A PRACTICAL METHODOLOGY FOR SERDES DESIGN

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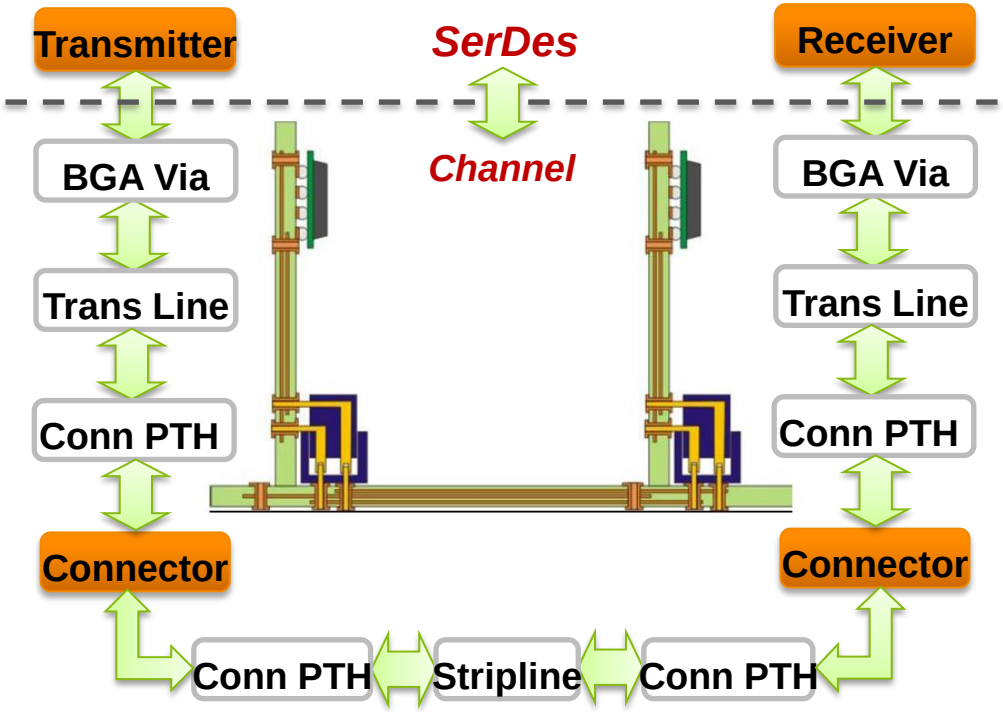
AGENDA

- Challenges in Traditional Simulation
- The DOE/RSM Solution
- CEI 28G-VSR IF Design with DOE
- Question and Suggestion for IBIS-AMI

SERDES & CHANNEL



- Transceiver Equalization
- Via impedance
- Trace impedance
- Trace loss
- Connector characteristics

MISSION IMPOSSIBLE

- Equalization settings
  - FFE
    - Precursor – 10 taps
    - Postcursor – 10 taps
  - CTLE
    - Off; Fixed; Adapt
  - DFE
    - Off; Fixed; Adapt
- Via impedance
  - 3 corners (TC/WC/BC)
- Trace impedance
  - 3 corners (TC/WC/BC)
- Connector characteristics
  - 3 corners (TC/WC/BC)
- Trace loss
  - 3 corners (TC/WC/BC)

Assuming 10min for each simulation case:

- Running bits: $1*10^6$
- Sampling per bit: 64
- Block size: 1024

Total time consumption of simulation:

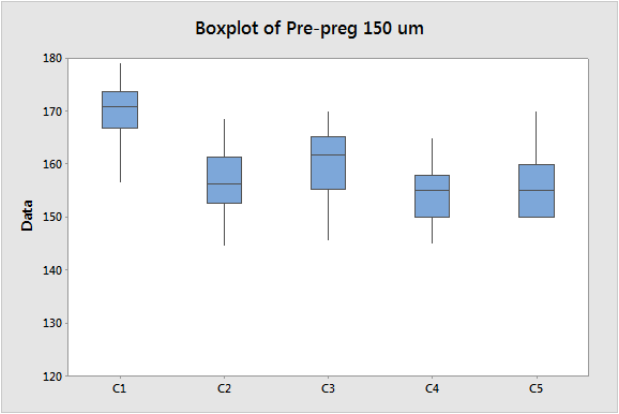
10*10*10*3^6

= 729000 minutes

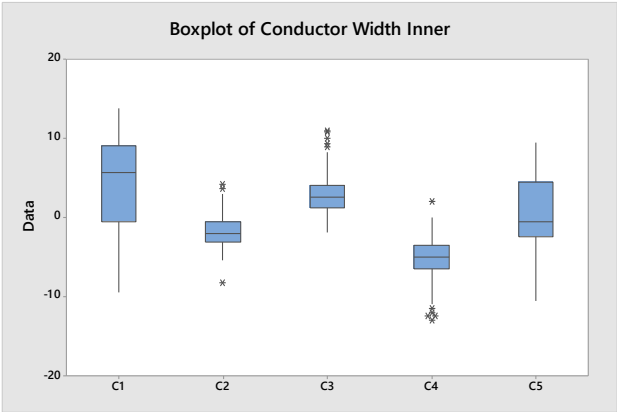
= **506.25days**

MANUFACTURING VARIATION

Dielectric thickness



Trace width inner



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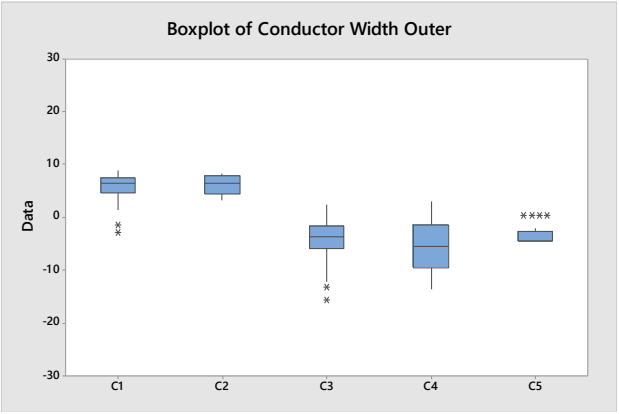

