100G 100m (& 20m) MMF Transceivers

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100G 100m (& 20m) Transceivers Summary

Presentation Objectives:

•Update set of attributes values for a 100G SR4 100 m MMF example link mode.

•Provide results from a study of link reach, margin and ability to remove retimers as a consequences of TP1 and TP4 jitter allocations, BER of the optical link and signal rate.

Conclusion:

The example link model including embedded retimers and maximum benefit of KR4 FEC shows support of operation over 100 m of OM4 fiber.

The ability to remove retimers and support operation over 100 m of OM4 does not seem likely without a significant upgrade of the transceiver attributes in the example link model or generous jitter budget allocation.

The ability to remove retimers and support operation over 20 m of OM4 appears feasible with upgrades in transceiver model attributes. However, maximum KR4 FEC benefit remains assumed and this may be problematic if the host requires strong DFE to recover an un-retimed signal from the optics.

Recommendation:

Additional effort should be applied to definition of TP1 and TP4 jitter allocation for the non-retimed case, especially to determine how to avoid a need in the host of a strong DFE in order to recover an un-retimed signal from the optics.
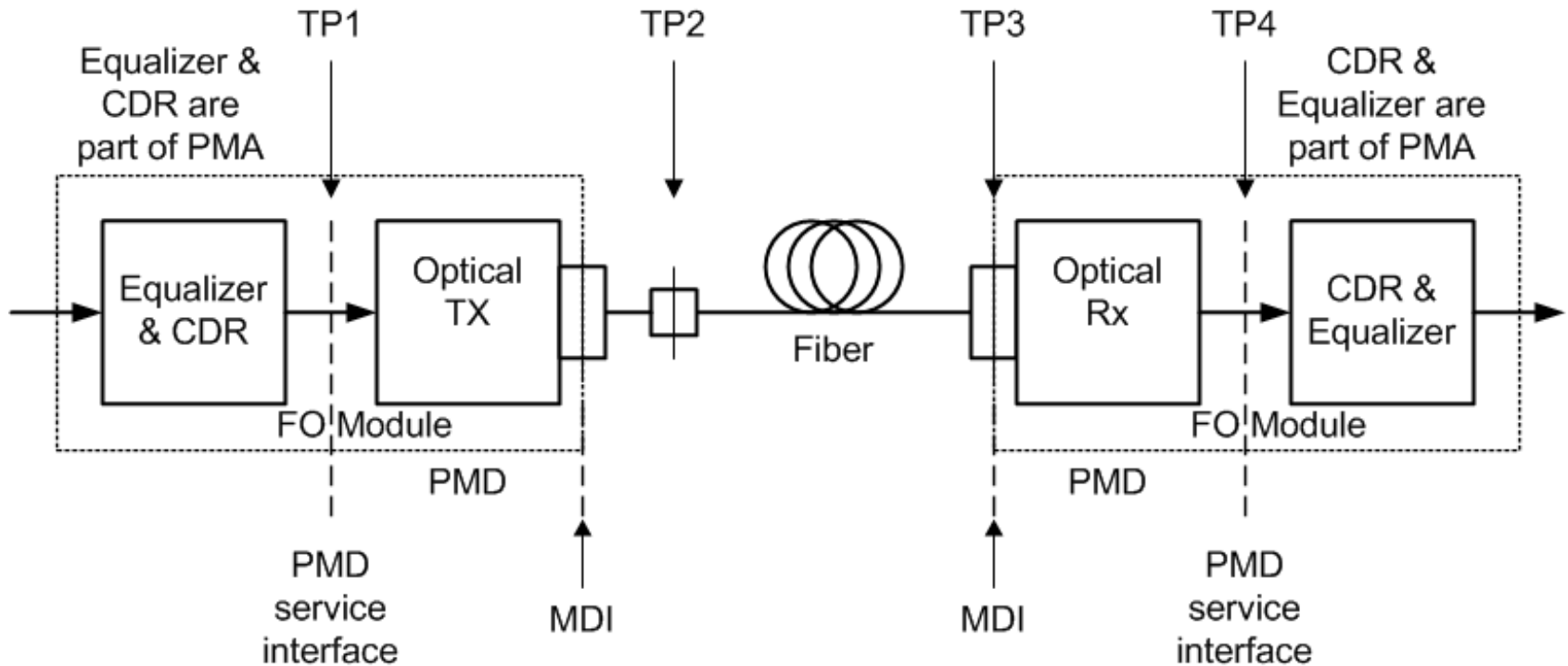
Fiber Optic Links Interfaces

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: Updates and Comments

<u>Optical Link Update Overview – see reference section for details</u>

•Reduced Q for the MMF link from Qo = 7.034 for a BER = 10^{-12} to Qi = 3.8119 yielding a BER = 6.90×10^{-5}, corresponding to the maximum benefit from KR4 FEC, enhances the Rx sensitivity by 10Log(Qo/Qi) = 2.66 dB and provides a larger signal power budget, now 8.3 dB.

