100G SR4 TDP Update

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Presentation Summary

Presentation Objectives:

- Show setup to define max TDP limit for 100GBASE-SR4
- Show setup to define TDP filter for 100GBASE-SR4
- Present Reference Tx Considerations

Fiber Optic Links Interfaces

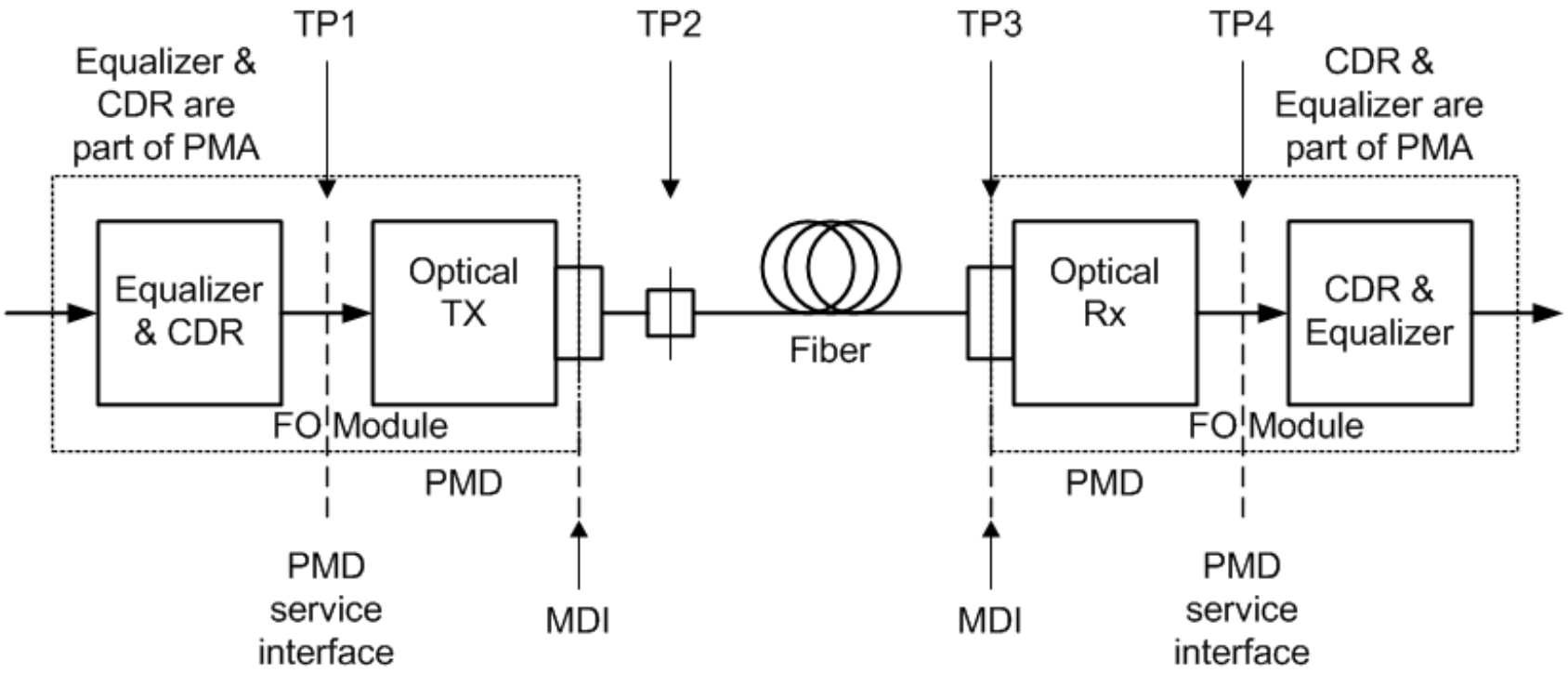


Figure 1

• 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: Developing TDP Requirements 1, Reference Case

