UBM

Novel Methodology of IBIS-AMI Hardware Correlation using Trend and Distribution Analysis for high-speed SerDes System

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MOTIVATION

- Most of IBIS-AMI correlation is performed under specific settings and small number of silicon parts
- This approach cannot guarantee accurate correlation throughout all other settings under distribution of real parts across PVT.
- Simulation results need to follow behavioral ***trends*** from real hardware measurements with all possible combinations of the controllable settings under reasonable tolerance.
- The results need to reflect the ***distribution*** of real measurement across PVT in order to achieve reliable simulation optimization in a mass production system.

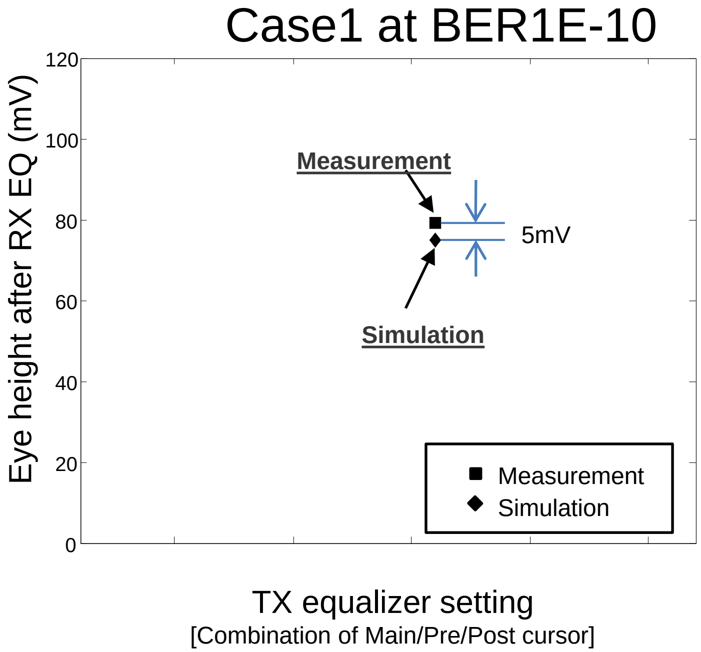
Trend Correlation

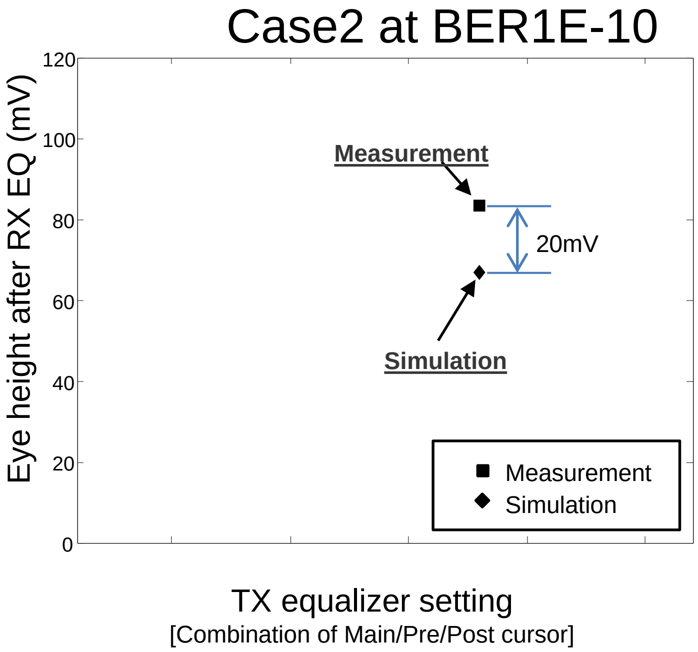
Main purpose of IBIS-AMI simulation

- To obtain the optimized SERDES equalizer setting which has the best performance.
- To support the optimized value for the initial equalizer setting.
- To evaluate SerDes IP early stage.

- If overall simulation result doesn't follow the measurement, the wrong SERDES setting may be the best optimum value.
- The effective methodology for correlating IBIS-AMI simulation to measurement should be needed.

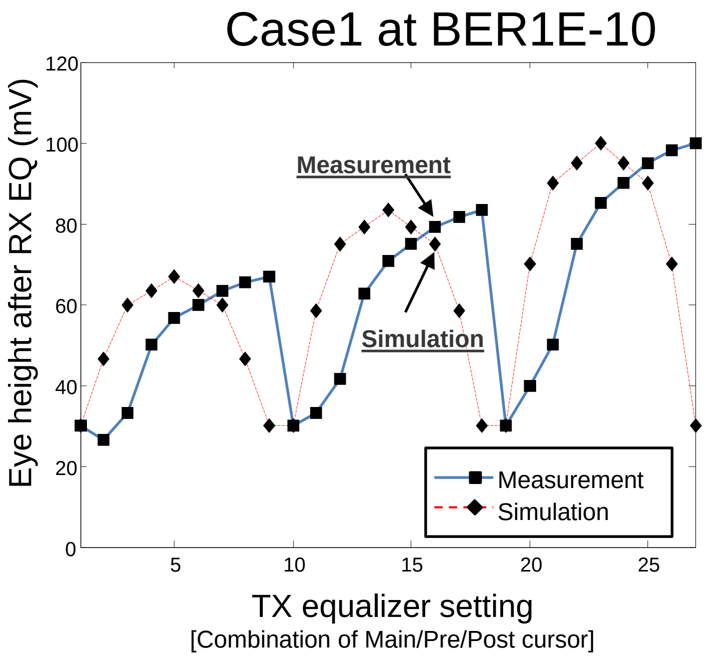
Comparison for two cases of correlation

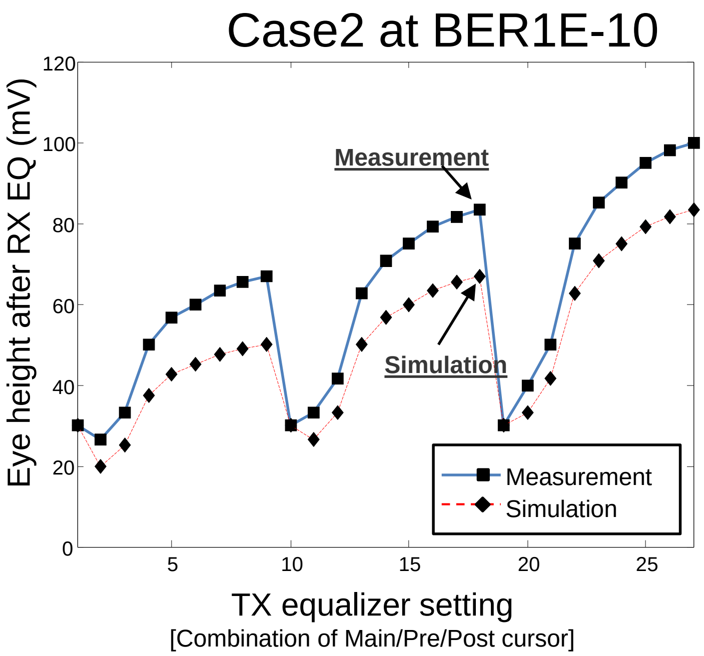




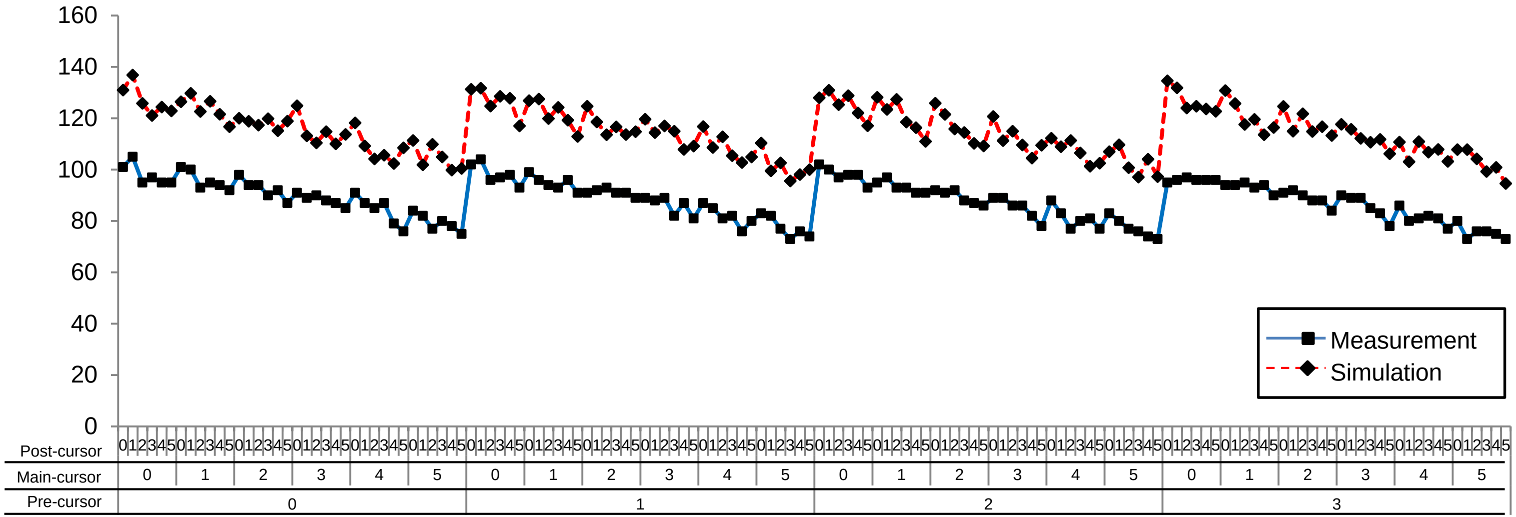
Comparison for two cases of correlation

Only few cases correlation can not represent all equalizer behavior performance!!





