Draft 100G SR4 TDP Update

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Presentation Summary

Presentation Objectives:

• Present update of TDP setup and requirements for 100G 100m MMF Tx

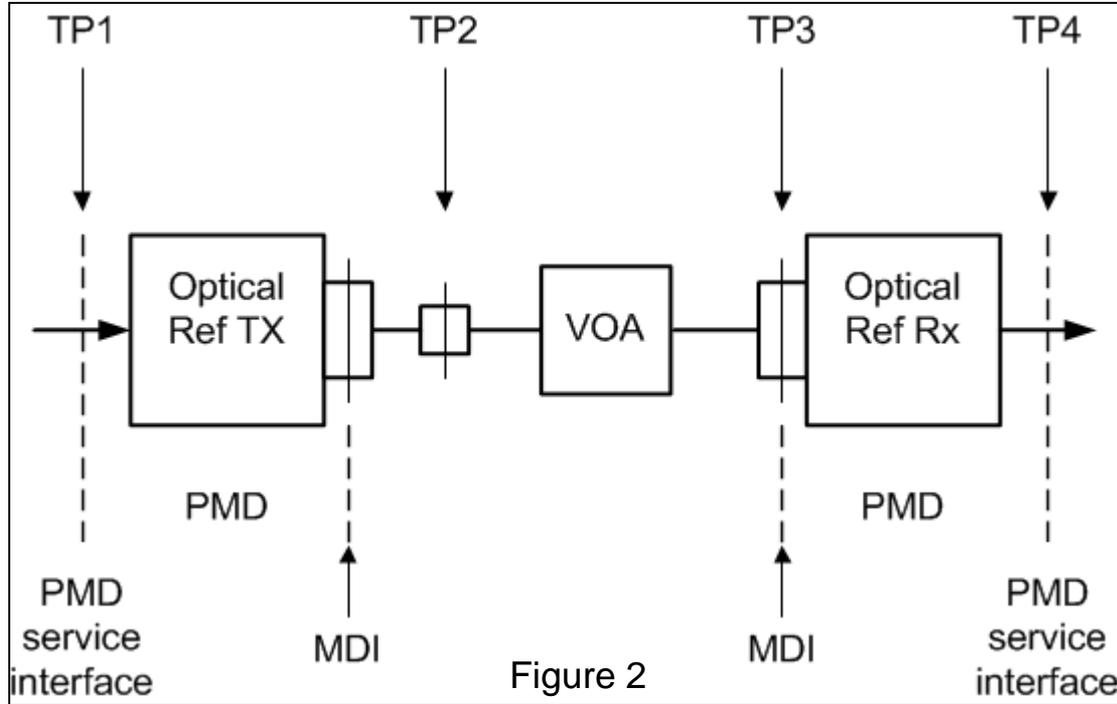• Present limitations of TDP metric for 100G 100m MMF

• Present alternative metric

Link Model References

http://www.ieee802.org/3/bm/public/may13/petrilla_04_0513_optx.pdf

http://www.ieee802.org/3/bm/public/may13/ExampleMMF%20LinkModel%20%20130503.xlsx

http://www.avagotech.com/docs/AV02-2485EN

100G SR4: Developing TDP Requirements 1

Figure 2

1) In setup of Figure 2, adjust VOA to yield TP4 TJ requirement. Measure OMA at TP3.
2) Determine residual link penalty if any.
3) 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.
•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.
•In the spread sheet link model cell L7, normally the entry for connector loss, is used to enter the VOA attenuation.

100G SR4 with KR4 FEC: Example Ref (ideal) Tx Attributes

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Center Wavelength	nm	860	
Spectral Width	nm	0.05	
OMA at max TDP	dBm	-3.0	
Extinction ratio	dB	4.77	
Tx output transition times, 20% -80%	ps	1.0	
$RIN_{12}OMA$	dB/Hz	-128	
RIN coefficient		0	
MPN coefficient		0	
Modal Noise Penalty	dB	0	
Tx reflectance, max	dB	-12	
Tx optical return loss tolerance, max	dB	12	

- 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 SR4 with KR4 FEC: Example Ref Rx Attributes

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Wavelength, min	nm	840	
Ref Rx sensitivity (OMA)	dBm	-14.60	-12.03 dBm at Q = 7.034
Rx Bandwidth	MHz	19,336	
RMS base line wander coefficient		0	
Rx reflectance, max	dB	-12	

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

100G SR4 with KR4 FEC: Example Ref Ch Attributes

Parameter	Unit	100G SR4	
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	For 850 nm center wavelength
Dispersion min Uo	nm	1316	
Dispersion So	ps/nm^{2}km	0.10275	
Fiber modal bandwidth	MHz·km	2000	
Reflection Noise Factor		0	
Signal power budget at max TDP	dB	11.60	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 representing the test setup for the TDP reference case.

