Channel Model Simulations for 112Gbps Backplane Applications

IEEE 802.3 100GEL Study Group Ad Hoc

Geoff Zhang, Xilinx

Feb. 26, 2018

Outline

- ❑ Introduction
- ❑ Simulation setup description
- ❑ Group-1: “Channel Simulations for 112G Backplane Analysis”
  1. Orthogonal Backplane Channels and xtalk
  2. Cabled Backplane Channels and xtalk
- ❑ Group-2: “Initial Host Backplane Channel Models & Development Plans”
  1. Backplane with 2 connectors, 30dB, 85ohm nominal impedance
  2. Backplane with 2 connectors, 30dB, 85ohm high-low-high impedance
  3. Backplane with 2 connectors, 30dB, 85ohm low-high-low impedance
- ❑ Comparison of two groups of channel models
- ❑ Summary and conclusions

Introduction

- Objective: define a single-lane 100 Gb/s PHY for operation over electrical backplanes supporting an insertion loss ≤ TBD dB at TBD GHz (*28GHz for 112Gbps PAM4 signaling*)
- Link models for the simulation are downloaded from

  http://www.ieee802.org/3/100GEL/public/tools/index.html

- Specifically, backplane channel models from the following two groups are used

Initial Host Backplane Channel Models & Development Plans

• Backplane with 2 connectors, 30dB, 85ohm nominal impedance • Backplane with 2 connectors, 30dB, 85ohm high-low-high impedance • Backplane with 2 connectors, 30dB, 85ohm low-high-low impedance	19-Jan-2018	Howard Heck	Intel

Group-2 channels

Channel Simulations for 112G Backplane Analysis

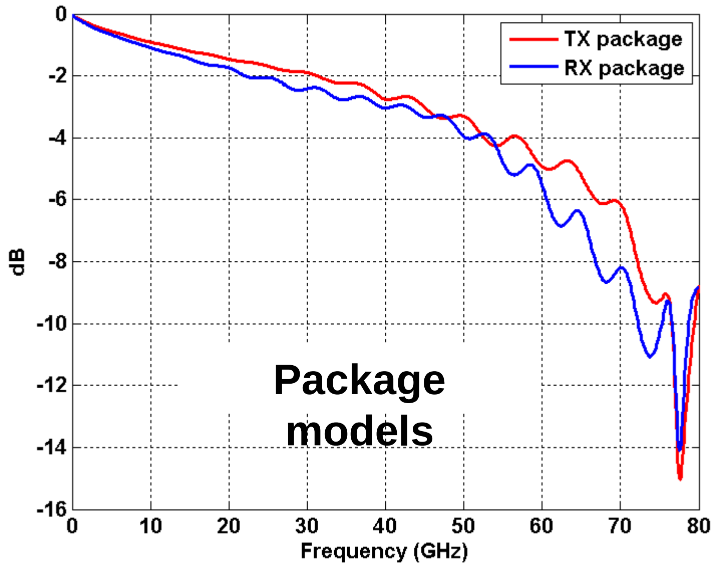
• Orthogonal Backplane Channels and xtalk • Cabled Backplane Channels and xtalk	19-Jan-2018	Nathan Tracy	TE Connectivity

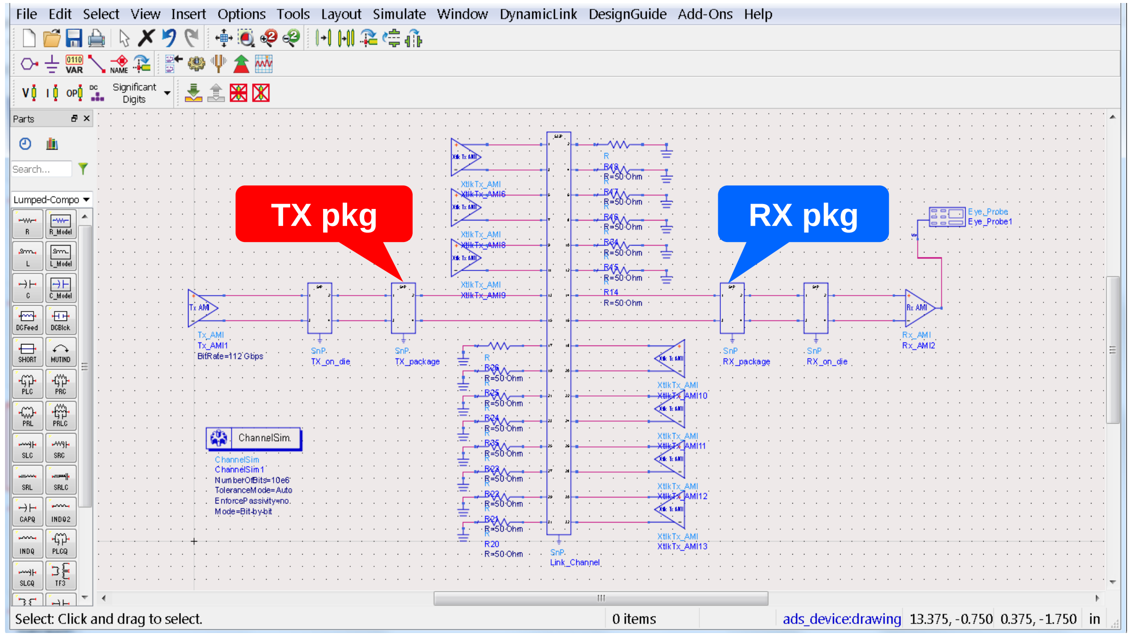
Group-1 channels

- The simulation model
  - The IBIS-AMI model is based on Xilinx 112G-PAM4 SerDes design in 16nm
- The simulation platform is the Keysight Advanced Design System (ADS)