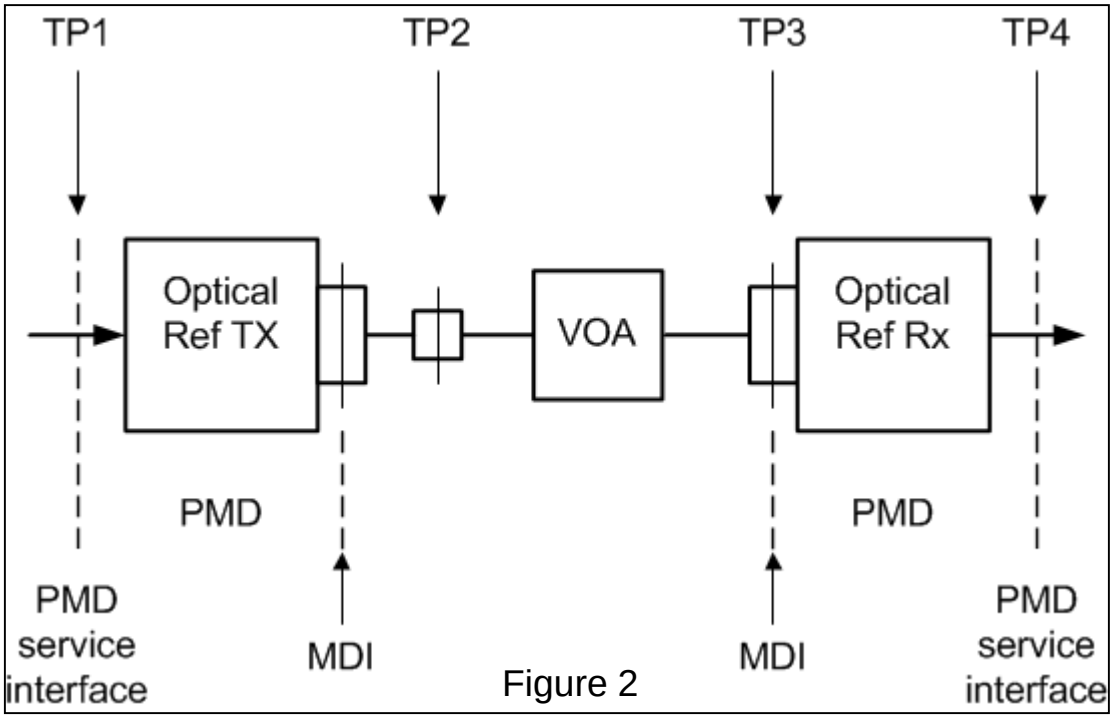


Figure 2

1) In setup of Figure 2, adjust VOA 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.
- 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: Ideal Ref 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	3.0	
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	

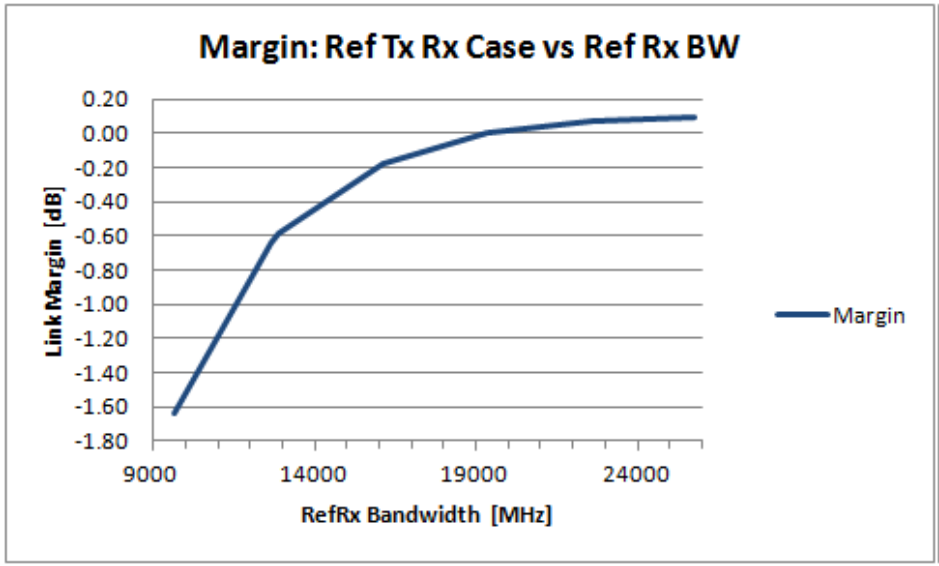
- Attributes and values in the above table represent an ideal device to use as a reference case. There's no expectation that such a transmitter can be implemented.
- Note that all noise sources are disabled.

