25Gb/s Signaling for 100G Backplanes: Time Domain SI Analysis

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Introduction

- Objective: backplane reach for 4-lane 100Gb/s PHY
  - Investigate maximum channel loss considering technical and economic feasibility

- Focus of the study
  - Signaling scheme: NRZ and PAM4
  - 25.78125Gb/s
    - 64b/66b coding without FEC
  - Channels:
    - 10GBASE-KR compliant channel
    - Lower loss channels
  - Time domain Signal Integrity (SI) analysis

Assumptions for Time Domain SI Simulations

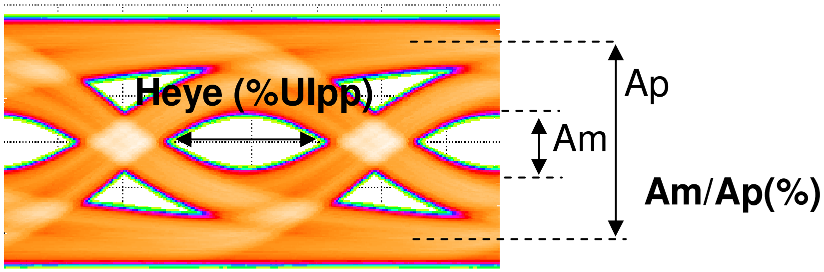
Transmitter Characteristics	Receiver Characteristics
▪ 1T FFE3 (1pre, 1 post) ▪ 1200mVppd launch amplitude ▪ 50Ohms ideal termination ▪ 2nd-order Butterworth filter, 0.25 UI Tr (20%-80%)	▪ 1T DFE20, 6dB peaking amp ▪ -6dB to 9.5dB DC gain range, linear ▪ 600mVppd AGC target at DFE summer output ▪ 50Ohms ideal termination ▪ 4th-order Butterworth filter at 0.75x symbol rate ▪ Ideal CDR (no algorithmic jitter)

Degradation Model (Actual IC implementation requires more comprehensive degradation model):

- 400fs rms RJ, 10% DJ (sine PM), 3% DCD
- 10nV/Hz amplitude Gaussian noise (1.4mV rms PAM4, 2mV rms NRZ)
- 20mVppd minimum receiver latch overdrive (voltage offset, quantization noise, …)
- No additional ISI due to analog front ends
- 40mm package model (21mm 100Ohms differential Tline (loss: 1.6dB @ 6.25GHz. 2.8dB @ 12.5GHz))

- **Simulation results**
  - Vertical and Horizontal eye opening margins at Rx sampling latch input, 1e-12 BER
  - 2.5M bits simulated, randomly generated,
  - 25.78125Gbaud

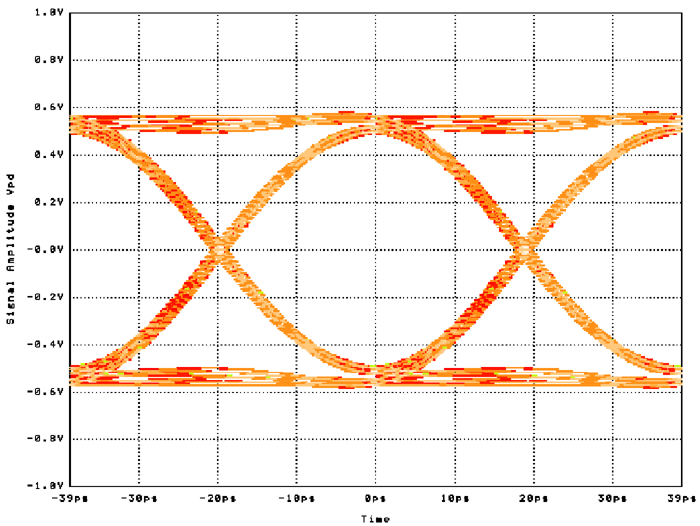
Equalized differential eye as seen at the Rx latch input

