

Modeling of MMIC Passive Structures for mm-wave Application



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Agenda

- Objectives
- Design of RMM (Raytheon Meta-Models)
 - DOE
 - Design Expert (Statistical Software)
- Integration of RMM
 - ADS
- Results RMM
- Model Composer
 - Results Composer
 - Step
 - Tee
- Conclusions

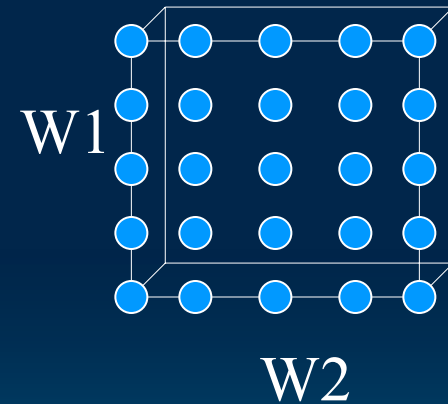
Objectives

- Parameterization of MMIC Passives Structures
 - Step
 - Tee
- Integration of Raytheon meta-models (RMM) into HP-ADS
- Design RMM based on Momentum responses
 - Raytheon Specifications:
 - 100 μm GaAs substrate
 - 0.2 μm thin film of Si_3N_4
 - Frequency range of (0.25-50 GHz)

Design of RMM

➤ DOE

- RMM of Step and Tee generated by
 - Full Factorial Designs
- Step (two design variables)
 - W1 (5 μ m to 500 μ m)
 - W2 (5 μ m to 100 μ m)
 - 25 runs
- Tee (three design variables)
 - W1 (5 μ m to 200 μ m)
 - W2 (5 μ m to 200 μ m)
 - W3 (5 μ m to 200 μ m)
 - 27 runs plus central points



Design Expert

➤ Powerful Statistical (Software)

- Creates and analyze models up to cubic order
- model validation by statistical tests
 - ANOVA
 - Analysis of Residuals
 - Box and Cox

The screenshot displays the Design-Expert 6.0.5 software interface. The title bar reads "C:\Program Files\DX6\DATA\mtee\phase\225phase.dx6 - Design-Expert 6.0.5". The menu bar includes "File", "Edit", "View", "Display Options", "Design Tools", and "Help". The toolbar contains icons for file operations and help. The left pane shows a tree view for "Notes for 225phase.dx6" with folders for "Design", "Status", "Evaluation", "Analysis", and "Optimization". The "Analysis" folder is expanded, showing sub-items like "s11a(Analyzed)", "s12a(Analyzed)", "s13a(Analyzed)", "s21a(Analyzed)", "s22a(Analyzed)", "s23a(Analyzed)", "s31a(Analyzed)", "s32a(Analyzed)", and "s33a(Analyzed)".

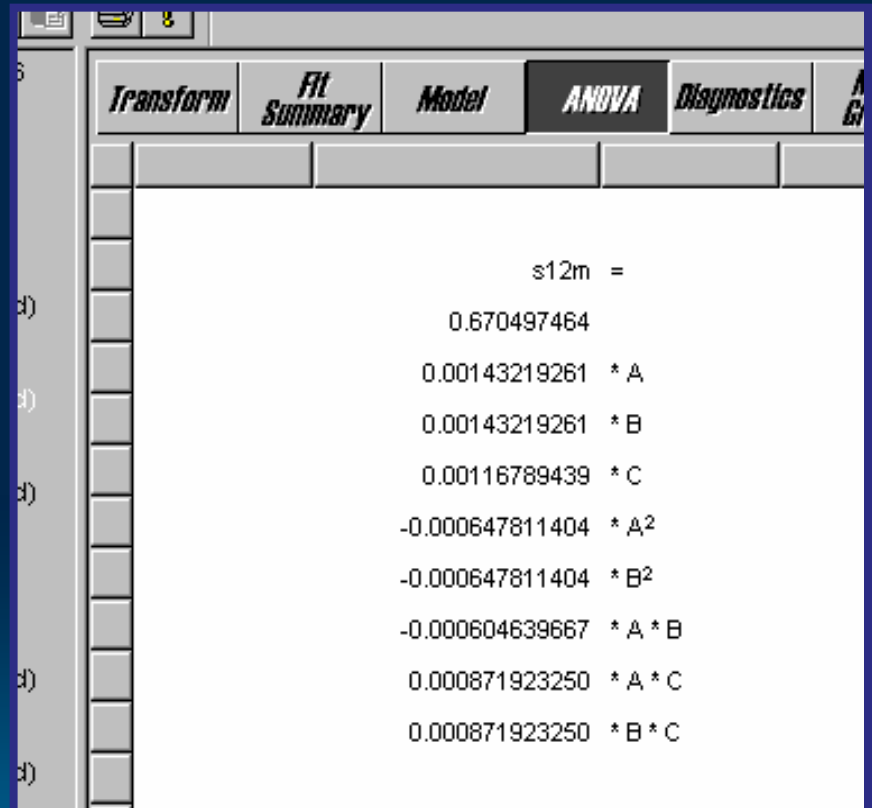
The main window has several tabs: "Transform", "Fit Summary", "Model", "ANOVA", "Diagnostics", and "Model Graphs". The "Transform" tab is active, showing a list of transformation options: "None", "Square root", "Natural log", "Base 10 log", "Inverse sqrt", "Inverse", "Power", "Logit", and "ArcSin sqrt". A blue arrow points from the "ANOVA" bullet point in the slide to the "Transform" tab. Another blue arrow points from the "Analysis of Residuals" bullet point to the "Diagnostics" tab.

Below the transformation list, a diagnostic plot is shown. The plot title is "None (lambda = 1.0)" and the equation is $y' = y$. The plot shows "Student Residual" on the y-axis and "Predicted Value" on the x-axis. The plot area is mostly empty, with a horizontal line at zero. Below the plot, it says "Use with a typical response." A blue arrow points from the "Analysis of Residuals" bullet point to the plot area.

At the bottom of the window, a note reads: "Response ranges from -3.14155422 to 3.14100912. A ratio greater than 10 usually indicates a transformation is required. For ratios less than 3 the power transforms have little effect."

Parameterization

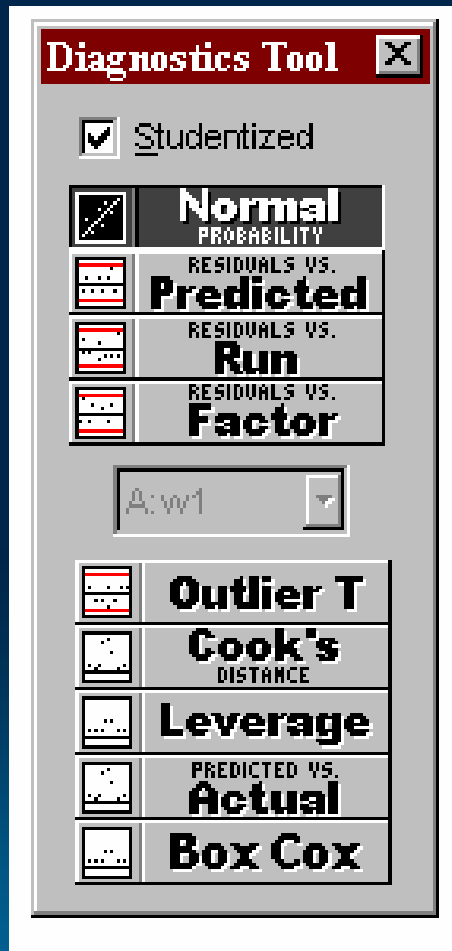
- Method for model creation
 - ANOVA (Analysis of Variance)
- Model created for:
 - S-parameters
 - Tee (18 models)
 - Step (8 models)
 - 26 frequency points



