

# **100G SR4 & RS(528, 514, 7, 10) FEC**

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# 100G SR4 & RS(528, 514, 7, 10) FEC Summary

## Presentation Objectives:

- Identify for high speed signals and initially expected optical 100G SR4 modules, the PMD service interface, MDI and test points.
- Describe incorporation of RS(528, 514, 7, 10) FEC into 100G SR4 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 SR4 100 m MMF link.

## Conclusion:

Incorporation of RS(528, 514, 7, 10) FEC into 100G SR4 links can increase the signal power budget by 2.25 dB over the budget for a link defined for a BER =  $10^{-12}$

$$RxS(Q_i) = RxS(Q_o) - 10\text{Log} (Q_o/Q_i) = RxS(Q_o) - 10\text{Log}(7.034/4.1865)$$

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 100 m MMF 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 SR4 & CAUI-4

## Optical Link

- Reducing Q for the MMF link from  $Q_0 = 7.034$  for a  $BER = 10^{-12}$  to  $Q_i = 4.1865$  for a  $BER = 1.42 \times 10^{-5}$  enhances the Rx sensitivity by  $10\log(Q_0/Q_i) = 2.25$  dB, providing a larger signal power budget.
- Enables >100 m OM4 reach with  $BER < 10^{-15}$  otherwise < 100 m OM4 with  $BER = 10^{-12}$
- Sensitivity based measurements (e.g. TDP and SRS) can be simpler, quicker and cheaper for a  $1.42 \times 10^{-5}$  BER than for a  $10^{-12}$  BER.

## CAUI-4

- Reducing Q for the MMF link from  $Q_0 = 7.034$  for a  $BER = 10^{-12}$  to  $Q_i = 4.3413$  for a  $BER = 7.08 \times 10^{-6}$  enhances the Rx sensitivity by  $20\log(Q_0/Q_i) = 4.19$  dB.
- Eye width and height measurement can be simpler, quicker and cheaper for a  $7.08 \times 10^{-6}$  BER than for a  $10^{-15}$  BER as in VSR.

