100G SR4 TxVEC Update

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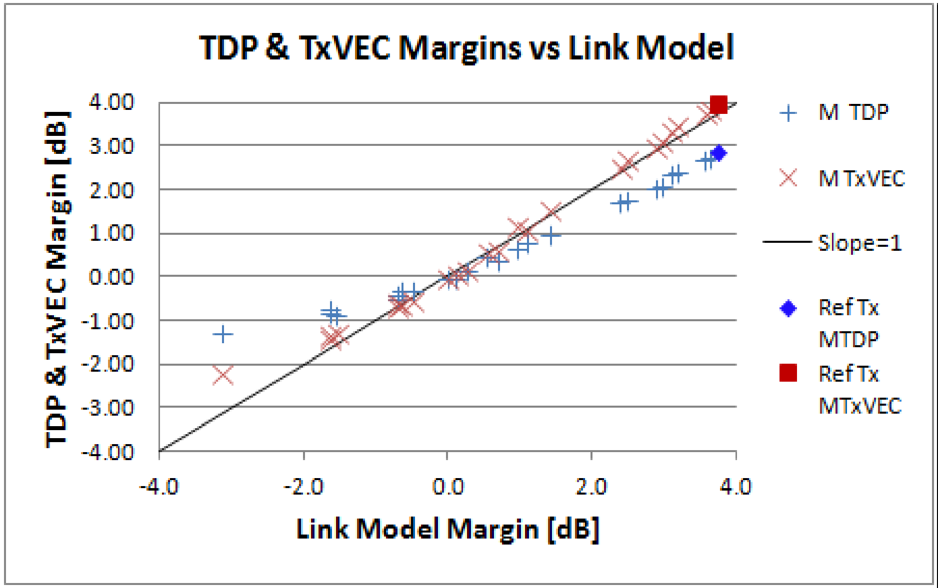
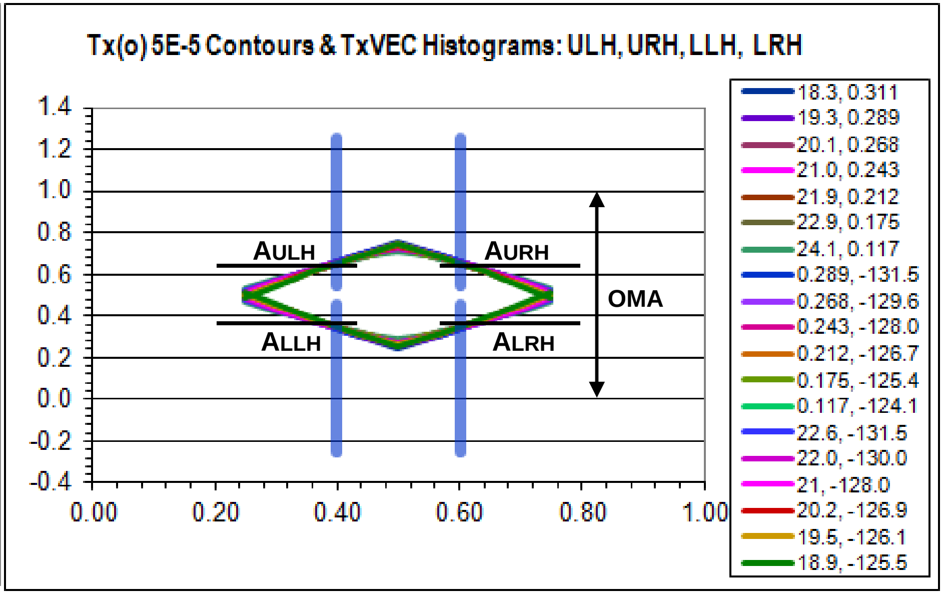
Presentation Summary

Presentation Objectives:

- Review/update proposed replacement for TDP
    - Extracted from petrilla_01_0314_optx.pdf
- Review experimental results
    - Extracted from petrilla_0101d0_0501

100G 100 m SR4: A metric to replace TDP (1 of 6)





•The chart on the left indicates that a TxVEC metric, where TxVEC is equal to the larger of the four quantities

TxVEC(ULH) = -10Log_{10}(2 x AULH - 1) where AULH is the signal amplitude at the 0.005th percentile level of the Upper Left Histogram

TxVEC(URH) = -10Log_{10}(2 x AURH - 1) where AURH is the signal amplitude at the 0.005th percentile level of the Upper Right Histogram

TxVEC(LLH) = -10Log_{10}(1 - 2 x ALLH) where ALLH is the signal amplitude at the 0.005th percentile level of the Lower Left Histogram

TxVEC(LRH) = -10Log_{10}(1 - 2 x ALRH) where ALRH is the signal amplitude at the 0.005th percentile level of the Lower Right Histogram

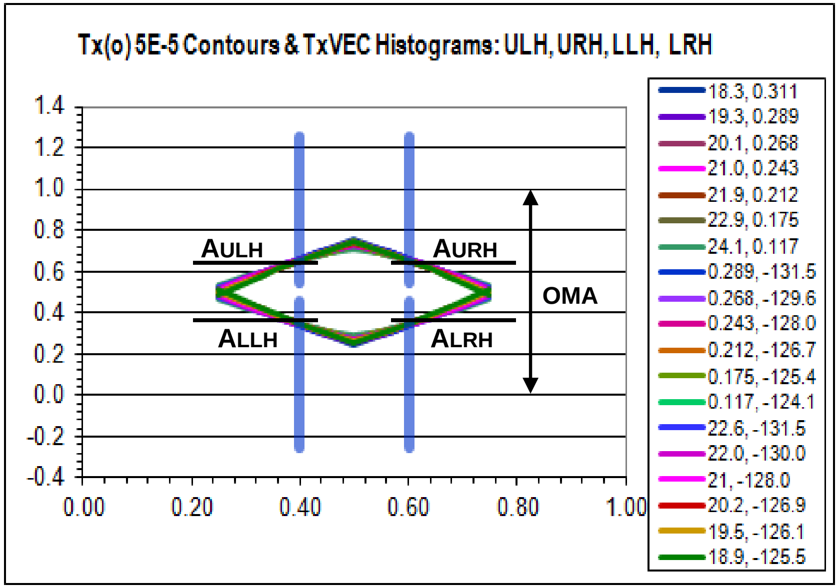
is better aligned with link model margin than a TDP metric . Here histograms are taken at ± 0.10 UI offsets from the center of the eye. OMA is the signal amplitude measured with the OMA measurement method normalized to a unit amplitude of 1.0.