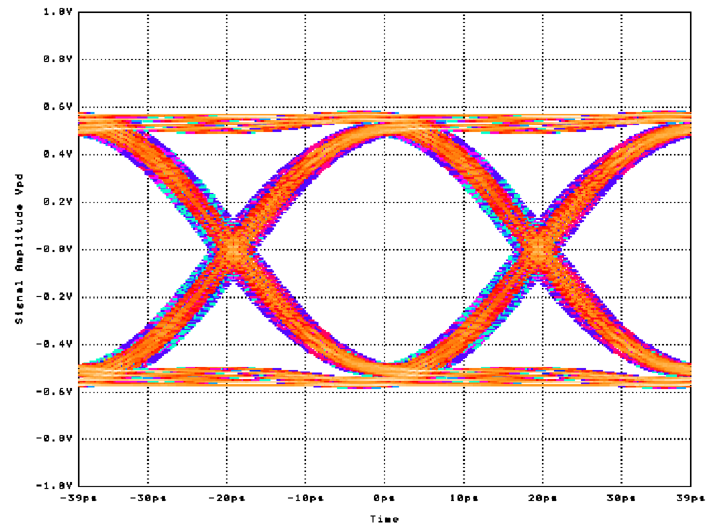


Eye Diagrams at Tx Package Output

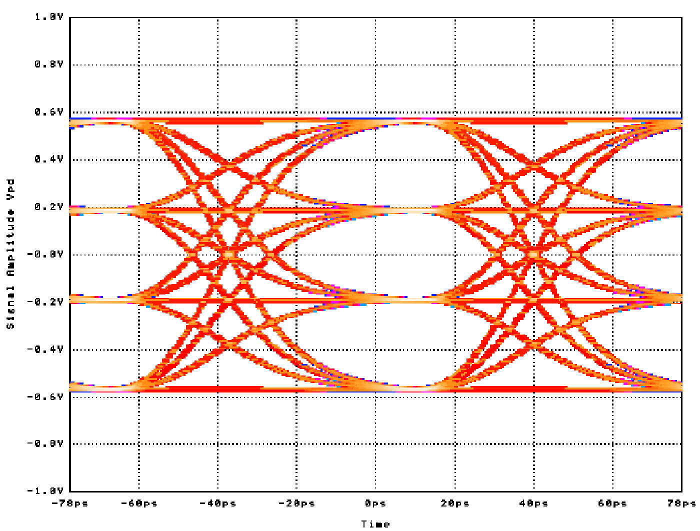
Without IC Degradation | With IC Degradation (DJ, DCD)