100G SR4 with KR4 FEC: Example Ref Tx Ref Rx Link & Jitter Attributes

Parameter	Unit	100G SR4	
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	11.50	Adjusted to yield zero margin
TP4 TJ at BER, max	UI	0.780	Model output
Residual Link Power Penalty	dB	0.10	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.
• For the Ref Tx, Ref Rx, reference channel and TP1 conditions defined above, a VOA attenuation entry of 11.50 dB should yield a TP4 TJ (BER = 5×10^{-5}) of 0.78 UI consistent with the TP4 requirement in the example link model for an S = -14.6 dBm.
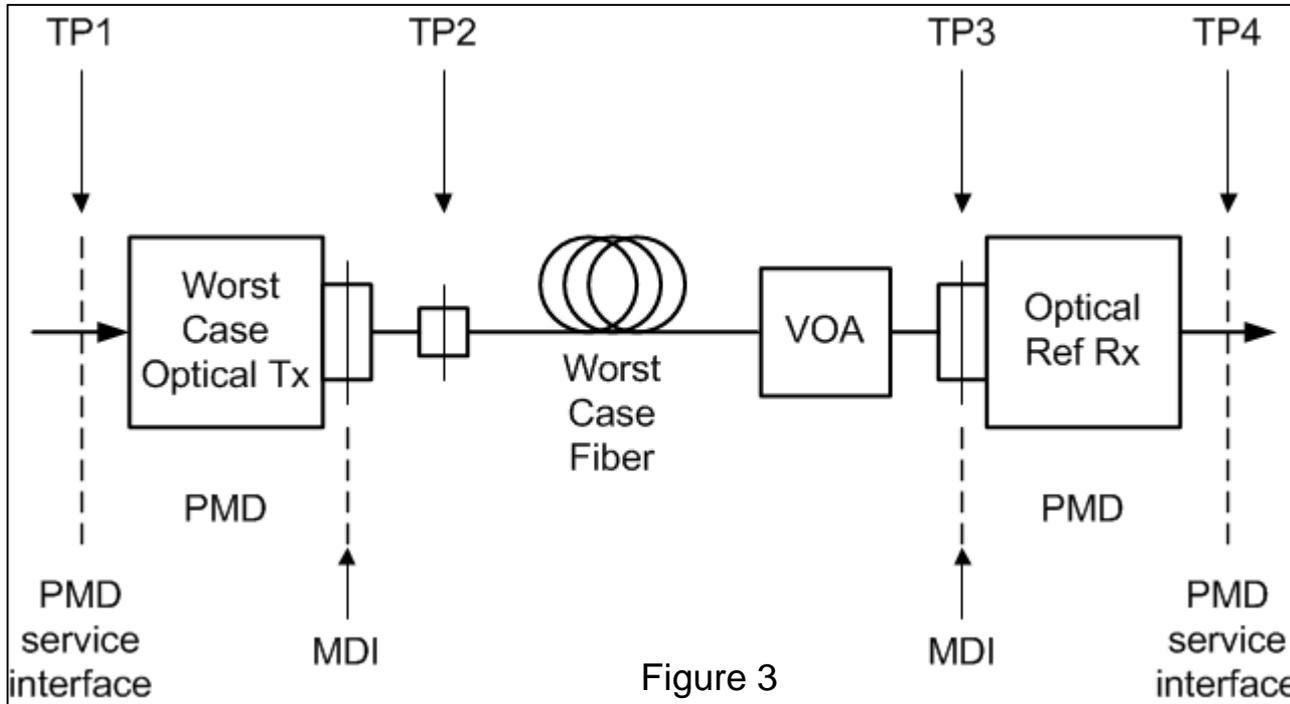
100G SR4: Developing TDP Requirements 2

Figure 3

1) Replace Ref Tx in Figure 2 with Worst Case Tx (except for center wavelength and spectral width), worst case TP1 conditions and Worst Case Fiber as shown in Figure 3.
2) Adjust VOA 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. This channel includes a VOA that is adjusted such that the requirements at TP4 are met.
•The difference between the signal level at TP3 for this case and S yields the max limit for TDP, now 4.08 dB.

# 100G SR4: Developing TDP Requirements 3
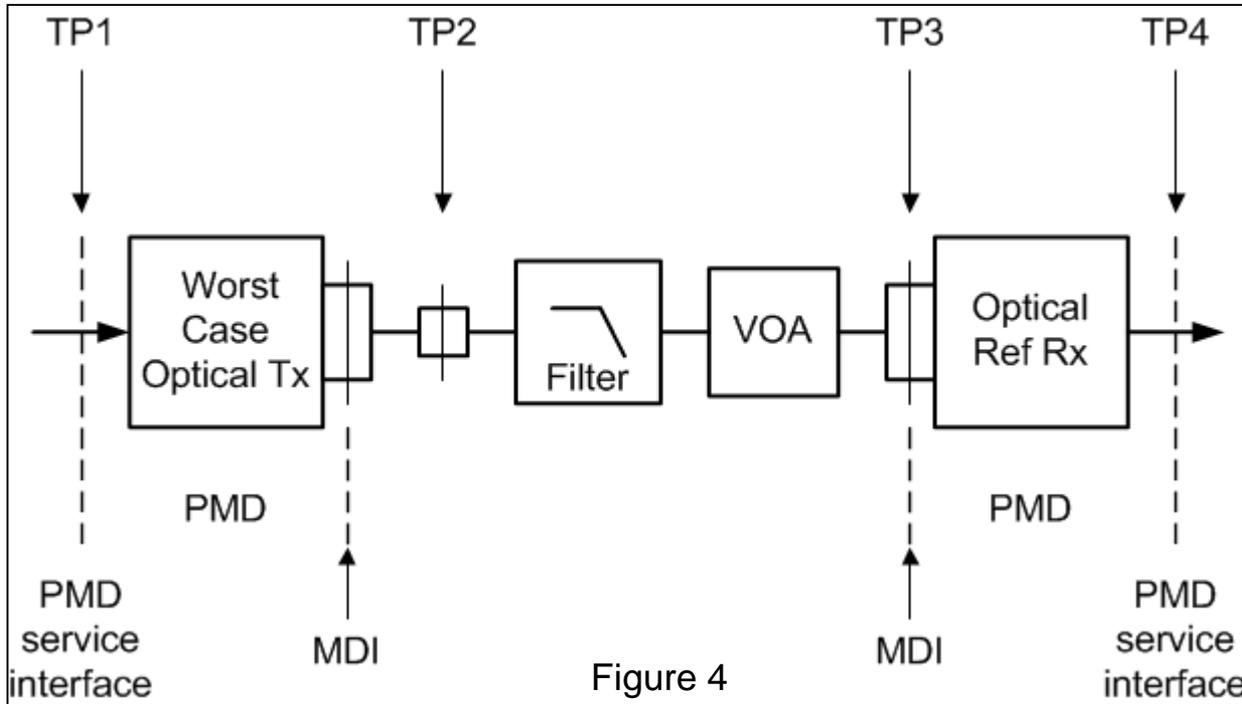
Figure 4

1) Replace Worst Case Fiber in Figure 3 with filter.
2) Adjust the VOA and Filter bandwidth to yield the same OMA at TP3, the same TP4 TJ and same total link penalties as seen in the setup of Figure 3.
3) Combine the bandwidth of the filter and Ref Rx and record as the Rx BW for the TDP measurement.

• Finally, the worst case channel is replaced by the reference channel and a filter is added to the Ref Rx input with a bandwidth that yields the same Ptotal central (link model cell T28) as did the worst case channel.

• Since the filter does not capture chromatic dispersion and mode partition noise, the spectral attributes of the Ref Tx are used for the worst case Tx and k(MPN) is set to 0 when determining the filter bandwidth (as is Pmn and the baseline wander coefficient).

• For the example link model, this filter in combination with the Ref Rx yields a BW of 16.21 GHz.

• TDP for 100G SR4 is now been defined only to capture effects of jitter delivered to TP1, Tx transition times, noise, e.g. RIN, and jitter contributed by the laser and deviations from Gaussian waveforms.