•Relaxed min ER to 3.0 dB, tightened Rx Sensitivity to -11.3 dB, tightened BLW coefficient to 0.025, relaxed TP3 DJ tolerance to 0.225 UI.

<u>CAUI-4</u>

•Expected to be defined as not relying on FEC & operating at a BER = 1E-12 or better

<u>CAUI-4 – SR4 – CAUI-4 Link</u>

•Maintains signal and baud rate of NRZ, 64b/66b encoded, 25.78125 Gb/s signals

<u>Comments</u>

•OMA at max TDP same as for 40GBASE-SR4 and 100GBASE-SR10

•Rx Sensitivity same as for 40GBASE-SR4 and 100GBASE-SR10 (mostly from KR4 FEC benefit, ~0.9 db from improved noise figure)

•Signal power budget same as for 40GBASE-SR4 and 100GBASE-SR10

Link Margin vs TP4 Eye Width & TP1 TJ, 110 m Reach
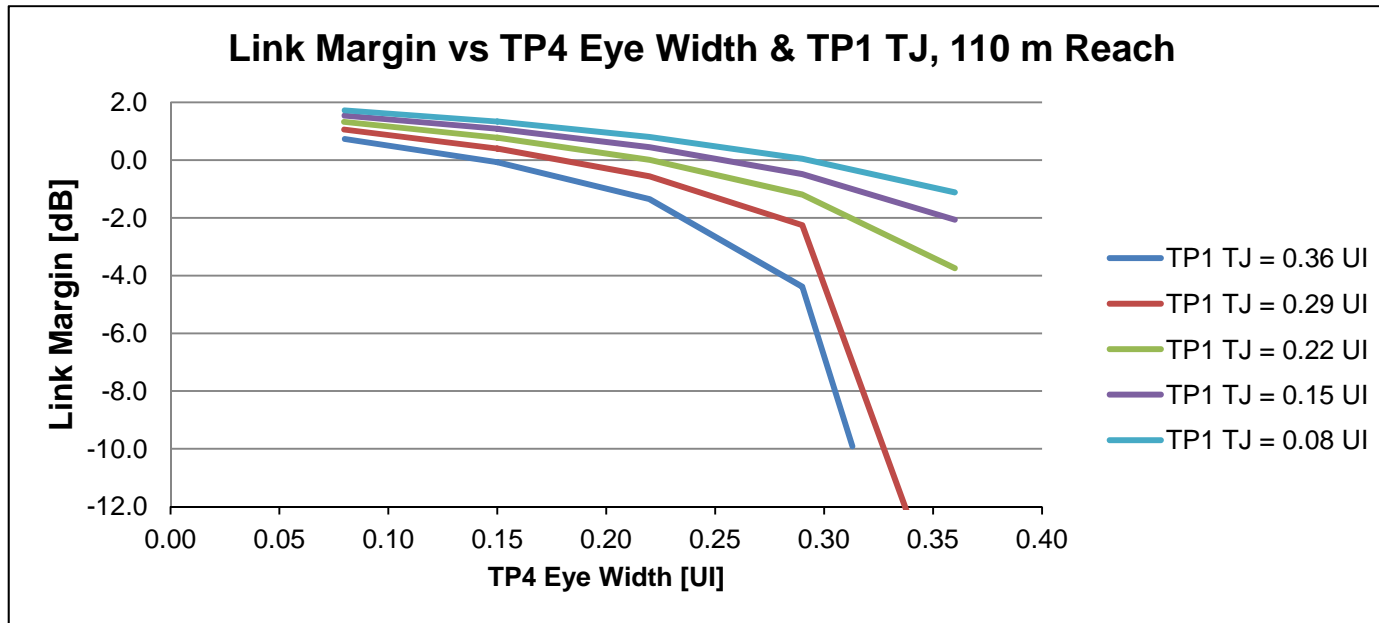
Results of sensitivity analysis based on example link model defined in reference section

•The above chart shows link margin for a 110 m reach of OM4 MMF for various TP1 and TP4 jitter allocations.

•TP1 TJ here is defined for a BER = 10^{-12}, based on the dual-Dirac model and arbitrarily sets TP1 RJ = TP1 DJ.

