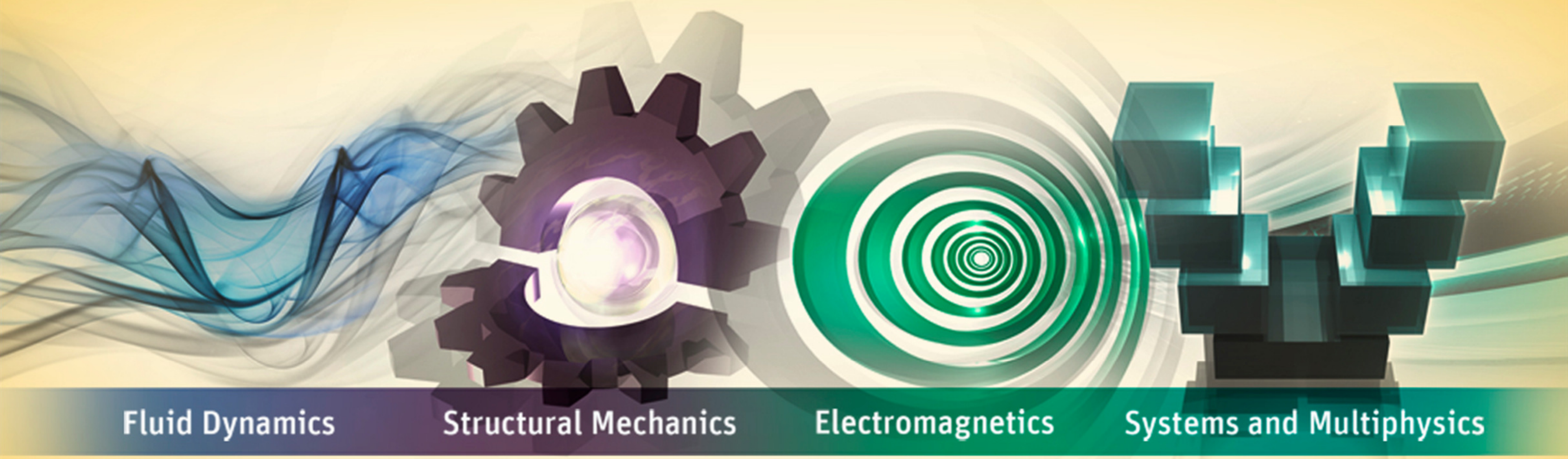
IBIS-AMI, industry adoption, and current challenges



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AMI Challenges Today

AMI models are compiled libraries and text files

- **No graphical representation**

Package model standard not finalized

- **User needs to manually add IC/package parasitics to channel model**
- **Large S-parameter issue**

Each IC vendor has different parameter set

- **No standards set**
- **Each vendor must document their models**

AMI simulations depend on accurate channel modeling

- **Passivity and causality problem**

No standard way to sweep parameters and channel corner effect

- **Need to create multiple .AMI files**
- **EDA tools need to parse arbitrary .AMI parameters**
- **Six-Sigma design at one flow**

SI Challenges Today

High Speed Serial channels are pushing the current limits of simulation. 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 and vendor specific device settings**
- **Specific Data patterns and coding schemes**
- **All types of jitter: RJ, DJ, UJ, PJ, etc.**
- **XTLK**
- **Clock Data Recovery circuits**
- **TX and RX may come from different vendors**
- **Corner and Manufacturing Variations**

IBIS AMI

AMI stands for Algorithmic Modeling Interface

It allows users to specify their own transmitter and receiver models as C-interface compiled libraries

- EDA tool supports Matlab as well as compiled DLLs
- faster signal processing algorithms
- intellectual property protection

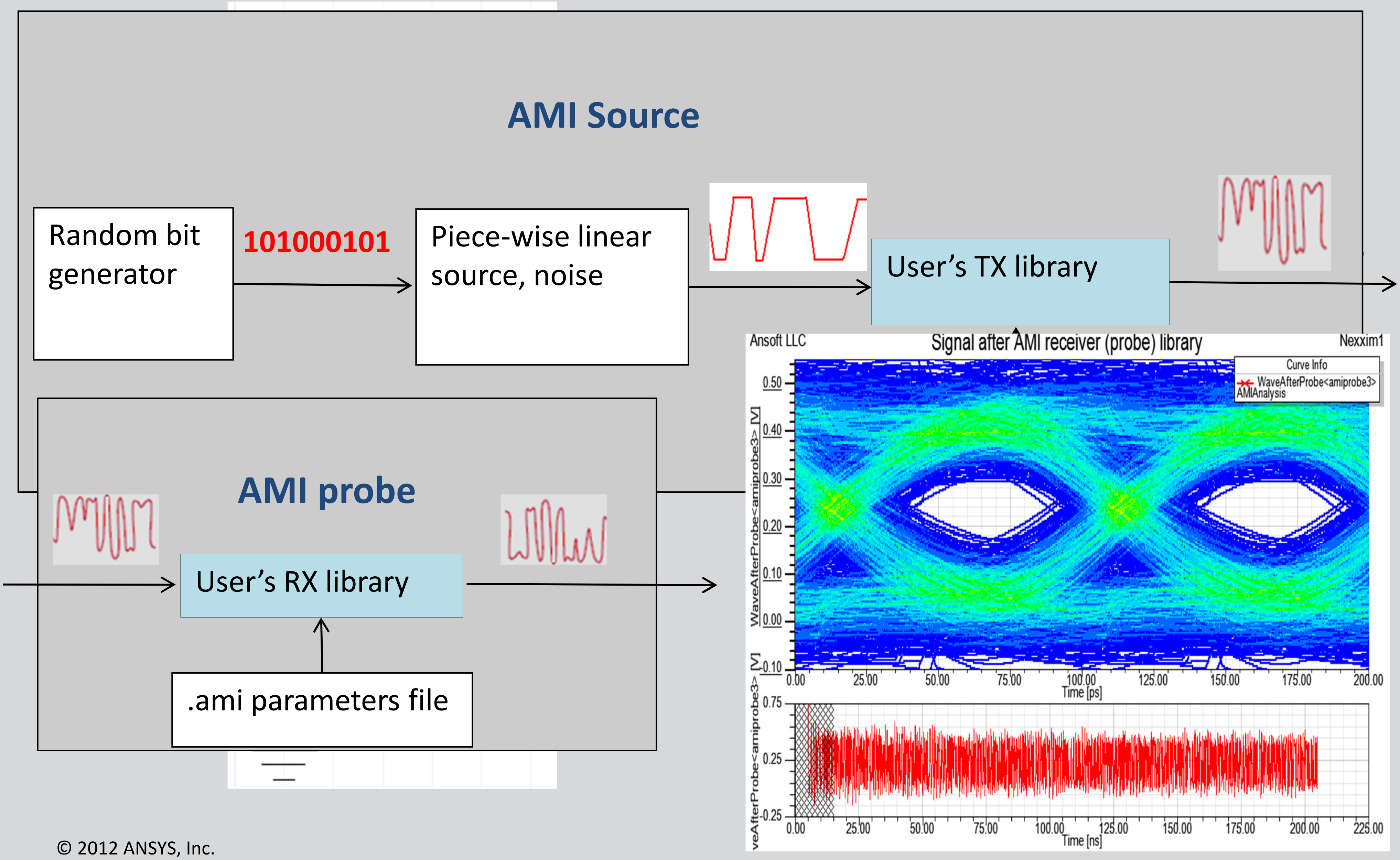
Mainly used in convolution (fast) transient engines for channel simulation