The screenshot shows the ANOVA table for a model. The response variable is labeled 's12m'. The model includes a constant term and main effects for factors A, B, and C. The ANOVA table is as follows:

Source	DF	SS	MS	F	P
Constant	1	0.670497464	0.670497464		
A	1	0.00143219261	0.00143219261		
B	1	0.00143219261	0.00143219261		
C	1	0.00116789439	0.00116789439		
A ²	1	-0.000647811404	-0.000647811404		
B ²	1	-0.000647811404	-0.000647811404		
A * B	1	-0.000604639667	-0.000604639667		
A * C	1	0.000871923250	0.000871923250		
B * C	1	0.000871923250	0.000871923250		

Model Validation

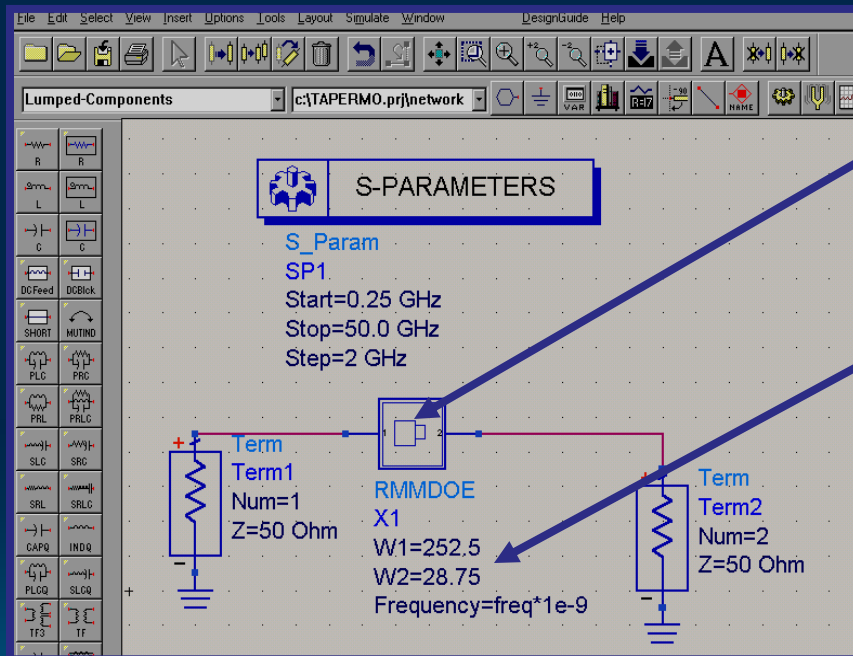


➤ Check Normality assumptions

➤ Stabilize variance

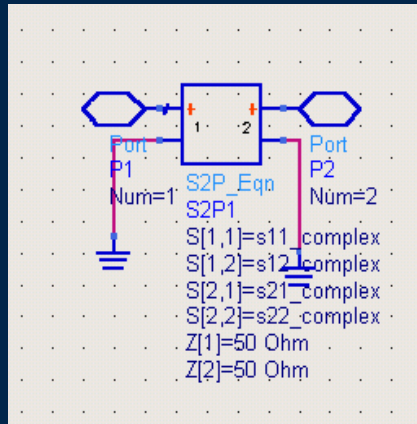
- Robust Modeling

INTEGRATION ADS STEP

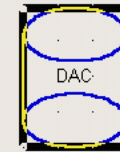


- RMM step component
- Design Variables
 - W1
 - W2
- Models valid from 0.25-50 GHz
- Valid for 100um GaAs

What is in the box?



Step



.DataAccessComponent
s11mag
File="s11mag.mdf"
Type=Generalized Multi-dimensional Data
InterpMode=Cubic
InterpDom=Polar
iVar1="Frequency"
iVal1=Frequency

Var
Eqn

VAR

s11mag_COEF

```
s11m_b0=file{s11mag, "b0"}  
s11m_b1=file{s11mag, "b1"}  
s11m_b2=file{s11mag, "b2"}  
s11m_b11=file{s11mag, "b11"}  
s11m_b22=file{s11mag, "b22"}  
s11m_b12=file{s11mag, "b12"}  
s11m_b13=file{s11mag, "b13"}  
s11m_b23=file{s11mag, "b23"}  
s11m_b12b2=file{s11mag, "b12b2"}  
s11m_b1b22=file{s11mag, "b1b22"}
```

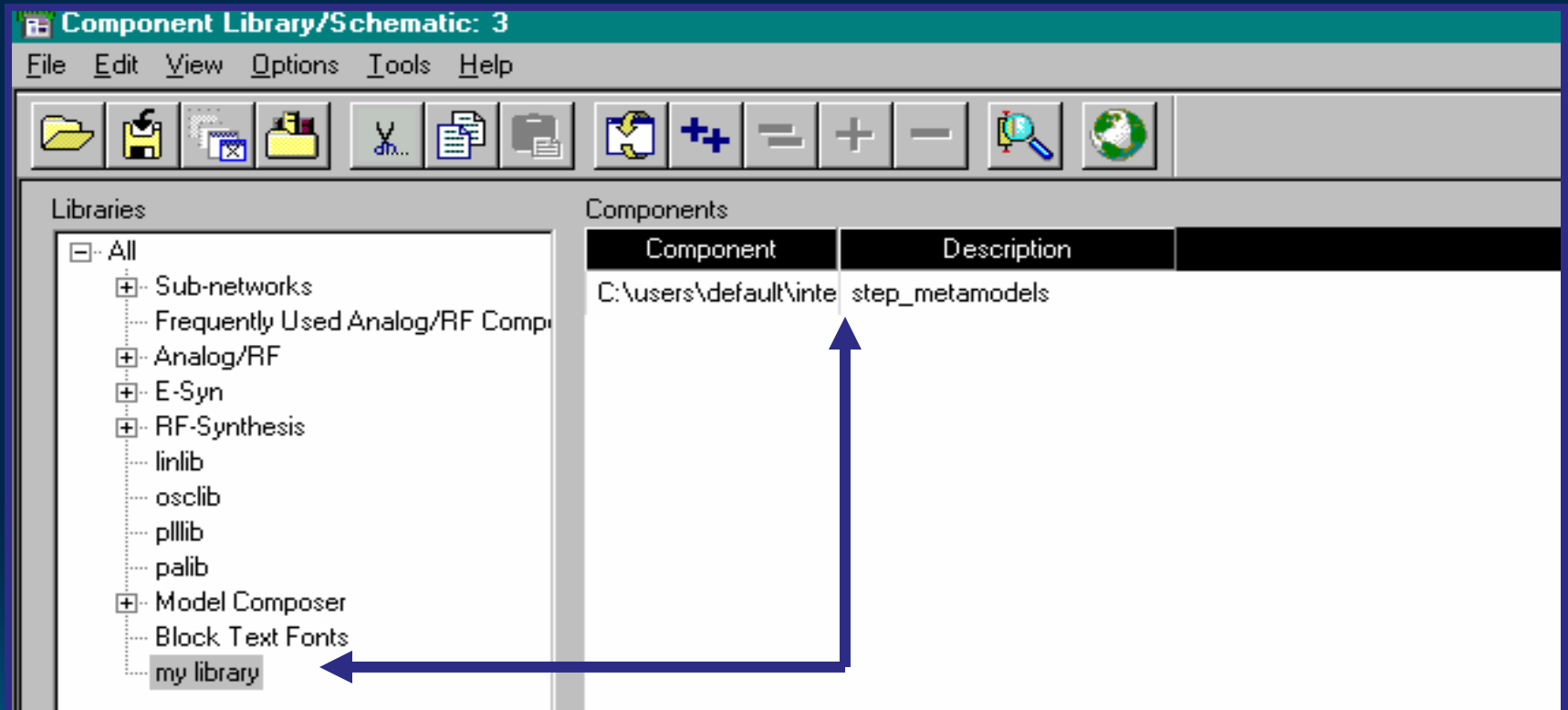
Var
Eqn

VAR

CALC_S11

```
s11m=s11m_b0+s11m_b1*W1+s11m_b2*W2+s11m_b11*  
s11m_UNT=if ( Frequency<=0.25) then (s11m^(1/1.38)) else  
s11a=s11a_b0+s11a_b1*W1+s11a_b2*W2+s11a_b11*W1  
s11_complex=s11m_UNT*(cos(s11a)+j*sin(s11a))
```

