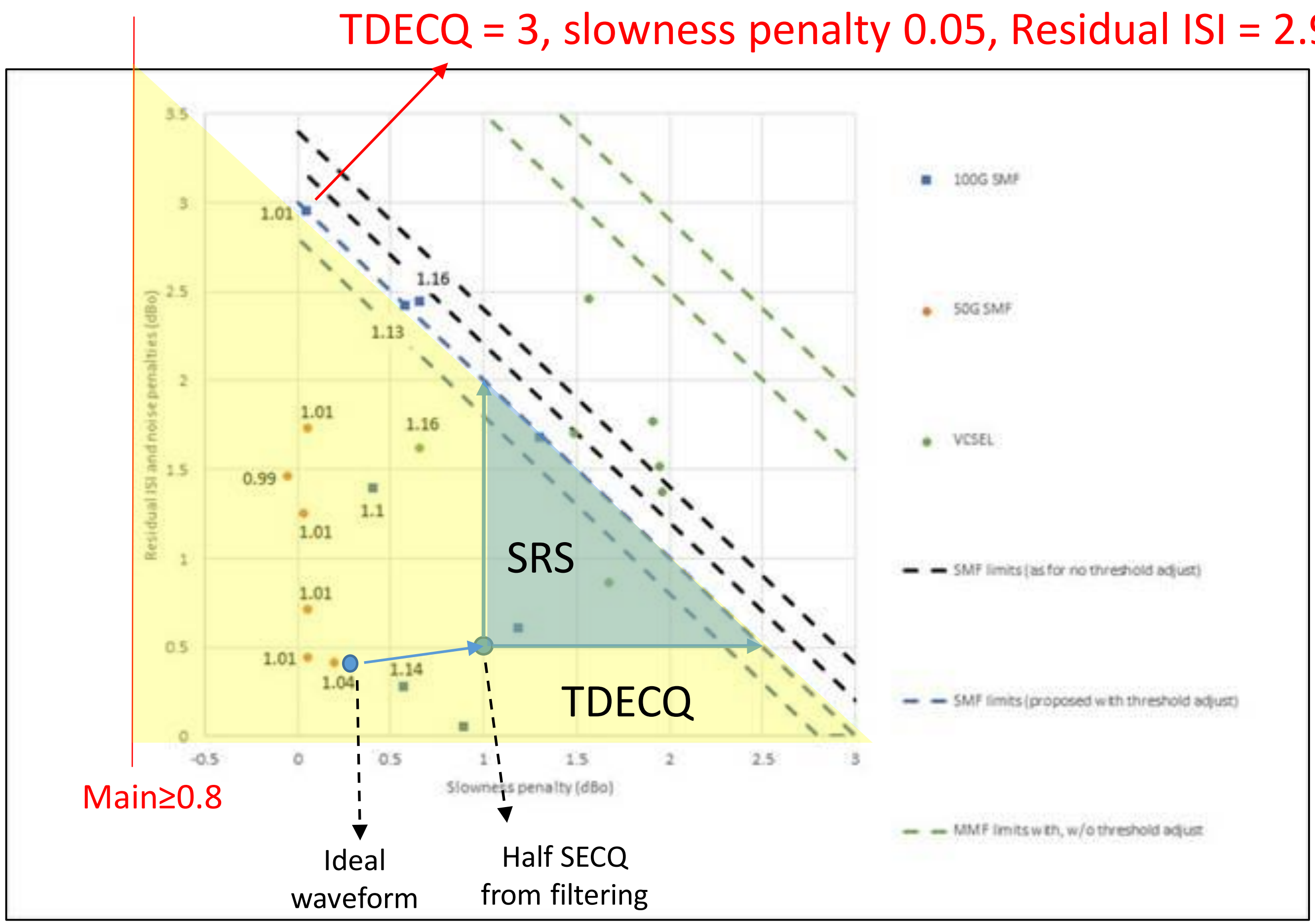
Background

- 802.3cd added TX constraints into last draft 3.3: specifically into 138.8.5.1, 139.7.5.4 and 140.7.5.1 ‘TDECQ reference equalizer’, where ‘*the reference equalizer for 50GBASE-SR, 50GBASE-FR and 50GBASE-LR 100GBASE-DR is a 5 tap, T spaced, feed-forward equalizer (FFE), where T is the symbol period. ….. The sum of the equalizer tap coefficients is equal to 1. Tap 1 or tap 2 has the largest magnitude tap coefficient, which is constrained to be at least 0.8*’.

- This is helping to avoid heavy over-emphasized transmitters, but solve just part of the problem, because most of <u>real</u> transmitter cases (gathered anonymous data) that are shown to lie into a region not currently covered by the Stressed receiver sensitivity method of 802.3bs.

- The proposal is to remove the low-pass filter constraint so to allow a better overlap between Stressed receiver sensitivity conformance test set-up and TDECQ, as well to limit some nasty TX conditions that can lead into a severe penalty on actual receivers.