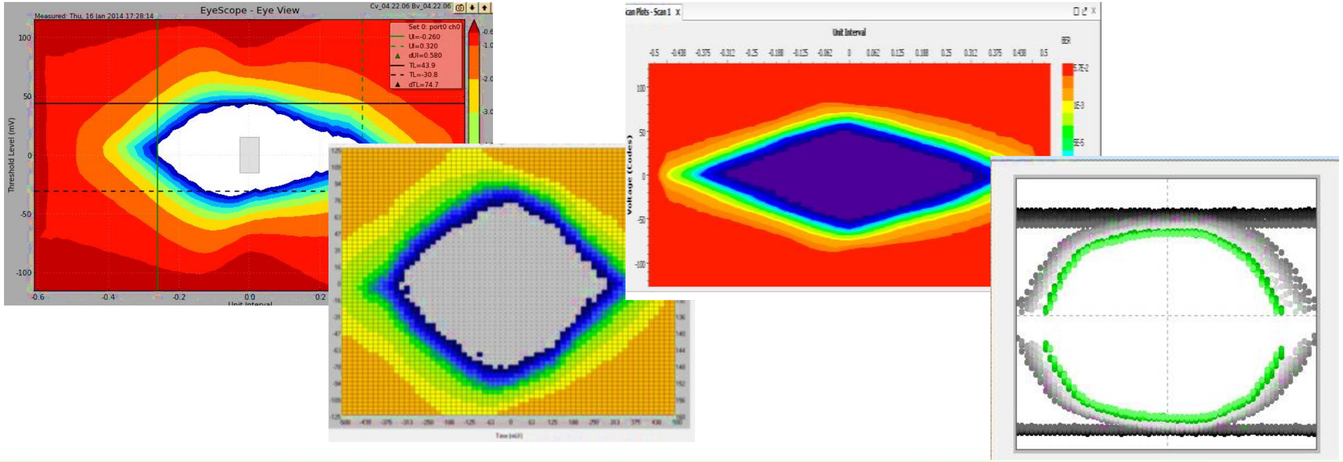
Trend Correlation



- **The trend correlation is:**
  - How eye opening trend after RX equalizer by TX equalizer setting.
  - The plot should be acquired by a large number of TX equalizer combination.
  - the optimized transceiver settings from the simulation can give a higher level of confidence with trend-matched simulation.

Requirement to do better correlation [Internal eye monitoring circuit]

- **It is difficult to measure the signal after RX equalizer.**
- **The latest scope has the ability of equalizer, but it is for generic function and not exactly same with ASIC's equalizer**
- **The internal eye diagram should be required**



Requirement to do better correlation
[Script for TX parameter sweep]

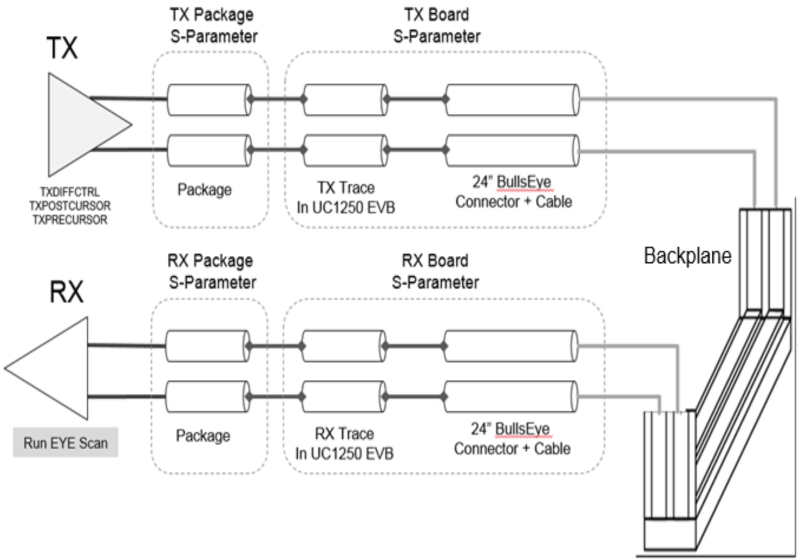
- **The internal eye diagrams should be measured with many combination of TX equalizer setting.**
- **It is very time consuming work if there is no TX parameter sweep script which measures**
- **Eye height and width for each TX equalizer setting need to be measured automatically.**

tx cmain	tx cpost	tx cpre1
14	9	0
14	9	1
14	9	2
14	9	3
14	10	0
14	10	1
14	10	2
14	10	3
14	11	0
14	11	1
14	11	2
14	11	3

Progress	v margin	h margin	h offset
Done	72.283	0.547	-0.0385
Done	83.202	0.66	0.013
Done	100.306	0.689	0.048
Done	102.784	0.696	0.0515
Done	68.368	0.523	-0.0445
Done	78.972	0.598	-0.049
Done	99.256	0.689	0.0125
Done	112.458	0.692	0.019
Done	85.122	0.612	0.02
Done	107.87	0.626	0.044
Done	97.978	0.633	-0.0375
Done	105.221	0.635	-0.0375

Measurement Set up

- Using Xilinx UltraScale GTH for 10Gbps and 16Gbps
- Using Xilinx UltraScale GTY for 28Gbps
- Eye Scan Parameters
  - Simulation eye height and eye width at BER 1E-10
  - HW Eye Scan: 1E-10 BER at each scan point



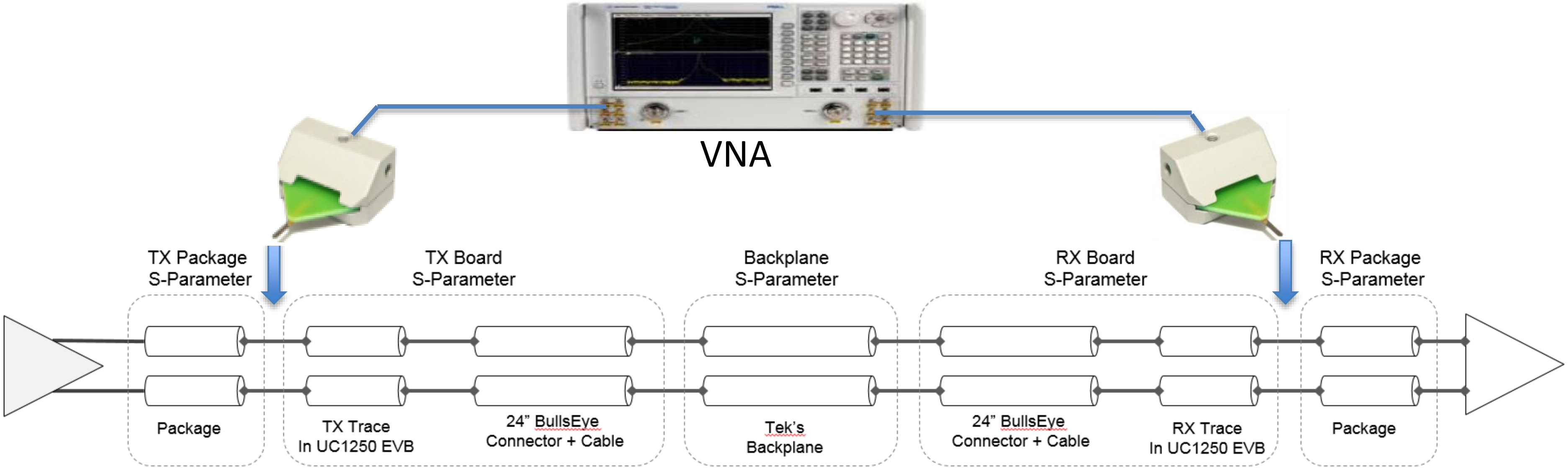
Test Cases

Line Rate	EQ mode	Loss of ISI Channel	Diff Insertion Loss
16.375Gbps	DFE	High Loss	23dB @ 8GHz
16.375Gbps	DFE	Med Loss	19dB @ 8GHz
10.3125Gbps	DFE	High Loss	24dB @ 5GHz
10.3125Gbps	DFE	Med Loss	18dB @ 5GHz
28Gbps	DFE	High Loss	28dB @ 14GHz
28Gbps	DFE	Med Loss	20dB @ 14GHz