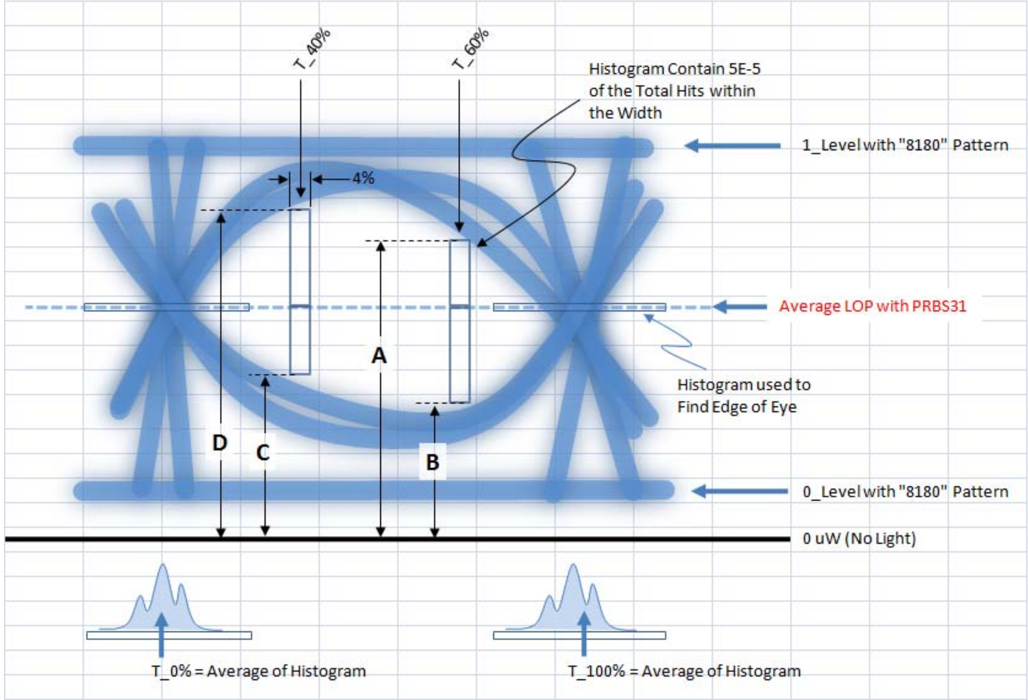
•Histrograms are used individually to cover non-symmetric waveforms, e.g. cases where the mean crossing point shifts from Pave.

•Note that there is no need for a reference transmitter for the TxVEC measurement. With the inability of TDP to predict link margin shown above, the use of a non-ideal Ref Tx to calibrate the Sensitvity of the Ref Rx is suspect.

•Also note that Fibre Channel uses a transmitter vertical eye closure metric, VECPq, for MMF transmitters and not TDP.

Updated: 100G 100 m SR4: A metric to replace TDP (1a of 6)





- The equations for TxVEC on the previous page are here updated to reflect better the effect of non-symmetrical waveforms.
- Instead of a normalized OMA, power levels, P(1), for the high level, P(0), for the low level and Pave (average LOP) are used.
- As before TxVEC is equal to the largest of the four quantities:

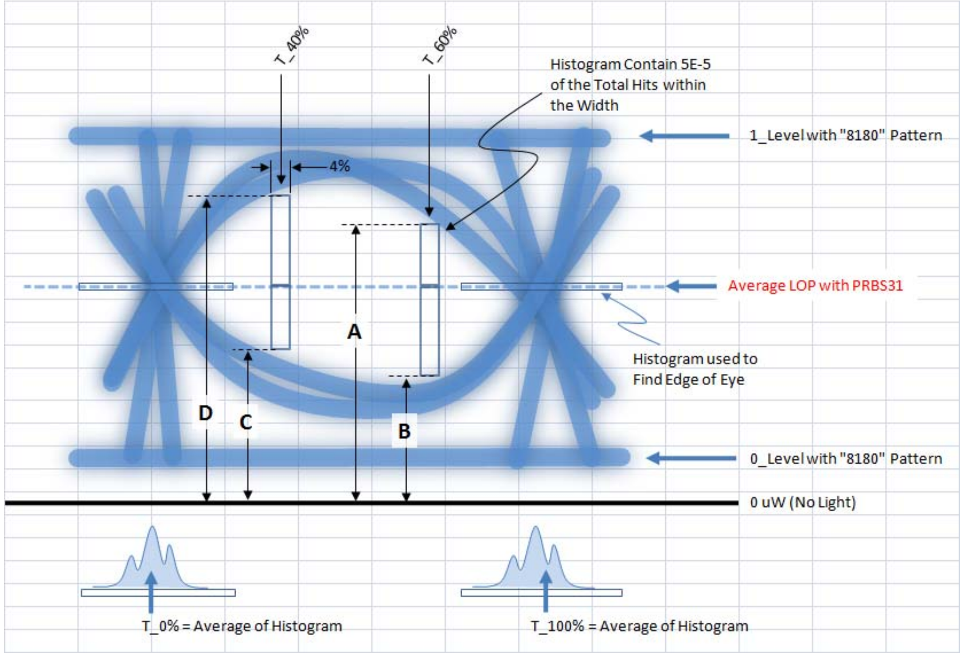
  TxVEC(ULH) = $10Log_{10}((P(1) - Pave)/(P(D) – Pave))$ where P(D) is the power at the 0.005th percentile level of the Upper Left Histogram

  TxVEC(URH) = $10Log_{10}((P(1) - Pave)/(P(A) – Pave))$ where P(A) is the power at the 0.005th percentile level of the Upper Right Histogram

  TxVEC(LLH) = $10Log_{10}((Pave – P(0))/(Pave – P(C)))$ where P(C) is the power at the 0.005th percentile level of the Lower Left Histogram

  TxVEC(LRH) = $10Log_{10}((Pave – P(0))/(Pave – P(B)))$ where P(B) is the power at the 0.005th percentile level of the Lower Right Histogram
- As before histograms are taken at ± 0.10 UI offsets from the center of the eye. OMA , P(1) and P(0) are the signal amplitude and high and low levels measured with the OMA measurement method.

100G 100 m SR4: A metric to replace TDP (2a of 6)



Proposed replacement text for 95.8.5

95.8.5 Transmitter Vertical Eye Closure

Transmitter Vertical Eye Closure (TxVEC) shall be as follows:

a) Each optical lane is tested individually with all other lanes in operation.

b) The transmitter is tested using an optical channel with an optical return loss of 12 dB.

c) Average launch power, Pave, shall be measured as defined in 95.8.3.

d) OMA and nominal "1" and "0" levels shall be measured as defined in 95.8.4.

e) The transmit eye is observed as defined in 95.8.7 with the following exception: eye mask coordinates are not applied.

f) The transmitter optical waveform is measured for vertical eye closure (TxVEC) with vertical histograms at ± 0.1 UI from the eye center. TxVEC is the larger of the four quantities:

TxVEC(ULH) = $10\mathrm{Log}_{10}((P(1) - Pave)/(P(D) - Pave))$ where P(D) is the power at the 0.005th percentile level of the Upper Left Histogram

TxVEC(URH) = $10\mathrm{Log}_{10}((P(1) - Pave)/(P(A) - Pave))$ where P(A) is the power at the 0.005th percentile level of the Upper Right Histogram

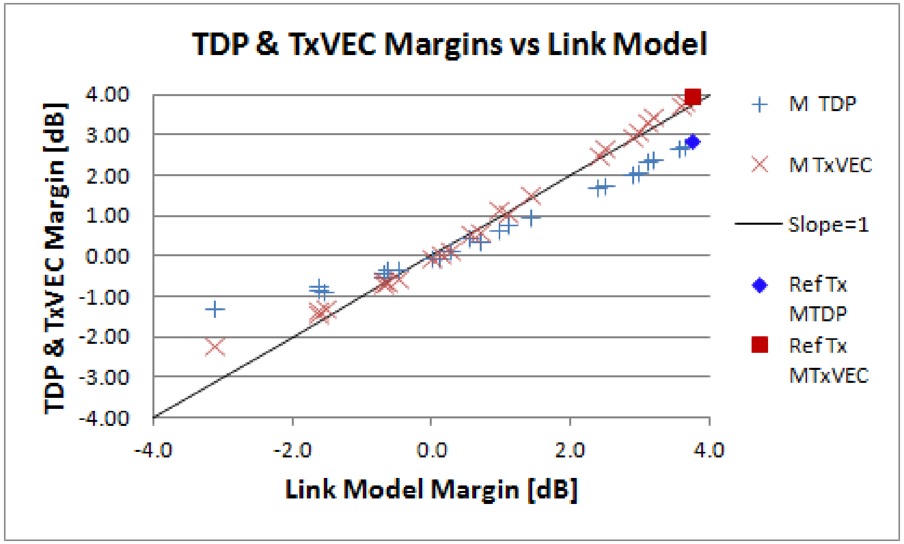
TxVEC(LLH) = $10\mathrm{Log}_{10}((Pave - P(0))/(Pave - P(C)))$ where P(C) is the power at the 0.005th percentile level of the Lower Left Histogram