- Designed to be used with fixed time step data

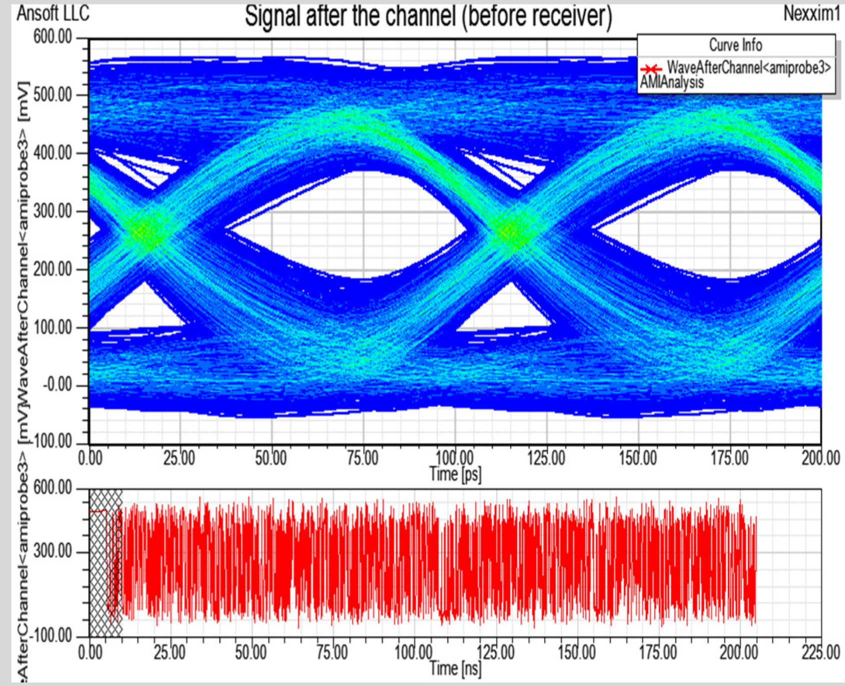
Introduced in IBIS 5.0 specs

- http://eda.org/pub/ibis/ver5.0/ver5_0.txt
- IBIS stand for "I/O Buffer Information Specification"; high-level buffer specification for circuit modeling
- In these specs the library is specified inside the IBIS wrapper and the interface is called IBIS-AMI
- In fact, AMI concept is independent of IBIS

AMI Circuit Example, time domain



Data Processing



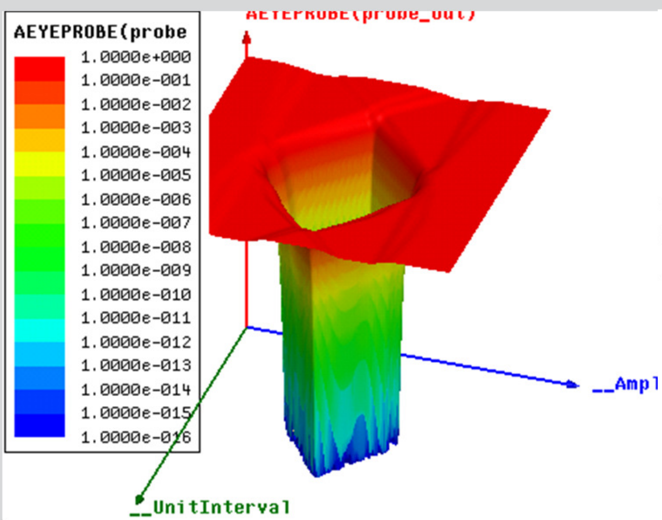
Impulse responses

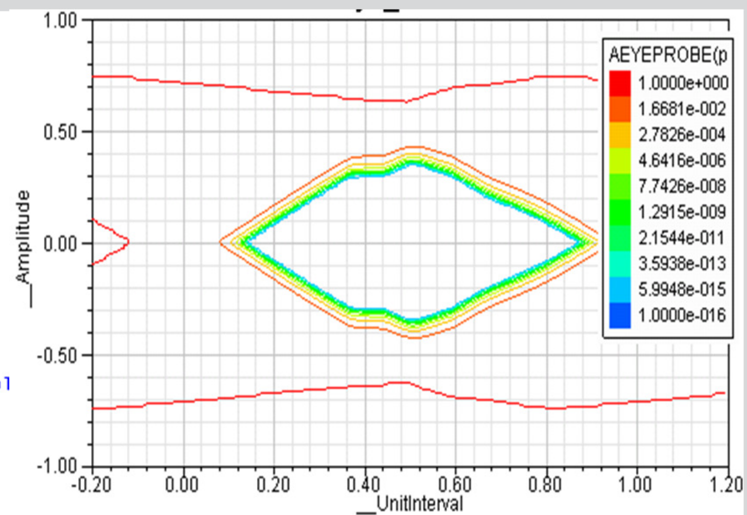
- Before and after AMI initialization
- frequency domain is also available

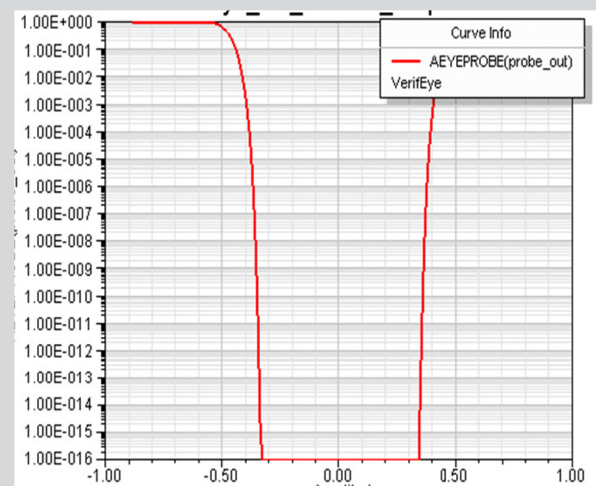
Transient data

Eye diagrams

- Bathtub plots
- Contour plots
- Bit-error-rate







Comparison of Simulation Types

Method	Analysis	Advantages	Disadvantages
Traditional IBIS	Transient	Fast	Not accurate
Transistor Level	Transient	Potentially Accurate Handles Non-Linear	Very Slow No Rx Eq IP Liability Not interoperable
Fast Convolution	Quickeye	Very Fast Handles EQ Includes Bit Patterns	Not Silicon Specific LTI Assumption
Statistical	Verifeye	Very Fast Handles EQ	Not Silicon Specific No Bit Patterns LTI Assumption
IBIS-AMI	AMI	Fast Handles Vendor EQ Includes Bit Patterns Not LTI limited	Implementations vary

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AMI simulations depend on accurate channel modeling

What can we do about non-passive, non-causal models?

