

Technical Discussion on 400GbE PMD for SMF Objectives

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- This presentation is in support of our proposals.
 - “takahara_3bs_01_1114” and “isono_3bs_01_1114”
- Technical discussion on key parameters in SMF objectives for 400GbE PMD
 - Receiver sensitivity
 - Bandwidth
 - Dispersion tolerance
 - MPI tolerance

Receiver Sensitivity

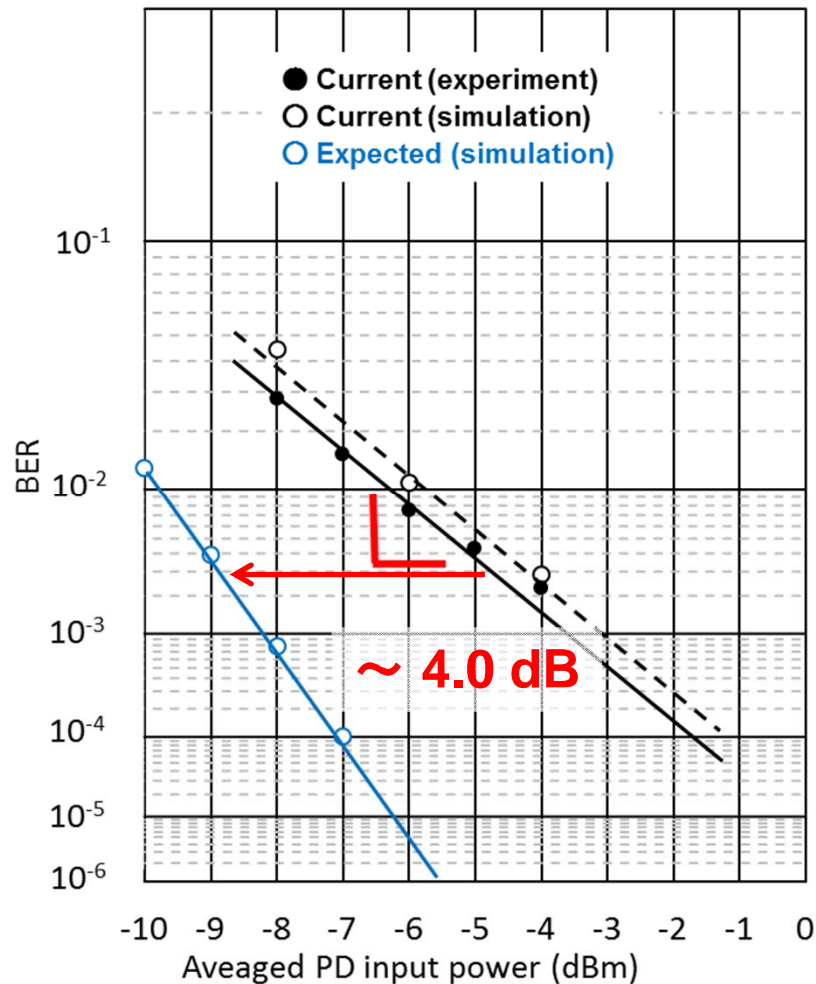
Specifications	Ref: NRZ 4x25G	NRZ 8x50G	PAM-4 8x50G	PAM-4 4x100G	DMT 4x100G
Proposed Sensitivity with Mux/Demux	-10.6	-12.6 ^(*1)	-11.6 ^(*3)	-8.4 ^(*1)	-5.0 ^(*6)
Measurement result		-8 ^(*2)	-8.0 ^(*4)	NG ^(*4) -5.3 ^(*5)	-5.0 ^(*6)

- 8x50G NRZ and 8x50G PAM-4 sensitivities are slightly better than 4x25G NRZ mainly because of FEC.
- In the real measurement, 8x50G NRZ measurement could not show clear advantage in sensitivity.

*1 Zhu_3bs_01_0714, @BER of 1e-3
 *2 ECOC2014 PD.2.4, @BER of 2e-4
 *3 xu_400_01a_0114 @BER of 3e-4
 *4 sone_3bs_01_0914
 *5 Bhatt_3bs_01_0714
 *6 takahara_3bs_01a_0914

Expected Improvement for 4x100G DMT

The receiver sensitivity for 4x100G DMT is improved to about 4dB in the target specification as shown in “takahara_3bs_01_1114”.