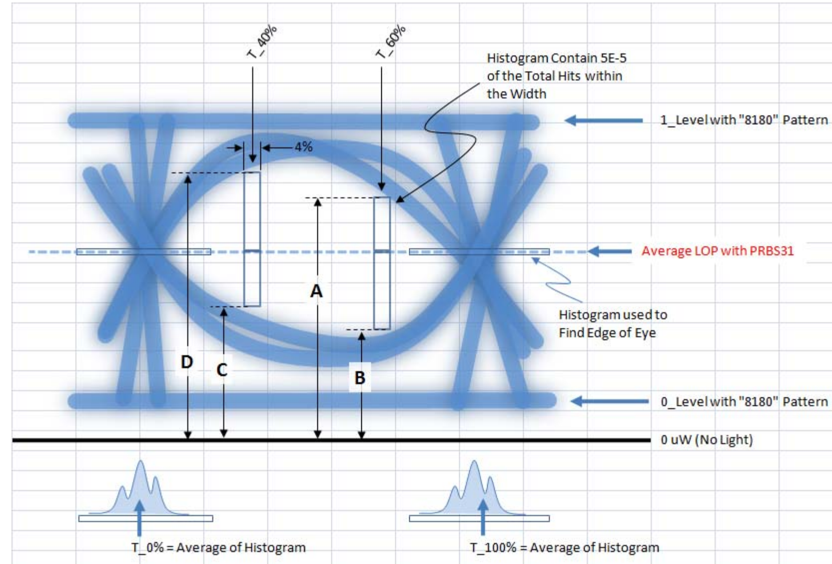
TxVEC(LRH) = $10\mathrm{Log}_{10}((Pave - P(0))/(Pave - P(B)))$ where P(B) is the power at the 0.005th percentile level of the Lower Right Histogram

g) The test setup illustrated in Figure 52-9 shows the reference method. Other measurement implementations may be used with suitable calibration.

h) TxVEC is defined for each lane, at the BER specified in 95.1.1 and is for the lane under test on its own. See 95.8.1.1 for multi-lane pattern considerations. NOTE—Sampling instant offsets have to be calibrated because practical receivers and decision circuits have noise and timing impairments. One method of doing this is via a jitter bathtub method using a known low-jitter signal.

Updated: 100G 100 m SR4: A metric to replace TDP (3a of 6)





- **Based on the new metric TxVEC, in Draft 2.0 replace**

in Table 95-6, Transmitter and dispersion penalty (TDP), each lane (max) = 5 dB

with Transmitter vertical eye closure, each lane (max) = 5 dB

in Table 95-6, Launch power in OMA minus TDP (min) = -8 dBm

with Launch power in OMA minus TxVEC (min) = -8 dBm

in Table 95-6, Optical Modulation Amplitude (OMA), each lane (min)[b] = -7.1 dBm

with Optical Modulation Amplitude (OMA), each lane (min)[b] = -7.1 dBm

in Table 95-6, footnote b, Even if the TDP < 0.9 dB, the OMA (min) must exceed this value.

with Even if the TxVEC < 0.9 dB, the OMA (min) must exceed this value.

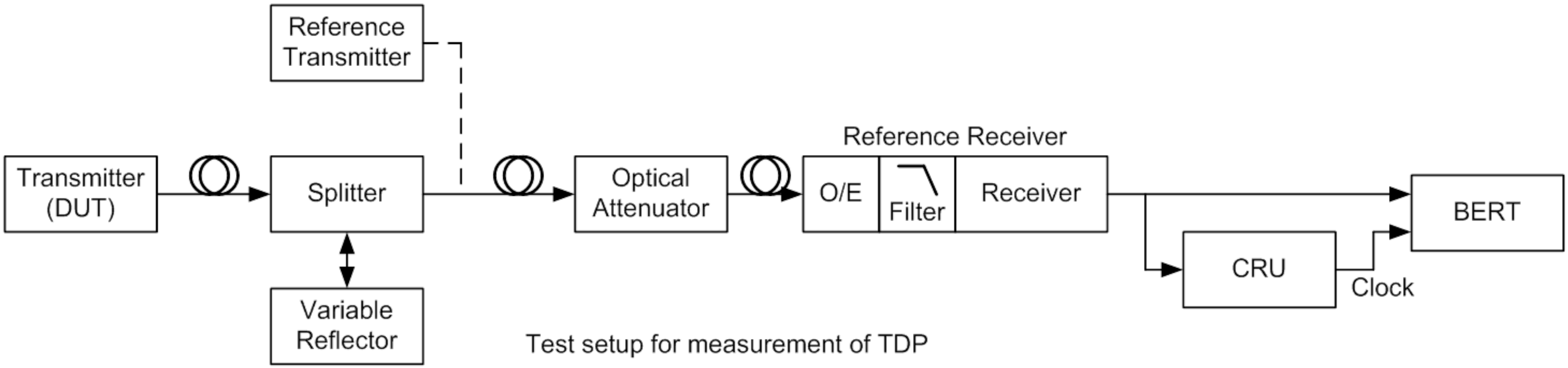
in Table 95-8, Power budget (for max TDP) = 8.2 dB

with Power budget (for max TxVEC) = 8.2 dB

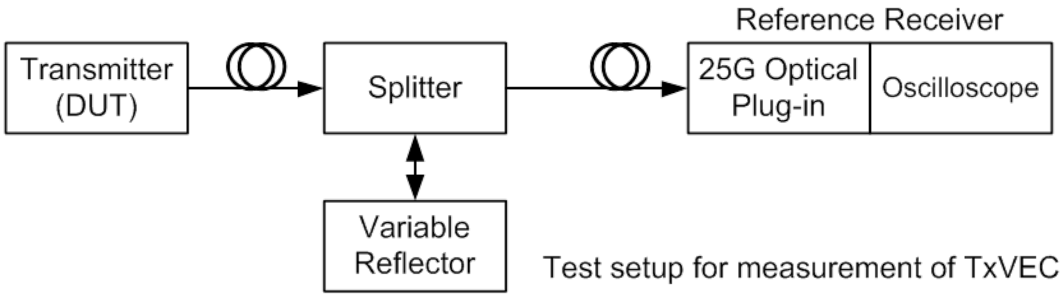
in Table 95-8, Allocation for penalties (for max TDP) = 6.3 dB

with Allocation for penalties (for max TxVEC) = 6.3 dB

New: 100G SR4: TDP & TxVEC Test Setups



Test setup for measurement of TDP



Test setup for measurement of TxVEC

TDP requires calibration of:

- Optical channel for 12 dB optical return loss
- Reference Transmitter for TDP
- Reference Receiver for bandwidth and filter frequency rolloff
- BERT sampling offset

TxVEC requires calibration of:

- Optical channel for 12 dB optical return loss
- Oscilloscope eye for histogram placement

- The above drawings show setups for measurement of TDP and TxVEC.
- Significant differences include:
  - Tx VEC setup does not need a Reference Transmitter.
  - Reference Receiver for TxVEC can be an oscilloscope with an optical plug-in.
- Setup and calibration of the TxVEC setup is expected to be significantly easier.

Review: 100G 100 m SR4: A metric to replace TDP (5 of 6)

Transmitter and dispersion penalty (TDP) Summary

•TDP results for MMF cases are not well aligned with margin calculations from the link model.

