Multiple reflected MPI analysis for 100G-PAM8 Transmission

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Overview

- Using photonic simulation tool, *VPItransmissionMaker^{TM}*, a further multiple reflected MPI analysis is carried out.

- A transmitter model for PAM-8 modulation with equal OMA symbols, A BERT model for PAM-8 based on Gaussian distributed histogram and 2 types of MPI emulator models, are introduced to calculate a PAM-8 transmission performance.
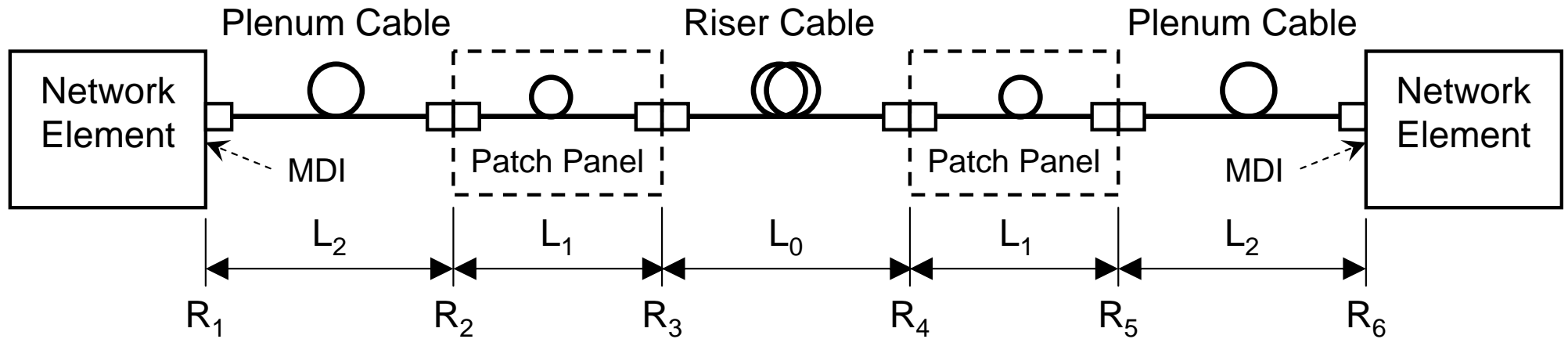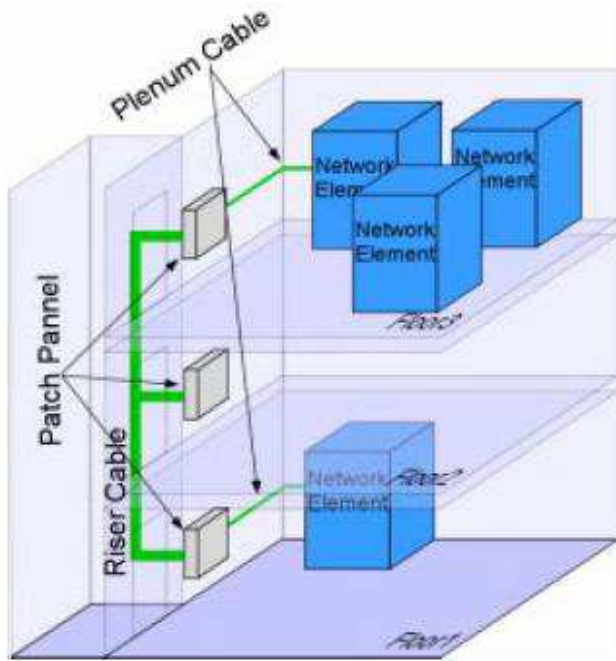
SMF-Link Model for 100G-PAM8


Table. Link model parameters

| Items	Symbol	Value	Remarks
MDI Reflectance (Tx/Rx)	R_1, R_6	Parameters	
Link Connector Reflectance	R_2 to R_5		
Riser Cable Length	L_0	476 m	Total: 500 m
		26 m	Total: 50 m
Cable Length in Patch Panel	L_1	2 m	
Plenum Cable Length	L_2	10 m	
Fiber loss	IL_{fiber}	0.3 dB/km	Typical
Connection loss	IL_{con}	0.5 dB	Typical

Model (nicholl_01b_0312)

Assumption: Patch panel and plenum cable have a same fibre length, respectively.