Bypass them

- Connect inputs to outputs directly and leave S-parameter model out of the simulation

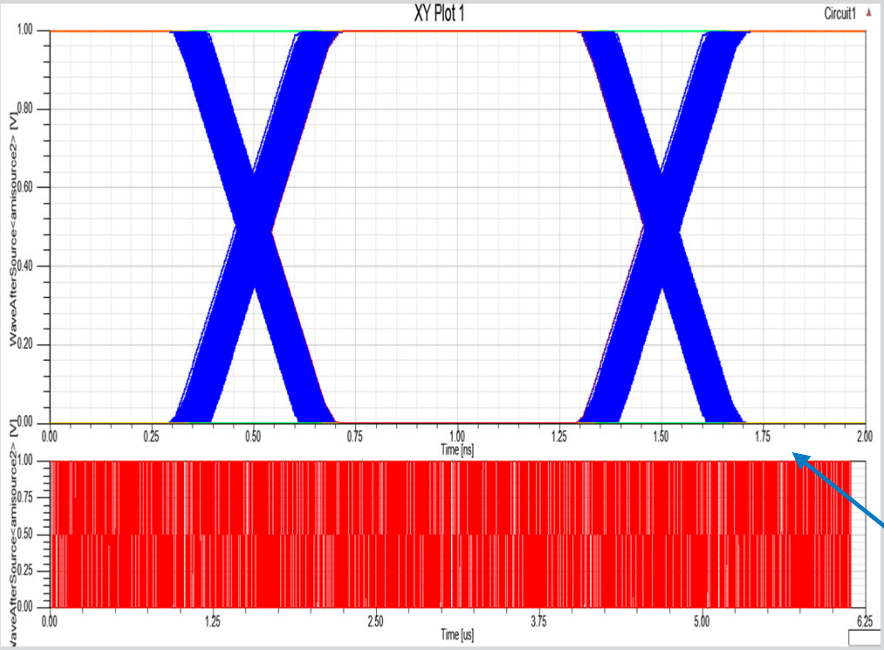
Leave them as-is

- The source S-parameter data is non-passive, but the circuit simulation model is sufficiently passive to simulate without problems

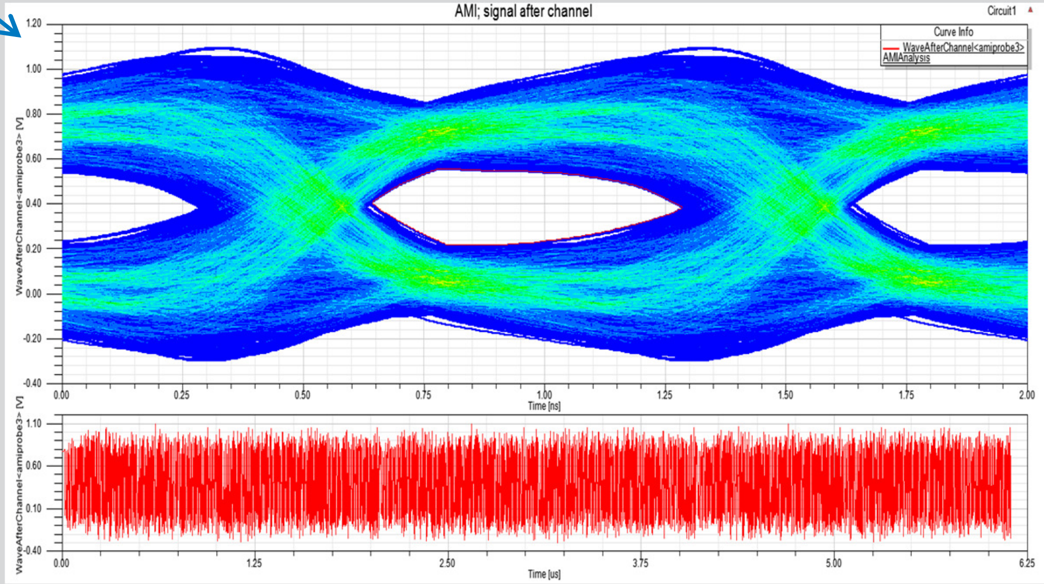
Enforce passivity and causality

- Built-in enforcement algorithms to generate passive and causal models

AMI simulations depend on accurate channel modeling



Channel ? passivity ? causality ?



Corner and Manufacturing Variations

- Usually SI engineers extract only the package or the pcb due to the trade-offs between capacity and simulation time
- For high speed channels, it is important to combine the package and pcb to capture the transitions in 3D
- Merging multi-layer package and pcb in 3D can be cumbersome

Corner effect information

Design Data | Corner Cases Zo-Attn | Parametric | Statistical | Tabular | Queue | Utility: NMF Packer

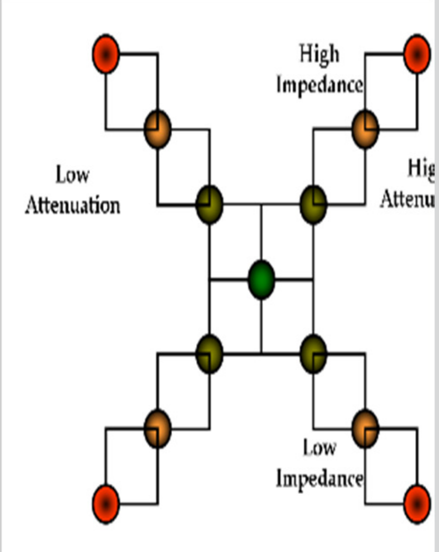
Degrees of Freedom [Cases]

○ 3-Level Corner [5] ○ 5-Level Corner [9] ◉ 7-Level Corner [13]

Load Settings | Save Settings | Default Settings | Generate Tabular Cases

☑ Single Nominal

Materials		7 point -	5 point -	3 point -	Nominal	3 point +	5 point +	7 point +
	Dielectric Constant	0.85	0.90	0.95	1.00	1.05	1.10	1.15
	Loss Tangent	0.70	0.80	0.90	1.00	1.10	1.20	1.30
	RMS Copper Roughness	0.25	0.50	0.75	1.00	1.25	1.50	1.75
	Copper Conductivity	0.80	0.84	0.87	0.90	0.93	0.96	1.00
Stack-up								
	Copper Thickness	0.85	0.90	0.95	1.00	1.05	1.10	1.15
	Dielectric Thickness	0.85	0.90	0.95	1.00	1.05	1.10	1.15
Geometry								
	Trace Width	0.85	0.90	0.95	1.00	1.05	1.10	1.15



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Assigning Variables – Layout Approach