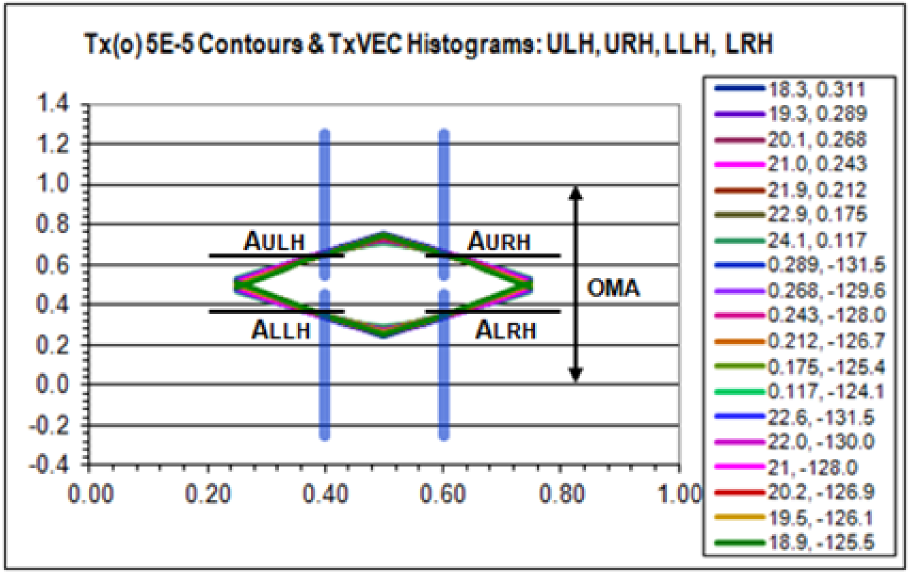
• TDP measurements require either an ideal reference transmitter or the ability to calibrate a reference for TDP with respect to the ideal. Since TDP results are not well aligned with link model margin, such a calibration seems problematic. Under estimating the TDP of the Ref Tx is easy, perhaps common, permitting test escapes.

•TDP requires a reference receiver with a non-standard BW that will need setup and calibration.

•The complexities with TDP has limited its acceptance and use in the industry.

•Since a TDP result is the difference between two optical Rx sensitivity measurement results, its accuracy and repeatability is driven by the accuracy and repeatability of optical Rx sensitivity measurements. Accuracy and repeatability of key attributes, such as TDP, are critical issues for operating life and other reliability tests where parametric drift is examined, setting tester guard bands and for correlating results between vendors and customers.

•TDP requiring bit error detection and counting places restrictions on test patterns.



Transmitter Vertical Eye Closure (TxVEC) Summary

•TxVEC results for MMF cases are better aligned with link model margin than TDP results, promising a better balance of test escapes with rejecting acceptable devices.

•TxVEC does not require a reference transmitter.

•The Ref Rx for TxVEC can be an oscilloscope with a standard optical plug-in for the 25G signal rate.

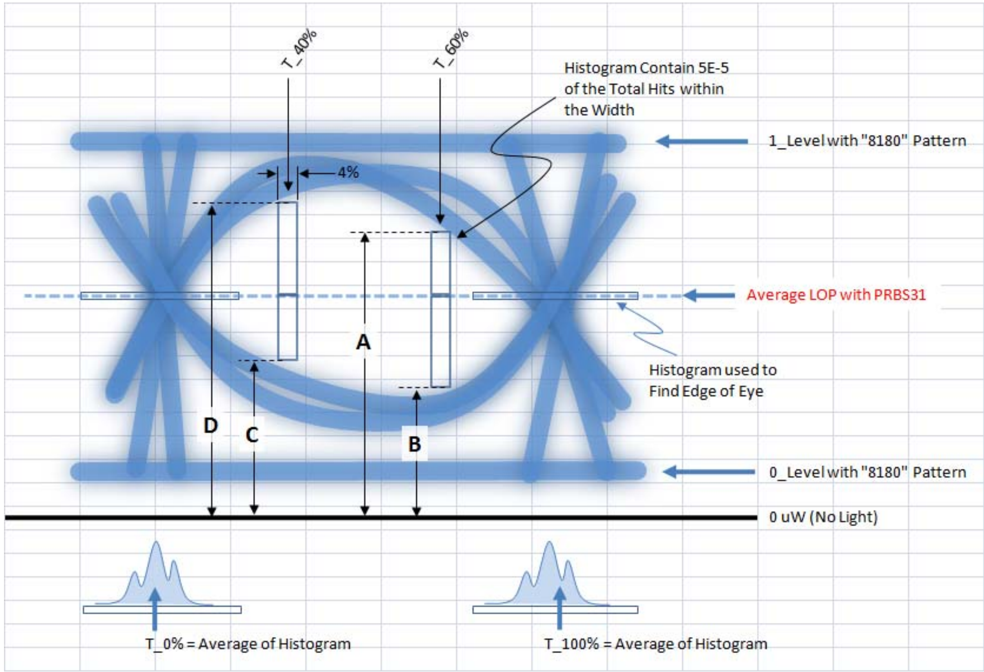
•TxVEC uses the same test setup as Tx eye mask test and $RIN_{12}OMA$ and same techniques as SRS VECP; no new equipment or techniques are needed.

New: 100G 100 m SR4: A metric to replace TDP (6a of 6)

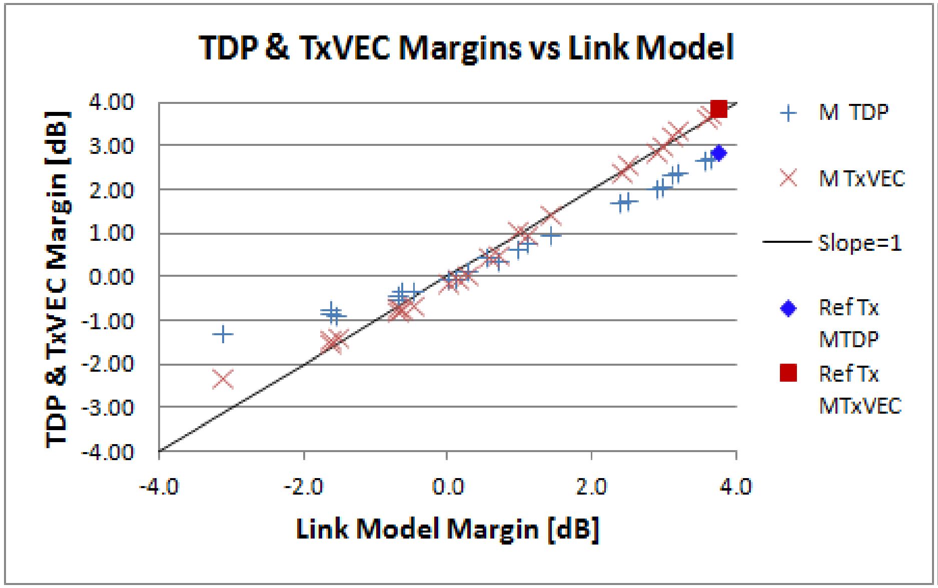
•TxVEC provides better results for MMF cases than TDP while using a simpler and friendlier test setup that is more likely to be adopted in the industry.

