100G PSM4 Link Model Update, TDP, Tx Eye Mask & SRS

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July 2013

100G PSM4 Link Model & Results Update

Presentation Objectives:

Update set of attribute values for 100G PSM4, 500 m SMF, example link model

Present TDP setup and requirements for 100G 500 m SMF Tx

Present Tx Eye Mask setup & coordinates

Present SRS setup & conditions – introduce SRS eye mask

Reference:

An example link model for 100G PSM4 is available at

http://www.ieee802.org/3/bm/public/may13/ExamplePSM_LinkModel_130514.xlsx

Fiber Optic Links Interfaces

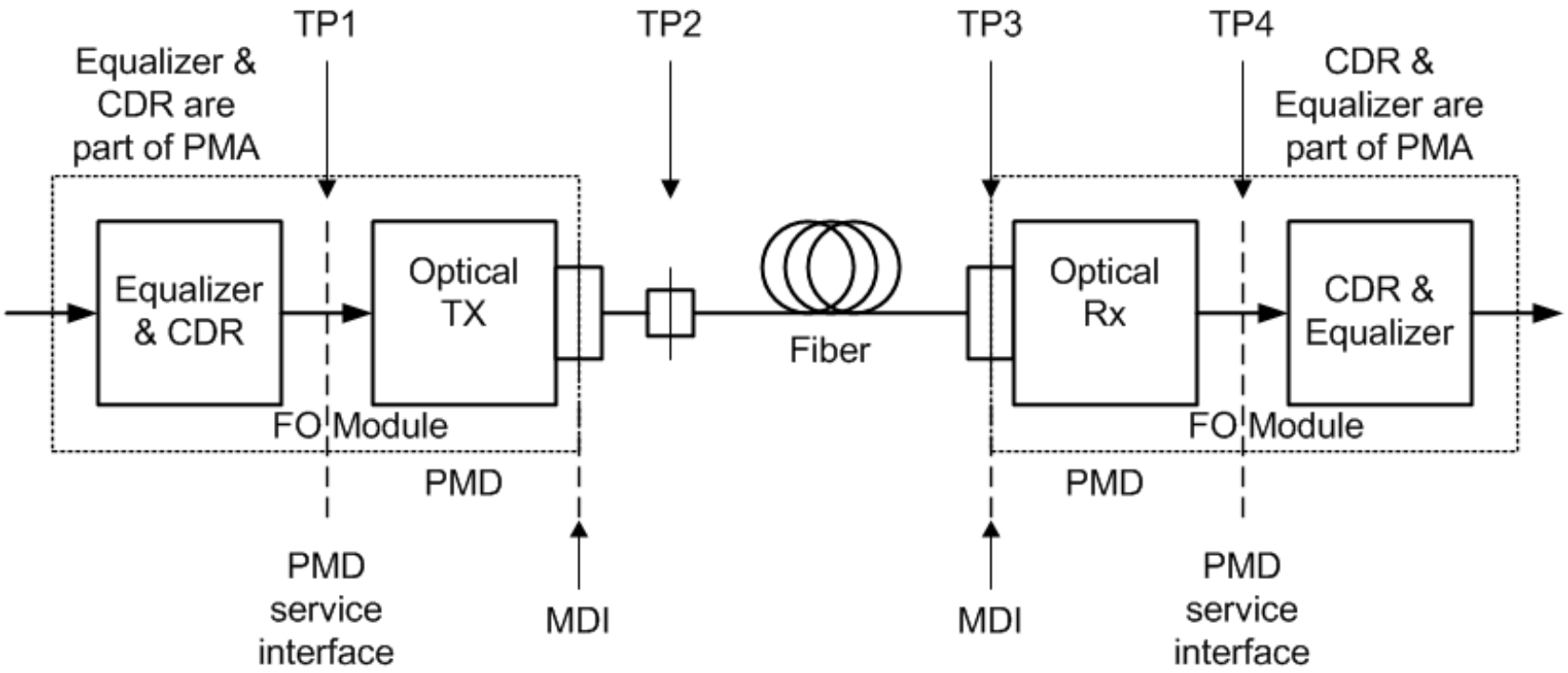


Figure 1

• For cases, as shown above in Figure 1, where retimers are incorporated in the optical module, the PMD service interface is not exposed. TP1 and TP4 remain as points on the PMD service interface and, consequently not exposed.

• The high speed signal inputs and outputs of the optical module are expected to be defined by CAUI-4.

