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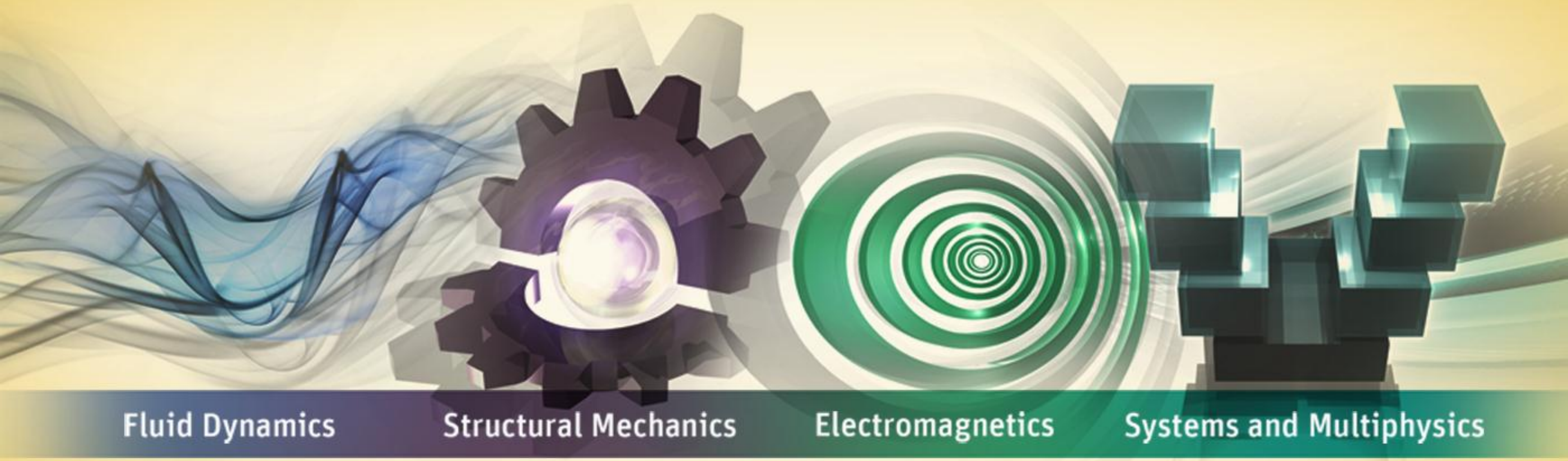
Anisotropic Substrates Variance for *IBIS-AMI Simulation*



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High speed Challenges Today

(1) High Speed Data Rate Issue

(2) Anisotropic Substrates Variance

(3) FEM solution to analysis Anisotropic Substrates Variance

(4) Anisotropic Substrates Variance for IBIS-AMI Simulation

(5) DOE Solution

High speed IO Challenges Today

As serial links become faster and more complex, it is ever more challenging to model the silicon in an accurate and efficient manner.

Models/Simulator need to handle current challenges:

- **Need to accurately handle very high data rates**
- **Simulate large number of bits to achieve low BER**
- **Non-linear, Time Variant Systems**
- **TX/RX equalization**
- **Specific Data patterns and coding schemes**
- **Non-convergence due to unstable models**
- **Channel Issue**

Circuit Simulation Issues with S-parameters

Passivity and Causality

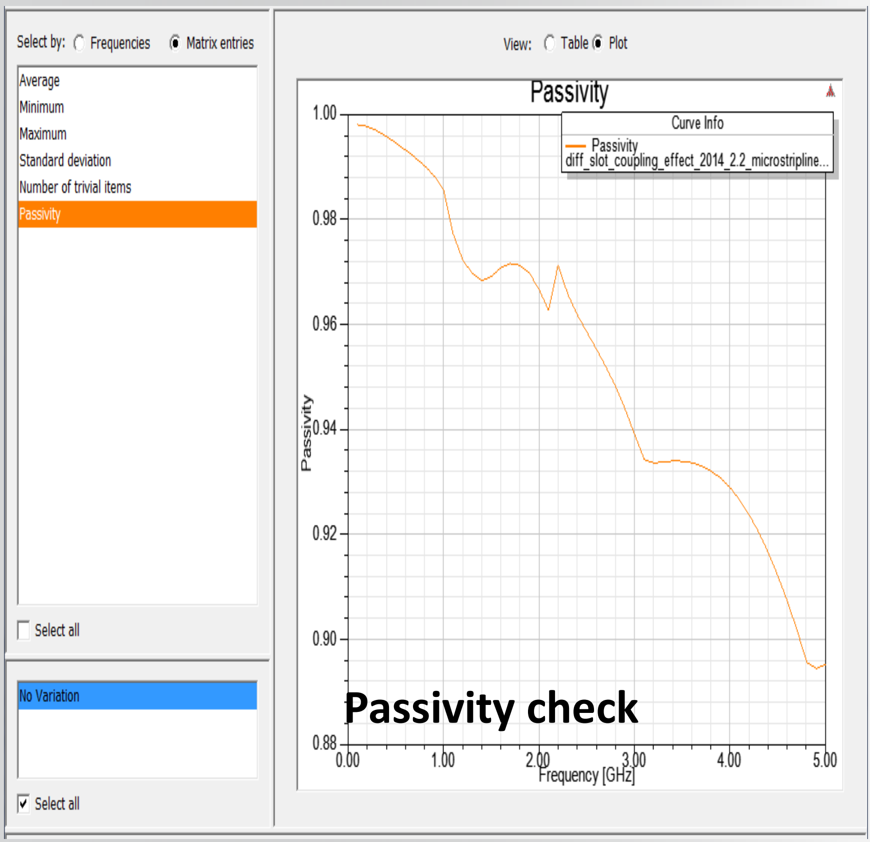
- Though S-parameters from a physics-based extraction tool should always be passive and causal, measured S-parameters often exhibit problems due to noise

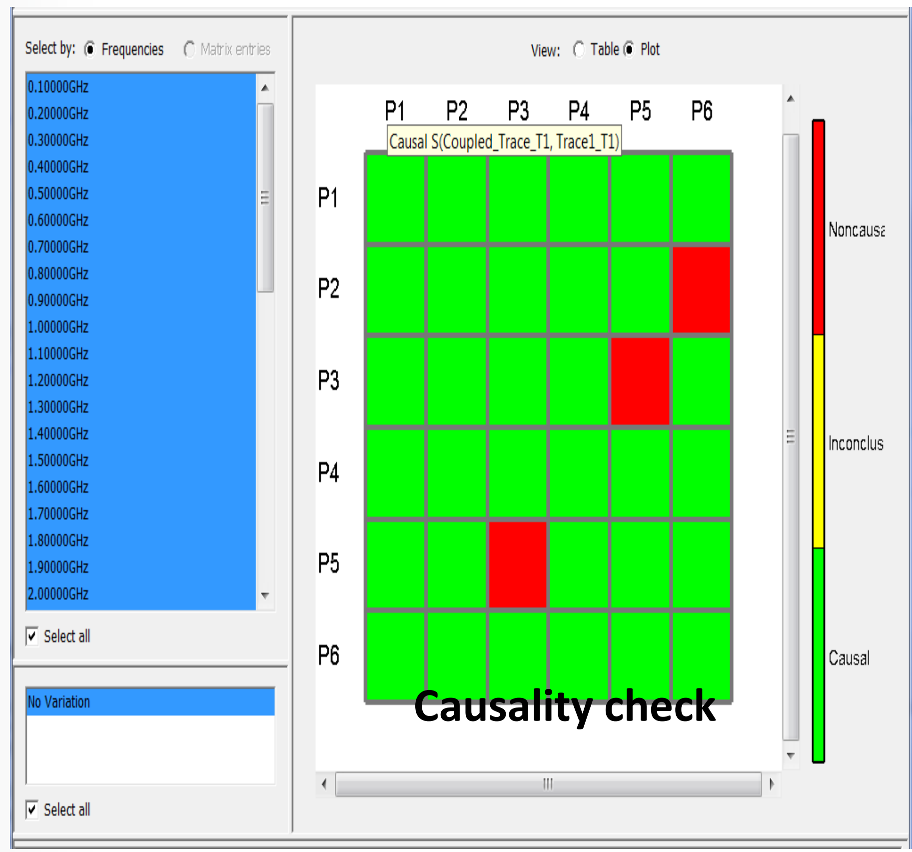
- State-space model for S-parameter data guarantees causality of the circuit simulator model

