# Advanced EDA Tools for Multi-Radio High-Frequency Accurate IC Design

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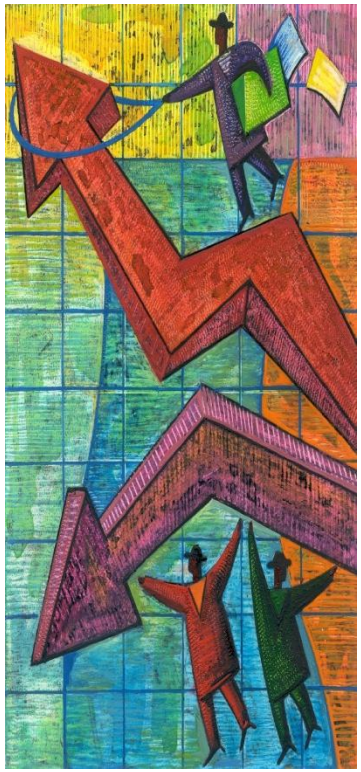
# CONTENTS

# INTRODUCTION

## TRENDS

RF DESIGN CHALLENGES

- Multiband
  - Number of different radios / wireless device is growing.
- Design Cycles
  - Time allowed for design is shrinking.
- Size
  - Amount of area for any given function is shrinking.
- Clock Speed
  - IC operating speed is increasing.
- Application Frequency
  - New applications are increasing operating frequency.
- Product Lifecycles
  - Lifetime of any given product is shrinking.
- Internet of Things
  - Number, standards and types of devices growing rapidly.