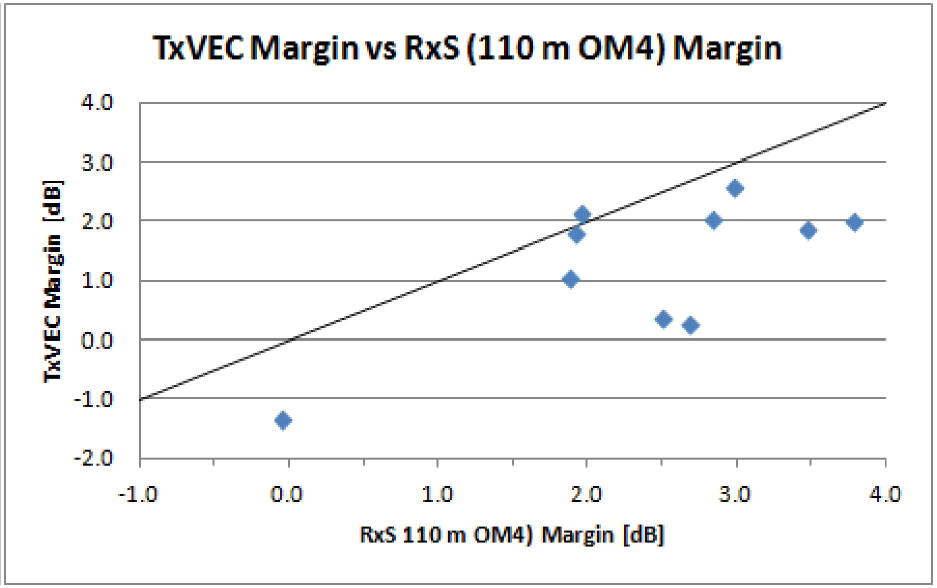
•The simpler and friendlier test requirements for TxVEC make it a preferable test even if TDP provided comparable results.

•802.3bm should replace TDP with TxVEC.

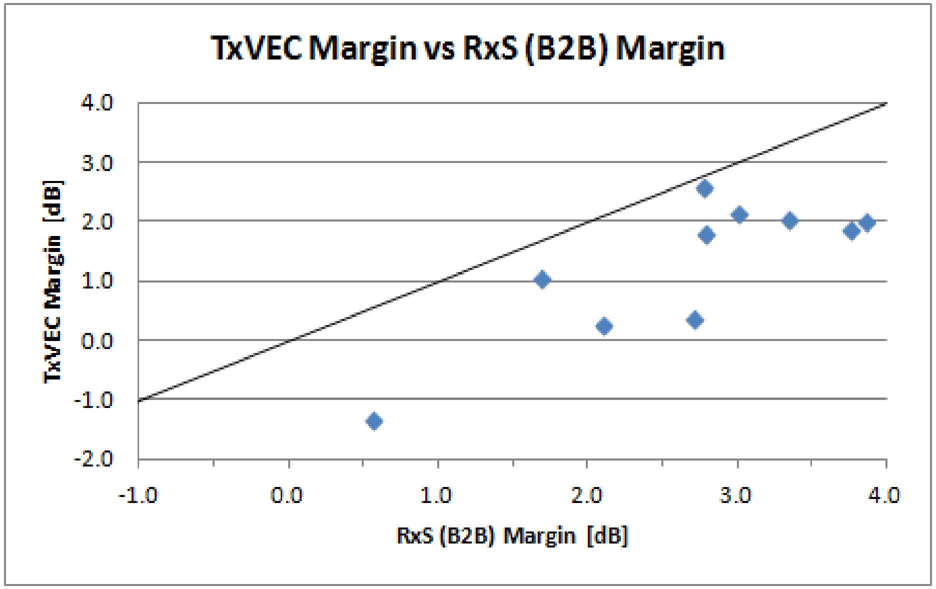


100G SR4 TxVEC Experimental Results

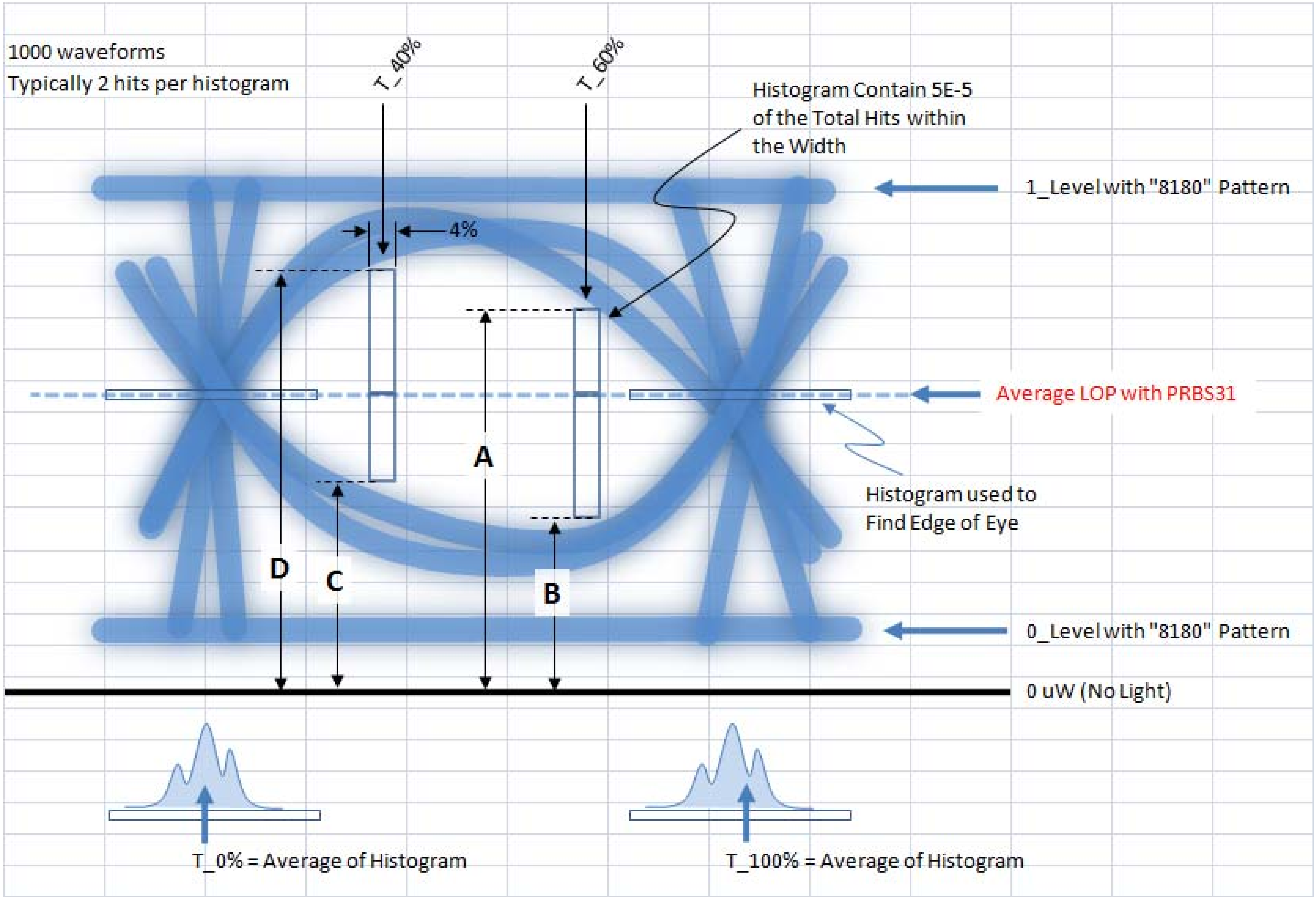




- An experiment was set-up at Avago Technologies to measure TxVEC on a set of 25G transmitters (Tx) and compare the results with the results of receiver sensitivity, RxS, measurements made using the same Tx set.
- The above left chart from prior presentations, shows the expected correlations to link margin for the metrics TDP and TxVEC.
- The charts to the right show correlations of emperical results for TxVEC with RxS margin for cases of minimum reach (B2B) of fiber and a worst case 100 m OM4 fiber; actually 110 m of 5022.7 MHz·km EMB fiber.
- RxS margin is used as an analogue for link margin.