- Two passivity enforcement algorithms
  - Convex programming
  - Perturbation

Check and Enforce Function

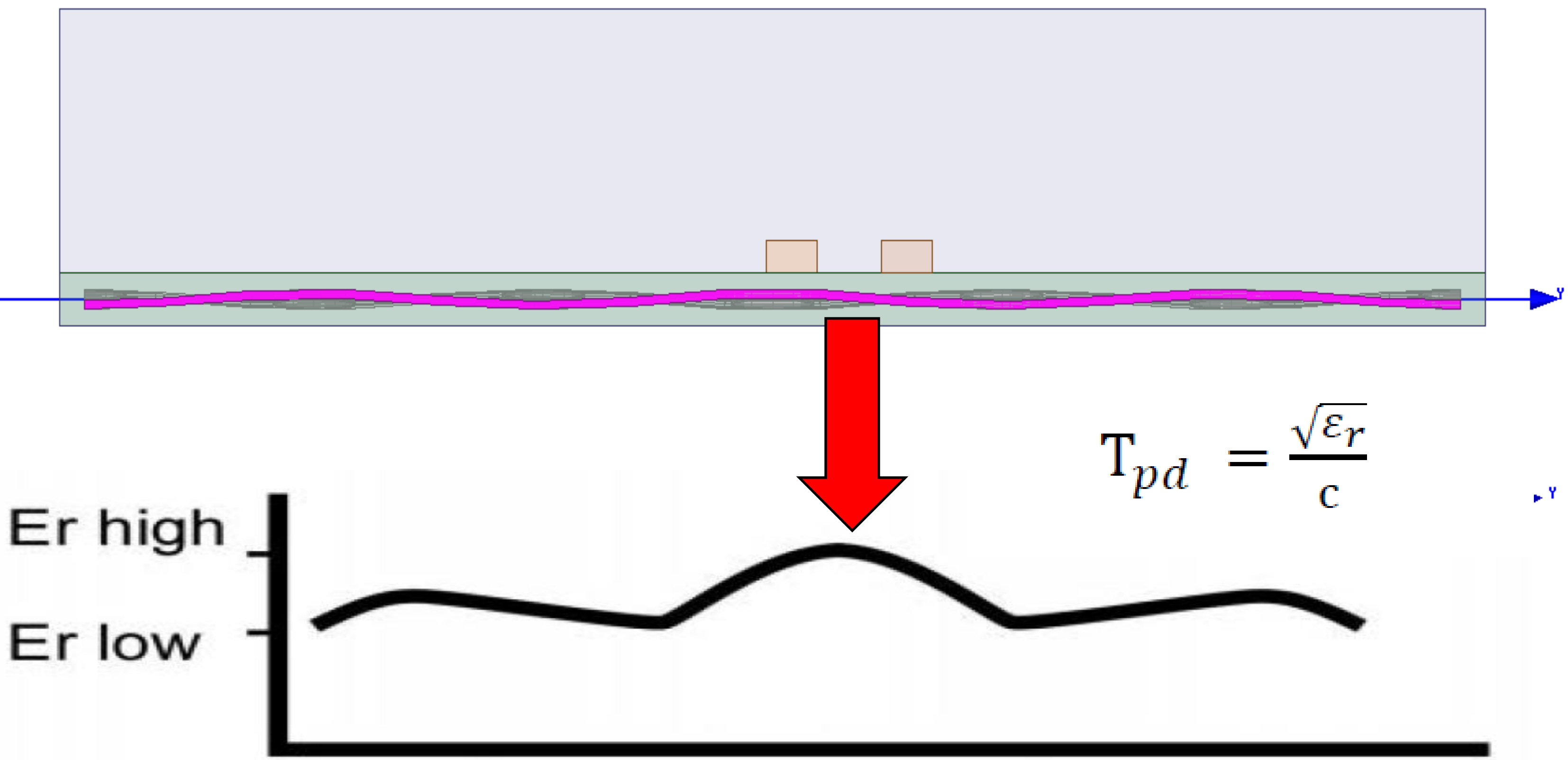
Check and Enforce passivity and causality