## CAUI-4 – SR4 – 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

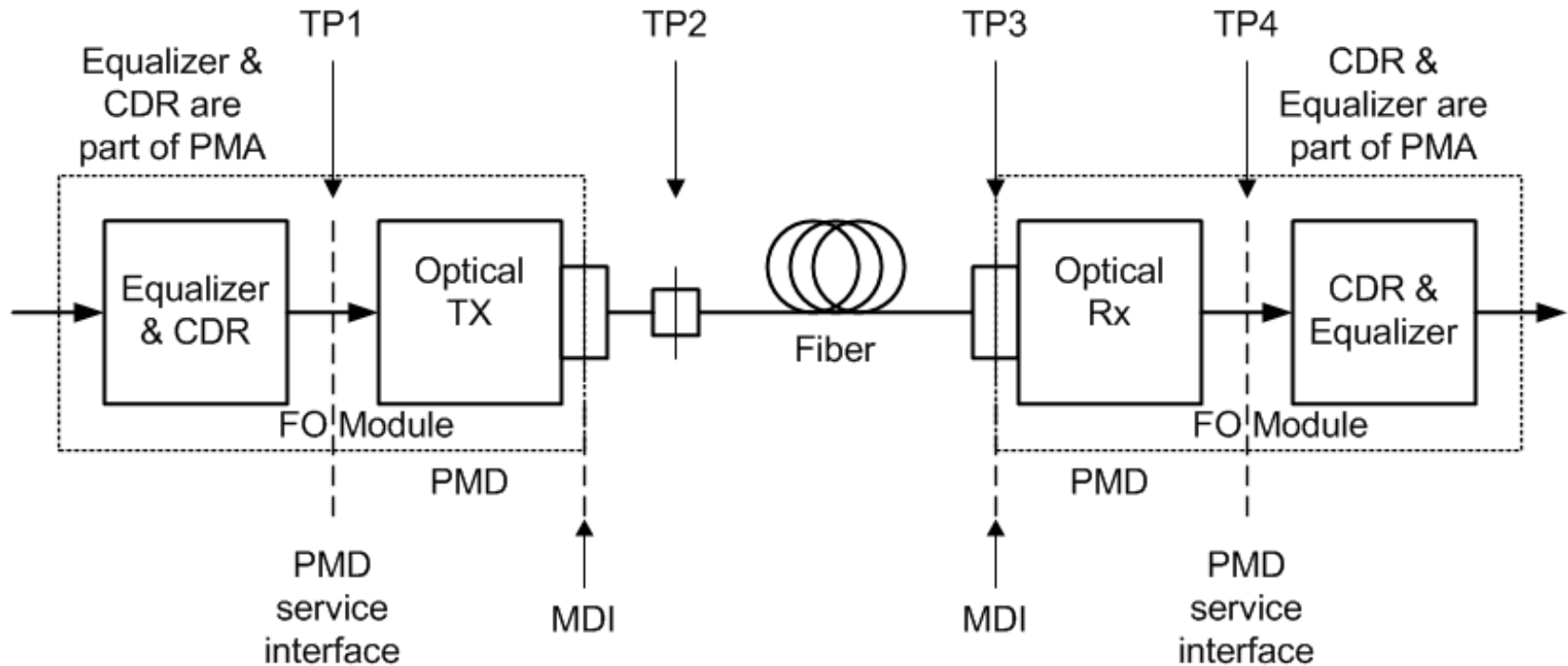


Figure 1

- 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 SR4 with FEC: Tx Link Model Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		4.1865 (1.42 E-5)	FEC corrects BER to < 0.5 E-15
Center Wavelength, min	nm	840	
Spectral Width, max	nm	0.6	
OMA at max TDP, min	dBm	-3	
Extinction ratio, min	dB	4	
Tx output transition times, 20% -80%, max	ps	21	
RIN <sub>12</sub> OMA, max	dB/Hz	-130	
RIN coefficient		0.7	
MPN coefficient		0.3	
Modal Noise Penalty	dB	0.15	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 FEC: Rx Link Model Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		4.1865 (1.42 E-5)	FEC corrects BER to < 0.5 E-15
Wavelength, min	nm	840	
Rx sensitivity (OMA), max	dBm	-10.55	-8.3 dBm at Q = 7.034
Rx Bandwidth, min	MHz	17,918	
RMS base line wander coefficient		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 FEC: Link Model Channel Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		4.1865 (1.42 E-5)	FEC corrects BER to < 0.5 E-15
Reach	m	120	
Fiber Attenuation	dB/km	3.5	For 850 nm center wavelength
Dispersion min Uo	nm	1316	
Dispersion So	ps/nm <sup>2</sup> 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	7.55	Model output
Connector & splice loss allocation	dB	1.5	
Fiber Insertion loss	dB	0.43	Model output
Allocation for penalties at max TDP	dB	4.41	Model output
Allocation for target TP4 eye at max TDP	dB	1.21	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 as examples.