•TP4 TJ and TP4 Eye Width here are defined for a BER = 6.9×10^{-5}; max benefit of KR4 FEC is assumed.

•Note that there's a region where the combined impact of TP1 and TP4 jitter allocation is modest and a region where it is severe.

• It's expected that operation without retimers requires supporting a TP4 eye and TP1 TJ allocation ~ 0.30 UI to 0.35 UI. For reference , for the nPPI interface defined in Annex 86A , TP1 TJ = ~ 0.30 UI and TP4 TJ = ~ 0.70 UI.

•The example link model does not support a 110 m OM4 reach where TP4 Eye Width and TP1 TJ allocations in combination are larger than ~0.44 UI.
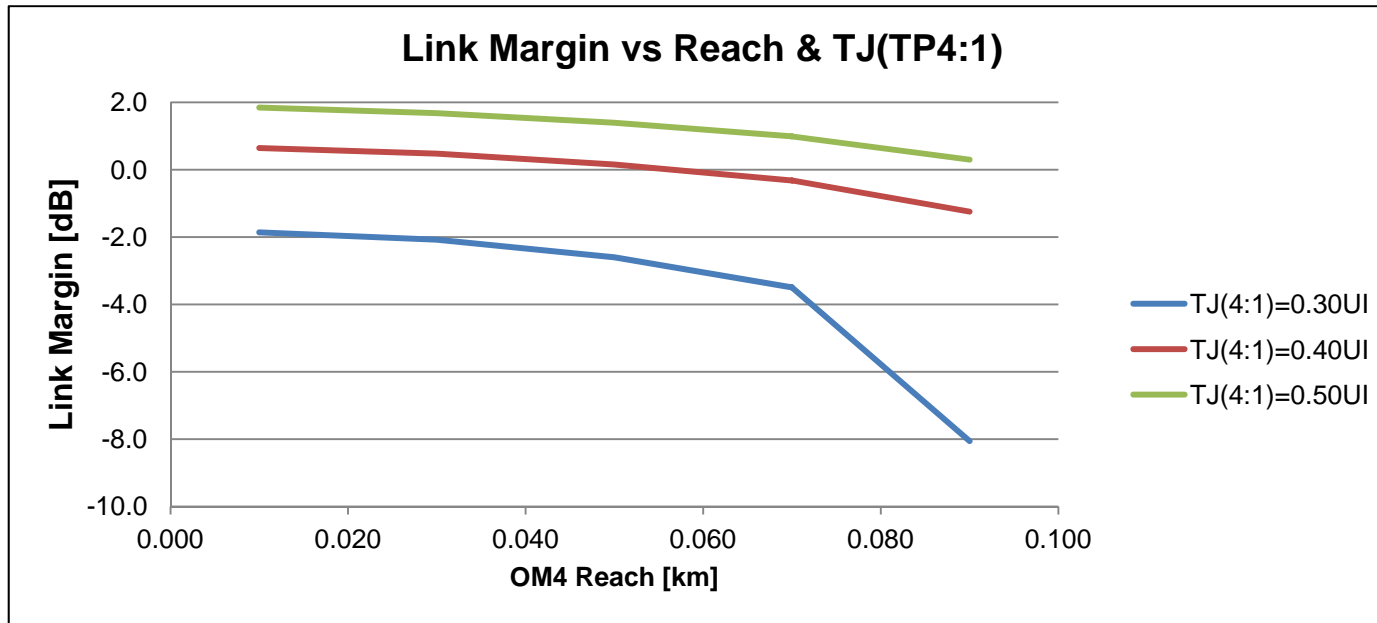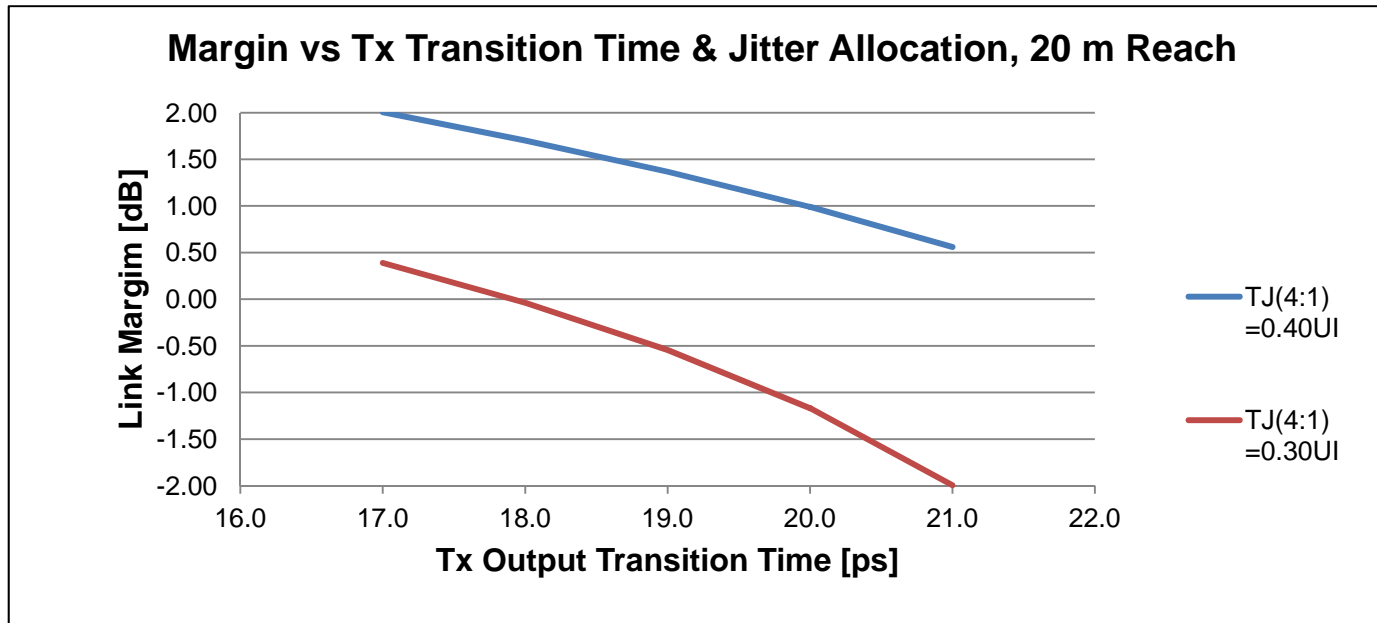
Link Margin vs Reach & TJ(TP4:1)