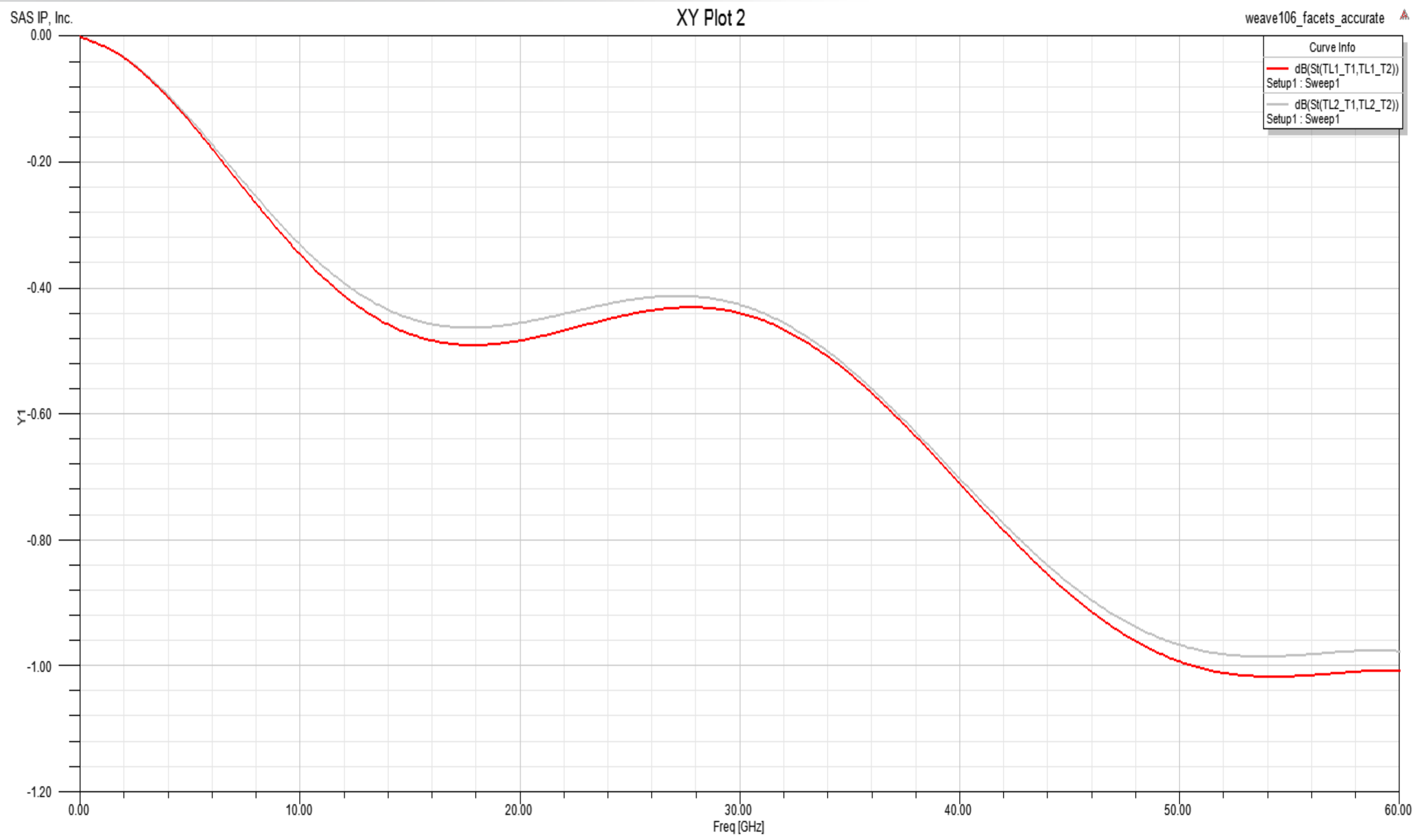
Anisotropic Substrates

FR4 Fiber Weave

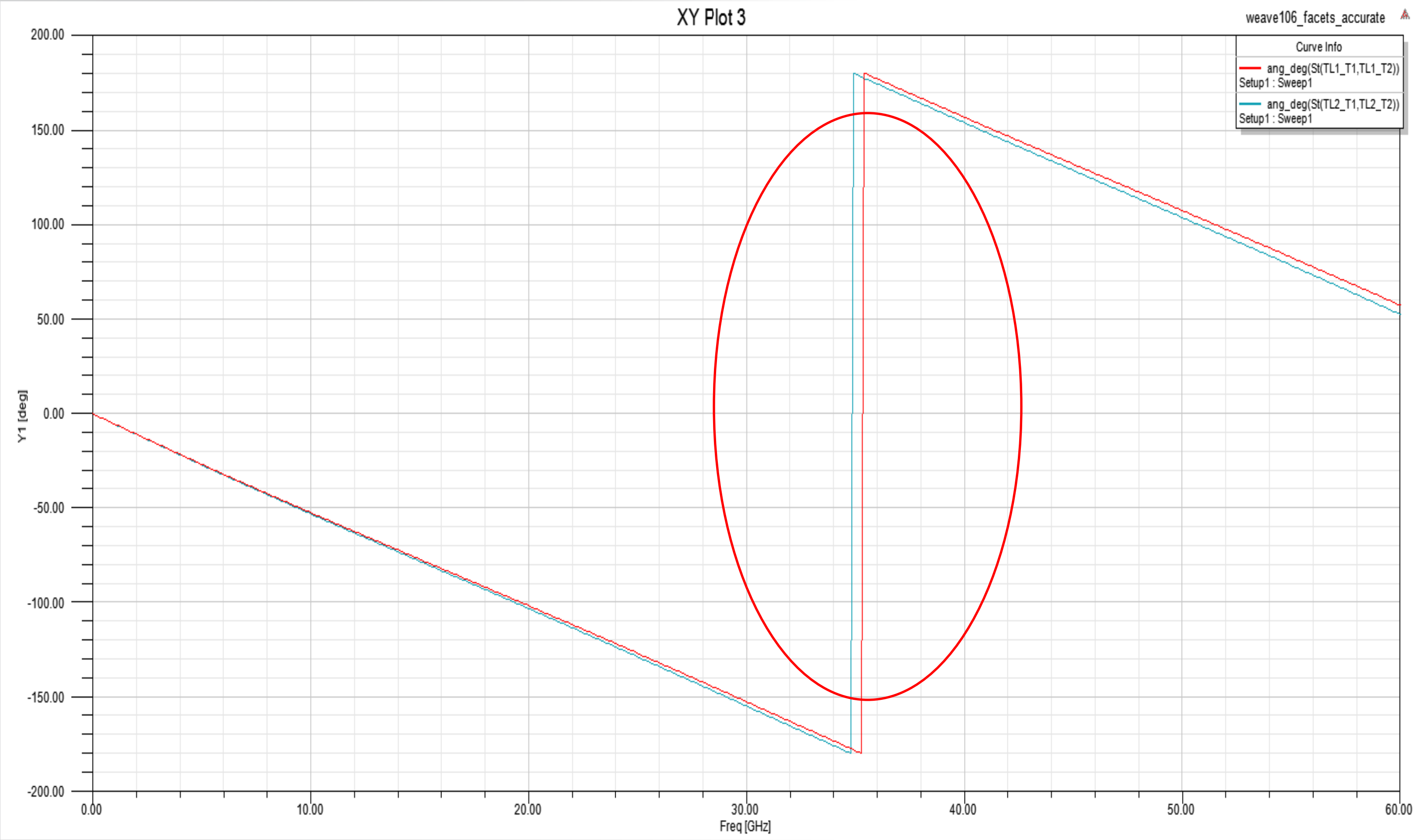


$$T_{pd} = \frac{\sqrt{\varepsilon_r}}{c}$$

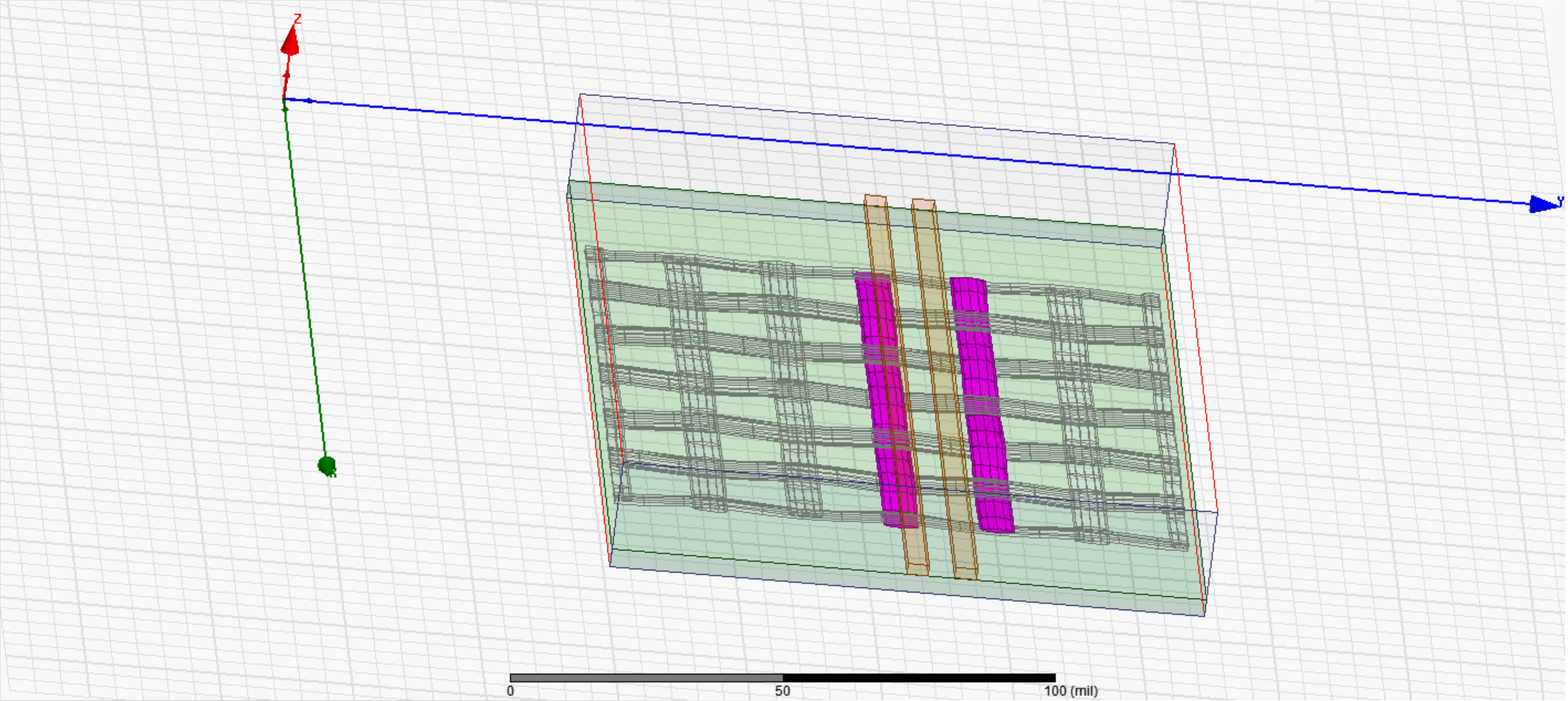
Insertion loss for one net



Differential skew Problem

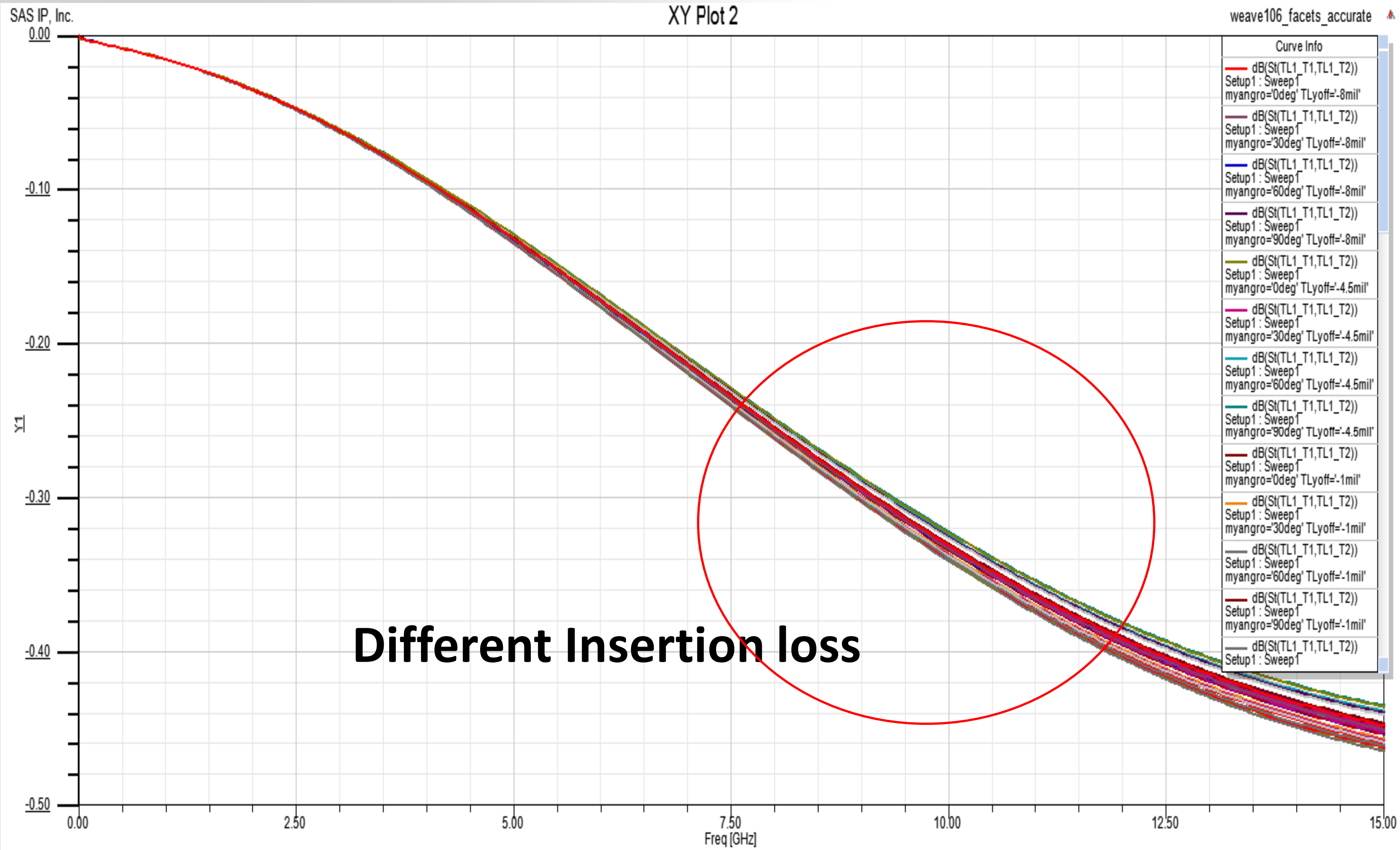


Anisotropic Substrates Variance

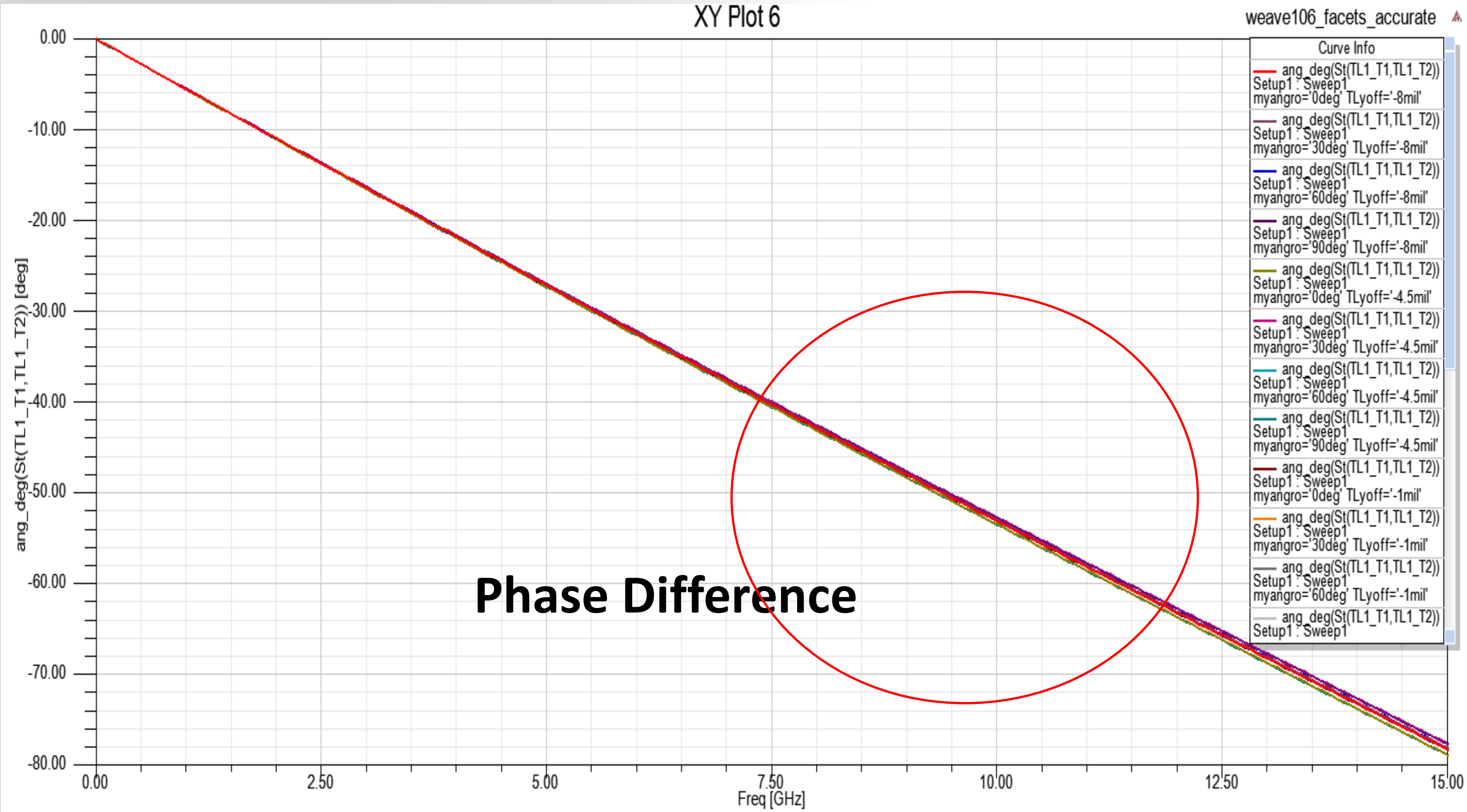


Change degree angle of rotation

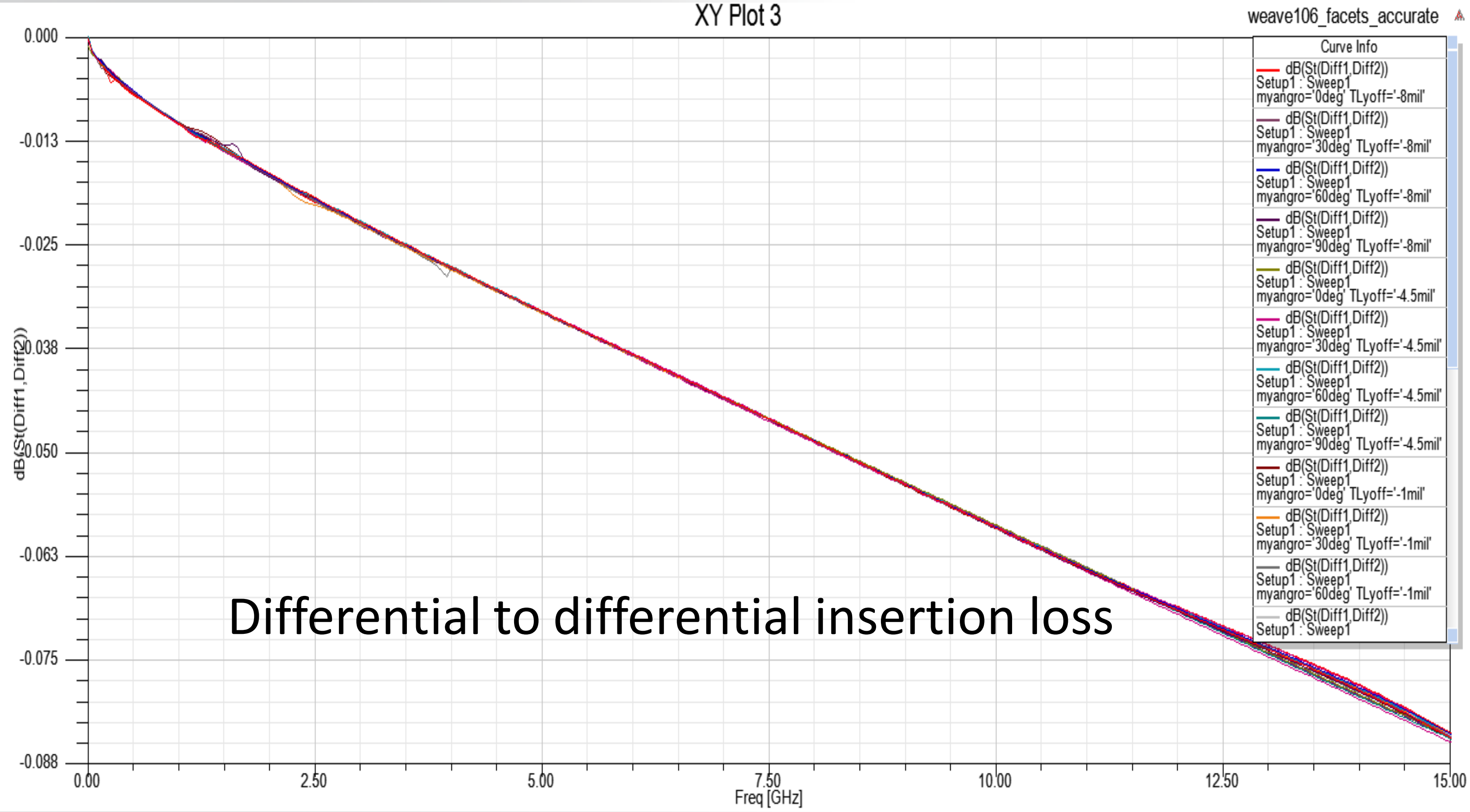
Anisotropic Substrates Variance



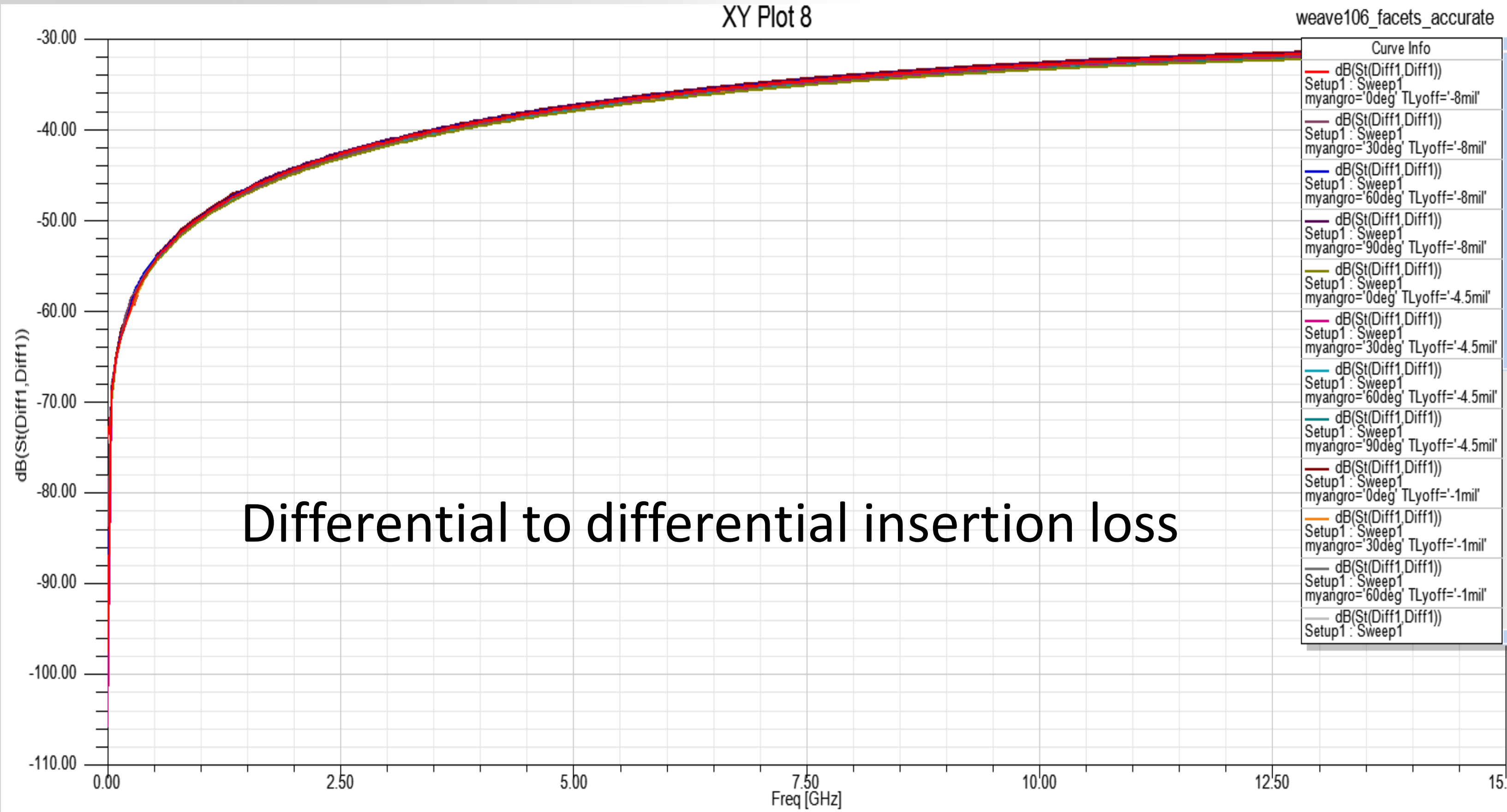