Simulation Setup in ADS

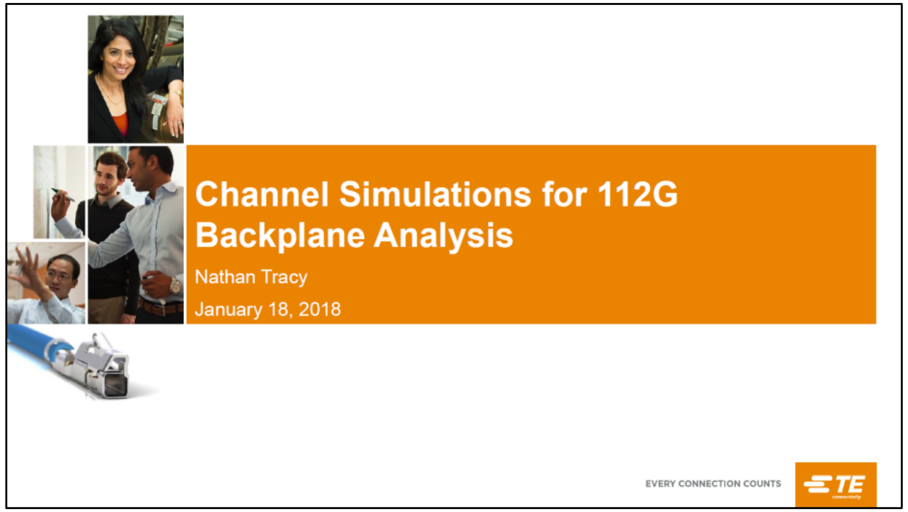
- The IBIS-AMI model (TT corner) for 112Gbps/PAM4 is simulated in ADS
  - An example of the ADS setup is shown below, with 1 THRU, 3 NEXT and 4 FEXT (reconstructed .32p model)
- Victim channel TX is set to 920mVdpp; a 3-tap FIR for de-emphasis whose settings are manually set
- Aggressors' TX output swing is set to 1000mVdpp, without de-emphasis applied
- RX side equalizer (CTLE, AGC, DSP) and CDR parameter values are all adaptively tuned
- Impairments (jitter, noise, nonlinearity, etc.) are either set as AMI parameters or included in the model
- Data pattern: PRBS23 with Gray coding (2M symbols for convergence and 10M for post-processing)
- The package models are shown below