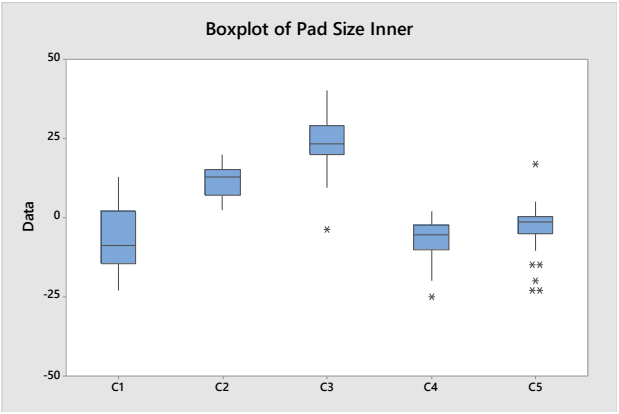

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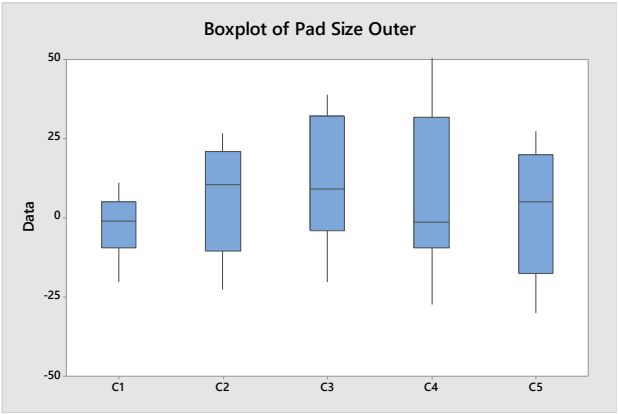

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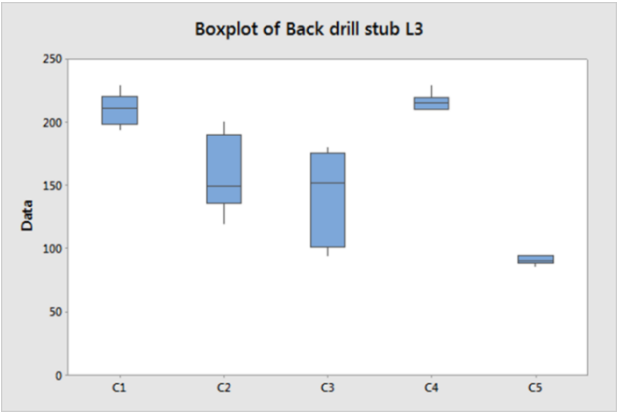
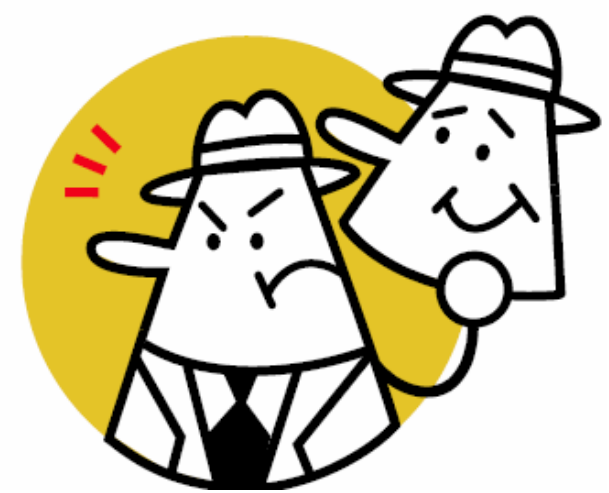


Back drilling stub

CHALLENGE

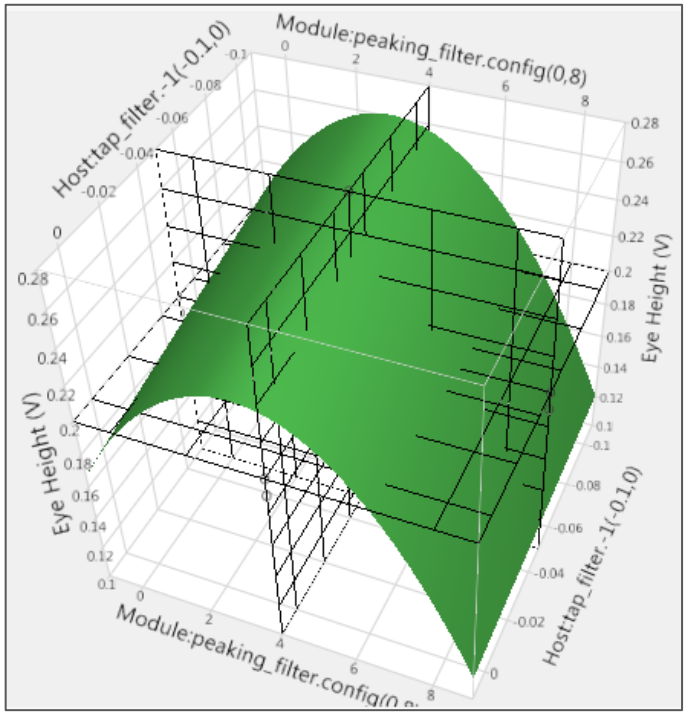
- Complex system design
  - How to manage conflicting objectives?
  - Millions of system configurations to check
- Analysis iteration time
  - How long will it take to get an answer?
  - If simulations take minutes and there are millions of setting to check it will take months to complete
- Design decisions
  - How to manage multiple design decisions?
- Manufacturing variation
  - How does this impact performance?
  - Can my design minimize the risk?