Raytheon Meta Models (RMM)



Custom Library of RMM into ADS

RMM versus MOM -Step

Run

$W1=252.5 \text{ } \mu\text{m}$

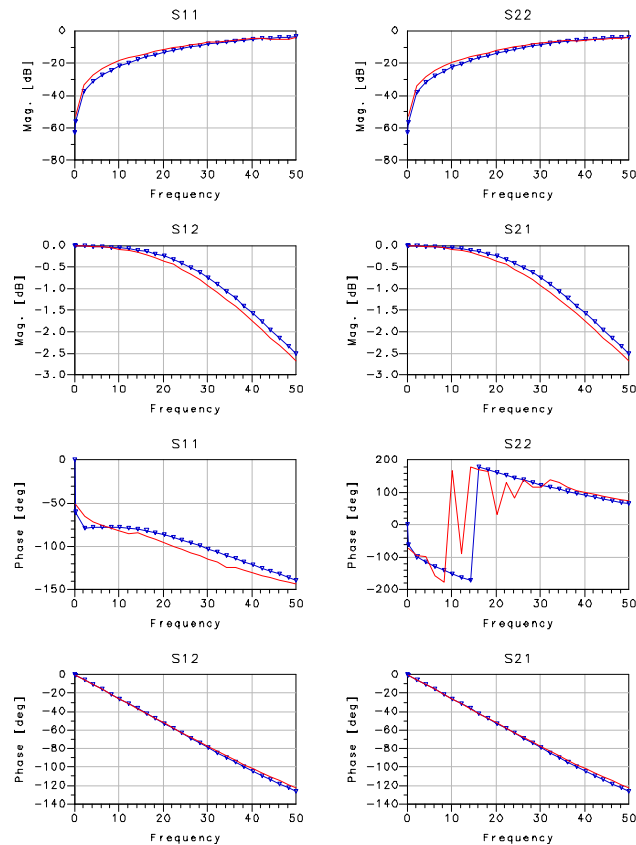
$W2= 28.75 \text{ } \mu\text{m}$

$L= 300 \text{ } \mu\text{m}$

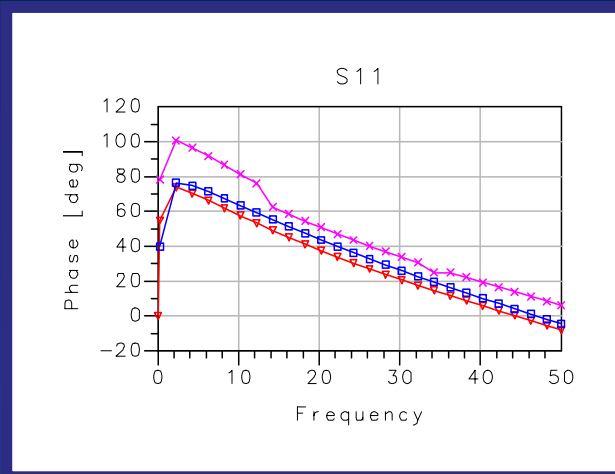
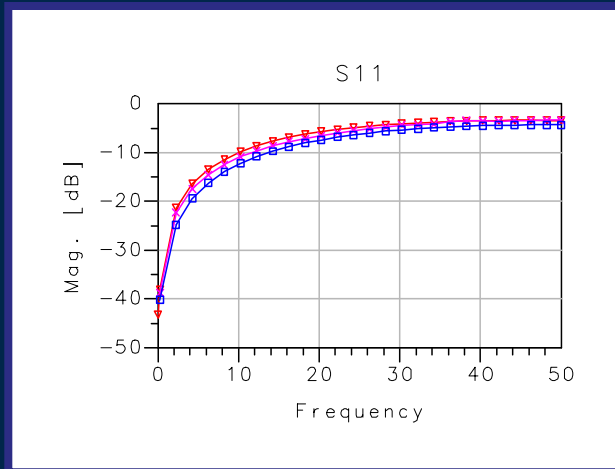
Legend

RMM Step= **red**

Mom= **blue**



STEP-RMM



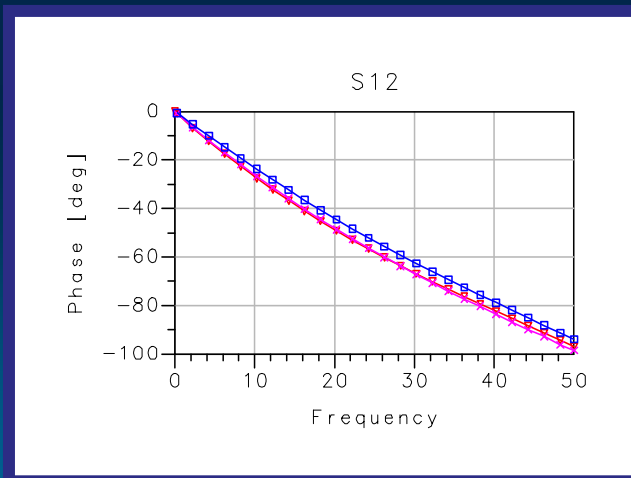
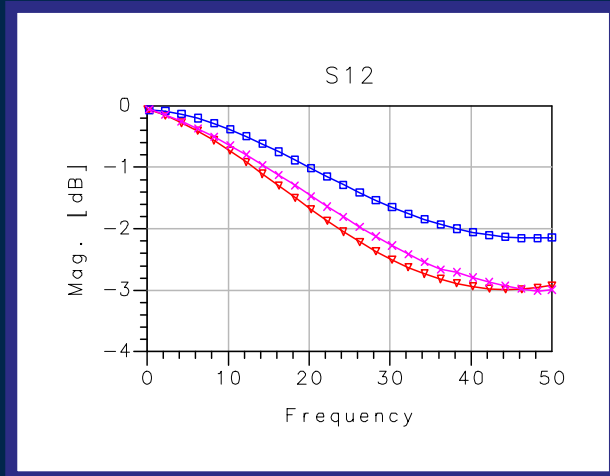
➤ Run:

- $W1 = 5 \text{ } \mu\text{m}$
- $W2 = 5 \text{ } \mu\text{m}$

➤ Legend:

- Blue \rightarrow Ads
- Pink \rightarrow RMM
- Red \rightarrow Momentum

RMMSTEP-CONT



➤ Run:

- $W1 = 5 \text{ } \mu\text{m}$
- $W2 = 5 \text{ } \mu\text{m}$

➤ Legend:

- Blue → Ads
- Pink → RMM
- Red → Momentum

What is Model Composer?