100G SR4: Developing TDP Requirements 4
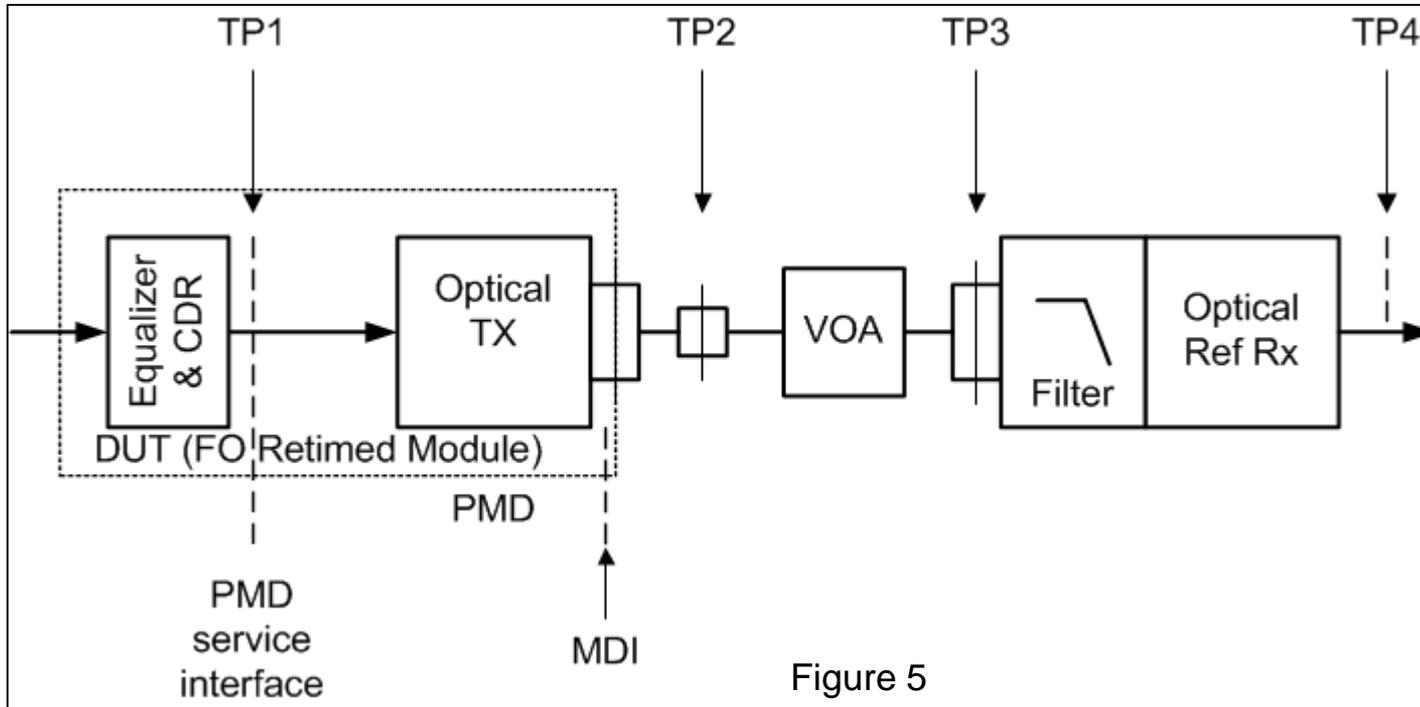
Figure 5

Testing a transceiver module for TDP:
1) Replace Worst Case Tx in Figure 4 with Tx DUT as shown in Figure 5.
2) Adjust the VOA to yield the same OMA at TP3, the same TP4 TJ and same total link penalties as seen in the setup of Figure 3.
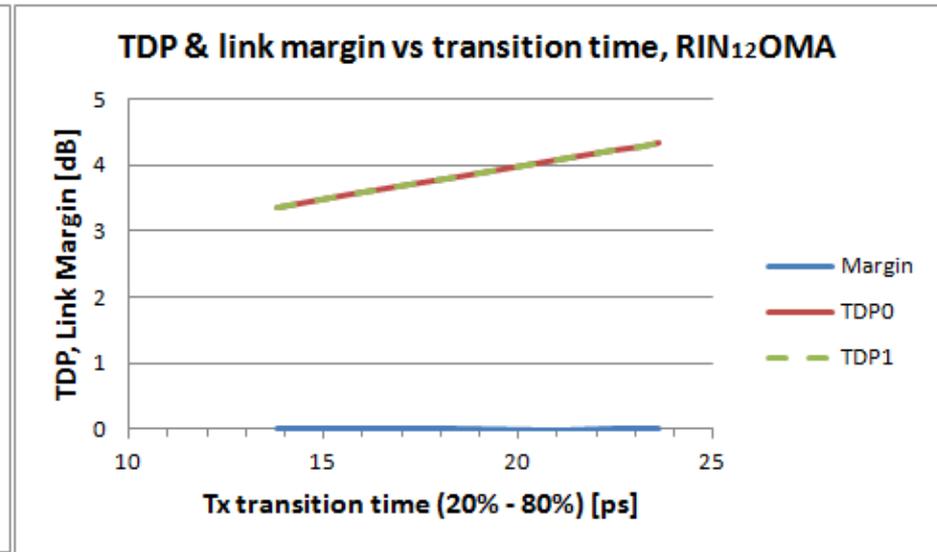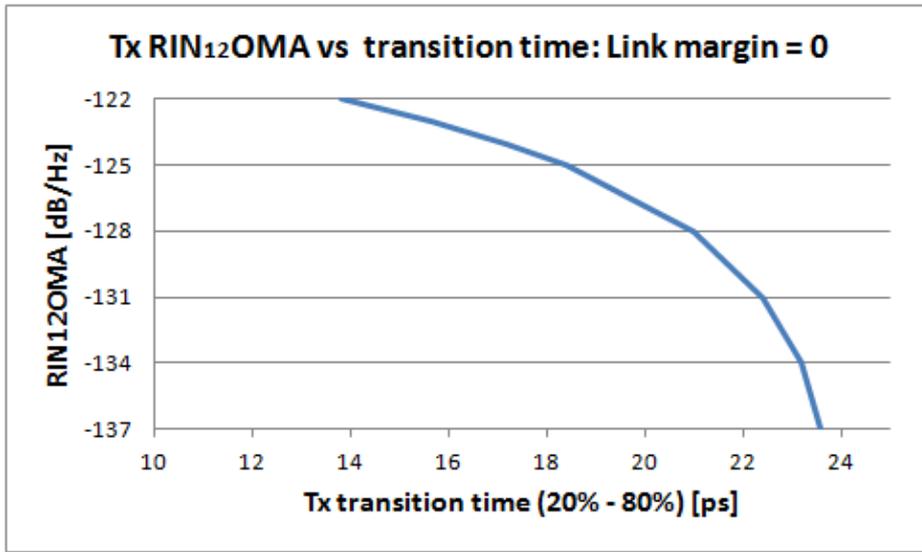3) Note the filter has been combined with the Ref Rx.