THE DOE/RSM SOLUTION

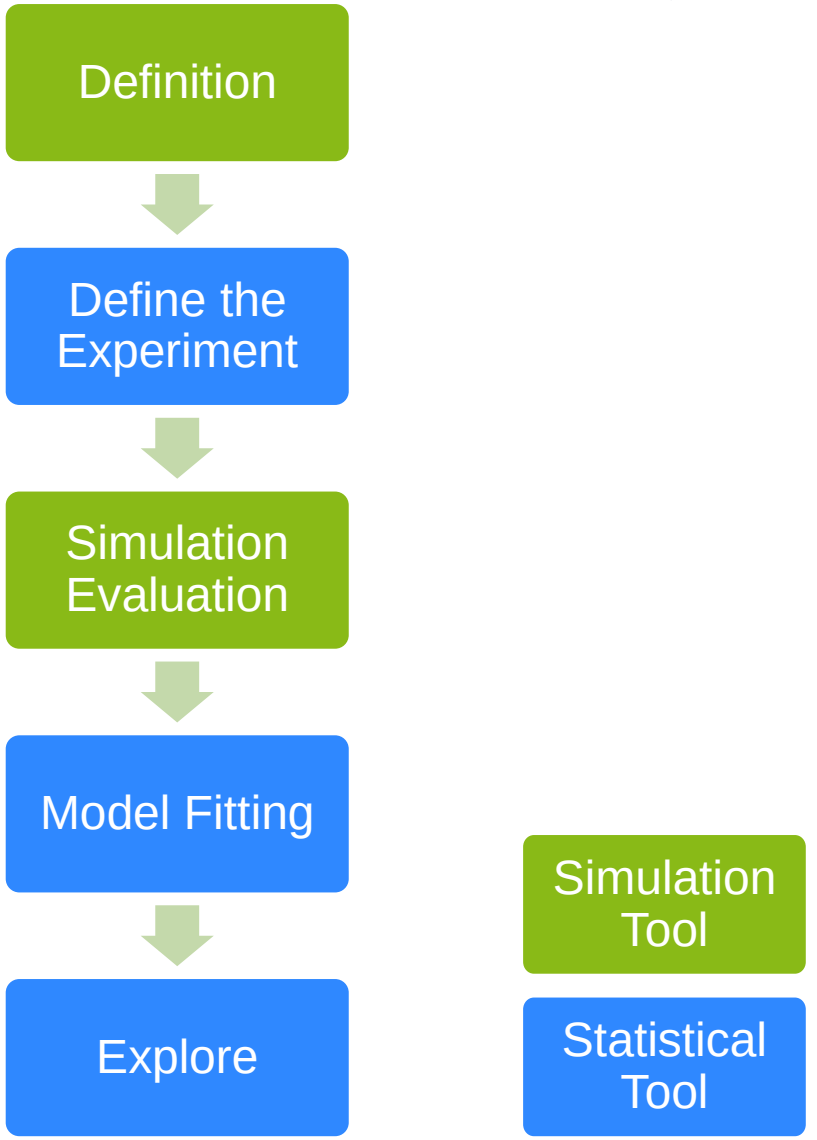
- The Ideal:
  - What if we had an equation where you put in the system conditions and out came system performance?

- Approximating the Ideal:
  - Statistically sample the parameter space
    - Design of Experiment (DOE)
  - Use your knowledge of the system under analysis to apply an appropriate model to the data
    - Response Surface Model (RSM)
  - Validate model
  - Utilize model to optimize and explore

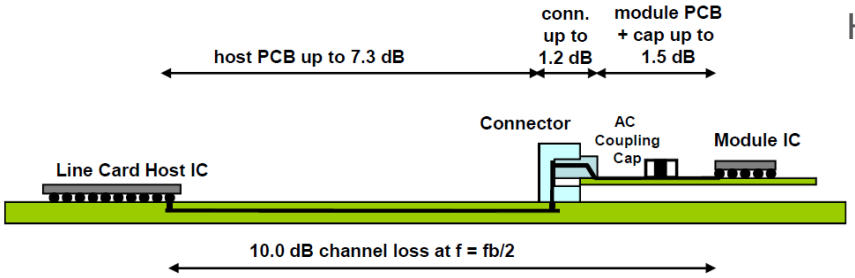


DESIGN OF EXPERIMENT PROCESS

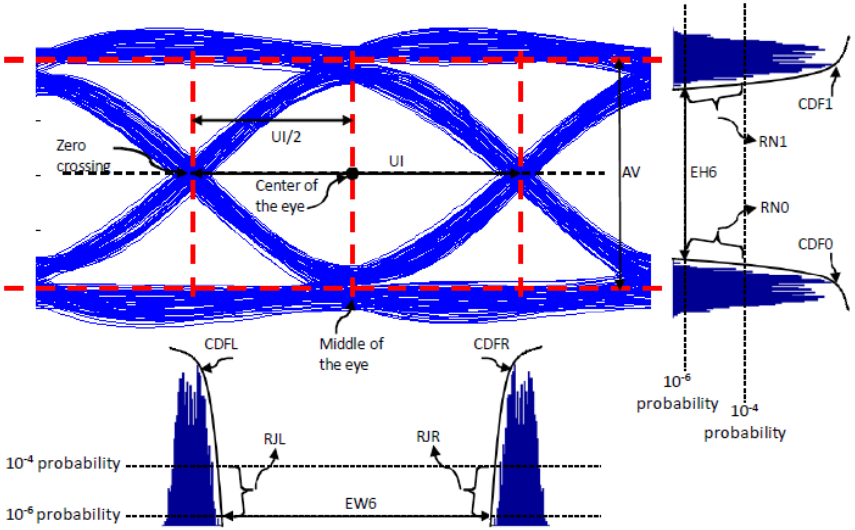
- Definition
  - Link topology
  - Parameter space
- Define the experiments
  - Define model
  - Create cases
- Simulation and evaluation
  - Simulate all cases
  - Quantify performance of all cases
- Model fitting
  - Response surface model
  - Least squares fit
- Explore
  - Virtual “what if” analysis
  - Optimize
  - Defects per million (DPM) analysis