50/100G Transmitter map versus current tap constraint and SRS.



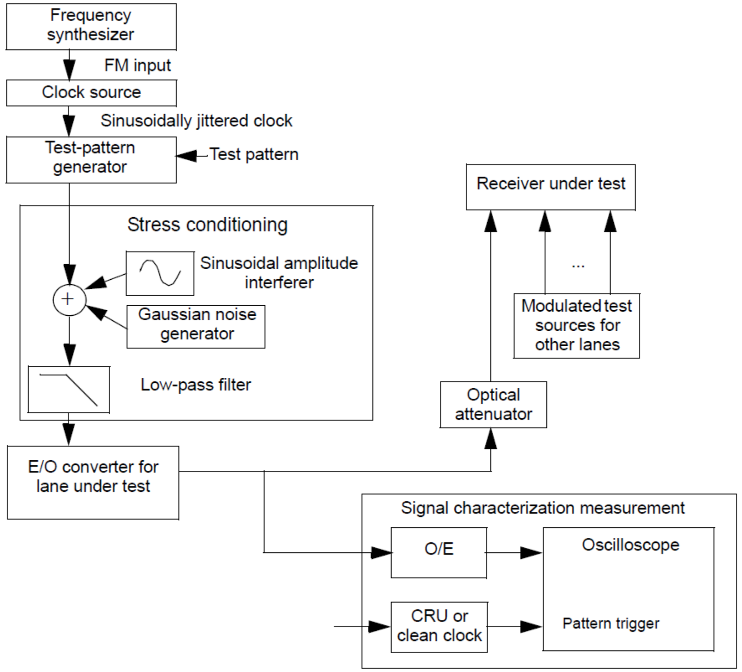
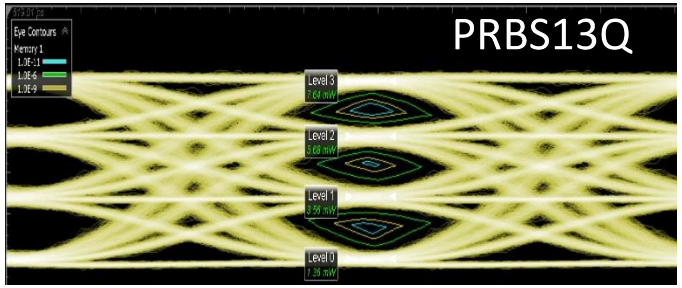


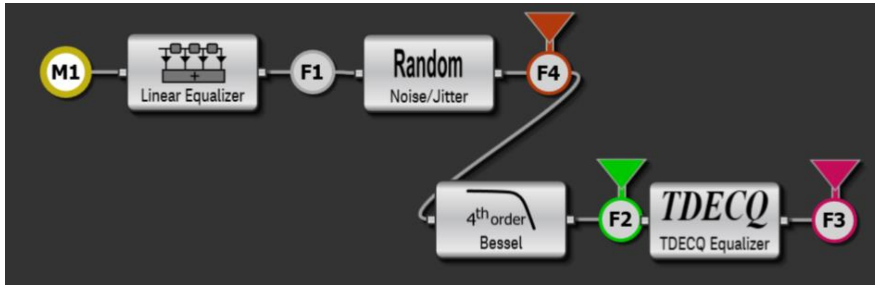
Figure 121–6—Stressed receiver conformance test block diagram

'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…'

Most of the 50G and 100G SMF transmitters are outside the SRS region (blue: note 50GBASE-LR and 100GBASE-DR currently share same TDECQ/SECQ limits).
There's a risk to do not screen receivers against current (?) transmitter technology limits, which can contain some very heavy distorted cases.
Next slides showing how (starting from GoldenEye) we tried to simulate the top-left eye conditions.