For the case where the ideal Tx in Figure 2, is used to calibrate the sensitivity of the combination of filter and Optical Ref Rx, i.e. a Ref Rx with a BW of 16.21 GHz instead of 19.336 GHz, a TDP penalty of 0.27 dB (all ISI) would be incurred.

100G SR4 with KR4 FEC: Example TDP Test Channel (each lane)

Parameter	Unit	100G SR4	
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	0.0	For 850 nm center wavelength
Dispersion min Uo	nm	1316	
Dispersion So	ps/nm^{2}km	0.10275	
Fiber modal bandwidth	MHz·km	2000	
Reflection Noise Factor		0	
Signal power budget at max TDP	dB	11.60	Model output
Fiber Insertion loss	dB	0.00	Model output
Attenuation (aka Connector loss)	dB	7.52	Adjusted to yield zero margin
Rx Bandwidth for TDP	MHz	16210	Adjusted to match Ptot of Ref Ch with100 m of OM4
Max TDP	dB	4.08	

Attributes and values in the above table provide a summary of the test channel using the TDP filter.
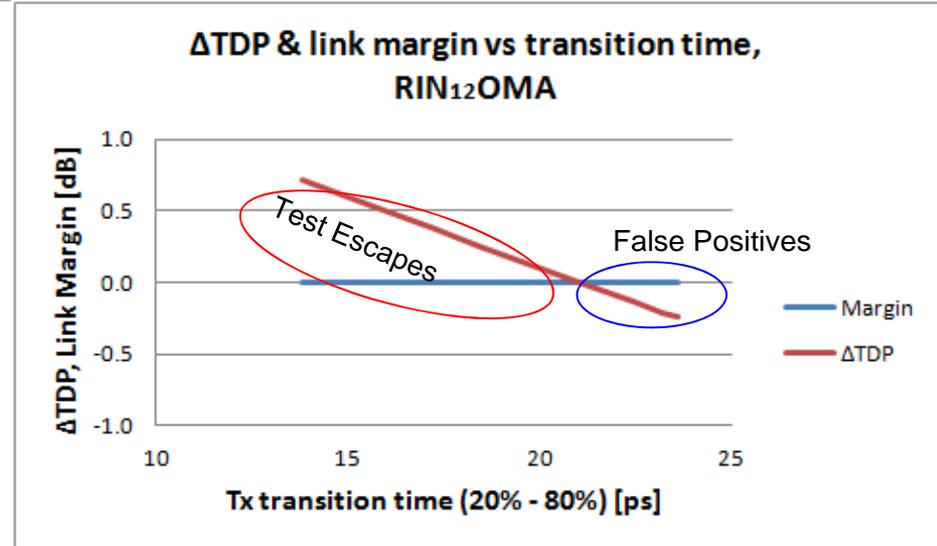
# 100G 100m SR4: Attribute tradeoffs using TDP & Link Margin 1

Tx RIN$_{12}$OMA vs transition time: Link margin = 0

TDP & link margin vs transition time, RIN$_{12}$OMA

Legend:
- Margin
- TDP0
- TDP1 (dashed)

ΔTDP & link margin vs transition time, RIN$_{12}$OMA

Test Escapes

False Positives

Legend:
- Margin
- ΔTDP

- The top left chart shows the tradeoff between Tx transition time and RIN$_{12}$OMA using the Example Link Model when holding link margin constant at 0 dB. The initial values in the Example Link Model are transition time = 21 ps and RIN$_{12}$OMA = -128 dB/Hz.

- The top right chart shows TDP values calculated for the combinations of transition times and RIN$_{12}$OMA . Here TDP0 is for a 100 m reach case and TDP1 is for the test filter case. While the link margin is constant the TDP results are not, i.e. TDP does not tradeoff transition time and RIN as the link model does.