100G PSM4 with 100G KR4 FEC: Example Link Model Tx Attributes

Parameter	Unit	100G PSM4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Center Wavelength, min	nm	1295	
Center Wavelength, max	nm	1325	
Spectral Width, max	nm	0.20	Note 1
OMA at max TDP, min	dBm	-2.6	Note 2
Extinction ratio, min	dB	3.5	
Tx output transition times, 20% -80%, max	ps	16	
$RIN_{12}OMA$, max	dB/Hz	-130	
RIN coefficient		0.7	
MPN coefficient		0	
Modal Noise Penalty	dB	0	
Tx reflectance, max	dB	-12	
Tx optical return loss tolerance, max	dB	11.9	Single point reflection equivalent to a 12 dB ORL Rx and four inline 35 dB ORL connectors

Attributes and values in the above table are provided in order to populate example link models and may not be normative.
Note 1, Model uses 0.2 nm spectral width to generate penalty equivalent to max expected from chirp.
Note 2, Trade-offs are defined for 100G PSM4 attributes, min OMA, center wavelength and TDP, as follows:
TX OMA ≥ MAX(-8.65 +$(\Delta\lambda)^2$/100, -8.05) + MAX(TDP, 0.8) dBm where $\Delta\lambda$ is center wavelength offset (in nm) from 1310 nm.

100G PSM4 with 100G KR4 FEC: Example Link Model Rx Attributes

Parameter	Unit	100G PSM4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Center Wavelength, min	nm	1295	
Center Wavelength, max	nm	1325	
Rx sensitivity (OMA), max	dBm	-9.67	-7.10 dBm at Q = 7.034, Note 1
Rx Bandwidth, min	MHz	19,336	
RMS base line wander coefficient		0.025	
Rx reflectance, max	dB	-7.94	Note 2

Attributes and values in the above table are provided in order to populate example link models and may not be normative.

Note1, Trade-offs are defined for 100G PSM4 attributes, Rx sensitivity (OMA), max and center wavelength, as follows:
RX SENS (OMA) = MAX(-11.89 +$(\Delta\lambda)^2$/100, -11.4) where $\Delta\lambda$ is center wavelength offset (in nm) from 1310 nm.

Note2, 100G PSM4 Rx reflectance is a single point reflection that generates an MPI equivalent to a -12 dB Rx reflectance and four inline connectors each at -35 dB reflectance. The single point equivalence was determined with the Upper Bound penalty calculation in “PAM MPI – Overview & Recommendations”,
http://www.ieee802.org/3/100GNGOPTX/public/may12/bhatt_01_0512_optx.pdf

100G PSM4 with 100G KR4 FEC: Example Link Model Channel Attributes

Parameter	Unit	100G PSM4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Reach	m	500	
Fiber Attenuation	dB/km	0.50	For 1310 nm center wavelength, 0.5146 dB/km at 1295 nm
Dispersion min Uo	nm	1324	
Dispersion So	ps/nm^2km	0.093	
Fiber modal bandwidth	MHz·km	10^6	
PolMD DGDmax	ps	2.24	Sq root dependency with fiber length
Reflection Noise Factor		0.60	
Signal power budget at max TDP	dB	7.07	Model output
Connector & splice loss allocation	dB	3.0	
Fiber Insertion loss	dB	0.26	Model output
Allocation for penalties at max TDP	dB	3.81	Model output Now includes Peye
Allocation for target TP4 eye at max TDP	dB	0	1.01 dB included in Allocation for penalties at max TDP
Additional insertion loss allowed	dB	0	Model output

Attributes and values in the above table are provided in order to populate example link models and may not be normative. Various model outputs are provided.

100G PSM4 with 100G KR4 FEC: Example Link Model Jitter Attributes

Parameter	Unit	100G PSM4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
TP1 RJrms tolerance, min	UI	0.0079	
TP1 DJ tolerance, min	UI	0.11	
TP3 DCD tolerance, min	UI	0.05	
TP3 DJ tolerance, min	UI	0.163	
TP4 J2, max	UI	0.568	Model output
TP4 TJ at BER, max	UI	0.780	Model output

Attributes and values in the above table are provided in order to populate example link models and may not be normative. Various model outputs are provided.

Nomenclature: Terms TP1, TP2, TP3 and TP4 are used as defined in 802.3 clause 86 and shown in above Figure 1. Note that TP1 is downstream of the input CDR and equalizer for an optical transmitter.