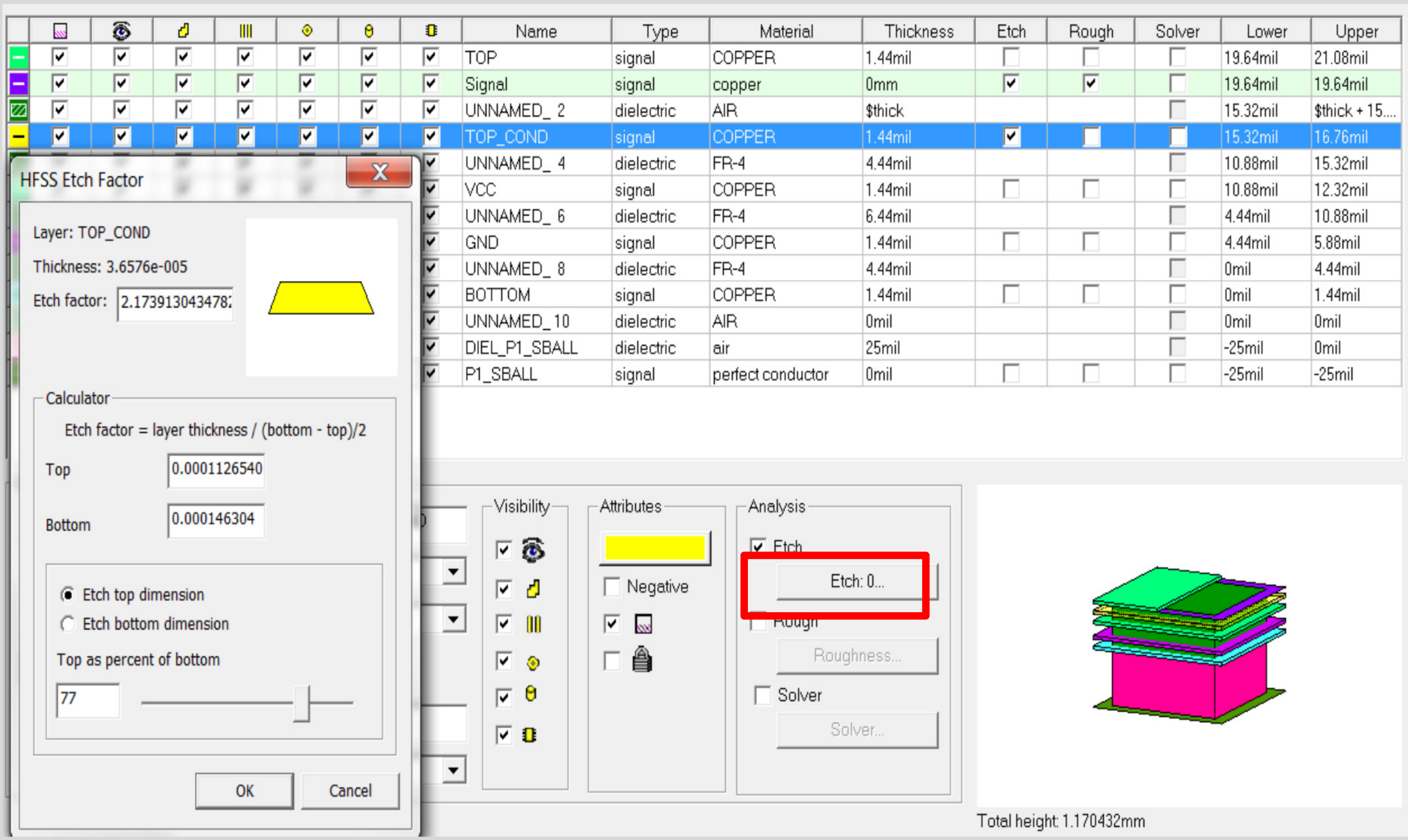
- **Dielectric Thickness**

							Name	Type	Material	Thickness	Etch	Rough	Solver	Lower	Upper
☑	☑	☑	☑	☑	☑	☑	TOP	signal	COPPER	1.44mil	☐	☐	☐	19.64mil	21.08mil
☑	☑	☑	☑	☑	☑	☑	Signal	signal	copper	0mm	☑	☑	☐	19.64mil	19.64mil
☑	☑	☑	☑	☑	☑	☑	UNNAMED_2	dielectric	AIR	4.32mil			☐	15.32mil	19.64mil
☑	☑	☑	☑	☑	☑	☑	TOP_COND	signal	COPPER	1.44mil	☐	☐	☐	15.32mil	16.76mil
☑	☑	☑	☑	☑	☑	☑	UNNAMED_4	dielectric	FR-4	4.44mil			☐	10.88mil	15.32mil
☑	☑	☑	☑	☑	☑	☑	VCC	signal	COPPER	1.44mil	☐	☐	☐	10.88mil	12.32mil
☑	☑	☑	☑	☑	☑	☑	UNNAMED_6	dielectric	FR-4	6.44mil			☐	4.44mil	10.88mil
☑	☑	☑	☑	☑	☑	☑	GND	signal	COPPER	1.44mil	☐	☐	☐	4.44mil	5.88mil
☑	☑	☑	☑	☑	☑	☑	UNNAMED_8	dielectric	FR-4	4.44mil			☐	0mil	4.44mil
☑	☑	☑	☑	☑	☑	☑	BOTTOM	signal	COPPER	1.44mil	☐	☐	☐	0mil	1.44mil
☑	☑	☑	☑	☑	☑	☑	UNNAMED_10	dielectric	AIR	0mil			☐	0mil	0mil
☑	☑	☑	☑	☑	☑	☑	DIEL_P1_SBALL	dielectric	air	25mil			☐	-25mil	0mil
☑	☑	☑	☑	☑	☑	☑	P1_SBALL	signal	perfect conductor	0mil	☐	☐	☐	-25mil	-25mil