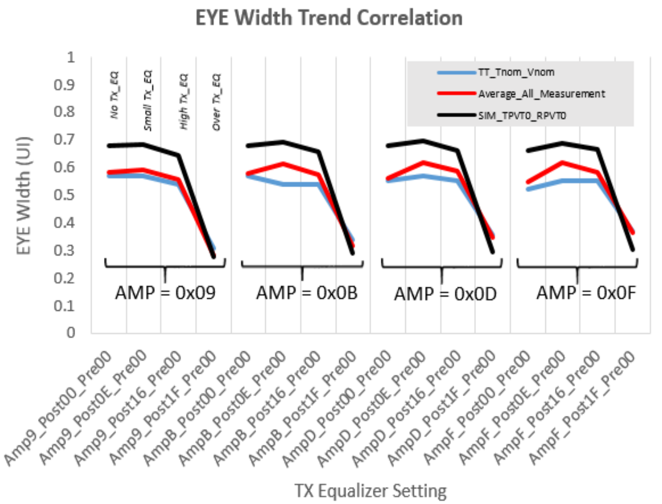
Line Rate	EQ Mode	Loss	MainCursor	PostCursor	PreCursor
16.375Gbps	DFE	High Loss	[B, D, E, F]	[00, 0E, 16, 1F]	[00]
16.375Gbps	DFE	Med Loss	[9, B, D, F]	[00, 0E, 16, 1F]	[00]
10.3125Gbps	DFE	High Loss	[9, B, D, F]	[00, 0E, 16, 1F]	[00]
10.3125Gbps	DFE	Med Loss	[6, 7, 9, A]	[00, 0A, 12, 16]	[00]
28Gbps	DFE	High Loss	[12,13,14,15]	[00, 0C, 12, 1B]	[00]
28Gbps	DFE	Med Loss	[12,13,14,15]	[00, 0C, 12, 1B]	[00]

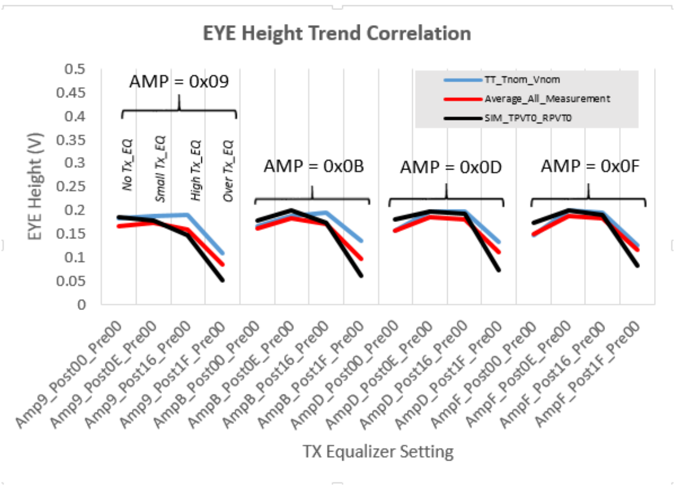
Measure Channel S-parameter

- Accurate s-parameter of channel is crucial for the correlation
- Measured s-parameter up to 50GHz without extrapolation



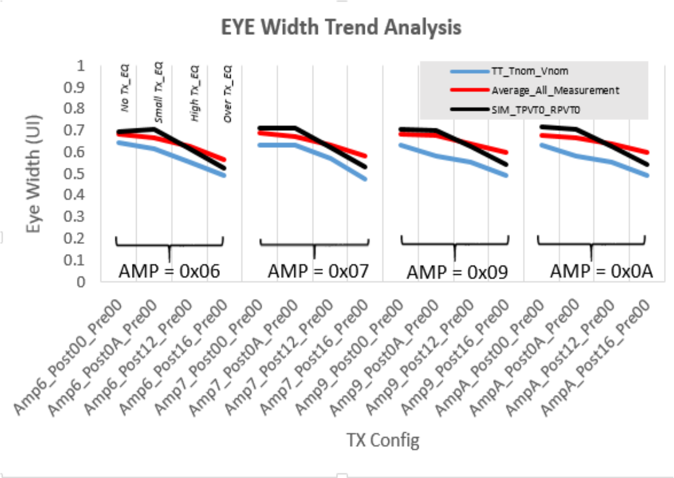
Case1: 10.3125Gbps High Loss DFE Result

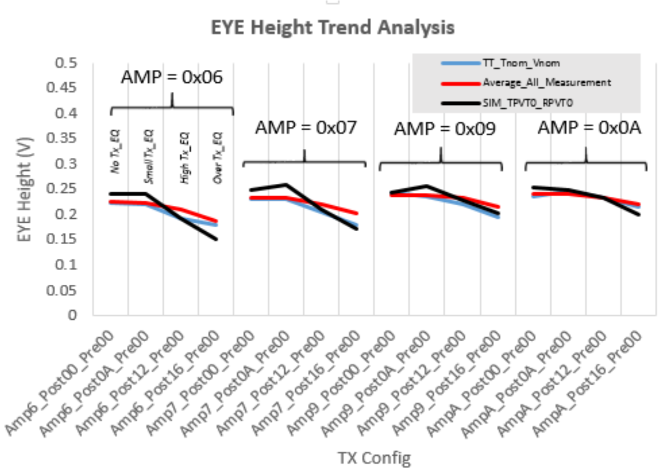




- **Used -24dB differential insertion channel at 5GHz**
- **Compare the results under [No TXEQ, Small TXEQ, High TXEQ, Over TXEQ[] at given amplitude**
- **Trends are matched well for both eye height and eye width**

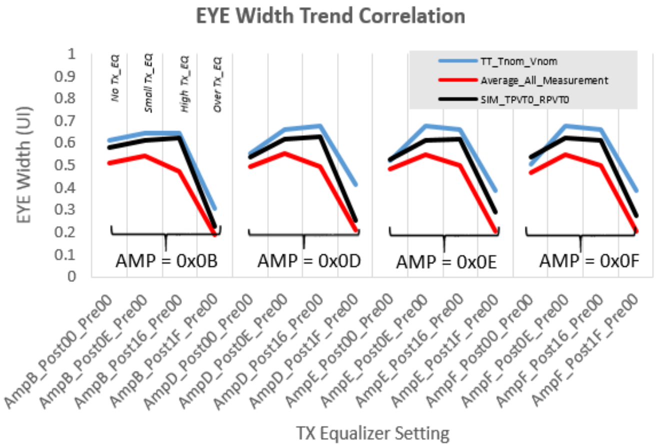
Case2: 10.3125Gbps Medium Loss DFE Result

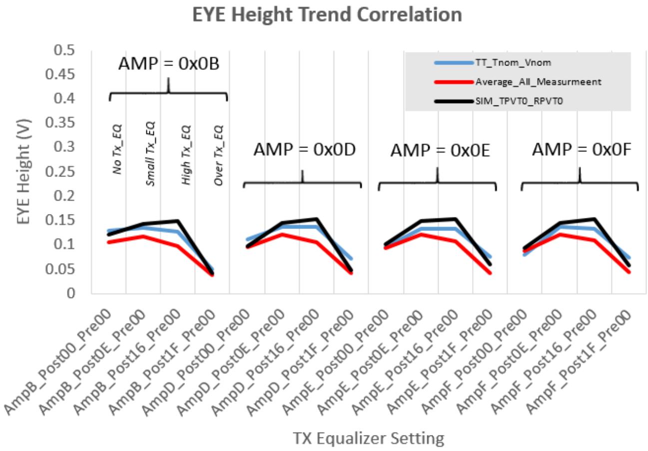




- **Used -18dB differential insertion channel at 5GHz**
- **Compare the results under [No TXEQ, Small TXEQ, High TXEQ, Over TXEQ[] at given amplitude**
- **Trends are matched well for both eye height and eye width**