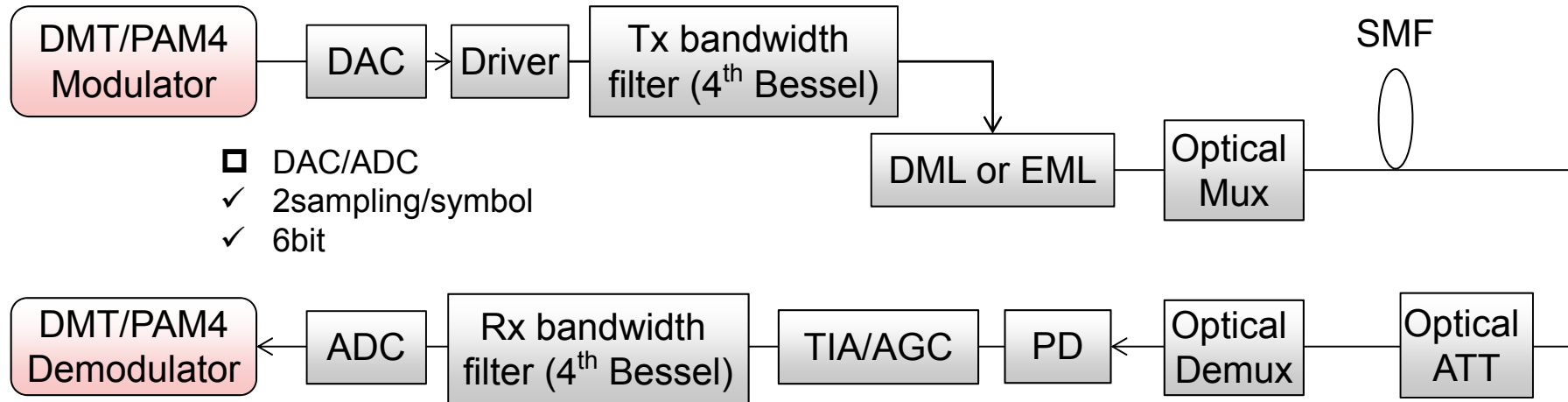


Parameter	Current	Target	Unit	Note
Sampling rate	64	←	GS/s	
TX bandwidth	12	18	GHz	EVB. Impairment was included
RX bandwidth	16	21	GHz	EVB. Impairment was included
Optical modulation index	0.42	0.45		
DML RIN	-148	←	dB/Hz	
Input referred noise	20	12	pA/ $\sqrt{\text{Hz}}$	Linear new TIA will be selected

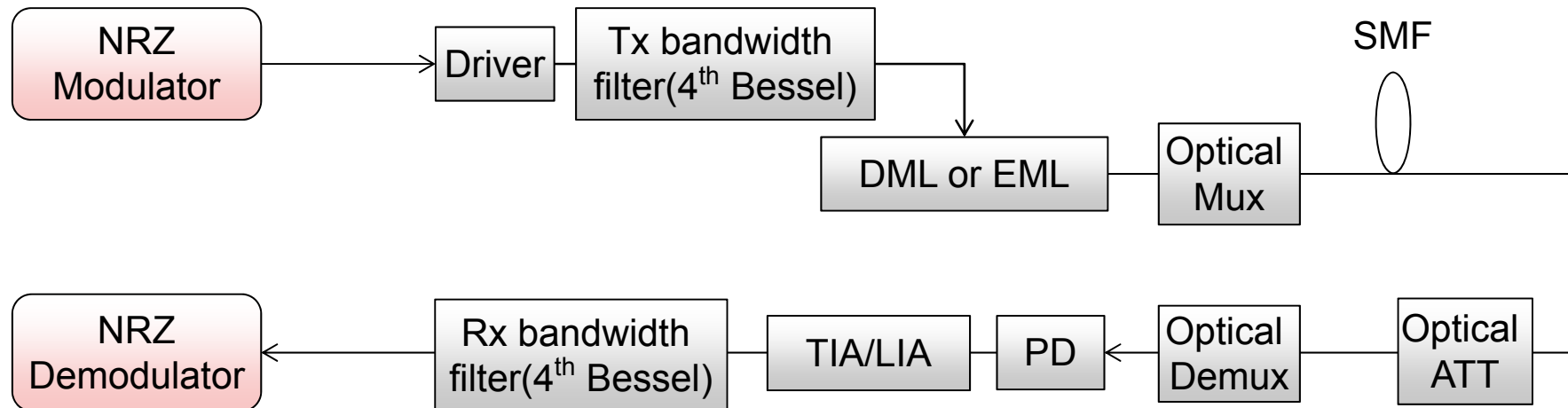
Simulation Platform for Performance Comparison