# INTRODUCTION

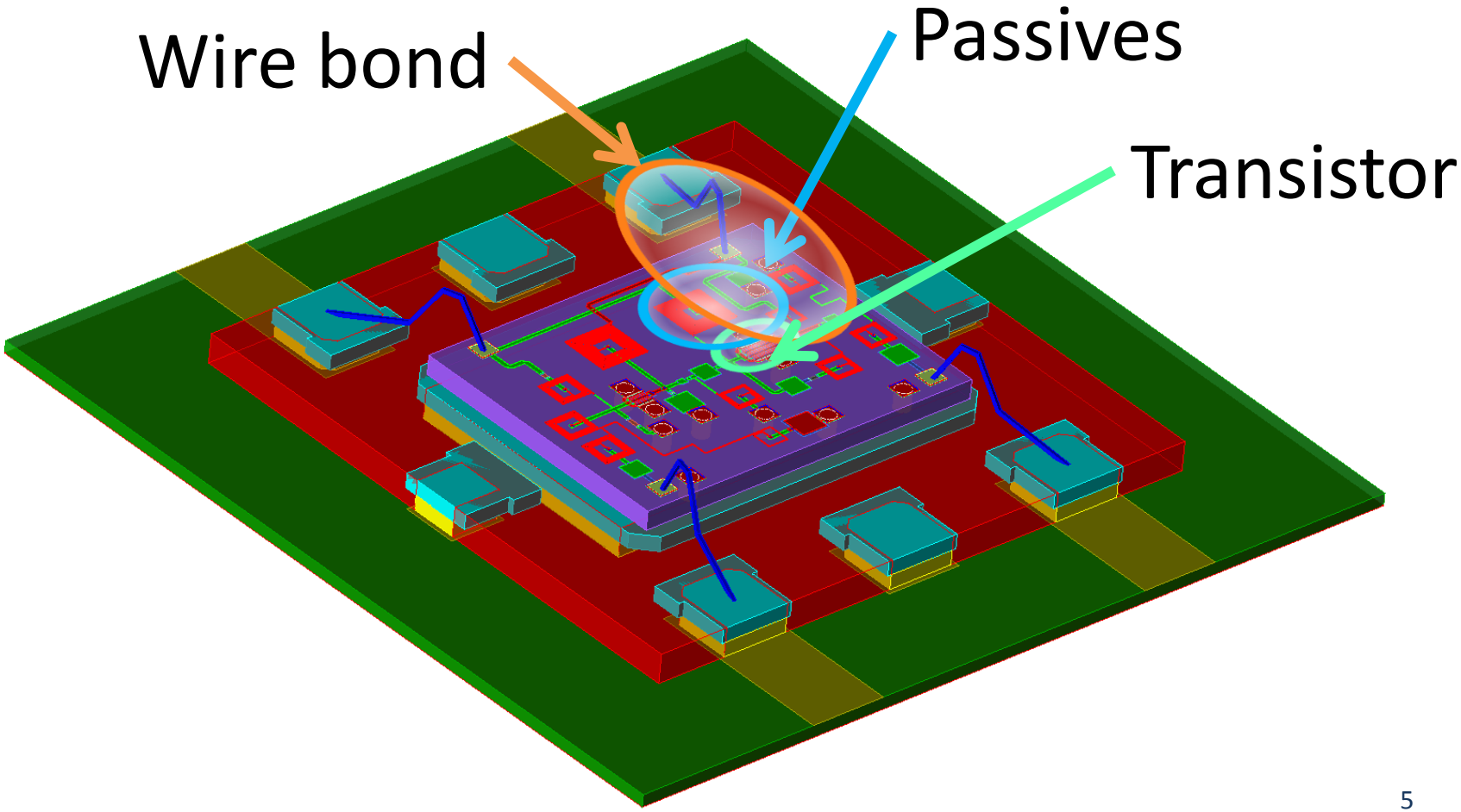
## RF DESIGN CHALLENGES

- Iterations
  - Generally the longest time, not to mention cost, for a single iteration is the prototype fabrication time.
  - Reduced number of design iterations is necessary to meet time-to-market expectations.
  - Improved simulation accuracy is required in order to reduce the number of iterations, yet the number of design passes to meet the specification has not changed substantially over the last 20 years.

- Tools
  - Electronic Design Automation (EDA) has roots in two basic approaches:
    - Circuit simulators
    - EM Field solvers
  - To overcome the limitations of both, EDA tools have incorporated the ability to paste in blocks of simulation results to permit "co-simulation" of circuit and EM results.
  - This approach is limited in its ability to accurately simulate circuit response and hence does not reduce the number of design cycles.