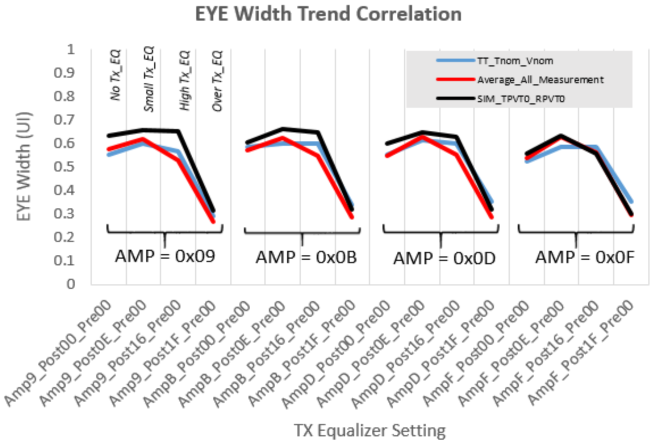
Case3: 16.3125Gbps High Loss DFE Result

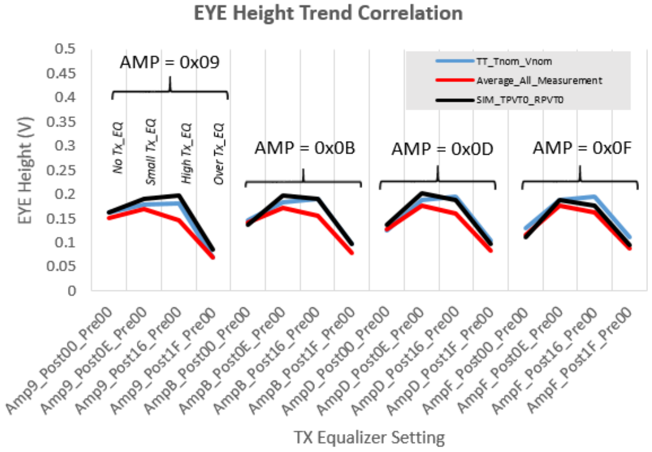




- **Used -23dB differential insertion channel at 8GHz**
- **Check the correlation under [No TXEQ, Small TXEQ, High TXEQ, Over TXEQ] at given amplitude**
- **Trends are matched well for both eye height and eye width**

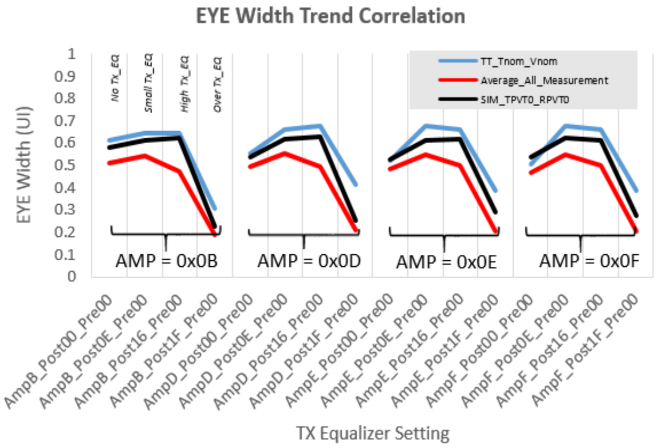
Case4: 16.3125Gbps Medium Loss DFE Result

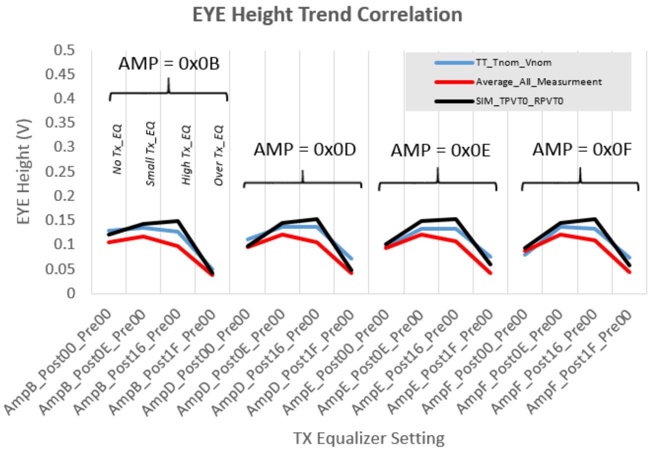




- **Used -19dB differential insertion channel at 8GHz**
- **Check the correlation under [No TXEQ, Small TXEQ, High TXEQ, Over TXEQ] at given amplitude**
- **Trends are matched well for both eye height and eye width**

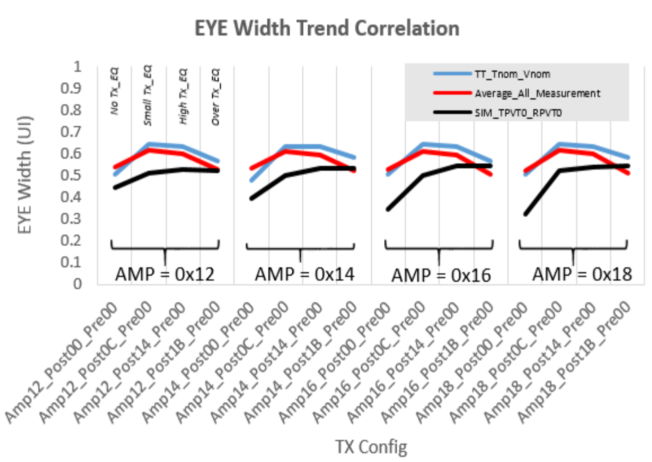
Case6: 28Gbps Medium Loss DFE Mode

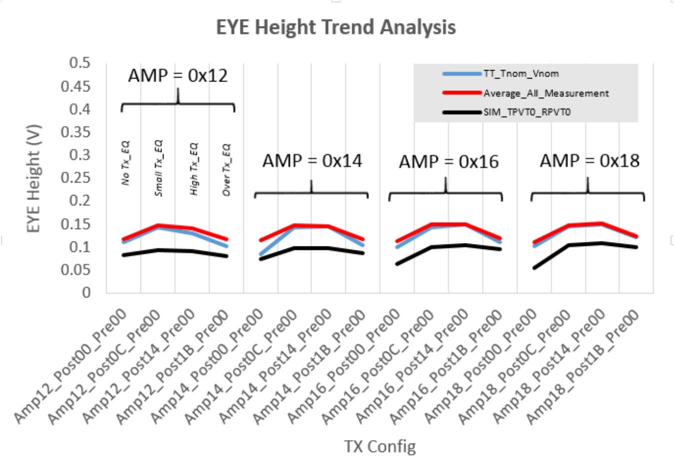




- **Used -19dB differential insertion channel at 14GHz**
- **Check the correlation under [No TXEQ, Small TXEQ, High TXEQ, Over TXEQ] at given amplitude**
- **Trends are matched well for both eye height and eye width**

Case5: 28Gbps High Loss DFE Mode





- **Used -28dB differential insertion channel at 14GHz**
- **Check the correlation under [No TXEQ, Small TXEQ, High TXEQ, Over TXEQ] at given amplitude**
- **Trends are matched well for both eye height and eye width**

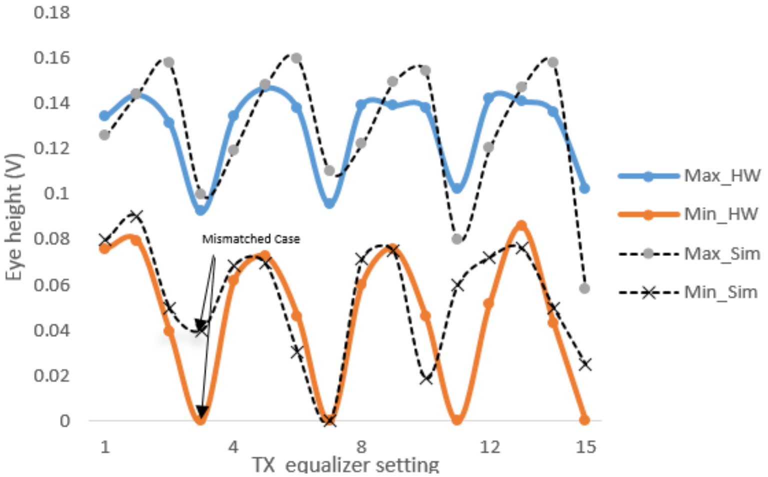
Distribution Correlation

The value of distribution analysis

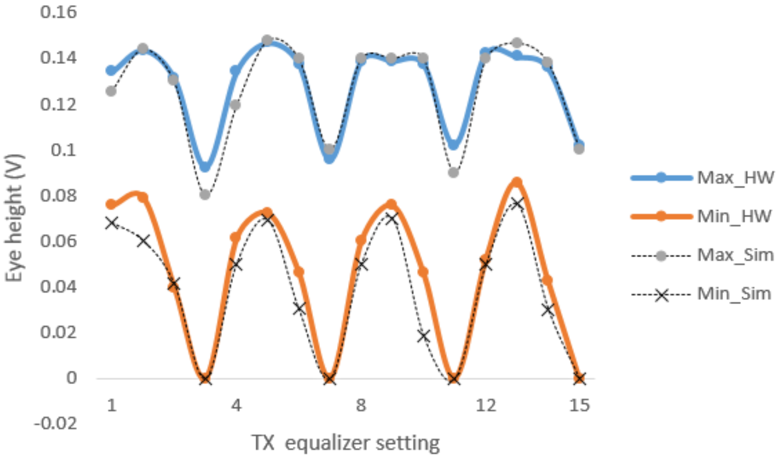
- IBIS-AMI simulation needs to cover the variation of devices
- IBIS-AMI simulation needs to represent the worst performance by PVT variation
- Distribution Analysis shows how well IBIS-AMI Simulation represents the boundary of hardware variation
- If simulation result would be better than the worst case measurement, it cannot guarantee the link performance in mass production system

Comparison for two cases of distribution analysis

IBIS-AMI simulation needs to represent the distribution of hardware under given condition!!



