ERICSSON

MODEL CORRELATION FOR IBIS-AMI

Asian IBIS Summit, Tokyo, Japan, November 12, 2018

Authors:

Wenyan Xie, Guohua Wang, David Zhang, Anders Ekholm

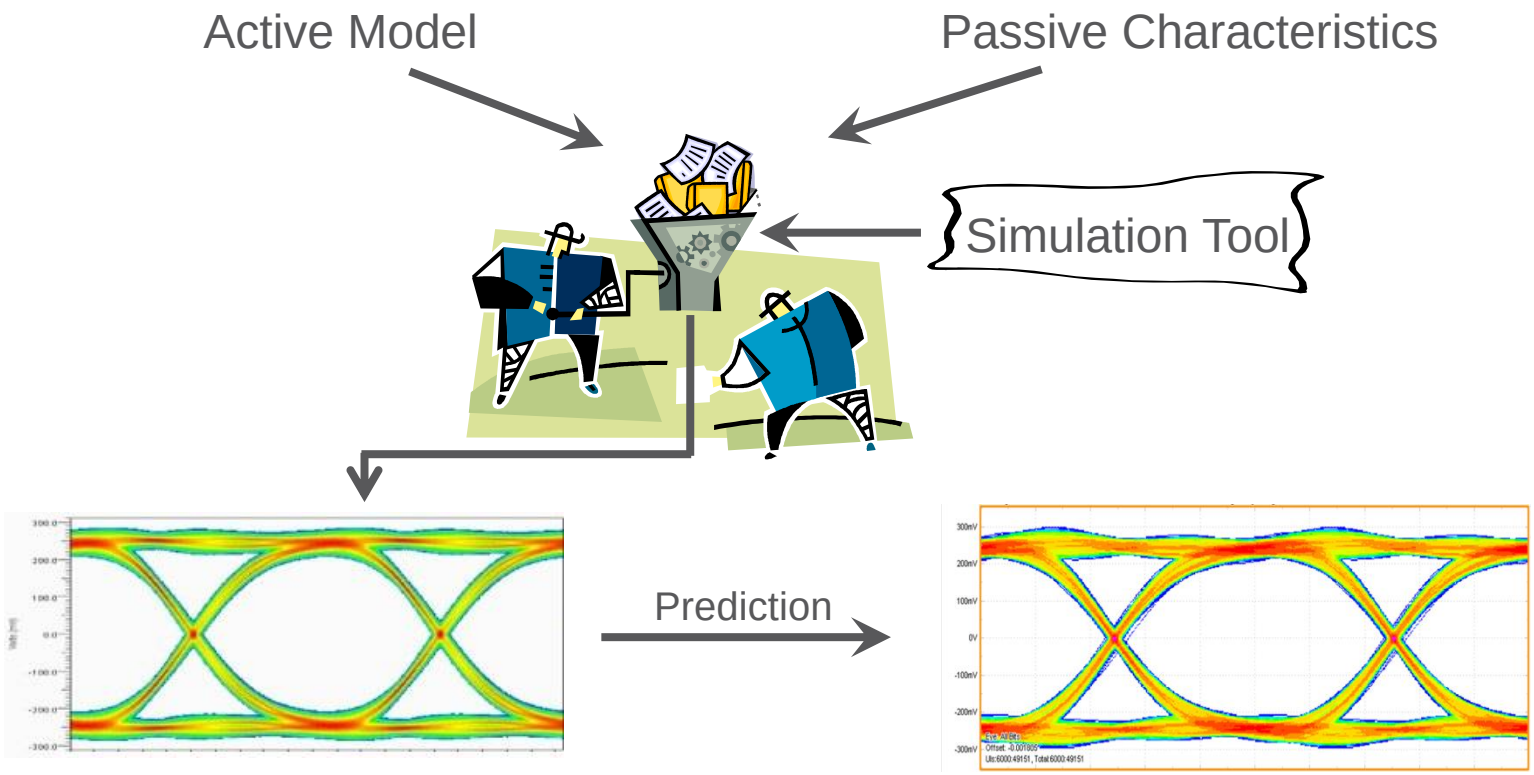
AGENDA

- Why IBIS-AMI correlation
- Correlation methodology for TX
- Correlation methodology for RX
- Correlation criteria
- Question and suggestion

AGENDA

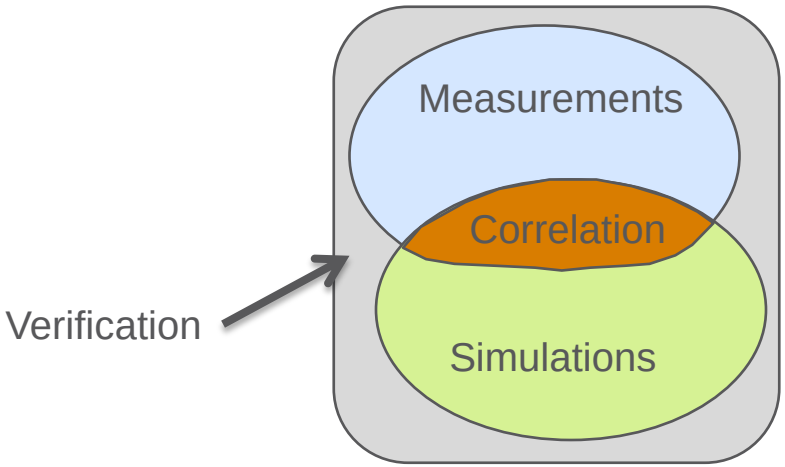
- Why IBIS-AMI correlation
- Correlation methodology for TX
- Correlation methodology for RX
- Correlation criteria
- Question and suggestion

WHY CORRELATION FOR IBIS-AMI



WHY CORRELATION FOR IBIS-AMI

› Correlation not only can verify simulation model's accuracy, but also can increase the verification coverage once model is matched to real tests. With the correlation, the simulation results can be the part of verification to cover some cases that measurement can not touch.



AGENDA

- Why IBIS-AMI correlation
- Correlation methodology for TX
- Correlation methodology for RX
- Correlation criteria
- Question and suggestion