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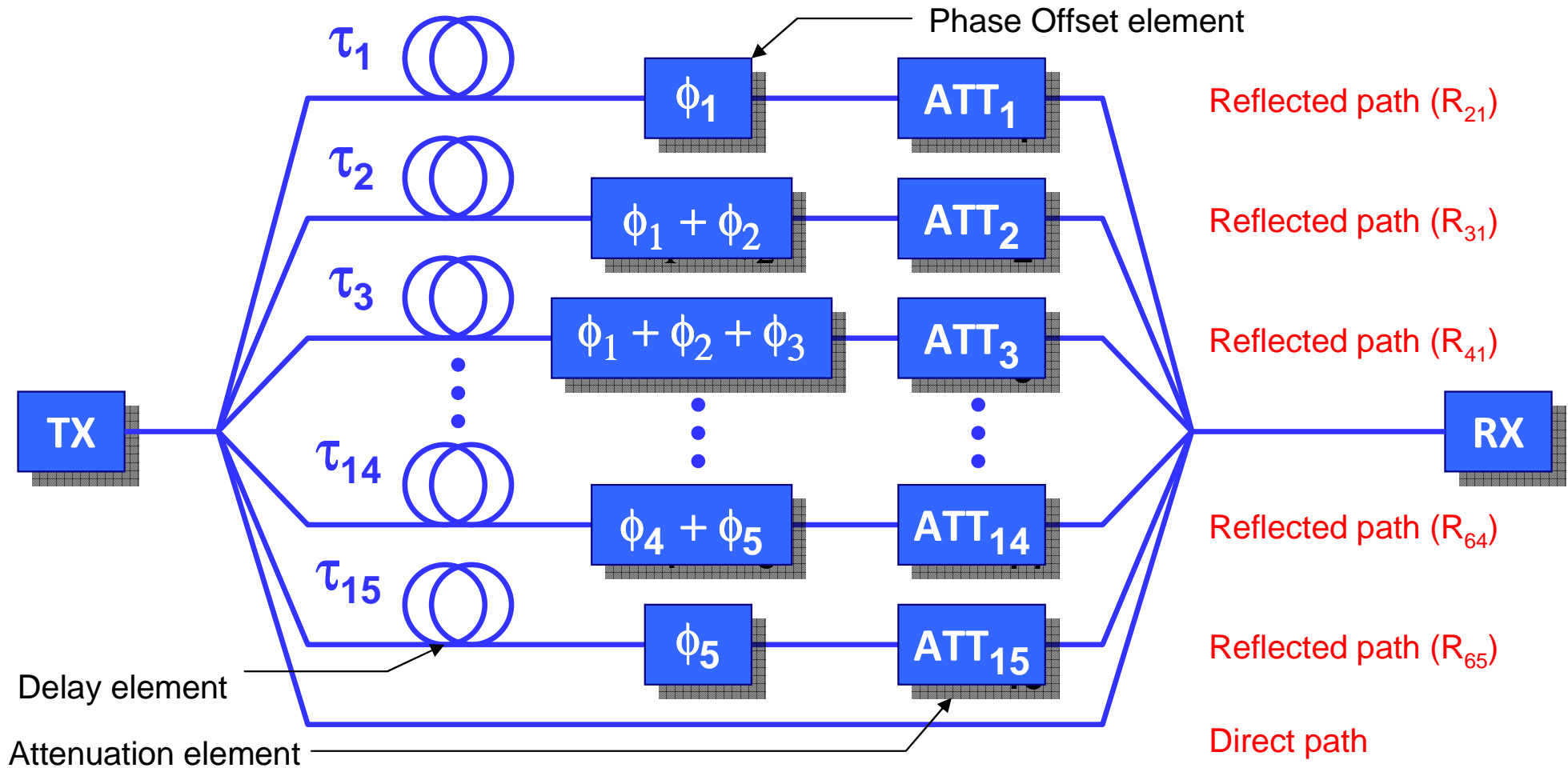
Simulation model (VPI) for PAM8 system
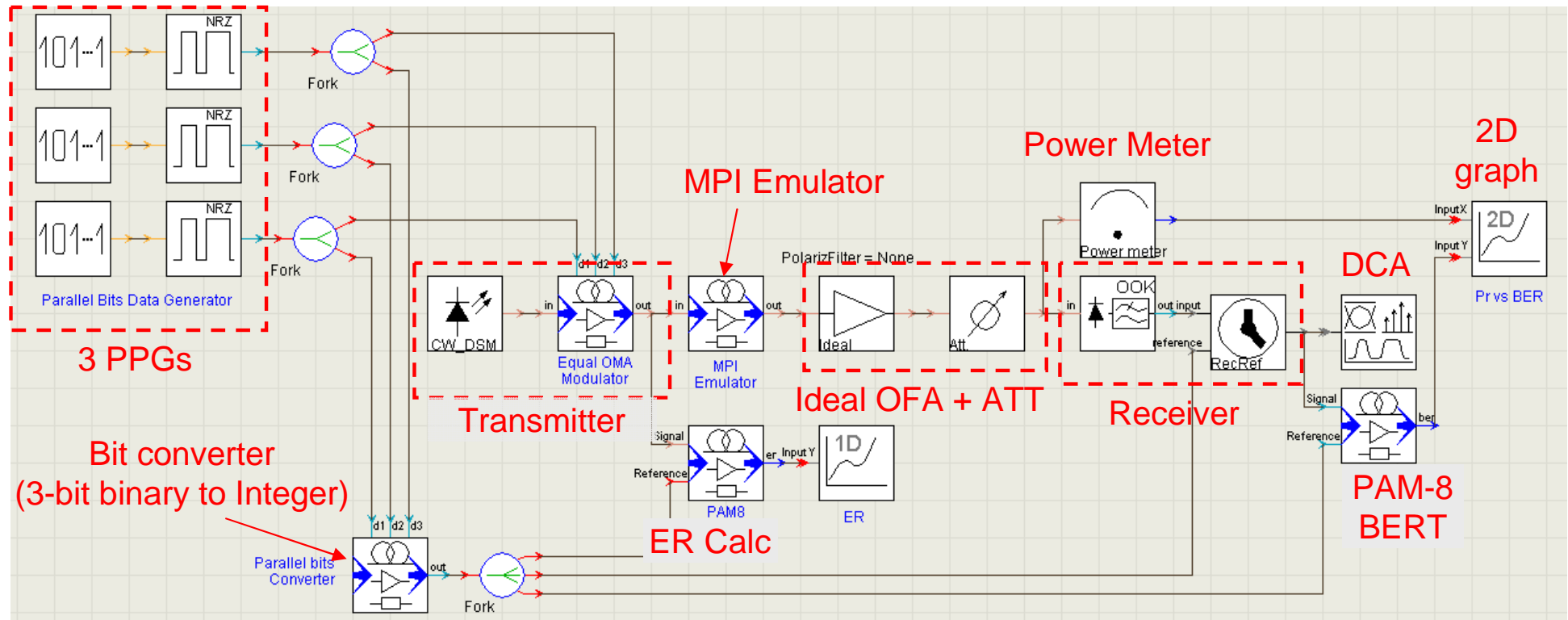
1. Three parallel Pulse Pattern Generators generate each independent PRBS pattern (2^7-1).
2. TX model is based on "nicholl_01b_0312," with taking extinction ratio into account.
3. MPI Emulator is created with a similar concept shown in "nicholl_01b_0312."
4. Receiver model is a default model, Rx_OOK.vtmg, from VPI.
5. Bit converter sort out symbol-by-symbol integers of PAM level and use as a reference.
6. PAM-8 BERT calculate bit error ratio using the formulas, erfc() in "nicholl_01b_0312."

