Proposal for 400GE Optical PMD for 2km SMF Objective based on 4 x 100G PAM4

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Summary

- This presentation provides a baseline proposal for
  - 2 km reach on duplex SMF (400GBASE-FR4)
- Approach is based on 100G/λ transmission on four CWDM wavelength channels using PAM4 signaling
- Link budget is based on KP4 FEC as a placeholder.

Supporters and Contributors

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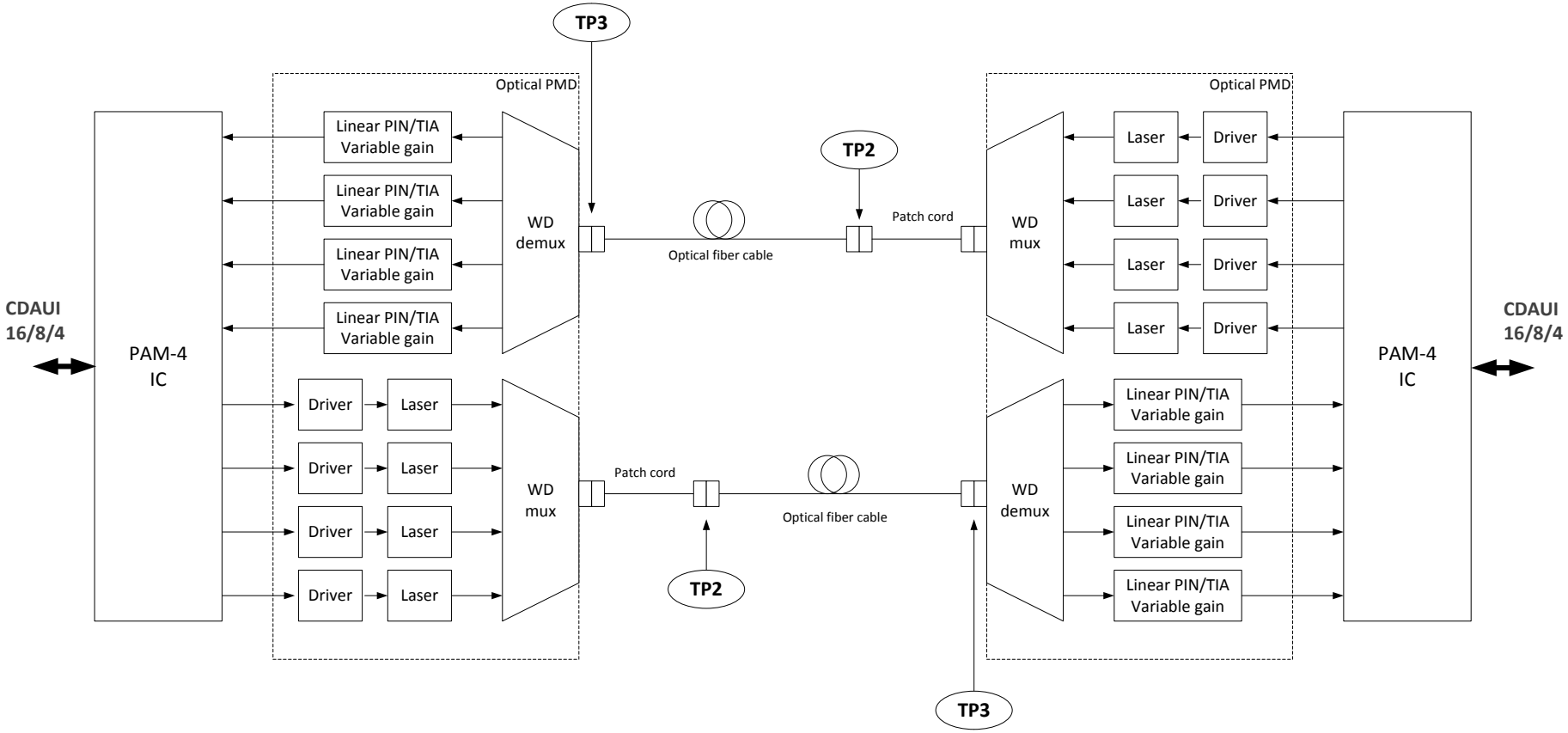
PMD Block Diagram – for Duplex SMF (2 km reach)

