Generating Tx Eye Masks

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Presentation Overview

- Tx Eye Mask Proposition
- Extended 10GbE Link Model
- Tx Eye Masks: Use & Generation
- Sensitivity Analysis
- Efficacy
- Base Case
- Recommendations for clause 86 items

Tx Eye Mask Proposition

- An extended 10GbE link model can be used to define Tx eye masks that ensure better than required signal characteristics at Rx inputs and compensate for differences between test set-ups and worst case link requirements.

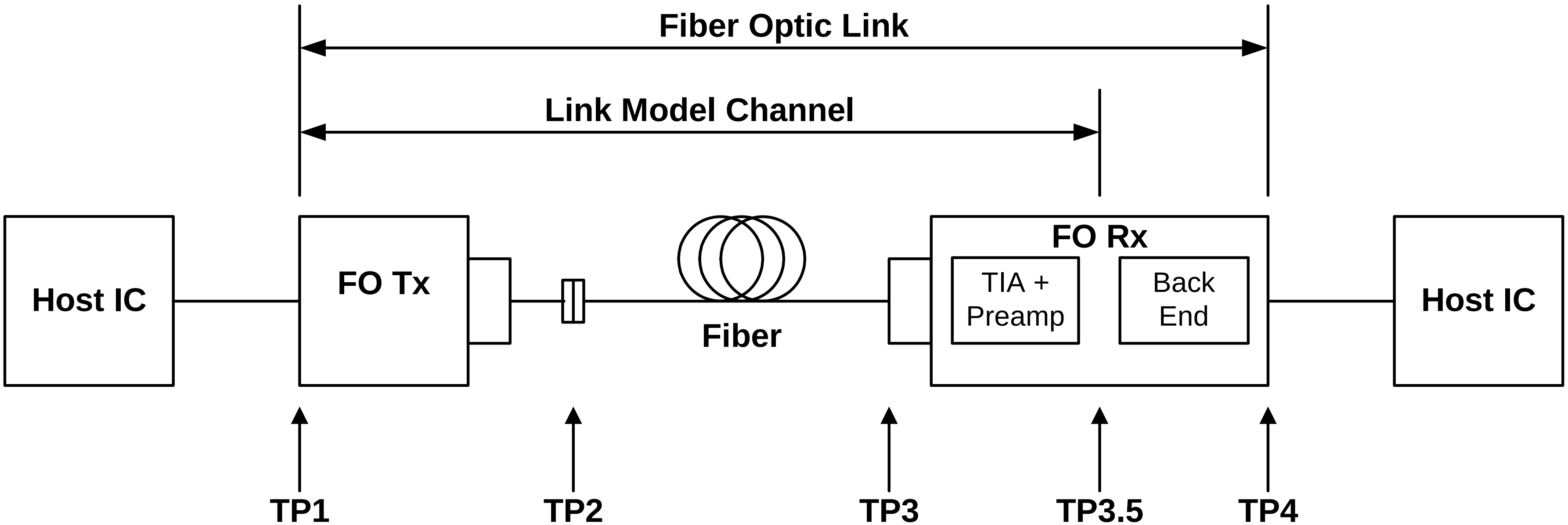
10G Ethernet Link Models

The link model (hereafter 10GbE) used in development of 10G Ethernet (10GEPBud3_1_16a.xls) is available at the IEEE P802.3ae 10Gb/s Ethernet Task Force Serial PMD documents website http://www.ieee802.org/3/ae/public/adhoc/serial_pmd/documents/ .

One of several available discussions, The 10G Ethernet Link Model, is available at the IEEE HSSG website http://www.*ieee802.org/3/hssg/public/nov06/dawe_01_1106.pdf .* This presentation includes an extensive list of references.

Extensions for the 10GbE model that include effects of source RJ at TP1 and DJ added between TP3.5 and TP4, calculates the open eye width at TP4, providing a means to harmonized power penalties and jitter are described in petrilla_01_1108.

Link Model Definition



- Fiber optic link and component specifications are often based on a link definition similar to that shown above. Shown in the above figure are functional link blocks and interfaces between blocks. In general, for standards, specifications apply at the interfaces. This can provide the basis for inter-operability among independently produced components.

- Ethernet has used the terms TP1, TP2, TP3 & TP4 for the interfaces. TP3.5 is added to represent better the decision point, that is, the end of the channel for the 10GbE model where penalty accounting is performed.

10GbE Link Model - Assumptions

- Transmitters have a Gaussian impulse response with a similar step response for rising and falling edges.
- Fibers have a Gaussian impulse response.
- Receivers have a non-equalized, raised-cosine response.
- The reference (or test) receiver has a 4-th order Bessel-Thomson (BT) response at 75% of the signal rate.
- Modal noise introduced by partial optical mode coupling in the cable plant is limited to a noise penalty, Pmn, of 0.3 dB by limiting the maximum connector loss to 1.5 dB.
- RIN is white over the frequency range of interest.

Additional Assumptions for Extension

- Jitter at the interfaces can be partitioned into random, RJ, and deterministic, DJ, components using Dual Dirac jitter methods. For the rest of this presentation, DJ refers to Dual Dirac DJ.
- The signal (amplitude) noise in the optical link is transformed into random (Gaussian) jitter by the non-vertical edges of the signal transitions.
- Input referred receiver noise is Gaussian.
- At the corners of the eye opening, the vertical closure due to the power penalties and signal loss coincides with the horizontal closure due to jitter.
- Receiver sensitivity includes the minimum output swing requirements for the receiver.

