100G PSM4 & RS(528, 514, 7, 10) FEC

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100G PSM4 & RS(528, 514, 7, 10) FEC Summary

Presentation Objectives:

•Identify for high speed signals and initially expected optical 100G PSM4 modules, the PMD service interface, MDI and test points.

•Describe incorporation of RS(528, 514, 7, 10) FEC into 100G PSM4 links with an example that allocates half of the benefit to the optics and half to PCB portions of the link.

•Present an exemplary set of values for link model attributes for a 100G PSM4 2 km SMF link.

Conclusion:

Incorporation of RS(528, 514, 7, 10) FEC into 100G PSM4 links can increase the signal power budget by 2.25 dB over the budget for a link defined for a BER = 10^{-12}
RxS(Qi) = RxS(Qo) -10Log (Qo/Qi) = RxS(Qo) - 10Log(7.034/4.1865)
while providing, after correction, a BER = 10^{-15}.

Recommendation:

Take advantage of 802.3bj adopted RS(528, 514, 7, 10) for their copper cable PHY and incorporate it in the 802.3bm 500 m SMF PHY and CAUI-4.

Fiber Optic Links with RS(528, 514, 7, 10) FEC

- 802.3bj has adopted RS(528, 514, 7, 10) FEC for their copper cable media variant, 100G CR4.
- The benefit of RS(528, 514, 7, 10) depends on the bit error generating characteristics of the link to which it's applied and on the target corrected BER.
- For a channel comprising benign electrical (e.g. VSR like) and optical links where no error propagating functions (e.g. DFE) are required, then bit error and consequently symbol error generation can be reasonably assumed to be random and independent (noise dependent) and an independent error model can be used to estimate benefits as follows.
  - RS(528, 514, 7, 10) consists of 528 symbols of 10 bits/symbol yielding a frame size of 5280 bits.
  - There are 514 data symbols and 14 parity symbols providing the ability to correct (528-514)/2 = 7 corrupted symbols.
  - The Frame Error Rate, FER, for operation without FEC for a BER = 1E-15 using binomial statistics (probability density function) is 5.28E-12. (Since VSR is defined for a BER of 1E-15, this BER is used for the base ratio.)
  - In a optical link, assume bit errors are noise generated, independent and random. Further, since there will be no required DFEs, error multiplication is not expected.
  - The worst case that can be corrected is 7 bit errors for 7 symbols with 1 bit error/symbol.
  - The case equivalent to operation without RS(528,514,7,10) is where 8 symbols are corrupted, since for only 7 or less all errors are corrected.
  - For operation with RS(528,514,7,10), a BER = 2.83E-5 yields an FER of 5.28E-12 (Q = 4.0266) to match the FER for a BER = 1E-15 (Q = 7.943) without FEC.
  - Allocating half of the error generation to the optics yields a BER = 1.42E-5 (Q = 4.1865) requirement for the optics.
  - Allocating half of the error generation to the electrical links (CAUI-4) yields a BER = 7.08E-6 (Q = 4.3413) requirement for each of the two CAUI-4 links.

Summary of RS(528, 514, 7, 10) benefits for 100G PSM4 & CAUI-4

Optical Link

•Reducing Q for the SMF link from Qo = 7.034 for a BER = 10^{-12} to Qi = 4.1865 for a BER = 1.42×10^{-5} enhances the Rx sensitivity by 10Log(Qo/Qi) = 2.25 dB, providing a larger signal power budget.

•Although a larger link budget isn't necessary for the SMF reach objective, it can be used to reduce Tx signal levels and loosen other Tx and Rx tolerances permitting cheaper and lower power consuming devices.

•Sensitivity based measurements (e.g. TDP and SRS) can be simpler, quicker and cheaper for a 1.42×10^{-5} BER than for a 10^{-12} BER.

CAUI-4

•Reducing Q for the SMF link from Qo = 7.034 for a BER = 10^{-12} to Qi = 4.3413 for a BER = 7.08×10^{-6} enhances the Rx sensitivity by 20Log(Qo/Qi) = 4.19 dB.

•Eye width and height measurement can be simpler, quicker and cheaper for a 7.08×10^{-6} BER than for a 10^{-15} BER as in VSR.