■ For 4x100G DMT, 8x50G PAM4 and 4x100G PAM4

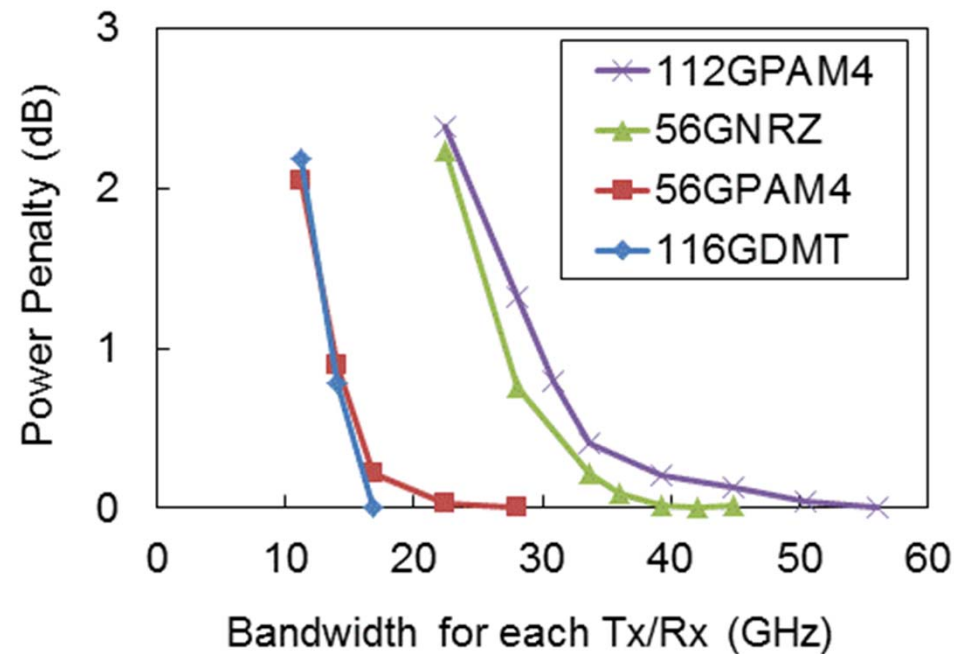


■ For 8x50G NRZ



In these models, the ideal CDR is used.(without phase margin)

Bandwidth Dependence



- 50G NRZ and 100G PAM-4 require approximately twice bandwidth than 50G PAM-4 and 100G DMT.
- 100G PAM4 and 50G NRZ are not preferred because of its highest requirements on Tx/Rx bandwidth.
- DMT is clearly efficient from the point of bandwidth requirement per bit.

Simulation Condition for Dispersion Tolerance

- Wavelength allocation for each case (ref.: xu_3bs_01_0714)

Allocation case	Nominal wavelength (nm)							
LAN-WDM	1295.56	1300.05	1304.58	1309.14				
8ch. option1	1286.66	1291.1	1295.56	1300.05	1304.58	1309.14	1313.73	1318.35
8ch. option2	1295.56	1300.05	1304.58	1309.14	1313.73	1318.35	1323	1327.69
8ch. option3	1277.89	1282.26	1286.66	1291.1	1295.56	1300.05	1304.58	1309.14
8ch. option4	1295.56	1297.8	1300.05	1302.31	1304.58	1306.85	1309.14	1311.43