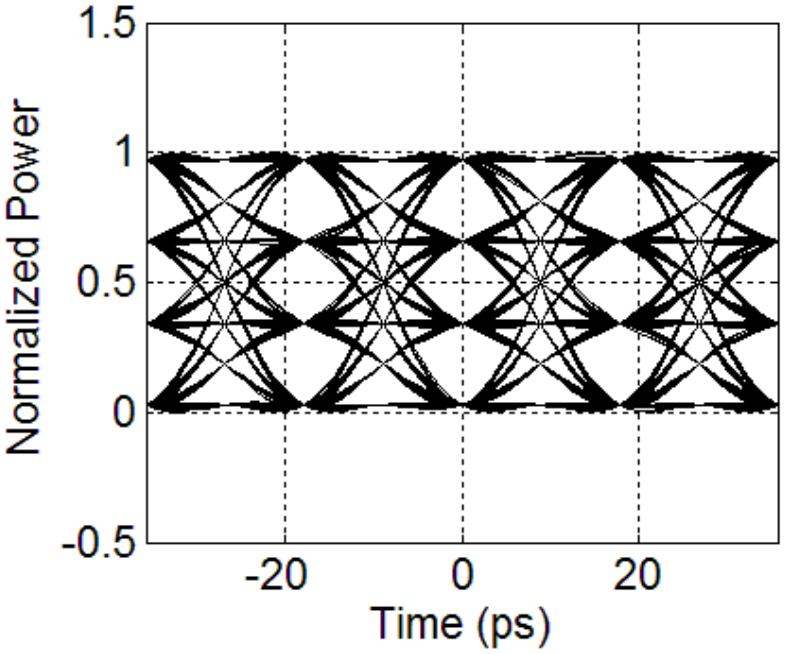


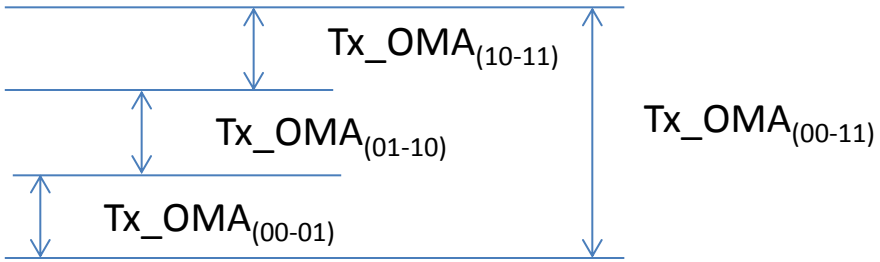
Transmitter Optical Specifications 4x100G PAM4

Description	400GBASE-FR4	Unit	Note
Input signaling rate, each lane (range)	103.125 +/-100 ppm	Gb/s	
Output signaling rate, each lane (range)[3]	106.25 +/-100 ppm	Gb/s	* Based on KP4 FEC
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm	* Aligned to 40GBASE-LR4 CWDM wavelength grid
Average launch power, each lane (max)	4.5	dBm	
Average launch power, each lane (min)	1.5	dBm	
Outer Optical Modulation Amplitude (OMA), each lane (max)[1,4]	6	dBm	
Inner Optical Modulation Amplitude (OMA), each lane (min)[2]	-2.8	dBm	
Average RIN, each lane (max)	-142	dB/Hz	
Optical return loss tolerance (max)	26	dB	
Transmitter reflectance (max)	-26	dB	
Extinction Ratio (min)[1]	5.5	dB	
Cascaded transmiter 3 dB electrical upper cutoff frequency (min)	20	GHz	From DAC input to TP2 (Informative)
Total harmonic distortion (max)	3	%	TBR

1. Measured with 10G test pattern for outer eye (00 to 11) modulation amplitude
2. Measured with 10G test pattern for minimum inner eye (00 to 01, 01 to 10, 10 to 11) modulation amplitude
3. Example only. Actual signaling rate will depend on final FEC selection
4. Outer Optical Modulation Amplitude min is not defined but will be no less than three times the minimum inner optical modulation amplitude.