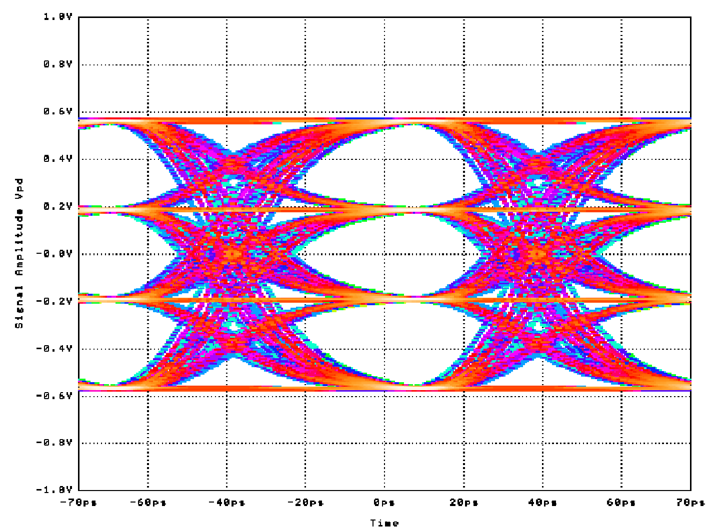
NRZ



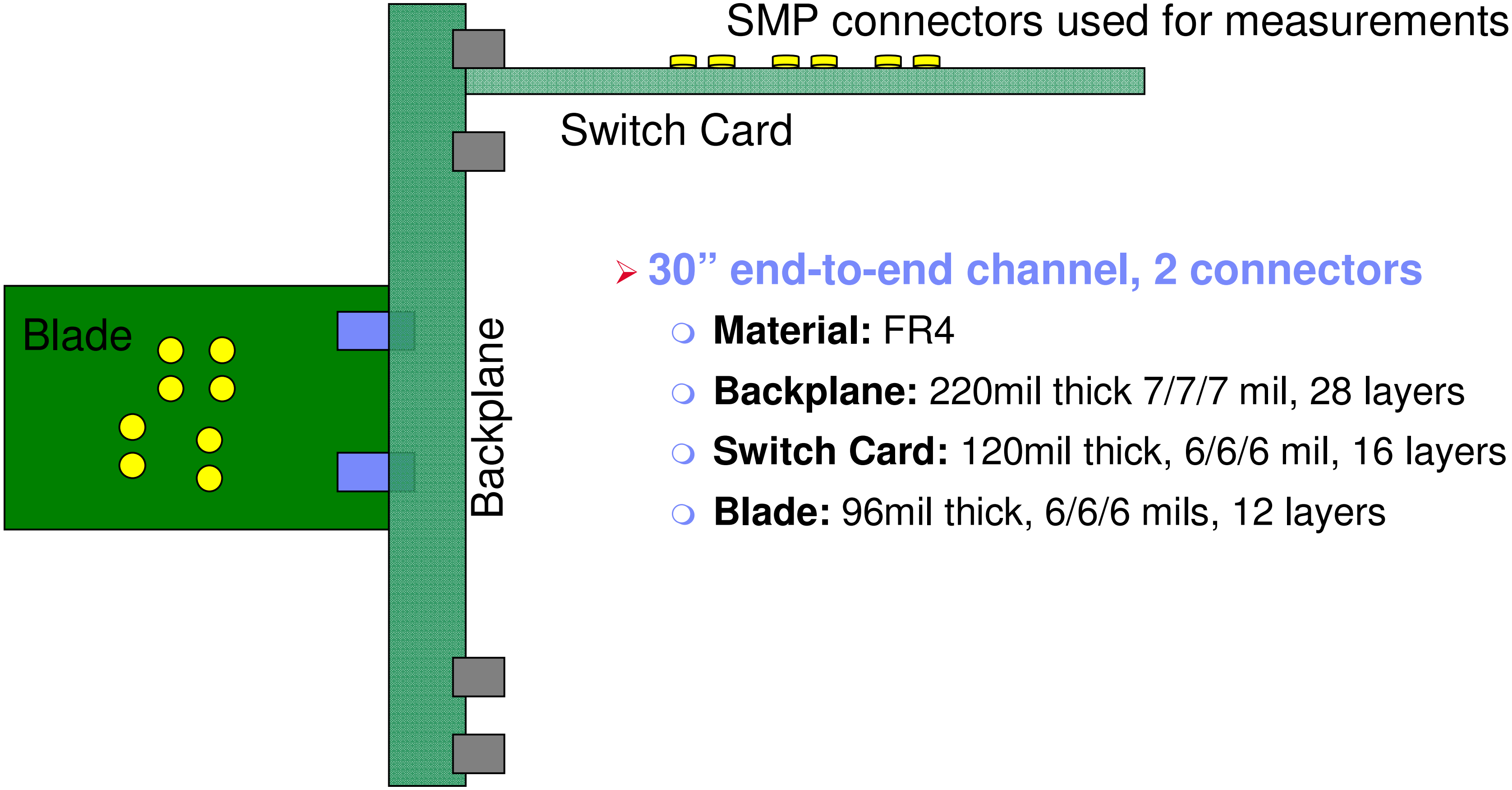


PAM4

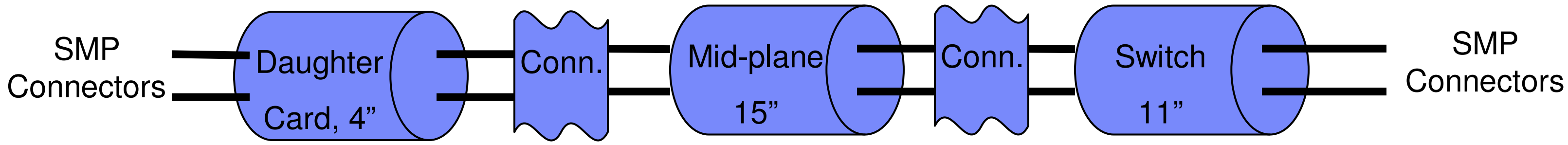




Existing IBM Blade Center 10GBASE-KR Channel
Connectivity Description

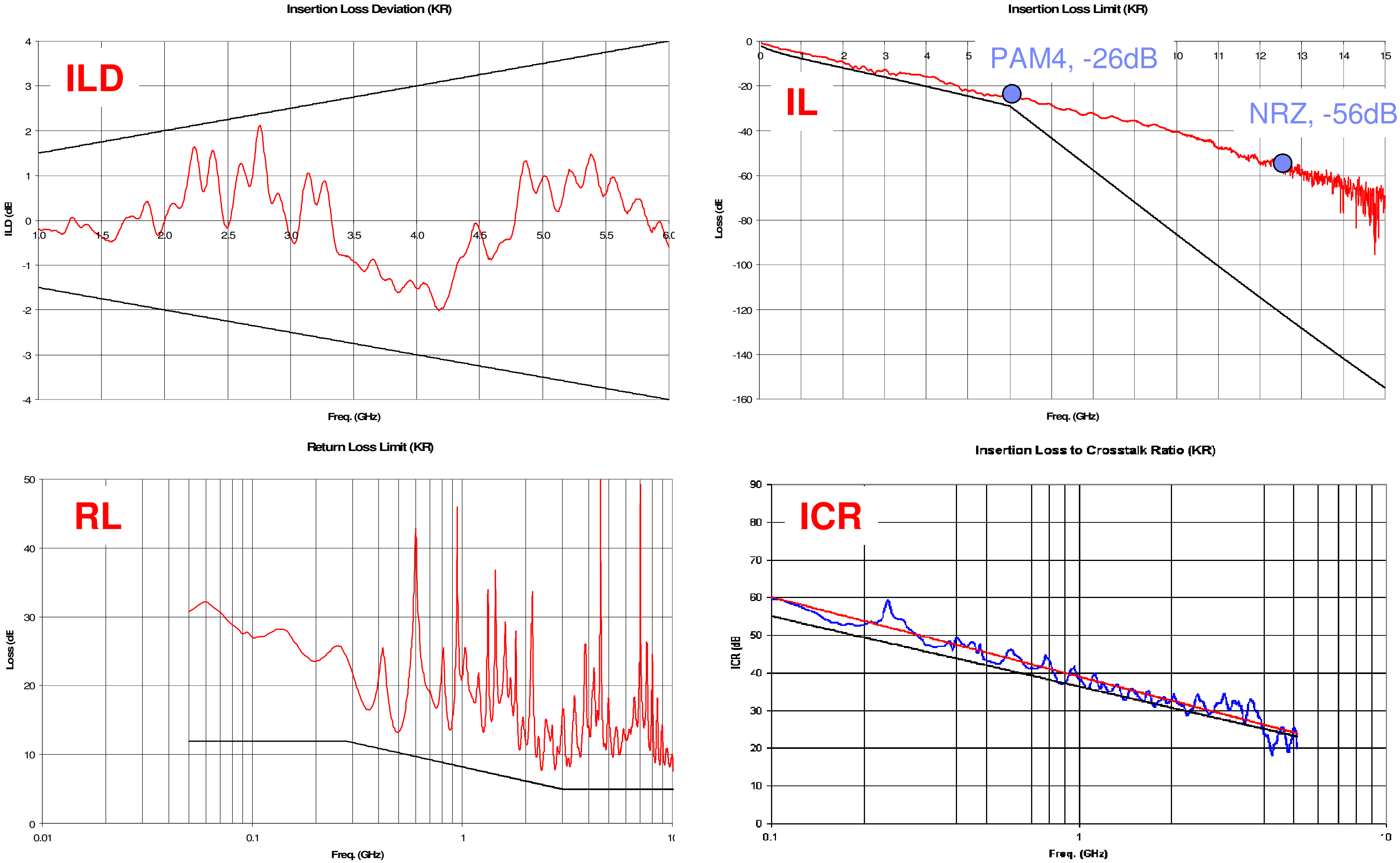


- **30" end-to-end channel, 2 connectors**
  - **Material:** FR4
  - **Backplane:** 220mil thick 7/7/7 mil, 28 layers
  - **Switch Card:** 120mil thick, 6/6/6 mil, 16 layers