Tx Eye Mask
Use & Opportunity

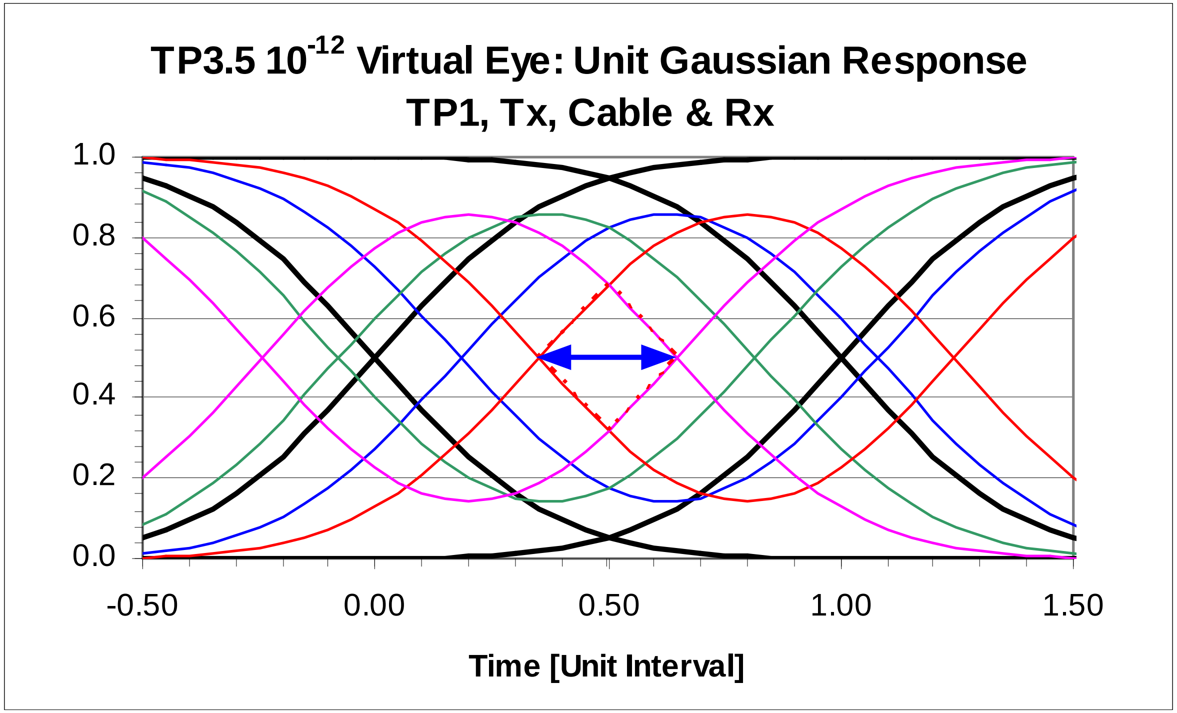
- Transmitter eye masks have been previously used to capture features not adequately covered by other parametric tests, e.g. overshoot & undershoot.
- For 10GbE a transmitter eye mask is used to address high probability (e.g. > 10^{-3}) of occurrence events.
- Transmitter eye tests are often performed at a virtual TP3.5 with a minimum cable plant to examine waveforms at the decision point. A filter, e.g. 75% signal rate, 4^{th}-order BT filter, is often used to reduce variability in results.
- Since a transmitter eye mask captures rise & fall times, distortion, jitter & noise, why not use it to replace rise and fall time tests, jitter, DCD & RIN? This allows tradeoffs among these parameters.
- If transmitter output OMA can be included as an absolute quantity instead of being normalized to a unit amplitude, then OMA can be included in the above tradeoffs. A mask, absolute for the eye opening and relative for the overshoot & undershoot, appears promising.

Tx Eye Mask
Generation - Overview

- The following pages present a method of generating eye masks based on BER contours, i.e.
  - show 10^-12 BER contours
  - show progression of required contour/eye from TP3.5 to TP2
  - show translation of contour into mask
  - show translation of contours and masks from 10^-12 to ~10^-5.

  Contour/Mask Generation Approach and/or Assumptions:
  - For contours each bit is at worst case DJ.
  - Receiver requirements are based on unstressed receiver sensitivity.
  - The Reference/Test Rx only contributes RJ and ISI generated DJ.
  - In test set-ups, observed optical-noise and random jitter beyond that due to TP1 jitter, RIN of the device under test, test receiver sensitivity or test equipment timing uncertainty, is due to modal noise associated with incomplete modal coupling at the optical connectors.
  - Although the Reference/Test Rx assumes a 4^{th}-Order BT response, no adjustment is made to the receiver time constant parameter in the spreadsheet.

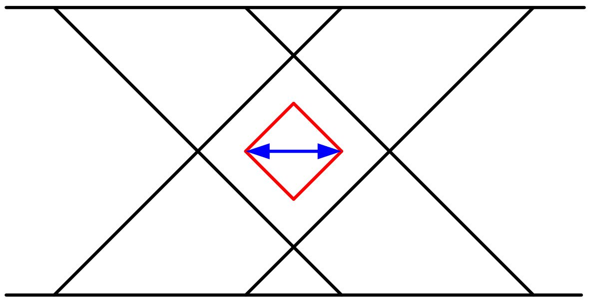
Tx Eye Mask - Generation at TP3.5



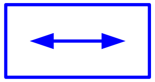
- The above figure shows eye contours generated at TP3.5, i.e. decision point for defined worst case link conditions. All Rx DJ allocation is also included. Impairments from the observing test equipment are not included. Note approximate diamond shape.
- The contours are generated as if every bit is at the maximum DJ. For PRBS patterns only 25% of the bits are isolated center bits in …010… or …101… patterns. Consequently, the contours are conservative.
- In the eye contour for TP3.5 recall that since the decision point in the receiver is followed by a high gain comparator and/or the Rx minimum output swing is included in the sensitivity test, BER requirements are satisfied even if the diamond is collapsed to the blue line. The required length of the blue is given by the eye opening required at TP3.5 plus any Rx contributed DJ generated after the decision point.

Tx Eye Mask – Simplified Rx Based Requirement

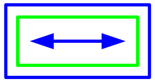
Generation – Progression (1)



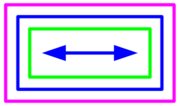
- 10^-12 eye contour needed for TP3.5



- Eye contour for a virtual TP3 adjusted for worst case Rx sensitivity. Eye Height = Rx sensitivity.