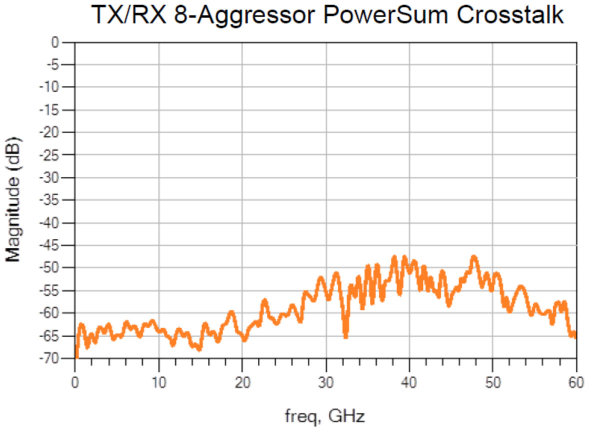


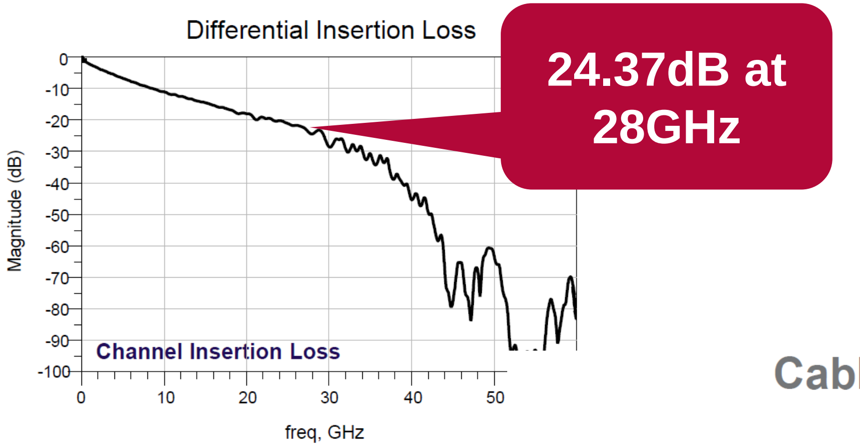
Channel Model Group-1

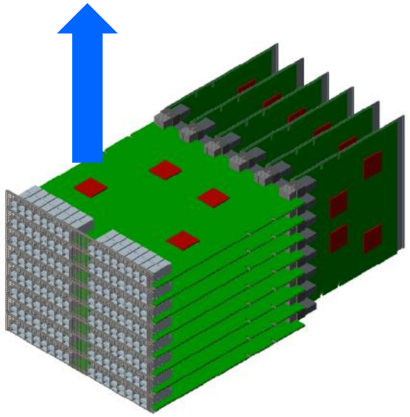
- Full description of the two channel models are provided in the document by Nathan Tracy