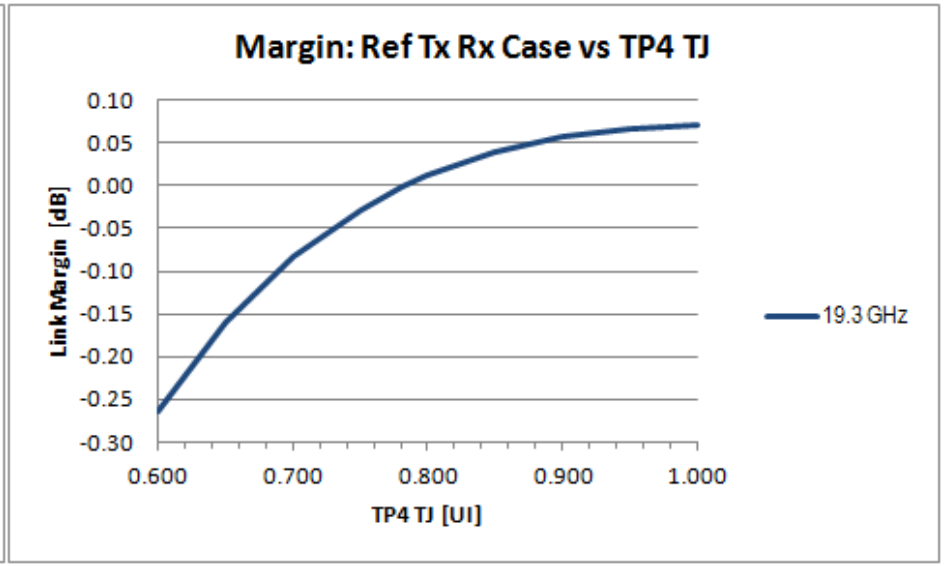
100G SR4: Ref Rx Attributes

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.
- Ref Rx sensitivity is arbitrary but better than that from a worst case Rx is recommended.

100G SR4: Ref Rx BW & TP4 TJ Considerations





•The above charts show the sensitivity of link margin to Ref Rx attributes of BW and TP4 TJ.
•The combination of a 19.3 GHz BW (0.75 x signal rate) and 0.78 UI TP4 TJ (0.22 UI output eye opening) yields a power penalty of 0.10 dB; all from ISI. Increasing the desired eye opening (forcing smaller TP4 TJ) or decreasing the BW will increase the power penalty.
•For example, decreasing the BW from 19.3 GHz to 12.6 GHz while keeping TP4 TJ = 0.78 UI changes the power penalty from 0.10 dB to 0.75 dB (0.65 dB margin loss).

100G SR4: Ref 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	2	
Fiber Attenuation	dB/km	0	
Dispersion min Uo	nm	1316	
Dispersion So	ps/nm^2km	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 representating the test setup for the TDP reference case.