Results of sensitivity analysis based on example link model defined in reference section

•A metric TJ(4:1) equal to TP4 TJ – TP1 TJ, essentially the UI portion allocated to the optics, is defined to aid analysis.

•The above chart shows link margin as a function of OM4 MMF reach for various TJ(4:1) jitter allocations.

•TP1 TJ here is defined for a BER = 10^{-12}, based on the dual-Dirac model and arbitrarily sets TP1 RJ = TP1 DJ.

•TP4 TJ and TP4 Eye Width here are defined for a BER = 6.9 x10^{-5} ; max benefit of KR4 FEC is assumed.

•Note that where the portion of the UI allocated to the optics is less than ~ 0.5 UI to 0.4 UI, significant margin losses occur.

•The example link model appears to support a 20 m OM4 reach for TJ(4:1) > ~ 0.4 UI. However this assumes maximum use of KR4 FEC which may not be valid if a strong DFE is needed in the host to recover the signal.

Margin vs Tx Transition Time & Jitter Allocation, 20 m Reach

Results of sensitivity analysis based on example link model defined in reference section

•The above chart, prepared to explore transceivers where TP1 and TP4 are exposed, i.e. without embedded retimers, shows link margin as a function of Tx output transition time for two TJ(4:1) jitter allocations.

•The chart indicates that for jitter allocations similar to those of PPI (Annex 86A), i.e. TJ(4:1) = 0.40 UI, a transceiver like that defined by the example link model (Tx output max transition time = 21 ps) can support a 20 m reach without retimers.

•For a 20 m OM4 reach, without retimers, where TJ(4:1) ~ 0.3 UI, a significant upgrade to the Tx of the example link model is required, e.g. reducing the max Tx output transition time from 21 ps to 18 ps.

• Since the above assumes use of KR4 FEC, the conclusion may not be valid if a strong DFE is needed in the host to recover the signal.