Transmitter Specifications





- Max OMA and ER specified based on outer $Tx\_OMA_{(00\text{-}11)}$
- Sensitivity and link budget based on inner $Tx\_OMA_{(00\text{-}01,01\text{-}10,10\text{-}11)}$
  - Spec applies to minimum of 3 inner eye transitions

Receiver Optical Specifications

Description	400GBASE-FR4	Unit	Note
Input signaling rate, each lane (range)	106.25 +/-100 ppm	Gb/s	
Output signaling rate, each lane (range)	103.125 +/-100 ppm	Gb/s	
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm	
Damage threshold (min)	7.0	dBm	
Average receive power, each lane (max)	4.5	dBm	
Average receive power, each lane (min)	-2.5	dBm	
Receiver Overload (Outer) (OMA), each lane (min)[1]	6	dBm	
Receiver Sensitivity (Outer) (OMA), each lane (max)[1]	-3.0	dBm	At pre-FEC BER of 2.1E-4
Receiver Sensitivity (Inner) (OMA), each lane (max)[2]	-7.8	dBm	At pre-FEC BER of 2.1E-4
Receiver reflectance (max)	-26	dB	

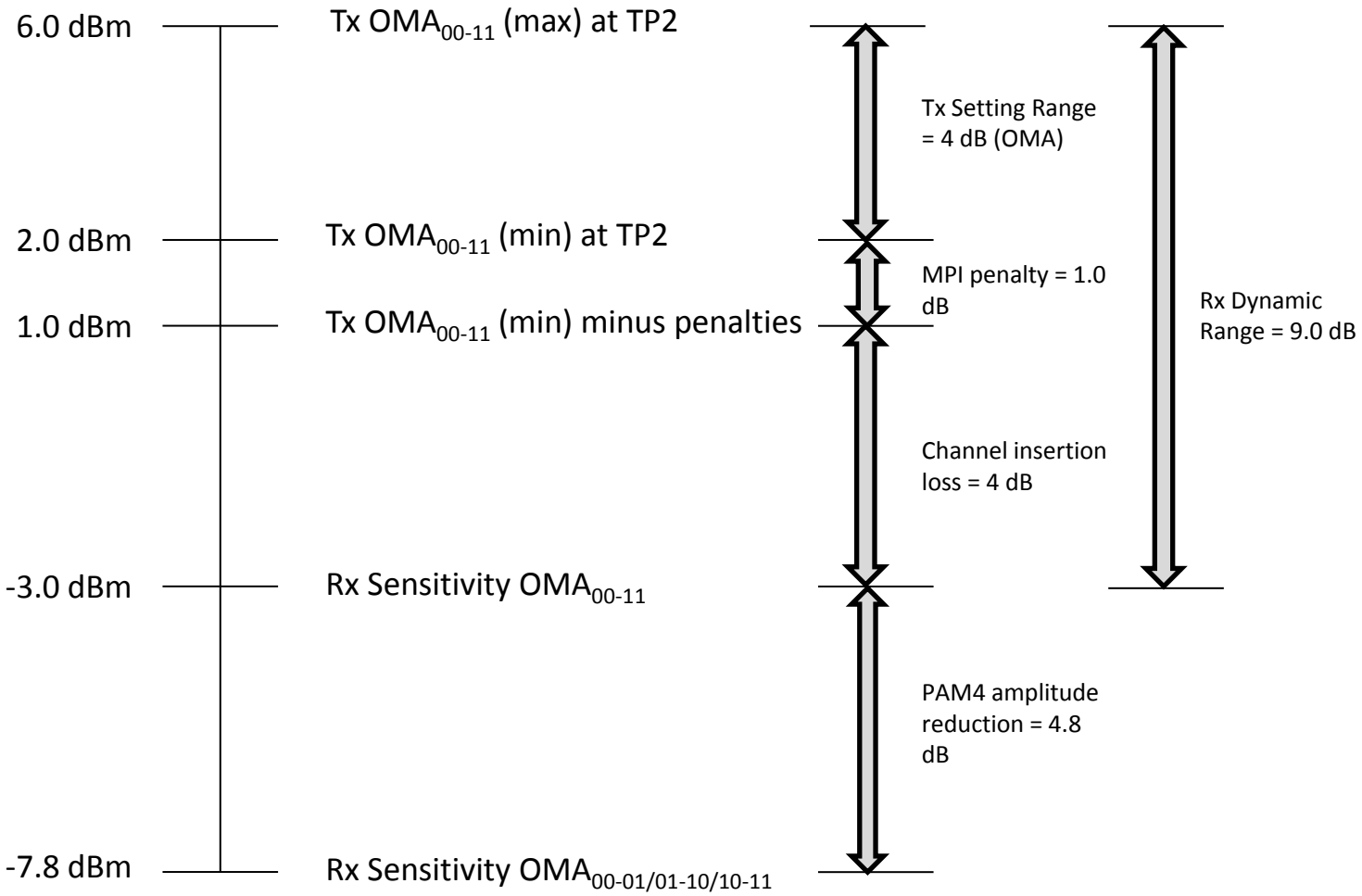
1. Informative spec on Rx sensitivity outer amplitude OMA
2. Normative specification Rx sensitivity each lane inner eye (00-01, 01-10, 10-11)
   - Based on back-to-back with worst case compliant transmitter
   - The three lanes not being tested shall be at 3dB higher power than the lane under test