100G SR4: 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	Forced 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 = $5x10^{-5}$) 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, Max TDP Limit

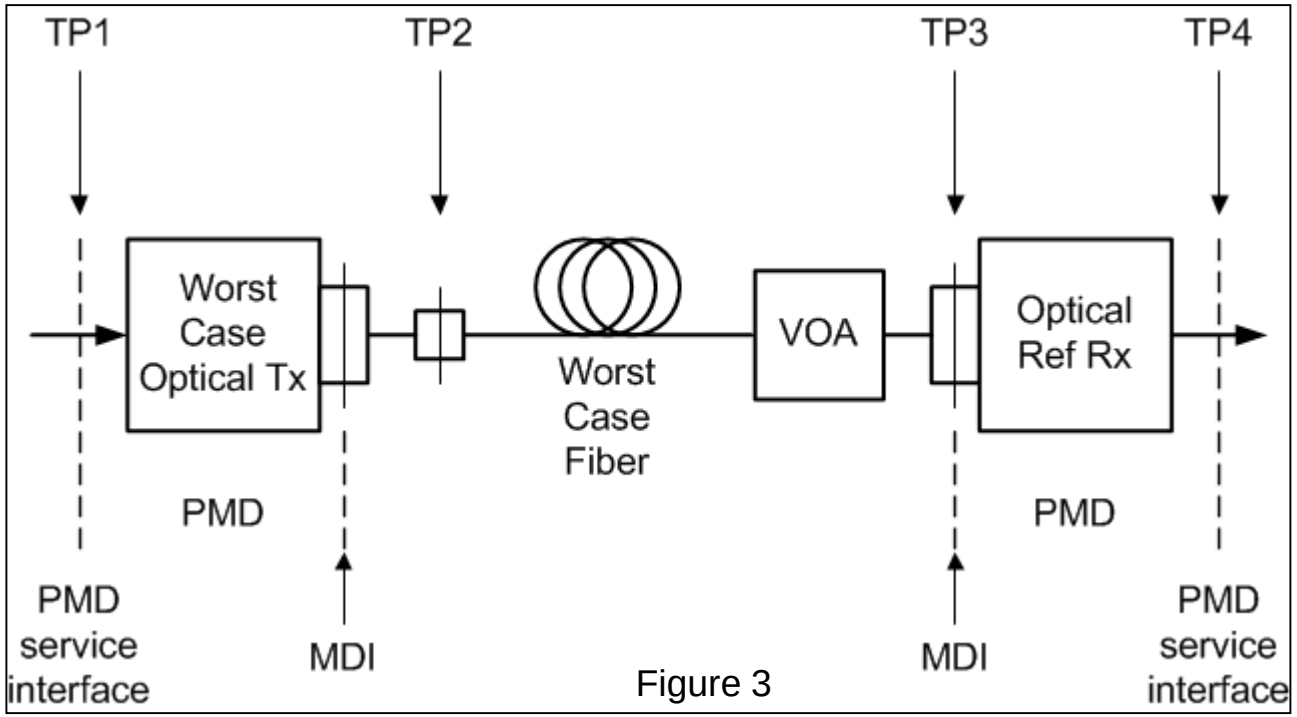


Figure 3

1) Replace Ref Tx in Figure 2 with Worst Case Tx, worst case TP1 conditions and Worst Case Fiber as shown in Figure 3. (Note exceptions for k_{MPN}, Pmn & Patt)
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 with exceptions: k_{MPN} = 0, Pmn = 0 dB, Patt = 0 dB.
- 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, here 4.96 dB.