CAUI-4 – PSM4 – CAUI-4 Link

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

•Provides finer granularity, on-line, bit error monitor

Fiber Optic Links Interfaces

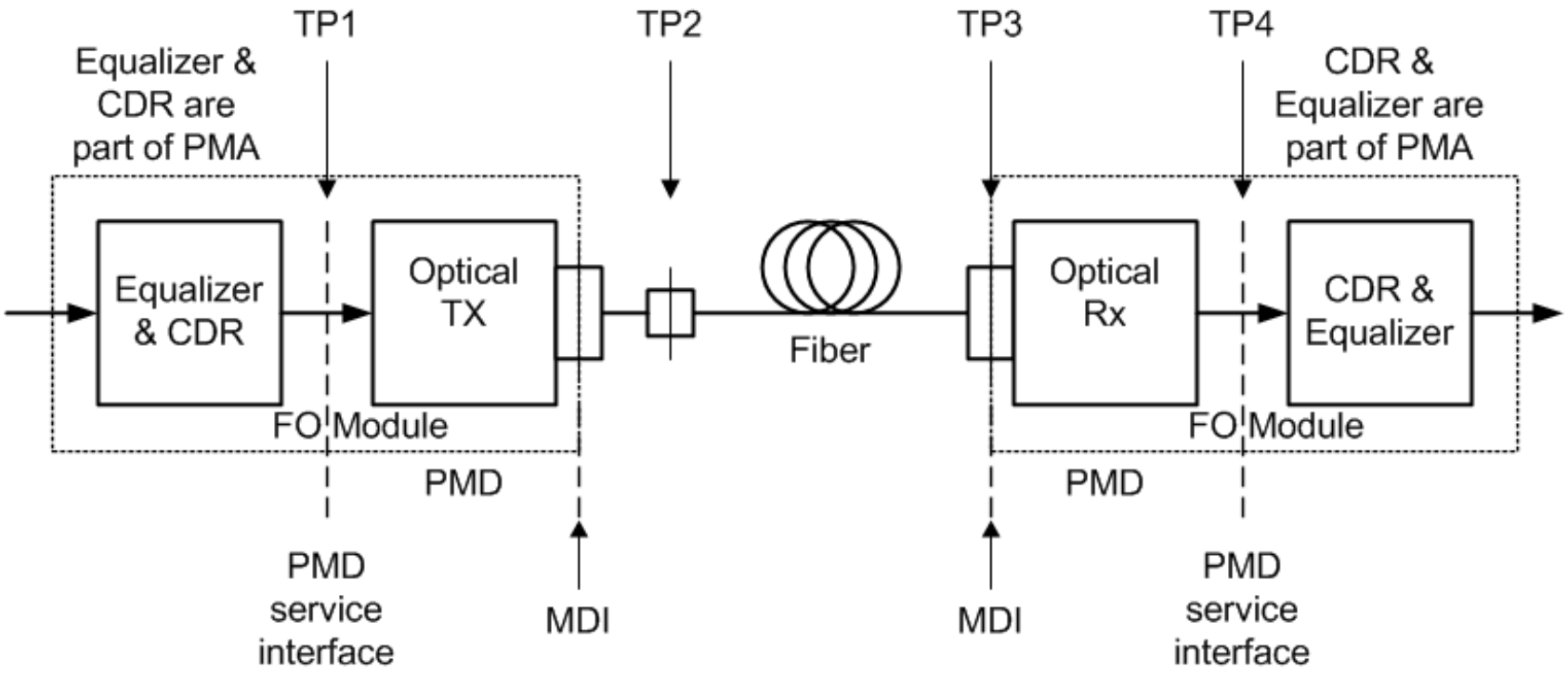


Figure 1

- 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 FEC: Tx Link Model Attributes (each lane)

Parameter	Unit	100G LR4	100G PSM4	
Signal rate	GBd	25.78125		
Q (BER)		7.034 (E-12)	4.1865 (1.42 E-5)	FEC corrects BER to < 0.5 E-15
Center Wavelength, min	nm	1294.53	1260	
Spectral Width, max	nm	0.2		Model uses 0.2 nm spectral width as a substitute for 30 dB min side-mode suppression ratio
OMA at max TDP, min	dBm	-0.1	-3.1	
Extinction ratio, min	dB	4		
Tx output transition times, 20% - 80%, max	ps	12	18	
$RIN_{20}OMA$, max	dB/Hz	-128	-128	
RIN coefficient		0.7		
Tx reflectance, max	dB	-12		
Tx optical return loss tolerance, max	dB	20		

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: Rx Link Model Attributes (each lane)

Parameter	Unit	100G LR4	100G PSM4	
Signal rate	GBd	25.78125		
Q (BER)		7.034 (E-12)	4.1865 (1.42 E-5)	FEC corrects BER to < 0.5 E-15
Wavelength, min	nm	1294.53	1260	
Rx sensitivity (OMA), max	dBm	-8.9	-9.61 (-7.36 at Q = 7.034)	
Rx Bandwidth, min	MHz	19,336		
RMS base line wander coefficient	dB/Hz	0.025		
Rx reflectance, max	dB	-26		

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)	4.1865 (1.42 E-5)	FEC corrects BER to < 0.5 E-15
Reach	km	10	2	
Fiber Attenuation	dB/km	0.4		For 1310 nm center wavelength
Dispersion, min Uo	nm	1324		
Dispersion, So	ps/nm^2km	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	8.5	6.51	Model output
Connector & splice loss allocation	dB	2.0	2.5	
Fiber Insertion loss	dB	4.06	0.84	Model output
Allocation for penalties at max TDP	dB	2.18	2.28	Model output
Allocation for target eye at max TDP	dB	0.23	0.89	Model output
Additional insertion loss allowed	dB	0.03	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.