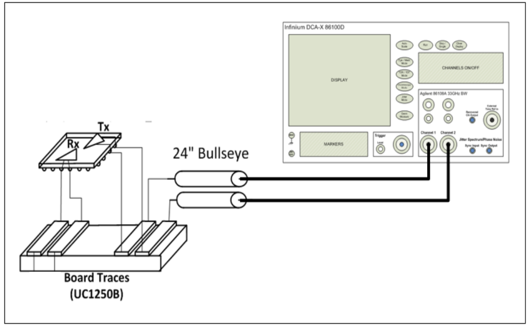
Case1. Simulation is better than measurement



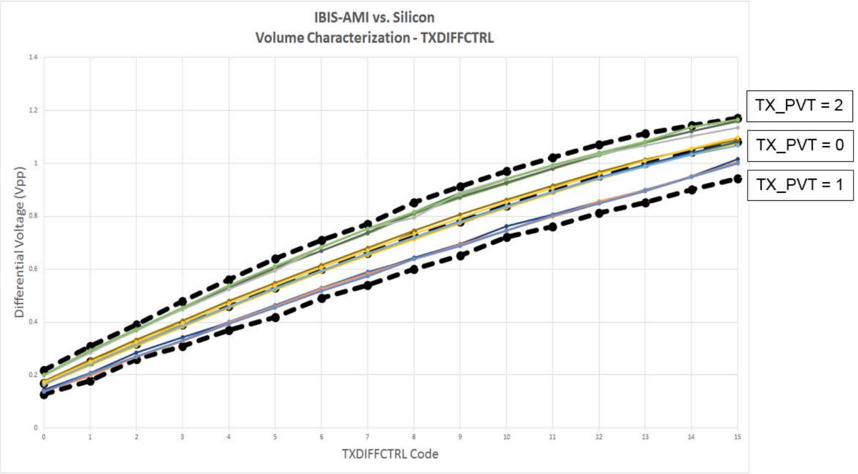
Case2. Simulation represents the distribution of measurement

The distribution of transmitter

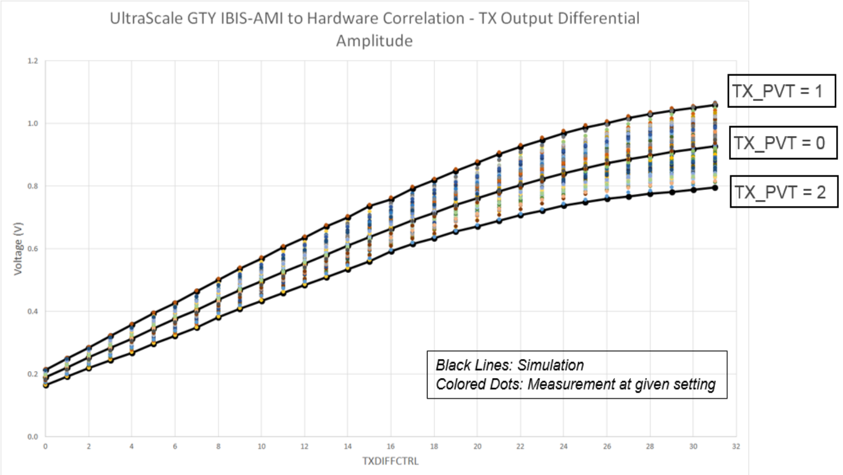
- The distribution of transmitter is also critical to analyze the one of receiver
  - The distribution of differential amplitude
  - The distribution of de-emphasis by postCursor
  - The distribution of de-emphasis by precursor