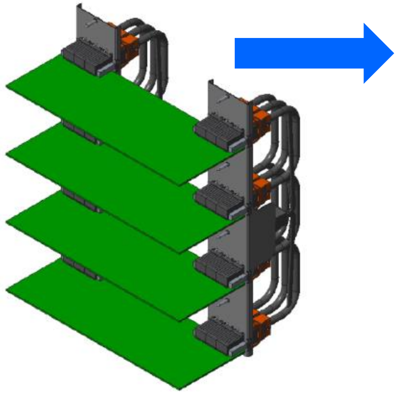

Channel Simulations for 112G Backplane Analysis
Nathan Tracy
January 18, 2018

Orthogonal Backplane Channel Results

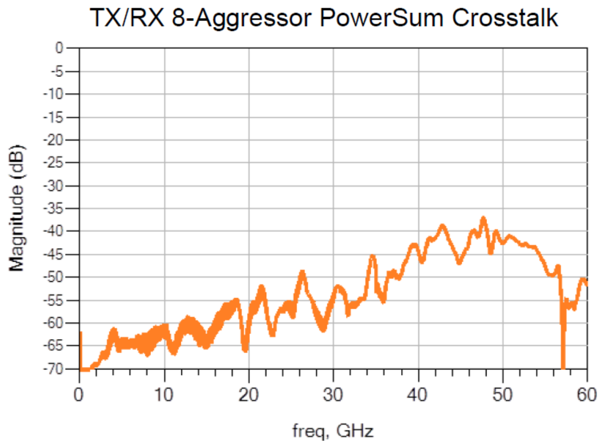


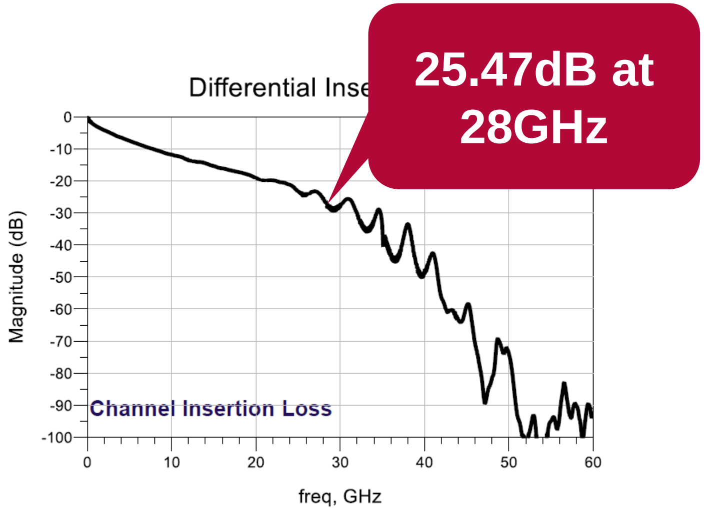






Cabled Backplane Channel Results



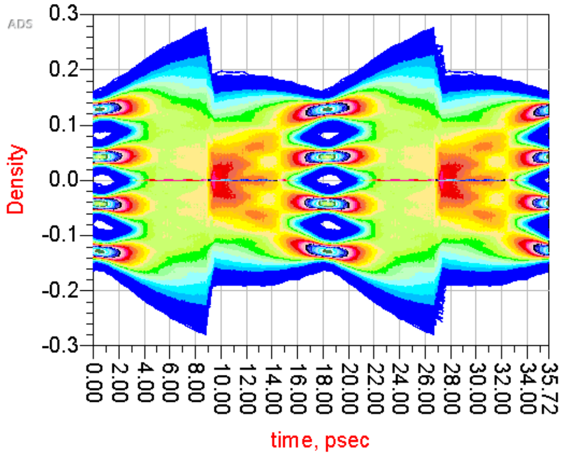


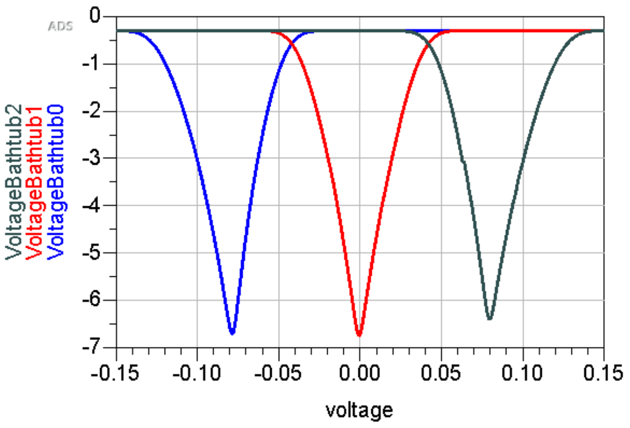
Simulation Results for Group-1

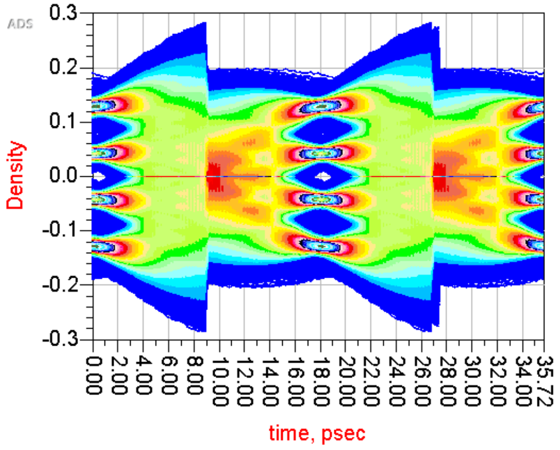
- Simulated link performance is summarized in the table
  - With TX FIR setting perturbations, link performance pretty much remained comparable

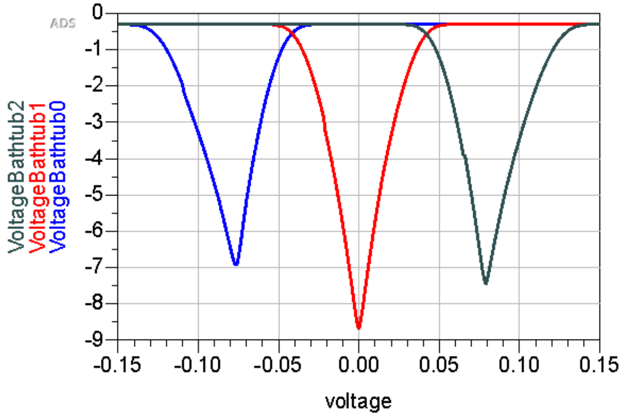
TX 3-tap FIR settings	[-0.075, 0.75, -0.175]	[-0.125, 0.75, -0.125]	[-0.175, 0.75, -0.075]
Orthogonal Backplane	8.22e-8	2.27e-7	1.94e-7
Cabled Backplane	3.11e-7	7.85e-8	3.51e-7

  - The eye diagrams at the data slicers and voltage bathtub curves for the orthogonal backplane channel with TX FIR = [-0.125, 0.75, -0.125] are shown below
    - Left: PRBS23 with 8M symbols (more than one complete cycle of the PRBS pattern)
    - Right: PRBS31 with 50M symbols (<2.33% of one complete cycle) – performance degradation is acceptable