- The bottom right chart shows the deviation in link margin and TDP from the initial combination of transition time = 21 ps and RIN$_{12}$OMA = -128 dB/Hz. Positive ΔTDP values may lead to test escapes and negative values may lead to rejecting acceptable units.
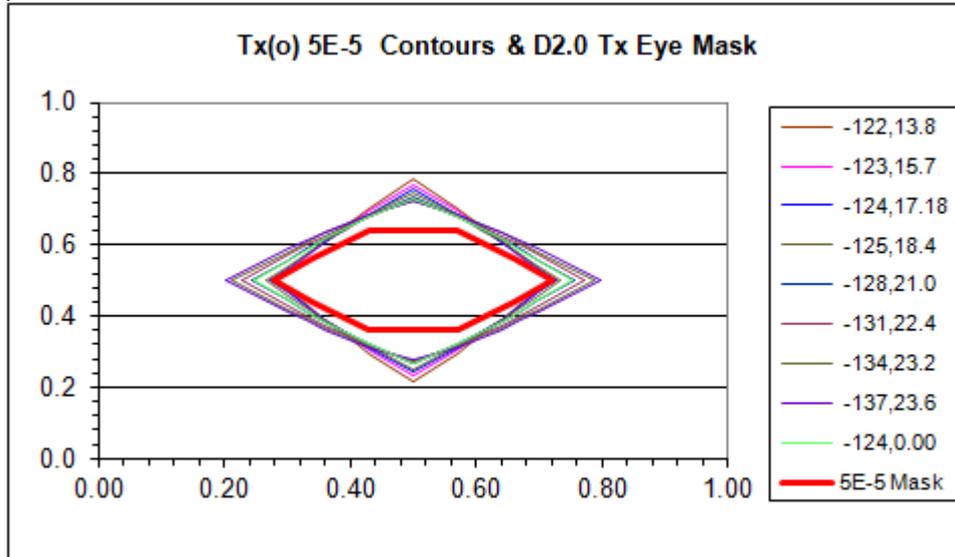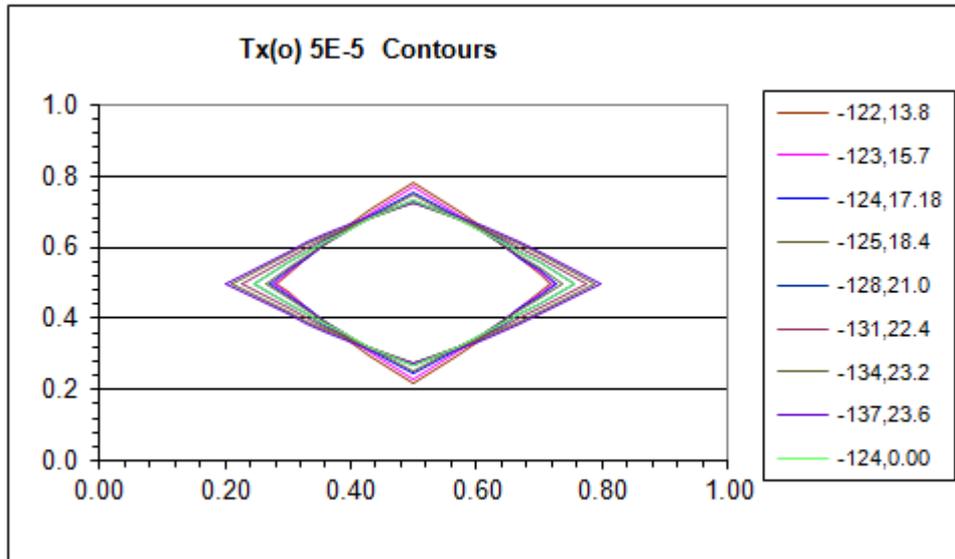
100G 100m SR4: Attribute tradeoffs using TDP & Link Margin 2
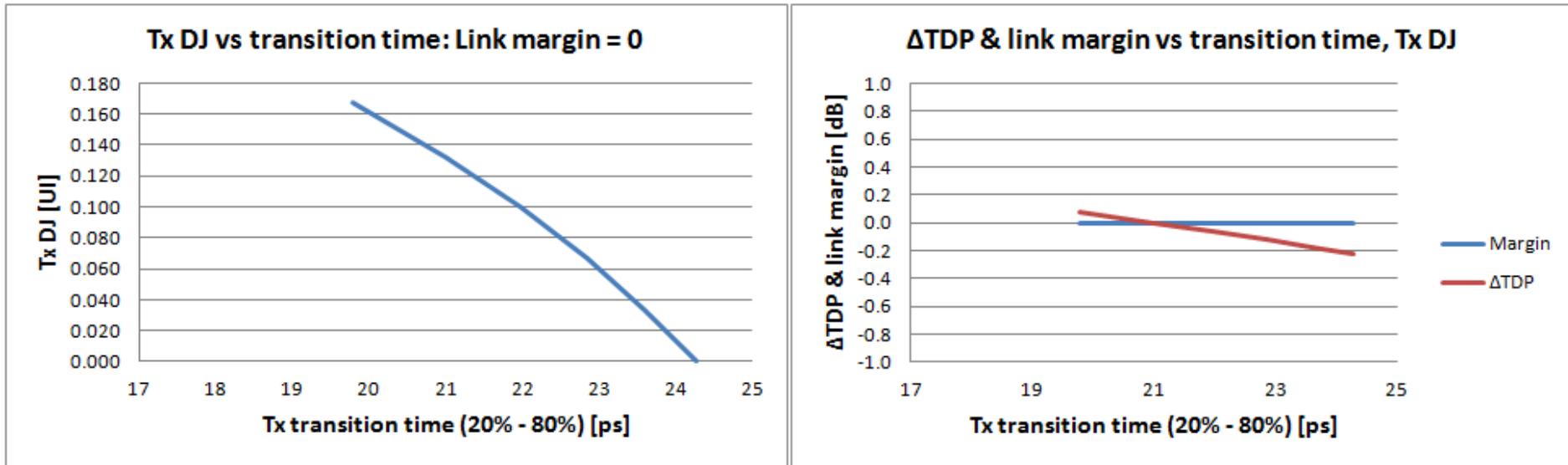
- Here the tradeoff between Tx transition time and Tx DJ is examined.
- Again, TDP does not provide the same tradeoff as the link model.

100G 100m SR4: Transition time & $RIN_{12}OMA$ tradeoff set TP2 contours

Tx(o) 5E-5 Contours

Legend:
- -122,13.8
- -123,15.7
- -124,17.18
- -125,18.4
- -128,21.0
- -131,22.4
- -134,23.2
- -137,23.6
- -124,0.00

Tx(o) 5E-5 Contours & D2.0 Tx Eye Mask

Legend:
- -122,13.8
- -123,15.7
- -124,17.18
- -125,18.4
- -128,21.0
- -131,22.4
- -134,23.2
- -137,23.6
- -124,0.00
- 5E-5 Mask

• The top chart shows 5E-5 contours of the Tx output (TP2) for the transition time and $RIN_{12}OMA$ combinations providing zero link margin used in an earlier page. Here a Gaussian response is assumed, consistant with the assumptions in the link model.

• The currently defined (draft 2.0) Tx eye mask is included in the bottom chart. It should be adjusted so that otherwise compliant transmitters are not rejected.

• Items to notice in this set of contours:

1, All of the Tx and TP1 attributes that are intended to be captured in the TDP metric are captured in the these contours.

2, The vertical position of a point on a contour represents the signal amplitude at that point relative to OMA and permits a measure of vertical eye closure.

3, There's a crossover point where the variations in time and amplitude are minimized and, perhaps, offering a tighter relationship with link margin than TDP offers.