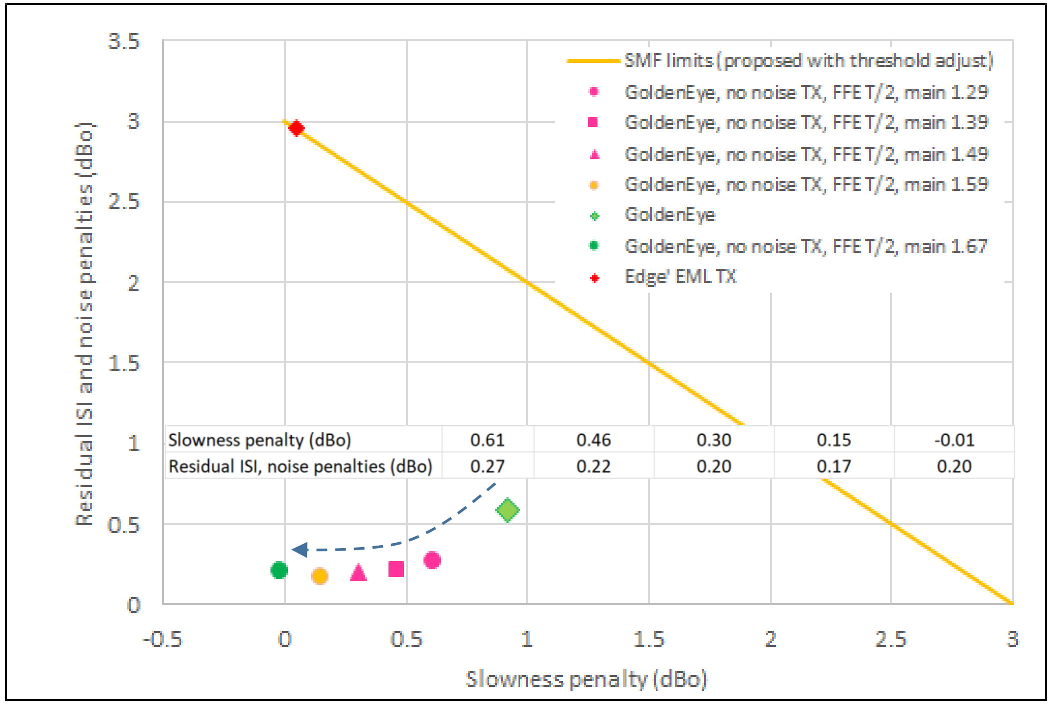
Simulation environment, conditions and results (1).





Using Keysight FlexDCA sim tool.
Added 5T/2 TX Fir over GoldenEye shared waveform (kept PRBS13Q for faster processing), random Noise/Jitter block and 4th order BT filter.

Slowness penalty (dBo)	0.92
Residual ISI, noise penalties (dBo)	0.58



Note the above is not a truly implementation, just a way to show that with proper emphasis it is possible to 'walk' the transmitter over the map.

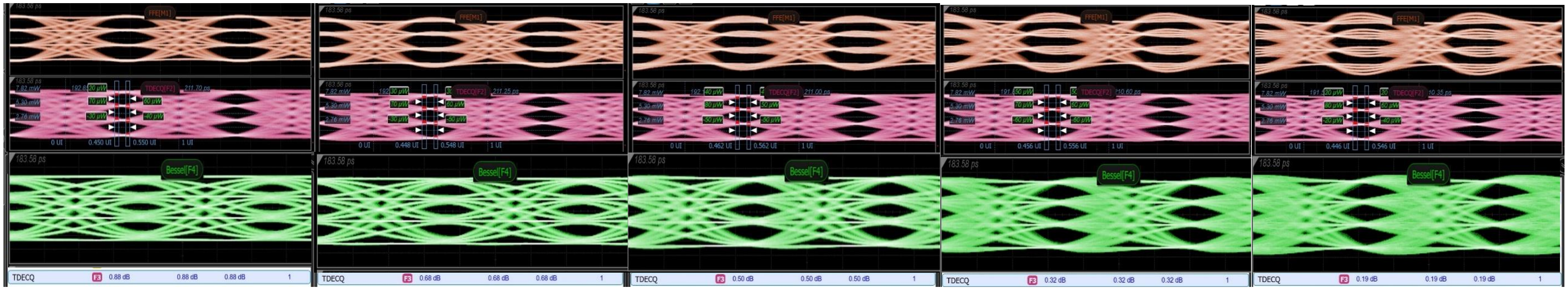
Next slide showing F4 (TX Fir), F2 (filtered w/Nyquist) and F3 (TDECQ with reference equalizer) eye diagrams evolution for left cases from M1, for different TX Fir.

Simulation environment, conditions and results (2).