100G PSM4: Developing TDP Requirements 1

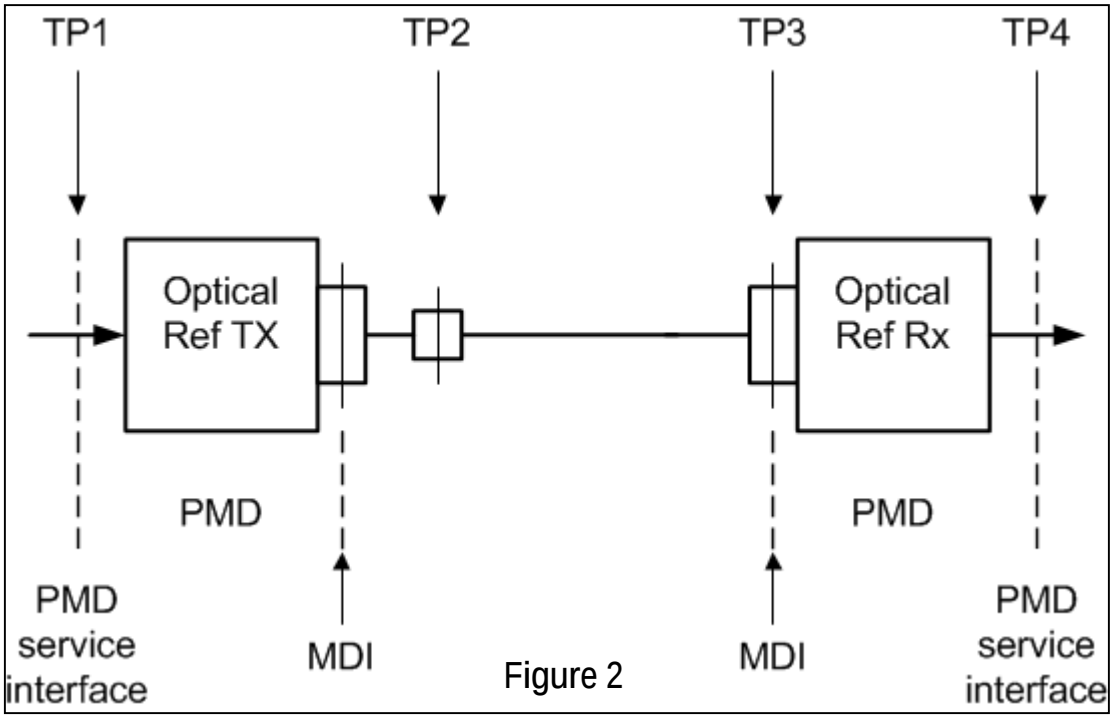


Figure 2

1) In setup of Figure 2, adjust Ref Tx OMA to yield TP4 TJ requirement.
2) Measure OMA at TP3.
3) Determine residual link penalty if any.
4) Record OMA + residual link penalty as Test Reference Sensitivity, S.

•The above figure shows a starting point for development of TDP requirements for a MMF link.
•This is entirely a link model excerise based on idealized reference devices and the defined worst case Tx operating at defined worst case TP1 conditions over the defined worst case optical channel.
•A reference transmitter, Ref Tx, and a reference receiver, Ref Rx, are defined. These are idealized devices and are not expected to be implemented.
•A VOA is not used due to the effect of attenuation on reflection penalty.
•The sensitivity, S, of the Ref Rx is defined by the signal level at TP3 at the point that the requirements at TP4 are met.
•Link model attributes for Ref Tx and Ref Rx, TP1 and TP3 are provided on following pages.

100G PSM4 with 100G KR4 FEC: Example Ref Tx Attributes

Parameter	Unit	100G PSM4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Center Wavelength	nm	1310	
Spectral Width	nm	0.05	
OMA at max TDP	dBm	-13.39	
Extinction ratio	dB	4.77	
Tx output transition times, 20% -80%	ps	1.0	
$RIN_{12}OMA$	dB/Hz	-130	
RIN coefficient		0	
MPN coefficient		0	
Modal Noise Penalty	dB	0	
Tx reflectance, max	dB	-50	

- Attributes and values in the above table represent an ideal device to use as a reference case. There's no expectation that such a transmitter can be implemented.
- Note that all noise sources are disabled.

100G PSM4 with 100G KR4 FEC: Example Ref Rx Attributes

Parameter	Unit	100G PSM4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Wavelength, min	nm	1295	
Wavelength, max	nm	1325	
Ref Rx sensitivity (OMA)	dBm	-13.50	-10.93 dBm at Q = 7.034
Rx Bandwidth	MHz	19,336	
RMS base line wander coefficient		0	
Rx reflectance, max	dB	-13.507	When used for TDP, set to value that yields same LP penalty with WC Tx as in WC link. When used as Ref Rx for, e.g., Tx Eye mask, set to 26 dB.