100G 100m SR4: A metric to replace TDP 1
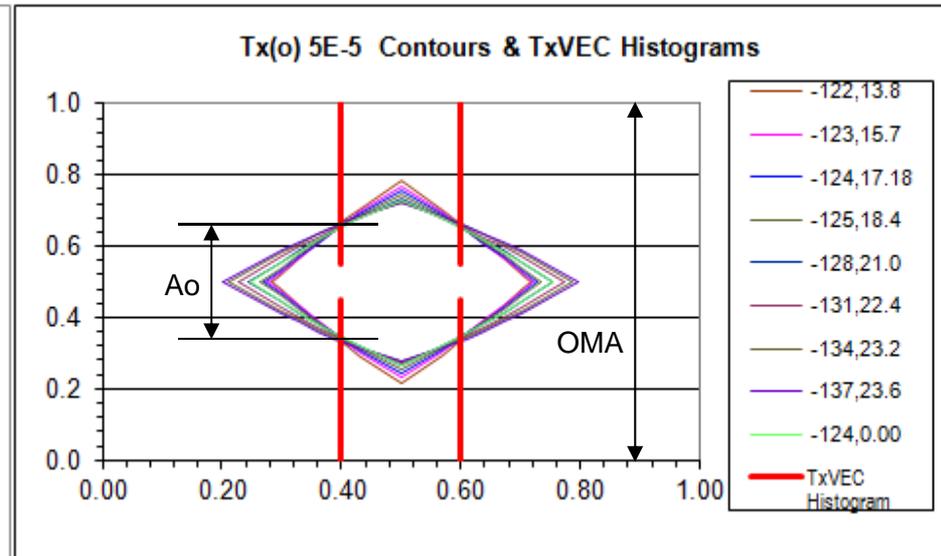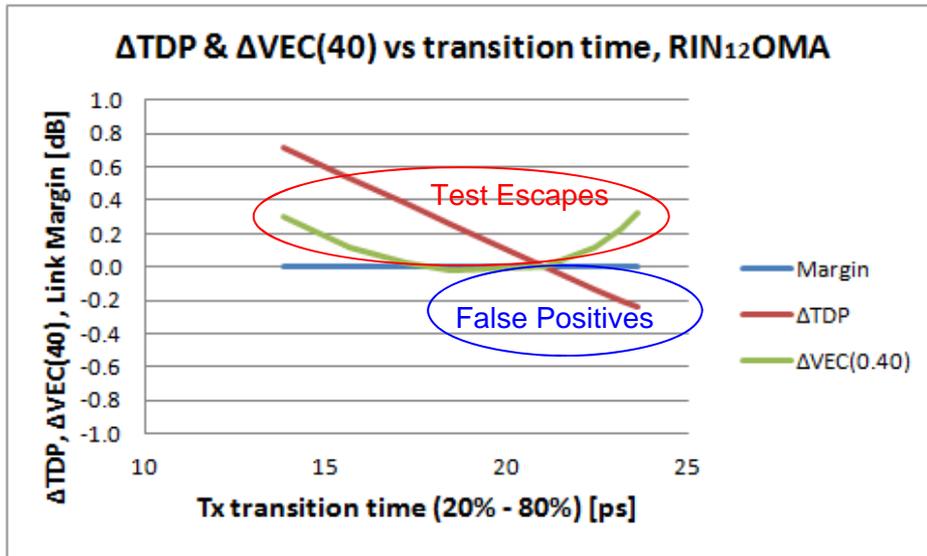
- The chart on the left indicates that a TxVEC metric, where TxVEC = 10Log10(OMA/Ao) can offer a better balance of test-escapes versus false-positives than a TDP metric . Here histograms are taken at ± 0.10 UI. Ao is the vertical eye height between 5E-5 points on the histogram tails. OMA is the sigmal amplitude measured with the OMA measurement method.

- The ΔVEC(0.40) line is based on deviation from TxVEC calculated for the Tx baseline condition of a 21 ps Tx transition time and a $RIN_{12}OMA$ of -128 dB/Hz. For this baseline condition TxVEC = 5.12 dB and based on this condition a TxVEC max = 5.1 dB is recommended.

- Note that there is no need for a reference transmitter for the TxVEC measurement.

- Also note that Fibre Channel uses a transmitter vertical eye closure metric for MMF transmitters and not TDP.
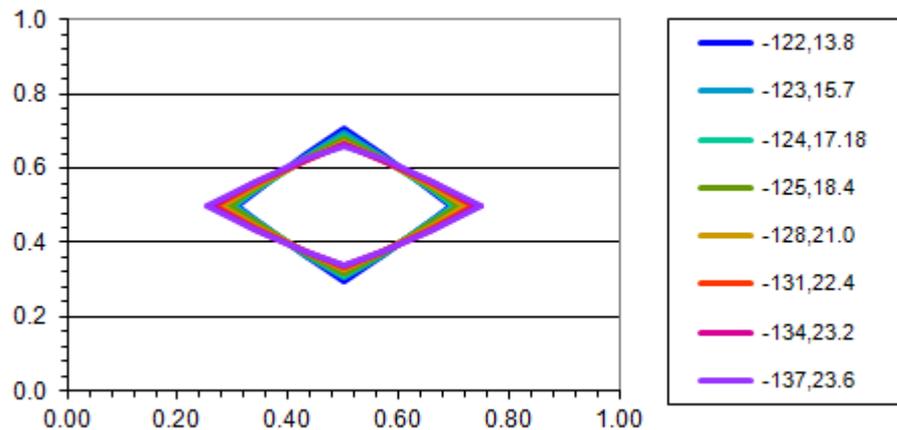
100G 100m SR4: A metric to replace TDP 2
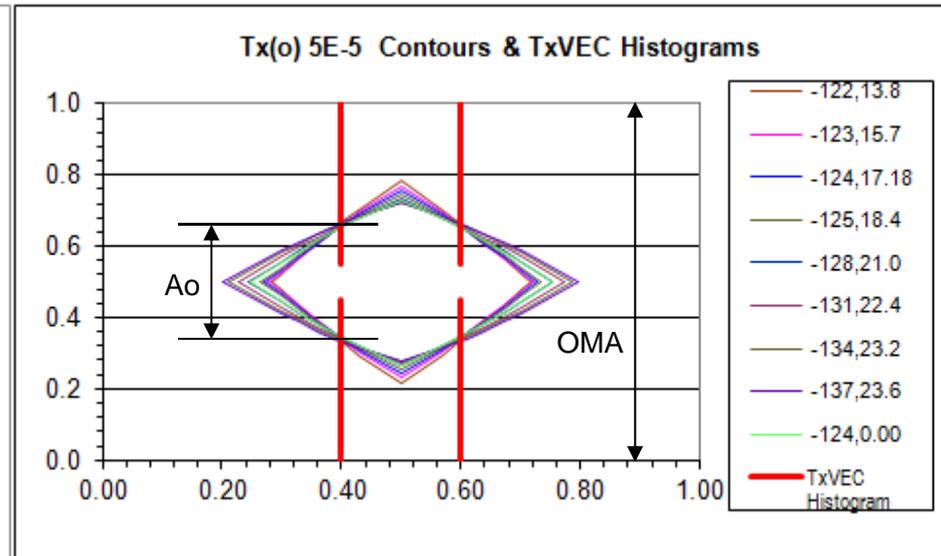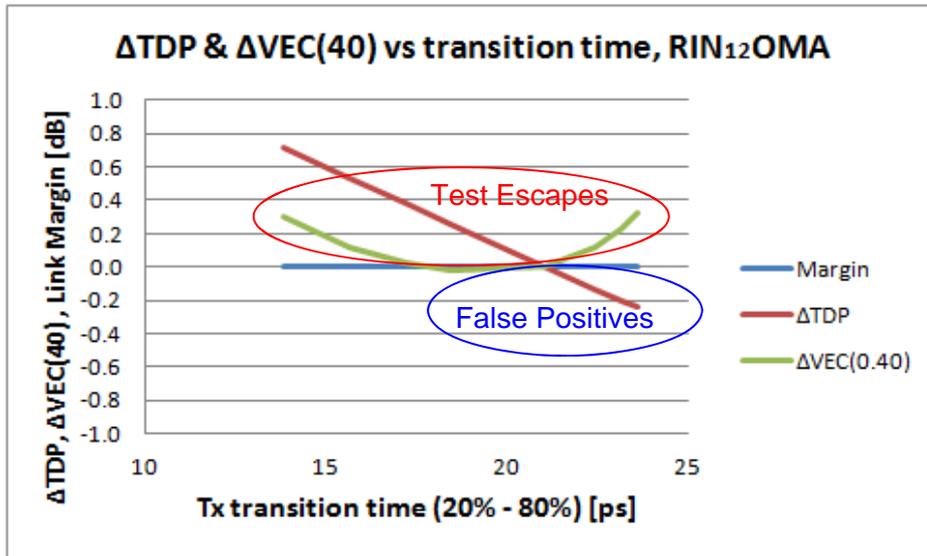
- Based on the new metric TxVEC, in Draft 2.0 replace