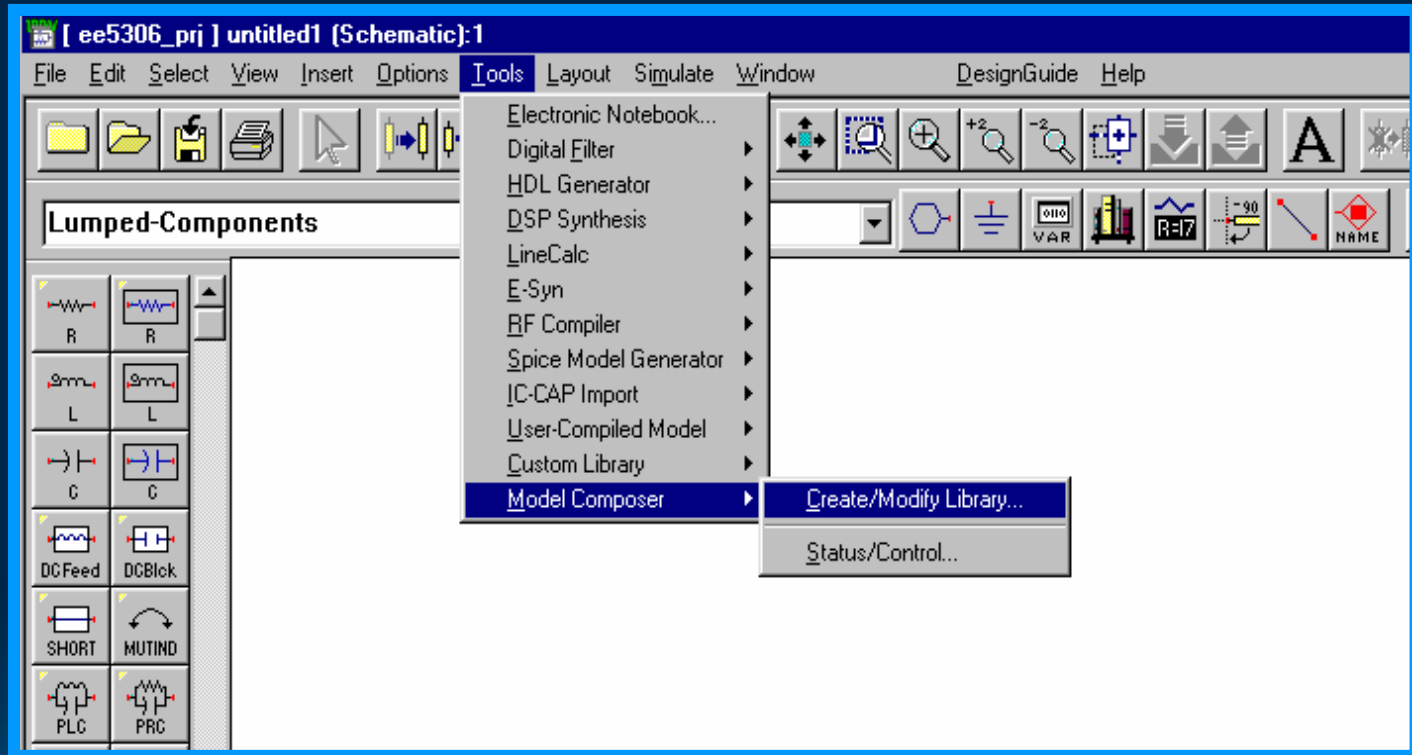
➤ Model Composer

Modeling tool for custom library generation

- Based on publication:
 - Adaptive CAD- Model Building Algorithm for General Planar Microwave Structures
- Models are generated based on Momentum Simulations
- Available in ADS latest version
- Libraries can be easily downloaded into others ADS versions



Composer ADS 2001



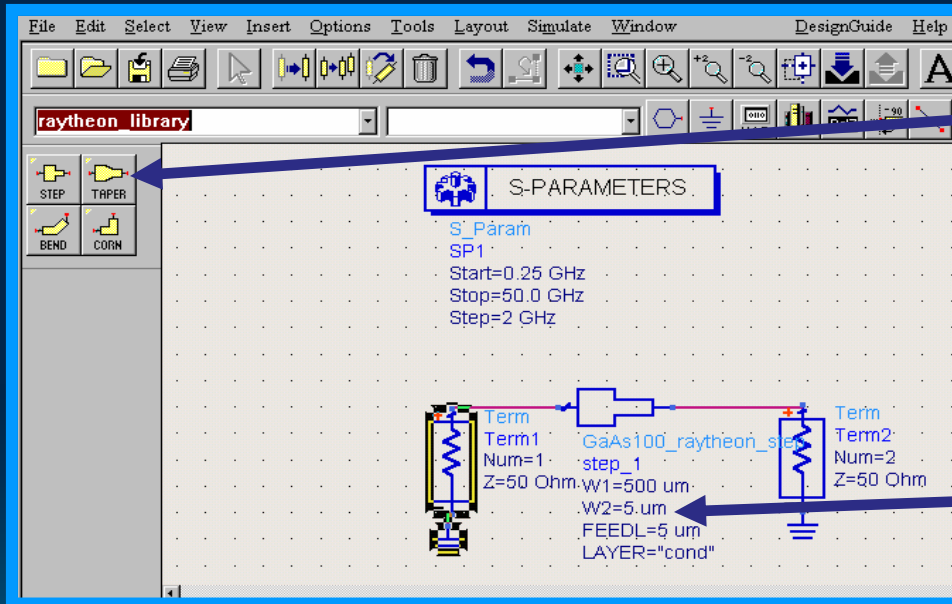
How it Works?

➤ *Parameterization in Composer*

- *Define*
 - Library
 - Substrate
 - Frequency Range
 - Passive Component
 - Design Variables



Model Composer



➤ Model Composer generates a library component palette

➤ Design Variables

- W1
- W2

Composer

- Custom library design parameters can be define as discrete list, continuous and global
- Substrates definitions can be download as a file
- Input data for parameterization comes from momentum simulation responses
- A preset feed line is needed in order to generate the layout in momentum for the component