  - **Blade:** 96mil thick, 6/6/6 mils, 12 layers



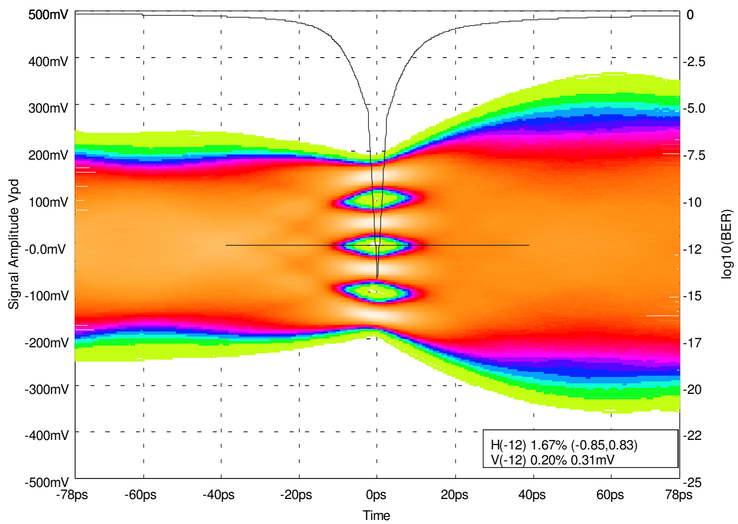
Existing IBM Blade Center 10GBASE-KR Channel

Compliance Plots from Measurements



Existing IBM Blade Center 10GBASE-KR Channel
PAM4 SI Simulation Results

Ideal IC



PAM-4 Margins at 1e-12 BER	Vertical Eye Margin (%)	Horizontal Eye Margin (%UIpp)
No IC Degradation model	<1	1.6