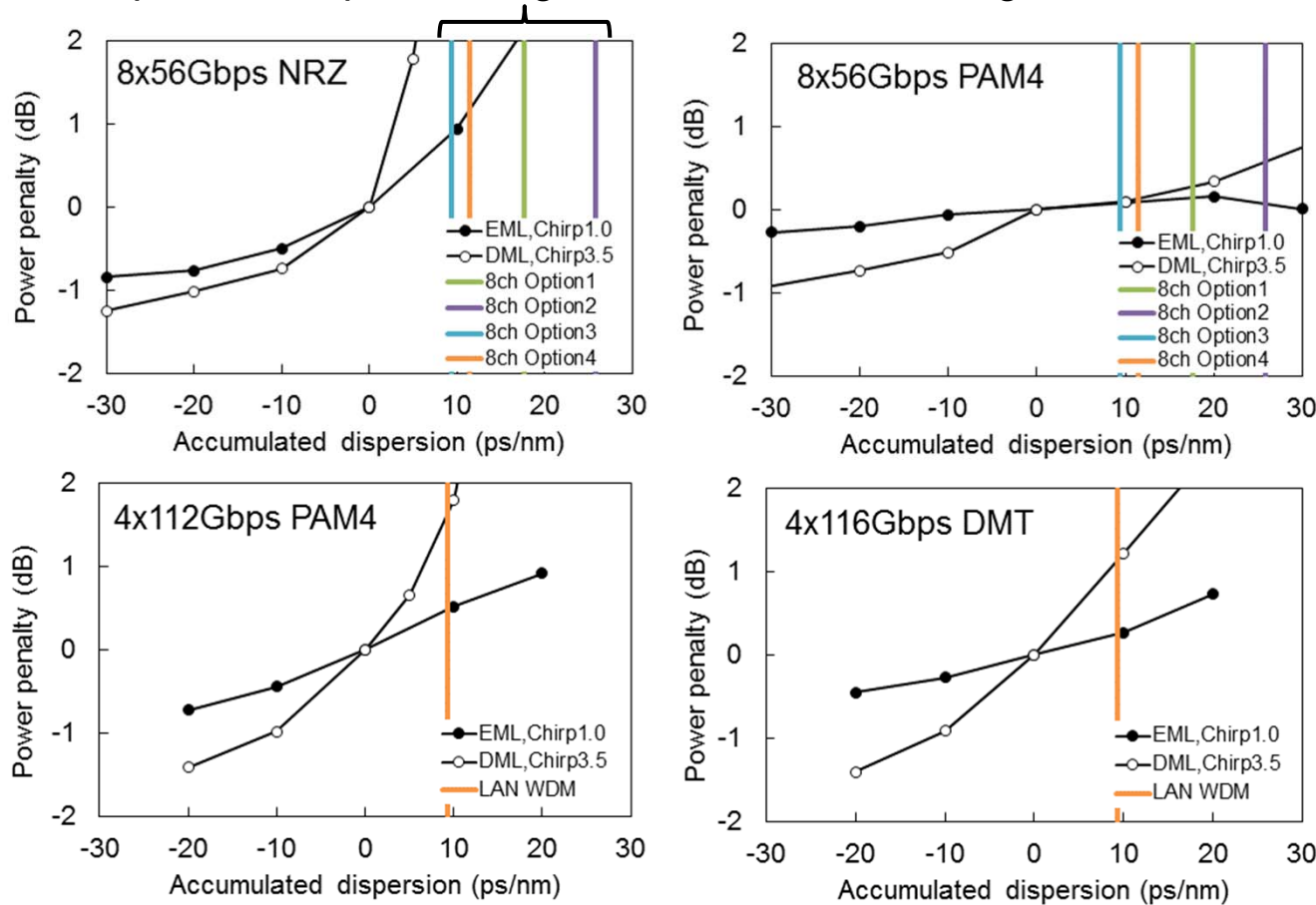
- Channel specification for dispersion (from IEEE802.3ba)

PMD type	Dispersion ^a (ps/nm)		Insertion loss ^b	Optical return loss ^c	Max mean DGD
	Minimum	Maximum			
SMF10km 100GBASE-LR4	$0.2325 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.2325 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	20 dB	0.8 ps
100GBASE-ER4	$0.93 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.93 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	20 dB	0.8 ps