CORRELATION METHODOLOGY FOR TX

› Procedure

Extract Passive Channel Characteristic

↓

Sync Measurement Condition to Simulation Environment

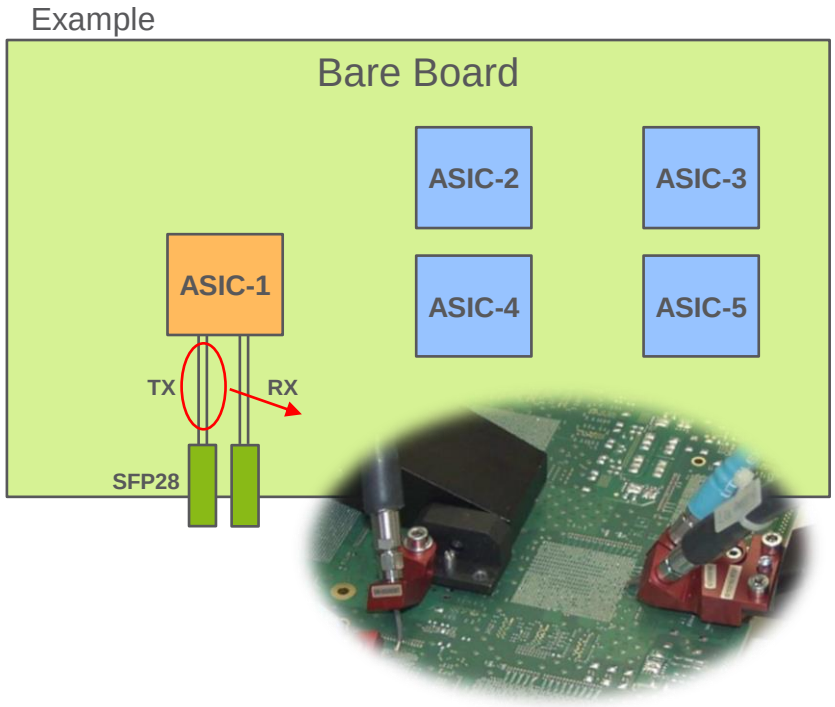
↓

Correlate TX Channel

↓

Evaluate and Archive

Example



CORRELATION METHODOLOGY FOR TX

› Procedure

Extract Passive Channel Characteristic

↓

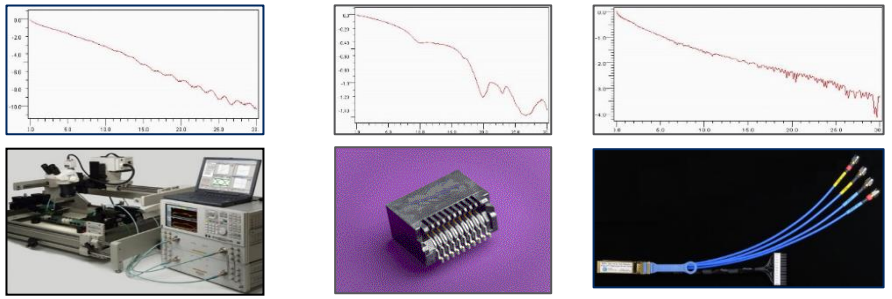
Sync Measurement Condition to Simulation Environment