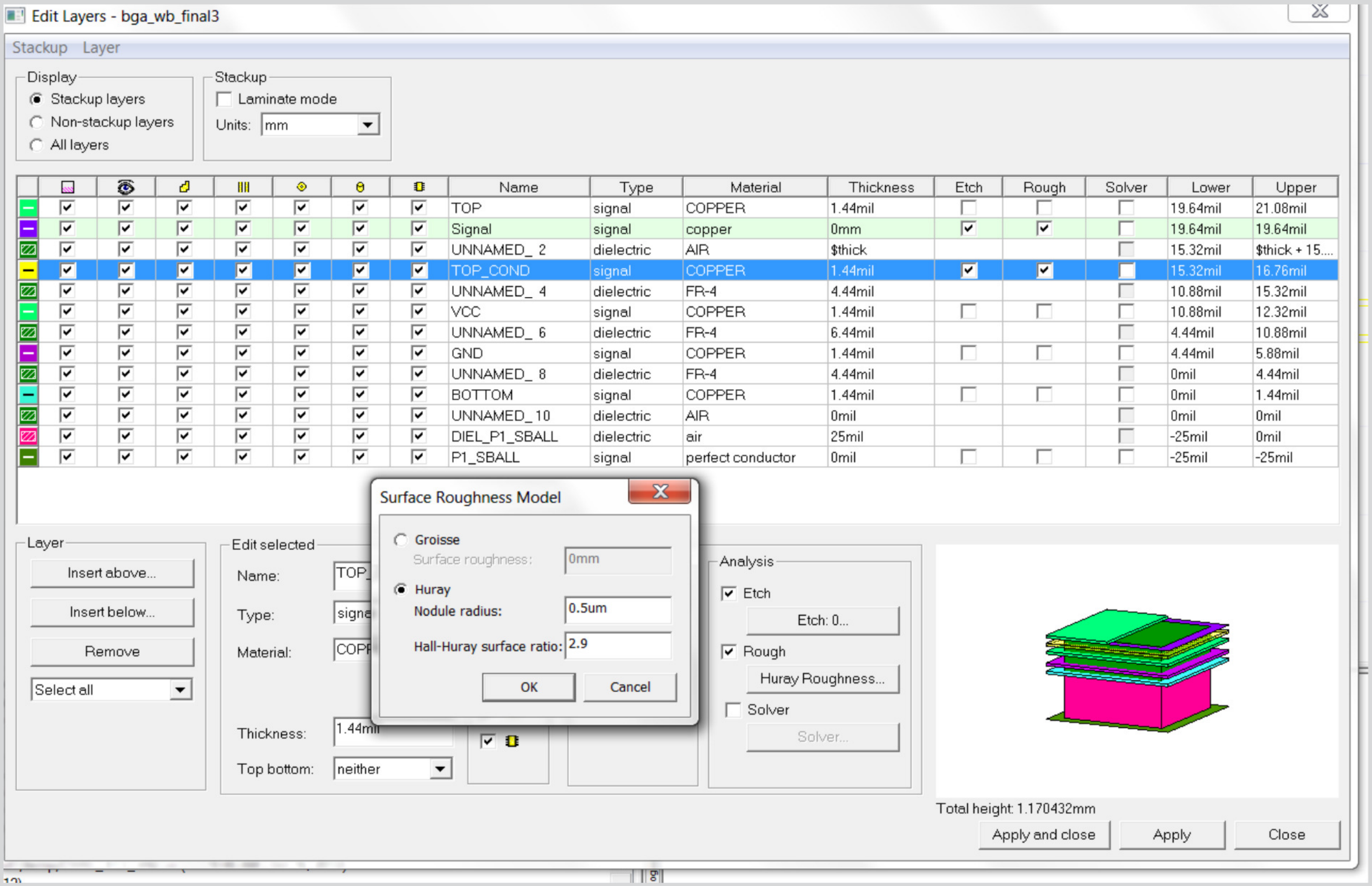
Type	Material	Thickness	Etch	Rough	Solver	Lower	Upper
ial	COPPER	1.44mil	☐	☐	☐	19.64mil	21.08mil
ial	copper	0mm	☑	☑	☐	19.64mil	19.64mil
ectric	AIR	$thick			☐	15.32mil	$thick + 15...
ial	COPPER	1.44mil	☐	☐	☐	15.32mil	16.76mil
ectric	FR-4	4.44mil			☐	10.88mil	15.32mil
ial	COPPER	1.44mil	☐	☐	☐	10.88mil	12.32mil
ectric	FR-4	6.44mil			☐	4.44mil	10.88mil
ial	COPPER	1.44mil	☐	☐	☐	4.44mil	5.88mil
ectric	FR-4	4.44mil			☐	0mil	4.44mil
ial	COPPER	1.44mil	☐	☐	☐	0mil	1.44mil
ectric	AIR	0mil			☐	0mil	0mil
ectric	air	25mil			☐	-25mil	0mil
ial	perfect conductor	0mil	☐	☐	☐	-25mil	-25mil