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MPI emulator modeling
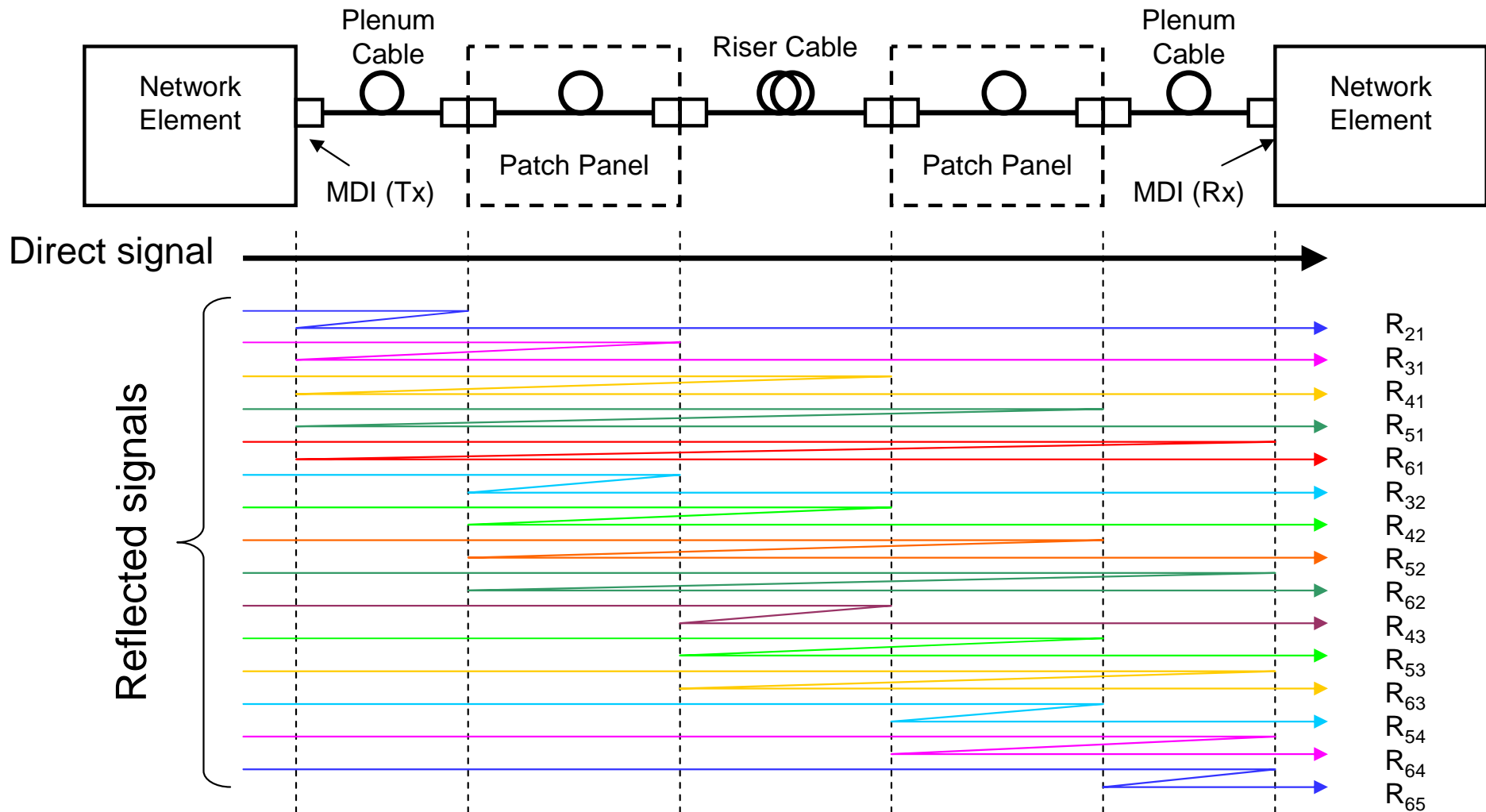
All 15 reflected signals are combined with a direct signal.

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MPI Emulator Model #1

Both delay and attenuation elements are set to the specified values, and all phase offset elements are set to 90 degrees (the largest Link RIN noise) as the worst case calculation.

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MPI Emulator Model #2

Both delay and attenuation elements are set to the specified values, but each phase difference from direct path is set as depending on a combination of 5 different random values.

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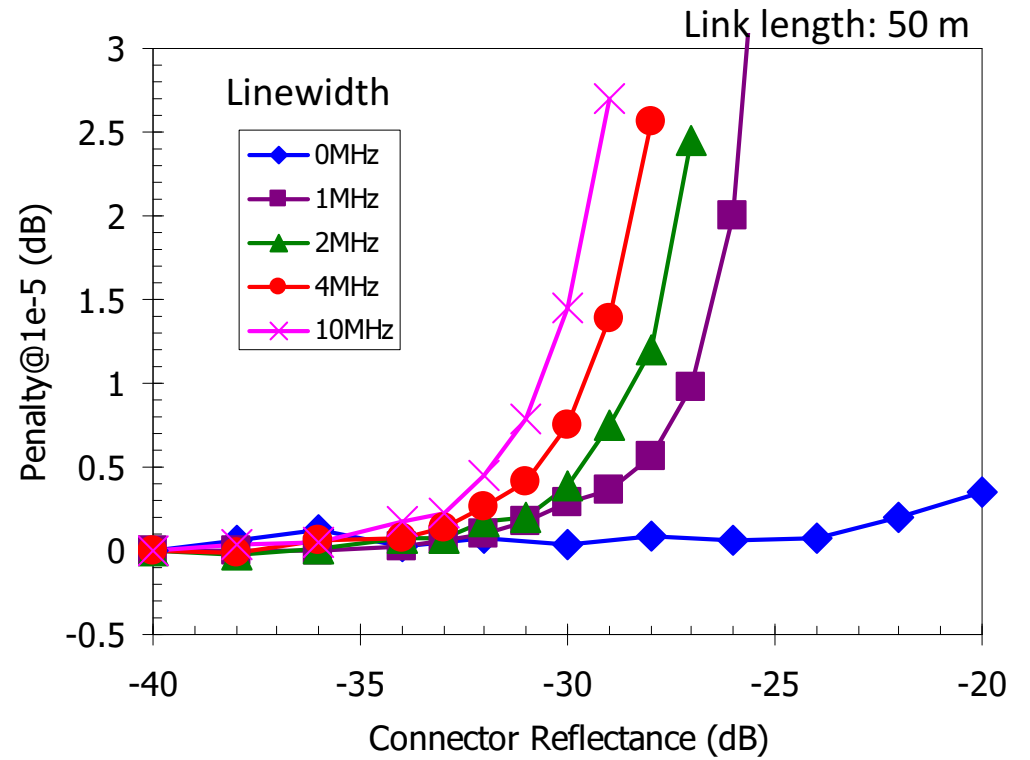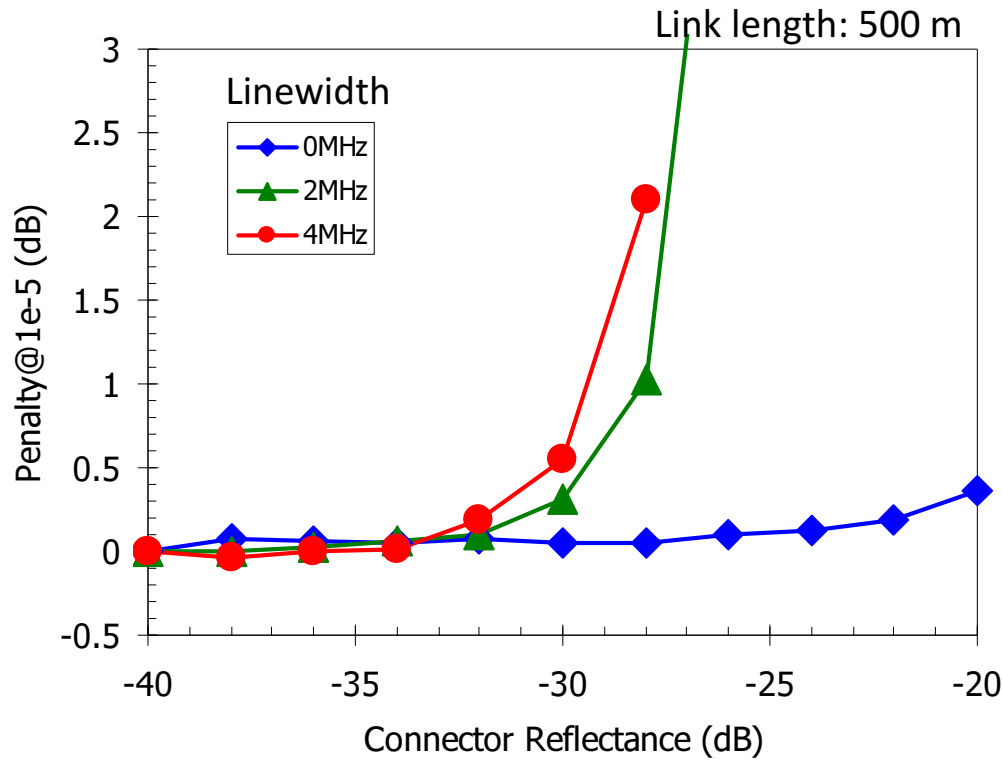# Link RIN penalty: Model #1