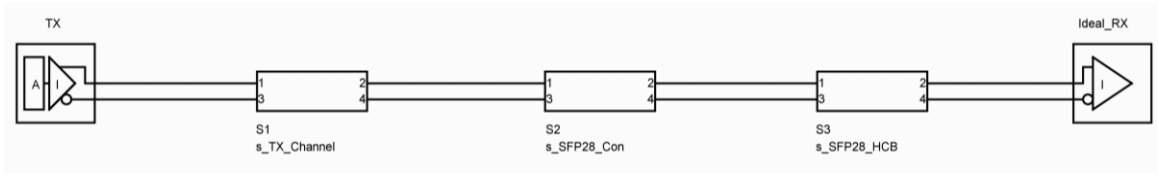
↓

Correlate TX Channel

↓

Evaluate and Archive

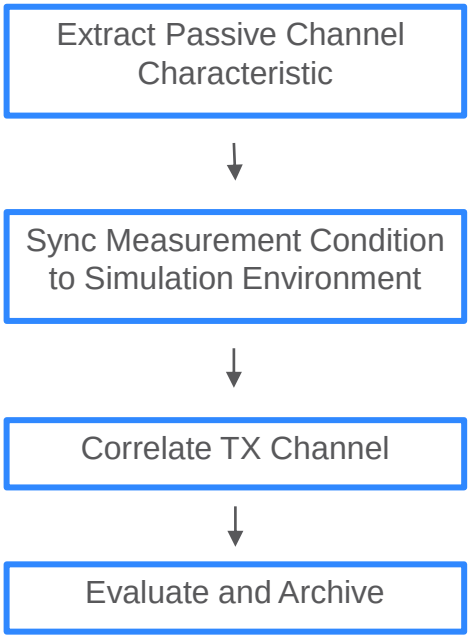




- PVT Settings
- Stimulus patterns
- Running bits
- Samples per bit

CORRELATION METHODOLOGY FOR TX

› Procedure

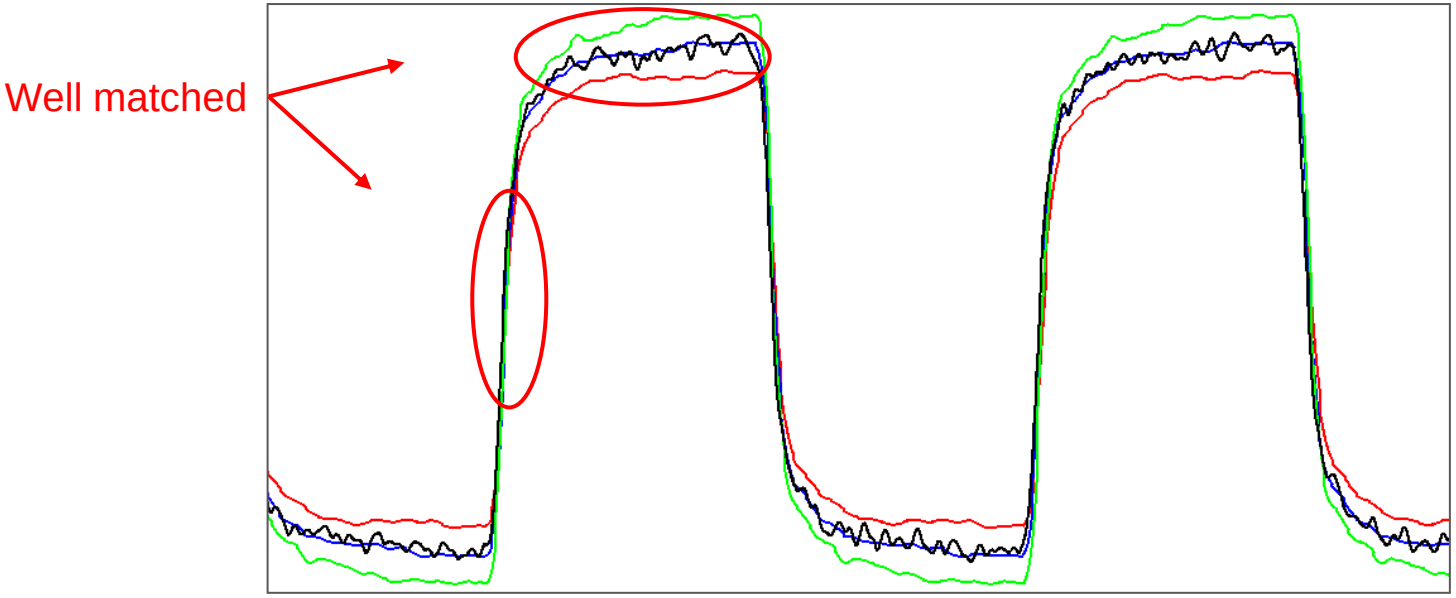


Item	TXDIFFCTRL[3:0]	TXPRECURSOR[4:0]	TXPOSTCURSOR[4:0]	Pattern	Output
Case1	0	0	0	slow clock	waveform.csv
Case2	1	0	0	slow clock	waveform.csv
Case3	2	0	0	slow clock	waveform.csv
Case4	3	0	0	slow clock	waveform.csv
Case5	4	0	0	slow clock	waveform.csv
Case6	5	0	0	slow clock	waveform.csv
Case7	6	0	0	slow clock	waveform.csv
Case8	7	0	0	slow clock	waveform.csv
Case9	8	0	0	slow clock	waveform.csv
Case10	9	0	0	slow clock	waveform.csv
Case11	10	0	0	slow clock	waveform.csv
Case12	11	0	0	slow clock	waveform.csv
Case13	12	0	0	slow clock	waveform.csv
Case14	13	0	0	slow clock	waveform.csv
Case15	14	0	0	slow clock	waveform.csv
Case16	15	0	0	slow clock	waveform.csv
Case17	8	5	0	slow clock	waveform.csv
Case18	8	10	0	slow clock	waveform.csv
Case19	8	15	0	slow clock	waveform.csv
Case20	8	20	0	slow clock	waveform.csv
Case21	8	0	5	slow clock	waveform.csv
Case22	8	0	10	slow clock	waveform.csv
Case23	8	0	15	slow clock	waveform.csv
Case24	8	0	20	slow clock	waveform.csv
Case25	8	0	25	slow clock	waveform.csv
Case26	8	0	31	slow clock	waveform.csv
Case27	8	5	5	slow clock	waveform.csv
Case28	8	5	10	slow clock	waveform.csv
Case29	8	10	5	slow clock	waveform.csv
Case30	8	10	10	slow clock	waveform.csv

Item	TXDIFFCTRL[3:0]	TXPRECURSOR[4:0]	TXPOSTCURSOR[4:0]	Pattern	Output
Case31	0	0	0	prbs7	waveform.csv&eye diagram
Case32	1	0	0	prbs7	waveform.csv&eye diagram
Case33	2	0	0	prbs7	waveform.csv&eye diagram
Case34	3	0	0	prbs7	waveform.csv&eye diagram
Case35	4	0	0	prbs7	waveform.csv&eye diagram
Case36	5	0	0	prbs7	waveform.csv&eye diagram
Case37	6	0	0	prbs7	waveform.csv&eye diagram
Case38	7	0	0	prbs7	waveform.csv&eye diagram
Case39	8	0	0	prbs7	waveform.csv&eye diagram
Case40	9	0	0	prbs7	waveform.csv&eye diagram
Case41	10	0	0	prbs7	waveform.csv&eye diagram
Case42	11	0	0	prbs7	waveform.csv&eye diagram
Case43	12	0	0	prbs7	waveform.csv&eye diagram
Case44	13	0	0	prbs7	waveform.csv&eye diagram
Case45	14	0	0	prbs7	waveform.csv&eye diagram
Case46	15	0	0	prbs7	waveform.csv&eye diagram
Case47	8	5	0	prbs7	waveform.csv&eye diagram
Case48	8	10	0	prbs7	waveform.csv&eye diagram
Case49	8	15	0	prbs7	waveform.csv&eye diagram
Case50	8	20	0	prbs7	waveform.csv&eye diagram
Case51	8	0	5	prbs7	waveform.csv&eye diagram
Case52	8	0	10	prbs7	waveform.csv&eye diagram
Case53	8	0	15	prbs7	waveform.csv&eye diagram
Case54	8	0	20	prbs7	waveform.csv&eye diagram
Case55	8	0	25	prbs7	waveform.csv&eye diagram
Case56	8	0	31	prbs7	waveform.csv&eye diagram
Case57	8	5	5	prbs7	waveform.csv&eye diagram
Case58	8	5	10	prbs7	waveform.csv&eye diagram
Case59	8	10	5	prbs7	waveform.csv&eye diagram
Case60	8	10	10	prbs7	waveform.csv&eye diagram