Anisotropic Substrates Variance



Anisotropic Substrates Variance



Anisotropic Substrates Variance



Differential to differential insertion loss

November 3, 2013

IBIS-AMI and statistical eye analysis

- Use the final impulse response from AMI analysis to run statistical eye analysis
- Linear modifications (AMI Init) from Tx and Rx AMI models taken into account
- AMI GetWave functionality cannot be used for statistical analysis as it is a purely time domain function

Data flow

AMI Transmitter (Tx)

↓

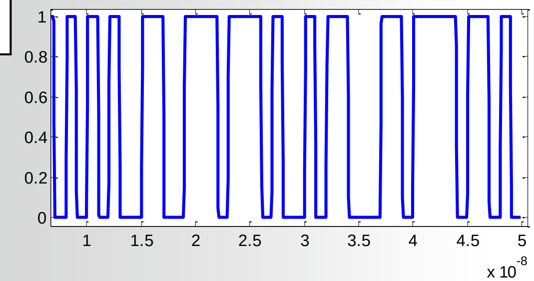
Linear Channel

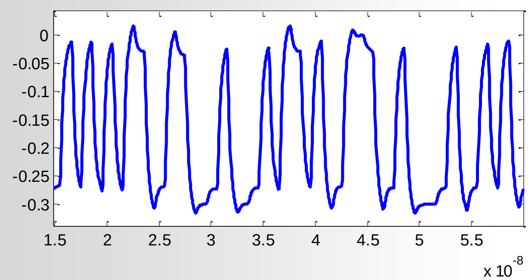
↓

AMI Receiver (Rx)

↓

Engine post-processing





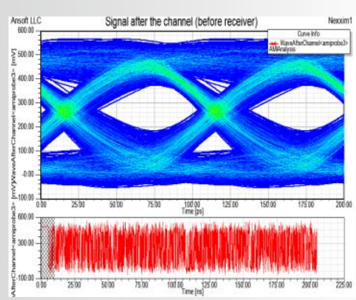
Very similar to Fast Convolution

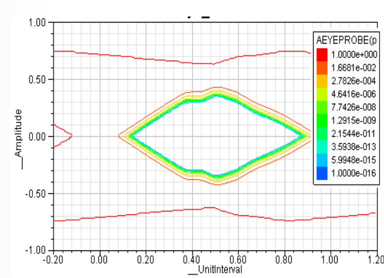
- No backward dependency

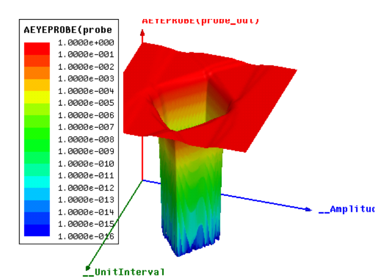
Transmitter and receiver are based on user supplied libraries.

Channel is characterized with impulse response function(s)

All signals are sampled with the constant time step and handled in blocks.