Link length: 500 m

Link length: 50 m

Table1. PAM-8 Penalty (500 m)

R (dB)	0 MHz	2 MHz	4 MHz
-26	0.10	5.15	N/A*
-30	0.05	0.31	0.55
-35	0.05	0.05	0.01

Table2. PAM-8 Penalty (50 m)

R (dB)	0 MHz	1 MHz	2 MHz	4 MHz	10 MHz
-26	0.06	2.00	N/A*	N/A*	N/A*
-30	0.04	0.28	0.38	0.76	1.45
-35	0.08	0.01	0.04	0.07	0.11

* N/A: BER curve shows error floor (> 1e-5)

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Link RIN penalty: Model #2

Link length: 500 m

Link length: 50 m
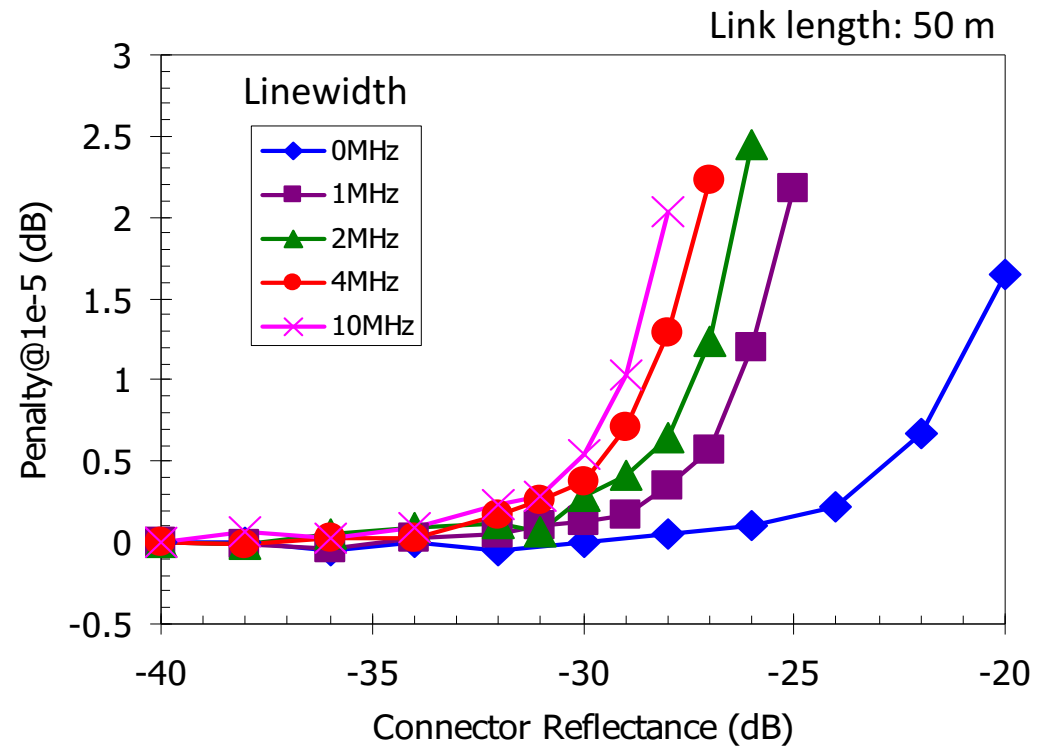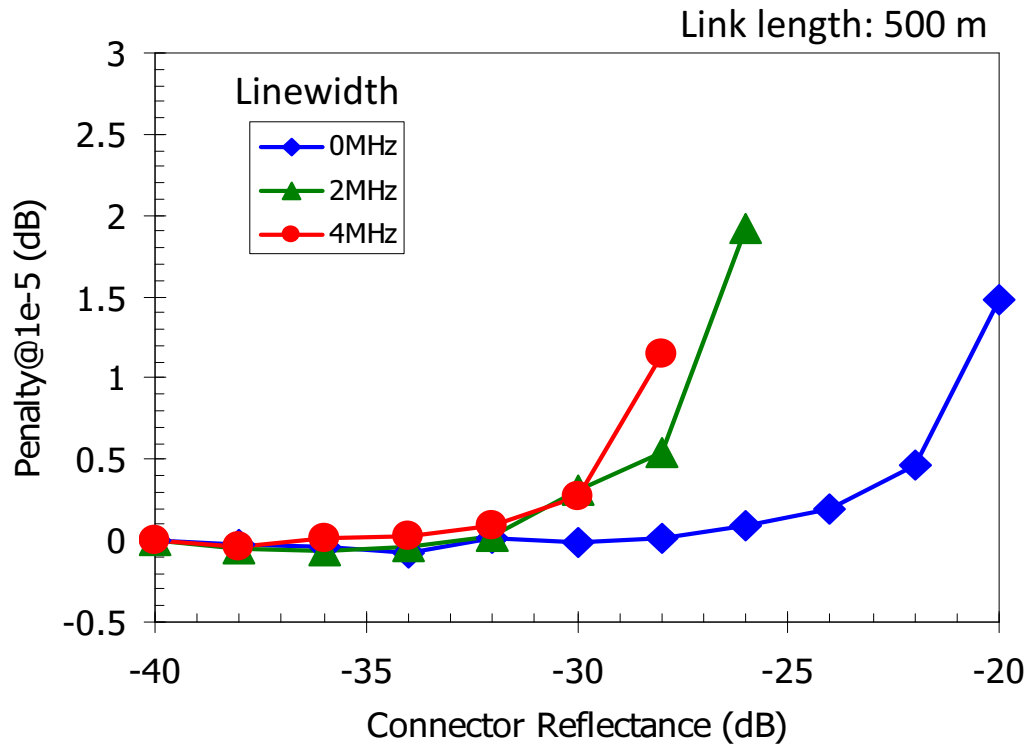
Table1. PAM-8 Penalty (500 m)

R (dB)	0 MHz	2 MHz	4 MHz
-26	0.09	1.92	N/A*
-30	-0.01	0.31	0.28
-35	-0.05	-0.05	0.02

Table2. PAM-8 Penalty (50 m)

R (dB)	0 MHz	1 MHz	2 MHz	4 MHz	10 MHz
-26	0.10	1.19	2.45	N/A*	N/A*
-30	0.00	0.13	0.28	0.37	0.54
-35	-0.02	-0.01	0.08	0.02	0.06

* N/A: BER curve shows error floor (> 1e-5)

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Summary

- A power penalty due to multiple reflected MPI is calculated by Monte Carlo approach with VPI.