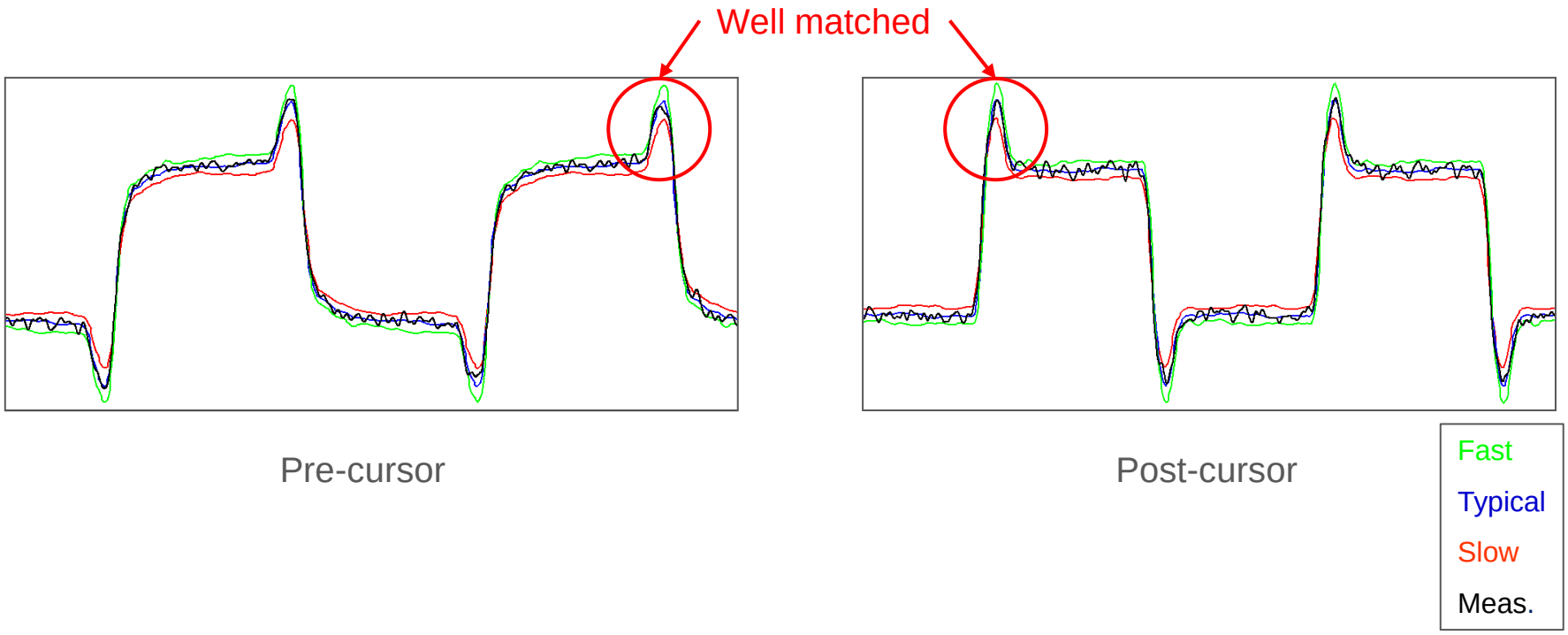
CORRELATION RESULTS FOR TX

› Slow Clock Pattern – Edge and Amplitude Voltage



CORELATION RESULTS FOR TX

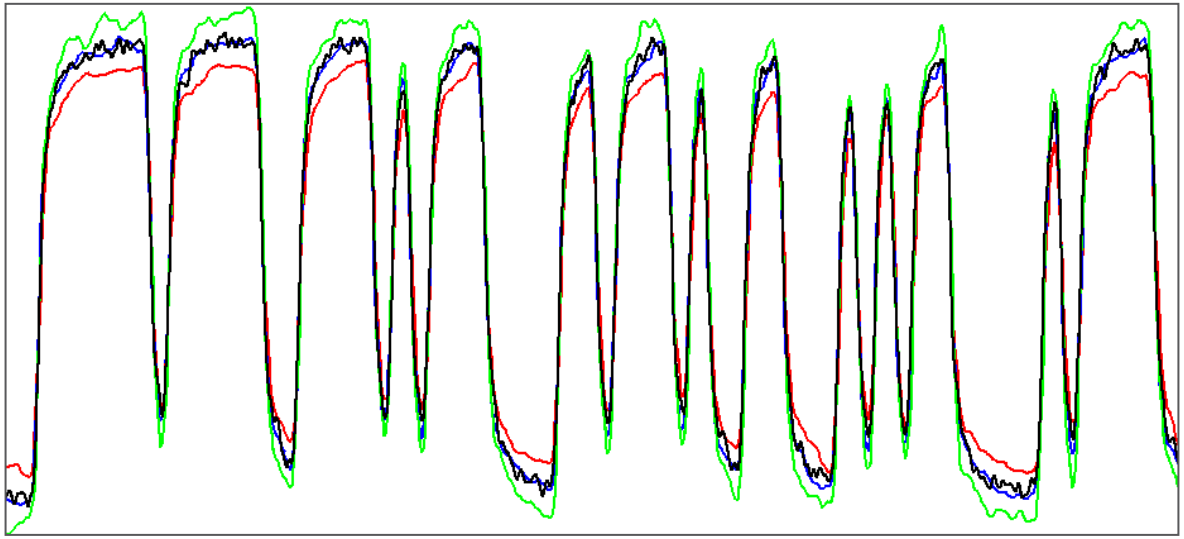
› Slow Clock Pattern – FFE Taps



CORRELATION RESULTS FOR TX

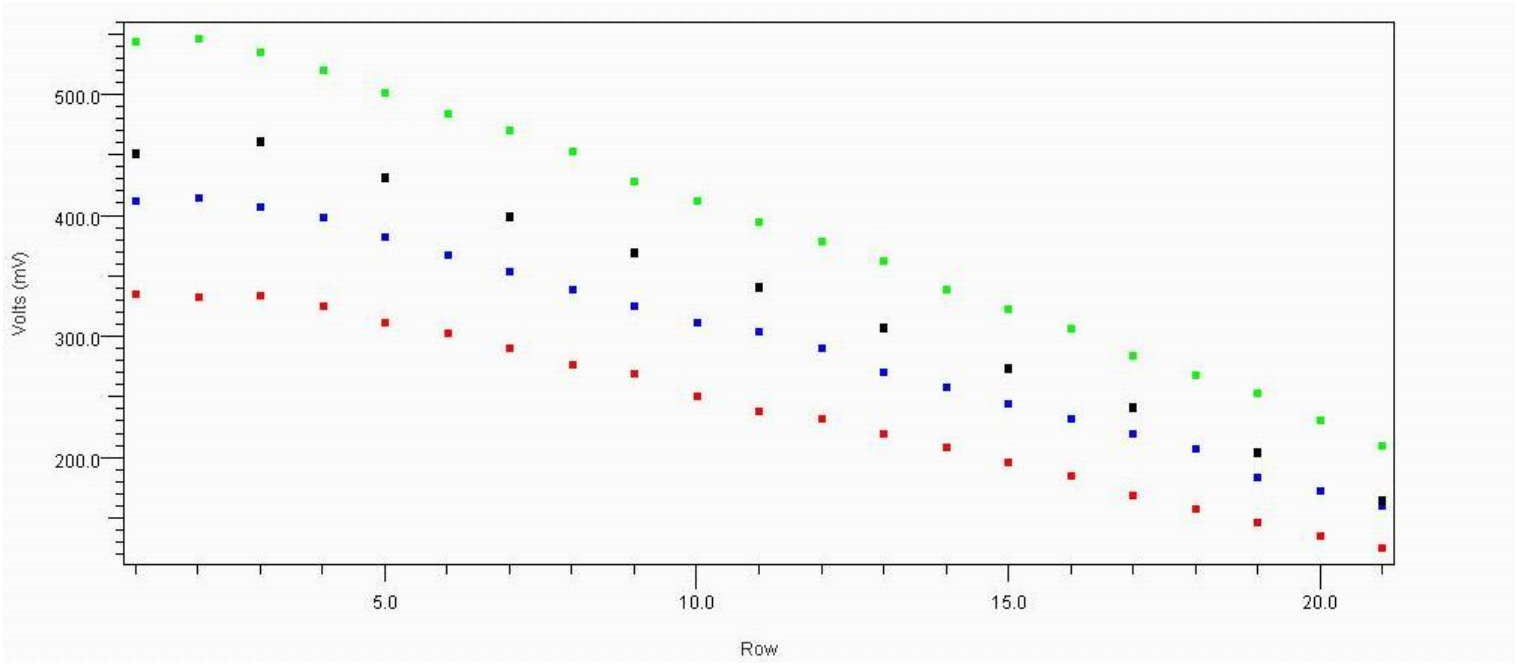
› PRBS7 Pattern – Fast Response

Well matched



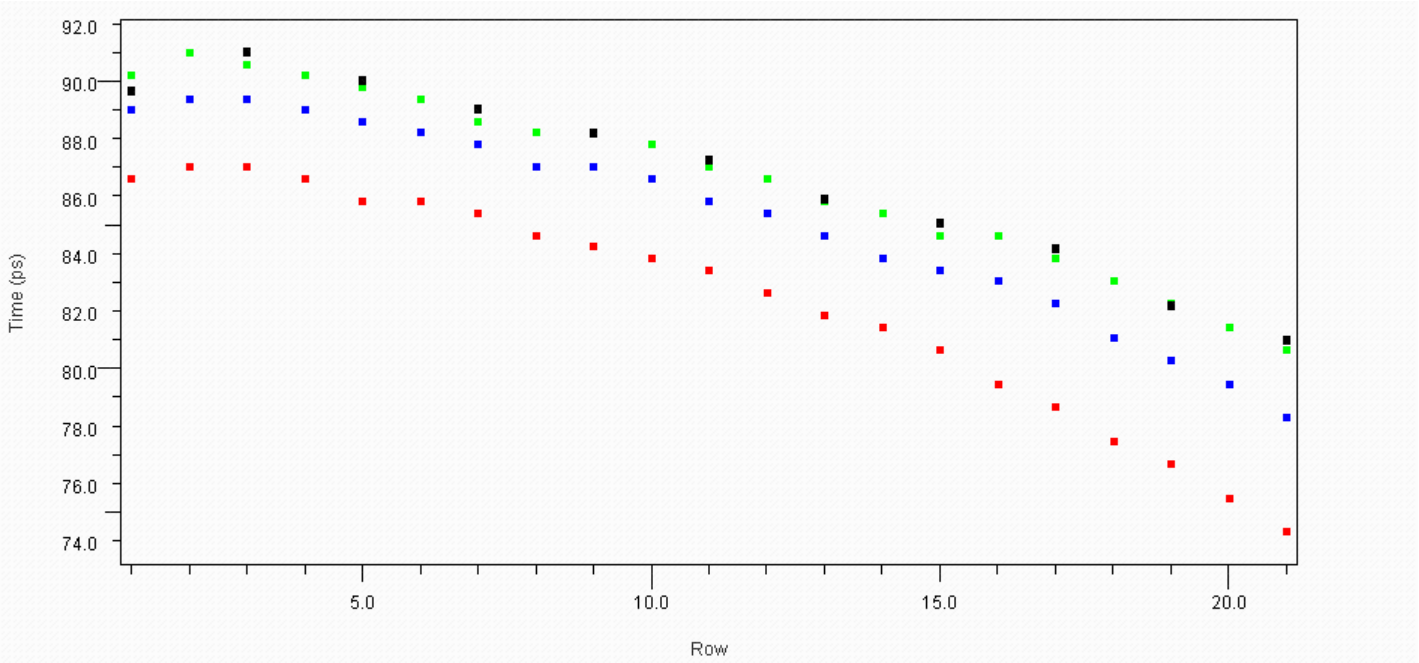
TREND CORRELATION FOR TAP

› Time Domain Eye Height – Precursor Sweep