CEI 28G-VSR



CEI-28G-VSR Channel



TP1a jitter and Eye Height parameters

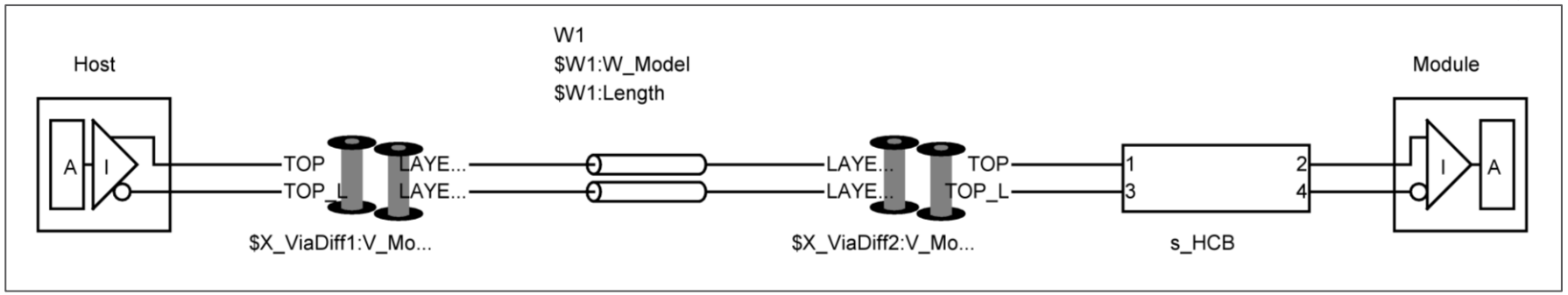
Host-to-Module Electrical Specifications at TP1a (host output)

Parameter	Min.	Max.	Units	Conditions
Differential Voltage pk-pk	-	900	mV	
Common Mode Noise RMS	-	17.5	mV	See Section 13.3.5
Differential Termination Resistance Mismatch	-	10	%	At 1 MHz See Section 13.3.6
Differential Return Loss (SDD22)	-	See Equation 13-19	dB	
Common Mode to Differential conversion and Differential to Common Mode Conversion (SDC22, SCD22)	-	See Equation 13-21	dB	
Common Mode Return Loss (SCC22)	-	-2	dB	From 250 MHz to 30 GHz
Transition Time, 20 to 80%	10	-	ps	See Section 13.3.10
Common Mode Voltage	-0.3	2.8	V	Referred to host ground
Eye Width at 10^{-15} probability (EW15)[1]	0.46	-	UI	See Section 13.3.11
Eye Height at 10^{-15} probability (EH15)[1]	95	-	mV	See Section 13.3.11

EW15 = 0.46UI

EH15 = 95mV

DEFINITION



Item	Design Para.	Factor	Factor Type	Min	Typ	Max
1	EQ: FFE	Host:Tap_Filter.-1	Continuous	-0.1	-	0
2	EQ: FFE	Host:Tap_Filter.1	Continuous	-0.2	-	0
3	EQ: CTLE	Module:peaking_filter.config	Continuous	0	-	8
4	Channel length (inch)	W_Length	Continuous	2	-	6
5	Dielectric constant	Er	Continuous	3.85	-	3.95
6	Loss tangent	Loss_Tangent	Continuous	0.075	-	0.085
7	Conductor roughness (RMS)	Conductor_Roughness	Continuous	0.2	-	0.3
8	Dielectric height (mil)	Dielectric_Height_H1	Continuous	4.3	-	4.7
9	Differential separation (mil)	Differential_Separation	Continuous	5.9	-	6.7
10	Trace width (mil)	Trace_Width	Continuous	3.5	-	4.3
11	Trace thickness (mil)	Trace_Thickness	Continuous	0.57	-	0.67
12	Via type with diff. stub (mil)	X_ViaDiff1_V_MODEL	Categorical	Stub_2mil	Stub_6mil	Stub_10mil

DEFINE THE EXPERIMENT

Custom Design

Responses

Add Response | Remove | Number of Responses...

Response Name	Goal	Lower Limit	Upper Limit	Importance
Eye Height	Maximize	0.095	.	.
Eye Width	Maximize	16.5	.	.

Factors

Add Factor | Remove | Add N Factors | 1

Name	Role	Changes	Values		
HOST:TAP_FILTER.-1	Continuous	Easy	-0.1	0	
HOST:TAP_FILTER.1	Continuous	Easy	-0.2	0	
MODULE:PEAKING_FILTER.CC	Continuous	Easy	0	8	
$W1:CONDUCTOR_ROUGHNI	Continuous	Easy	0.2	0.4	
$W1:DIELECTRIC_HEIGHT_H1	Continuous	Easy	4.3	4.7	
$W1:DIFFERENTIAL_SEPARAT	Continuous	Easy	5.9	6.7	
$W1:ER	Continuous	Easy	3.6	4.4	
$W1:LENGTH	Continuous	Easy	2	6	
$W1:LOSS_TANGENT	Continuous	Easy	0.006	0.02	
$W1:TRACE_THICKNESS	Continuous	Easy	0.57	0.67	
$W1:TRACE_WIDTH	Continuous	Easy	3.5	4.3	
$X_VIADIFF1:V_MODEL	Categorical	Easy	Diff_Via_LongStub	Diff_Via_MiddleStub	Diff_Via_ShortStub

Define Factor Constraints

Model

Main Effects | Interactions | RSM | Cross | Powers | Remove Term

Name	Estimability
Intercept	Necessary
HOST:TAP_FILTER.-1	Necessary
HOST:TAP_FILTER.1	Necessary
MODULE:PEAKING_FILTER.CONFIG	Necessary
$W1:CONDUCTOR_ROUGHNESS	Necessary
$W1:DIELECTRIC_HEIGHT_H1	Necessary
$W1:DIFFERENTIAL_SEPARATION	Necessary
$W1:ER	Necessary