The distribution of differential amplitude



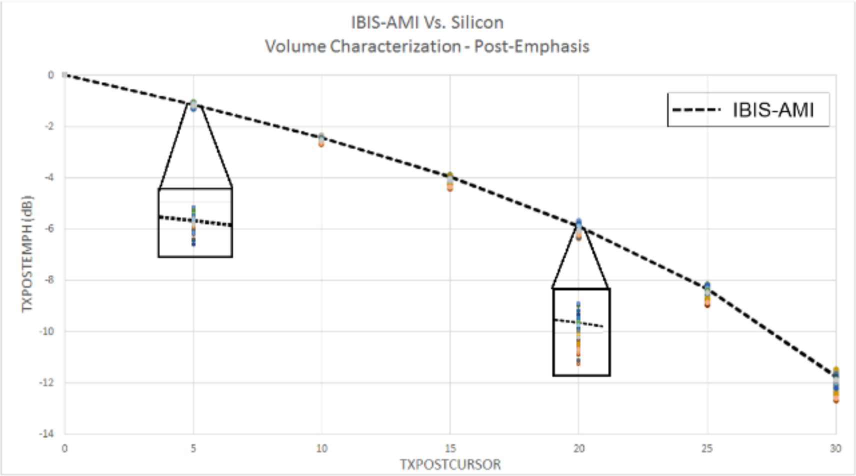
Xilinx UltraScale GTH at 10.3125Gbps



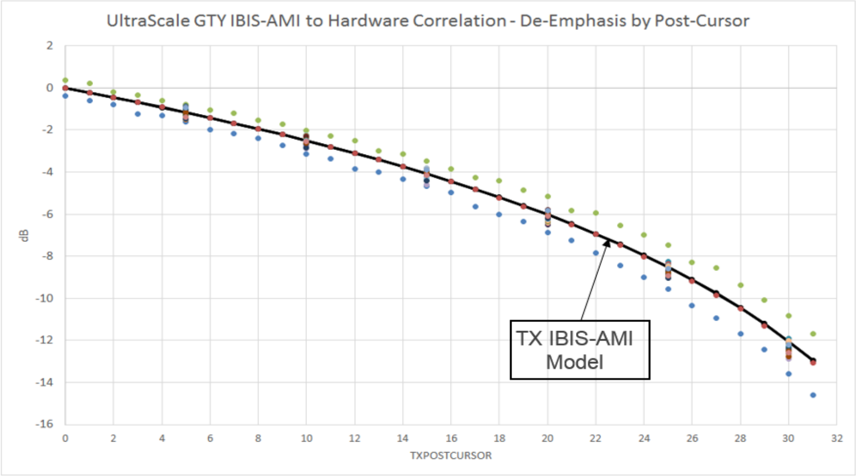
Xilinx UltraScale GTY at 28Gbps

- IBIS-AMI model represents the distribution of hardware measurement well

The distribution of de-emphasis by postCursor



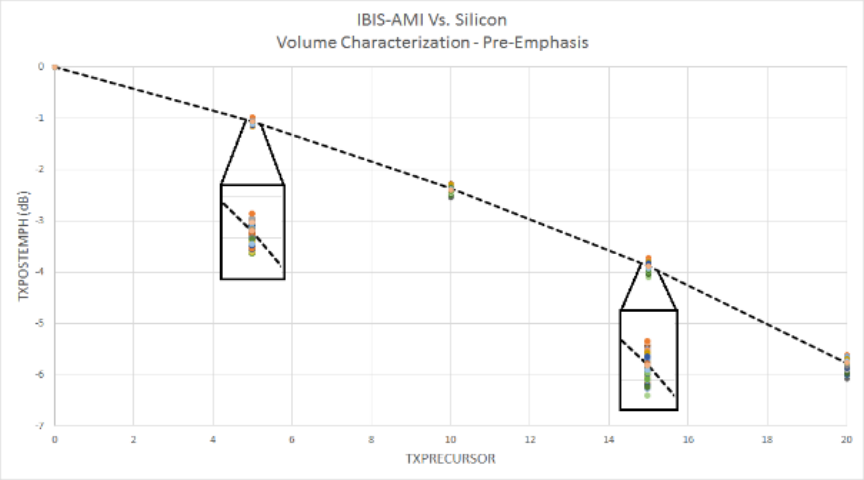
Xilinx UltraScale GTH at 10.3125Gbps



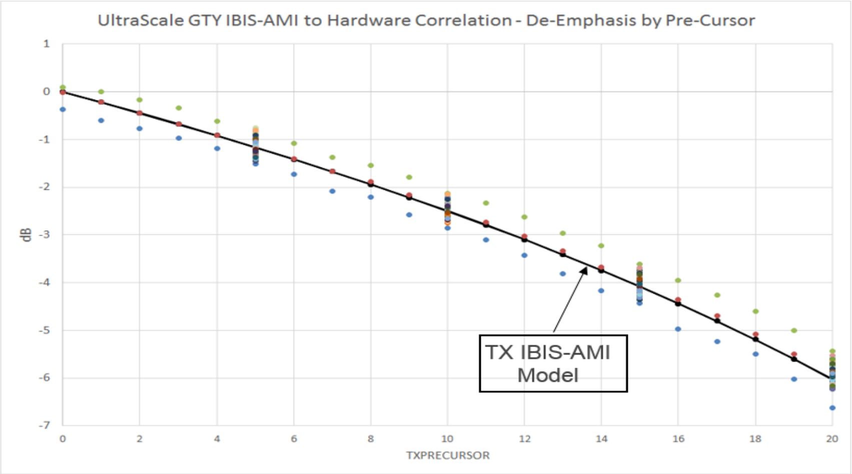
Xilinx UltraScale GTY at 28Gbps

- IBIS-AMI model locates at the center of hardware distribution

The distribution of de-emphasis by preCursor



Xilinx UltraScale GTH at 10.3125Gbps



Xilinx UltraScale GTY at 28Gbps

- IBIS-AMI model locates at the center of hardware distribution

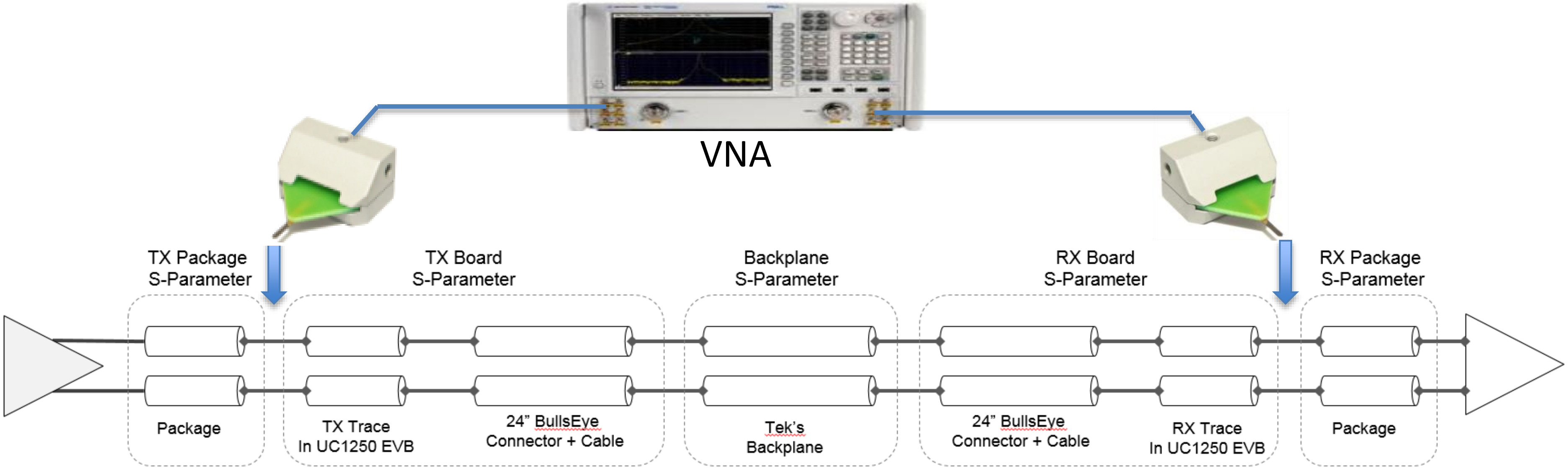
Test Cases for receiver distribution analysis

Line Rate	EQ mode	Loss of ISI Channel	Diff Insertion Loss
16.375Gbps	DFE	High Loss	23dB @ 8GHz
16.375Gbps	DFE	Med Loss	19dB @ 8GHz
10.3125Gbps	DFE	High Loss	24dB @ 5GHz
10.3125Gbps	DFE	Med Loss	18dB @ 5GHz
28Gbps	DFE	High Loss	28dB @ 14GHz
28Gbps	DFE	Med Loss	20dB @ 14GHz

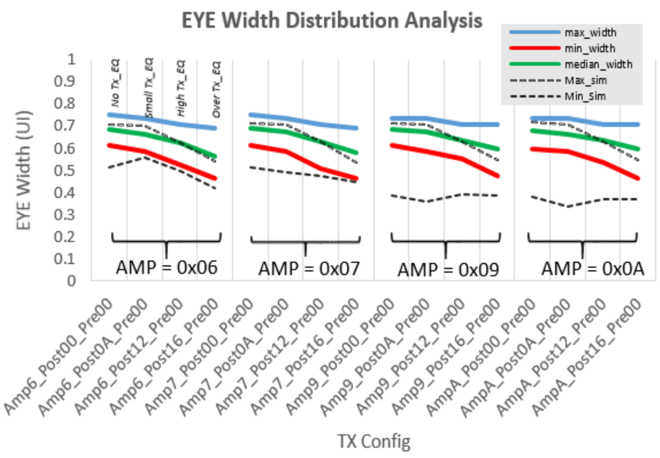
Line Rate	EQ Mode	Loss	MainCursor	PostCursor	PreCursor
16.375Gbps	DFE	High Loss	[B, D, E, F]	[00, 0E, 16, 1F]	[00]
16.375Gbps	DFE	Med Loss	[9, B, D, F]	[00, 0E, 16, 1F]	[00]
10.3125Gbps	DFE	High Loss	[9, B, D, F]	[00, 0E, 16, 1F]	[00]
10.3125Gbps	DFE	Med Loss	[6, 7, 9, A]	[00, 0A, 12, 16]	[00]
28Gbps	DFE	High Loss	[12,13,14,15]	[00, 0C, 12, 1B]	[00]
28Gbps	DFE	Med Loss	[12,13,14,15]	[00, 0C, 12, 1B]	[00]

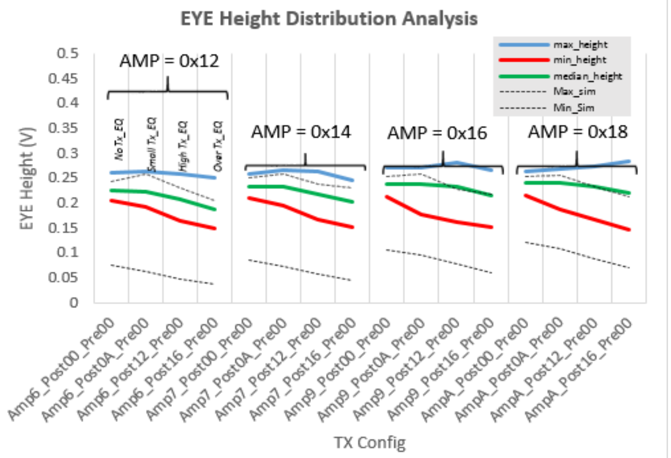
Measure Channel S-parameter

- Accurate s-parameter of channel is crucial for the correlation
- Measured s-parameter up to 50GHz without extrapolation



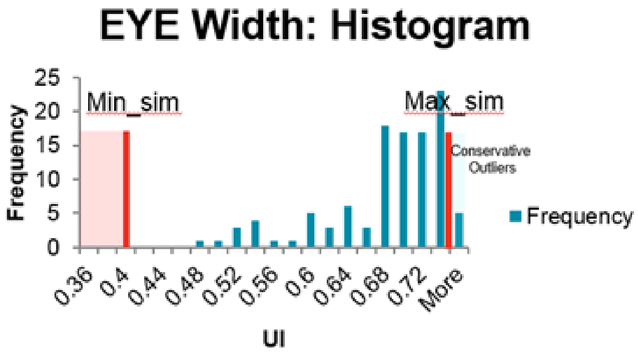
Case1: 10.3125Gbps Medium Loss DFE Result