Assigning Variables

- **Etching Factor**

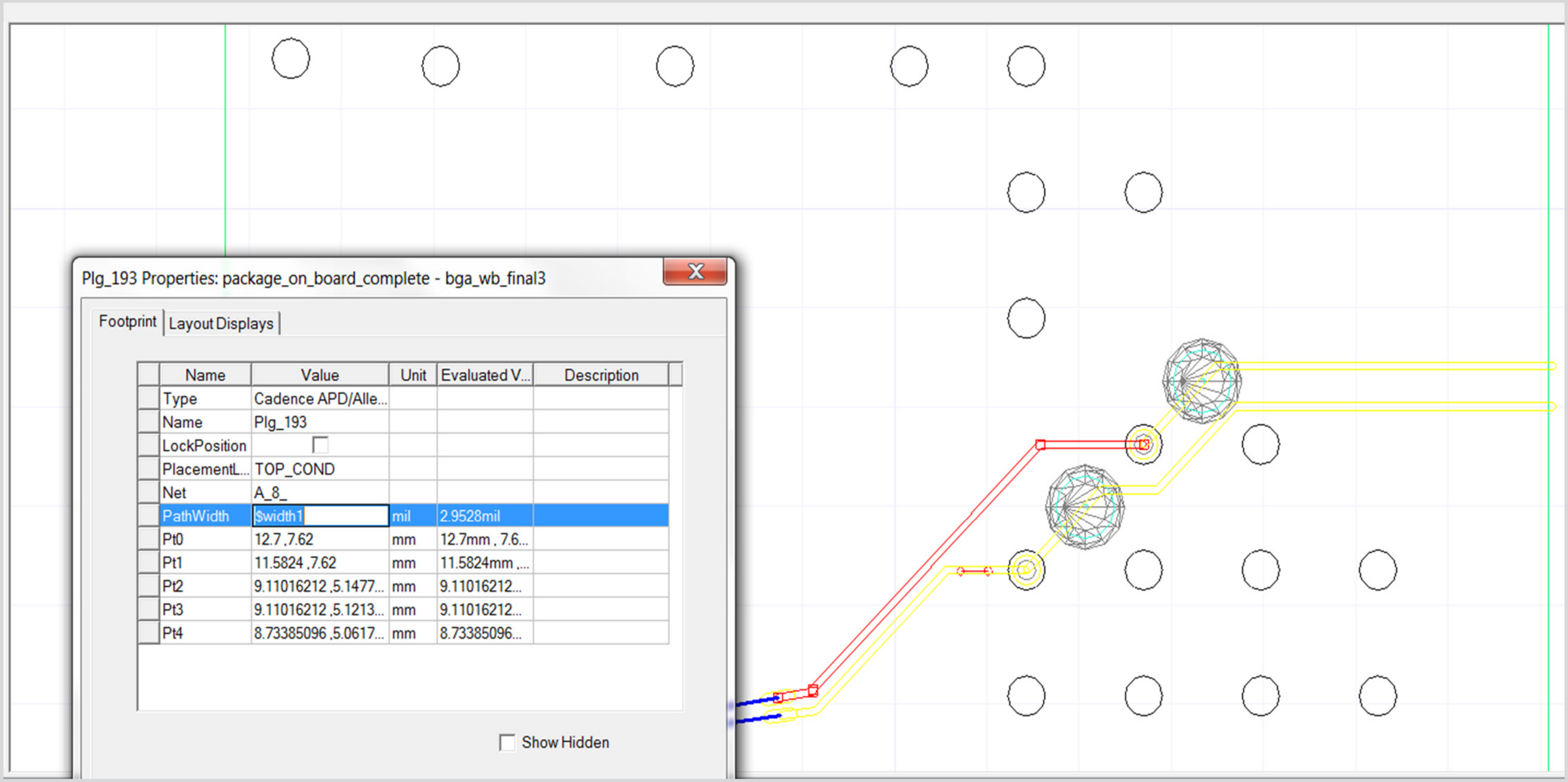


Roughness model : Huray model



Assigning Variables

- **Trace Width**



CSV Import for Parametric Analysis

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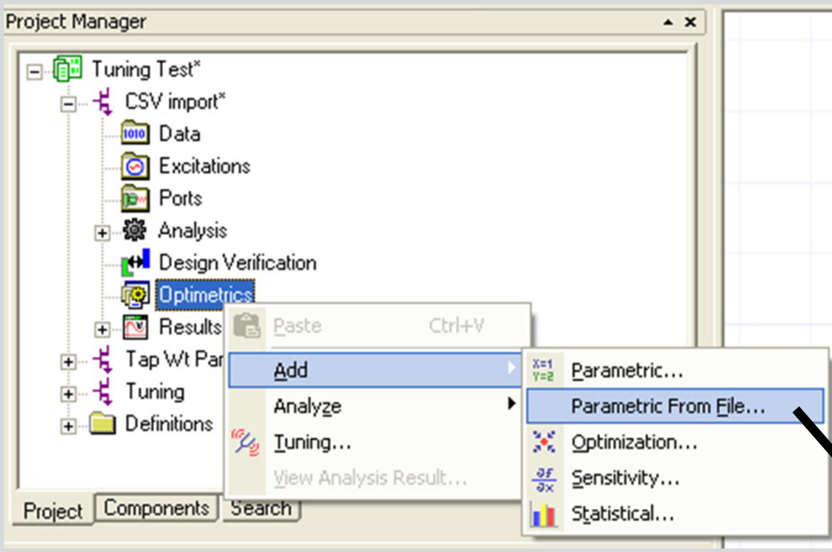
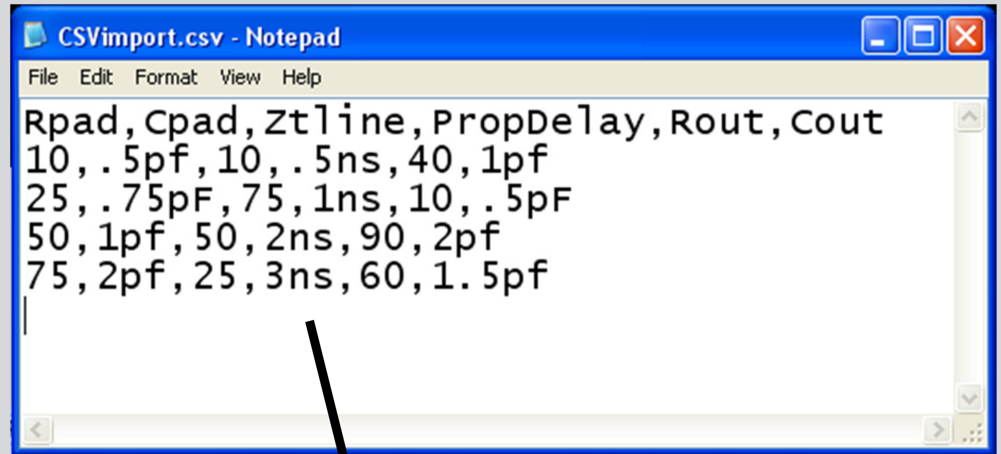
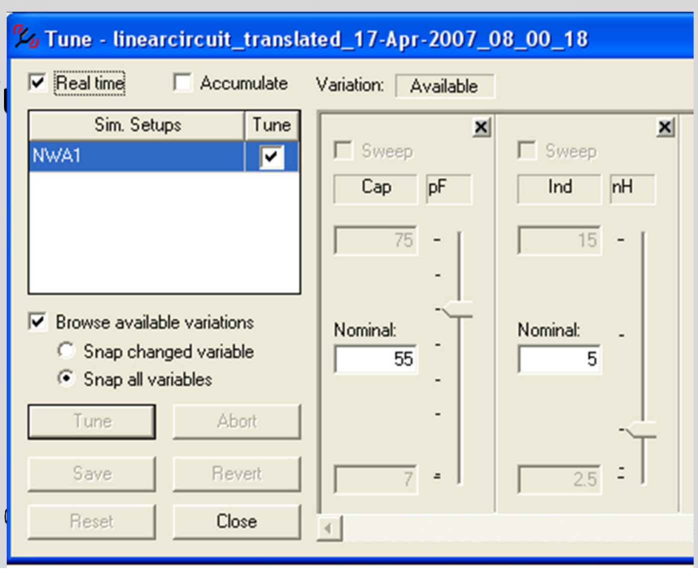
Parametric Batch Mode