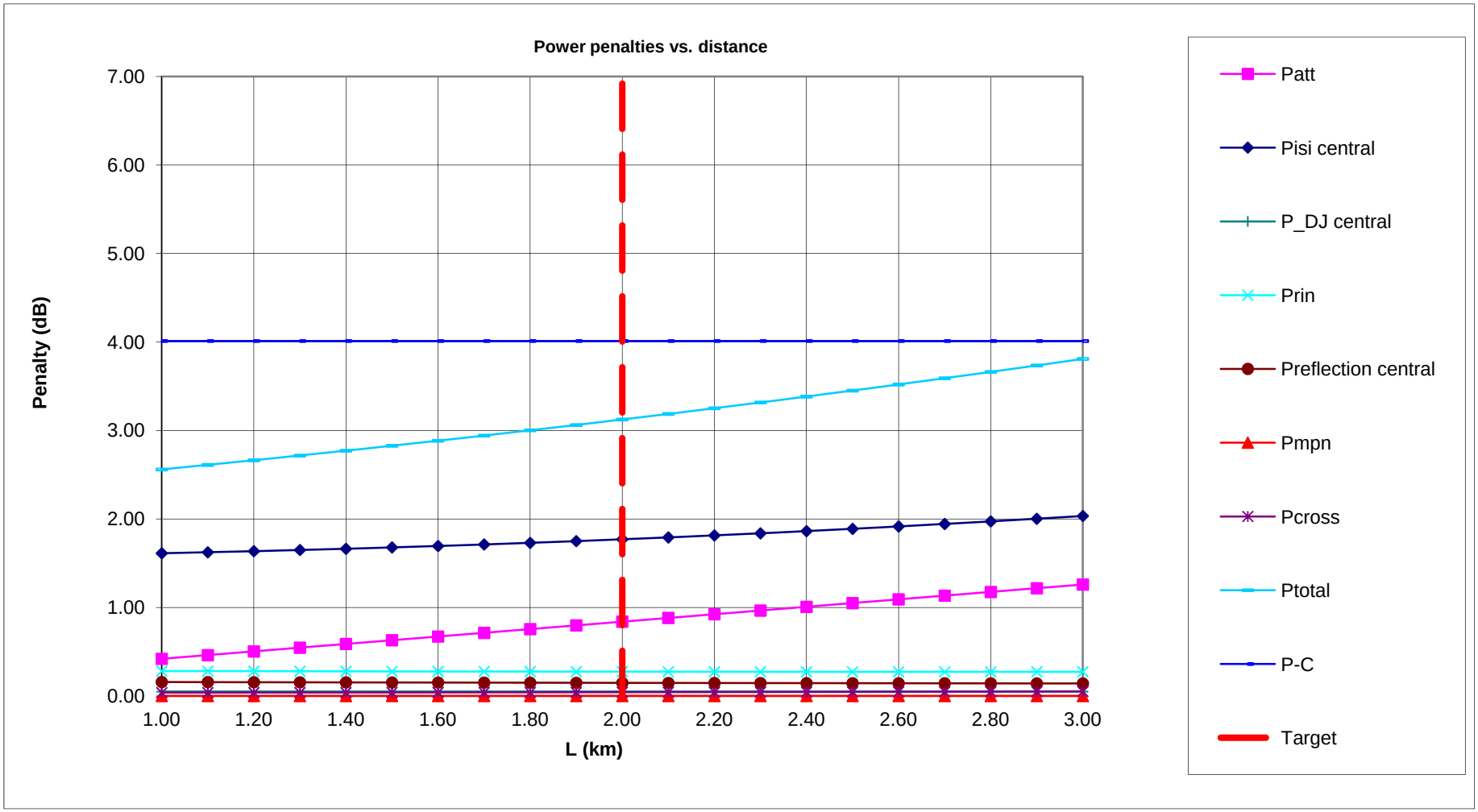
100G PSM4 with FEC: Link Model Jitter Attributes (each lane)

Parameter	Unit	100G LR4	100G PSM4	
Signal rate	GBd	25.78125		
Q (BER)		7.034 (E-12)	4.1865 (1.42 E-5)	FEC corrects BER to < 0.5 E-15
TP1 RJrms tolerance, min	UI	0.0079	0.0079	
TP1 DJ tolerance, min	UI	0.11	0.11	
TP3 DCD tolerance, min	UI	0.08	0.07	
TP3 DJ tolerance, min	UI	0.16	0.16	
TP4 J2, max	UI	0.61	0.54	Model output
TP4 TJ at BER, max	UI	0.90	0.78	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 Jitter Attributes (each lane)



The above chart 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 0.89 dB.