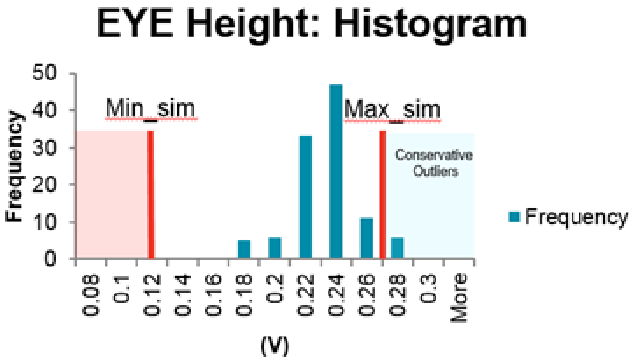




- **Used -19dB differential insertion channel at 5GHz**
- **The worst case of hardware distribution is above the worst result of simulation across all of TX settings**

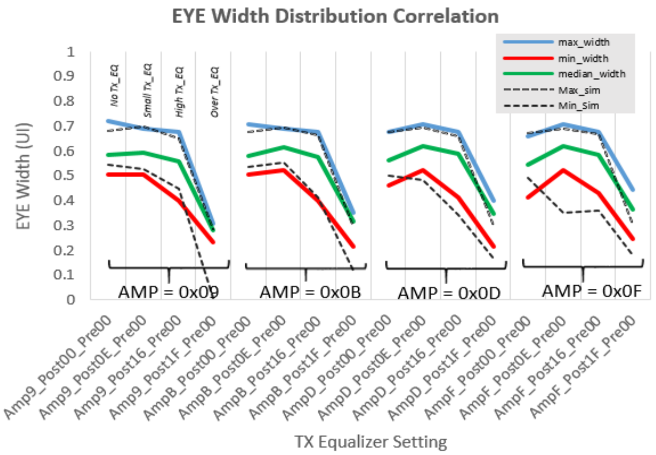
Case1: 10.3125Gbps Medium Loss DFE Result (cont.)

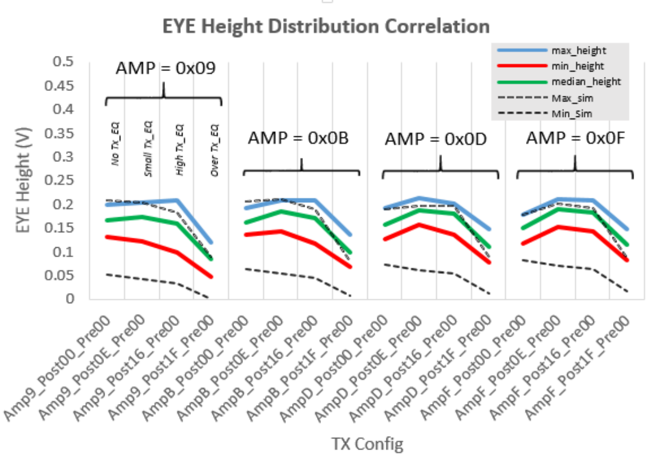




- **Spot Check at “Small TXEQ” at AMP = 0x09 shows the detail histogram between hardware and IBIS-AMI simulation**
- **There are “Conservative Outliers” which is showing the model is conservative than hardware**

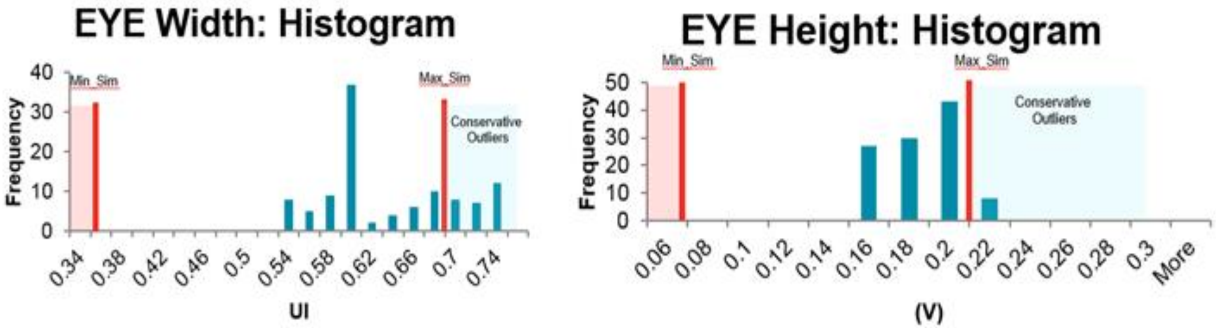
Case2: 10.3125Gbps High Loss DFE Result





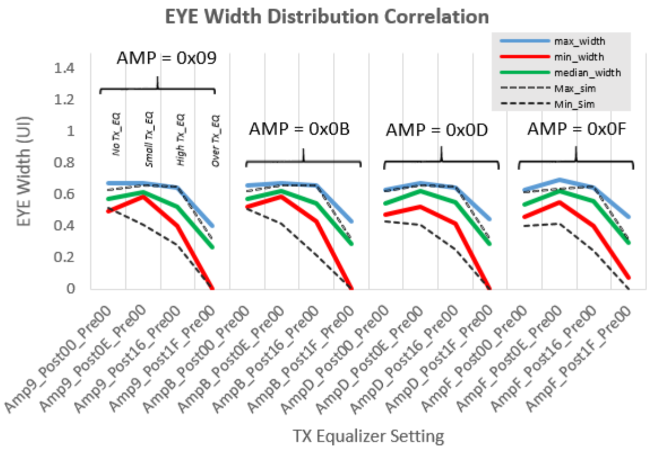
- **Used -24dB differential insertion channel at 5GHz**
- **The worst case of hardware distribution is above the worst result of simulation across all of TX settings**

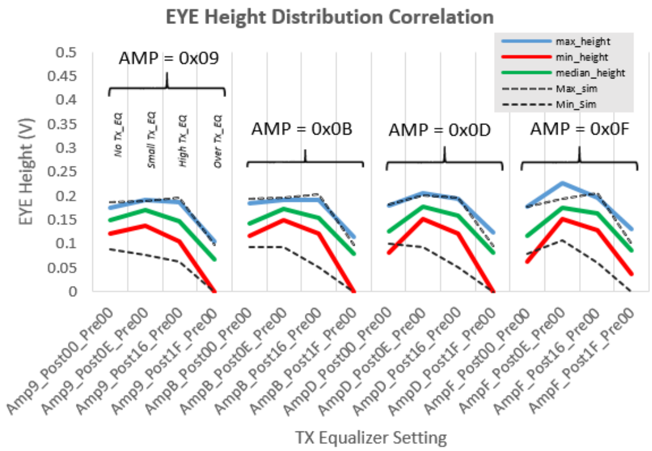
Case2: 10.3125Gbps High Loss DFE Result (cont.)



- **Spot Check at "Small TXEQ" at AMP = 0x0F shows the detail histogram between hardware and IBIS-AMI simulation**
- **There are "Conservative Outliers" which is showing the model is conservative than hardware**

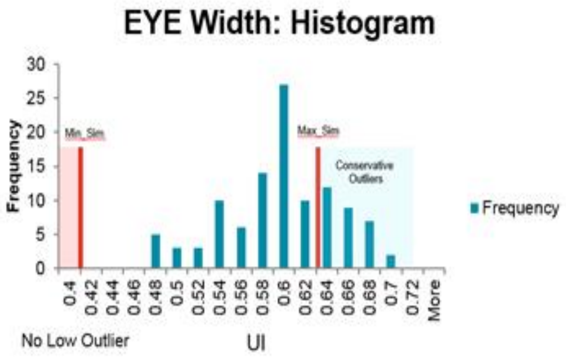
Case3: 16.325Gbps Medium Loss DFE Result

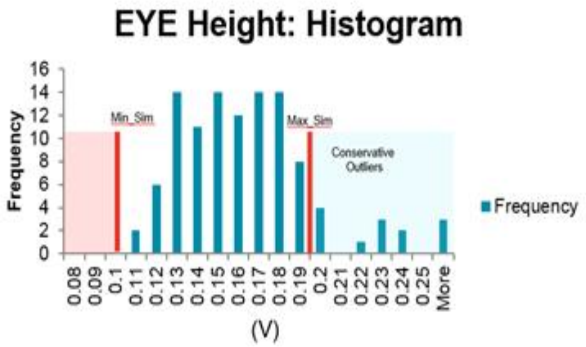




- **Used -19dB differential insertion channel at 5GHz**
- **The worst case of hardware distribution is above the worst result of simulation across all of TX settings**

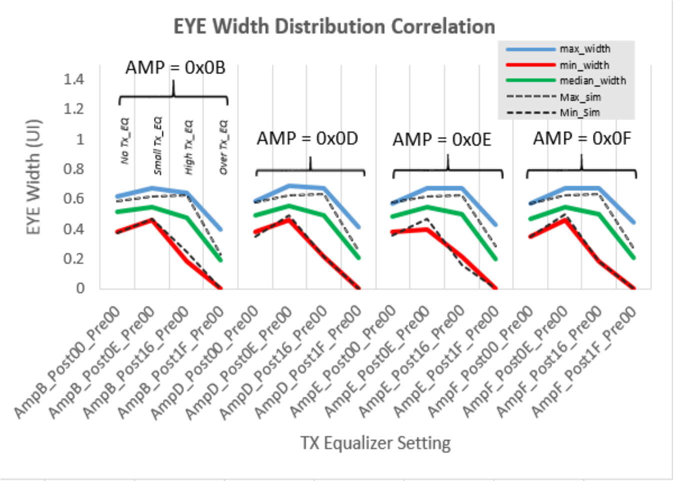
Case3: 16.325Gbps Medium Loss DFE Result (cont.)