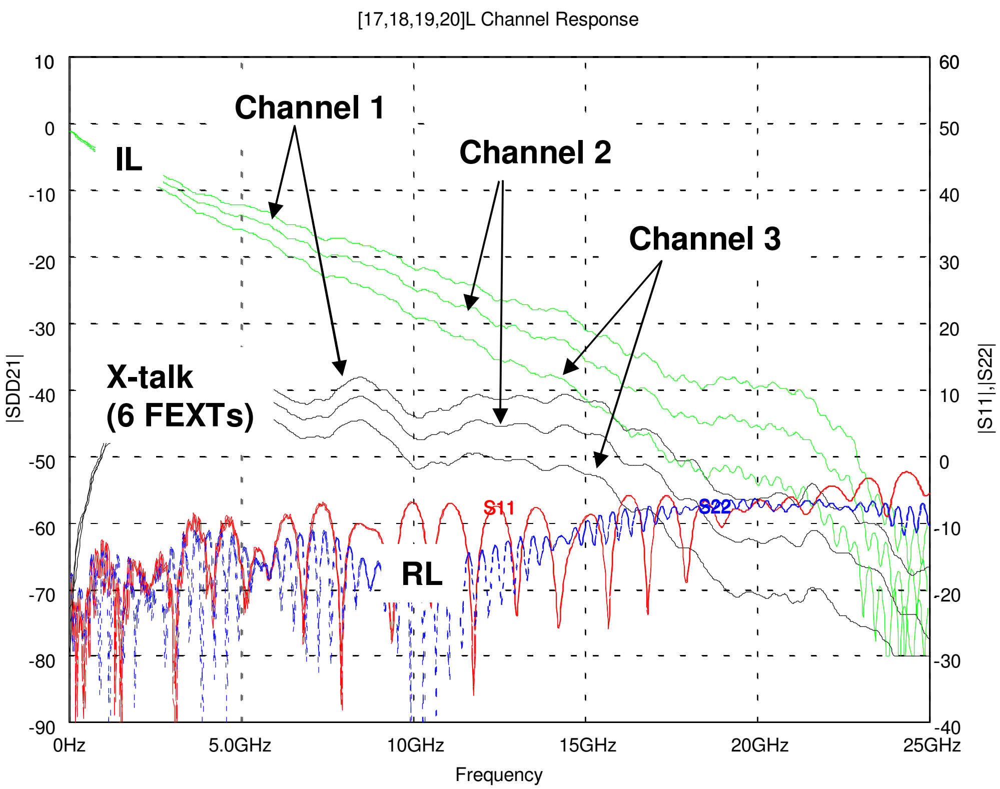
Neither NRZ or PAM4 can support 25Gb/s operation across a compliant 10GBASE-KR channel

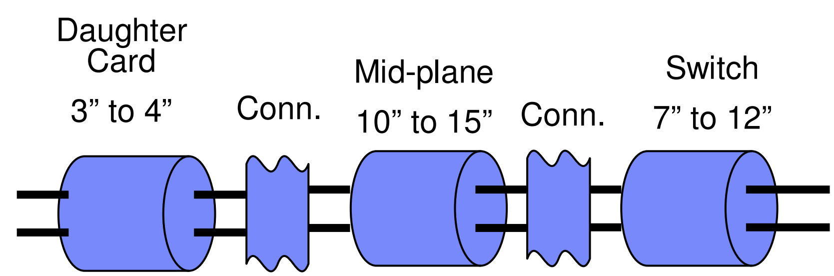
X-talk includes 2 FEXT and 2 NEXT aggressors

Simulated Lower Loss Backplane Channels

- 3 backplane channels investigated (modeled channels, BGA to BGA)

Insertion Loss (dB)	@ 6.44 GHz	@ 12.9 GHz	Delta (GHz)
Channel 1	15.0	26.0	11.0
Channel 2	17.1	30.7	13.6
Channel 3	19.8	35.3	15.6