- Optical modulator candidates and typical value for their chirp on simulation
 - DML: chirp 3.5
 - EML: chirp 1.0

Dispersion Tolerance

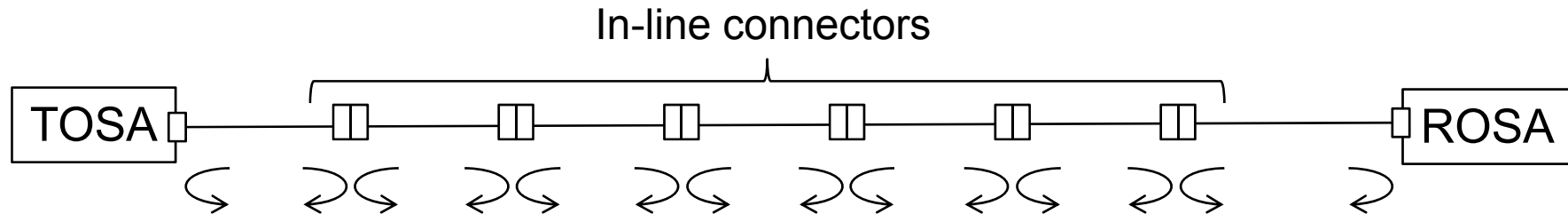
We focus on positive dispersion region because of main degradation due to positive chirp.



- 8x50G NRZ has large difference on dispersion penalty due to wavelength allocation and chirp of the Tx modulator.
- 8x50G NRZ is not preferred because of its poor tolerance to dispersion.
- 4x100G DMT and 8x50G PAM4 practically support 10km PMD.

Reference Model for MPI Specification

■ Reference model

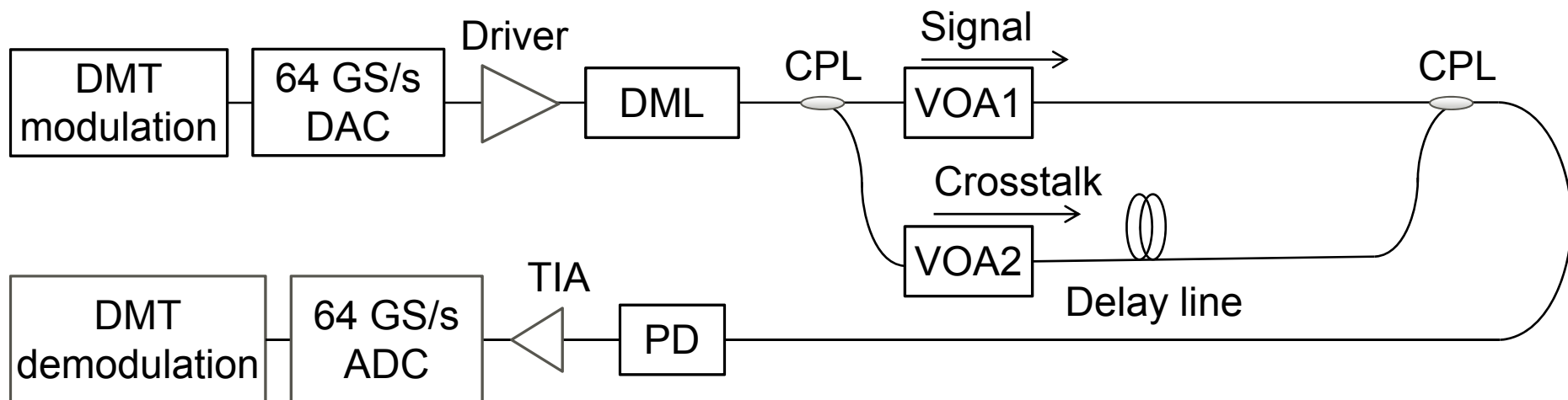


Case	Reflectance			Note
	TOSA	In-line Connectors	ROSA	
1	-26dB	4 connectors, -35dB	-26dB	Reports in September meeting
2	-26dB	4 connectors, -26dB* ¹	-26dB	Increase of reflectance of in-line connectors
3	-26dB	6 connectors, -26dB* ¹	-26dB	Increase of reflectance and the number of in-line connectors