After TX Fir

TDECQ eye

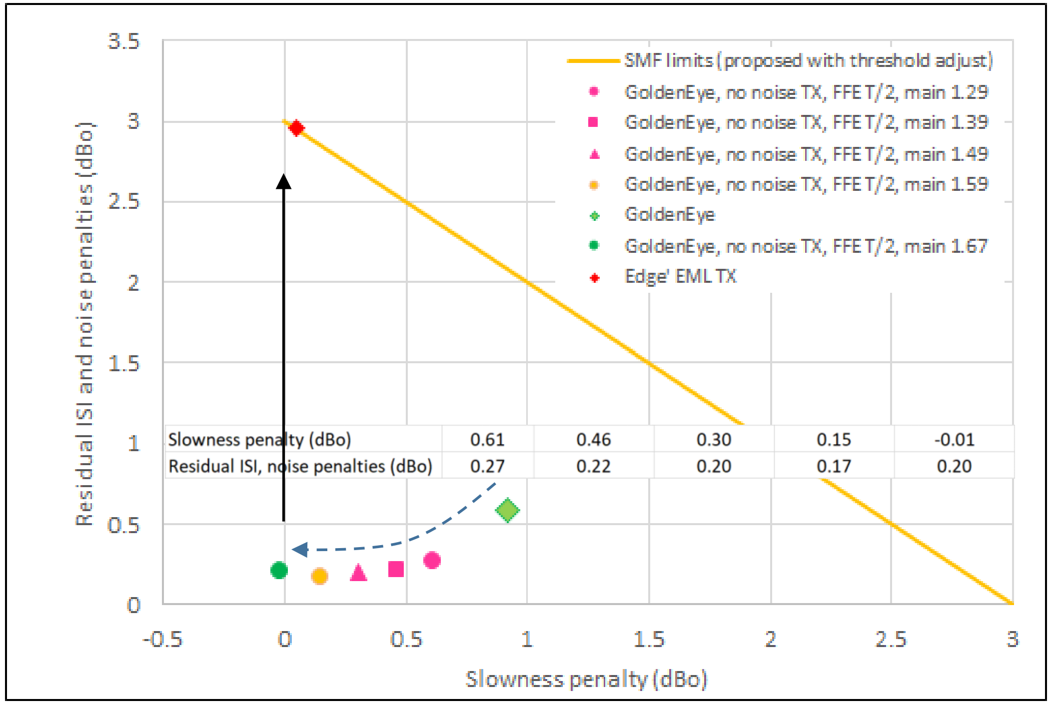
After filter



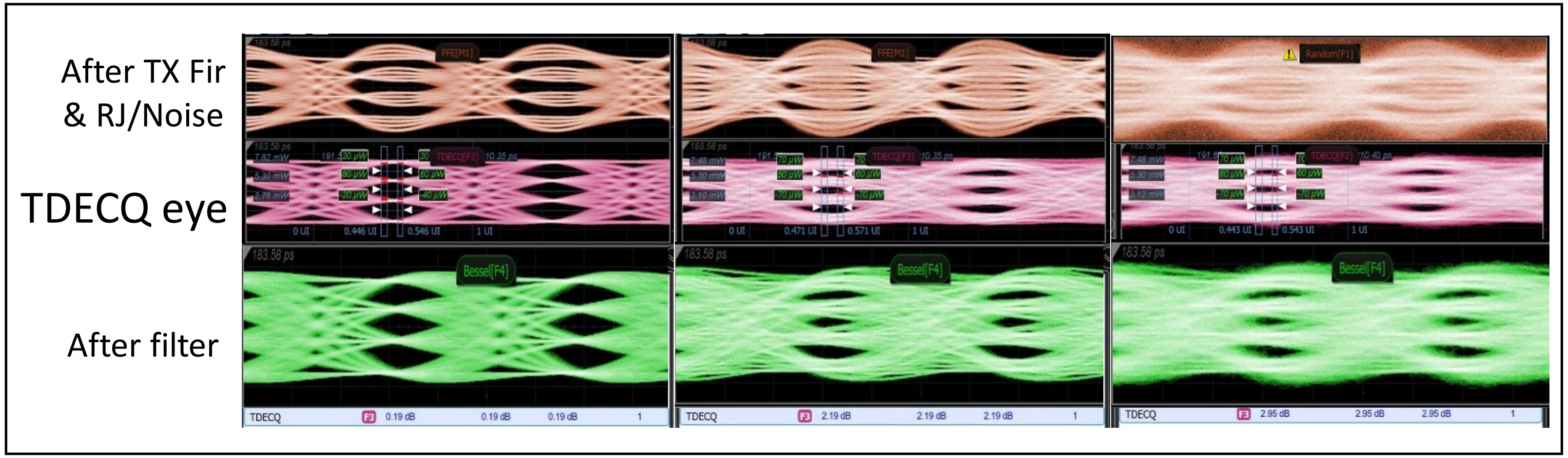
TDECQ	0.88	0.68	0.5	0.32	0.19
Slowness penalty (dBo)	0.61	0.46	0.30	0.15	-0.01
Residual ISI, noise penalties (dBo)	0.27	0.22	0.20	0.17	0.20

Qualitatively, TDECQ improvement doesn't seem to mean 'signal quality' improvement, because added distortions.

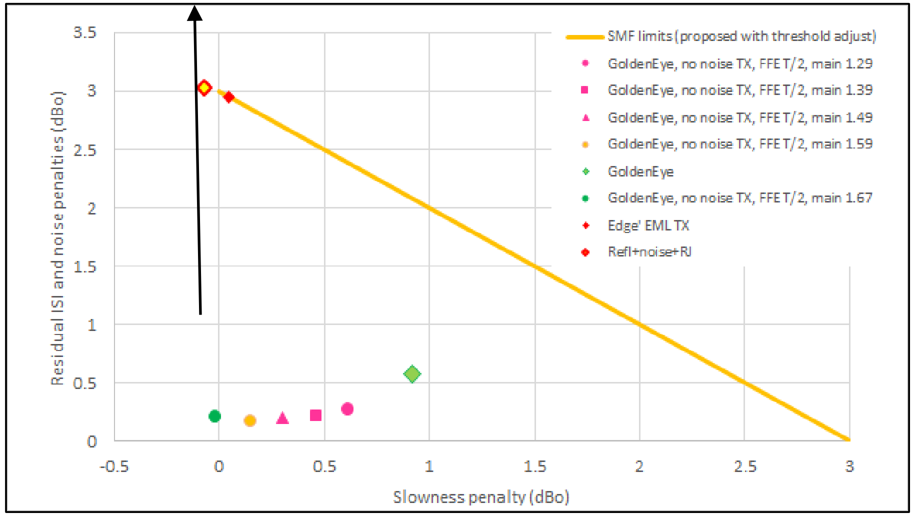
Next slide showing a posible way to get a waveform like the 'Edge' Point at the top-left of the transmitter map (just one of the possible conditions).