Attributes and values in the above table represent an ideal device to use as a reference case.

100G PSM4 with 100G KR4 FEC: Example Ref Ch Attributes (each lane)

Parameter	Unit	100G PSM4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Reach	m	2	
Fiber Attenuation	dB/km	0.50	For 1310 nm center wavelength
Dispersion min Uo	nm	1324	
Dispersion So	ps/nm^2km	0.093	
Fiber modal bandwidth	MHz·km	10^6	
PolMD DGDmax	ps	0.14	Sq root dependency with fiber length
Reflection Noise Factor		0.60	
Signal power budget at max TDP	dB	0.11	Model output
Fiber Insertion loss	dB	0.00	Model output

Attributes and values in the above table are provided in order to populate a link model representating the test setup for the TDP reference case.

100G PSM4 with 100G KR4 FEC: Example Ref Tx Ref Rx Link & Jitter Attributes

Parameter	Unit	100G PSM4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
TP1 RJrms	UI	0	
TP1 DJ	UI	0	
TP3 DCD	UI	0	
TP3 DJ	UI	0	
Attenuation (aka Connector loss)	dB	0	Set to 0 for max reflection penalty
TP4 TJ at BER, max	UI	0.780	Model output
Residual Link Power Penalty	dB	0.11	ISI penalty for TP4 TJ = 0.78 UI

- Attributes and values in the above table represent an ideal input at TP1 to use as a reference case. There's no expectation that such an input can be realized.
- Note that the only noise in the link is the noise that determines the sensitivity of the Ref Rx
- Nomenclature: Terms TP1, TP2, TP3 and TP4 are used as defined in 802.3 clause 86 and shown in above Figure 1 and Figure 2.