- 2 types of MPI model are introduced.

- Results indicate as follows;

  – Penalty depends on a linewidth of laser source, same result as previous Link-RIN analysis (kogure_01_0312).

  – In order to use DFB-LD source with conventional spectral linewidth (~10 MHz), MDI and Link connection reflectance should be, at least, <30 dB.

Thank you!

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# Appendix

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Parameter List of Simulation

Parameters		Value	Units	Remarks
Wavelength	Tx	1309.14	nm	Frequency: 229.0 THz
Spectral width	Tx	0, 1, 2, 4, 10	MHz	
Base Extinction ratio	Tx	6.0	dB	Between highest and lowest
Source RIN	Tx	-149	dB/Hz	
SMSR	Tx	50	dB	100 GHz shifted from main mode
Tx Rise/Fall time	Tx	6.3	ps	20/80%, 9.5 ps (10/90%)
Responsivity	Rx	0.8	A/W	
Rx bandwidth	Rx	32.0	GHz	w/ 4th Bessel filter
Input referred noise	Rx	25	pA/sqrt(Hz)	Dark current: 100pA (negligible)
Symbol rate	Link	37.3	Gbaud	
Link length	Link	50 & 500	m	Refractive index: 1.47, no fiber model
Reflectance	Link	-20 to -40	dB	Including MDI
Phase difference	Link	0 to 90	deg	Randomized, or Fixed at 90 deg
State of Polarization	Link	same as Tx	-	All reflected signals have the same SOP
Data pattern	Link	PRBS 2^7-1	-	Sequence is randomized, 20 times

Tx Rise/Fall time
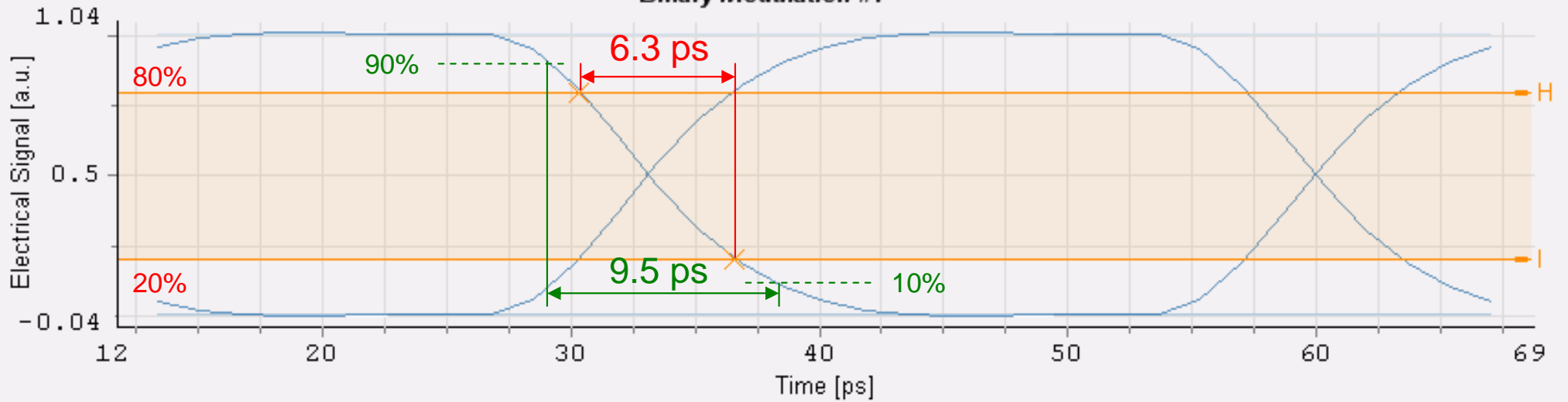
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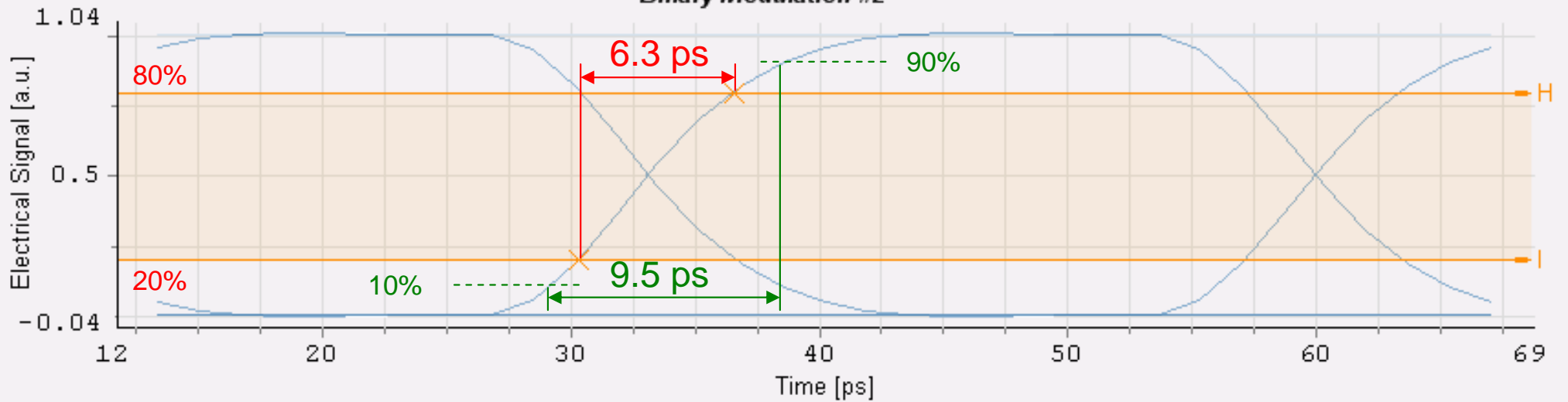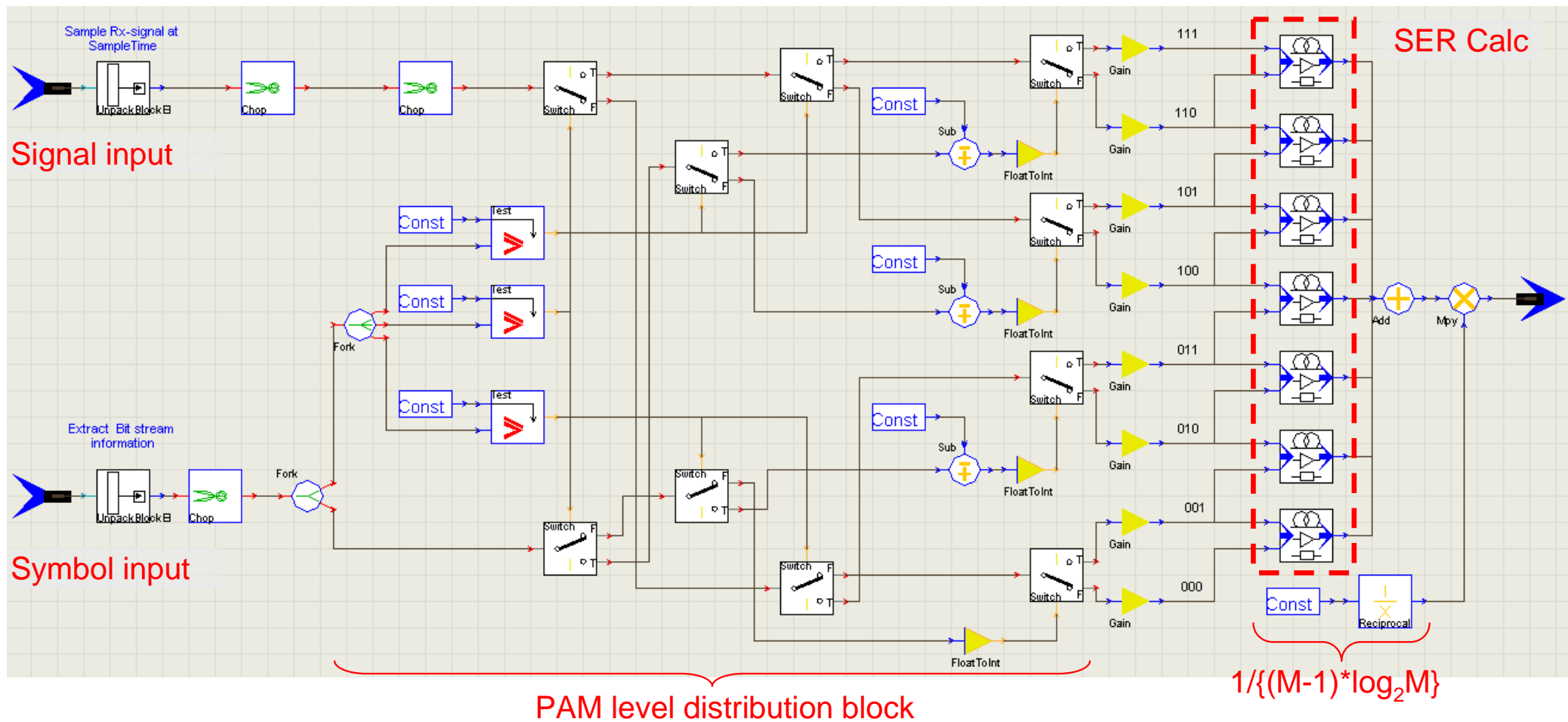
PAM8 BERT w/ Gaussian distributed histogram