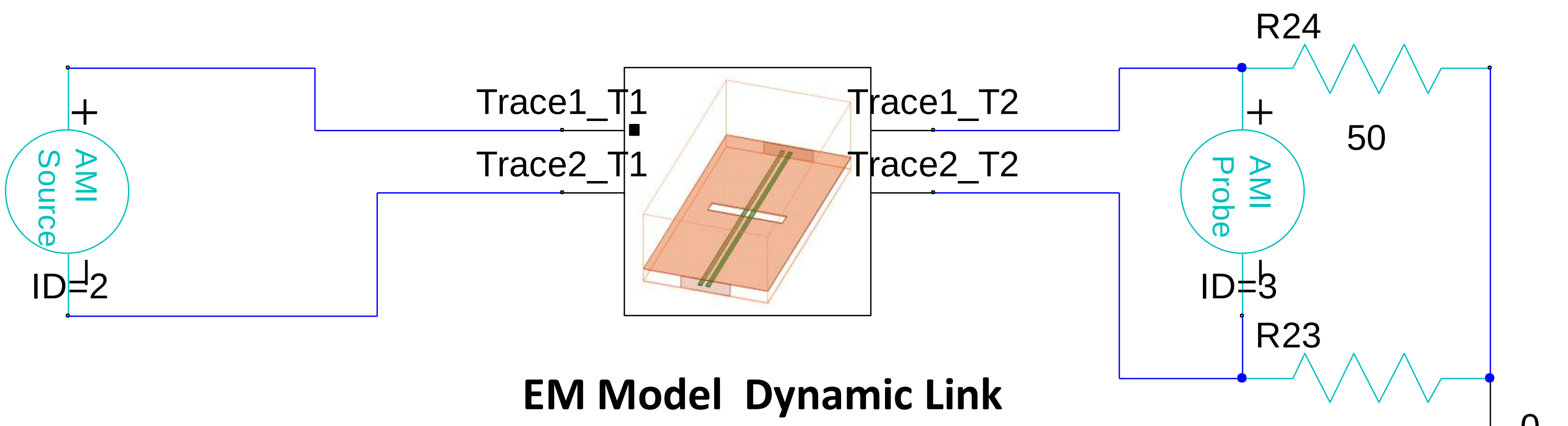




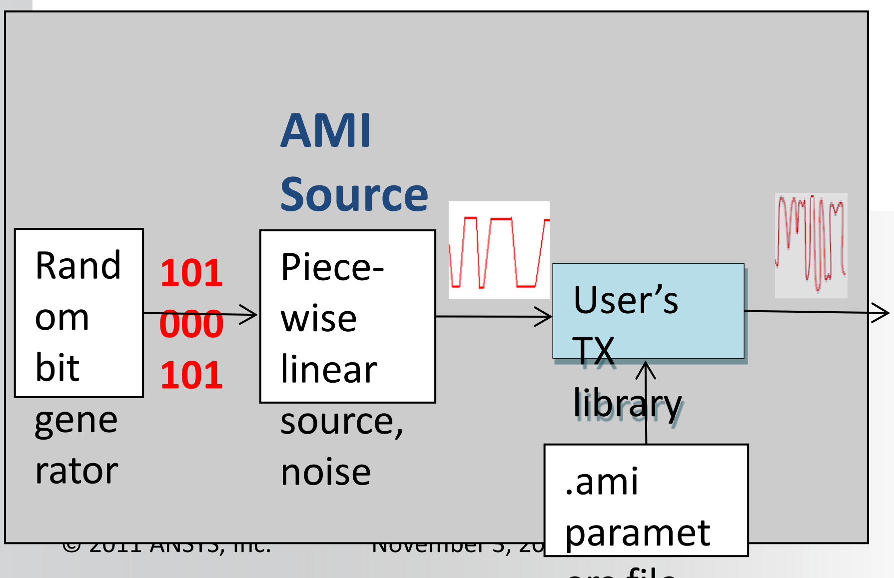


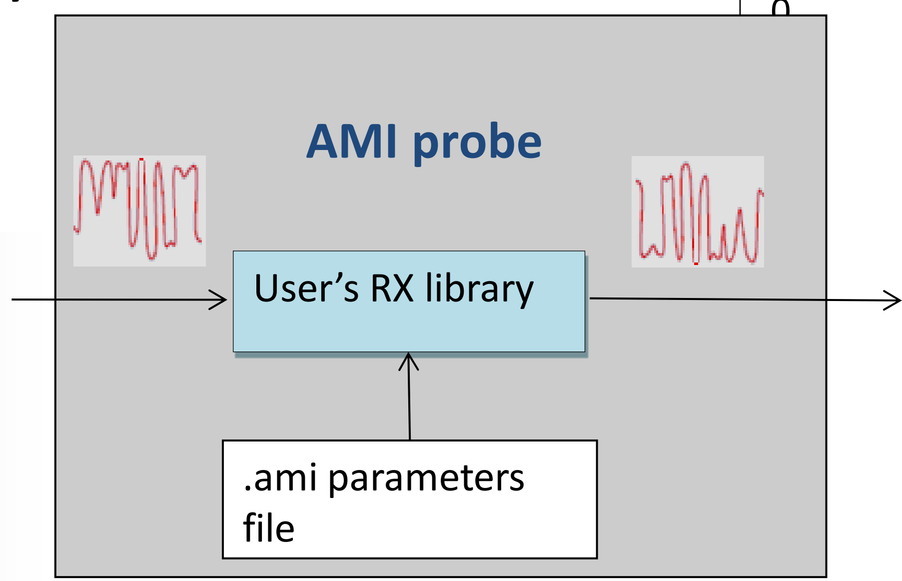
EM and Circuit Co-simulation

EM Channel for AMI Analysis

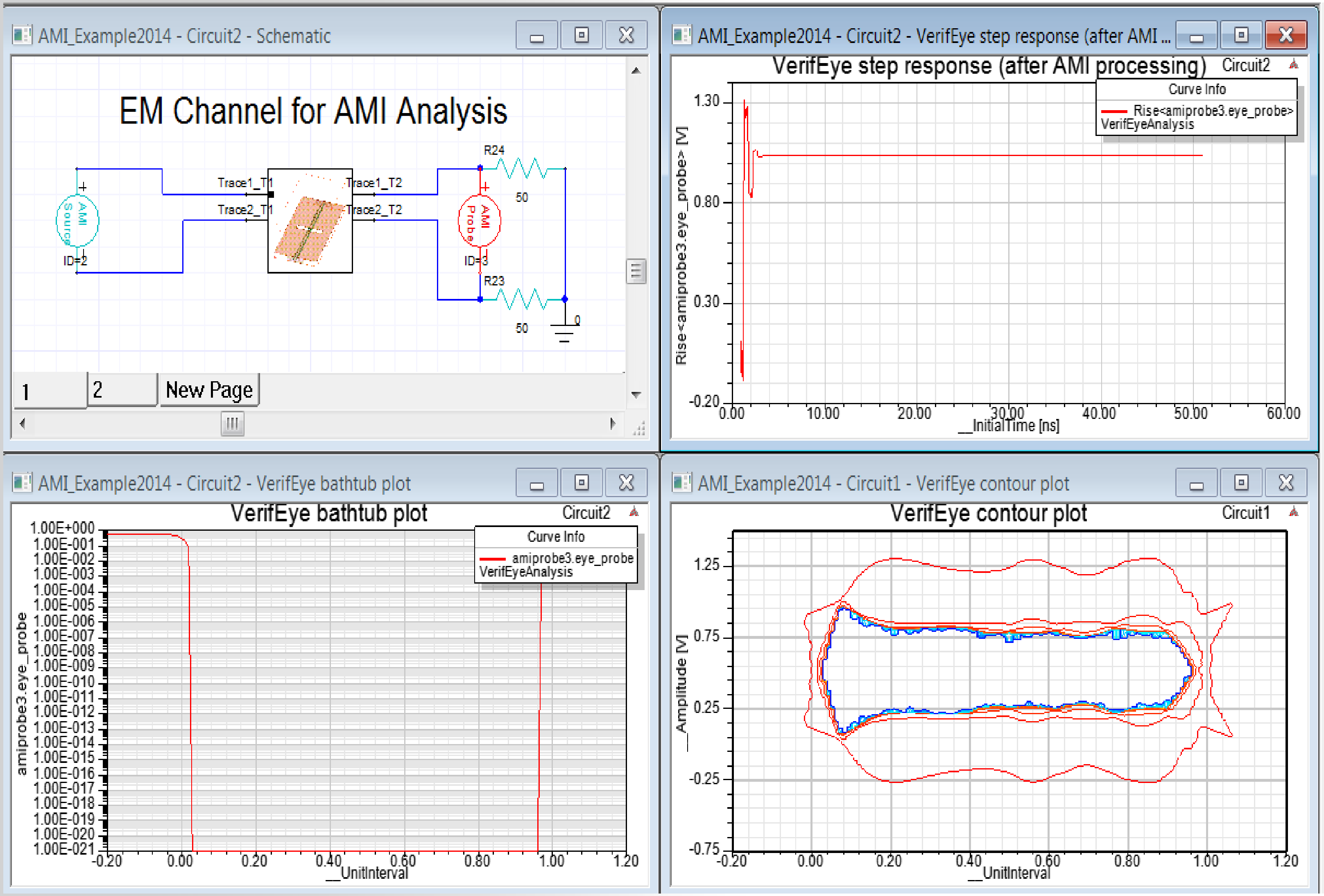


EM Model Dynamic Link



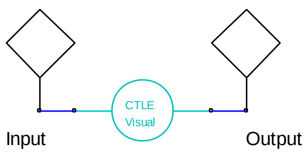


Statistical Eye Analysis Result

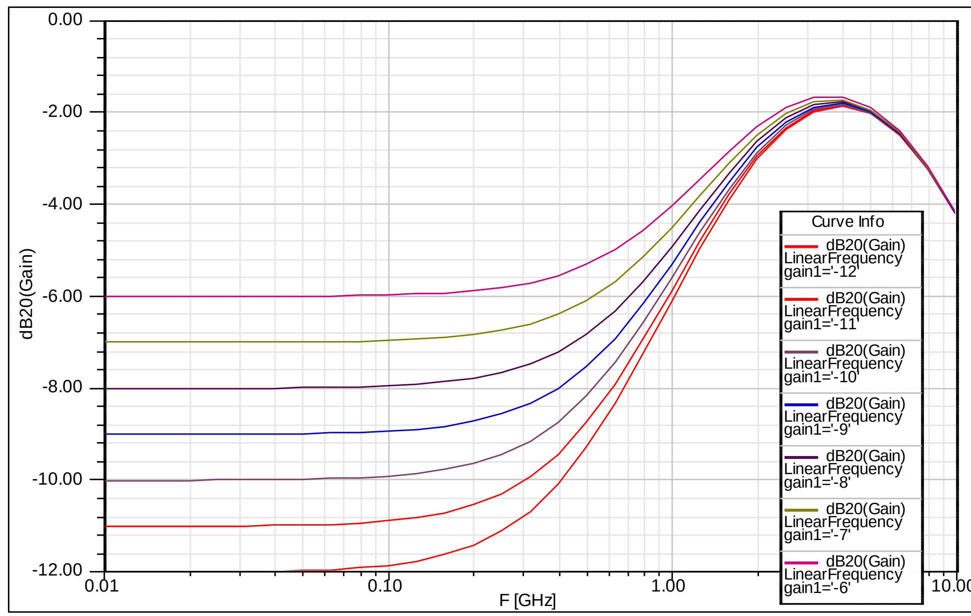


Circuit equalization techniques problem

CTLE Gain with PCIe3.0 Parameters



p1=p1
p2=8GHz
z=pow(10,(gain1/20))*p1
gain=gain1



This example shows the response plot of a CTLE for PCIe 3.0 for different values of gain. Parameters of the CTLE component are:

1. 'p1' LF Pole = 2 GHz
2. 'p2' HF Pole = 8 GHz
