100G PSM4 Link Model and Results

John Petrilla: Avago Technologies

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Supporters

•David Cunningham	Avago Technologies
•Jon Anderson	Oclaro
•Chris Bergey	Luxtera
•Brian Welch	Luxtera
•Tom Palkert	Luxtera

100G PSM4 Link Model and Results

Presentation Objectives:

- Present an example link model
- Update previously presented exemplary set of values
  - Allocation of all FEC benefit to optical link
  - Min OMA, wavelength range and TDP tradeoffs
  - Revised worst case Tx – Rx combination
  - Relaxed ER and Rx Reflectance

Conclusion:

A link model with attributes acceptable to multiple transceiver suppliers is available

- Providing confidence in successful inter-operation of transceivers from multiple sources
- Providing a technical basis for a baseline document
- Enabling performance & cost comparisons with key attributes of 100G LR4

Fiber Optic Links Interfaces

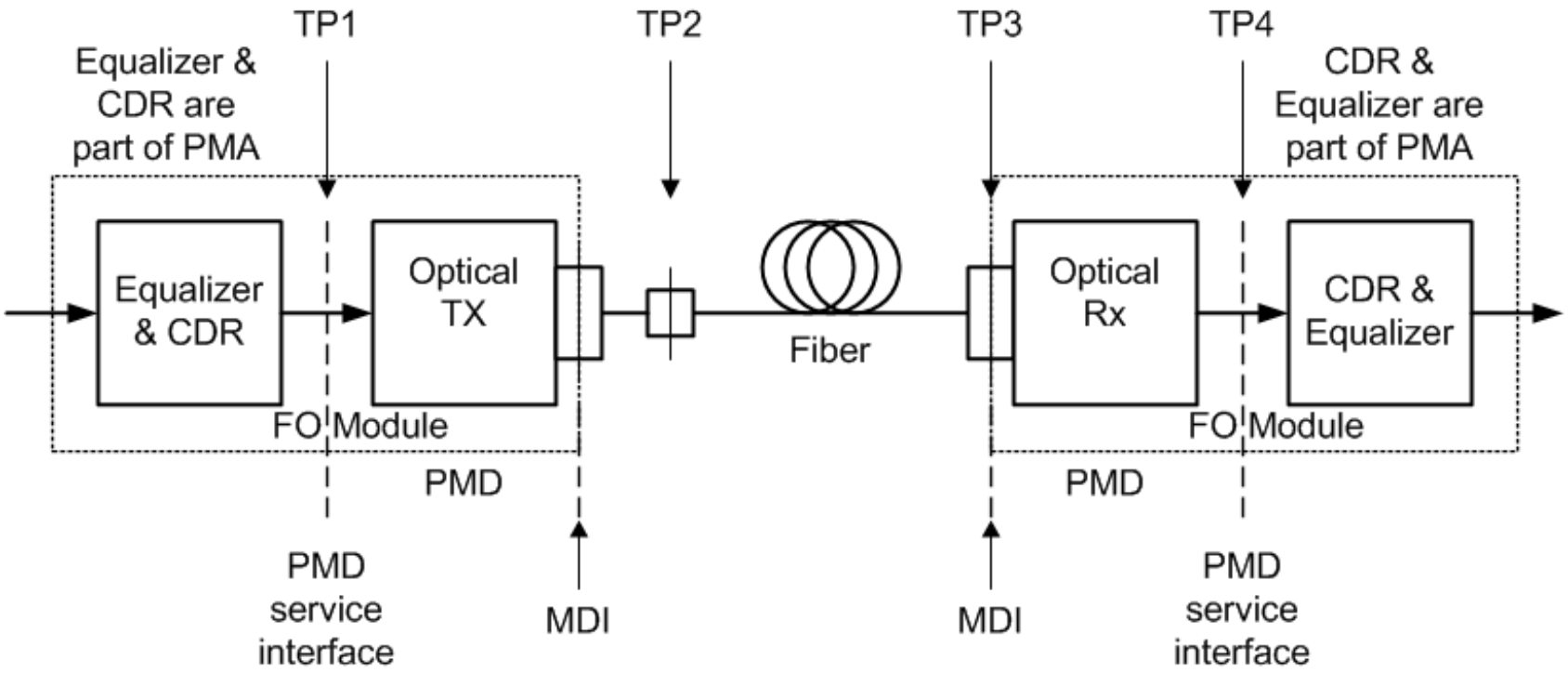


Figure 1

- 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.

