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 Si₃N₄
    - 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 (5µm to 500µm)
  - W2 (5 µm to 100µm)
    - 25 runs
- Tee (three design variables)
  - W1 (5 µm to 200µm)
  - W2 (5 µm to 200µm)
  - W3 (5 µm to 200µm)
    - 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
Parameterization

- Method for model creation
  - ANOVA (Analysis of Variance)

- Model created for:
  - S-parameters
    - Tee (18 models)
    - Step (8 models)
  - 26 frequency points
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?

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
CALC_S11
s11m=s11m_b0+s11m_b1*W1+s11m_b2*W2+s11m_b11*W1*W2+s11m_b22*W1*W2+s11m_b111*W1^2+s11m_b12b2*W1*W2+s11m_b1b22*W1^2
s11m_UNT=if ( Frequency<=0.25) then (s11m*(1/1.38)) else
s11a=s11a_b0+s11a_b1*W1+s11a_b2*W2+s11a_b11*W1^2+s11a_b22*W1^2
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 um
W2= 28.75 um
L= 300 um

Legend
RMM Step= red
Mom= blue
STEP-RMM

- **Run:**
  - $W_1 = 5 \text{ um}$
  - $W_2 = 5 \text{ um}$

- **Legend:**
  - Blue $\rightarrow$ Ads
  - Pink $\rightarrow$ RMM
  - Red $\rightarrow$ Momentum
- **Run:**
  - $W1 = 5 \text{ um}$
  - $W2 = 5 \text{ um}$

- **Legend:**
  - **Blue** $\rightarrow$ Ads
  - **Pink** $\rightarrow$ RMM
  - **Red** $\rightarrow$ 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
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 defined as discrete list, continuous and global.
- Substrates definitions can be downloaded 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
Pass A

S21

Frequency (Ghz)

S11

Frequency (Ghz)

S21

Frequency (Ghz)

S21

Frequency (Ghz)
Pass G

**S11**
- **dB** vs. **Frequency (Ghz)**
- **Phase (deg)** vs. **Frequency (Ghz)**

**S21**
- **dB** vs. **Frequency (Ghz)**
- **Phase (deg)** vs. **Frequency (Ghz)**

- **Composer**
- **ADS**
- **Momentum**
- **Measure**
Ads Constraint Step

- **Constraint**
  - $0.1 < \frac{W_2}{W_1} < 10$

- **Run**
  - $W_1 = 5 \text{um}$
  - $W_2 = 100$

where $\frac{w_2}{w_1} = 20$

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

Error S11mag

Error S12mag

Error S22mag
Pass A
Mask 399-10-A

Run
W1=70 um
W2=70 um
W3=70 um
TEE-PASS A

**S11**

- Frequency (Ghz)
- dB
- Composer
- ADS
- Momentum
- Measure

**S21**

- Frequency (Ghz)
- dB
- Composer
- ADS
- Momentum
- Measure

**S11**

- Frequency (Ghz)
- phase (deg)
- Composer
- ADS
- Momentum
- Measure

**S21**

- Frequency (Ghz)
- phase (deg)
- Composer
- ADS
- Momentum
- Measure
ADS Constraint Tee

- **Tee constraint**
  - W widest < 5 * W narrow
- **Random Run**
  - W1 = 200 um
  - W2 = 5 um
  - W3 = 5 um
  - L = 5 um

**Legend**
- Mom = purple
- Composer = blue
- Ads = red
Errors Tee
Composer versus Measures

[Graphs showing error percentages for S11, S12, and S22 magnitudes across different frequencies.]
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