*1: Reference from 100GBASE-LR4 draft

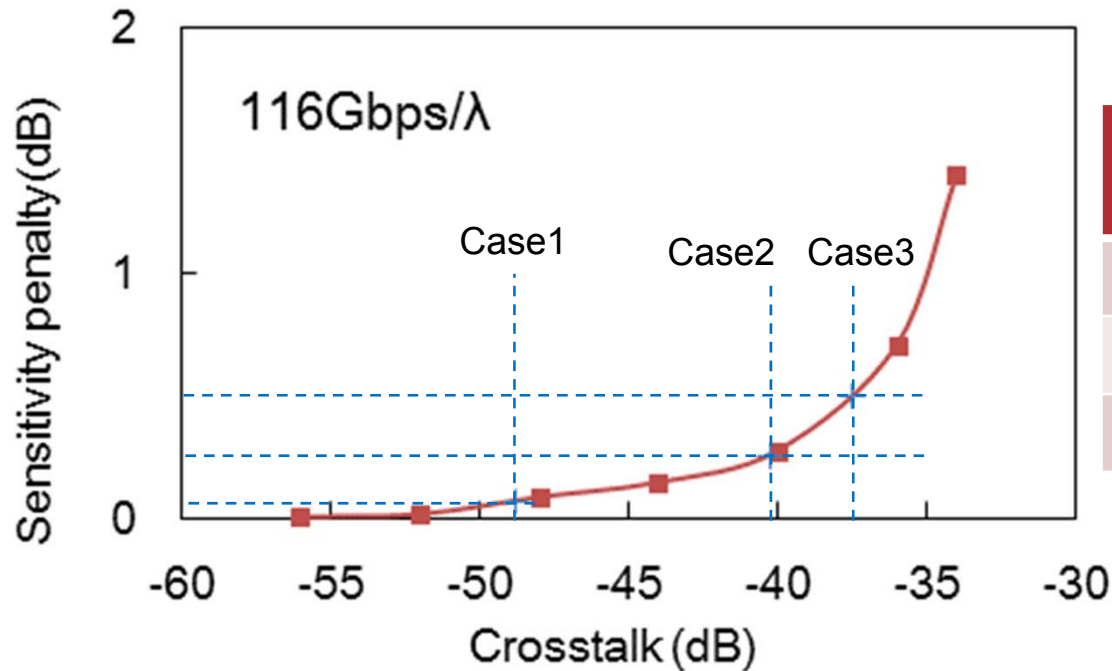
Simulation Model for MPI

- 116 Gbps Discrete Multi-Tone (DMT)
- Use of target parameters for 4x100G DMT (“takahara_3bs_01_1114”)
- MPI emulated by interfering signal with attenuated signal copy
- Adjusted for worst case condition
 - Aligned polarization of signal with copy/crosstalk signal for maximum interference



(DML: Directly modulated laser, VOA: Variable optical attenuator, CPL: Coupler, PC: Polarization controller, TIA: Trans-impedance amplifier)

MPI Tolerance for DMT



Case	Crosstalk*1	Sensitivity penalty
1	-49dB	<0.1dB
2	-40dB	0.3dB
3	-37.5dB	0.5dB

(Ref.: farhood_01_1112)

- -37.5dB crosstalk translates to 0.5dB sensitivity penalty.
- DMT can allow degradation for -26dB reflectance and 6 connectors.

- Performance comparison on key parameter for 400G PMD alternatives in 10km SMF objectives.
 - 4x100G DMT and 8x50G PAM4 are preferred from the point of view about requirements on Tx/Rx bandwidth and dispersion tolerance.
 - 4x100G DMT has advantage for cost and power consumption over 8x50G PAM4 as shown in “isono_3bs_01_1114”.

- MPI tolerance for DMT (with worst case conditions)
 - Less than 0.5dB in our proposed model
 - Reflectance of TOSA, ROSA and in-line connector is -26dB(common specification).
 - The number of in-line connector is increased to 6(worse specification).



Thank you