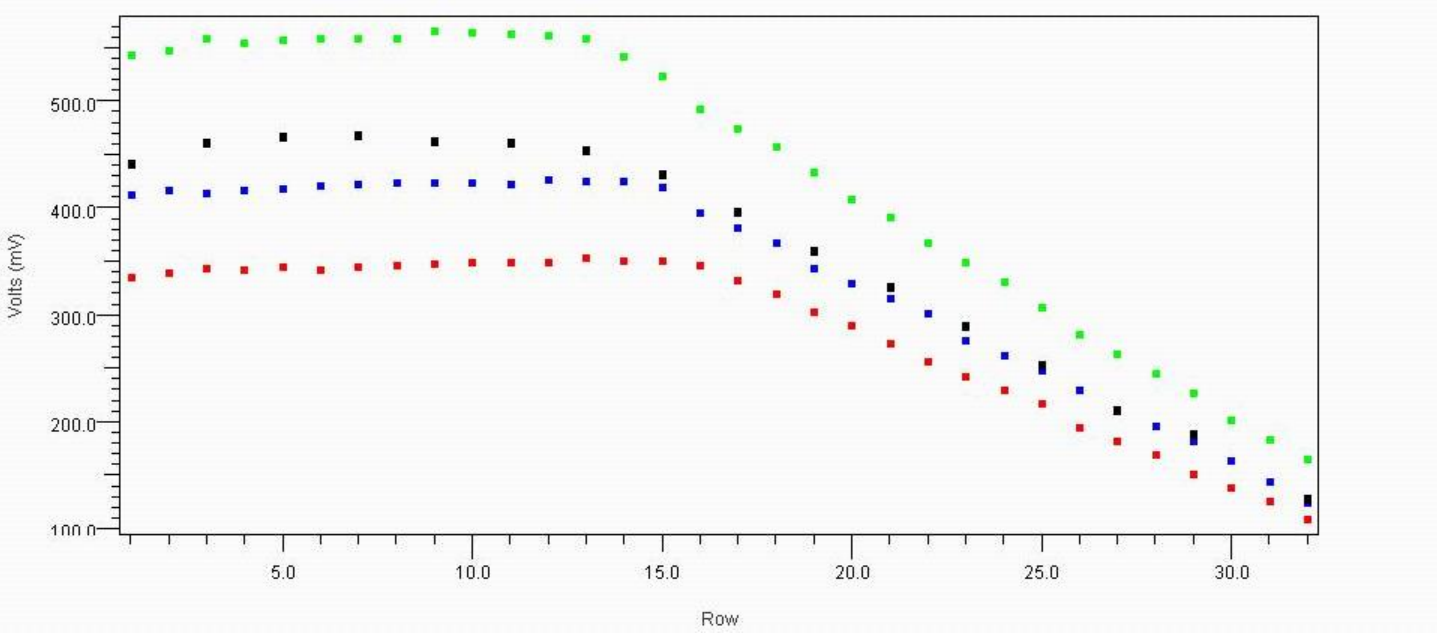
TREND CORRELATION FOR TAP

› Time Domain Eye Width – Precursor Sweep



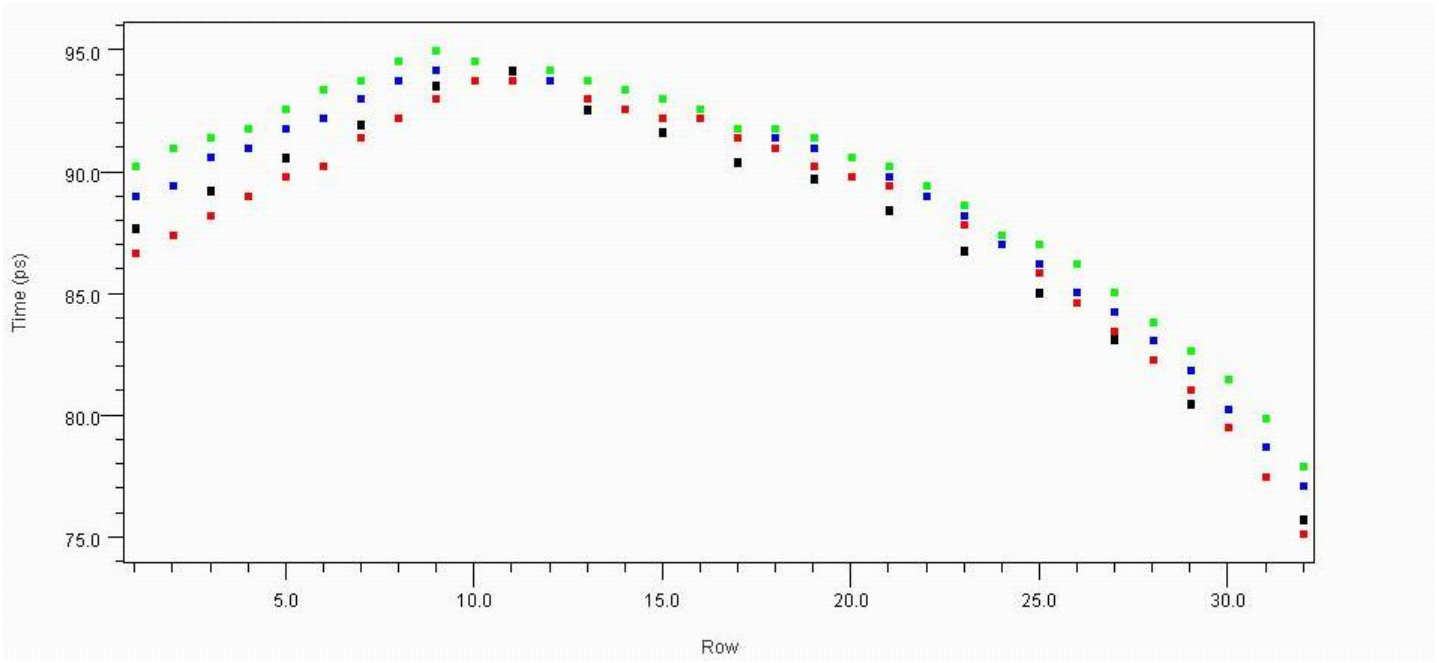
TREND CORRELATION FOR TAP

› Time Domain Eye Height – Postcursor Sweep



TREND CORRELATION FOR TAP

› Time Domain Eye Width – Postcursor Sweep



AGENDA

- Why IBIS-AMI correlation
- Correlation methodology for TX
- Correlation methodology for RX
- Correlation criteria
- Question and suggestion for