100G SR4: Developing TDP Requirements 3, TDP Filter BW

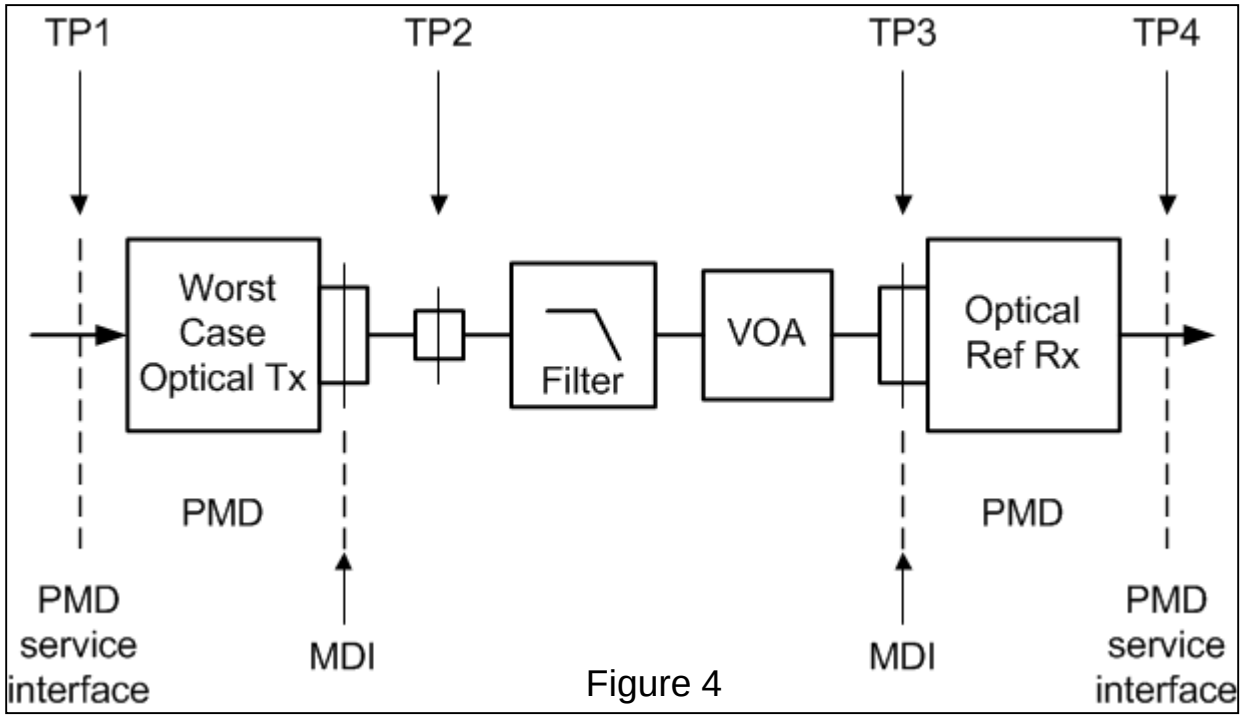


Figure 4

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 mode partition noise, k(MPN) is set to 0 when determining the filter bandwidth as is Pmn and the baseline wander coefficient. See exceptions on previous page.
•For the example link model, this filter in combination with the Ref Rx yields a BW of 12.613 GHz.