Alias Terms

Design Generation

Group runs into random blocks of size: 2

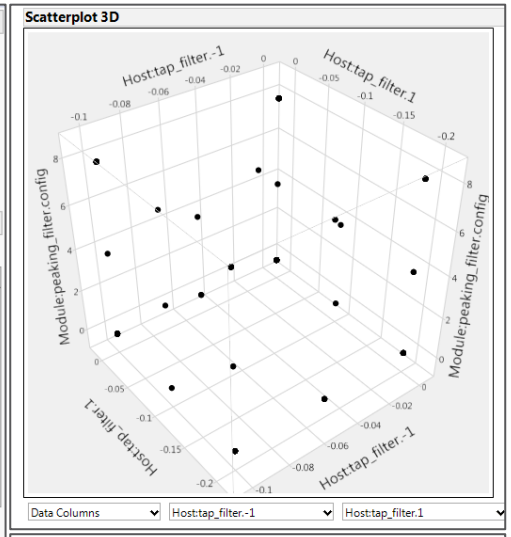
Number of Center Points: 0

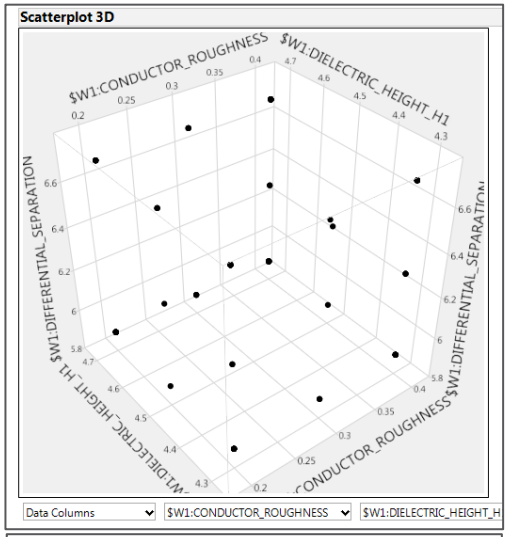
Number of Replicate Runs: 0

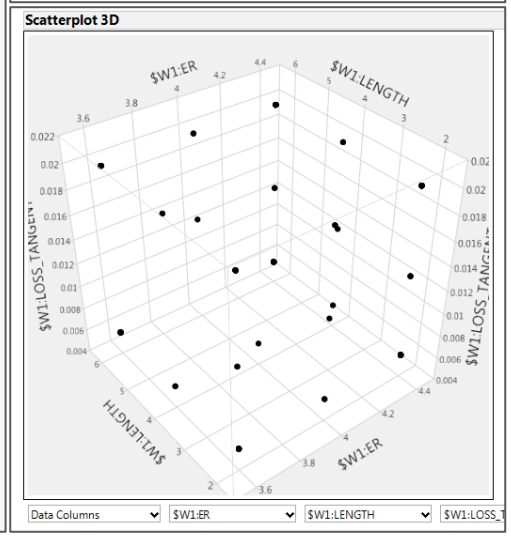
Number of Runs:

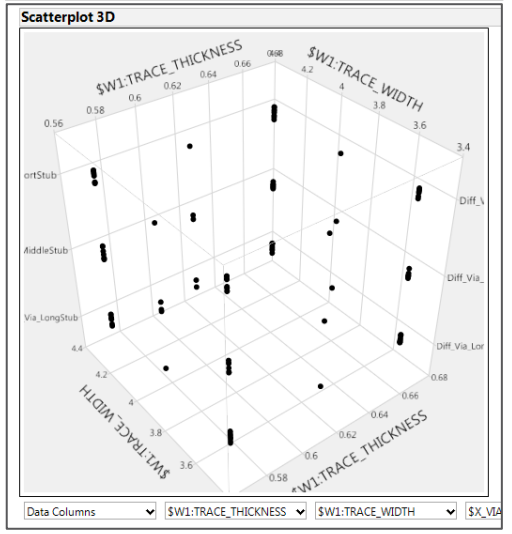
- Minimum 102
- Default 108
- User Specified 108