CORRELATION METHODOLOGY FOR RX

› Procedure

Extract Passive Channel Characteristic

↓

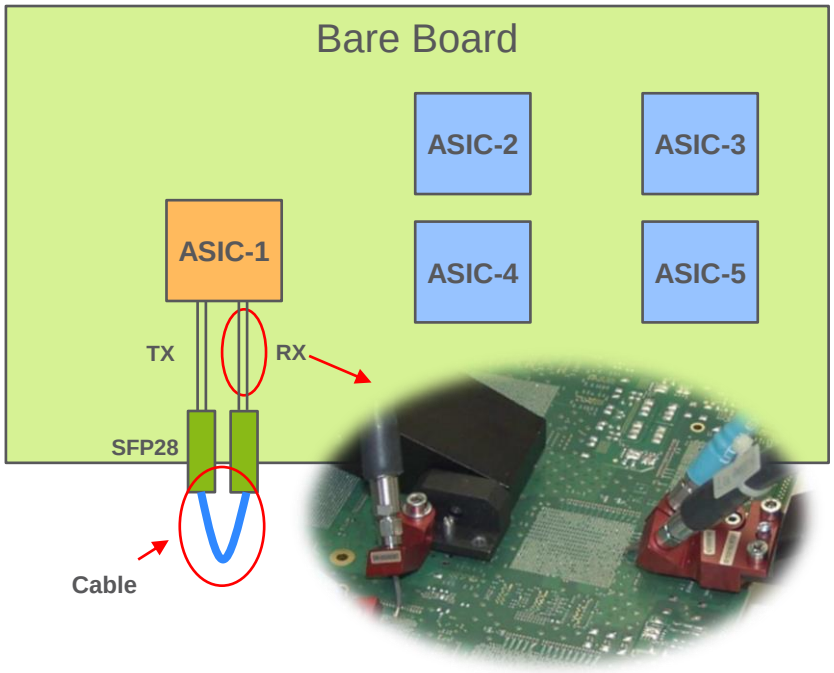
Sync Measurement Condition to Simulation Environment Sweep TX taps

↓

Correlate RX Channel

↓

Evaluate and Archive



CORRELATION METHODOLOGY FOR RX

› Procedure

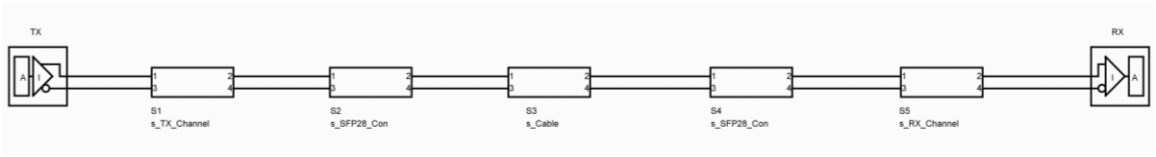
Extract Passive Channel Characteristic

↓

Sync Measurement Condition to Simulation Environment Sweep TX taps

→

- Cable Length:
  - 0.6m
  - 1.0m
  - 1.8m
  - 3.0m
  - 5.0m



↓

Correlate RX Channel

- PVT Settings
- Stimulus patterns
- Running bits
- Samples per bit
- Taps sweep

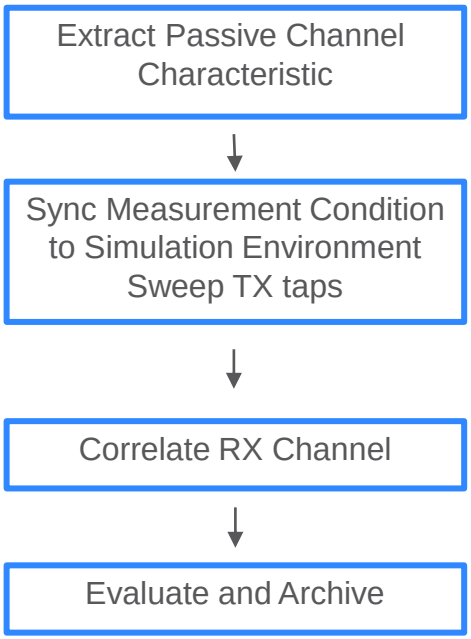
- RX CTLE adapt
- RX CTLE and DFE adapt

↓

Evaluate and Archive

CORRELATION METHODOLOGY FOR RX

› Procedure

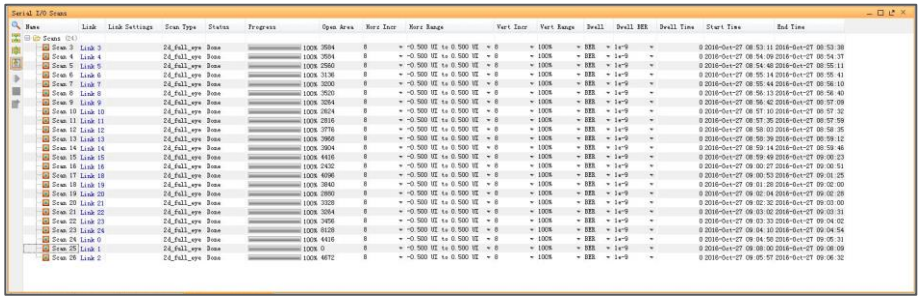


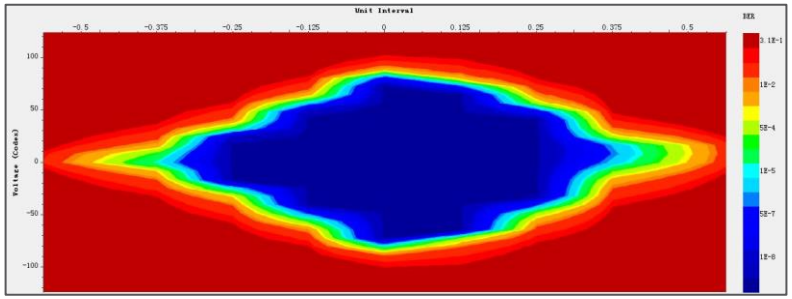
Item	TXDIFFCTRL[3:0]	TXPRECURSOR[4:0]	TXPOSTCURSOR[4:0]	RX Equalization	Pattern	Output
Case1	8	0	0	CTLE Adapt Only	prbs7	Internal eye
Case2	8	5	0	CTLE Adapt Only	prbs7	Internal eye
Case3	8	10	0	CTLE Adapt Only	prbs7	Internal eye
Case4	8	15	0	CTLE Adapt Only	prbs7	Internal eye
Case5	8	20	0	CTLE Adapt Only	prbs7	Internal eye
Case6	8	0	5	CTLE Adapt Only	prbs7	Internal eye
Case7	8	0	10	CTLE Adapt Only	prbs7	Internal eye
Case8	8	0	15	CTLE Adapt Only	prbs7	Internal eye
Case9	8	0	20	CTLE Adapt Only	prbs7	Internal eye
Case10	8	0	25	CTLE Adapt Only	prbs7	Internal eye
Case11	8	0	31	CTLE Adapt Only	prbs7	Internal eye
Case12	8	5	5	CTLE Adapt Only	prbs7	Internal eye
Case13	8	5	10	CTLE Adapt Only	prbs7	Internal eye
Case14	8	10	5	CTLE Adapt Only	prbs7	Internal eye
Case15	8	10	10	CTLE Adapt Only	prbs7	Internal eye
Case16	8	0	0	DFE&CTLE Adapt	prbs7	Internal eye
Case17	8	5	0	DFE&CTLE Adapt	prbs7	Internal eye
Case18	8	10	0	DFE&CTLE Adapt	prbs7	Internal eye
Case19	8	15	0	DFE&CTLE Adapt	prbs7	Internal eye
Case20	8	20	0	DFE&CTLE Adapt	prbs7	Internal eye
Case21	8	0	5	DFE&CTLE Adapt	prbs7	Internal eye
Case22	8	0	10	DFE&CTLE Adapt	prbs7	Internal eye
Case23	8	0	15	DFE&CTLE Adapt	prbs7	Internal eye
Case24	8	0	20	DFE&CTLE Adapt	prbs7	Internal eye
Case25	8	0	25	DFE&CTLE Adapt	prbs7	Internal eye
Case26	8	0	31	DFE&CTLE Adapt	prbs7	Internal eye
Case27	8	5	5	DFE&CTLE Adapt	prbs7	Internal eye
Case28	8	5	10	DFE&CTLE Adapt	prbs7	Internal eye
Case29	8	10	5	DFE&CTLE Adapt	prbs7	Internal eye
Case30	8	10	10	DFE&CTLE Adapt	prbs7	Internal eye