100G PSM4: Developing TDP Requirements 2

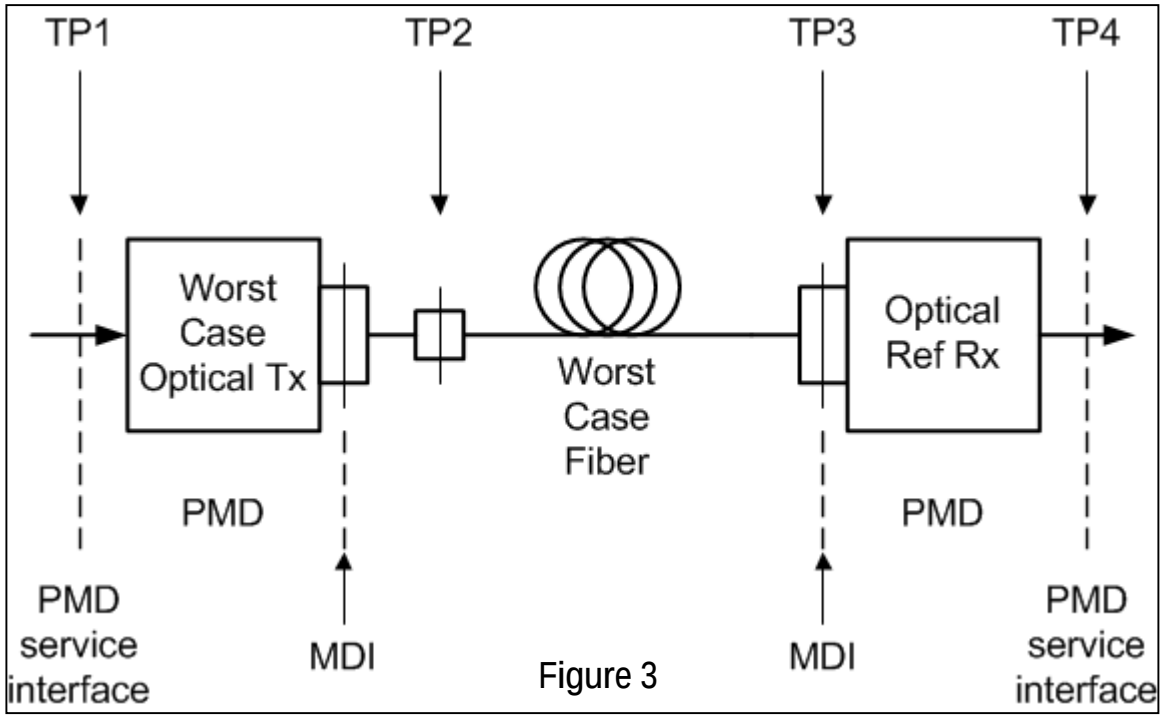


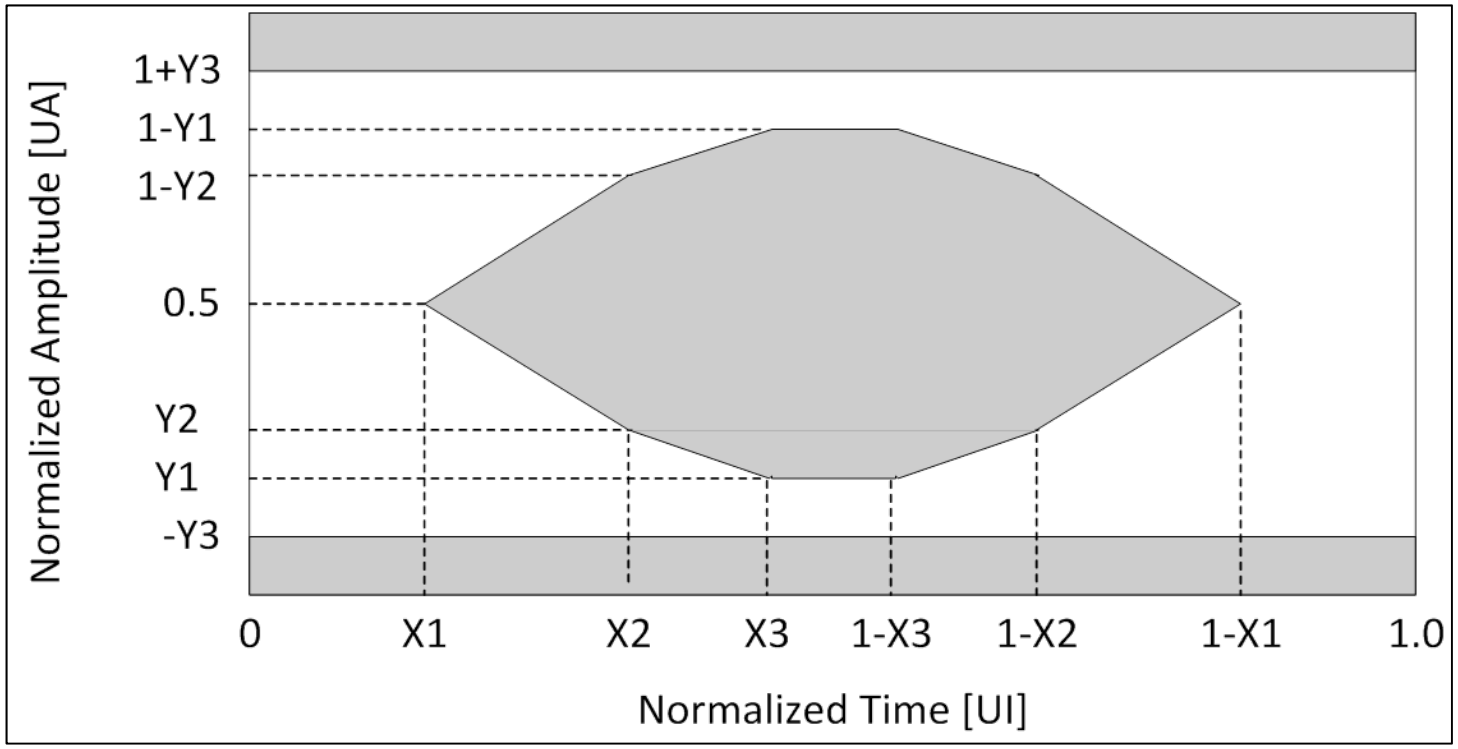
Figure 3

1) Replace Ref Tx in Figure 2 with Worst Case Tx, worst case TP1 conditions and Worst Case Fiber as shown in Figure 3.
2) Adjust Tx OMA to yield TP4 TJ requirement.
3) Record OMA at TP3
4) Max TDP = OMA – Ref Rx S.