- SER calculation is based on Gaussian distributed histogram with only adjacent PAM levels.
- BER calculation is accumulated all SER with $1/\{(M-1)*\log_2 M\}$ correction.
- Mean and standard deviation of each PAM level are collected and calculated.
- The decision threshold of each symbol is optimized to minimize its SER.

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# MPI Emulator Model #1 (VPI Galaxy)
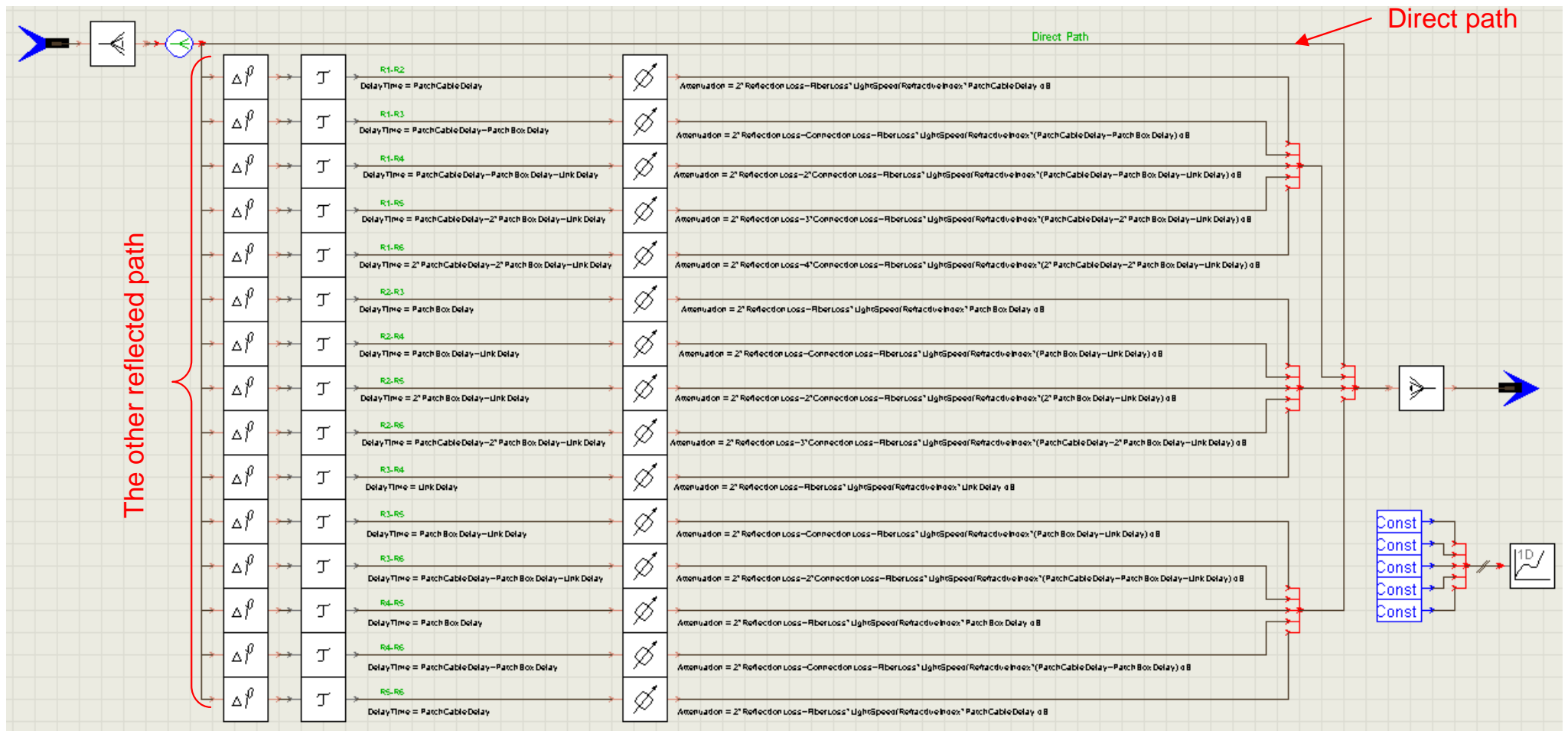
All 15 paths provide specific delay time and attenuation related to its double reflection, and all phase differences from the direct path are 90 degree.