100G SR4: BER & Link Model Results
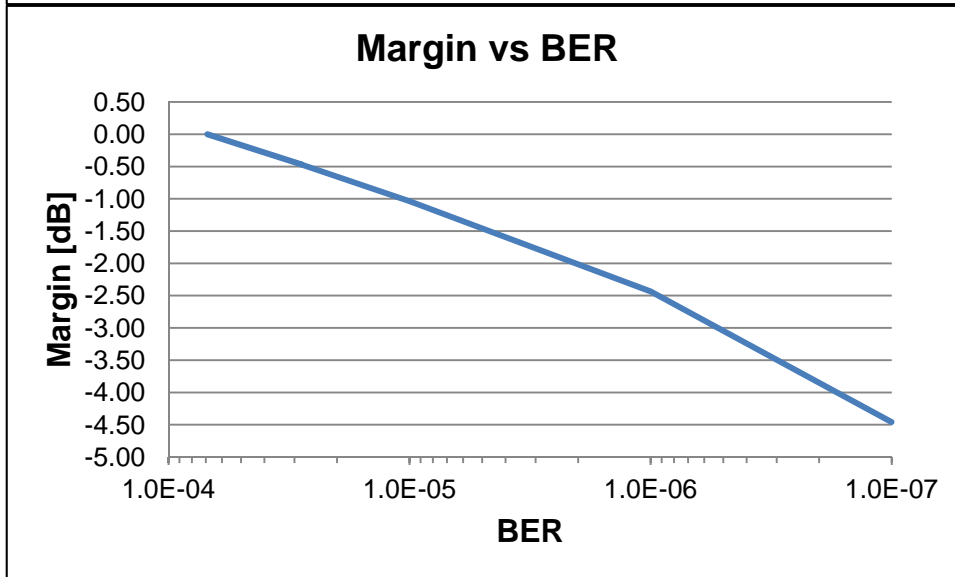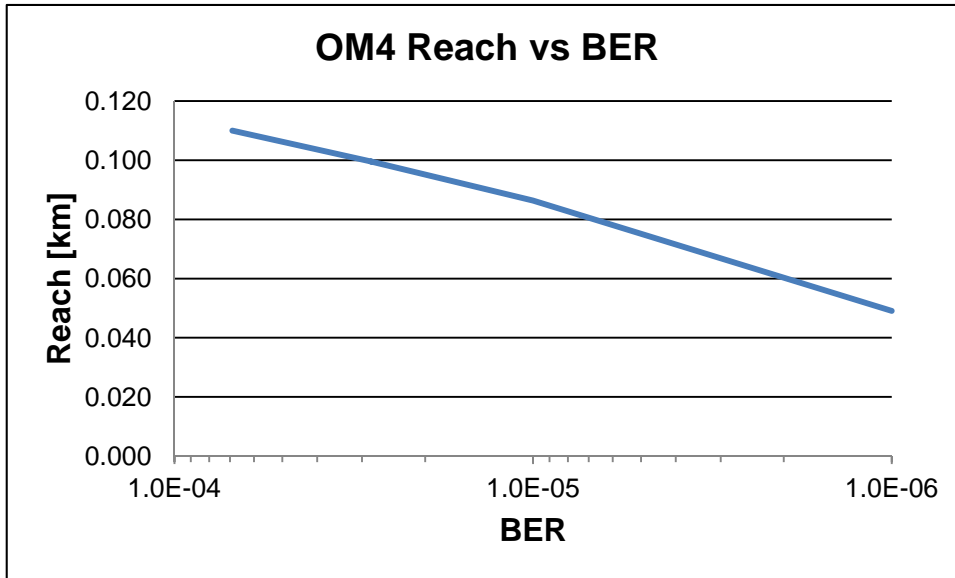
OM4 Reach vs BER

Margin vs BER

<u>Results of sensitivity analysis based on example link model defined in reference section</u>

- In the charts on the left Reach and Margin are shown as a function of BER for the optical link defined by the example link model.

- Here retimers are embedded in the Tx and Rx: TP1 TJ = 0.22 UI, TP4 TJ = 0.78 UI and TJ(4:1) = 0.56 UI.

- An increase in the BER requirement from 6.9×10^{-5} to 2.8×10^{-5} results in a margin loss of 0.46 dB or an OM4 reach reduction from 110 m to 100 m.