- Eye contour for an observed TP3 adjusted for worst case Rx sensitivity and difference between the worst case receiver and the test equipment receiver.



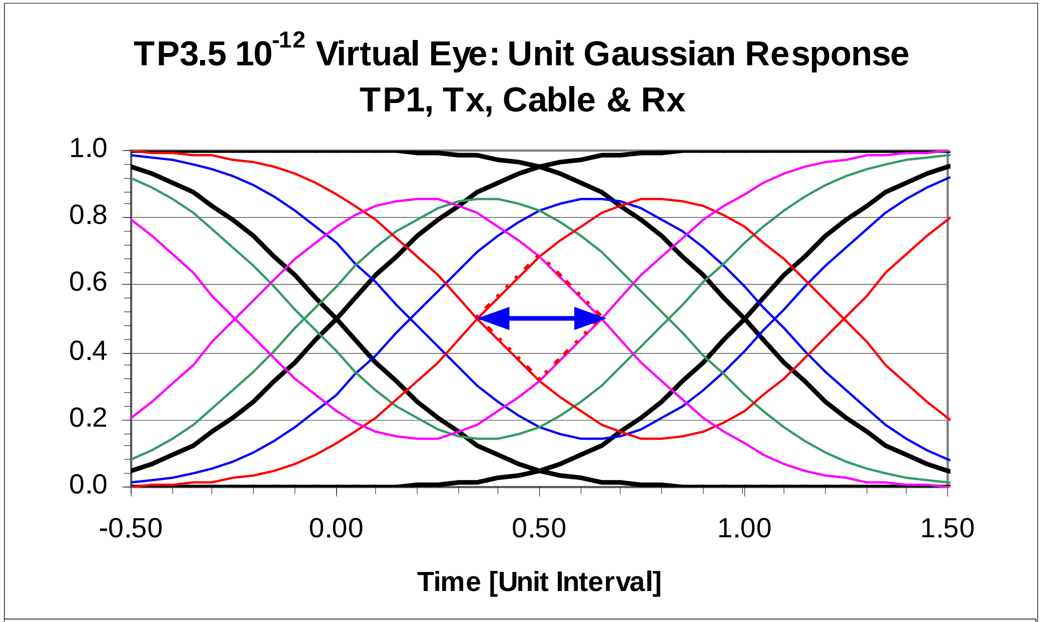
- Eye contour for an observed TP2 adjusted for worst case Rx sensitivity and difference between the worst case receiver and the test equipment receiver and further adjusted for channel losses and penalties.

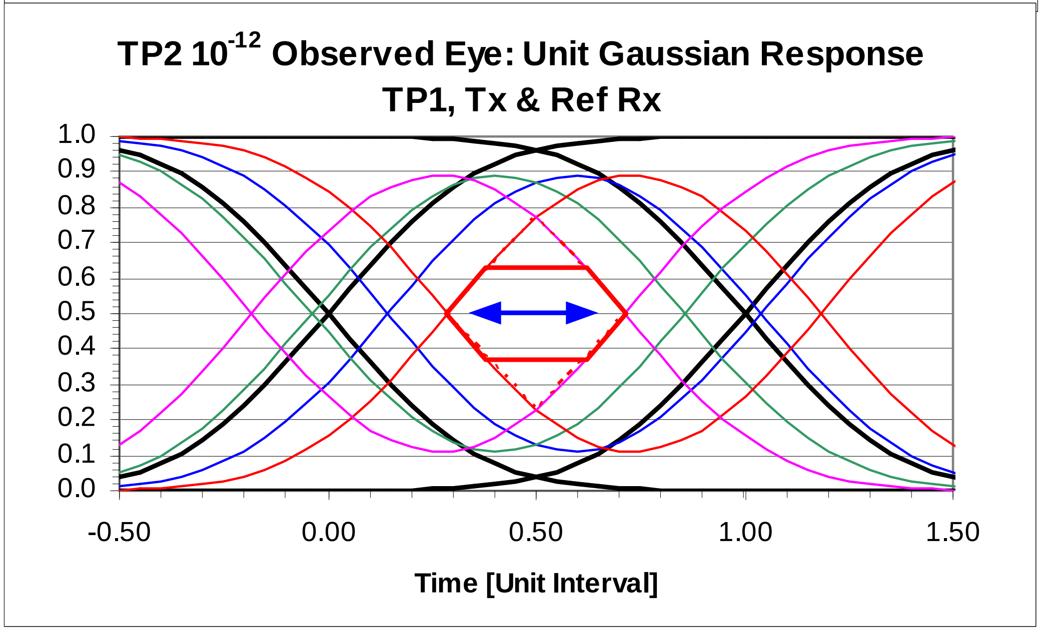
- Here the above figure shows a simplified eye contour for TP3.5. Again, the BER requirement is satisfied by the blue line. On the right a progression is shown beginning with the eye contour required at TP3.5 and working upstream to the output of the transmitter. There, for brevity only eye height adjustments are discussed. Adjustments are, however, also required for eye width. The combined effect may produce rounded or semi-ellipsoidal ends.

Tx Eye Mask

Generation – Progression (2)

- Repeating the previous page, an eye mask can be based on the input signal requirements of the Rx. Here the height is based on the unstressed sensitivity and link penalties and the ends are based on the simplified diamond-shaped eye contour yielding a six-sided polygon.