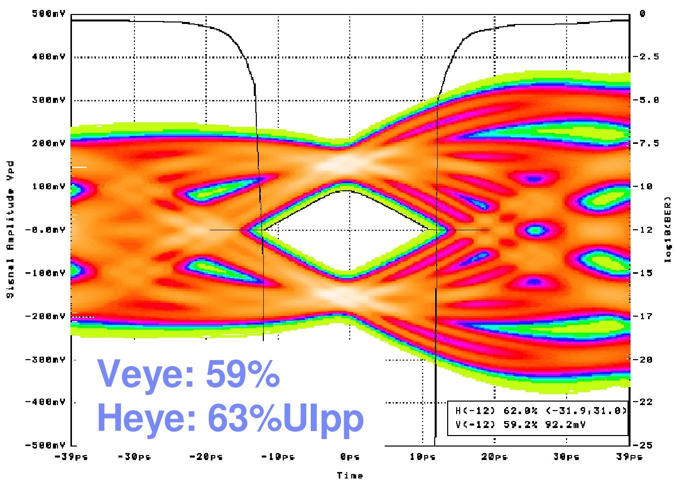


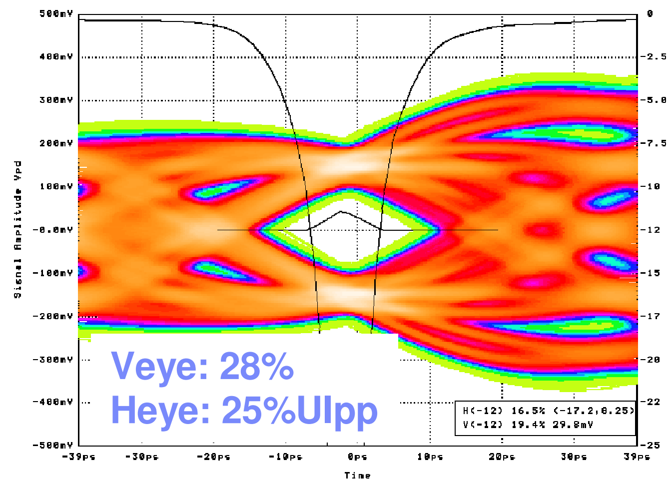
NRZ and PAM4 SI Simulation Results

Channel 1 (IL: 26dB NRZ, 15dB PAM4)