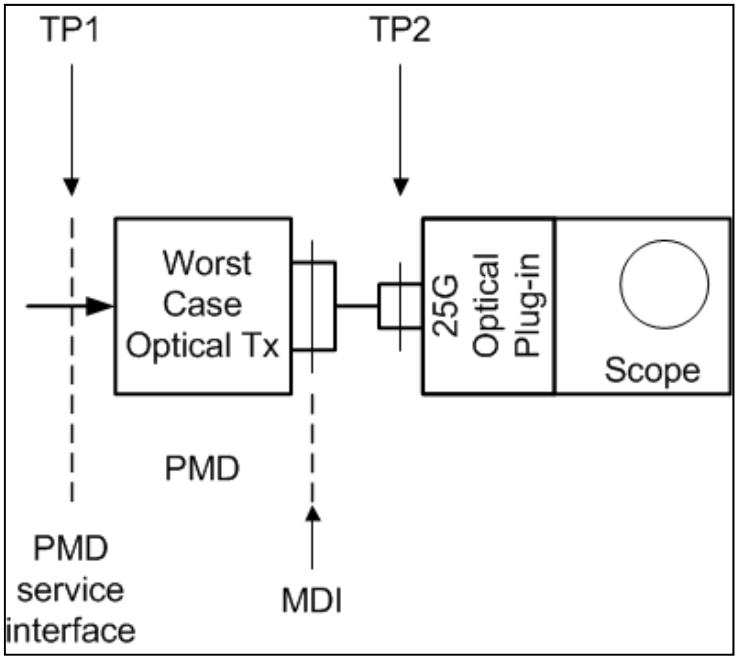
•Now that the sensitivity, S, of the Ref Rx has been established, the Ref Tx and reference channel is replaced by the worst case Tx operating with the worst case TP1 conditions and the worst case optical channel

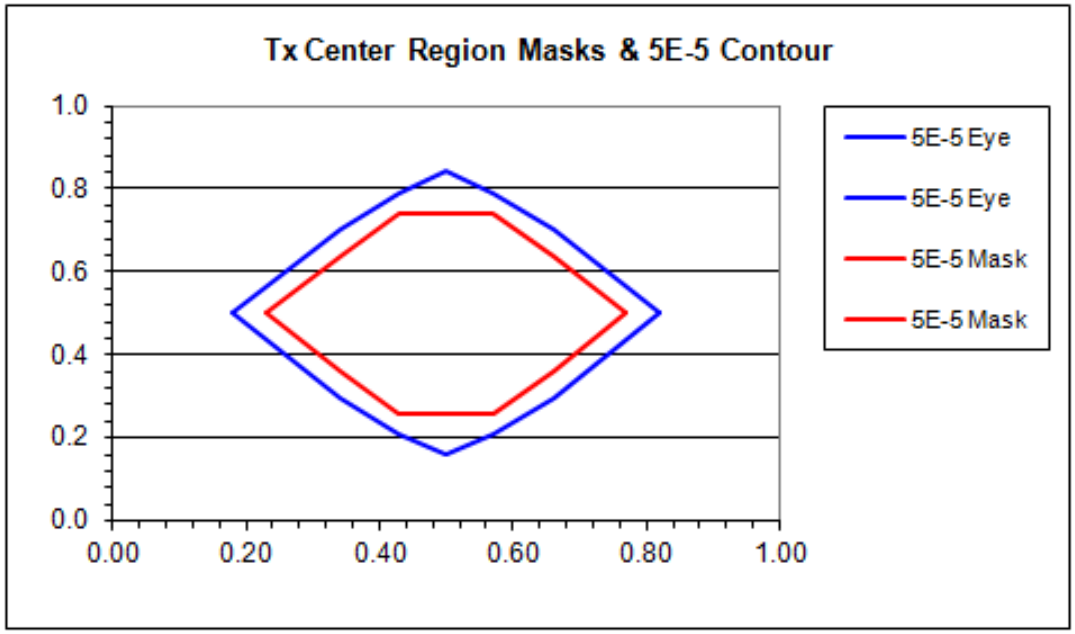
•The difference between the signal level at TP3 for this case and S yields the max limit for TDP, here 3.81 dB.

Eye Mask Coordinates Reference/Definition



100G PSM4: Developing Tx Eye Mask Requirements





•The Worst Case Tx and worst case TP1 conditions used to determine Max TDP are used to define the coordinates for the Tx Eye mask.