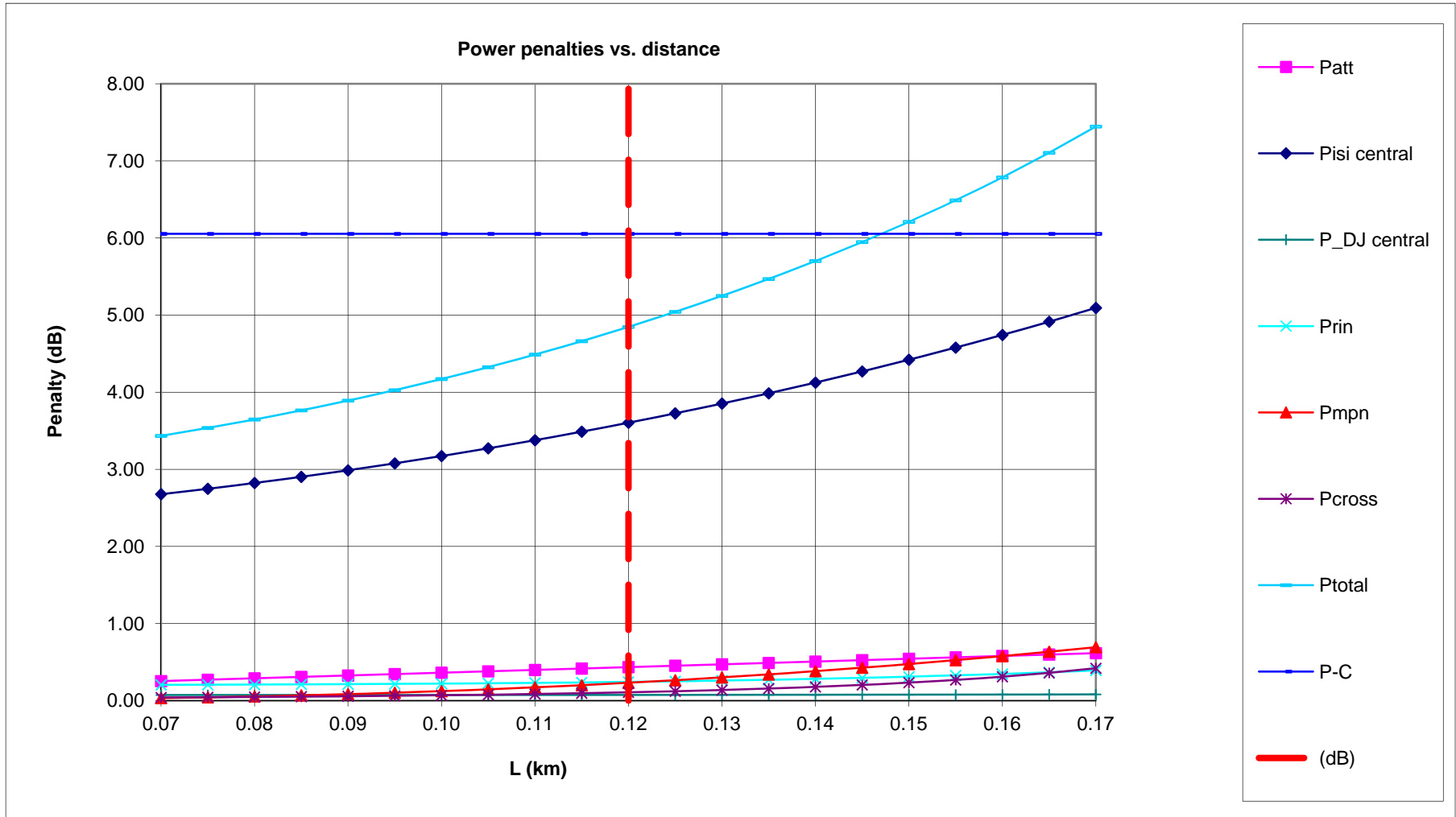
# 100G SR4 with FEC: Link Model Jitter Attributes (each lane)

Parameter	Unit	100G SR4	
Signal rate	GBd	25.78125	
Q (BER)		4.1865 (1.42 E-5)	FEC corrects BER to < 0.5 E-15
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	0.16	
TP4 J2, max	UI	0.55	Model output
TP4 TJ at BER, max	UI	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 86 and shown in above Figure 1. Note that TP1 is downstream of the input CDR and equalizer for an optical transmitter.

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



- The above chart is provided by the example link model.
- It does not show the power required for the target TP4 eye opening,  $P_{eye}$ , nor include  $P_{eye}$  in  $P_{total}$ . For the example link model,  $P_{eye}$  at 120 m equals 1.21 dB.
- Note for this example  $P_{isi}$  central is at the recommended max limit of 3.6 dB at 120 m.