100G SR4: Signal Rate & Link Model Results

OM4 Reach vs Signal Rate

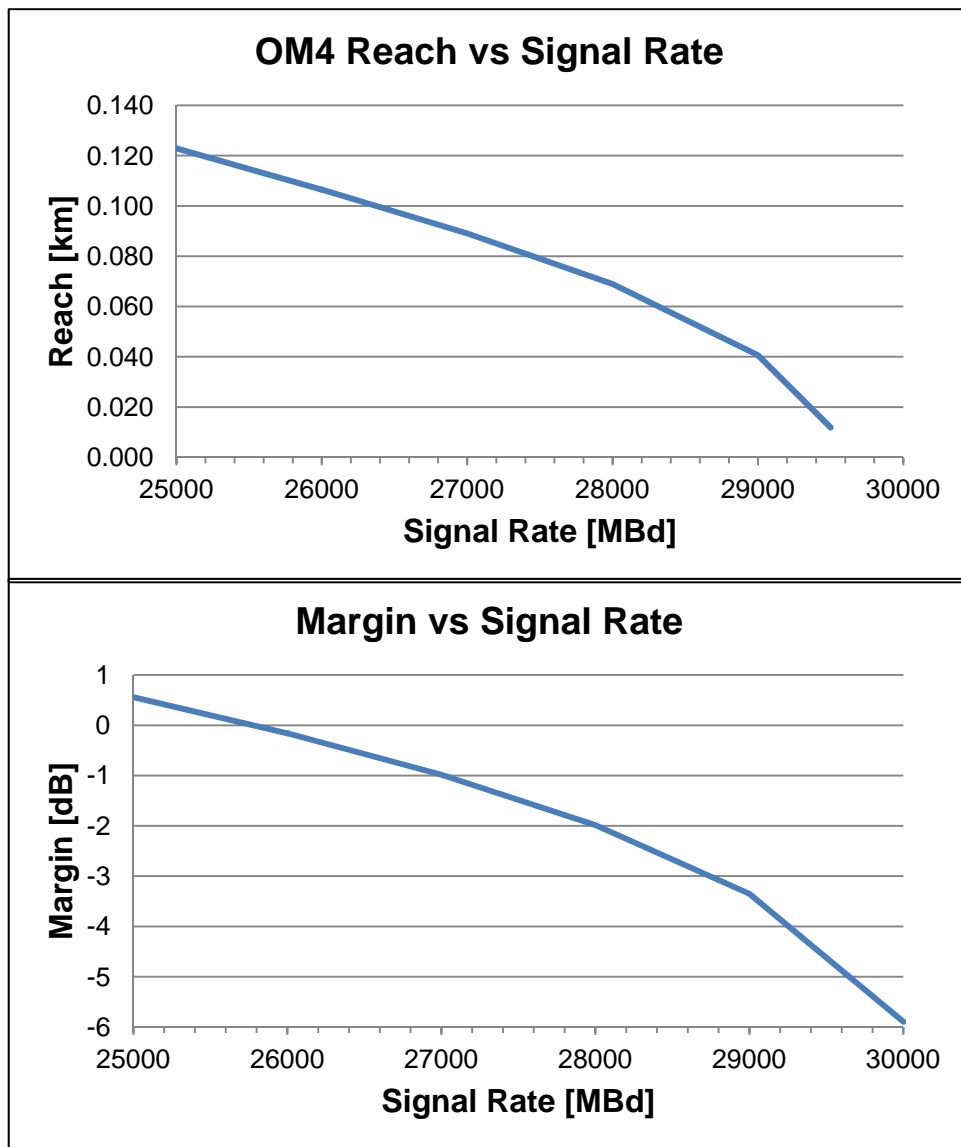Reach [km] vs Signal Rate [MBd]

Margin vs Signal Rate

Margin [dB] vs Signal Rate [MBd]

Results of sensitivity analysis based on example link model defined in reference section

• In the charts on the left OM4 reach and link margin are shown as a function of signal rate for the optical link defined by the example link model.

• Here retimers are embedded in the Tx and Rx: TP1 TJ = 0.22 UI, TP4 TJ = 0.78 UI and TJ(4:1) = 0.56 UI.

• An increase in the signal rate from 25.78 GBd to 27.0 GBd results in a margin loss of 0.98 dB or an OM4 reach reduction from 110 m to 89 m.

• For this analysis Rx sensitivity is scaled inversely with signal rate according to 10Log(SigRate(i) / SigRate(o)).