Link Model Notes

ExamplePSM LinkModel 121105 prep'd for 802.3bm use as an example of an MMF link model based on 10GEPBud3_1_16a

This version adds extensions to 10GEPBud3_1_16a that provide for inclusion of TP1 jitter allocations and estimates of jitter and eye width at TP4.

The tab Base includes entries in cells A39:H52 to provide for calculation of TP4 jitter. These calculations are based on row 28 being aligned with the target reach and for link margin, cell W28, = 0.

Base tab cell G7 has been redefined as the combined DJ at TP3, Rx contributed DJ, RJ at TP1 & target TP4 eye width. The 'DJ at TP3' value is now entered (in units of UI instead of ps) in cell F44.

Base(c) tab is slaved to the Base tab except it maintains the original definition of cell G7, DJ at TP3.

The difference in the link penalties between the tabs Base and Base(c) yields the power required for the target TP4 eye, Peye.

To account for Peye in the calculation of Stressed Rx Sens OMA, the value in tab Base(c) cell W3 is zeroed out.

To match the definition of VECP in Clause 52, calculations were added to Base(c) tab cells W12 & W13 to account for included noise.

The equations in AQ18:27 and AQ29:38 were corrected.
See"10GbE Notes" tab for 10GEPBud3_1_16a notes.

Tab 1310S is included unchanged from 10GEPBud3_1_16a for reference.

Link Model Extensions – Base Tab

	A	B	C	D	E	F	G	H	I
39	TP4 Eye Width Extension: J Petrilla Avago Technologies								
40	Reach	Peye			TP1 RJ, UI =	0.110	4.27	ps for BER=E-12	
41	m	dB			TP1 RJrms, UI =	0.0079	0.31	ps	
42	2000	0.36			TP1 RJ(@BER), UI =	0.061	2.37	ps	
43					TP1 DJ, UI =	0.110	4.27	ps	
44	BER =	2.8E-05			TP3 DJ wo ISI, UI =	0.160	6.21	ps	
45	Qjit@BER				TP3.5 DJisi, UI =	0.004	0.16	ps	
46	3.861				DJ at TP4, UI =	0.177	6.87	ps	
47	Qjit@BER=E-12				RJ(link noise), UI =	0.720	27.9	ps	
48	6.937				Cum RJ(TP4), UI =	0.723	28.0	ps	
49	Q(@Jn)	k(DJ)			TP4 TJ(@BER), UI =	0.900	34.9	ps	
50	2.576	0.85			TP4 J2, UI =	0.419	16.2	ps	
51	6.109	1.0			TP4 J9, UI =	0.814	31.6	ps	
52					TP4 Eye Width, UI =	0.100	3.9	ps	

Caution: Calculations are based on the target reach aligned with row 28.

- Inputs are normally indicated by **bold** fonts.
- Cell A42 provides the target reach.
- Cell B42 provides the power required to support the TP4 values in cells F49:52 when the link margin, cell W28, equals 0

- Cell G47 links TP4 jitter calculations to the penalty calculations via cell G7.
- Based on the premise that what isn't DJ & eye width (cell G7) is RJ, cell G47 yields RJ based on the additional assumption that the noise related power penalties in aggregate yield RJ.
- For the case where the link margin (cell W28) equals 0, the eye closure due to power penalties is matched with eye closure due to jitter.
- The model requires inputs for all DJ and RJ at TP1 (cells F40 and F43:46).
- Cells A46, A48, A50 and A51 are Q values for the target BER and J2 and J9 jitter.
- Cells B50 and B51 are discounting factors for DJ in J2 and J9 calculations.
- There are two common use cases.
  - Use cell G7 to force one of the TP4 attributes, e.g. TP4 TJ to a desired value and check the link margin, cell W28.
  - Use one of the Tx, cable plane or Rx attributes, to force cell link margin, cell W28 to 0, and check the TP4 attributes.