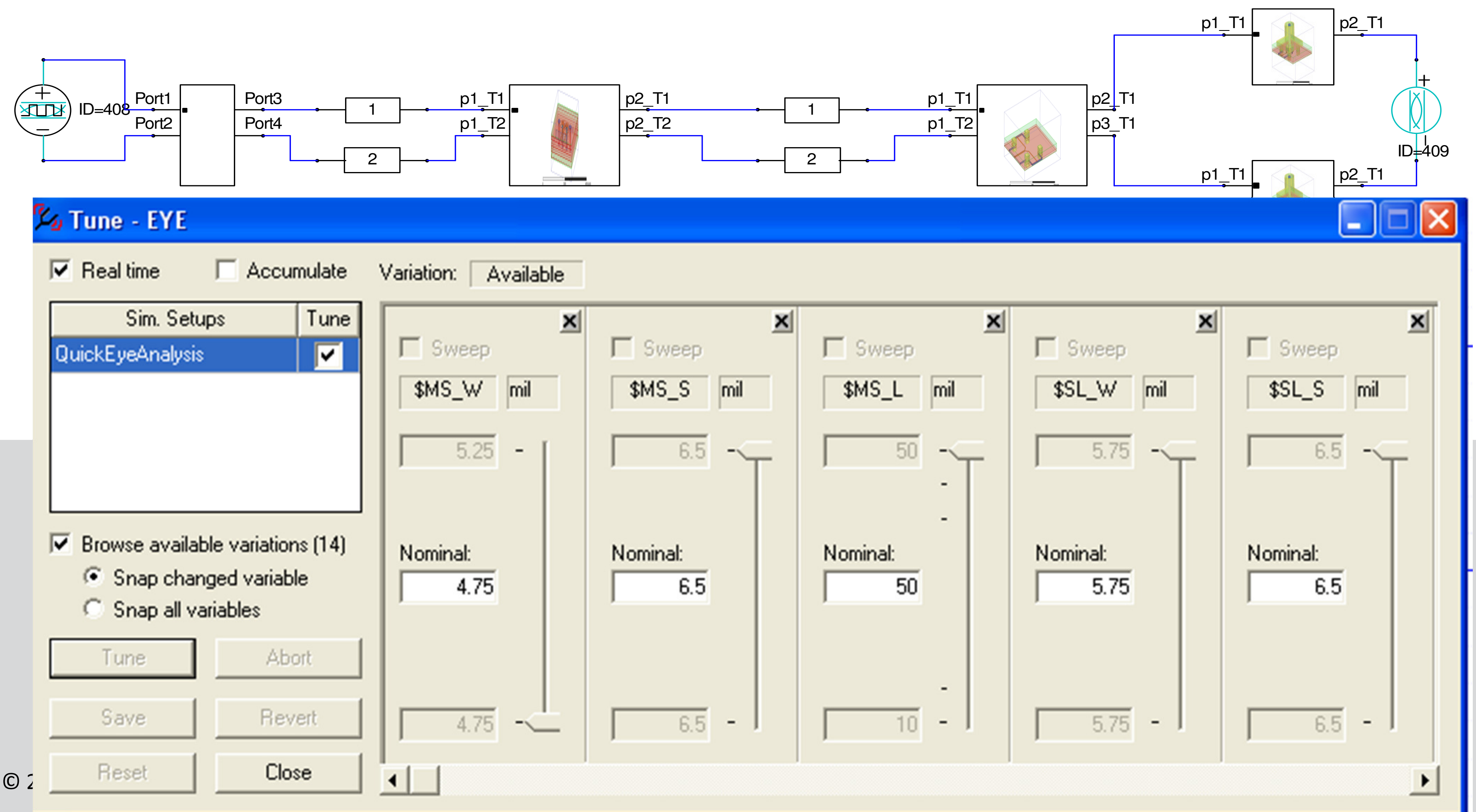
Rpad	Cpad	Ztline	PropDelay	Rout	Cout
10	.5pf	10	.5ns	40	1pf
25	.75pF	75	1ns	10	.5pF
50	1pf	50	2ns	90	2pf
75	2pf	25	3ns	60	1.5pf

T

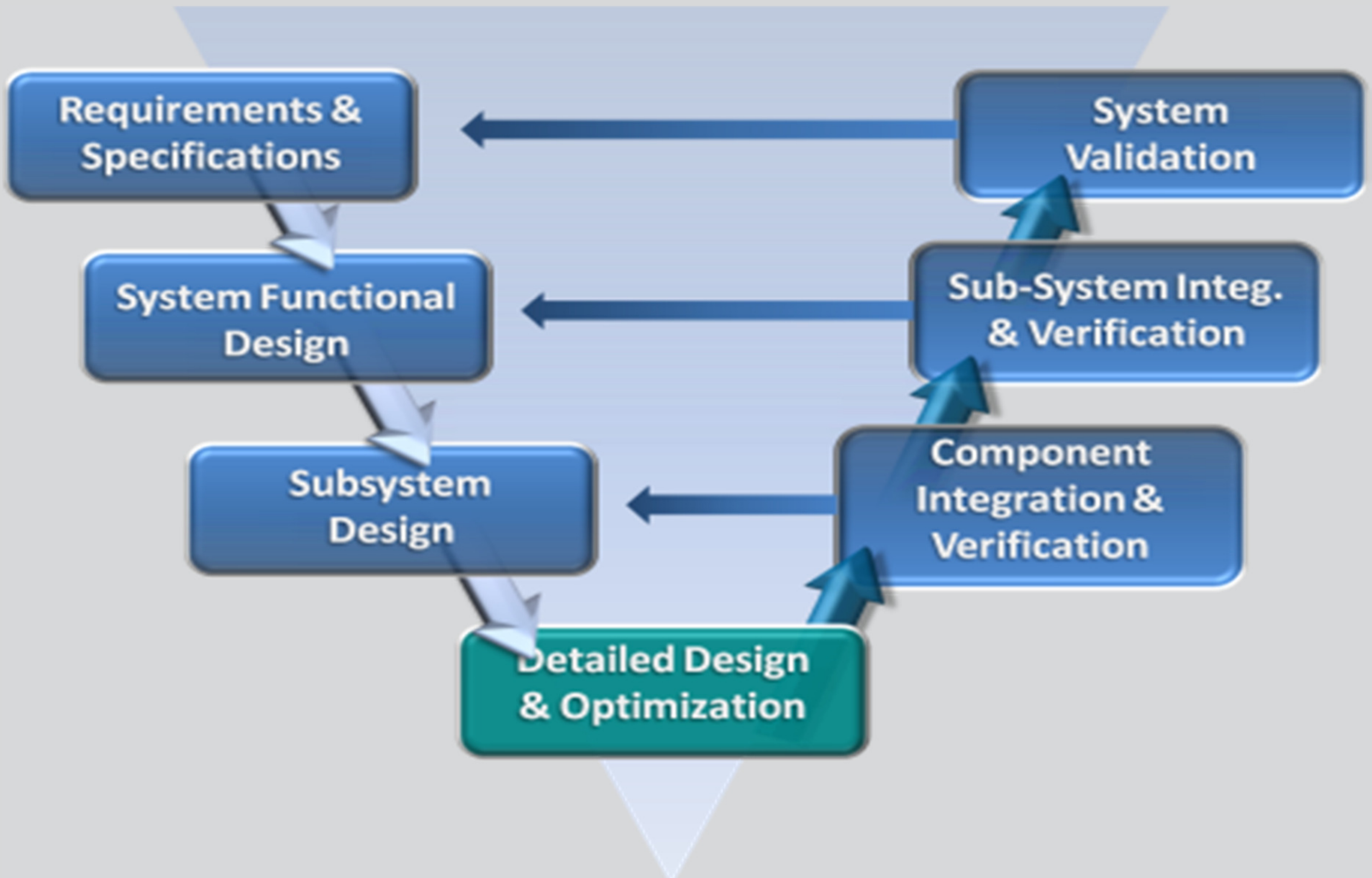


Handle all of geometric project and tune for Prbs31 at Tool and Design of Experiments analysis