- Sweep Cable Length:
  - 0.6m
  - 1.0m
  - 1.8m
  - 3.0m
  - 5.0m

CORRELATION WITH INTERNAL EYE

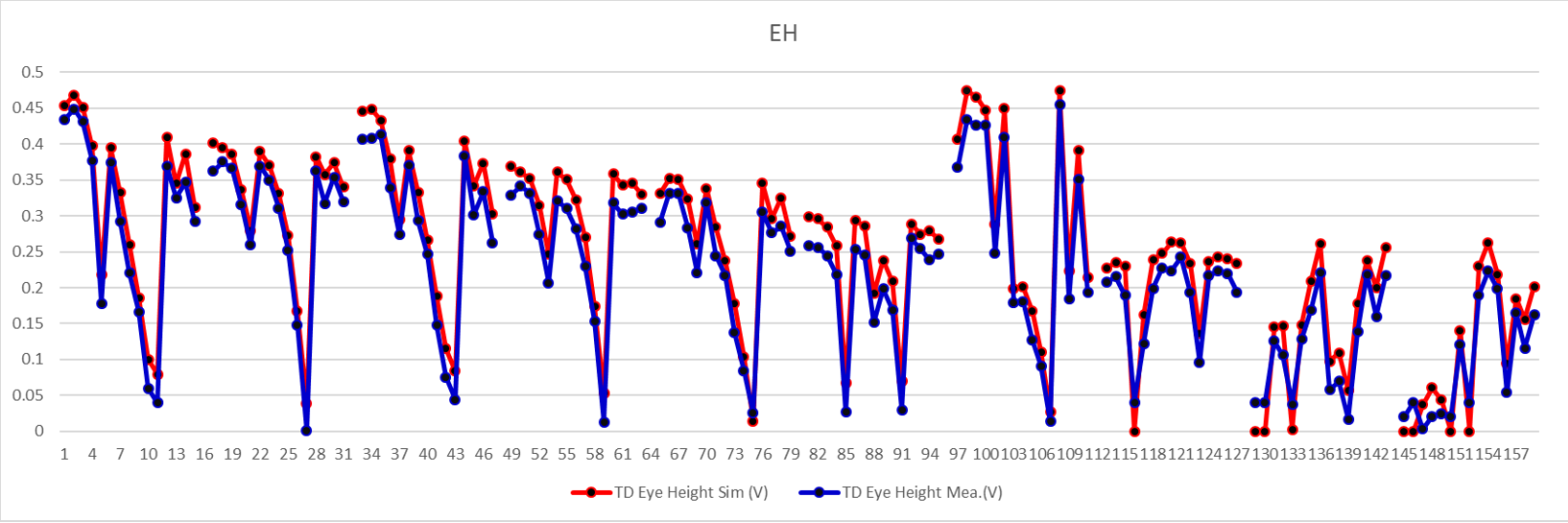
› Now scanning RX internal eye with different TX tap settings





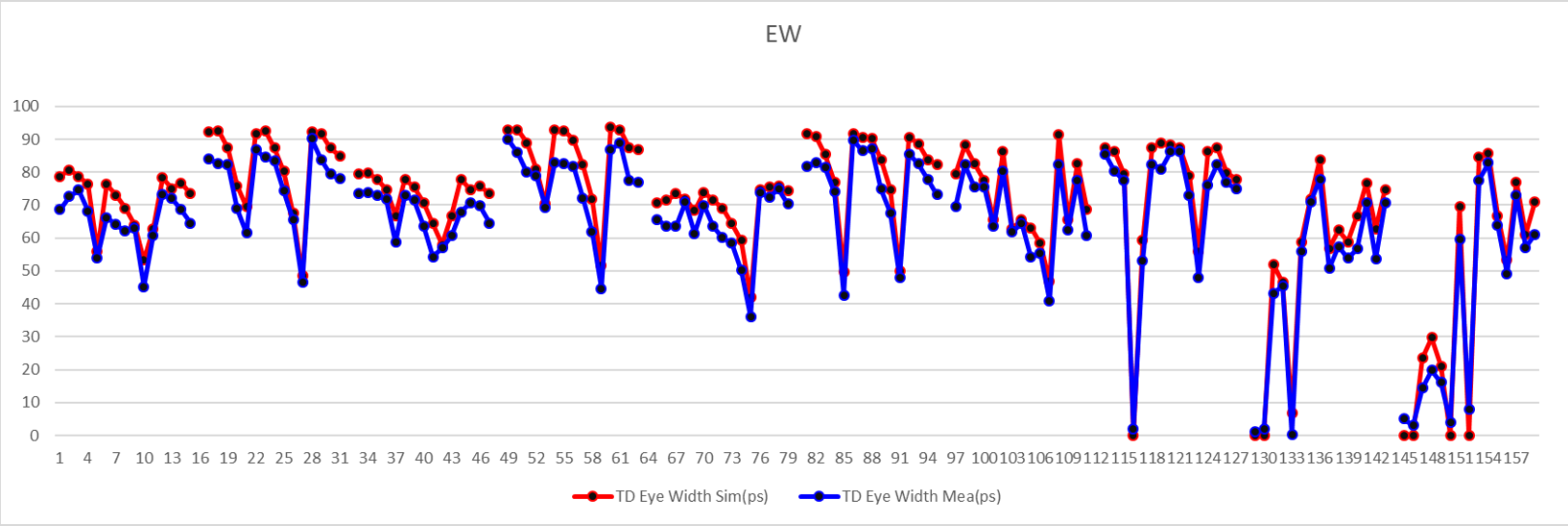
CORRELATION RESULTS FOR RX

› Trend Correlation – Time Domain Eye Height



CORRELATION RESULTS FOR RX

› Trend Correlation – Time Domain Eye Width



AGENDA

- Why IBIS-AMI correlation
- Correlation methodology for TX
- Correlation methodology for RX
- Correlation criteria
- Question and suggestion for