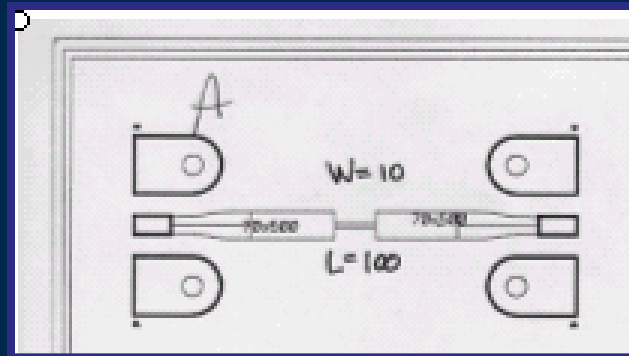
Composer Results

MMIC Measurements against composer



MMIC Pass A

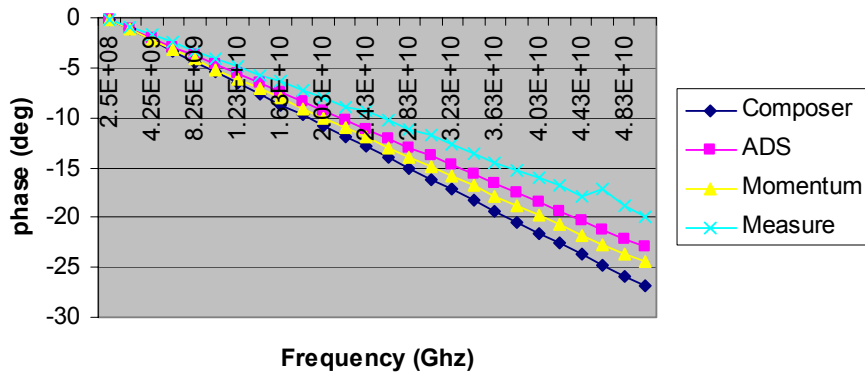
Mask 399-09-A



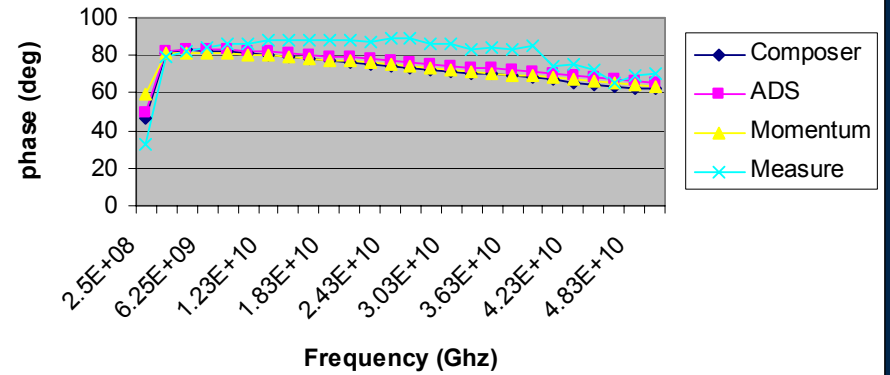
The screenshot shows a circuit simulation software interface. The title bar reads "[Raytheon_RMM_prj] invento_composer_pasA (Schematic):3". The menu bar includes File, Edit, Select, View, Insert, Options, Tools, Layout, Simulate, Window, DesignGuide, and Help. The toolbar contains various icons for file operations, navigation, and simulation. The "Lumped-Components" panel is active, showing a list of components: R, L, C, DCFeed, DCBlok, SHORT, MUTIND, PLC, PFC, PRL, PRLC, SLG, and SRC. The main workspace displays a schematic diagram of a transmission line structure. The schematic includes a series of components: Term1 (Z=50 Ohm), MSub1 (Subst="MSub1", W=70 um, L=500 um), TL1 (W=70 um, FEEDL=5 um, LAYER="cond"), GaAs100_raytheon_step1 (W1=70 um, W2=10 um, FEEDL=5 um, LAYER="cond"), TL3 (W=10 um, L=100 um, Subst="MSub1"), GaAs100_raytheon_step2 (W1=10 um, W2=70 um, FEEDL=5 um, LAYER="cond"), TL2 (W=70 um, L=500 um, Subst="MSub1"), and Term2 (Z=50 Ohm). The component properties for MSub1 and S-PARAMETERS are displayed in a pop-up window. The status bar at the bottom shows "0 items", "wire", "3,808, 3,028", "3,151, 3,336", "in", "A/R/F", and "SimSche".