Link Model Tx Section – Base Tab

	A	B	C	D	E	F	G	H
1	Spreadsheet by Del Hanson, David Cunningham, Piers Dawe, David Dolfi Agilent Technologies							
2	Basics	Input=	Bold			Ts(20-80)	18.0	ps
3		Q=	4.02661			Ts(10-90)	27	ps
4		Base Rate=	25781.3	MBd		RIN(OMA)	-128	dB/Hz
5	Transmitter					RIN at MinER	-136.3	dB/Hz
6		Wavelength Uc	1295	nm		RIN_Coef=	0.70	
7		RMS Width, Uw	0.20	nm		DJ+ & TP4eye	10.8	ps inc. DCD
8		Tx pwr OMA=	-3.10	dBm		DCD_DJ=	1.9	ps TP3
9		Min. Ext Ratio=	3.50	dB		Effect. DJ=	0.24	(UI) ex DCD
10		"Worst"ave.TxPwr	-1.94	dBm		MPN k(OMA)	0	
11		Ext. ratio penalty	4.17	dBo		Tx eye height	40.5%	
12	Tx mask	X1=	0.3	UI		Refl Tx	-12	dB
13		X2=	0.4	UI		ModalNoisePen	0	dB
14		Y1=	0.25			Tx mask top	0.2	UI

- Inputs are normally indicated by **bold** fonts.
- With the exception of the use of cell G7, there are no changes within this section.
- Note the entry for Q, cell C3, is set for a BER = 2.8E-5. See calculation in cell B44.

Link Model Case & Cable Plant Section – Base Tab

	I	J	K	L	M	N	O	P	Q
1						Rev.	3.2/3		This file
2	Case:	1310nm serial		SMF			Attenuation=	0.424	dB/km
3	*Target*		Target reach	2.00	km	*Fiber*	at	1310	nm
4	*and*		L_start=	1	km		C_att=	0.29	
5	*graph*		L_inc=	0.1	km		Attenuation=	0.43	dB/km
6			Power Budget P=	6.2	dB		at	1295	nm
7			Connections C	2.00	dB		Disp. min. Uo=	1324	nm
8			Pwr.Bud.-Conn.Loss	4.2	dB		Disp. So=	0.093	ps/nm^2*km
9			C1=	480	ns.MHz		Disp. D1=	-2.79	ps/(nm.km)
10			Reflection Noise factor	0.6	no units				
11			Effective Rate	27138	MBd		PolMD DGDmax	4.47	ps at target 2km
12			Tb_eff=	37	ps		BWm=	1E+06	MHz*km
13			Effective Rec Eye	0.21	UI		Eff. BWm=	1.5E+05	MHz*km

- Caution: Calculations in A40:H52 are based on the target reach aligned with row 28.
- The calculation, Target Reach = L start + 10 x L increment was inserted in cell L3.
- Inputs are normally indicated by **bold** fonts.
- There are no other changes in this section.

Link Model Rx Section – Base Tab

	R	S	T	U	V	W	X
1		10GEPBud3_1_16a.xls			of	17-Oct-01	
2			Model/format rev	3.1.16a	of	31-Oct-01	
3		NomSens OMA	-9.30	dBm	Margin	0.00	dB at
4	*Receiver*	Refl Rx	-12	dB	*Answer!*		0.12 km
5		Rec_BW=	19,336	MHz	Test Rx BW	19,336	MHz
6		c_rx	329	ns.MHz			
7		T_rx(10-90)	17.0	ps	Test Source ER=		
8		TP4 Eye	8	ps	*Test Tx*	6	dB
9		Opening		(=Tx eye)	TestERpen.	2.23	dBo
10		RMS Baseline wander SD	0.0125	fraction of 1/2 eye			
11					V.E.C.P.	1.87	dBo
12		P_BLW(no ISI)	0.01	dB			Stressed
13		P_BLW	0.01	dB			Rx sens

- Inputs are normally indicated by **bold** fonts.
- There are no changes to this section.

100G PSM4 Link Model: FEC Update

Optical Link

•Reducing Q for the SMF link from Qo = 7.034 for a BER = 10^{-12} to Qi = 4.02661 for a BER = 2.83×10^{-5} enhances the Rx sensitivity by 10Log(Qo/Qi) = 2.42 dB, providing a larger signal power budget.