 in Table 95-6, Transmitter and dispersion penalty (TDP), each lane (max) = 5 dB
     with Transmitter vertical eye closure, each lane (max) = 5.1 dB

 in Table 95-6, Launch power in OMA minus TDP (min) = -8 dB
     with Launch power in OMA minus TxVEC (min) = -8.1 dB

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

TP3o 5E-5 Contours

-122,13.8
-123,15.7
-124,17.18
-125,18.4
-128,21.0
-131,22.4
-134,23.2
-137,23.6

TP3o 5E-5 Contours & SRS D2.0 Eye Mask

-122,13.8
-123,15.7
-124,17.18
-125,18.4
-128,21.0
-131,22.4
-134,23.2
-137,23.6
SRS Mask

• The top chart shows 5E-5 contours of the fiber output (TP3) for the transition time and RIN$_{12}$OMA combinations providing zero link margin used in an earlier page.

• The currently defined (draft 2.0) SRS eye mask is included for reference in the bottom chart. Since it captures one of several apparently equivalent worst case TP3 eyes, it may be acceptable as is.

Tx(o) 5E-5 Contours

Legend:
- -122,13.8
- -123,15.7
- -124,17.18
- -125,18.4
- -128,21.0
- -131,22.4
- -134,23.2
- -137,23.6
- -124,0.00

Tx(o) 5E-5 Contours & D2.0 Tx Eye Mask

Legend:
- -122,13.8
- -123,15.7
- -124,17.18
- -125,18.4
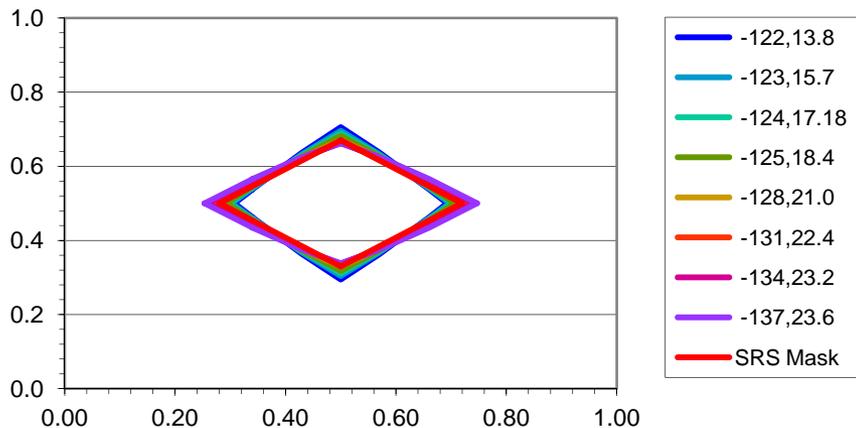- -128,21.0
- -131,22.4
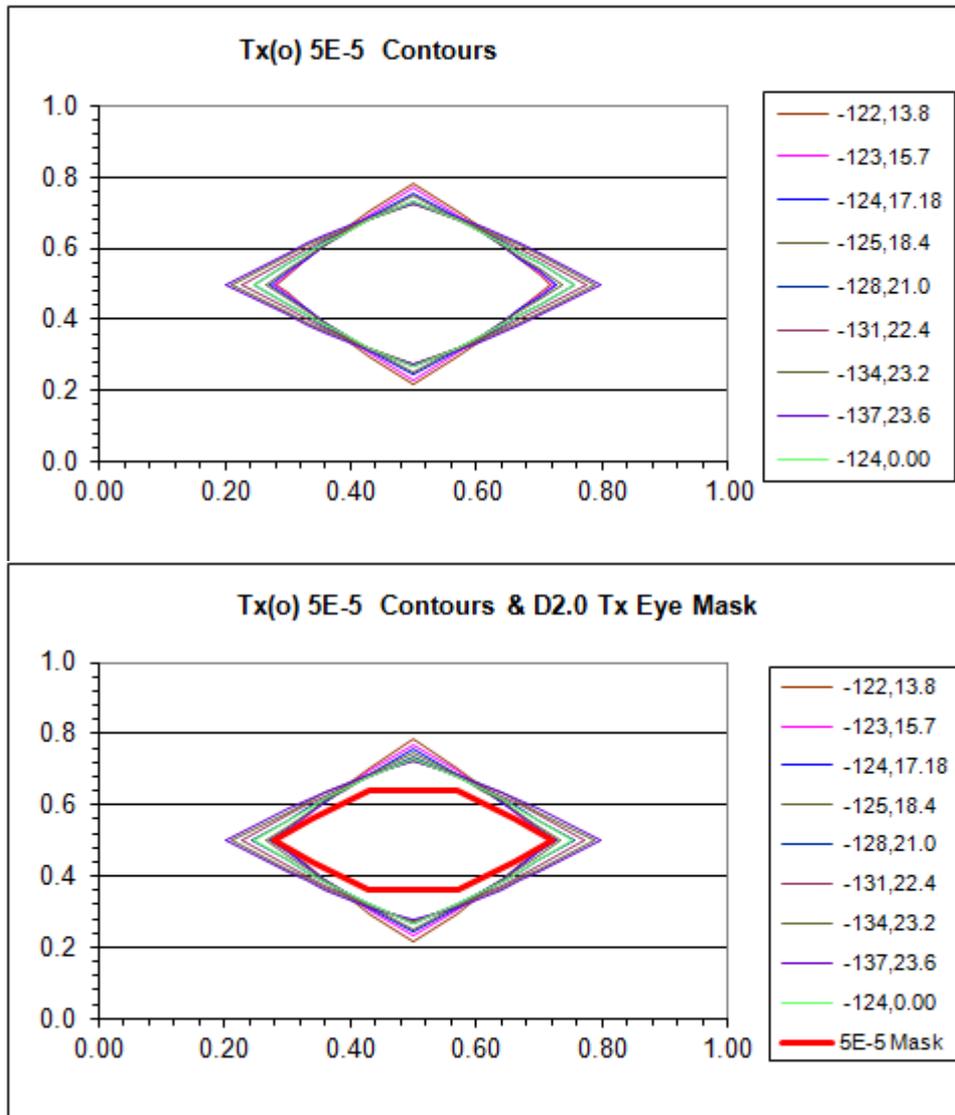- -134,23.2
- -137,23.6
- -124,0.00
- 5E-5 Mask

• The top chart shows 5E-5 contours of the Tx output (TP2) for the transition time and RIN$_{12}$OMA combinations providing zero link margin used in an earlier page. Here a Gaussian response is assumed, consistant with the assumptions in the link model.