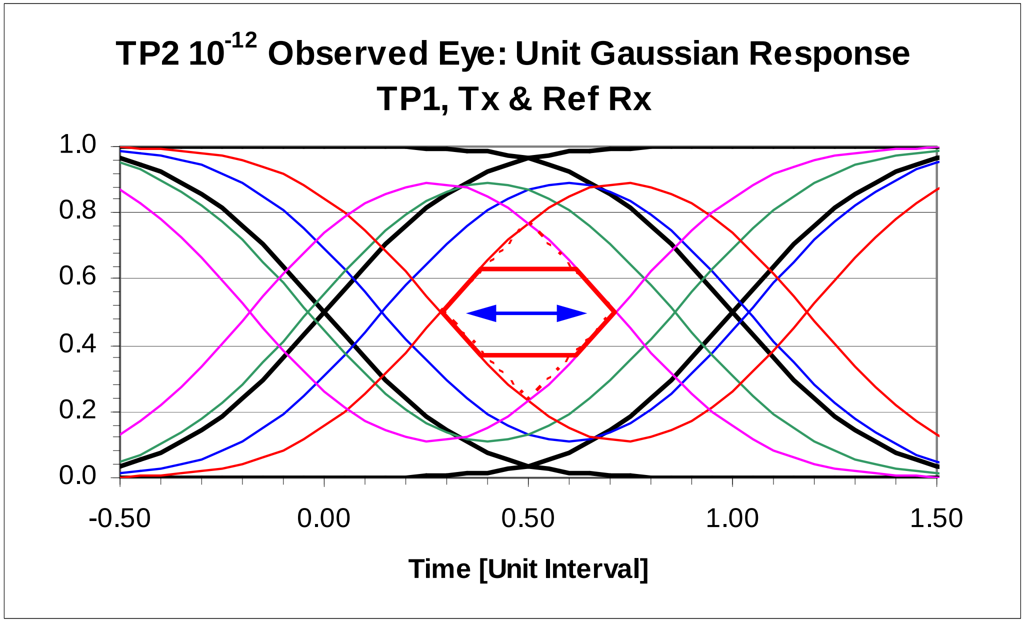


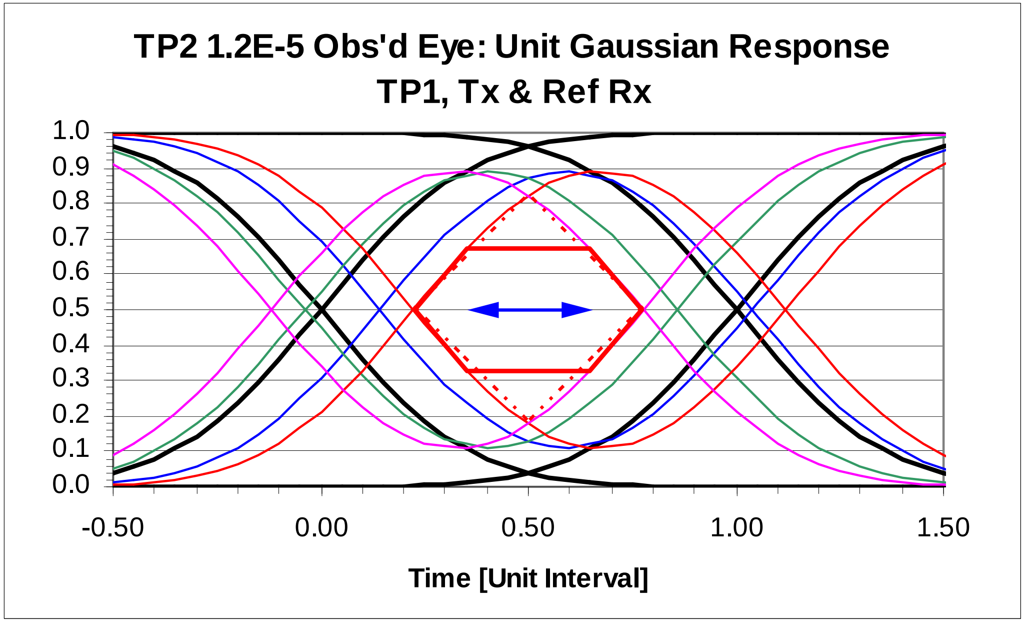
Tx Eye Mask

Generation Lower Q Contours

- Contours for higher BER can be used to define equivalent but less time consuming measurements. Here, for comparison with BER = 1E-12 contours, contours are also plotted for a test based on BER = 1.23E-5 e.g. rejecting on 11 hits in 1000 waveforms where each waveform comprises 1350 samples, 60% of which are in the UI of interest.

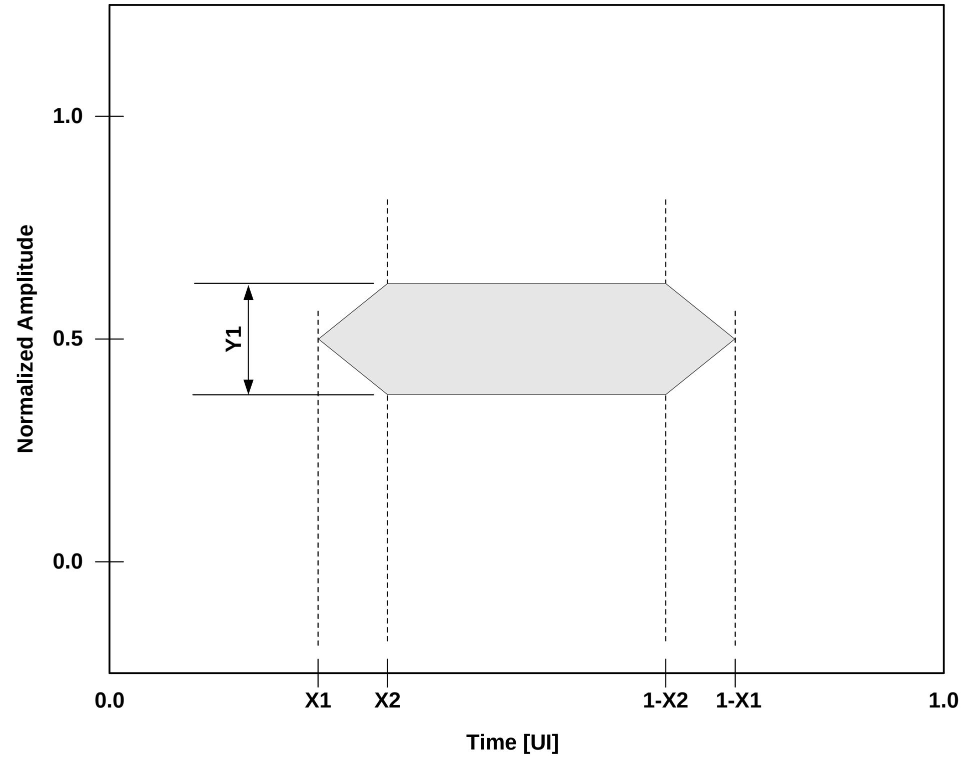
  Rejecting on a larger number of hits should reduce the variability of the margin result. Note that the contour represents a mean position for which there's a confidence interval and associated measurement variability. It's expected that the width of the confidence interval and associated measurement variability is inversely related to the square root of the reject value.