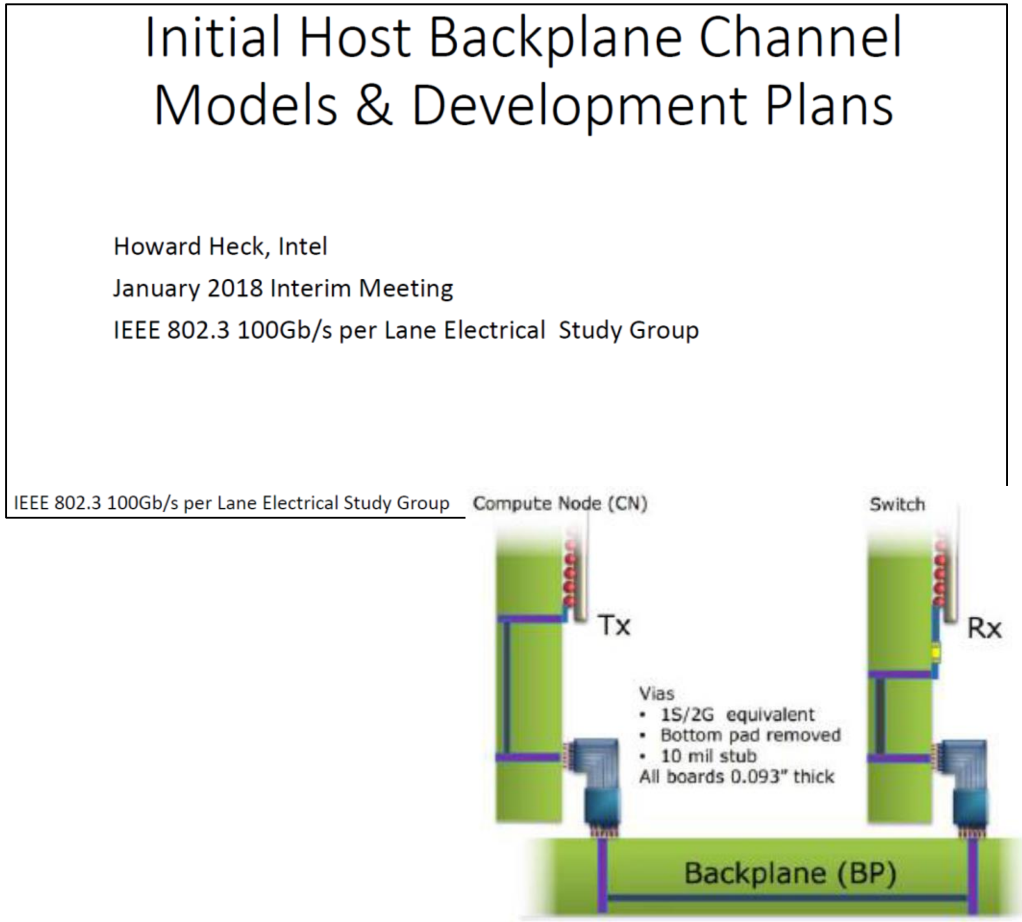


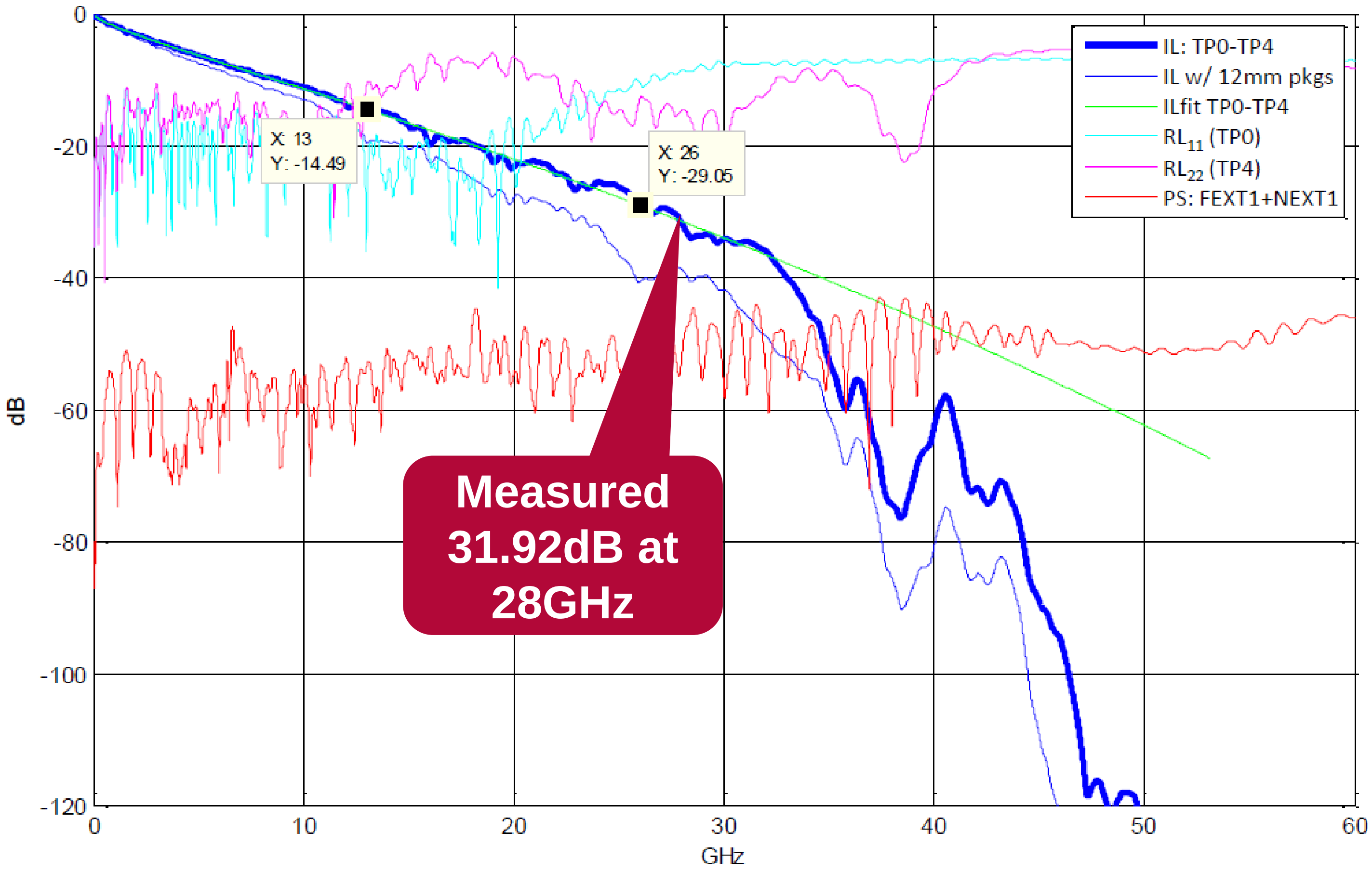




Channel Model Group-2