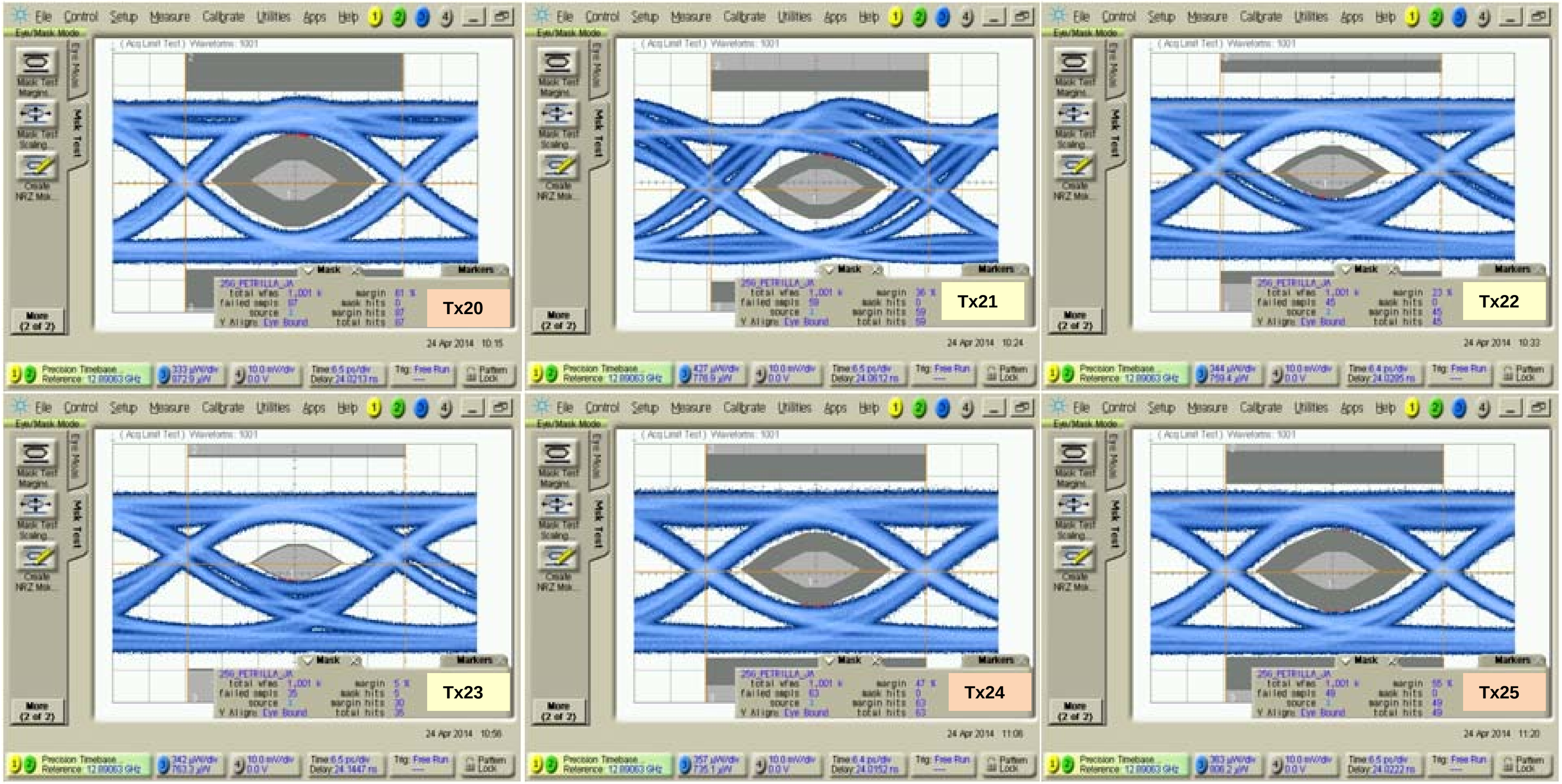


100G SR4 TxVEC Measurements



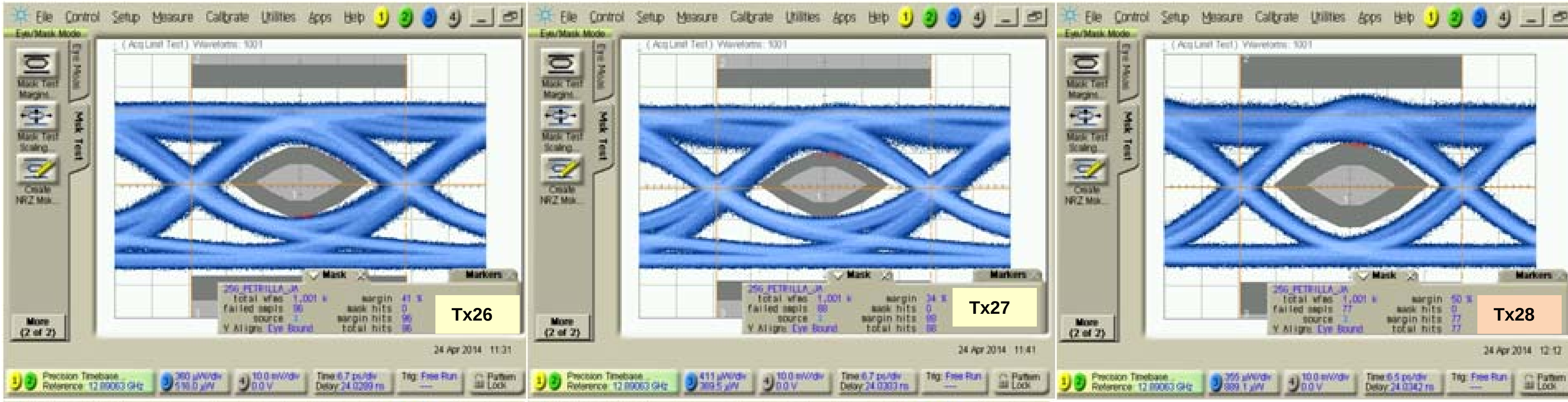
The above image shows the attributes as measured in the experiment.

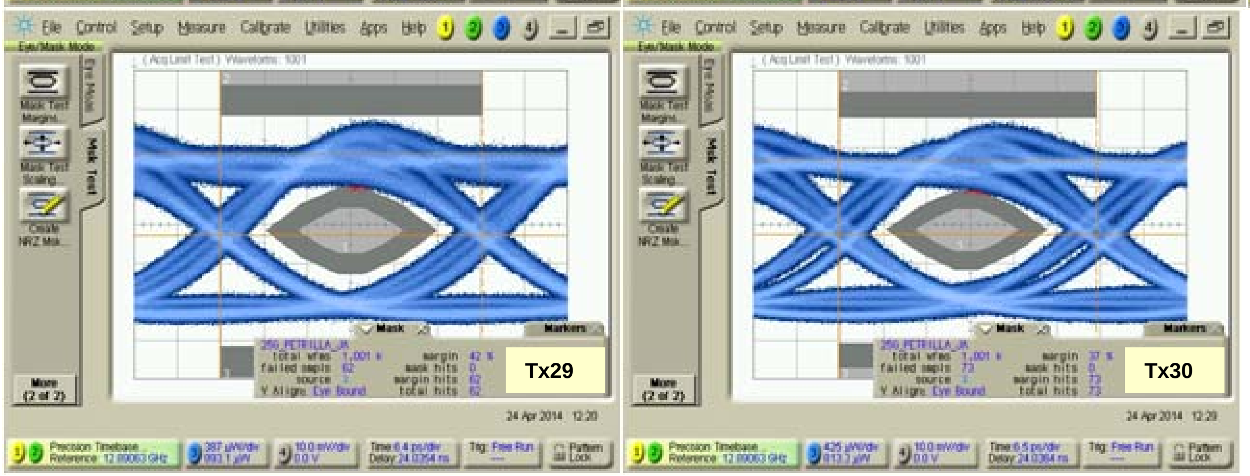
Tx Output Eyes for Experimental Tx Set (1 of 2)



- Eyes using a 25GbE optical plug-in are shown above for six of the experimental transmitters.
- The 802.3bm D2.2 Cl 95 eye mask is included to help judge eye quality.
- Drive conditions for the transmitters were tuned to produce certain eye characteristics and the eyes are not representative of normal devices.