Simulation environment, conditions and results (3).



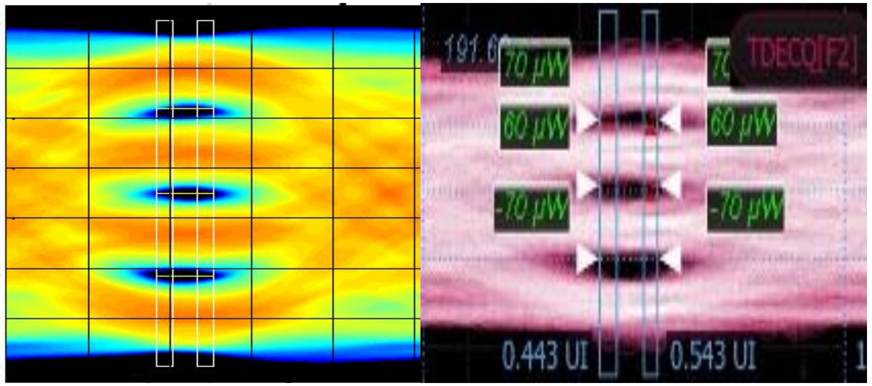
TDECQ	0.88	2.19	2.95
Slowness penalty (dBo)	0.61	-0.11	-0.07
Residual ISI, noise penalties (dBo)	0.27	2.30	3.02



To emulate distortion, a reflection was added at 6UI -> TDECQ = 2.3dB.
Added RJ (990fs) and noise (90uW, ≈1% signal strength) -> TDECQ = 2.95dB.

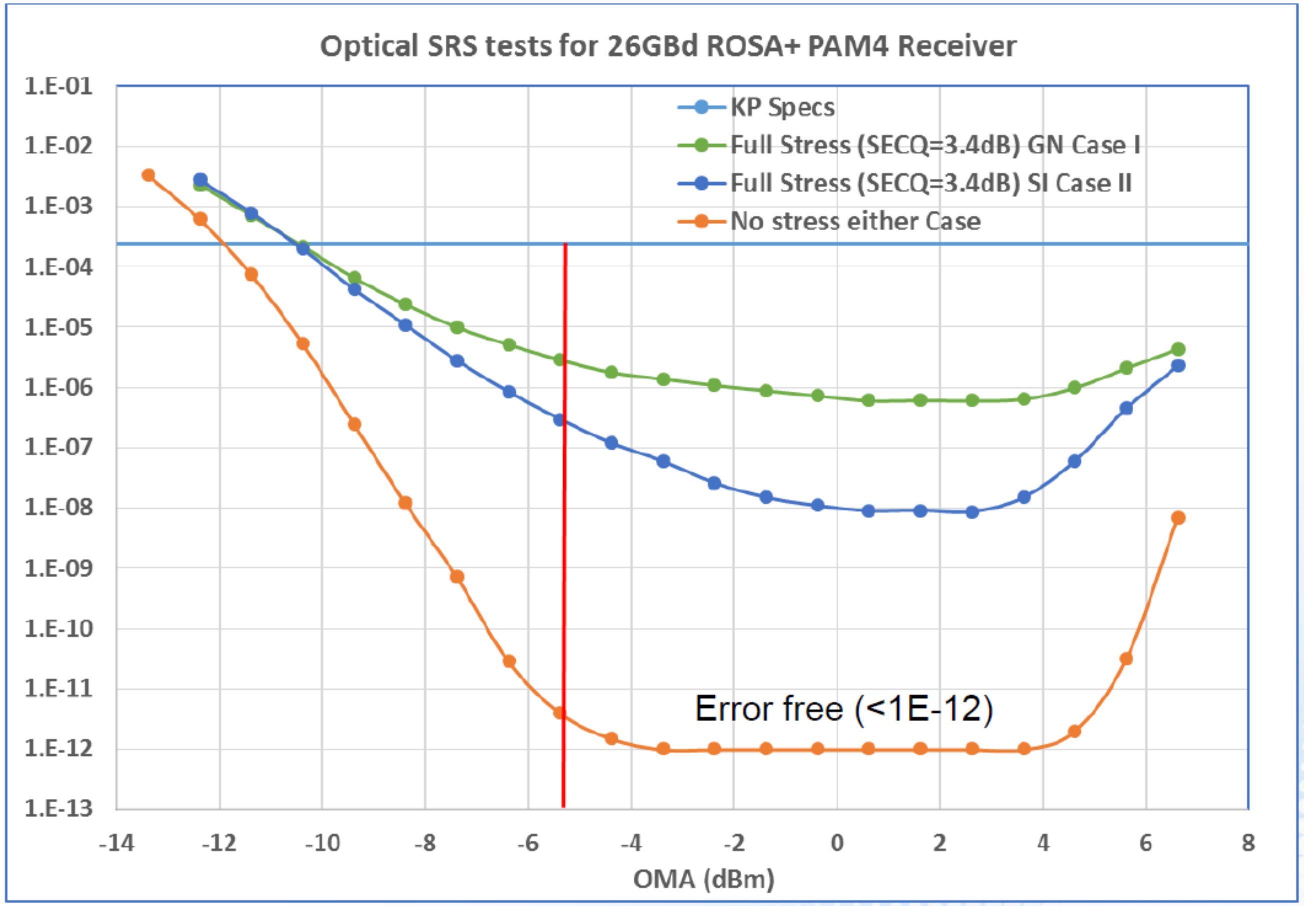
What would happen to an actual receiver, tested with a more benign SRS when this kind of eye is present at TP3 ?
Are we already protected against this eye by RINxOMA specs ?