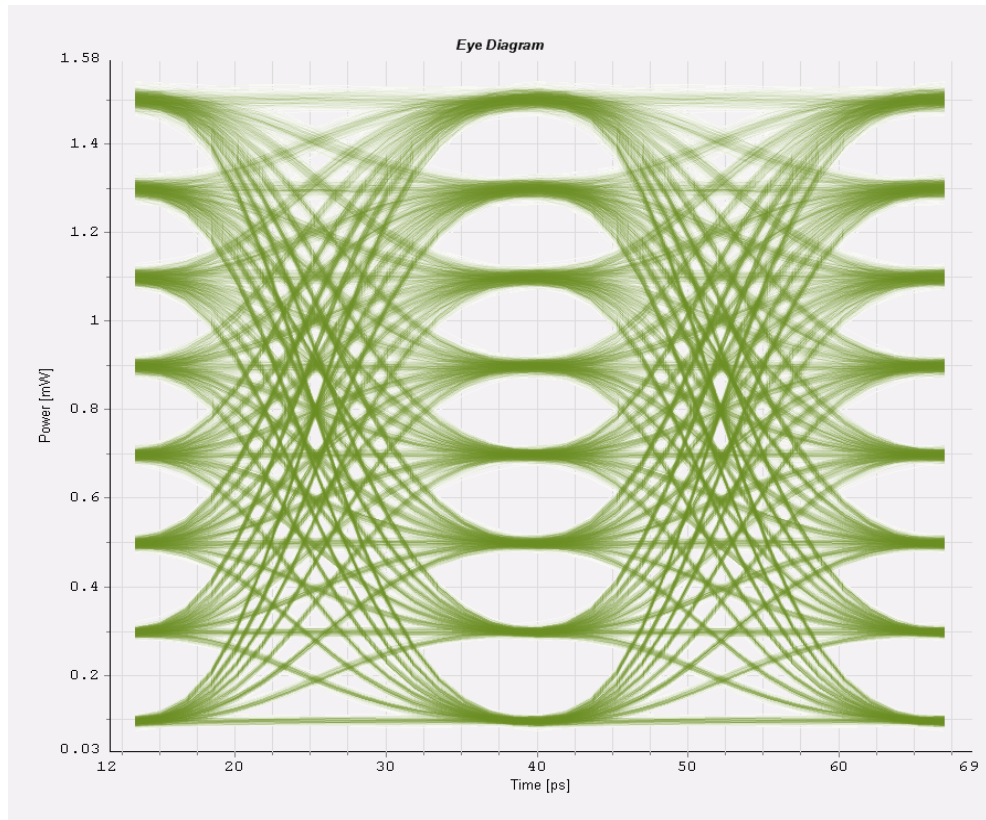# MPI Emulator Model #2 (VPI Galaxy)
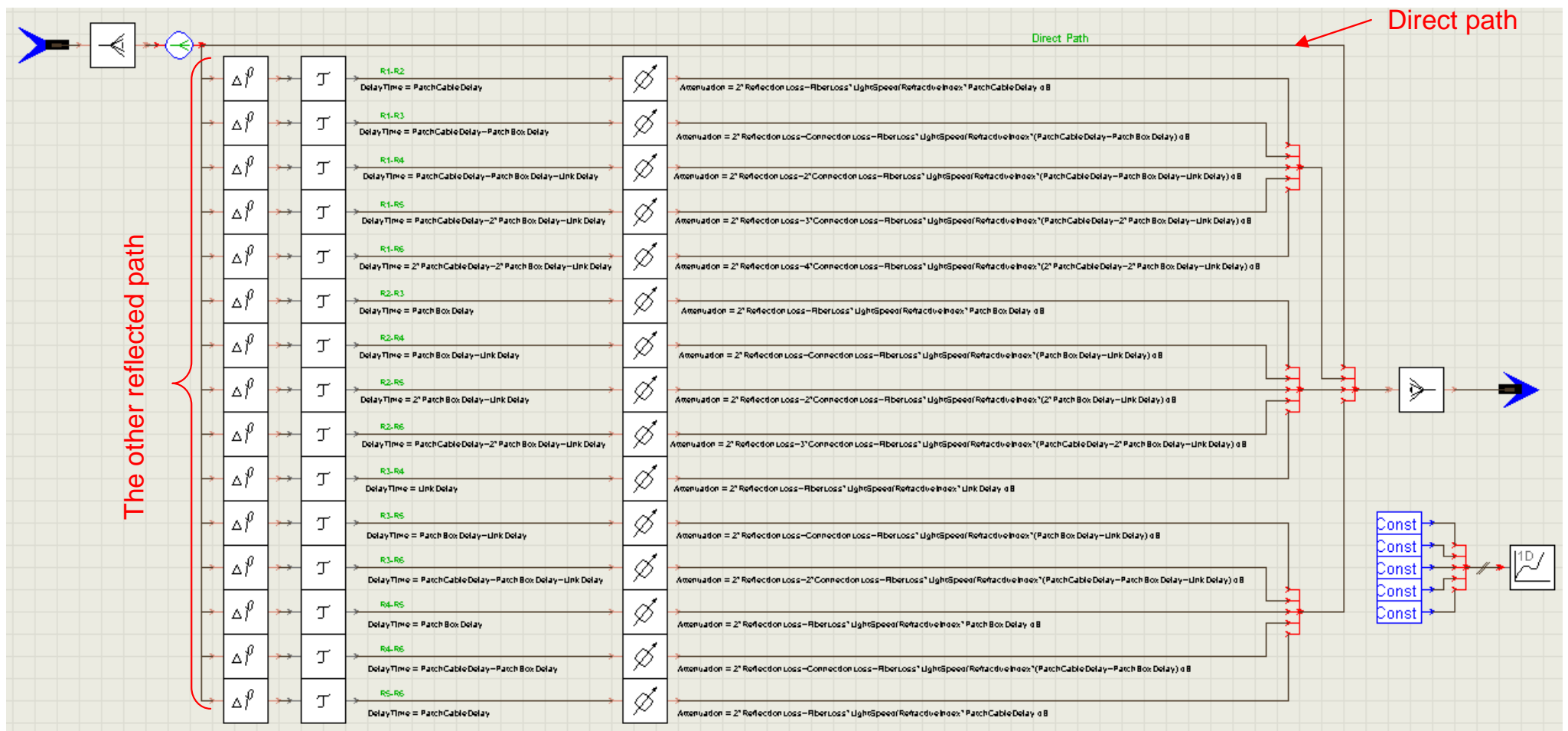
All 15 paths provide specific delay time and attenuation related to its double reflection, but phase differences from the direct path depend on 5 random phases caused by each deterministic reflection.
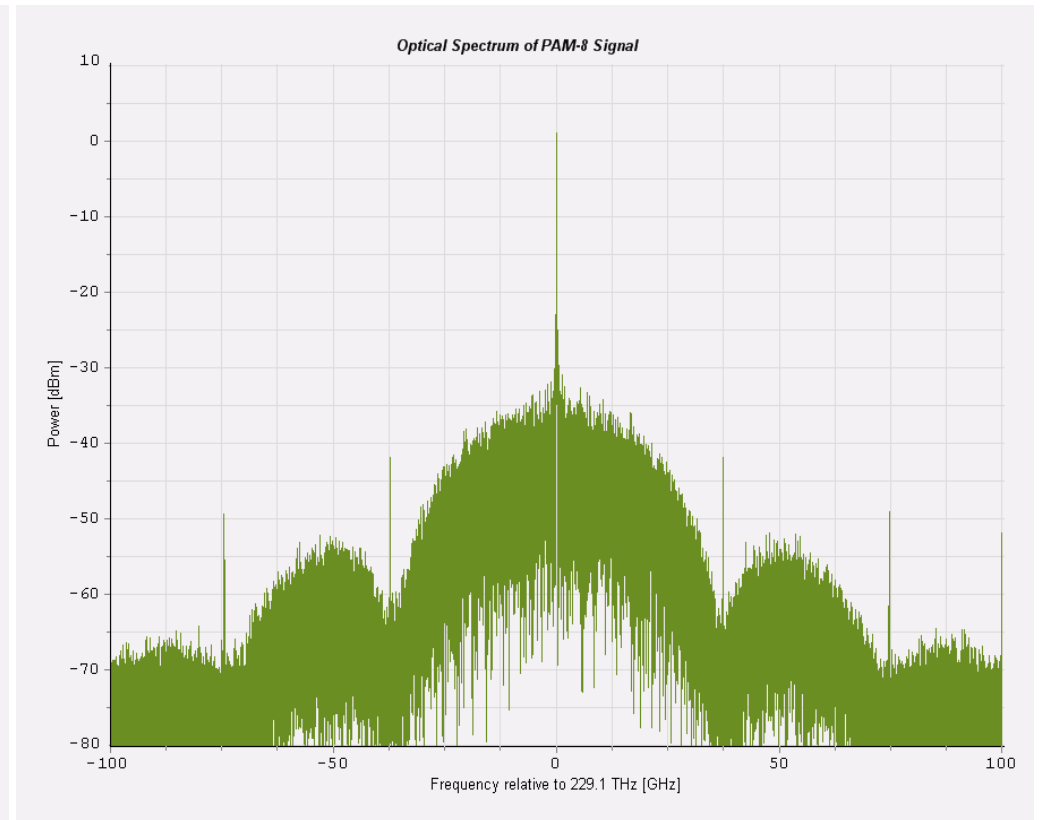
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Phase setting for MPI Emulator Model #3