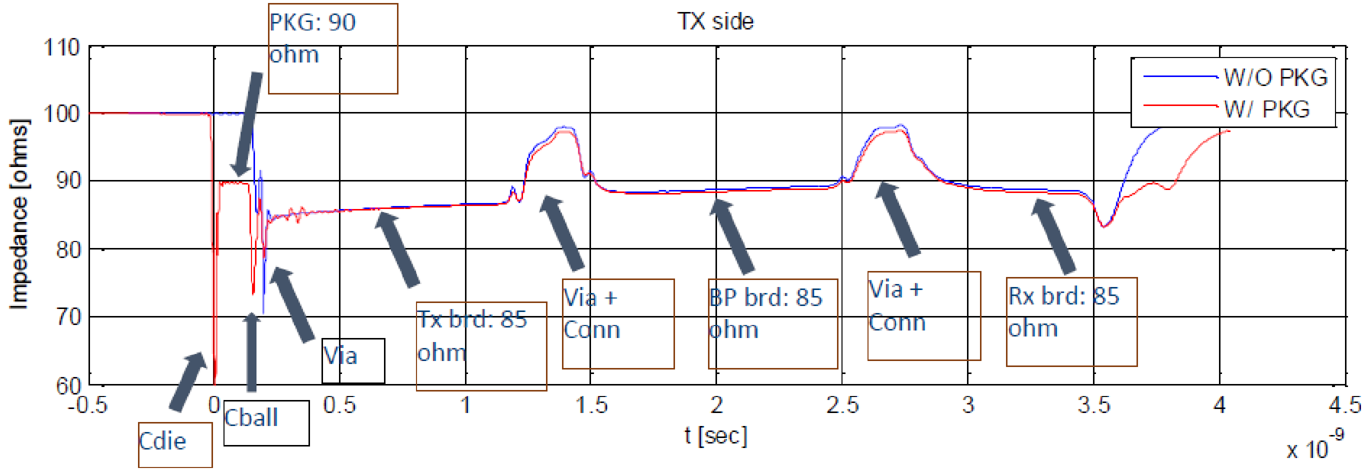
- Full description of the models for the 3 channels are provided in the document by Howard Heck