Similar eye as the one simulated into [dawe_061318_3cd_adhoc-v2]



GN impact measurements – (chang_3cd_01_1117)

- Same SECQ=3.4dB but with different BER behavior



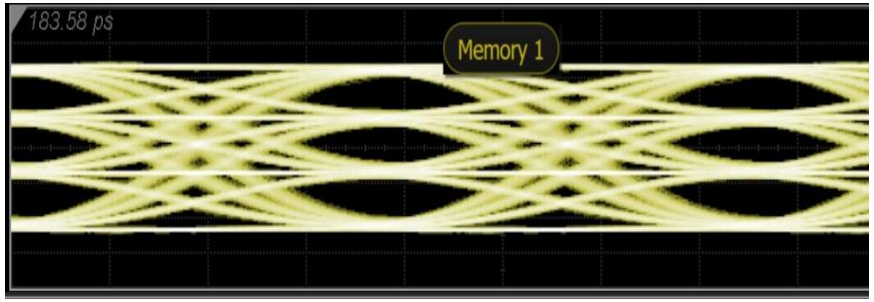
As per schube_011718_3cd_adhoc, and according to chang_3cd_01_1117, the top-left transmitter should represent a case in which we are '***Overstressing** the receiver (e.g. if more Gaussian noise is used than the worst-case allowable transmitter) and causing unnecessary yield hit*'.

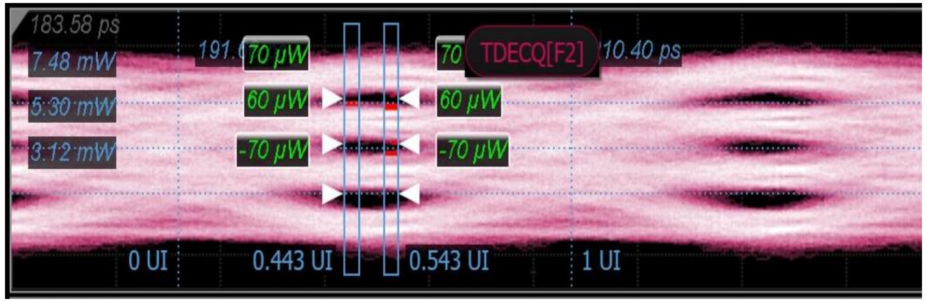
A receiver compliant to 'full stress Case II' can get into troubles when interoperate with a transmitter closer to 'full stress Case I'.

Should the (simulated) distortion be well emulated by SI in the SRS tester? (blue curve).

Is the transmitter naturally bounded against distortion?

RINxOMA and SNDR (see 120D.3.1.6) are two parameters that can give and idea of the degradation occurring for the right case in terms of noise and distortion (Left: not equalized GoldenEye, right: distorted and noisy TDECQ = 2.95dB).





$$RIN_xOMA = -20 \times \log_{10}(Q_{sq}) - 10 \times \log_{10}(BW) \qquad \text{dB/Hz}$$