Make Design





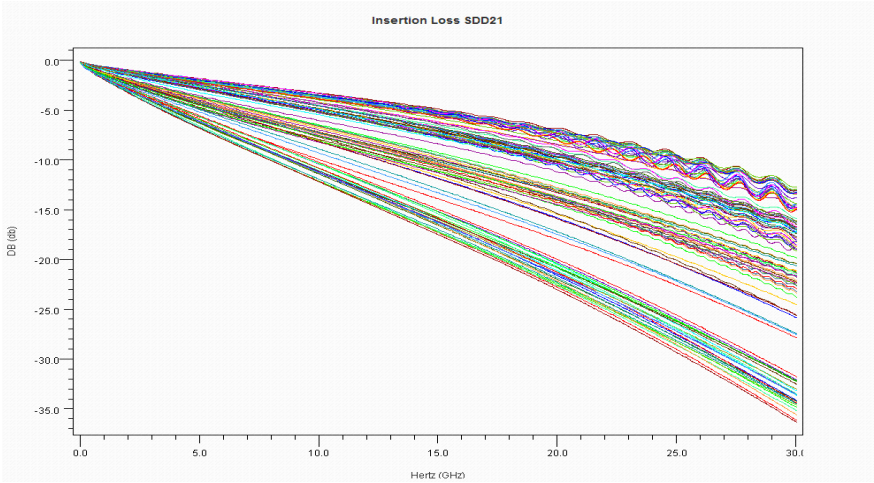


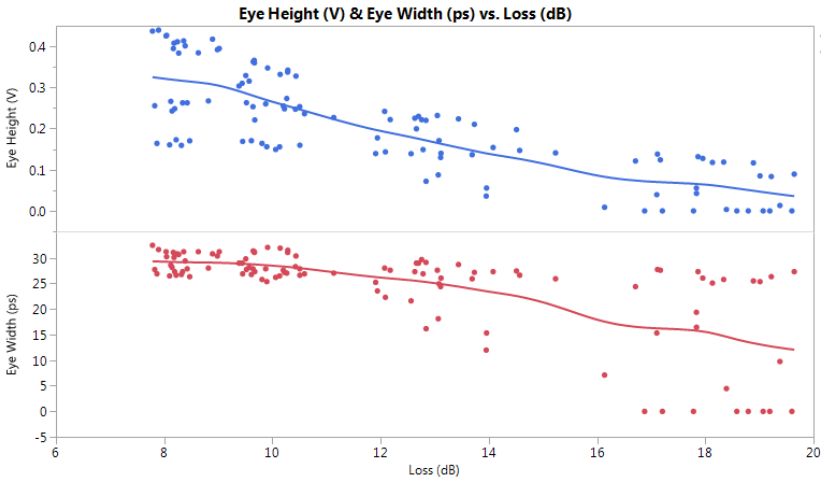


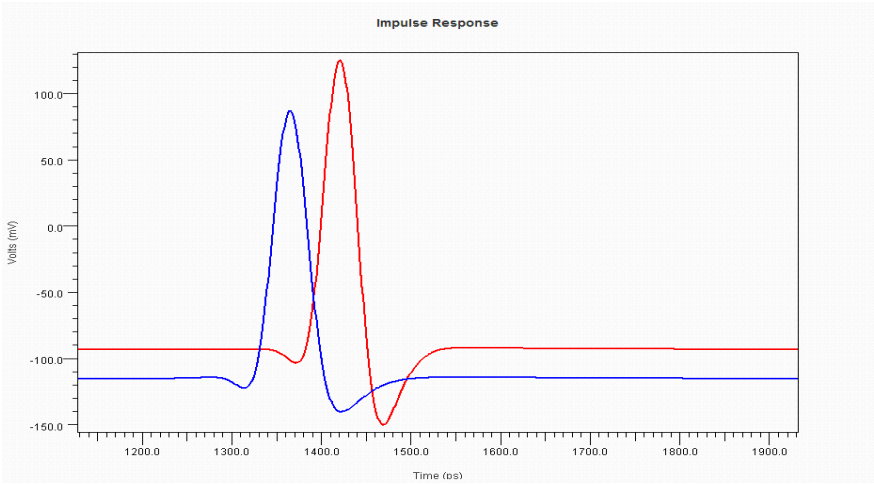
3D plots for parameter space

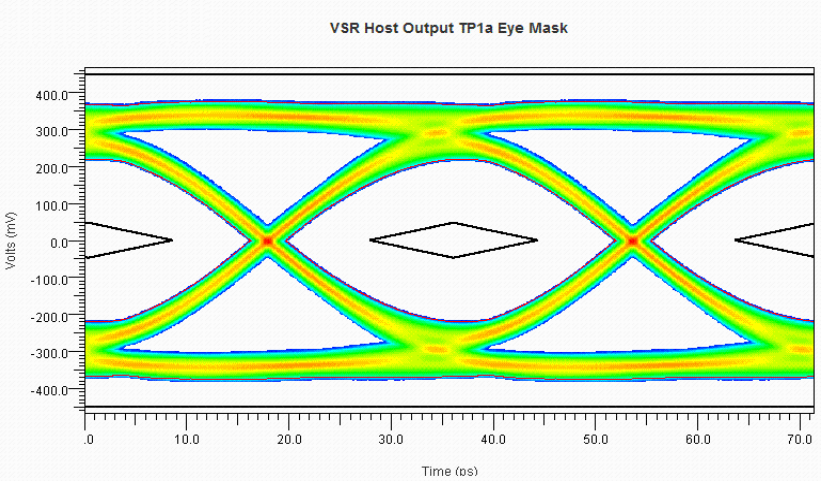
SIMULATION EVALUATION

- Run the simulation and evaluate the results



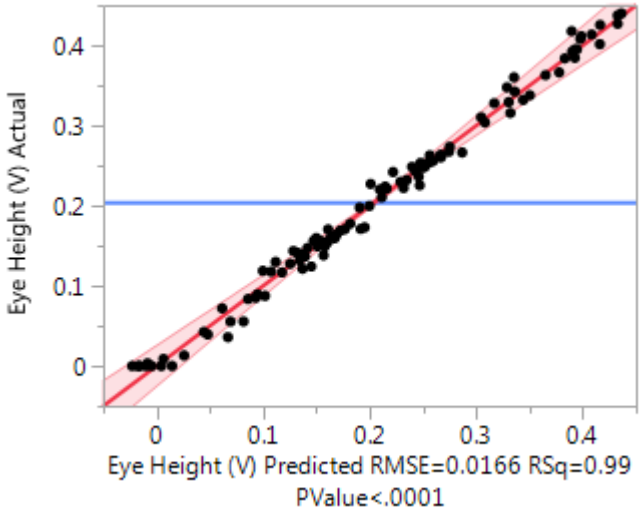




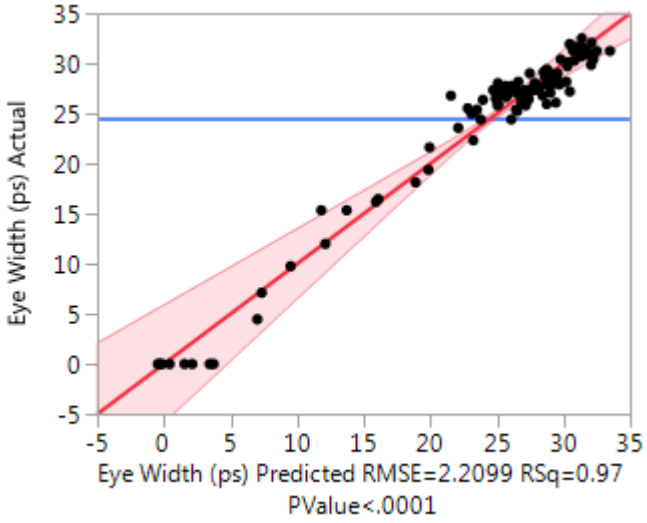


MODEL FITTING

- Model fitting is the process of finding the equation (or surface) which best matches the data points
- Verify quality of fitting