•FEC was used used to reduce Tx signal levels and loosen other Tx (ER) and Rx (Sensitivity and Optical Return Loss) requirements permitting cheaper and lower power consuming devices.

•Sensitivity based measurements (e.g. TDP and SRS) can be simpler, quicker and cheaper for a 2.83×10^{-5} BER than for a 10^{-12} BER.

CAUI-4

•Expected to be defined as not relying on FEC

CAUI-4 – PSM4 – CAUI-4 Link

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

100G PSM4 with FEC: Tx Link Model Attributes (each lane)

Parameter	Unit	100G LR4	100G PSM4	
Signal rate	GBd	25.78125		
Q (BER)		7.034 (E-12)	4.02661 (2.83E-5)	FEC corrects BER to < E-15
Center Wavelength, min	nm	1294.53	1295	
Spectral Width, max	nm	0.2		Note 1
OMA at max TDP & w.l. offset, min	dBm	-0.1	-3.1	Note 2
Extinction ratio, min	dB	4	3.5	
Tx output transition times, 20% - 80%, max	ps	12	18	
RINcOMA, max	dB/Hz	-130	-128	Note 3
RIN coefficient		0.7		
Tx reflectance, max	dB	-12		
Tx optical return loss tolerance, max	dB	20	12	

Attributes and values in the above table are provided in order to populate example link models and are not presented as specification recommendations.
Note 1, Model uses 0.2 nm spectral width to generate penalty equivalent to max expected from chirp.
Note 2, Trade-off are available for min OMA, center wavelength and TDP. See anderson_01_1112
Note 3, For 100G LR4, c = 20 and for 100G PSM4, c = 12.

100G PSM4 with FEC: Rx Link Model Attributes (each lane)

Parameter	Unit	100G LR4	100G PSM4	
Signal rate	GBd	25.78125		
Q (BER)		7.034 (E-12)	4.02661 (2.83E-5)	FEC corrects BER to < E-15
Wavelength, min	nm	1294.53	1295	
Rx sensitivity (OMA), max	dBm	-8.6	-9.3 (-6.88 at Q = 7.034)	
Rx Bandwidth, min	MHz	19,336		
RMS base line wander coefficient	dB/Hz	0.025	0.0125	
Rx reflectance, max	dB	-26	-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 PSM4 with FEC: Link Model Channel Attributes (each lane)

Parameter	Unit	100G LR4	100G PSM4	
Signal rate	GBd	25.78125		
Q (BER)		7.034 (E-12)	4.02661 (2.83E-5)	FEC corrects BER to < E-15
Reach	km	10	2	
Fiber Attenuation	dB/km	0.424		For 1310 nm center wavelength
Dispersion, min Uo	nm	1324		
Dispersion, So	ps/nm^{2}km	0.093		
PolMD DGD max	ps	10	4.47	Sq root dependency with length
Reflection Noise Factor		0.6		
Signal power budget at max TDP	dB	8.50	6.20	Model output
Connector & splice loss allocation	dB	2.00	2.00	
Fiber Insertion loss	dB	4.30	0.86	Model output
Allocation for penalties at max TDP	dB	1.93	2.98	Model output
Allocation for target eye at max TDP	dB	0.27	0.36	Model output
Additional insertion loss allowed	dB	0.0	0.0	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 as examples.