Pass A

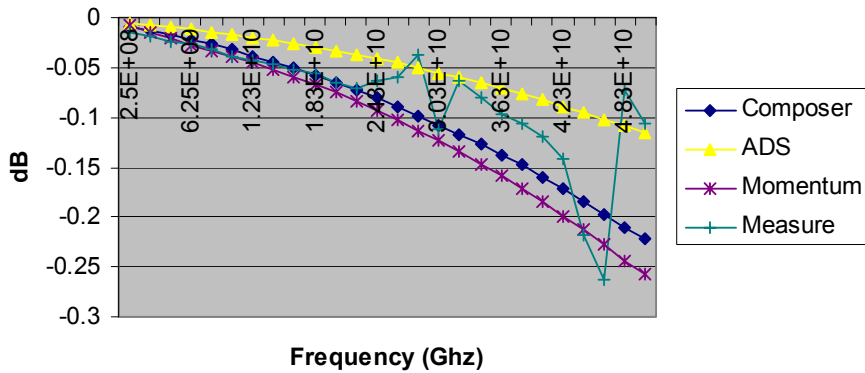
S21



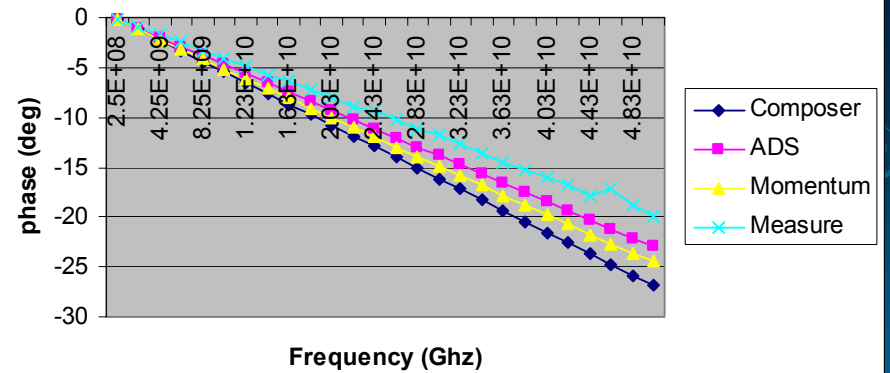
S11



S21

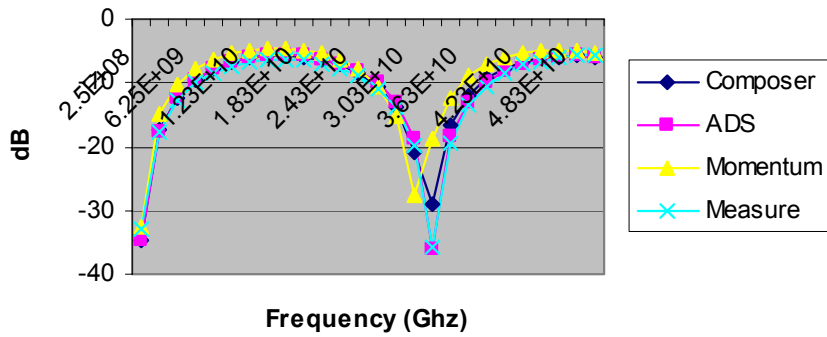


S21

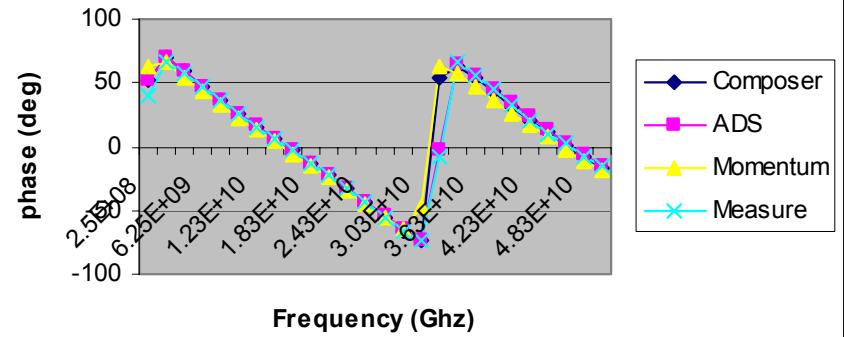


Pass G

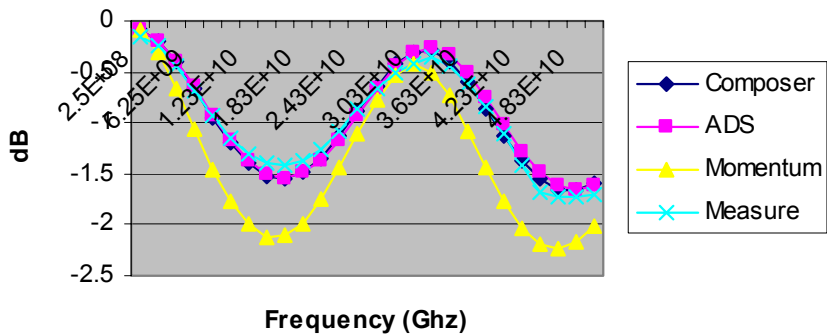
S11



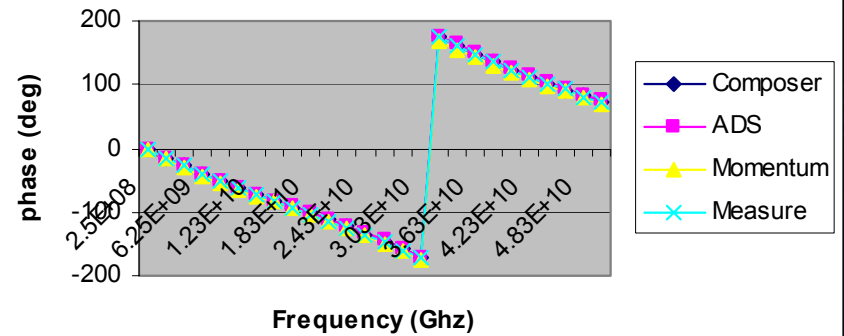
S11



S21



S21



Ads Constraint Step

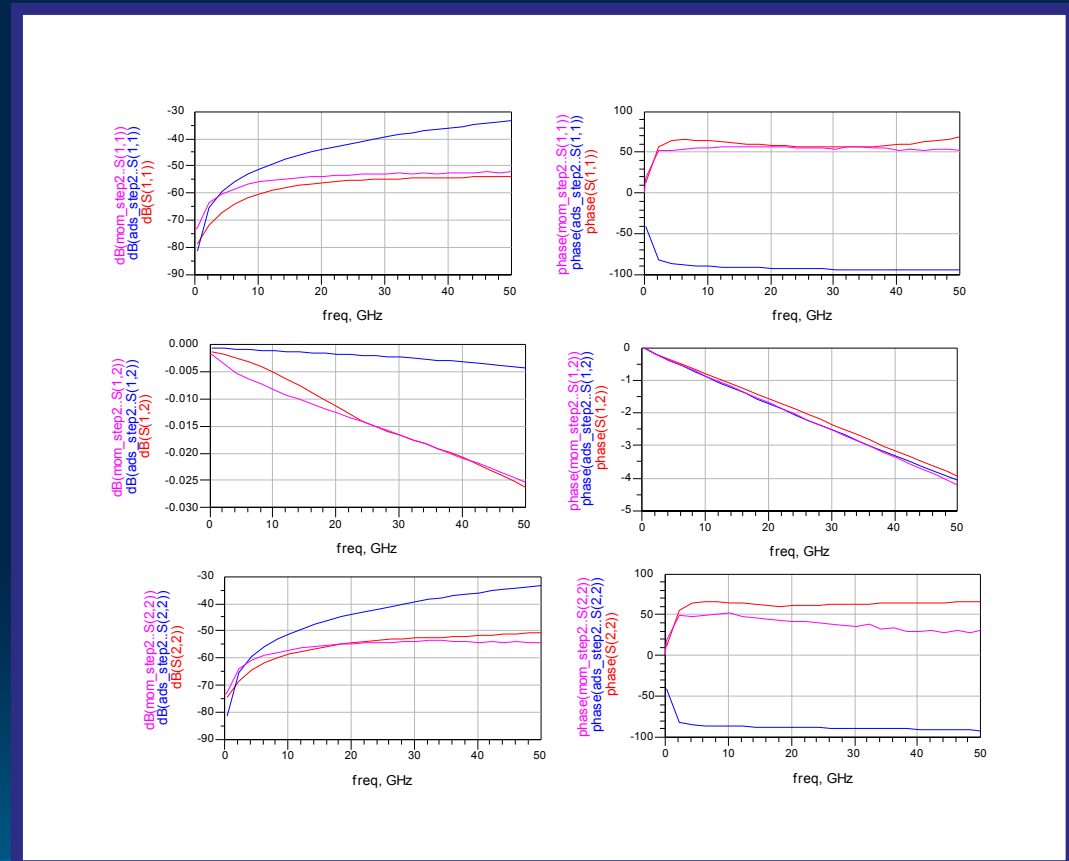
- Constraint
 - $0.1 < W2/W1 < 10$
 - Run
 - $W1 = 5\mu\text{m}$
 - $W2 = 100$
- where $w2/w1 = 20$

Legend

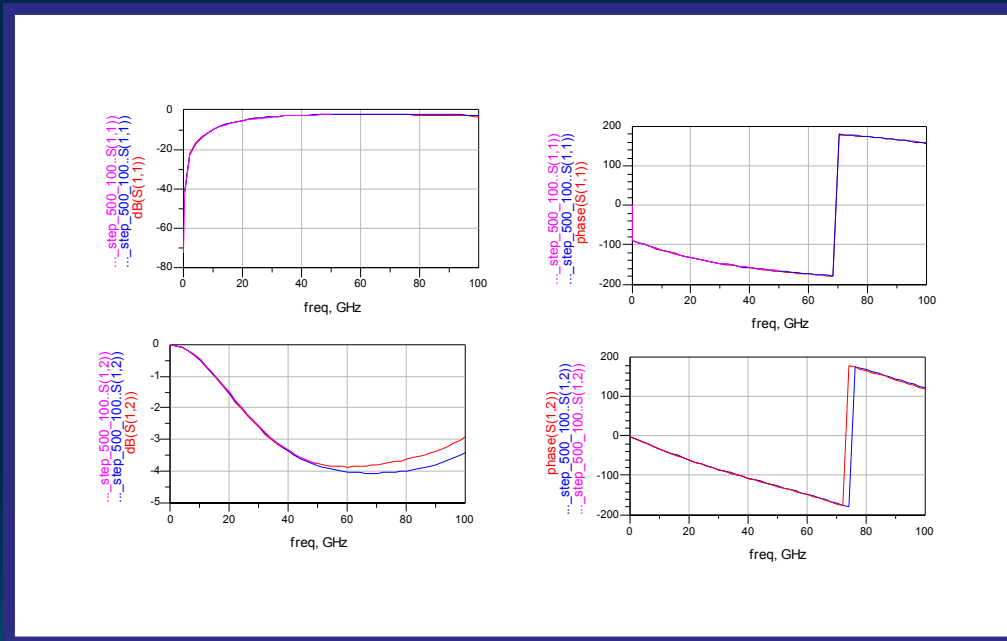
Mom = pink

Composer = red

Ads = blue



Valid ADS Run



➤ $W2/W1=0.25$

➤ Run

- $W1=500$ um
- $W2=100$ um
- $L=300$ um

➤ Freq Range

- 0.25 to 100 GHz

Legend

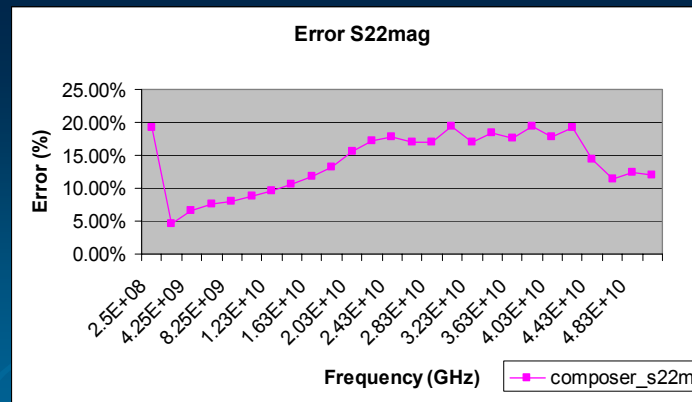
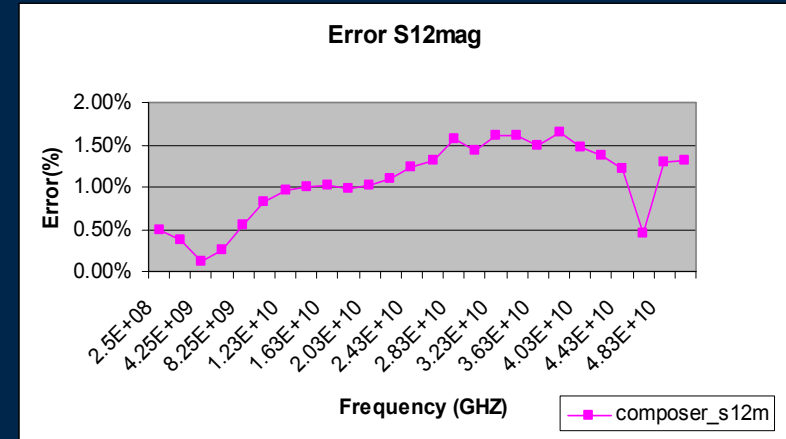
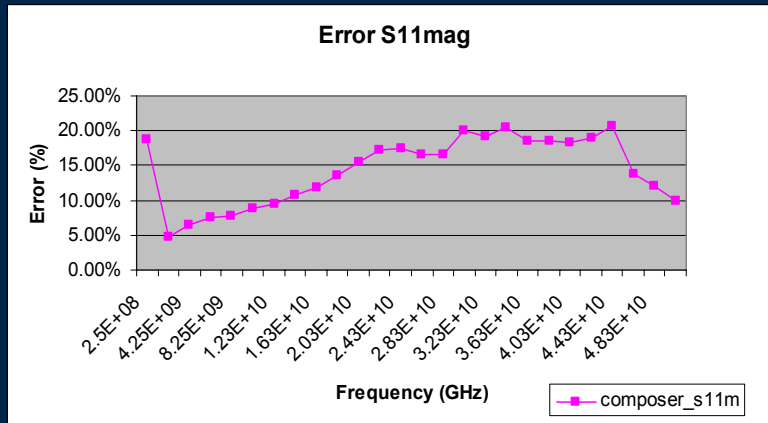
Mom = pink