100G SR4: Developing TDP Requirements 4, Combined TDP Filter & Ref Rx

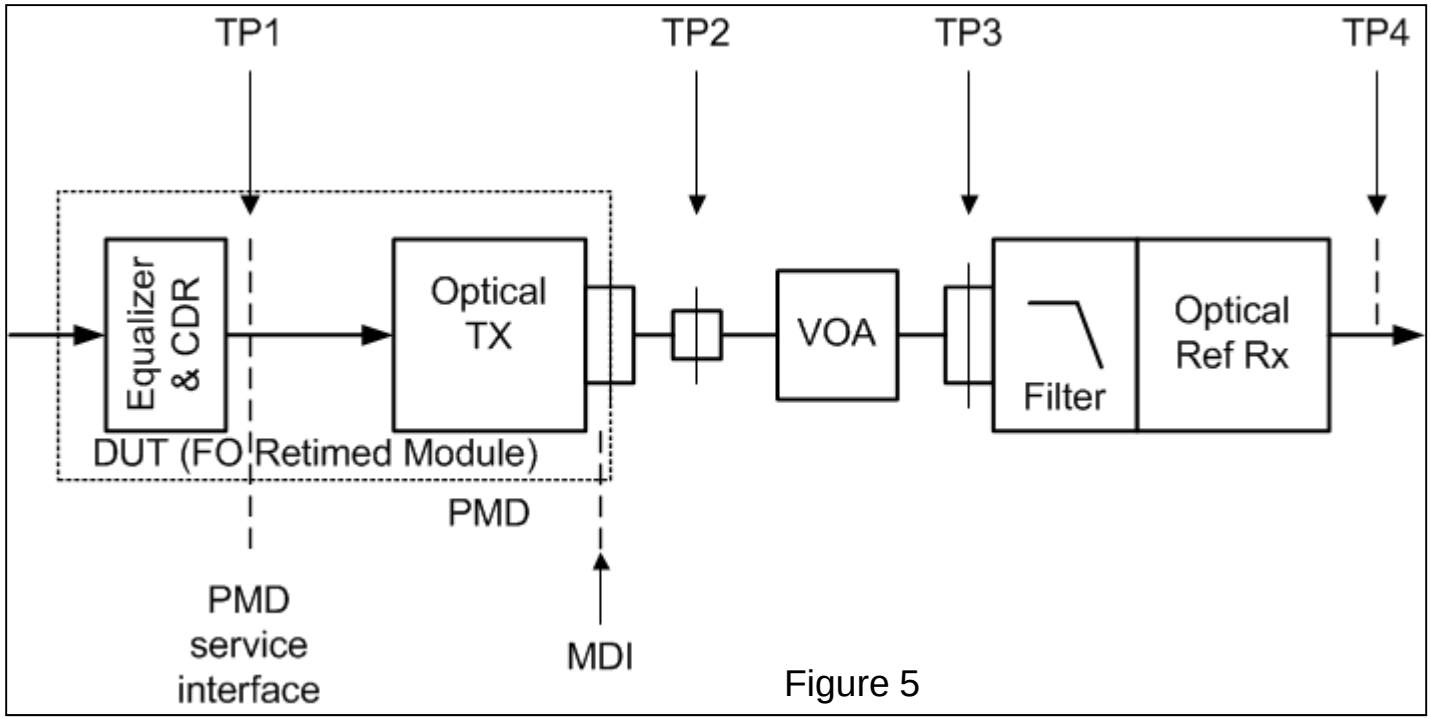
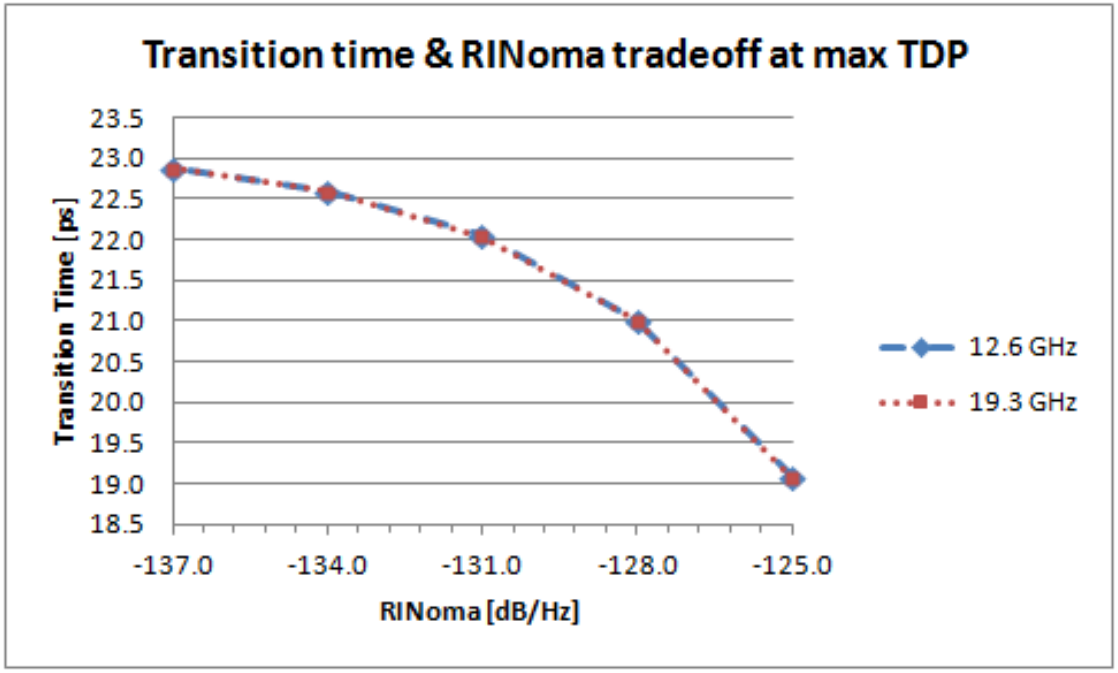


Figure 5

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 12.613 GHz instead of 19.336 GHz, a penalty of 0.65 dB (all ISI) would be incurred. See chart on page 7. The max TDP limit does not change.