• The currently defined (draft 2.0) Tx eye mask is included in the bottom chart. It should be adjusted so that otherwise compliant transmitters are not rejected.

Placeholder for new Tx eye mask proposal

Reference/Backup Material

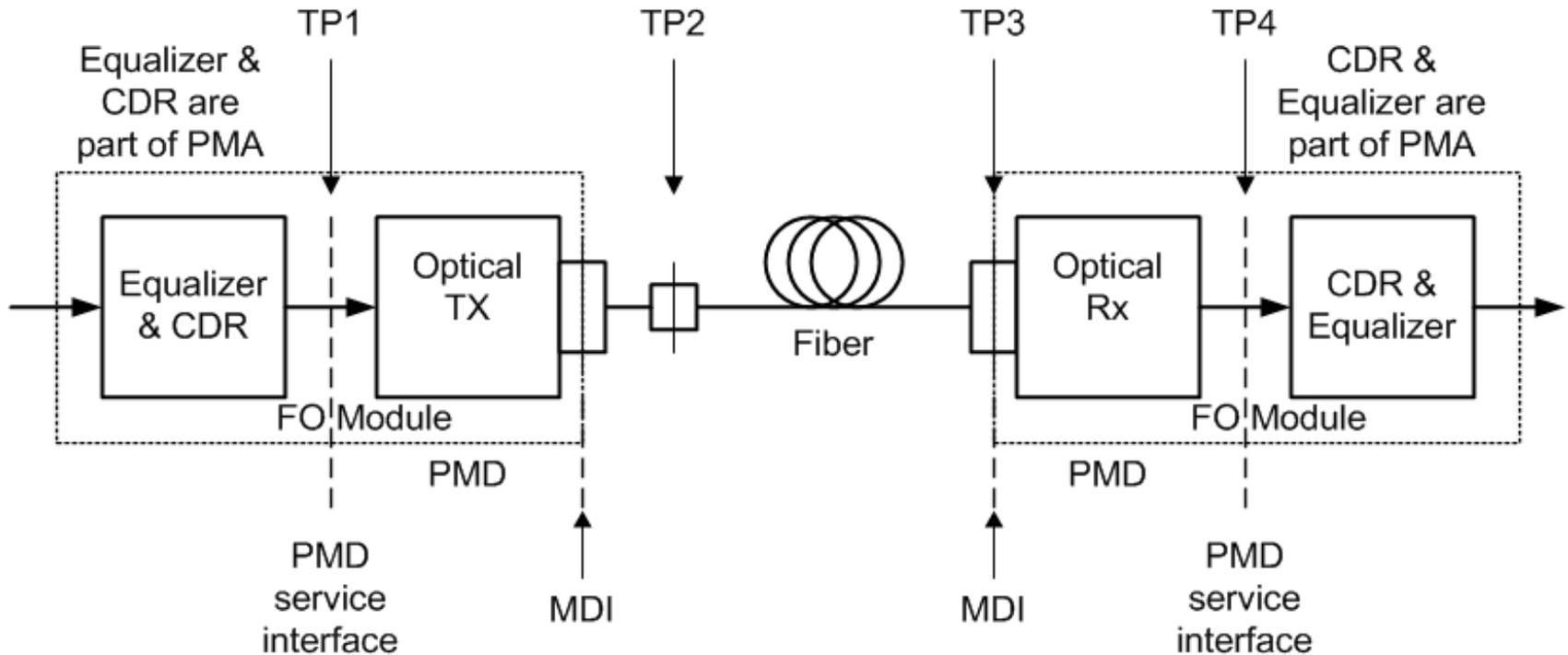# Fiber Optic Links Interfaces

Figure 1

• For cases, as shown above in Figure 1, where retimers are embedded 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 SR4 with KR4 FEC: Example Link Model Tx Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Center Wavelength, min	nm	840	
Spectral Width, max	nm	0.60	
OMA at max TDP, min	dBm	-3.0	
Extinction ratio, min	dB	3.0	
Tx output transition times, 20% -80%, max	ps	21	
$RIN_{12}OMA$, max	dB/Hz	-128	
RIN coefficient		0.7	
MPN coefficient		0.3	
Modal Noise Penalty	dB	0.129	Scaled with Q^2
Tx reflectance, max	dB	-12	
Tx optical return loss tolerance, max	dB	12	

Attributes and values in the above table are provided in order to populate example link models and are not presented as specification recommendations.

100G SR4 with KR4 FEC: Example Link Model Rx Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Center Wavelength, min	nm	840	
Rx sensitivity (OMA), max	dBm	-11.2	-8.63 dBm at Q = 7.034
Rx Bandwidth, min	MHz	18,047	
RMS base line wander coefficient		0.025	
Rx reflectance, max	dB	-12	

Attributes and values in the above table are provided in order to populate example link models and are not presented as specification recommendations.

100G SR4 with KR4 FEC: Example Link Model Ch Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.0E-5)	FEC corrects BER to < 1.0E-12
Reach	m	100	
Fiber Attenuation	dB/km	3.5	For 850 nm center wavelength
Dispersion min Uo	nm	1316	
Dispersion So	ps/nm²km	0.10275	
Fiber modal bandwidth	MHz·km	4400	For 840 nm center wavelength, 4700 MHz·km at 850 nm
Reflection Noise Factor		0	
Signal power budget at max TDP	dB	8.20	Model output
Connector & splice loss allocation	dB	1.50	
Fiber Insertion loss	dB	0.36	Model output
Allocation for penalties at max TDP	dB	6.34	Model output Includes Peye Comment 100
Allocation for target TP4 eye at max TDP	dB	0	1.88 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 are not presented as specification recommendations.   Various model outputs are provided.

100G SR4 with KR4 FEC: Example Link Model Jitter Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		3.8905 (5.00E-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	0.243	
TP4 J2, max	UI	0.592	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 are not presented as specification recommendations.   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.

Eye Mask Coordinates Reference/Definition