Optical Link Budget

Description	400GBASE-FR4	Unit	Note
Power budget at maximum link penalty	5.0	dB	
Operating distance	2000	m	
Channel insertion loss	4.0	dB	
Allocation for MPI penalty	1.0	dB	
Additional insertion loss allowed	0	dB	

Reference: conroy_3bs_01a_0914
Showed BER over 2km of 2.5×10^{-4}

2km PAM4 Optical Link Model



Summary

- Baseline proposal for a 2km SMF 400GE PMD based on PAM4 modulation with 100G/λ using 4 wavelengths on a CWDM grid
- Sensitivity defined based on a KP4 FEC with a 2.1E-4 BER threshold for a 1E-15 corrected BER

Backup – Link budgets for 2km PAM proposals

	cole-PAM4-2km			lewis-PAM4-2km		
	26.6 Gbaud			53.1 Gbaud		
	AOP	OMA		AOP	OMA	
ER, min	4.5			5.5		
Total AOP, max	13.2			10.5		
	-9.0			-6.0		
TP2 Tx max	4.2	4.0	ER=4.5dB	4.5	6.0	ER=7.6dB
Setting range	-4.5	-4.5		-3.0	-4.0	
TP2 Tx min	-0.3	-0.5	ER=4.5dB	1.5	2.0	ER=5.5dB
Ch IL	-5.0	-5.0		-5.0	-5.0	
TP3 Rx min	-5.3	-5.5		-3.5	-3.0	
Demux loss	-3.0	-3.0		-2.0	-2.0	
PD min	-8.3	-8.5		-5.5	-5.0	
TP3 Rx Sensitivity, OMA00-01		-10.3			-7.8	
Additional penalties		1.2			0.0	Penalties embedded in CH IL
TP3 OMA00-01 equivalent at PD		-14.5			-9.8	