Composer = red

Ads = blue

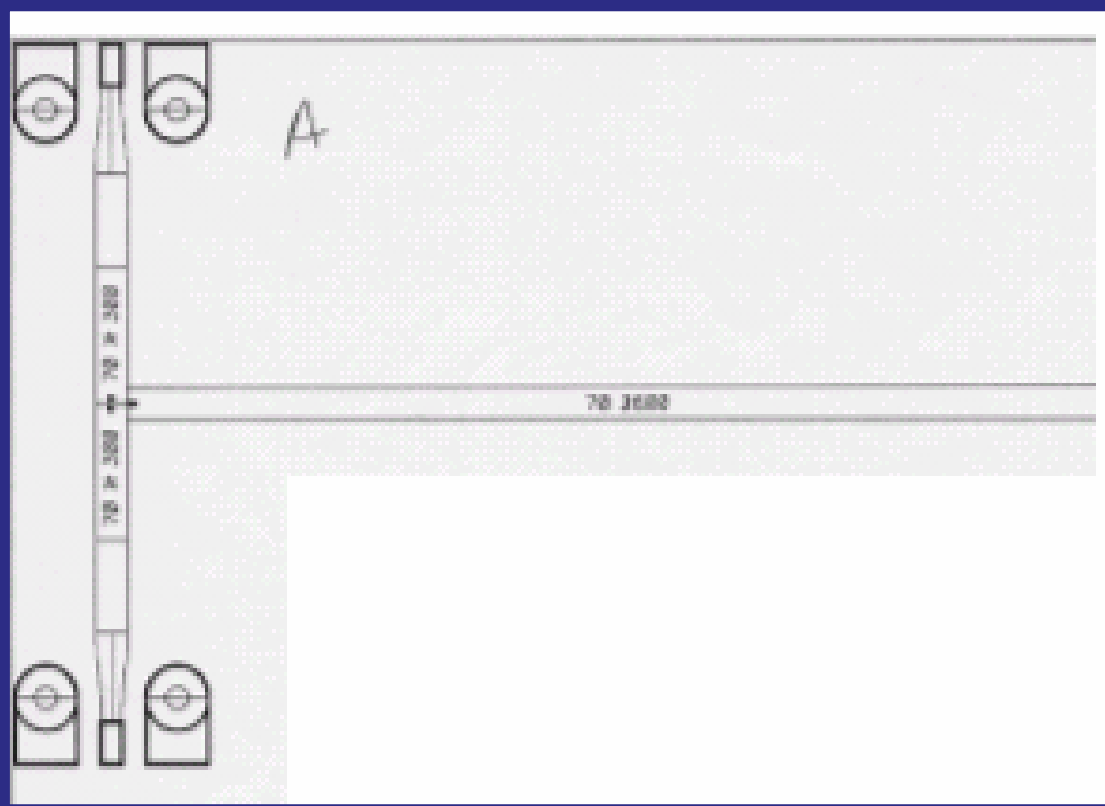
Step Errors

Measurements versus Composer



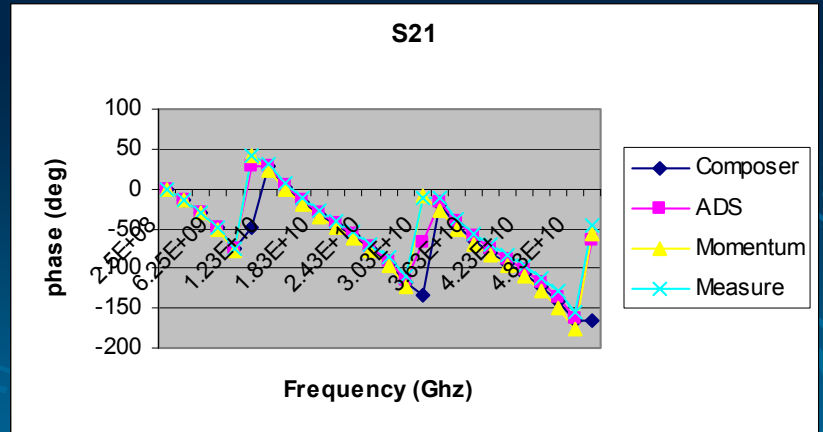
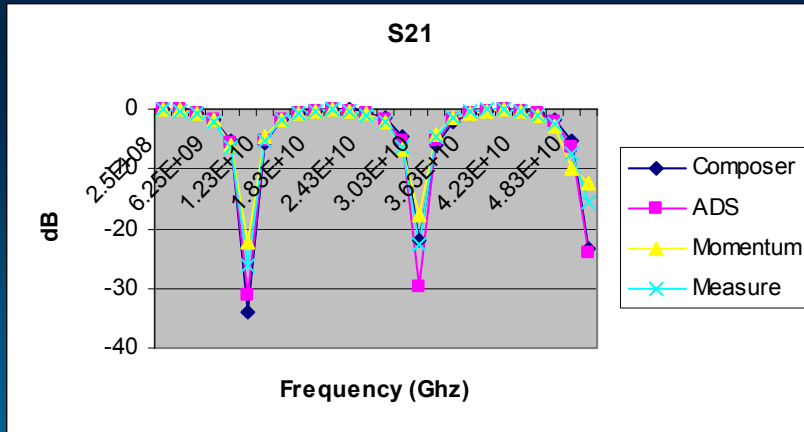
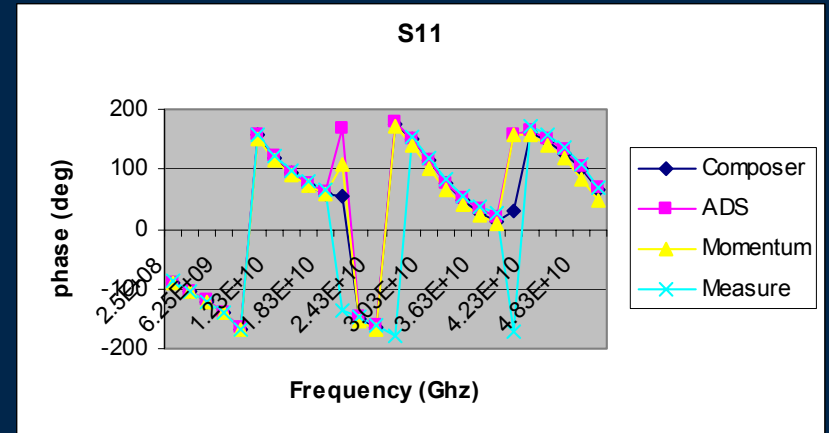
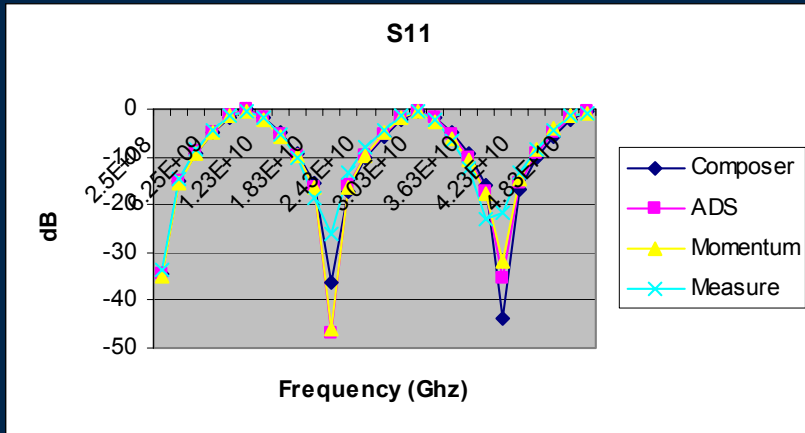
Pass A