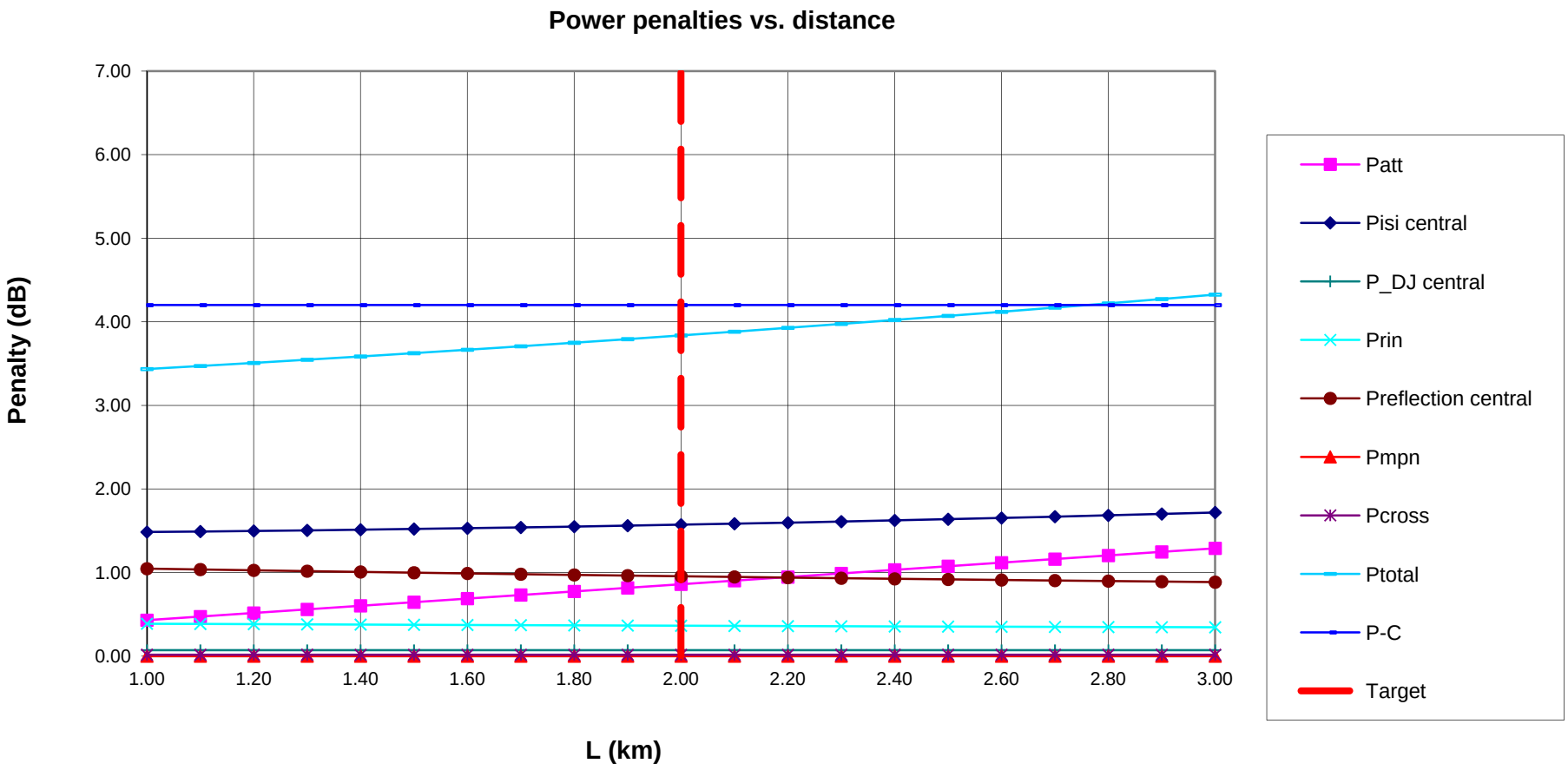
100G PSM4 with FEC: Link Model Jitter Attributes (each lane)

Parameter	Unit	100G LR4	100G PSM4	
Signal rate	GBd	25.78125		
Q (BER)		7.034 (E-12)	4.02661 (2.83E-5)	FEC corrects BER to < E-15
TP1 RJrms tolerance, min	UI	0.0054	0.0079	
TP1 DJ tolerance, min	UI	0.087	0.11	
TP3 DCD tolerance, min	UI	0.05	0.05	
TP3 DJ tolerance, min	UI	0.087	0.16	
TP4 J2, max	UI	0.36	0.42	Model output
TP4 TJ at BER, max	UI	0.85	0.90	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 as examples.

Nomenclature: Terms TP1, TP2, TP3 and TP4 are used as defined in 802.3 clause 88 and shown in above Figure 1. Note that TP1 is downstream of the input CDR and equalizer for an optical transmitter.

100G PSM4 with FEC: Link Model Penalties (each lane)



The above chart is taken from the tab Base(c) of the ExamplePSM_LinkModel_121105. It does not show the power required for the target TP4 eye opening, Peye, nor include Peye in Ptotal. For this example, Peye at 2 km equals 0.36 dB.