$$SNDR = 10\log_{10}\left(\frac{p_{max}^2}{\sigma_e^2 + \sigma_n^2}\right)$$

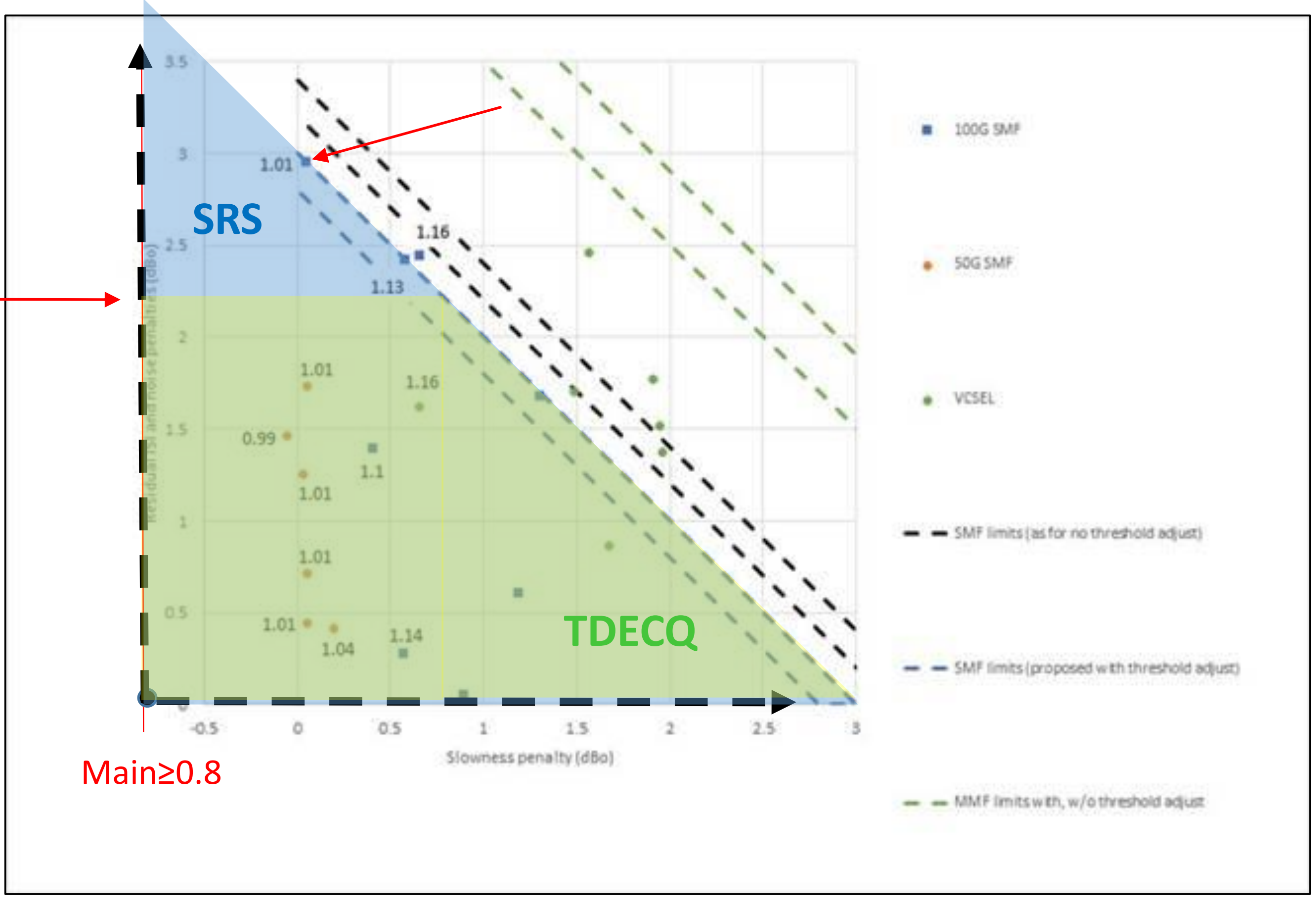
(SNDR ‘transmit equalizer’ should be set equivalent to TDECQ receiver reference equalizer).

Are these two parameters contained into the single definition of TDECQ -10*log10(Ceq) < xx dB ?

Enhancing SRS: half-SECQ filter constraint removal.

Where RINxOMA start to limit this region?

Do we accept any kind of (residual) distortion that pass TDECQ?



<u>SRS region should contain the TDECQ transmitter map</u> (not viceversa), to ensure that actual developments won't get into interoperability issues. To extend the SRS (SECQ) region, one option is to remove the constraint on SECQ due to Low-pass filter or allow emphasis to the SRS tester and then allow freedom to Sinusoidal Interference and Gaussian noise to build-up the stressor up to SECQ limits.

Top-left corner (hard to implement into SRS too) should respresent a TX case in which lot of noise and distortion are present.
So we firstly need to understand if we are already protected by the RINxOMA spec that should screen-out some of these cases, where for distortion an SNDR limit can be an option.

Comments

- Most of real transmitter cases (gathered anonymous data) are shown to lie into a region not currently covered by the Stressed receiver sensitivity method.

- Since top-left region of transmitter map is proportional to residual distortion/noise, we firstly need to understand whether there are already some 'natural' limits to the top-left transmitters (RINxOMA and SNDR in case of heavy distorted signal ?)

If not, we need to ensure that SRS covers that portion by a proper calibration.

One option would be to remove the 'half SECQ' requirement from filter during calibration.