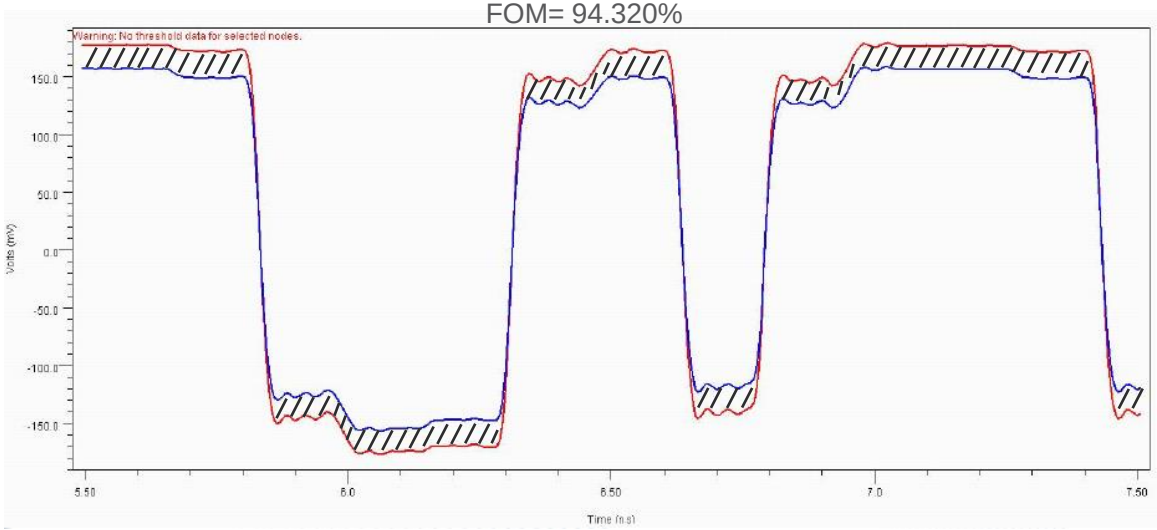
CORRELATION CRITERIA

› Figure of Merit (FOM)

$$FOM = 100 \cdot \left[1 - \frac{\sum_{i=1}^{N} \left| X_i(golden) - X_i(DUT) \right|}{\Delta X \cdot N} \right]$$

FOM Value	Qualitative Metric
> 99%	Excellent
> 95%	Very Good
> 90%	Good
< 90%	Poor

FOM= 94.320%

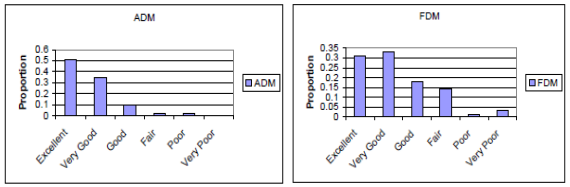


CORRELATION CRITERIA

› Feature Selective Validation (FSV)

The Feature Selective Validation (FSV) method is one of the candidate techniques for the quantitative validation of computational electromagnetics (CEM), particularly within electromagnetic compatibility (EMC) and Signal Integrity (SI).

It is based on the decomposition of the original data into two parts: amplitude (ADM) data and feature data(FDM). The former will account for the slowly varying data across the data set and the latter will account for the sharp peaks and troughs.

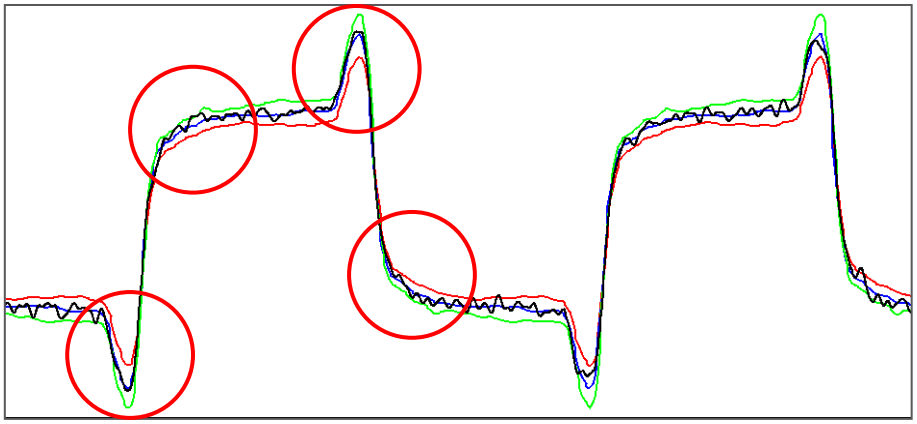


FSV value (quantitative)	FSV interpretation (qualitative)
Less than 0.1	Excellent
Between 0.1 and 0.2	Very good
Between 0.2 and 0.4	Good
Between 0.4 and 0.8	Fair
Between 0.8 and 1.6	Poor
Greater than 1.6	Very poor

Reference
1. Roy Leventhal, “Correlation of Model Simulations and Measurements”, Leventhal Design & Communications Presented June 5, 2007 IBIS Summit Meeting, San Diego, California
2. D.Di Febo, F.de Paulis, A.Orlandi “Feature Selective Validation- A new approach for new Engineers” European IBIS Summit Naples, May11, 2011

CORRELATION CRITERIA

- More metrics to correlate
  - Besides 5 metrics “high level, low level, rise time, fall time, and duty cycle”, more metrics are necessary: slew rate, cursor pillars..and the metrics should have different weight in final score calculation.



Reference
1. David Banas, “IBIS-to-Spice Correlation *a story of 5 metrics”,* Presented June 5, 2007 IBIS Summit San Diego, California

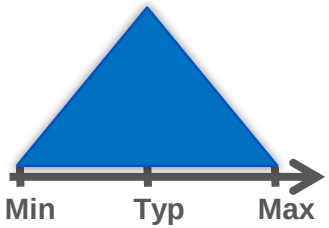
AGENDA

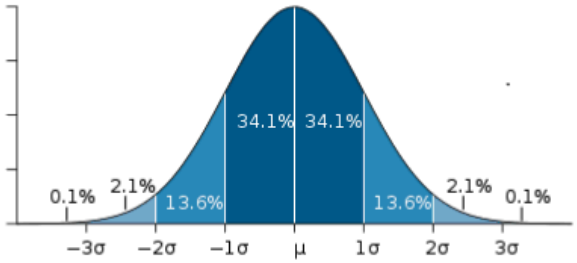
- Why IBIS-AMI correlation
- Correlation methodology for TX
- Correlation methodology for RX
- Correlation criteria
- Question and suggestion

QUESTION AND SUGGESTION

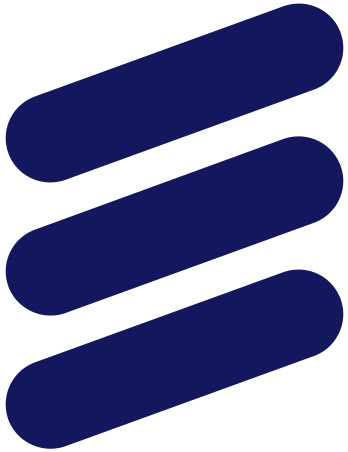
› In the paper, Measurement is on Typical corner. No Fast and Slow corners measurement data. So,
Can we trust the Fast and Slow corners simulation data, even though Typical correlates very well?
How much do the corners of AMI model match the real silicon's behavior? 99.99%…? It is a statistical problem.

› We need to introduce the statistical distribution for Fast/Typical/Slow corners of IBIS.





› We need more metrics for correlation evaluation. Some are proposed in this paper.



ERICSSON