Tx Eye Mask
Generation – Specification

- A specification version of a Tx eye mask could have just one region as shown in the figure on the right.
- As shown in the figure three parameters, X1, X2 & Y1, can define the mask for a six-sided polygon.



- Here if the value of Y1 is expressed in terms of normalized amplitude, a relative eye mask results and OMA is removed from the transmitter attribute tradeoffs. Where Y1 is expressed in units of power, OMA can be included in tradeoffs with rise and fall time, RIN and jitter.

Tx Eye Mask
Generation – Final Points

- Transmitter attributes, center wavelength and spectral width, are not covered.
- An absolute optical power mask is sensitive to power coupling. Unfortunately OMA and LOP are not best measured with a DCAJ and relative masks may have an advantage.
- Noise injected into the signal path, e.g. from partial mode coupling, will be captured and degrade the measurement if not properly included in calibration.
- Moving to a criteria of accepting a higher hit count, e.g. 10 hits vs 0 hits (perhaps better expressed as rejecting on 11 hits vs 1 hit) should improve the variability of the measurement result. The variability should be related to the ratio between the square root of the reject levels.

40GBASE-SR4 & 100GBASE-SR10 Proposal

Link Model Transmitter Attributes (Each Lane) – Base Case

- **Min OMA: -3.0 dBm**
- **Min ER: 3.0 dB**
- **Min Center Wavelength: 840 nm**
- **Max RMS Spectral Width: 0.65 nm**
- **Max Transition Time (20%, 80%): 35.6 ps**
- **Max RIN12OMA: -130 dB/Hz**
- **RIN Coefficient: 0.70**
- **Mode Partition Noise Coefficient: 0.30**
- **Min Optical Reflection Tolerance: -12 dB**
- **TP1 Jitter Allocation: TJ = 0.300 UI, DJ = 0.150 UI**
- **TP2 Jitter Allocation: TJ = 0.488 UI, DJ = 0.284 UI**

40GBASE-SR4 & 100GBASE-SR10 Proposal

Link Model Receiver Attributes (Each Lane) – Base Case

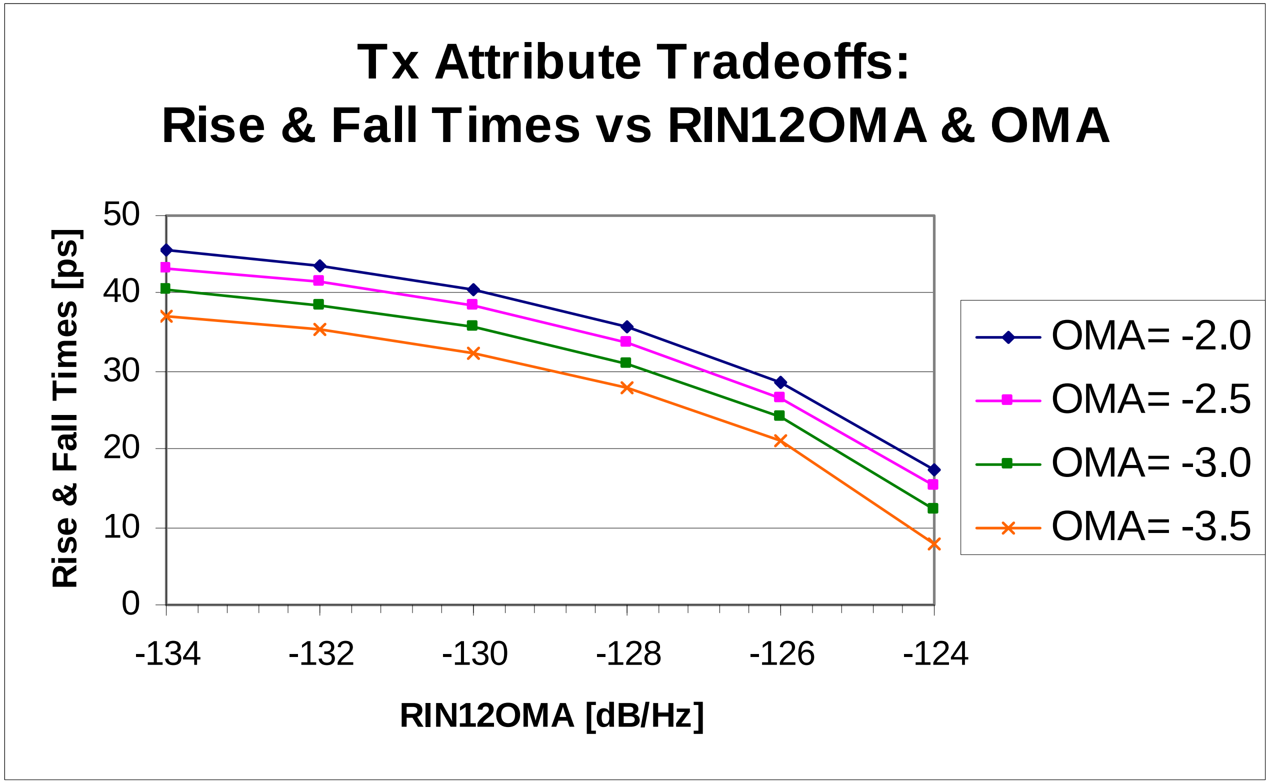
- **Max Sensitivity: -11.3 dBm**
- **Min Bandwidth: 7500 MHz**
- **RMS Base Line Wander: 0.025**
- **Max Rx Reflection: -12 dB**
- **TP3 Jitter Allocation: DJ = 0.284 UI, DCD = 0.103 UI**
- **TP3 Jitter Allocation: TJ = 0.511 UI**
- **TP4 Jitter Allocation: TJ = 0.700 UI**
- **TP4 Jitter Allocation: DJ = 0.367 UI**