Example Link Model Reference Information

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

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		3.8119 (6.90E-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	Previously 4.0
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	0.126	Scaled with Q
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)		3.8119 (6.90E-5)	FEC corrects BER to < 1.0E-12
Wavelength, min	nm	840	
Rx sensitivity (OMA), max	dBm	-11.3	-8.34 dBm at Q = 7.034 Previously -8.09
Rx Bandwidth, min	MHz	18,047	
RMS base line wander coefficient		0.025	Previously 0.0125
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)		3.8119 (6.90E-5)	FEC corrects BER to < 1.0E-12
Reach	m	110	Previously 100
Fiber Attenuation	dB/km	3.5	For 850 nm center wavelength
Dispersion min Uo	nm	1316	
Dispersion So	ps/nm^{2}km	0.10275	
Fiber modal bandwidth	MHz·km	4400	For 840 nm center wavelength
Reflection Noise Factor		0	
Signal power budget at max TDP	dB	8.30	Model output
Connector & splice loss allocation	dB	1.50	
Fiber Insertion loss	dB	0.40	Model output
Allocation for penalties at max TDP	dB	4.32	Model output
Allocation for target TP4 eye at max TDP	dB	2.08	Model output
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.
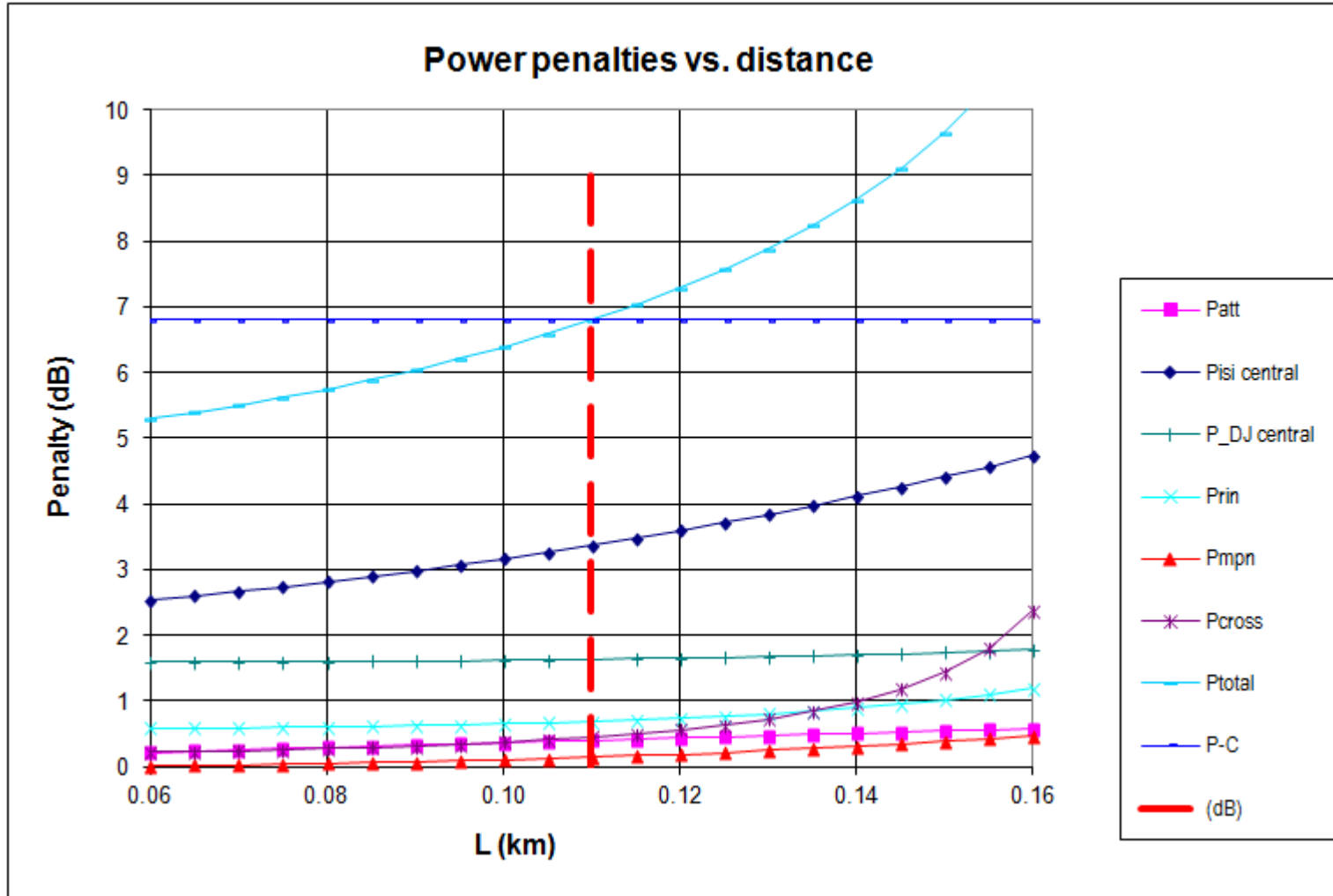
100G SR4 with KR4 FEC: Example Link Model Jitter Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		3.8119 (6.90E-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	0.225	Previously 0.23
TP4 J2, max	UI	0.438	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.