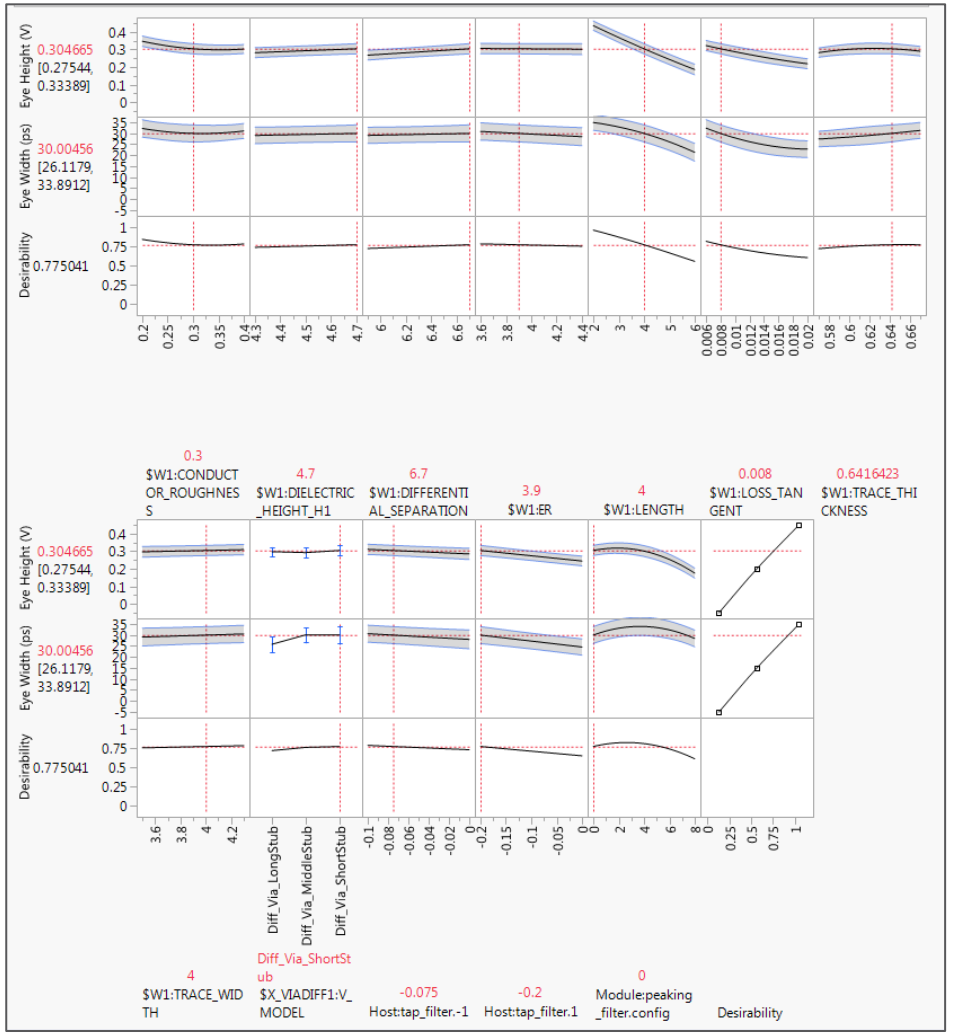
Summary of Fit	
RSquare	0.991304
RSquare Adj	0.981756
Root Mean Square Error	0.016616
Mean of Response	0.204904
Observations (or Sum Wgts)	108



Summary of Fit	
RSquare	0.967963
RSquare Adj	0.932785
Root Mean Square Error	2.209945
Mean of Response	24.539
Observations (or Sum Wgts)	108