Tx Output Eyes for Experimental Tx Set (2 of 2)

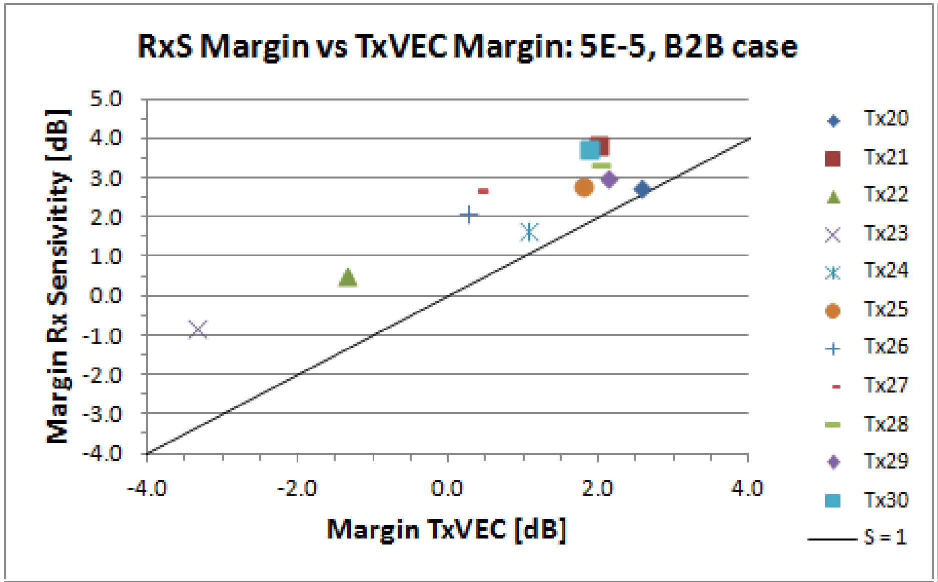


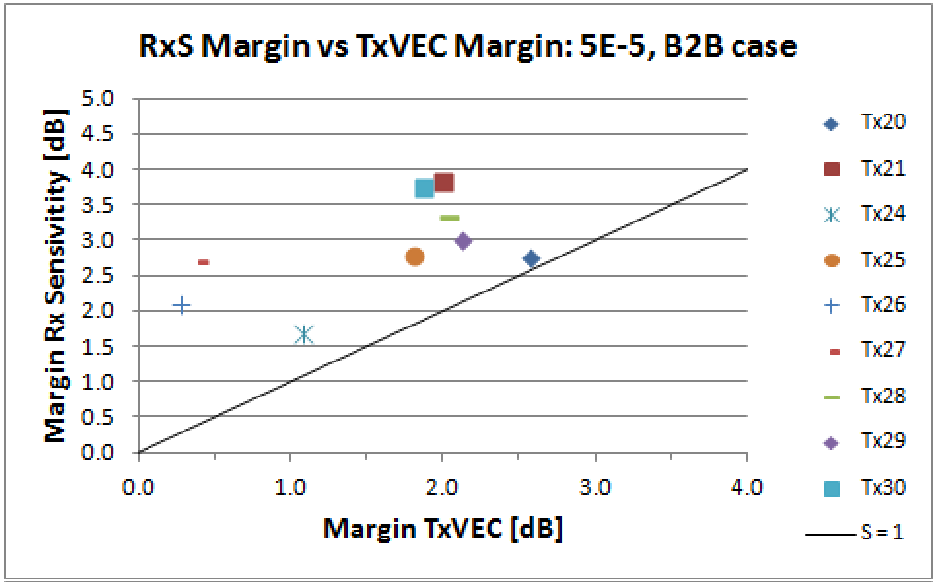


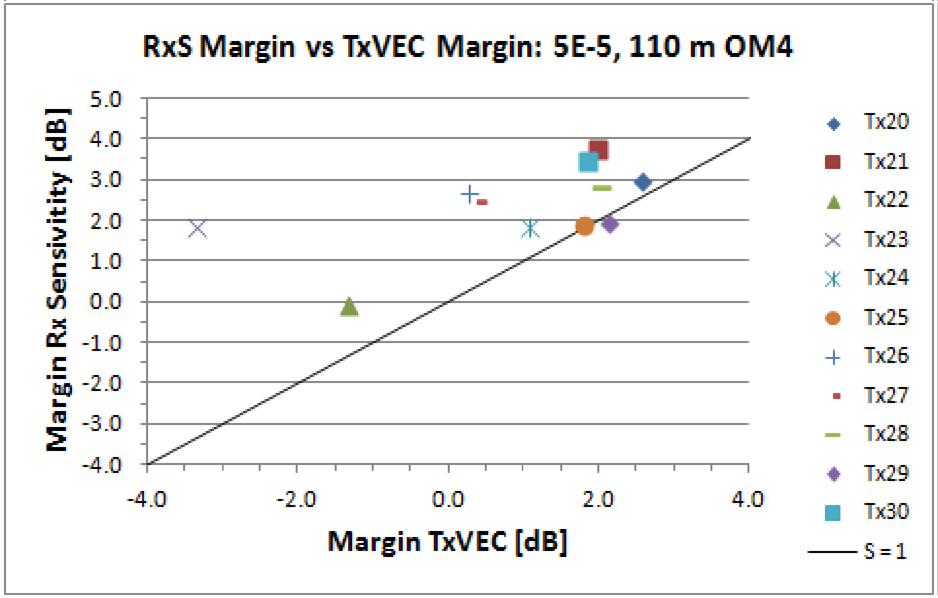
- Devices T20, T24, T25 & T28 waveforms appear the most Gaussian with eyes that appear the most symmetrical.

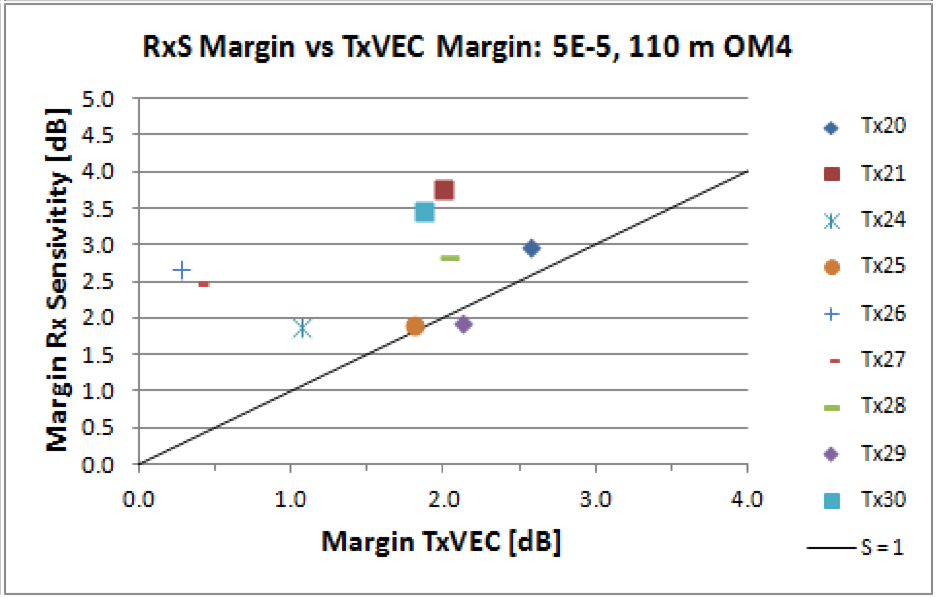
- Eyes using a 25GbE optical plug-in are shown above for five of the experimental transmitters.
- The 802.3bm D2.2 Cl 95 eye mask is included to help judge eye quality.
- Drive conditions for the transmitters were tuned to produce certain eye characteristics and the eyes are not representative of normal devices.