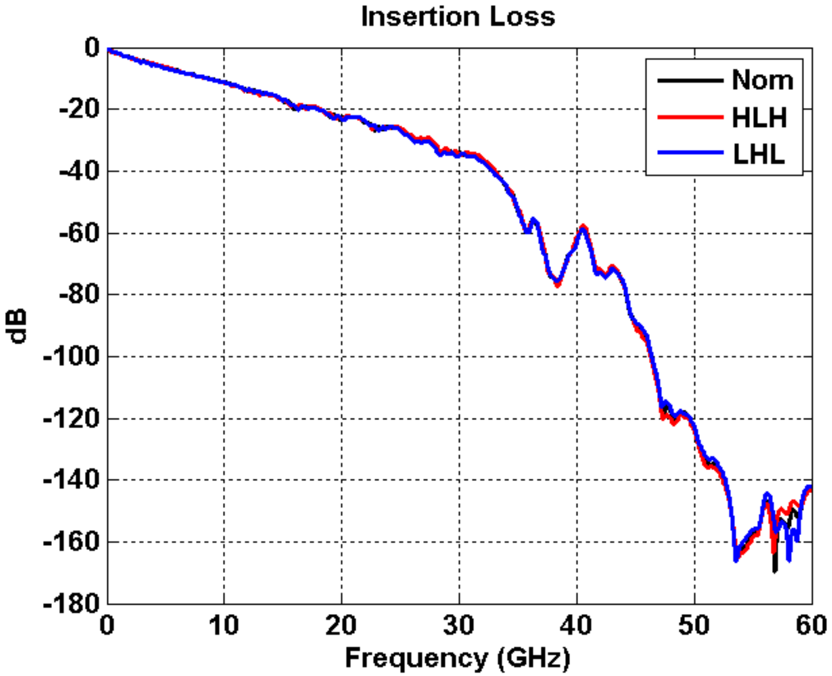


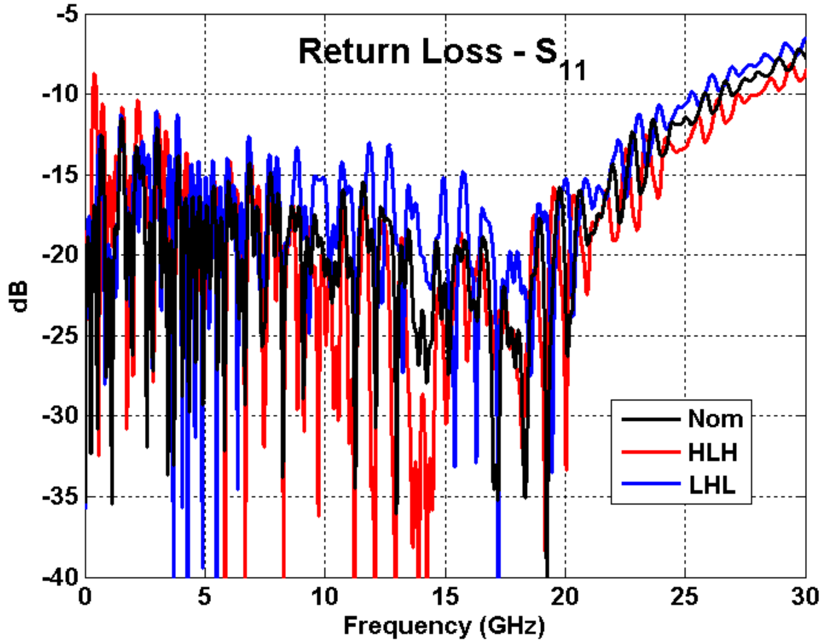


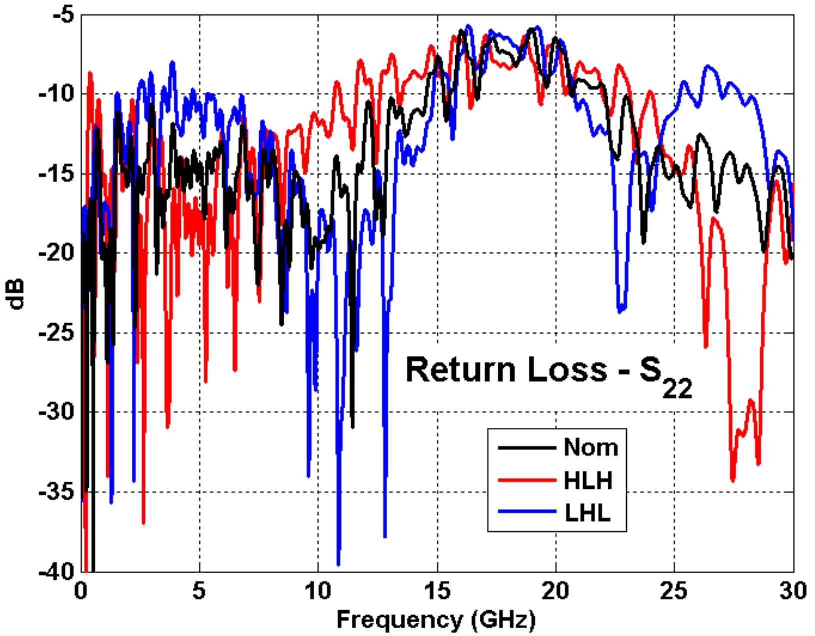
Channel Model Group-2 (Con't)

- In Group-2 the impedances of TX board, backplane, and RX board are varied to form Nom, HLH, and LHL
  - Insertion losses are almost the same
  - Return losses are very different







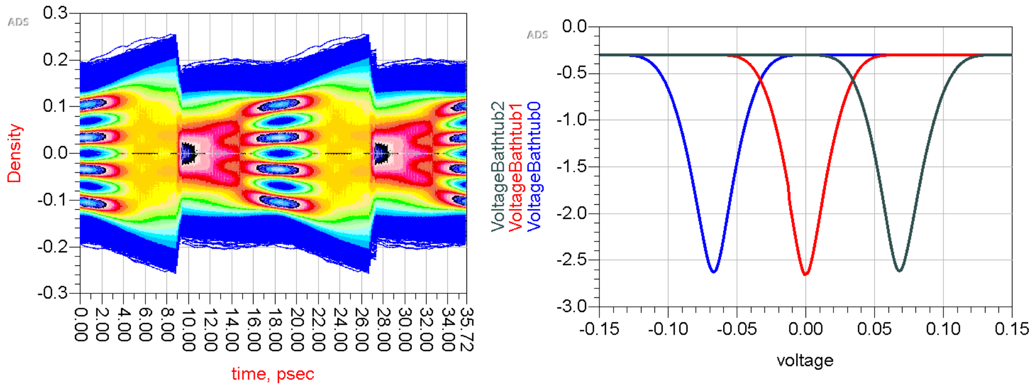


Simulation Results for Group-2

- Simulated link performance is summarized in the table

Channels with full crosstalk	heck_100GEL_85ohm _hlh_01_011718	heck_100GEL_85ohm _lhl_01_011718	heck_100GEL_85ohm _nom_01_011718
[-0.075, 0.75, -0.175]	3.22e-3	3.31e-3	3.21e-3
[-0.125, 0.75, -0.125]	2.81e-3	3.11e-3	2.92e-3
[-0.175, 0.75, -0.075]	2.18e-3	2.43e-3	2.07e-3