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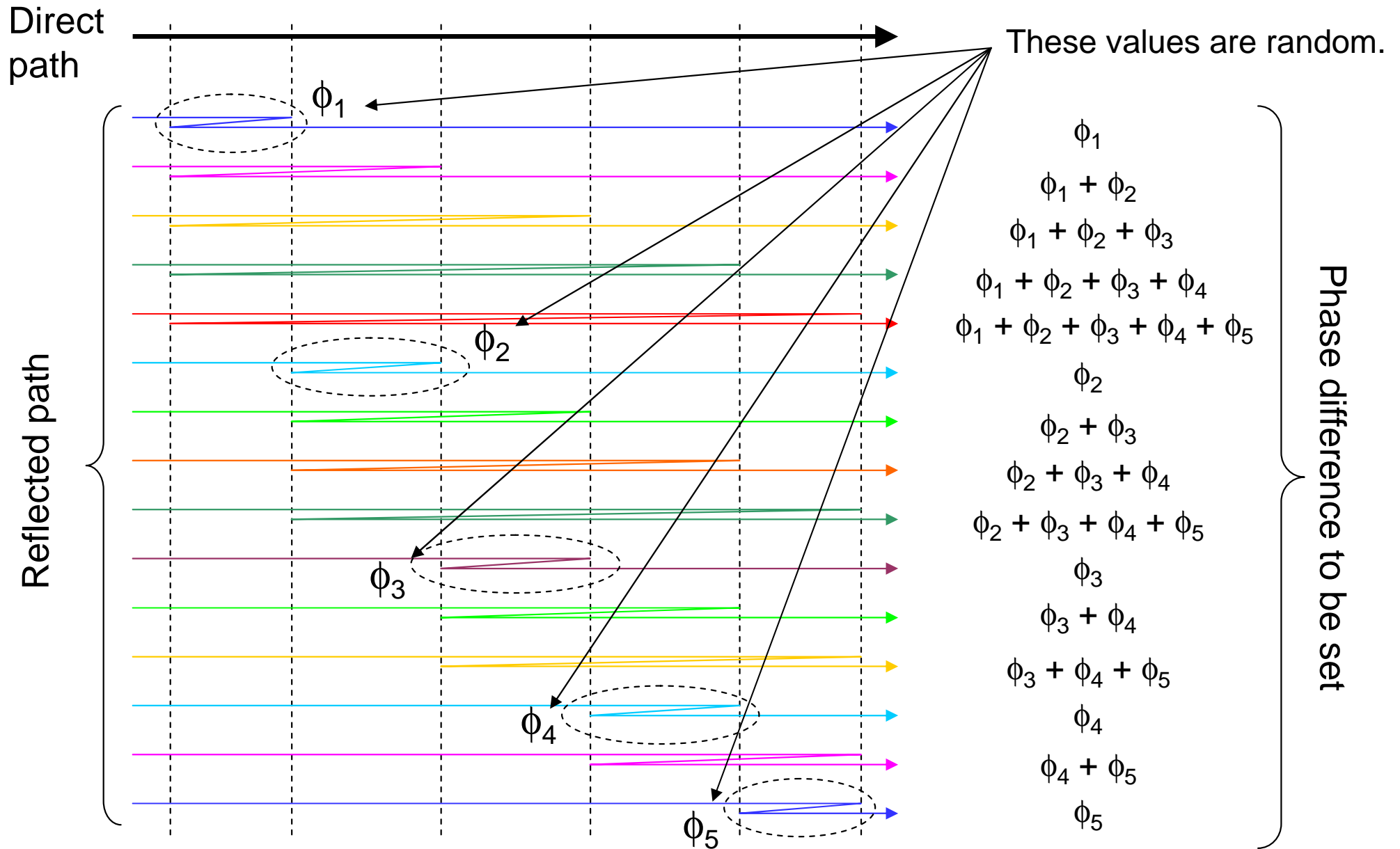
PAM-8 Eye Pattern & Optical Spectrum

100G-PAM8 Eye pattern
(Symbol rate: 37.3 Gbaud)

100G-PAM8 Optical Spectrum
(Symbol rate: 37.3 Gbaud)
(OSA resolution: minimum ~5 MHz)

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