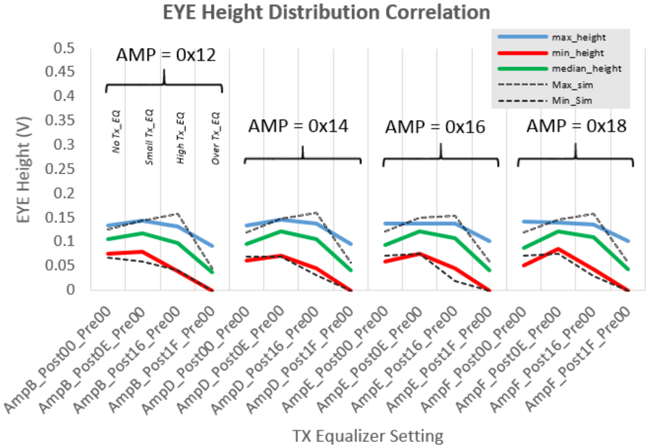




- **Spot Check at "Small TXEQ" at AMP = 0x0F shows the detail histogram between hardware and IBIS-AMI simulation**
- **There are "Conservative Outliers" which is showing the model is conservative than hardware**

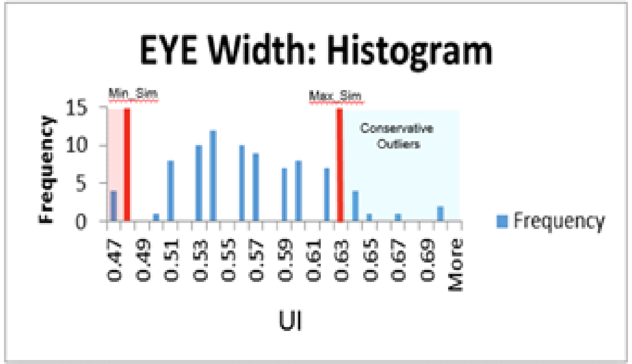
Case4: 16.325Gbps High Loss DFE Result

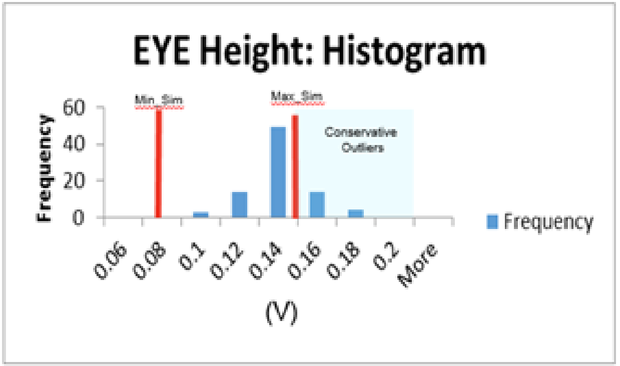




- **Used -19dB differential insertion channel at 8GHz**
- **The worst case of hardware distribution is above the worst result of simulation across all of TX settings**

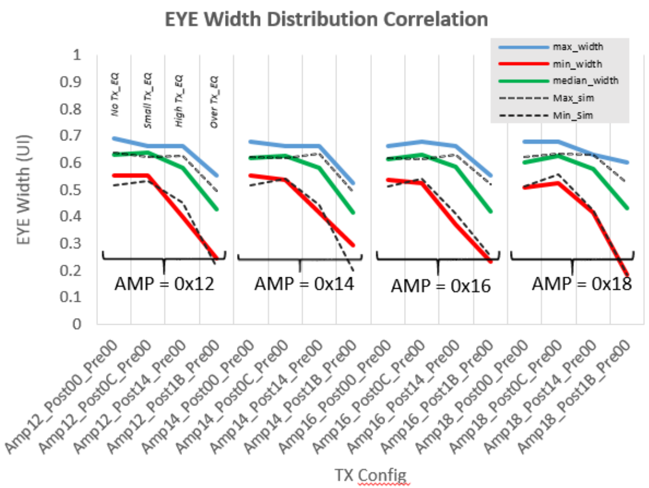
Case4: 16.325Gbps High Loss DFE Result (cont.)

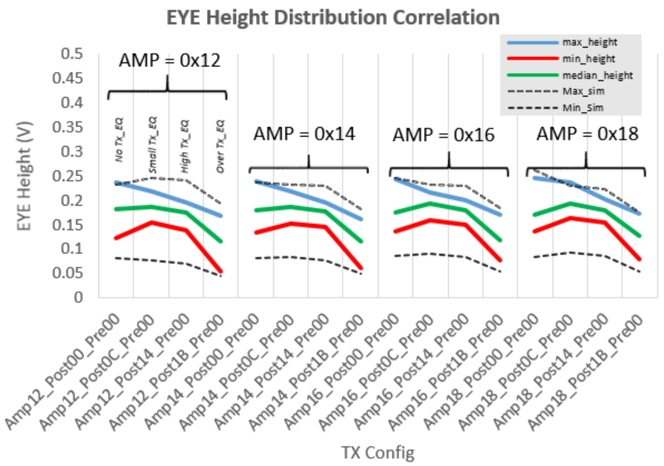




- **Spot Check at "Small TXEQ" at AMP = 0x0F shows the detail histogram between hardware and IBIS-AMI simulation**
- **There are "Conservative Outliers" which is showing the model is conservative than hardware**

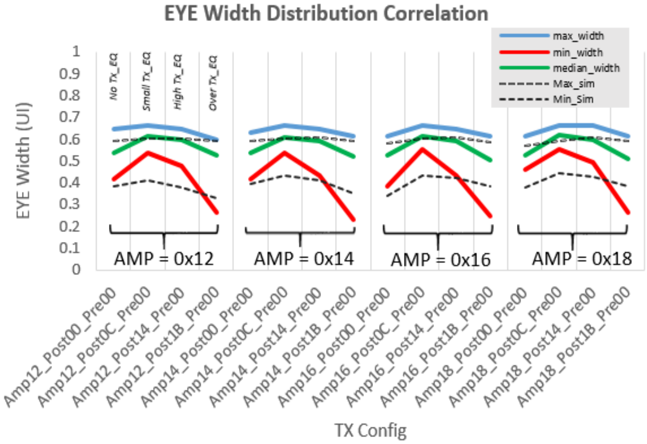
Case5: 28Gbps Medium Loss DFE Result

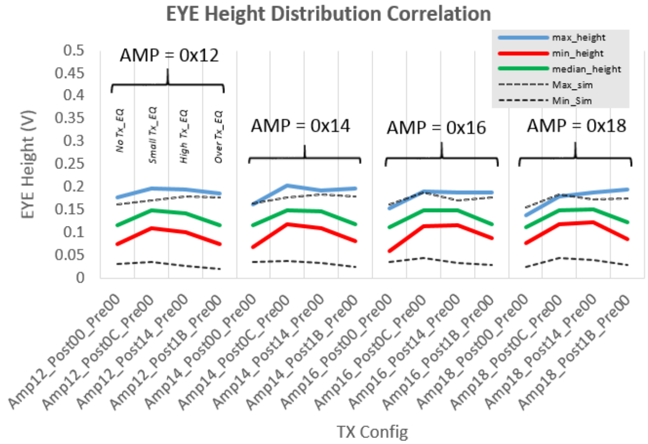




- **Used -19dB differential insertion channel at 14GHz**
- **The worst case of hardware distribution is above the worst result of simulation across all of TX settings**

Case6: 28Gbps High Loss DFE Result





- **Used -28dB differential insertion channel at 14GHz**
- **The worst case of hardware distribution is above the worst result of simulation across all of TX settings**

Conclusion

- Trend Correlation is required to optimize the setting for given channel
- Distribution Correlation is required to reduce the risk by PVT variation
- IBIS-AMI model needs to designed carefully to cover both trend and distribution correlation
- New methodology of correlation is applied successfully to Xilinx UltraScale GTH / GTY at 10.3125Gbps, 16.325Gbps and 28Gbps

Thank you!

QUESTIONS?