Ideal IC + X-talk | IC degradation + X-talk

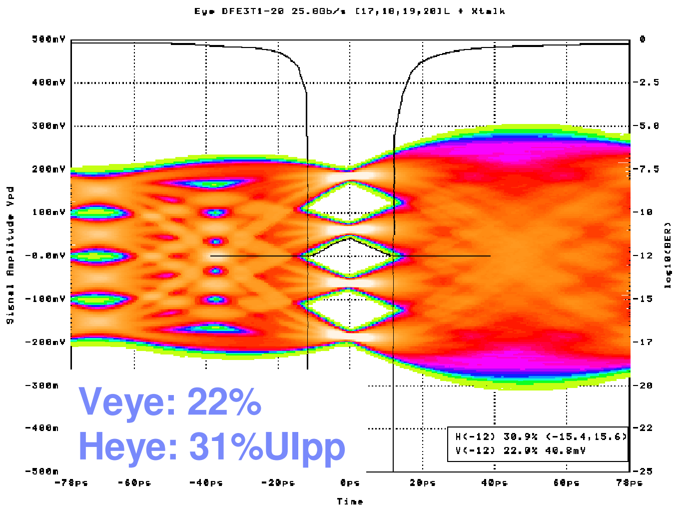
NRZ

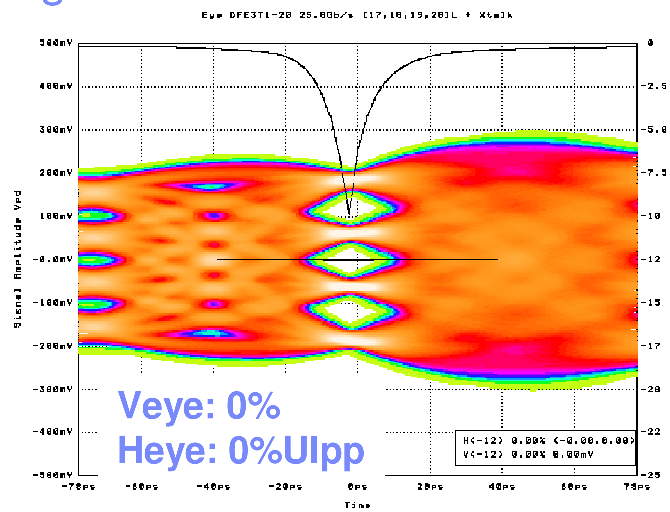




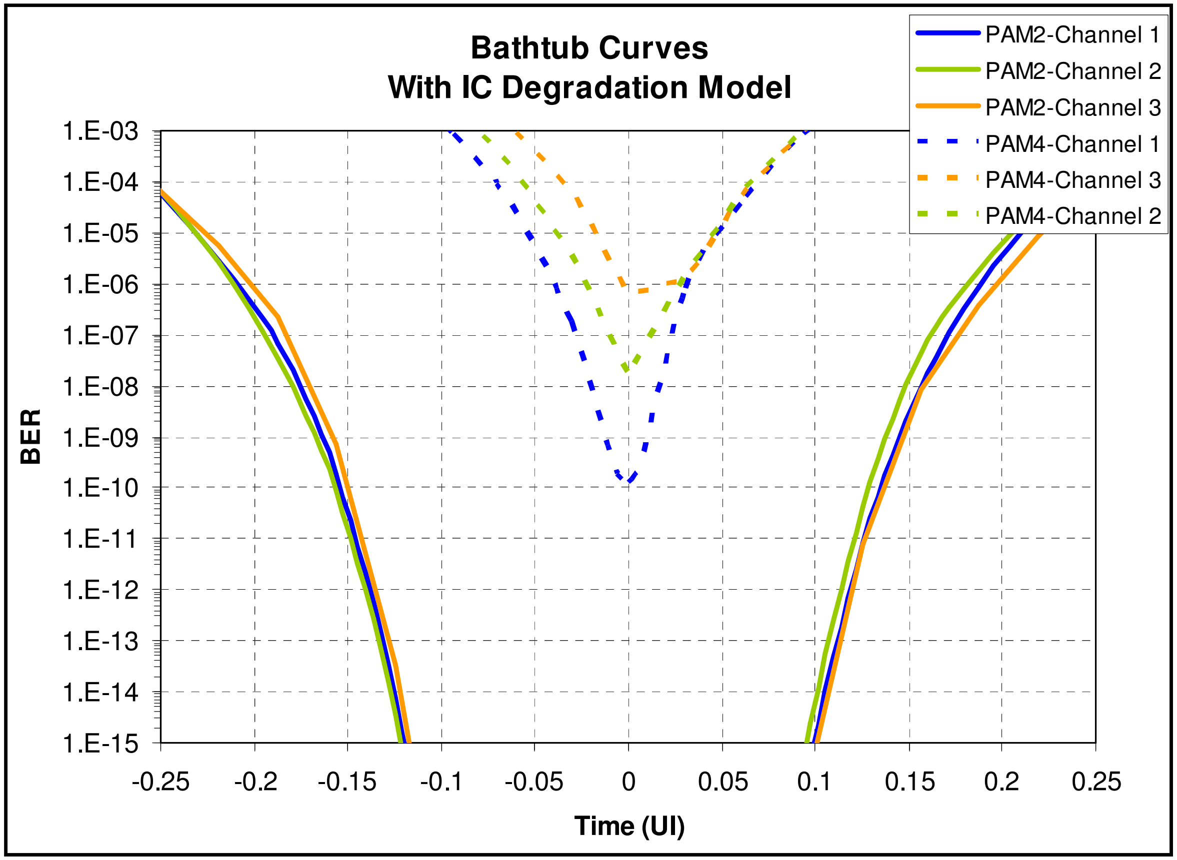
1e-12 BER Eye Margins

PAM-4





NRZ and PAM4 SI Simulation Results

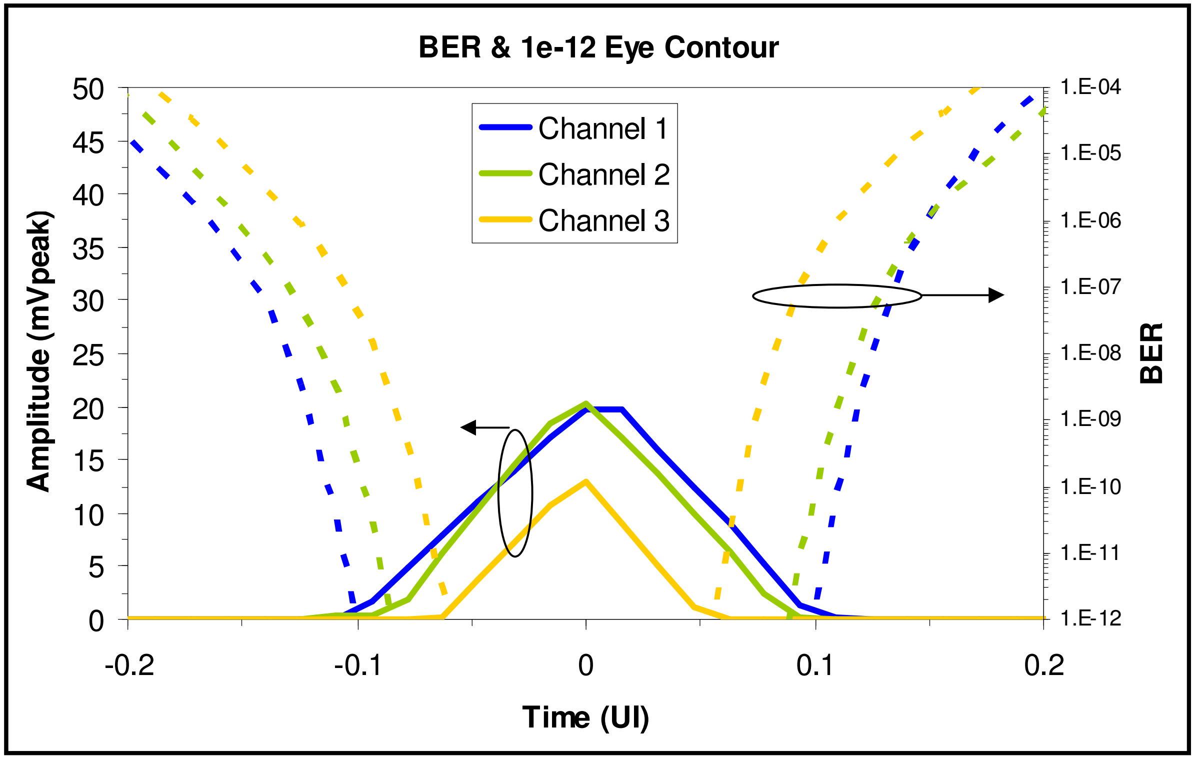


Insertion Loss (dB)	@ 6.44 GHz	@ 12.9 GHz
Channel 1	15.0	26.0
Channel 2	17.1	30.7
Channel 3	19.8	35.3

- No improvements seen when peaking applied to PAM4
- NRZ includes fixed 6dB Peaking

- A basic IC degradation model is necessary for realistic SI analysis
- A complete, implementation based, SI model required to simulate absolute link margins

SI Analysis using a Comprehensive NRZ WC IC Model



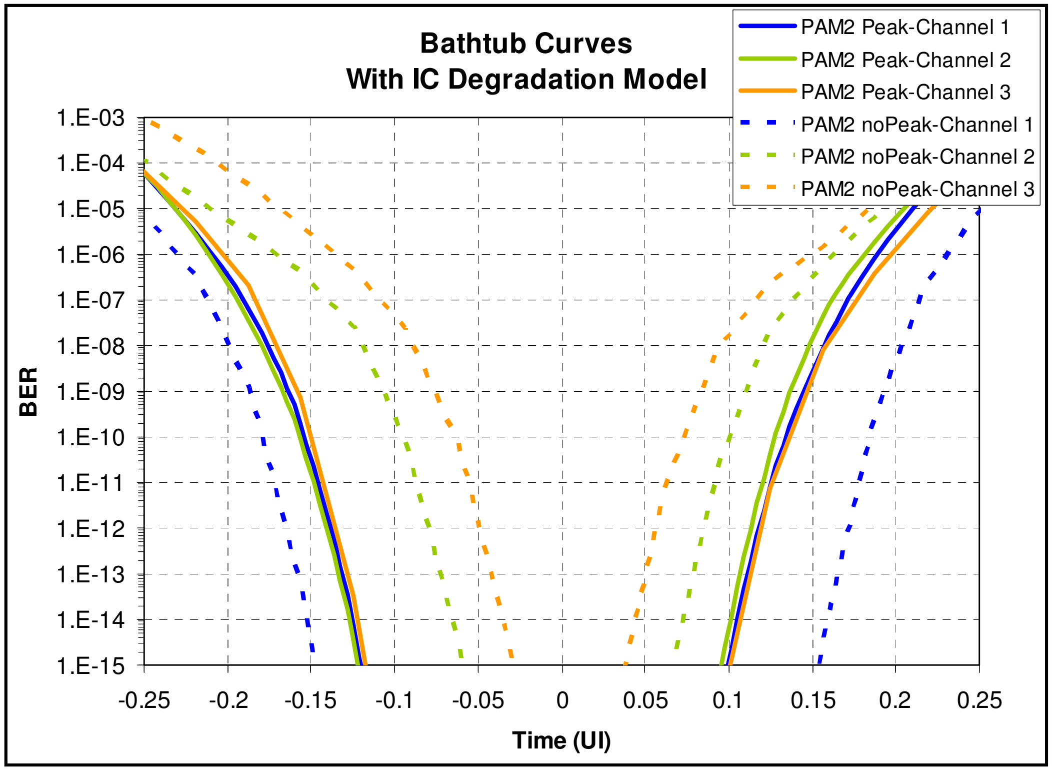
NRZ Margins at 1e-12 BER	Max Vert. Eye Margin (%Ap)	Max Horz. Eye Margin (%UIpp)	BER Floor
Channel 1 (26dB @12.9GHz)	15	20	3.9e-49
Channel 2 (31dB @ 12.9GHz)	15	16	4.1e-41
Channel 3 (35dB @12.9GHz)	10	10	1.8e-28

Summary

- Channel losses ≤30dB at 12.9GHz are technically and economically feasible for 25Gb/s transmission
  - Based on silicon implementation using established signaling and equalization techniques (FFE, CTLE, DFE)
  - Low loss dielectrics, better connectors, better board manufacturing technology,… readily available for long reach links
  - NRZ achieves >15% eye margins at 1e-12 BER
    - Our simulation results show inferior performance using PAM4 signaling
    - More analysis needed to define the compliance limits of practical channels

Backup

NRZ Signaling – Effect of Peaking



Peaking Response