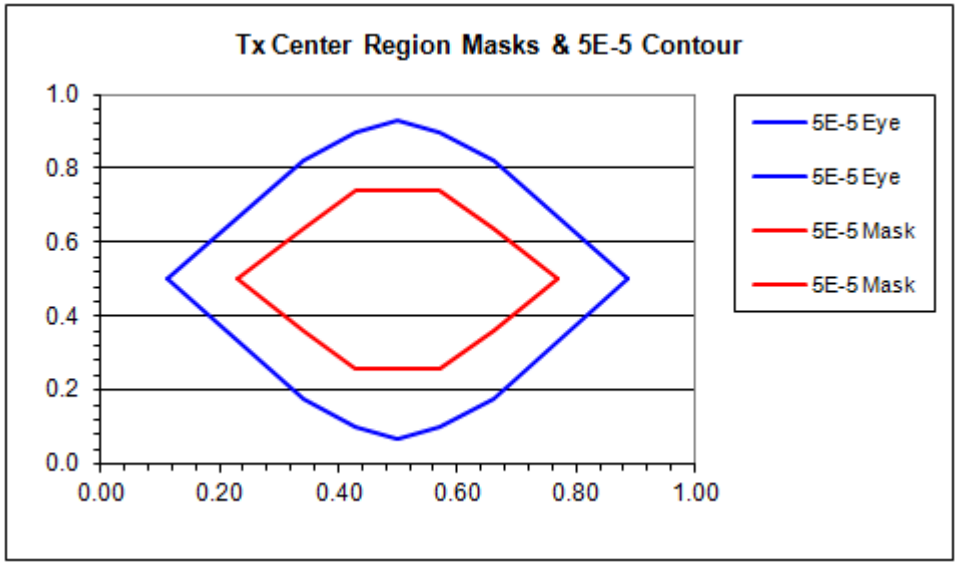
•A link model can be setup to represent an oscilloscope with an optical plugin that matches the sensitivity and bandwidth characteristics of the Ref Rx.

•The 5E-5 jitter contour at TP2 as observed by the Ref Rx can be determined from the link model.

•Since the Tx Eye mask is used to control aberrant waveforms and not jitter mask coordinates are chosen to provide a mask slightly relaxed from the 5E-5 contour.

•Proposed mask coordinates are X1 = 0.23 UI, X2 = 0.34 UI, X3 = 0.43 UI, Y1 = 0.26 UA, Y2 = 0.36 UA , Y3 = 0.40

100G PSM4: Clause 96.8.5.1 Reference Tx Requirements



Reference Tx Requirements in 96.8.5.1

a) Rise/fall times of less than 12 ps at 20% to 80%.

b) The output optical eye is symmetric and passes the transmitter optical waveform test of 96.8.7.

c) In the center 20% region of the eye, the worst-case vertical eye closure penalty as defined in 87.8.11.2 is less than 0.5 dB.

d) Total Jitter less than 0.2 UI peak-to-peak.

e) RIN of less than –140 dB/Hz.

f) Transmitter reflectance less than –50 dB.

•A link model can be used to examine the performance, including TDP, of a Tx defined in 96.8.5.3.

•The above chart shows a 5E-5 jitter contour for a Tx with 11.4 ps transition times, RINoma of -134 dB/Hz, ER of 4.77 dB, ORL of 50 dB, TP2 TJ of 0.20 UI. It provides generous margin to the Tx Eye mask. Such a Tx will have a VECP at 0.5 UI of ~ 0.5 dB and ~ 0.86 dB at 0.4 UI and 0.6 UI and a TDP of ~ 1.0 dB. When such a Tx is used as a reference Tx, 1.0 dB should be added to the TDP value yielded from the measurement.

• A VECP ≤ 0.5 dB between 0.4 UI and 0.6 UI appears to require transition times < 8 ps.

100G PSM4: Developing SRS Requirements

•To test the optical Rx, the worst case signal expected at TP3 should be reproduced as the Rx input condition.

• This represents the worst case Tx operating with the worst case TP1 conditions over the worst case fiber including the maximum connector loss.

•The amplitude of this stressed signal is determined by the min OMA at max TDP adjusted by the max channel insertion loss and power penalties (yielding SRS OMA) and further reduced by the ISI power penalty associated with the Ref Rx (yielding VECP).

•The example link model includes calculations for SRS OMA (cell X28 for 500 m) and VECP (cell W11).