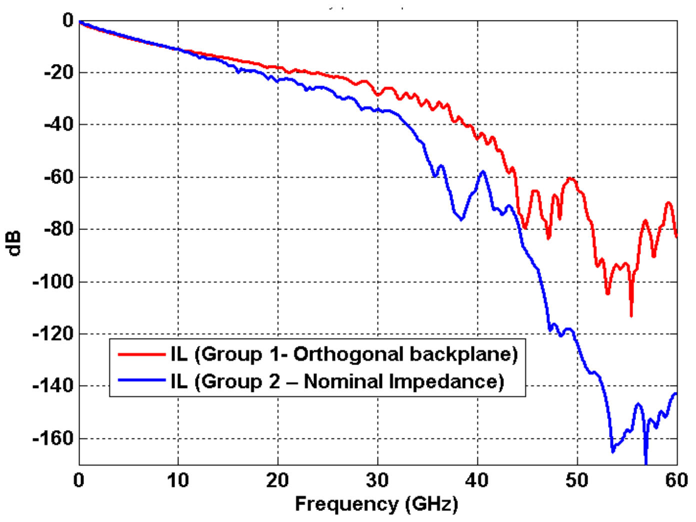
- It is seen that link channels in Group-2 performed much worse than those in Group-1
  - Since the 3 channels performed similarly, impedance variation did not seem to be the main cause for link performance degradation comparing with Group-1
- The BER performance is again not a strong function of TX FIR settings, within a certain range

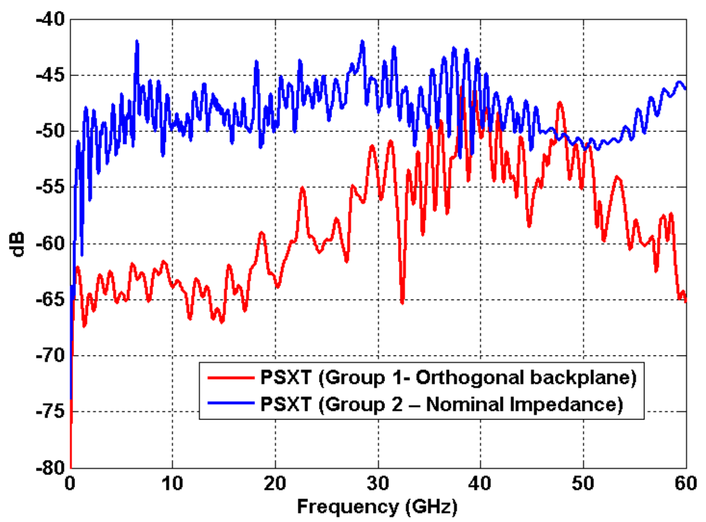


Eye diagram and voltage bathtubs for "Nom" and FIR = [-0.125, 0.75, -0.125]

Comparison of two groups of models

- Taking one link channel from each group for a quick comparison
  - Group-1 has ~7dB less insertion loss at 28GHz than that in Group-2
  - Group-1 also has >10dB less aggregated crosstalk up to 30GHz
- With TX FIR fixed at [-0.125, 0.75, -0.125], the following sims are performed for better understanding of the differences
  - Crosstalk is one of the dominant factors; by using the aggressor channels from Group-1, the Group-2 link performance improved by ~1.5 orders; while Group-1 channel BER increased by about 2 orders by using the crosstalk aggressor channels from Group-2
  - Group-2 THRU channel also needs to be improved, as even without crosstalk, its performance is approximately 2 orders worse than Group-1 links with crosstalk





<table>
<tr><th>Simulation Configurations</th><th>Intrinsic setup</th><th>Crosstalk from the other Group</th></tr>
<tr><td>Group-1: Orthogonal Backplane</td><td>2.27e-7</td><td>1.10e-5</td></tr>
<tr><td rowspan="2">Group-2: heck_100GEL_85ohm_nom_01_011718</td><td>2.42e-3</td><td>9.84e-5</td></tr>
<tr><td colspan="2">5.35e-5 (without crosstalk)</td></tr>
</table>

Extending Group-1 channel losses

- Extending the channel insertion loss, using the orthogonal channel in Group-1 as an example, by cascading the channel with a small piece of PCB
  - The crosstalk to the receive input is not changed
  - It is seen that the insertion loss can be extended to 30dB ball to ball for the channels in Group 1 with good margin

Ball-to-Ball IL (dB)	**24.37**	**26.26**	**28.06**	**29.82**	**31.66**	**33.45**
Simulated BER	**2.27e-7**	**3.84e-7**	**1.81e-6**	**5.93e-6**	**3.74e-5**	**1.45e-4**

- For the case 31.66dB with crosstalk, the simulated BER is 3.74e-5
  - The channel in Group-2 31.92dB; with the same crosstalk from Group-1, the simulated BER is 9.84e-5

Summary and Conclusions

- Two groups of channel models have been simulated at 112Gbps for PAM4 signaling
- Group-1 channels showed pretty good performance and robustness
  - There is not much difference in terms of the final BER between the orthogonal backplane and the cabled backplane configurations
- Group-1 outperformed Group-2 by about 4 order in the simulated BER
  - It is interesting to observe that the 3 variations in impedance profiles did not cause much BER difference
    - This is believed to be SerDes receiver architecture dependent
  - It is obvious that Group-2 channels need to reduce the amount of crosstalk coupling
  - It would be good if the channel insertion loss can be reduced to 30dB ball-to-ball
- With the package models used, it is concluded that, as long as the crosstalk is well controlled like the links in Group-1, the LR spec can be defined at 35dB bump-to-bump