40GBASE-SR4 & 100GBASE-SR10 Proposal

Link Model Channel Attributes (Each Lane) – Base Case

- **Signal Rate: 10.3125 GBd**
- **BER: < 10^{-12} (Q = 7.034)**
- **100 m of OM3**
- **1.5 dB connector loss allocation**
- **Signal Power Budget: 8.3 dB**
- **Attenuation = 0.36 dB**
- **Center Eye Penalties**
  - **Pisi = 1.45 dB**
  - **Pdj = 0.22 dB**
  - **Pmn = 0.30 dB**
  - **Pmpn = 0.02 dB**
  - **Prin = 0.15 dB**
  - **Pcross = 0.14 dB**

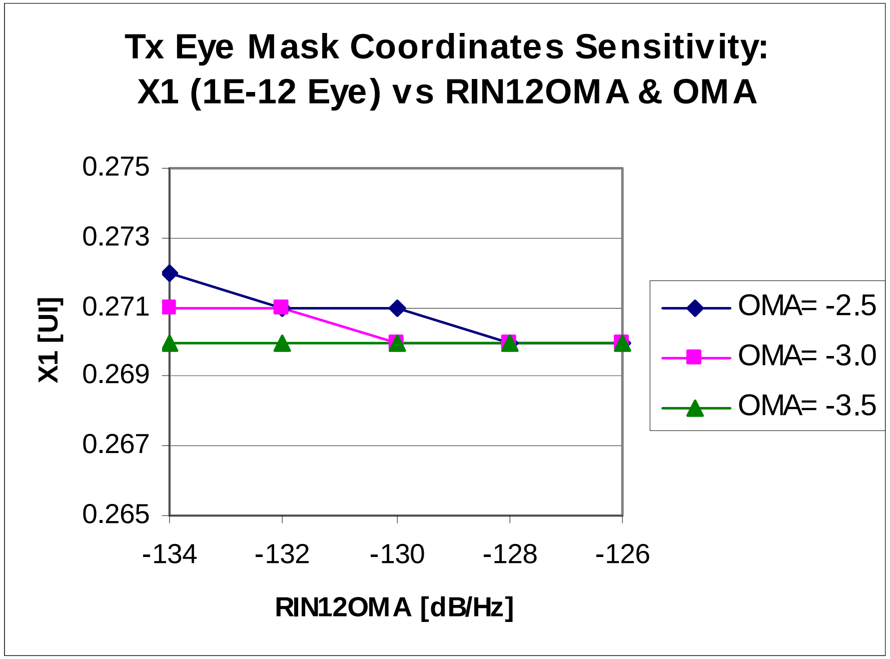
Aggregated Tx Attribute Tradeoffs

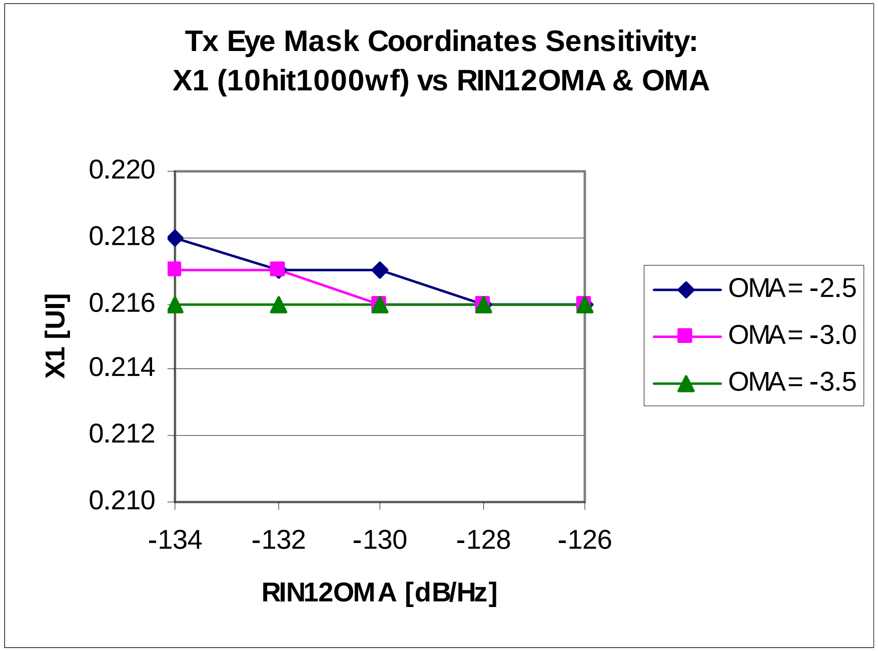


- The above figure shows tradeoffs among Tx rise and fall times, RIN12OMA and OMA for constant TP1 and TP4 jitter allocations and all other parameters at worst case values. Here values of RIN12OMA higher than -128 dB/Hz were explored to check for a noise floor.