3. 'z' zero frequency = 'p1' * pow(10, 'gain'/20)
4. 'gain' DC gain in dB = gain1

How to decide gain and pole value ??

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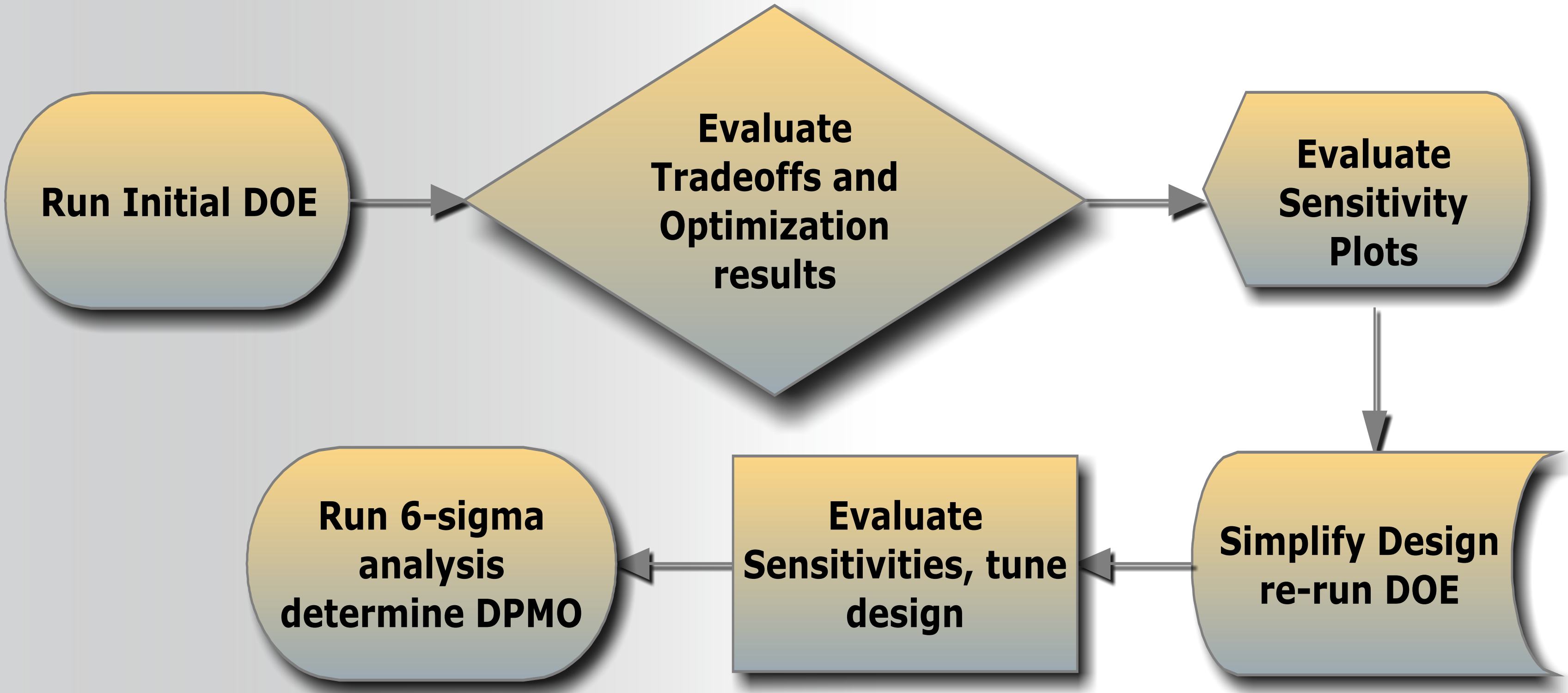
How to do that?

- **Set up the DOE to sweep through the models to calculate the eye height and eye width for these cases**

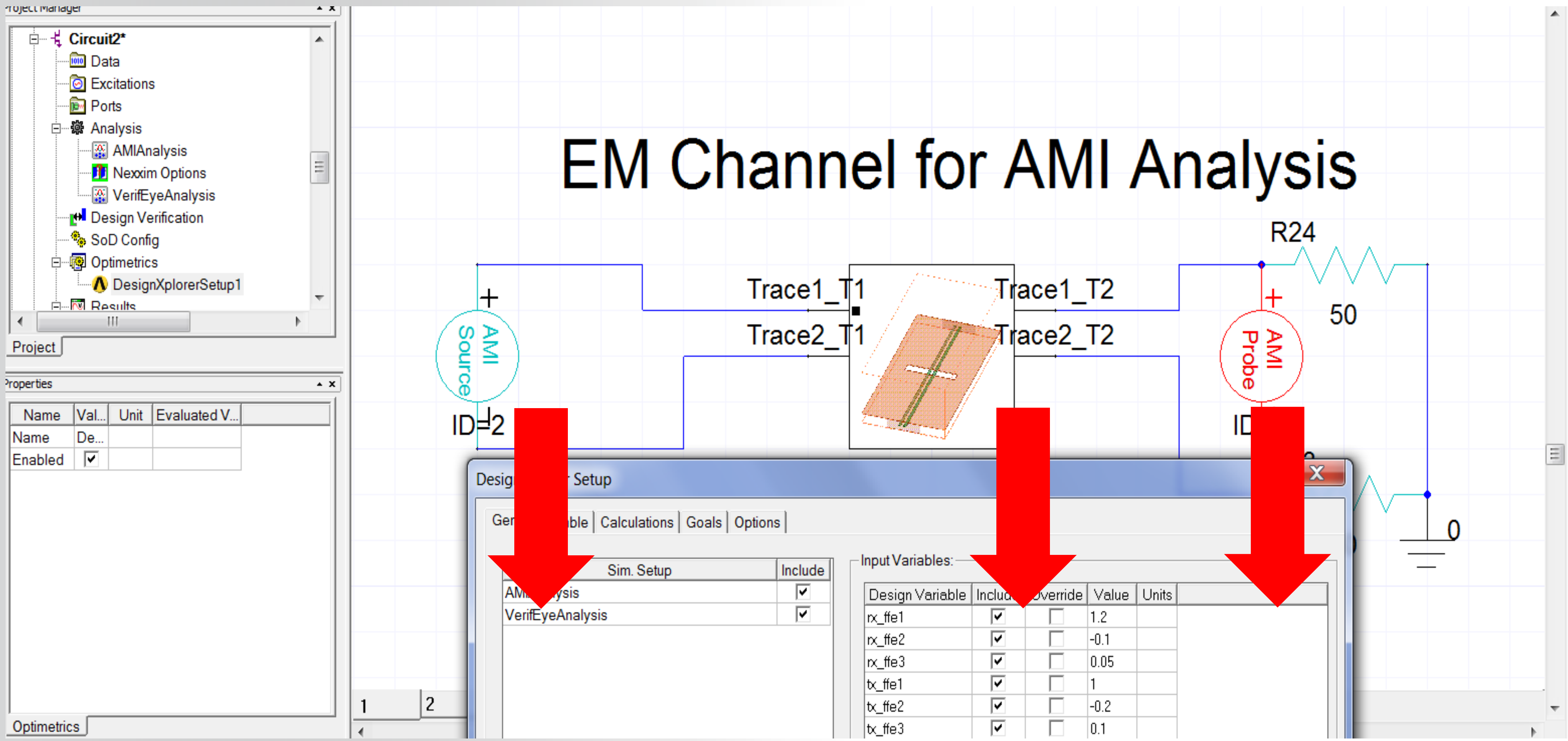
- **The portions of the channel containing the PCB was modeled using a full-wave 3D electromagnetic extraction tool. A dynamic EM file was used to capture the channel's behavior. There are several variations of this structure that we want to include in the sensitivity analysis.**