Correlation of 100G SR4 TxVEC results with RxS results



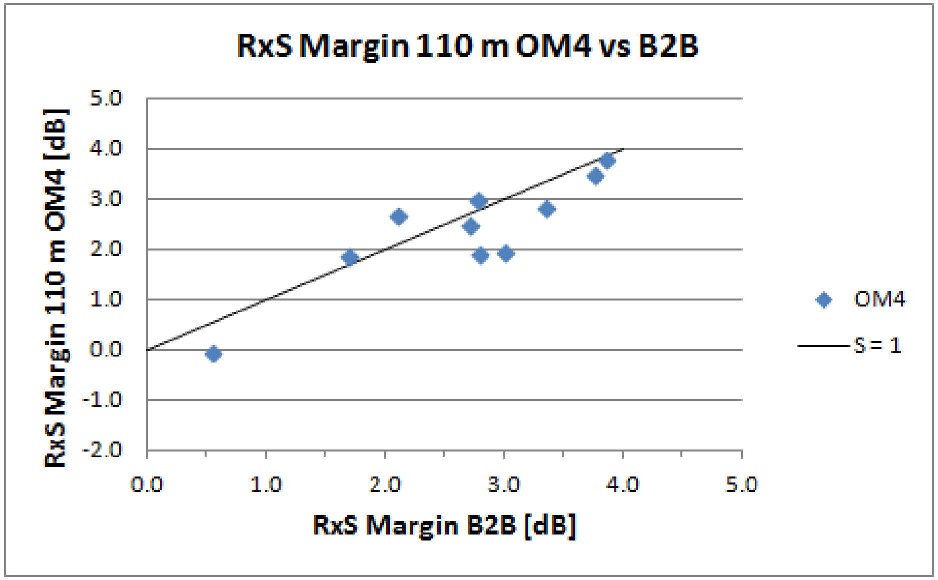


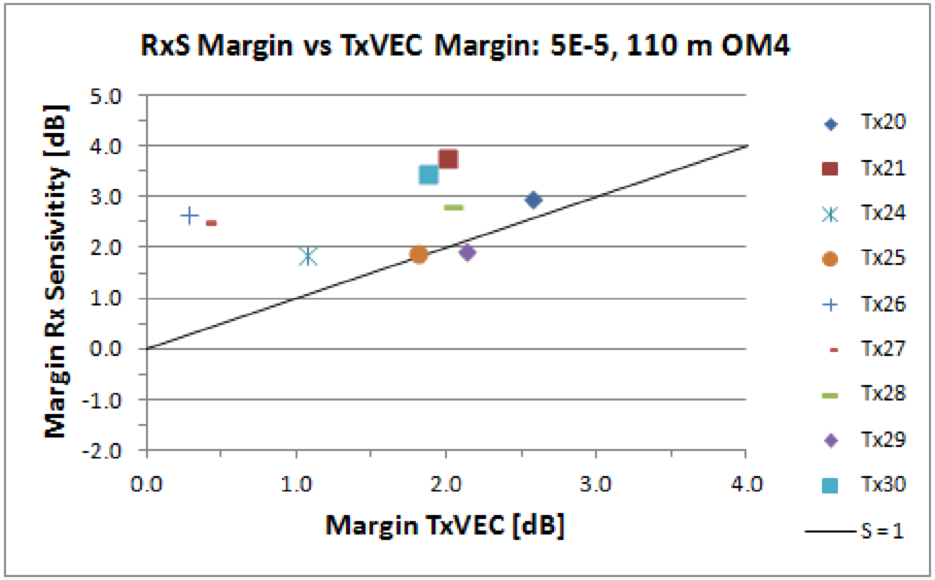




The above charts shows the correlation between TxVEC and RxS margins for B2B and 110 m OM4 cases.

Correlation of 100G RxS results for B2B & 110 m OM4 cases





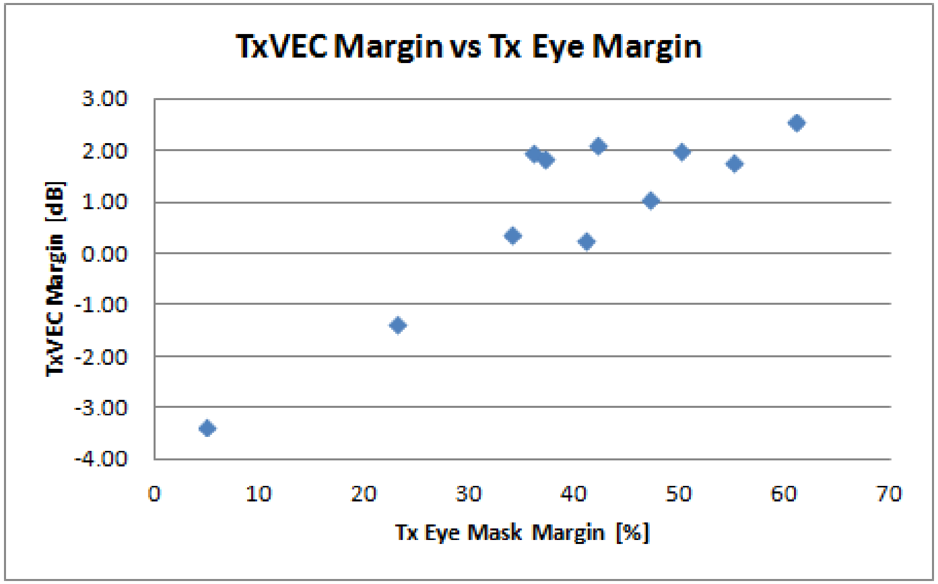
•The left chart shows a range of ~ 1.8 dB for RxS(OM4) margin & RxS(B2B) margin result pairs. The range includes the variation between two RxS measurements and the effect of the OM4 fiber. It's accepted in the industry that a range of 1 dB for RxS repeatability is very tight.

• In the right chart a range of ~ 2.7 dB for RxS(OM4) margin is shown for all transmitters with positive TxVEC margin. For the Gaussian group, T20, T24, T25 & T28, the range is 0.70 dB.

•The ability to predict worst case 100G SR4 link performance based on TxVEC results appears reasonably aligned with simulations for the Gaussian group, less so for the entire group. Fortunately, link margin estimates are conservative for most of the non-Gaussian group..

•Since link margin estimates based on TxVEC results appear to be within the range of errors found for link margin estimates based on TDP results and TxVEC is a significantly easier measurement to implement, 802.3bm should replace TDP with a TxVEC metric.

Correlation of 100G SR4 TxVEC & Eye Mask Margins



•The above chart shows the correlation between Tx Eye Mask margin results and TxVEC margin results, provided to show the range of eye quality included in this experiment.