- Starting point being lowest noise ($\leq$ TX RINxOMA) and lowest ISI ('fast' transmitter) as target.
- Target SECQ can be then reached in three ways:
    1. One where just ISI 'from filtering' is added (still just including SJ).
    2. One other where just 'noise' (from sinusoidal jitter, sinusoidal interferer, and Gaussian noise generator) is added.
    3. Any combination of the 1 and 2 up to SECQ limit for each PMD.

In this way, the SRS tester developer will have the possibility to move across vertical and horizontal direction (or any mix) and emulate the actual transmitter map.

  - Still actual SRS tester should include emphasis capability.

THANK YOU

BACK-UP

120D.3.1.6 Transmitter output noise and distortion

Signal-to-noise and distortion ratio (SNDR) is measured at the transmitter output using the following method, with transmitters on all lanes enabled, with identical transmit equalizer settings, and the lanes not under test transmitting PRBS31Q or a valid 200GBASE-R or 400GBASE-R signal.

Compute the linear fit to the captured waveform and the linear fit pulse response, $p(k)$, and error, $e(k)$, according to 120D.3.1.3. Denote the standard deviation of $e(k)$ as σ_e.

Using the same configuration of the transmitter equalizer, measure the RMS deviation from the mean voltage at a fixed low-slope point in runs of at least 6 consecutive identical PAM4 symbols. PRBS13Q includes such a run for each of the PAM4 levels. The average of the four measurements is denoted as σ_n.

SNDR is defined by Equation (120D–7) where p_{max} is the maximum value of $p(k)$.

$$SNDR = 10\log_{10}\left(\frac{p_{max}^2}{\sigma_e^2 + \sigma_n^2}\right) \quad (120D–7)$$

120D.3.1.3 Linear fit to the measured waveform

The following test procedure shall be followed to determine the linear fit pulse response, linear fit error, and normalized transmitter coefficient values.

For each configuration of the transmit equalizer, capture at least one complete cycle of the PRBS13Q test pattern (120.5.11.2.1) at TP0a per 85.8.3.3.4.

Compute the linear fit pulse response $p(k)$ and linear fit error $e(k)$ from the captured waveform per 85.8.3.3.5 using $N_p = 200$ and $D_p = 2$. The aligned symbols $x(n)$ are assigned normalized amplitudes −1, −*ES*, *ES*, and 1 to represent the PAM4 symbol values 0, 1, 2, and 3 respectively. *ES* is defined to be $(|ES1| + |ES2|)/2$ where *ES1* and *ES2* are defined in 120D.3.1.2.

Define $r(k)$ to be the linear fit pulse response with *Local_eq_cm1* and *Local_eq_c1* set to zero.

For each configuration of the transmit equalizer, compute the normalized transmit equalizer coefficients, $c(i)$, according to 92.8.3.5.1.

The clock recovery unit (CRU) used in the output waveform measurement has a corner frequency of 4 MHz and a slope of 20 dB/decade

68.6.7 Transmitter signal to noise ratio

The system under test shall meet the RIN_xOMA specification, given in Table 68–3 as $RIN_{20}OMA$, when measured using the procedure given in 58.7.7. A different measurement procedure for the same quantity, giving approximately the same results, uses the setup shown in Figure 68–8 and proceeds as follows:

a) Measure OMA, using a square wave and following the method of 68.6.2
b) Using the same square wave, measure the rms noise over flat regions of the logic ONE and logic ZERO portions of the square wave, as indicated in Figure 68–4, compensating for noise in the measurement system. The optical path and detector combination are configured for a single dominant reflection with the reflector adjusted to produce an optical return loss, as seen by the system under test, equal to the optical return loss tolerance (min) specified in Table 68–3. The length of the single-mode fiber is not critical, but should be in excess of 2 m. The polarization rotator is capable of transforming an arbitrary orientation elliptically polarized wave into a fixed orientation linearly polarized wave, and should be adjusted to maximize the noise. The receiver of the system under test should be receiving a signal that is asynchronous to that being transmitted. If possible, means should be used to prevent noise of frequency less than 1 MHz from affecting the result. Q_{sq} is given by Equation 68–2:

$$Q_{sq} = \frac{\text{OMA}}{\text{logic ONE noise (rms)} + \text{logic ZERO noise (rms)}} \quad (68–2)$$

where OMA and rms noise are measured in the same linear units of optical power, for example mW.
c) RIN_xOMA is then computed using the relationship shown in Equation 68–3:

$$RIN_xOMA = -20 \times \log_{10}(Q_{sq}) - 10 \times \log_{10}(BW) \quad \text{dB/Hz} \quad (68–3)$$

where BW is the low-pass bandwidth of oscilloscope minus high-pass bandwidth of the measurement system. For the specified measurement setup, BW is approximately 7.5×10^9 Hz.

Q_{sq} may be computed from the RIN_xOMA using the relationship shown in Equation 68–4:

$$Q_{sq} = 10^{-RINxOMA/20} / \sqrt{BW} \quad (68–4)$$