- **To illustrate the results of this sensitivity analysis, we present sweeping of two of the variables: Change degree angle of rotation and equalization parameters**

DOE Methodology

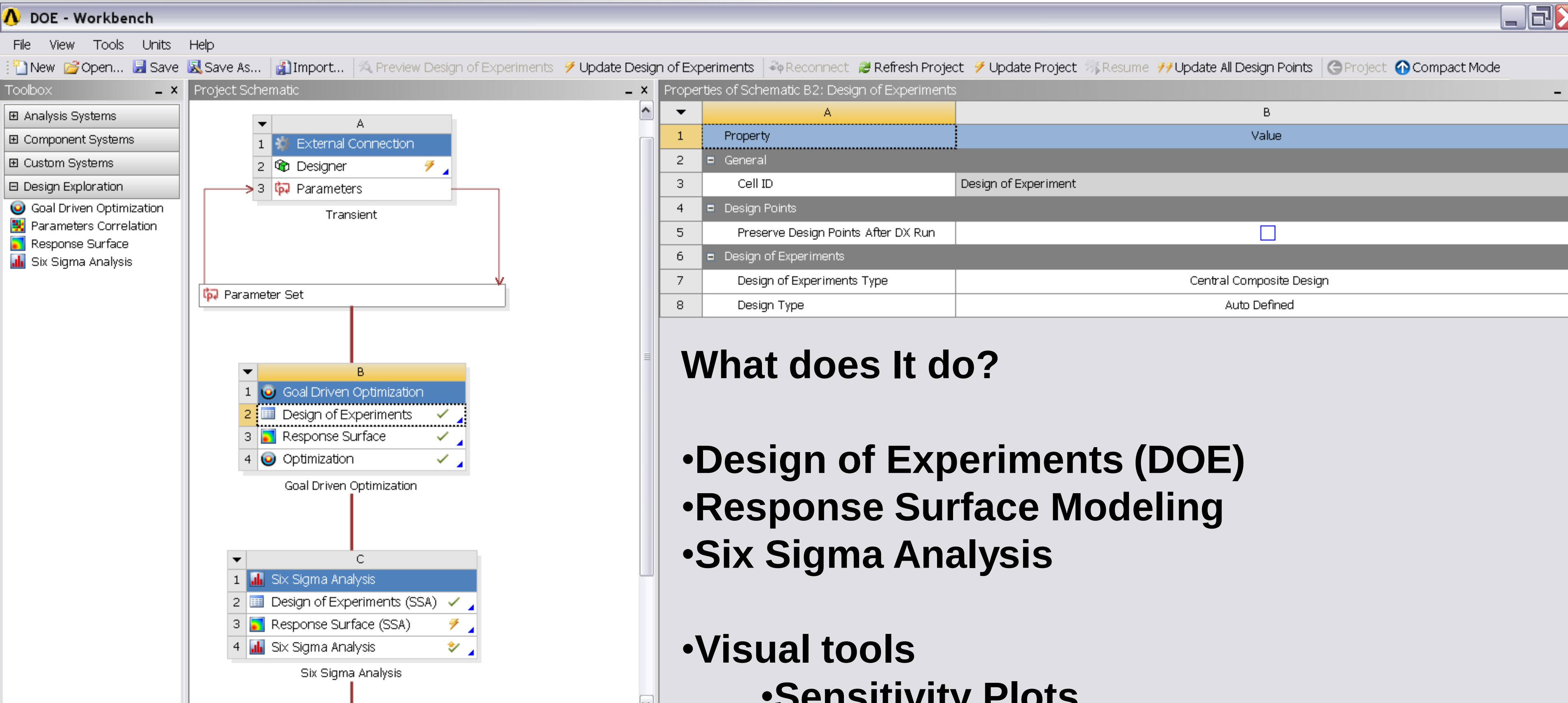


DOE setup



Circuit2*
Data
Excitations
Ports
Analysis
AMIAnalysis
Nexxim Options
VerifEyeAnalysis
Design Verification
SoD Config
Optimetrics
DesignXplorerSetup1
Results
Project
Name
Val...
Unit
Evaluated V...
Enabled
Optimetrics
EM Channel for AMI Analysis
R24
50
Trace1_T1
Trace2_T1
Trace1_T2
Trace2_T2
AMI Source
AMI Probe
ID=2
0
Calculations
Goals
Options
Sim. Setup
Include
VerifEyeAnalysis
Input Variables:
Design Variable
Override
Value
Units
rx_ffe1 1.2
rx_ffe2 -0.1
rx_ffe3 0.05
tx_ffe1 1
tx_ffe2 -0.2
tx_ffe3 0.1

Any parametric analysis



What does It do?

- Design of Experiments (DOE)
- Response Surface Modeling
- Six Sigma Analysis

- Visual tools
  - Sensitivity Plots
  - Correlation Matrices
  - Parallel charts w Pareto Front display

Why Response Surface Modeling?

- Response Surface Modeling enables the designer to model and consider all aspects of a high speed channel design. Fit a statistical model to outputs of the design as a function of the change in input variables. A DOE table is used to select design points to solve explicitly for and the statistical model so to speak, "fills in the gaps"

- Optimized conditions and worst case scenarios are obtainable within the set of all possible design combinations within a realistic simulation timeframe.

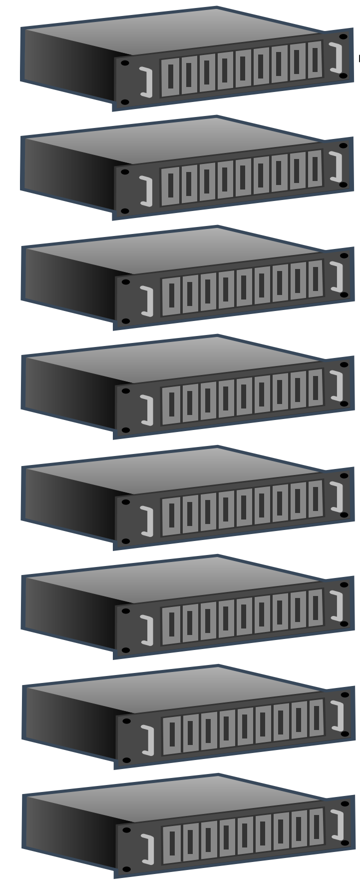
- For example, this case, consider 8 variables or "factors", if each variable has only 5 variations or "levels" we are looking at a huge number of possible combinations in order to find optimal solutions and or worst case scenarios.

$$Combinations = Levels^{Factors} = 5^8!!!!$$

Speed Issue – HPC solution

Table of Schematic B2: Design of Experiments

	A	B	C	D	E
1	Name	P1 - Socket_Index	P2 - Via_Index	P3 - Board_TLine_length (in)	P4 - Board_Dielectric_...
2	1	9	1	8	2.35
3	2	9	1	4	2.35
4	3	9	1	12	2.35
5	4	9	1	8	1.8
6	5	9	1	8	2.9
7	6	9	1	4	1.8
8	7	9	1	12	1.8
9	8	9	1	4	2.9
10	9	9	1	12	2.9
11	10	8	1	8	2.35
12	11	8	1	4	2.35
13	12	8	1	12	2.35
14	13	8	1	8	1.8
15	14	8	1	8	2.9
16	15	8	1	4	1.8
17	16	8	1	12	1.8
18	17	8	1	4	2.9
19	18	8	1	12	2.9
20	19	10	1	8	2.35
21	20	10	1	4	2.35
22	21	10	1	12	2.35
23	22	10	1	8	1.8
24	23	10	1	8	2.9
25	24	10	1	4	1.8
26	25	10	1	12	1.8
27	26	10	1	4	2.9



Summary

- In this presentation, we can see the anisotropic substrates variance of PCBs, it effects phase difference between the differential pair

- Simulations on both EM dynamic models and IBIS-AMI models are applied to produce eye diagrams to check channel variance performance

- Circuit equalization techniques are applied at the Tx and Rx receiver to improve channel performance

- It is more efficient to get best channel performance by DOE and HPC solution