Tx Eye Mask Coordinates

Sensitivity to Attribute Tradeoffs (1)

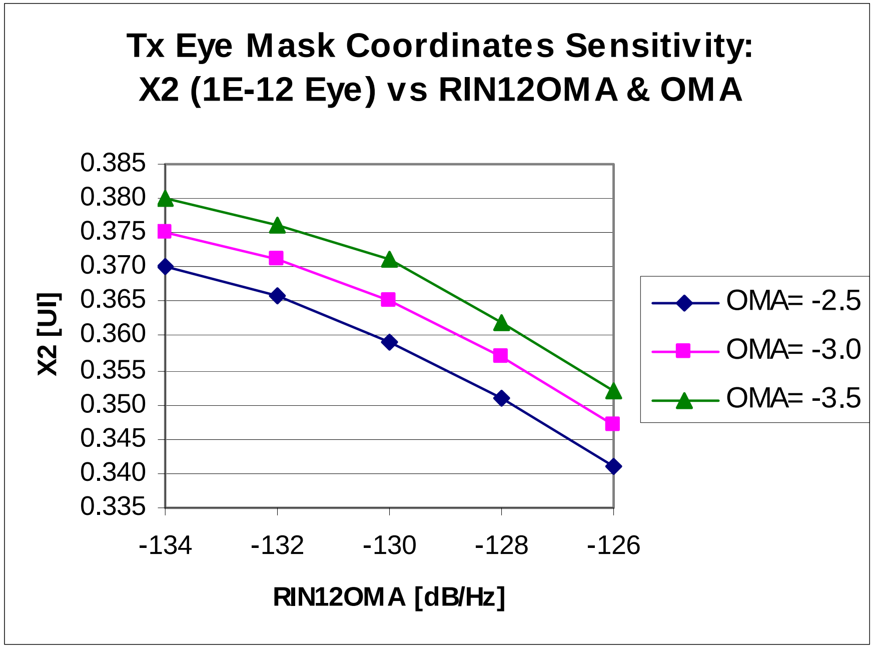


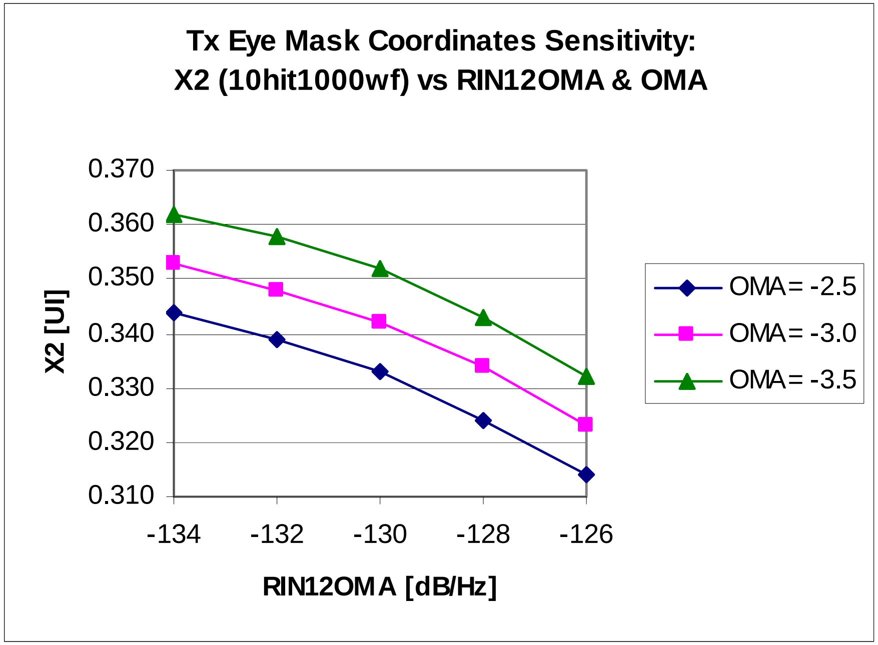


- The above figures show the sensitivity of eye mask coordinate X1 to the Tx rise & fall times, RIN12OMA and OMA tradeoffs shown on the previous page.

Tx Eye Mask Coordinates

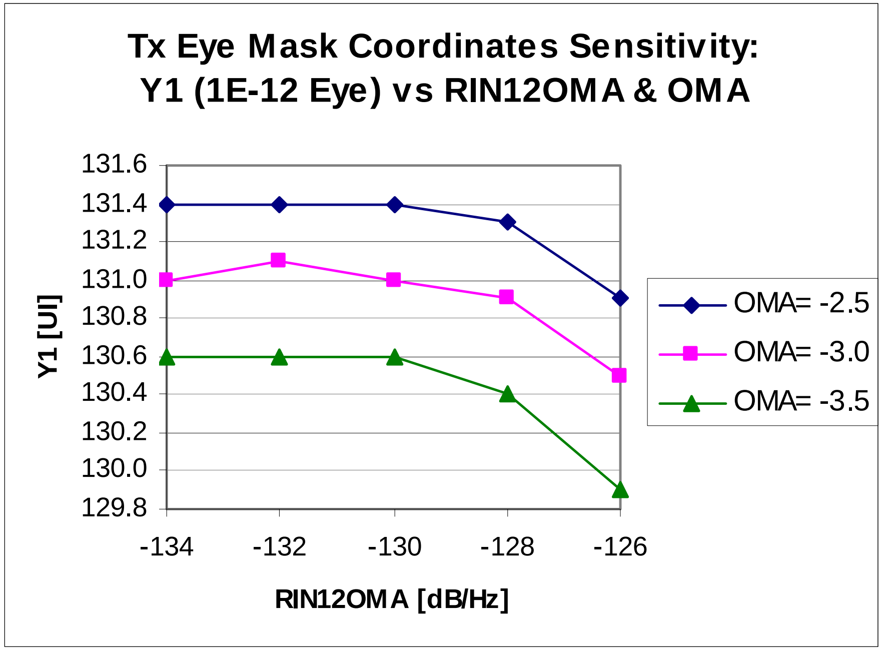
Sensitivity to Attribute Tradeoffs (2)