Mask 399-10-A



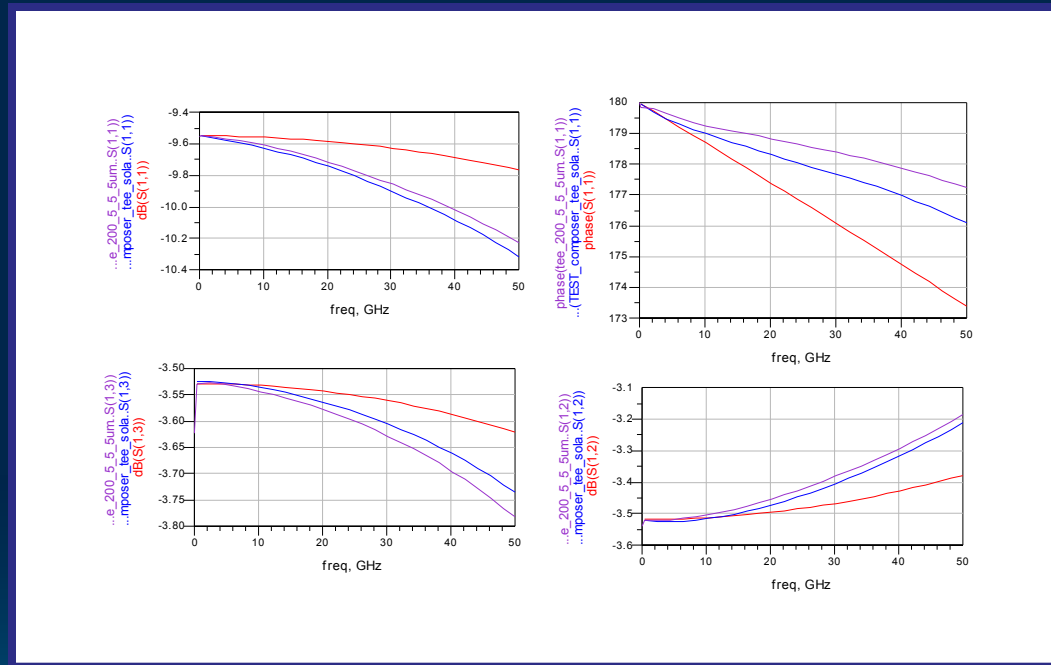
Run
W1=70 um
W2=70 um
W3=70 um

TEE-PASS A



ADS Constraint Tee

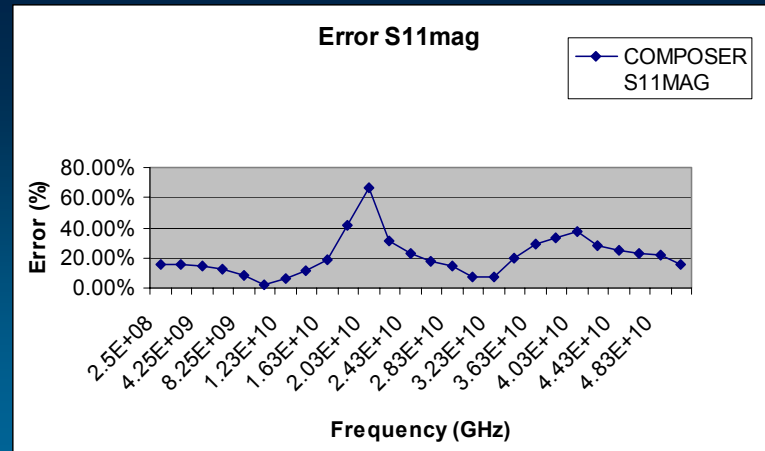
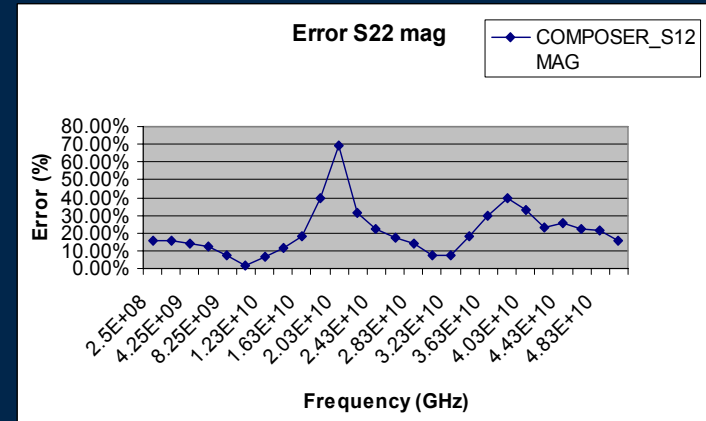
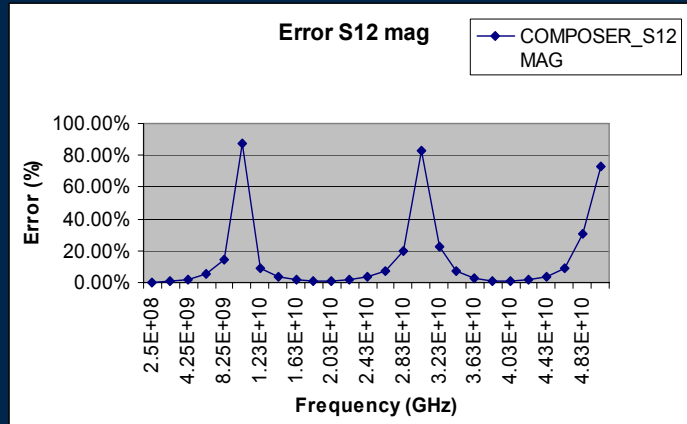
- Tee constraint
- W widest $5 \cdot W$ narrow
- Random Run
 - $W1 = 200 \text{ } \mu\text{m}$
 - $W2 = 5 \text{ } \mu\text{m}$
 - $W3 = 5 \text{ } \mu\text{m}$
 - $L = 5 \text{ } \mu\text{m}$



Legend
Mom = purple
Composer = blue
Ads = red

Errors Tee

Composer versus Measures



Conclusions

- Ads step and tee predict accurately when parameter dimension are within ads model constraint
- Composer duplicate accurately momentum response and measurements
- Composer is a alternative for modeling beyond 50 GHz

Conclusions

- RMM methodology duplicate accurately momentum response
- Libraries for step, taper, bend and corner are available until 100 GHz