PRBS31

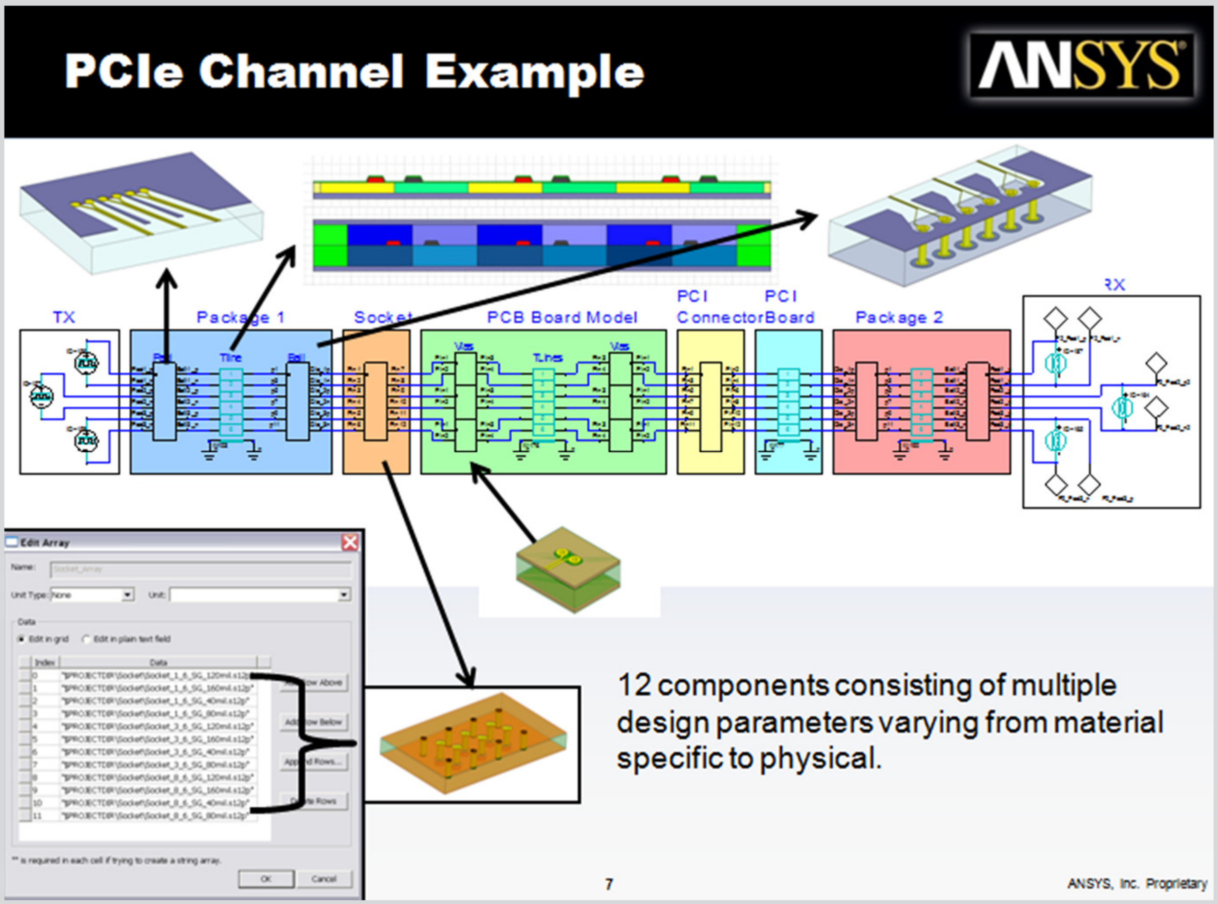


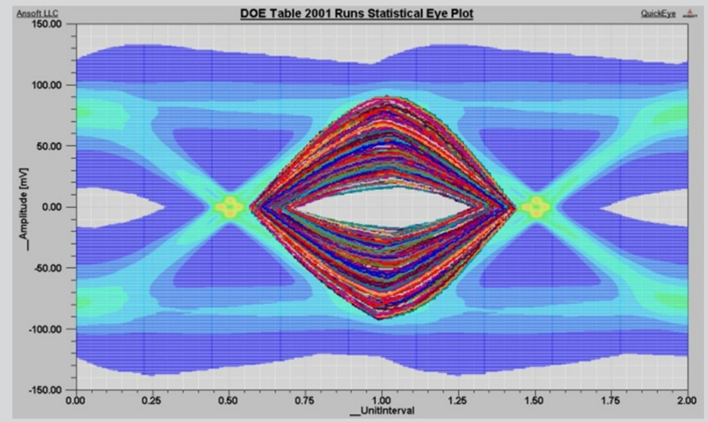
Channel "V" Design for AMI solution

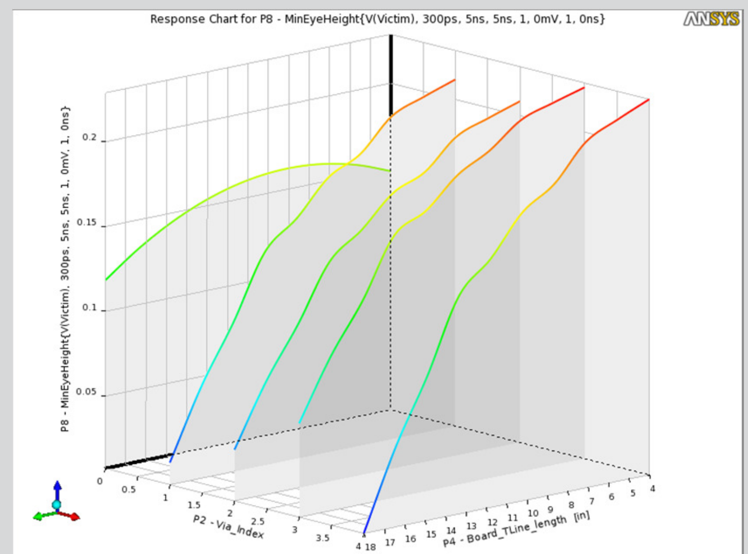


Simulation Approaches :DOE way

- we showed how we can use DOE way to investigate surface responses of a channel design with hundreds parametric variations. But we still had to break down the 3D component designs to small chunks of the board or package to keep simulation times reasonable







AMI Analysis flow

(1) Compute impulse response of the channel (as well of aggressor impulse responses)

- Regular transient analysis

(2) Initialize AMI libraries with the channel response

- Libraries can modify impulse responses

In a loop:

- Generate a block of transmitted bits
- Convert a list of bits into a piecewise-linear rise-fall signal
- Push the signal through the transmitter
- Convolve the signal with the channel
- Push the signal through the receiver
- Post-process the results (eye and bit-error-rate plots)

AMI Analysis flow

(3) Add FFE weight parameter

(4) Add Corner and Manufacturing Variations

(5)Uses the final impulse response from AMI analysis to run VerifEye (statistical eye) analysis

(6) Use DOE way to investigate surface responses of a channel design with hundreds parametric variations and find root cause with min-eye

(7) Six-Sigma Report

Conclusions

Today, It is not easy for SI engineer to take care AMI parameters and high Speed Serial channels manufacturing variations. We need to enforce passive and causal models for channel .By using channel V design , we can do large capacity simulation , and get the best solution for AMI Channel model .