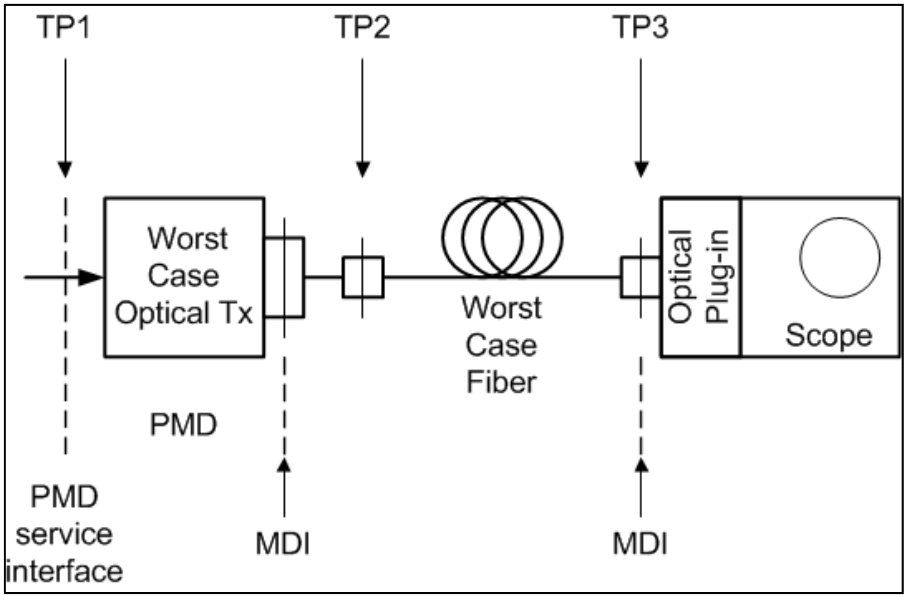
•Since VECP is defined for the center of the eye, the tab Base(c) provides the approporiate values for SRS OMA (-7.42 dBm) and VECP (1.21 dB).

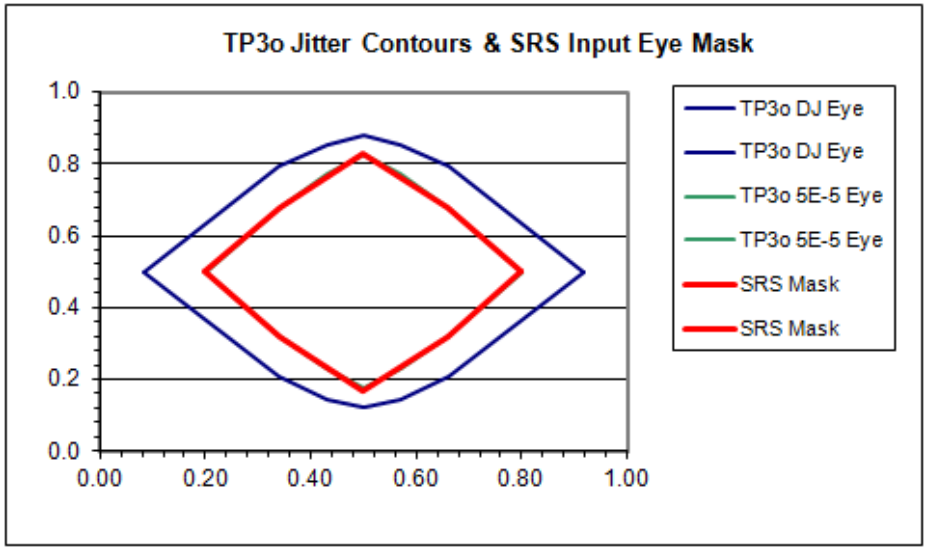
•In the Base(c) tab, the TP4 eye requirement is not included as an element of DJ so that the power penalties are calculated at the center of the eye.

•In addition to vertical stress, jitter is added(J in Clause 52, J2 and J9 in Clause 86) for horizontal stress. A link model can be setup to calculate the expected worst case jitter at TP3. Since this link is operating at a max BER = 5E-5, J2 (0.29 UI) and J4 (0.39 UI) may be appropriate choices for jitter stress.

•An SRS input eye mask is proposed as a check to ensure the the stress conditions are applied as intended.

100G PSM4: Developing SRS Requirements





•As with determining the coordinates for the Tx eye mask, a link model can be setup to determine stressed receiver conditions that represent the worst case conditions expected at TP3.

•Here the worst case fiber including maximum connector loss is inserted between the worst case Tx and scope used to observe the jitter contours at TP2.

•In the above right chart, two jitter contours are shown. At the center of the eye, the height of the DJ eye corresponds to a VECP of 1.2 dB.

•Coordinates for the proposed 5E-5 SRS input eye mask are X1 = 0.19 UI, X2 = 0.34 UI, X3 = 0.5 UI, Y1 = 0.17 UA, Y2 = 0.32 UA, Y3 = 0.4 UA.