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Power penalties vs. distance

Legend: Patt, Pisi central, P_DJ central, Prin, Pmpn, Pcross, Ptotal, P-C, (dB)

- The above chart is provided by the example link model for TP1 DJ = TP1 RJ = 0.11 UI and TP4 TJ = 0.78 UI
- It distributes the power required for the target TP4 eye opening, Peye, in other power penalties. For the example link model, Peye at 110 m of OM4 equals 2.08 dB yielding 0 dB margin at 110 m of OM4.
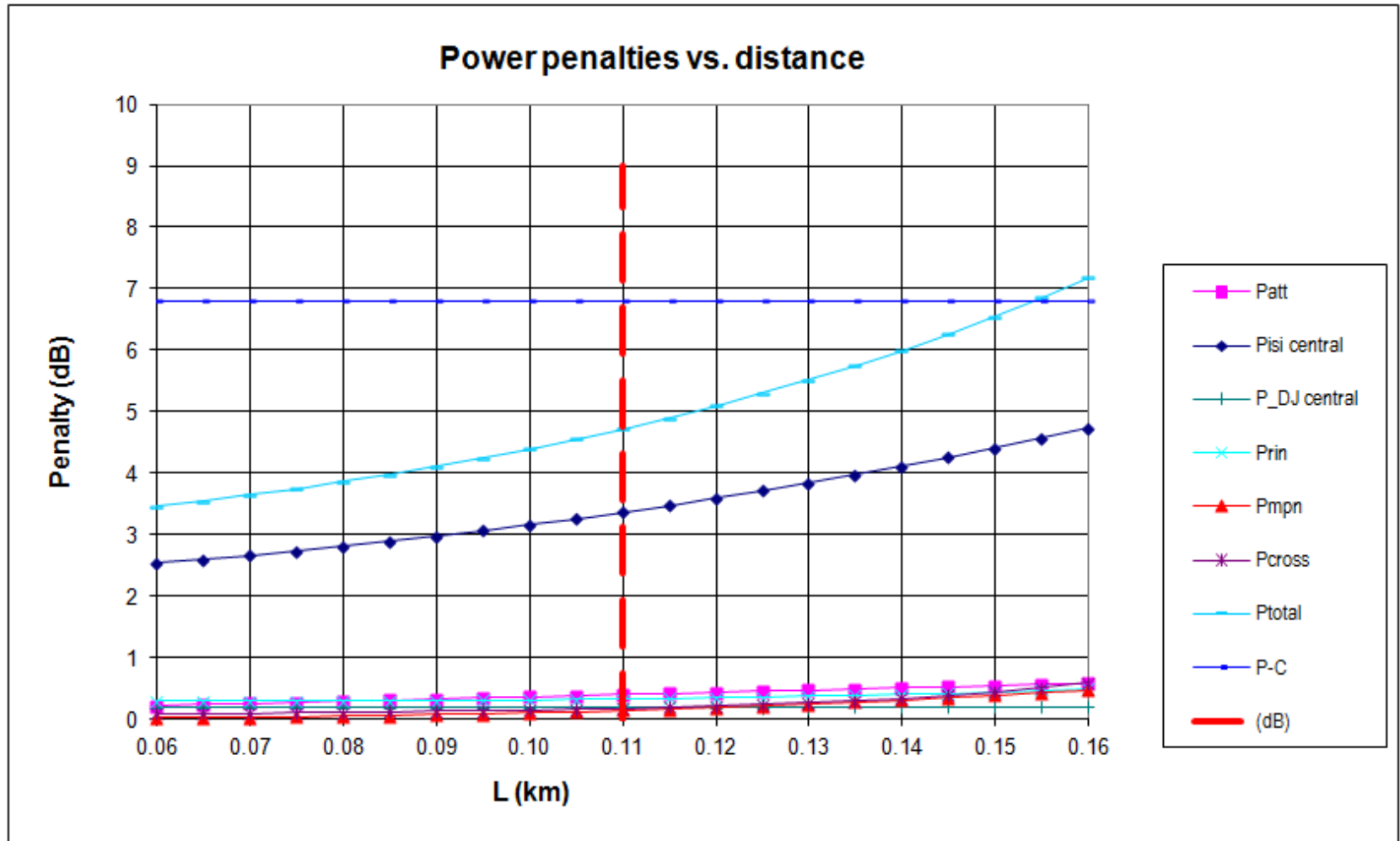
Power penalties vs. distance

- The above chart is provided by the example link model for TP1 DJ = TP1 RJ = 0.11 UI and TP4 TJ = 0.78 UI
- It does not show the power required for the target TP4 eye opening, Peye, nor include Peye in Ptotal. For the example link model, Peye at 100 m of OM4 equals 2.08 dB yielding 0 dB margin.