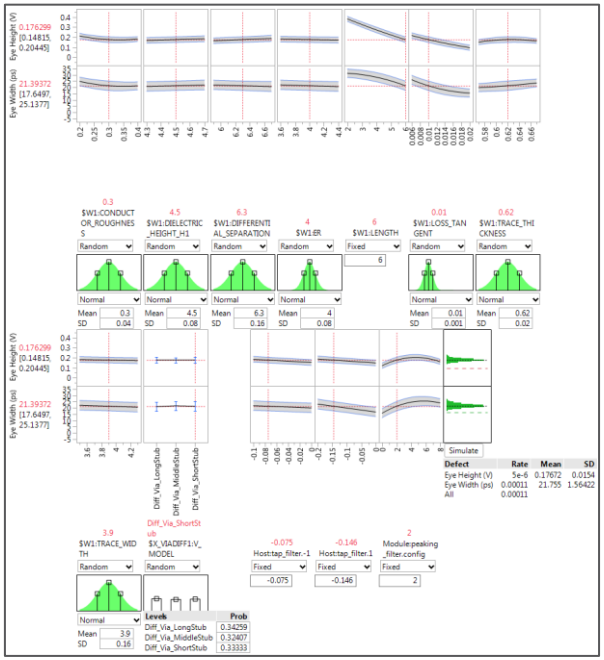
EXPLORE: PREDICTION PROFILER

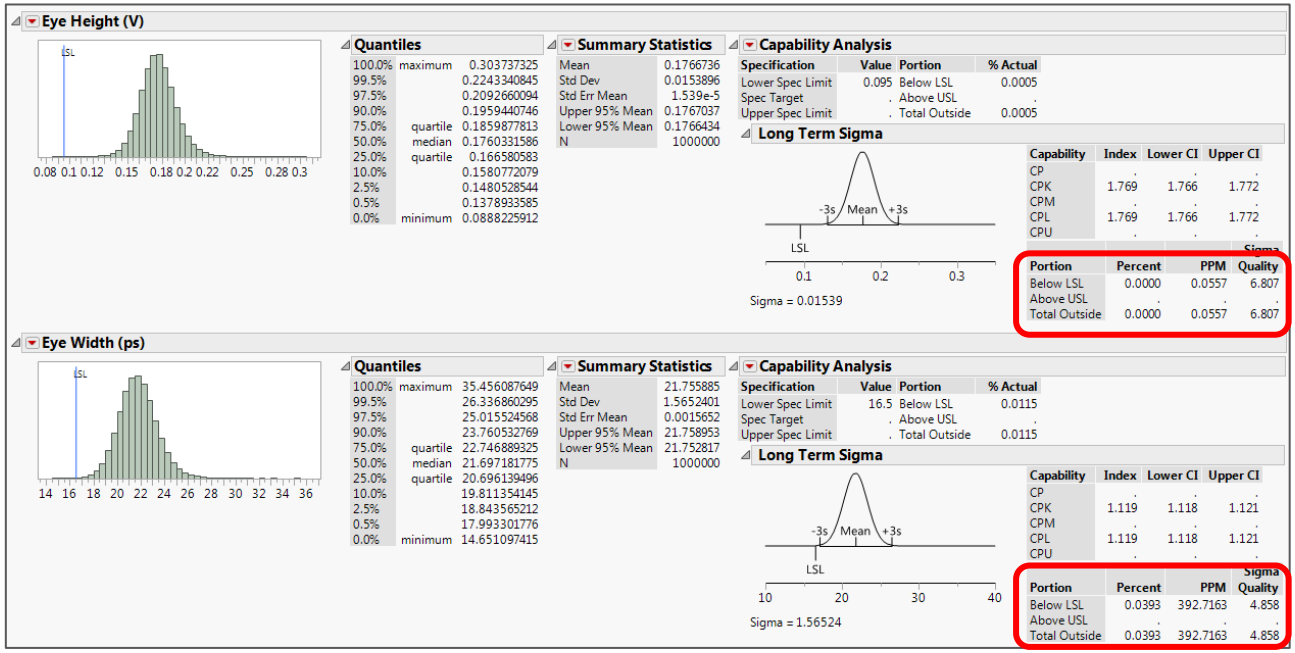
- Confidence interval
  - Quality of model fitting
- Slope
  - Influence
  - Importance
  - Sensitivity
- Vertical red line
  - “What if ” analysis
  - Interactions
- Desirability function/Optimization
  - Best case of design factors
  - Worst case of manufacturing factors
  - Robustness to minimize variation impact



EXPLORE: DPM ANALYSIS

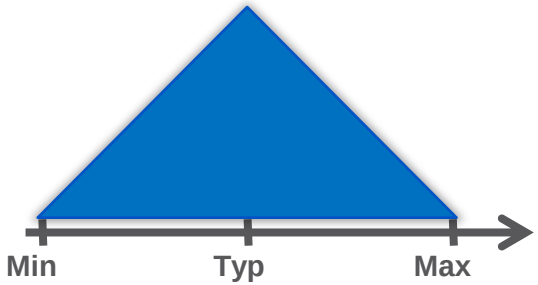
- Use the Equation Simulator to evaluate the response equation at millions of conditions.
- Assign a sampling distribution to each factor, i.e. trace length, manufacturing variation etc.
- Millions of system configurations can be evaluated in seconds to obtain realistic predicted yield plots.





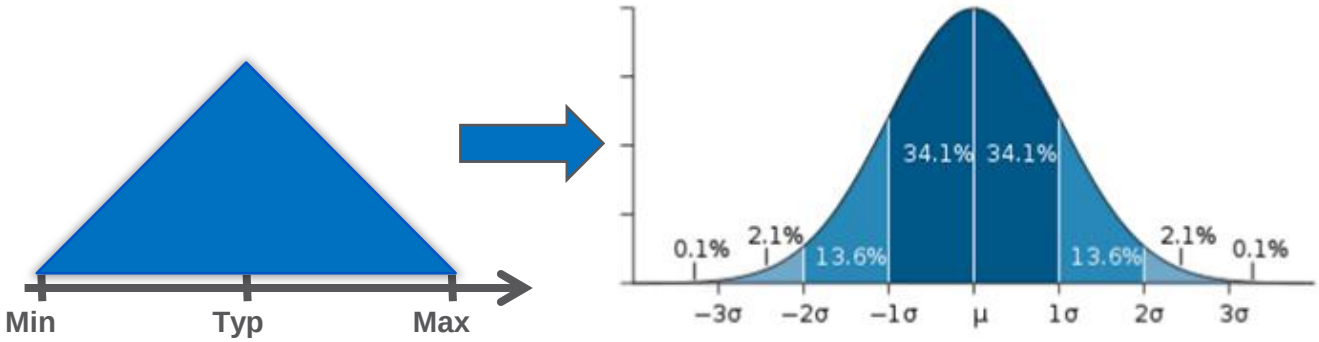
QUESTION FOR IBIS-AMI

- IBIS-AMI currently and traditionally uses a *Typ, Min, Max* parameter definition.
- This is based on a *Best/Worst* case scenario analysis. E.g. 100% confidence.
- Best/Worst case analysis has served us well during the years and still does in some cases, however more and more cases will not reach design closure using Best/Worst case analysis.
- When it does not reach design closure how will we know how many of our produced units will fail ???



SUGGESTION FOR IBIS-AMI

- If we add an option to IBIS-AMI to support distribution data for parameters as an average/mean and a variation/sigma.
- If we feel we can not assume a standard distribution we could even add support for other distributions.
- These parameters could be used in DOE analysis scenarios and could help us predict confidence intervals for our products as well as DPM (Defect Per million) predictions.



CONCLUSION

- Our design work is moving beyond *Best Case, Worst Case* analysis.
- We need to start working on an infrastructure both in modeling and tool support for statistical analysis.
- We need to ensure that we can get the correct information from IC and PCB vendors on parameter distributions.
- SI/PI statistical analysis is the next step to ensure our product quality.

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