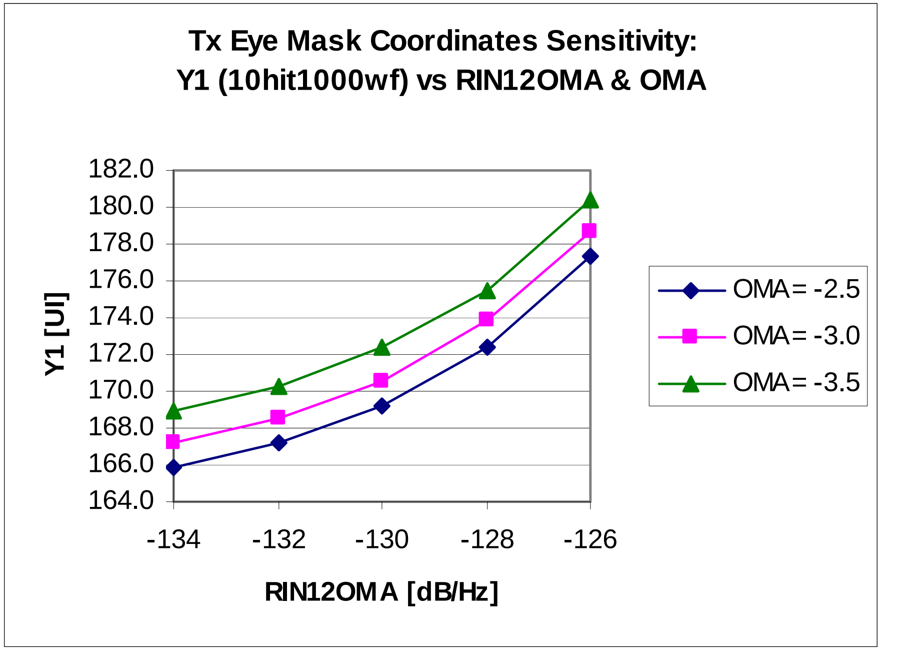




- The above figures show the sensitivity of eye mask coordinate X2 to the Tx rise & fall times, RIN12OMA and OMA tradeoffs shown on an earlier page.

Tx Eye Mask Coordinates
Sensitivity to Attribute Tradeoffs (3)





- The above figures show the sensitivity of eye mask coordinate Y1 to the Tx rise & fall times, RIN12OMA and OMA tradeoffs shown on the previous page.

Tx Eye Mask Efficacy

				10 Hit 1000 Waveforms				
OMA	Ts	RINoma	TP4 Eye	X1	y(x=0.2243)	X2	y(x=0.3545)	Y1
dBm	ps	dB/Hz	UI	UI	UI	UI	UI	uW
-3.00	35.60	-130.00	0.300	0.2243	0.5000	0.3545	0.6758	176.2
-4.00	28.43	-130.00	0.300		0.5072		0.7051	163.29
-4.00	35.60	-141.85	0.300		0.5130		0.6871	148.94
-3.00	28.43	-127.13	0.300		0.4960		0.6954	195.91
-3.00	40.44	-133.89	0.300		0.5031		0.6638	164.00
-2.00	35.60	-127.98	0.300		0.4922		0.6689	213.16
-2.00	40.44	-130.00	0.300		0.4944		0.6559	196.79

The Tx eye mask was evaluated with combinations of Tx output OMA, Tx rise and fall times, and RINoma. The baseline case is shown in the top row. All subsequent row show combinations of Tx output OMA, Tx rise and fall times, and RINoma that from the link model provide a TP4 Rx output open eye width of 0.30 UI. None of these would pass the Tx Eye Mask test indicating that not all combinations that would be acceptable to the link model would pass this eye mask.

TDP Efficacy

OMA	Ts	RINoma	TP4 Eye	TDP
dBm	ps	dB/Hz	UI	dB
-3.00	35.60	-130.00	0.300	-1.33
-4.00	35.60	-141.85	0.300	-2.12
-4.00	28.43	-130.00	0.300	-1.82
-3.00	28.43	-127.13	0.300	-1.00
-3.00	40.44	-133.89	0.300	-1.58
-2.00	40.44	-130.00	0.300	-0.75
-2.00	35.60	-127.98	0.300	-0.48

A TDP test that included OMA was also evaluated. Ref Tx and Rx were defined and a value of 1.33 dB was determined as the difference in penalties between the Ref Tx and worst case Tx for a worst case 100 m fiber without attenuation, connector loss or modal noise noise. The baseline case is shown in the top row. All subsequent row show combinations of Tx output OMA, Tx rise and fall times, and RINoma that from the link model provide a TP4 Rx output open eye width of 0.30 UI. Of these, three would be rejected and three would pass the TDP test indicating that some units that pass the link model would fail the TDP test and some units that fail the link model would pass the TDP test.

Generating Tx Eye Masks
Conclusions, Clause 86 TBDs and open items

- **It has been shown that a Rx-requirement-based Tx mask can be defined using the extended 10GbE link model described in petrilla_01_1108.**
- **Such an eye mask can be defined for a higher BER, e.g. 1E-5, but provide equivalent coverage as one defined for a lower BER, e.g. 1E-12.**
- **Such a Tx eye mask, if using an absolute value signal amplitude (OMA) instead of a relative value, brings OMA into tradeoffs with RIN, Tx rise & fall times and Tx contributed DJ, holding promise for yield improvements and reduced testing.**
- **Such a Tx eye mask , if using an absolute value signal amplitude (OMA) instead of a relative value, appears conservative as not all Tx attribute combinations that provide adequate link margin would pass the Tx eye mask.**
- **This presentation addresses the following open items in clause 86.**

1. **Table 86-8, Use Tx eye mask as “aggregate signal parameter” and drop OMA and RIN12OMA as normative**
2. **Table 86-8, Provides coordinates for Tx eye mask: X1 = 0.225 UI, X2 = 0.355 & Y1 = 176 uW (X3, Y2 & Y3 are not needed) and a drawing for such an eye mask.**