100G SR4: Effect of Ref Rx BW on Tx attributes tradeoffs



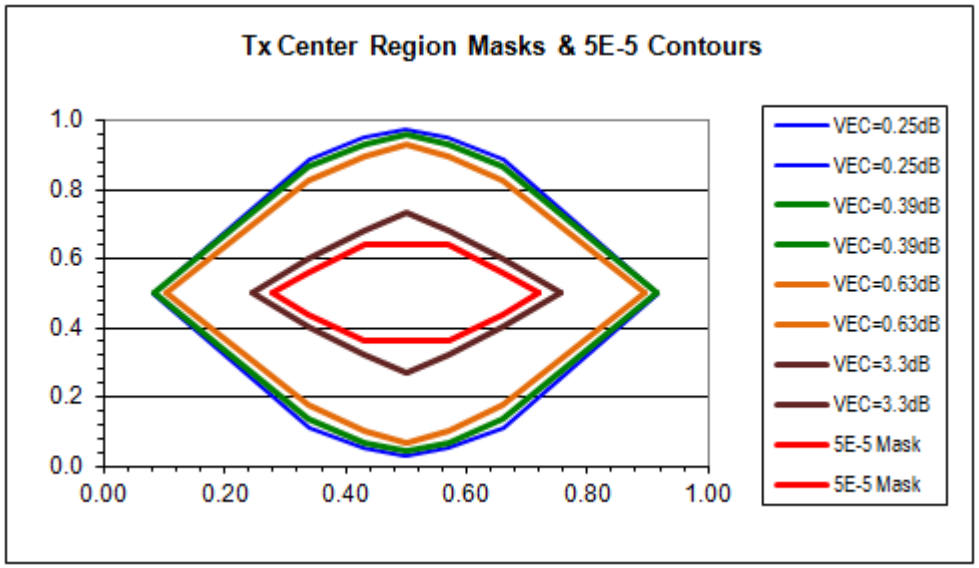
•The above chart show the results from two cases: a Ref Rx with a 19.3 GHz BW and 100 m OM4 and a Ref Rx with a 12.6 GHz BW and 2 m of OM3.
•For both cases TDP was forced to 4.96 dB for combinations of transition time and RINoma.
•The results overlap.

100G SR4: 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^2km	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	6.64	Adjusted to yield zero margin
Rx Bandwidth for TDP	MHz	12613	Adjusted to match Ptot of Ref Ch with100 m of OM4
Max TDP	dB	4.96	

Attributes and values in the above table provide a summary of the test channel using the 12.6 GHz TDP filter.

100G SR4: Reference Tx Considerations



VEC(0.50)	VEC(0.43)	TDP	tr & tf	TP1 TJ
dB	dB	dB	ps	UI
0.25	0.46	1.49	8	0.10
0.39	0.65	1.68	10	0.10
0.63	0.99	2.02	12	0.12
3.3	4.4	4.96	21	0.22

- As state above the ideal Ref Tx used to determine the max TDP limit is not expected to be realizable.
- The chart on the left shows results from several Tx cases (including a worst case Tx and the 5E-5 Eye mask) and the table below it lists attributes and expected TDP for these cases.
- In the table two values of Vertical Eye Closure, VEC, are provided: VEC(0.50) for the center of the eye and VEC(0.43) for an offset of 0.07 UI from the center aligned with a corner of the eye mask.
- Realizing a Ref Tx with a VEC ≤ 0.5 dB between 0.4 UI and 0.6 UI appears unlikely.
- A Ref Tx with a VEC ≤ ~1 dB and an associated TDP of ~2 dB seems more reasonable.