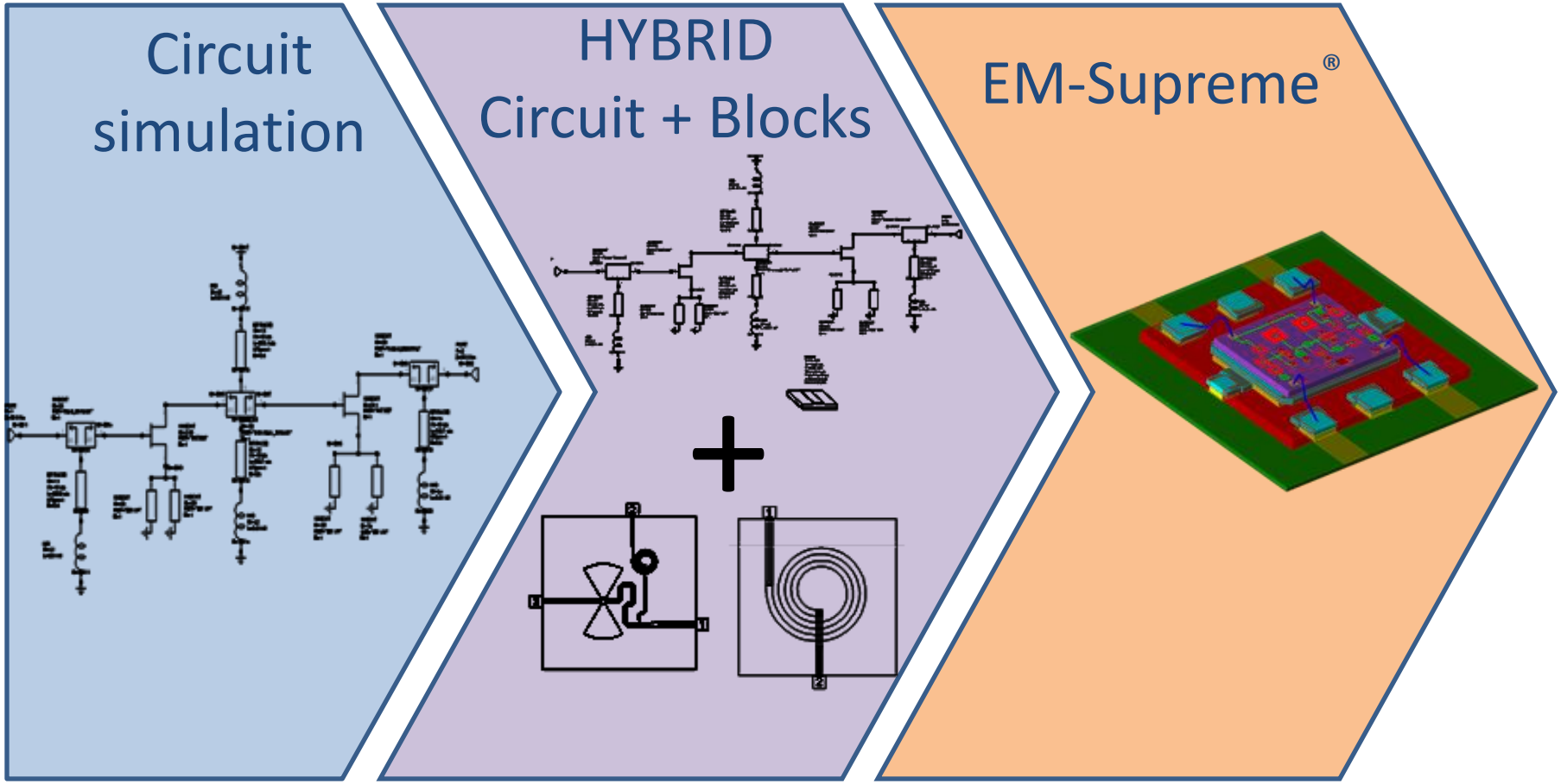
# INTRODUCTION

## RF DESIGN CHALLENGES



# EDA Evolution

## EVOLUTION / ACCURACY



# EM SIMULATOR COMPARISON

| Company | PedaSoft | Sonnet | CST | Ansys | Zeland | IMST |
|---|---|---|---|---|---|---|
| Product | EM-Core® | Sonnet | CST-Ems | HFSS | IE3D | Xccel |
| Geometry | 2.5 & 3D | 2.5D | 3D | 3D | 3D | 3D |
| Method | FDTD | MoM | FIM | FEM | MoM | FDTD |
| Time Domain | √ | X | √ | X | X | √ |
| Freq Domain | X | √ | √ | √ | √ | X |
| Accuracy | High | Medium | High | High | High | High |
| Memory | Medium | Medium | High | High | Medium | High |
| Speed | Medium | Fast | Medium | Medium | Medium | Fast |
| Shielded | √ | √ | √ | √ | √ | √ |
| Radiated | √ | X | X | √ | X | X |
| DXF | √ | √ | √ | √ | √ | √ |
| Customizable | √ | X | X | X | X | X |
| Cost | Low | Medium | High | High | Medium | Medium |

# EM-SUPREME® OVERVIEW

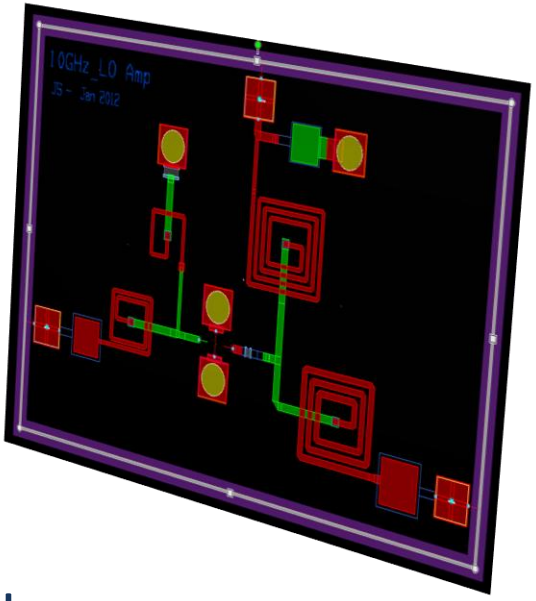
## SYSTEM SIMULATOR COMPARISON

| Company | PedaSoft | Agilent | AWR | Ansys |
|---|---|---|---|---|
| Product | EM-Supreme® | ADS + Momentum | MWO + AXIEM | Nexxim + HFSS |
| Geometry | 2.5 & 3D | 2D | 2.5D | 3D |
| Method | FDTD | FEM/MOM | MoM | FEM |
| Time Domain | √ | X | X | X |
| Freq Domain | X | √ | √ | √ |
| Circuit EM Hybrid | √ | √ | √ | √ |
| Active EM Hybrid | √ | X | X | X |
| Circuit + Active EM | √ | Co-simulation | Co-simulation | Co-simulation |
| Active Models | Unlimited | Limited | Limited | Limited |
| Accuracy | High | Medium | Medium | High |
| Memory | Medium | Low | Medium | High |
| Speed | Medium | Fast | Fast | Medium |
| Shielded | √ | √ | √ | √ |
| Radiated | √ | X | X | HFSS Only |
| DXF | √ | √ | √ | √ |
| Customizable | √ | X | X | X |
| Cost | Medium | High | High | High |

# Why Fully Integrated Solution?

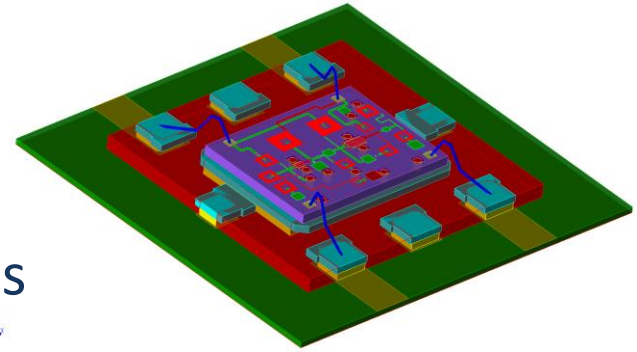
Fully Integrated Solution features:

- Layout can be dissected to look at:
  - Coupling
  - Isolation
  - Interference
- Transient Analysis of Subcircuits
- Tx / Rx Multitone Analysis
- Load Pull / Source Pull
- Gain & Harmonics
- Radiation
- Software can be customized to meet specific customer requirements.



# EM-SUPREME® OVERVIEW

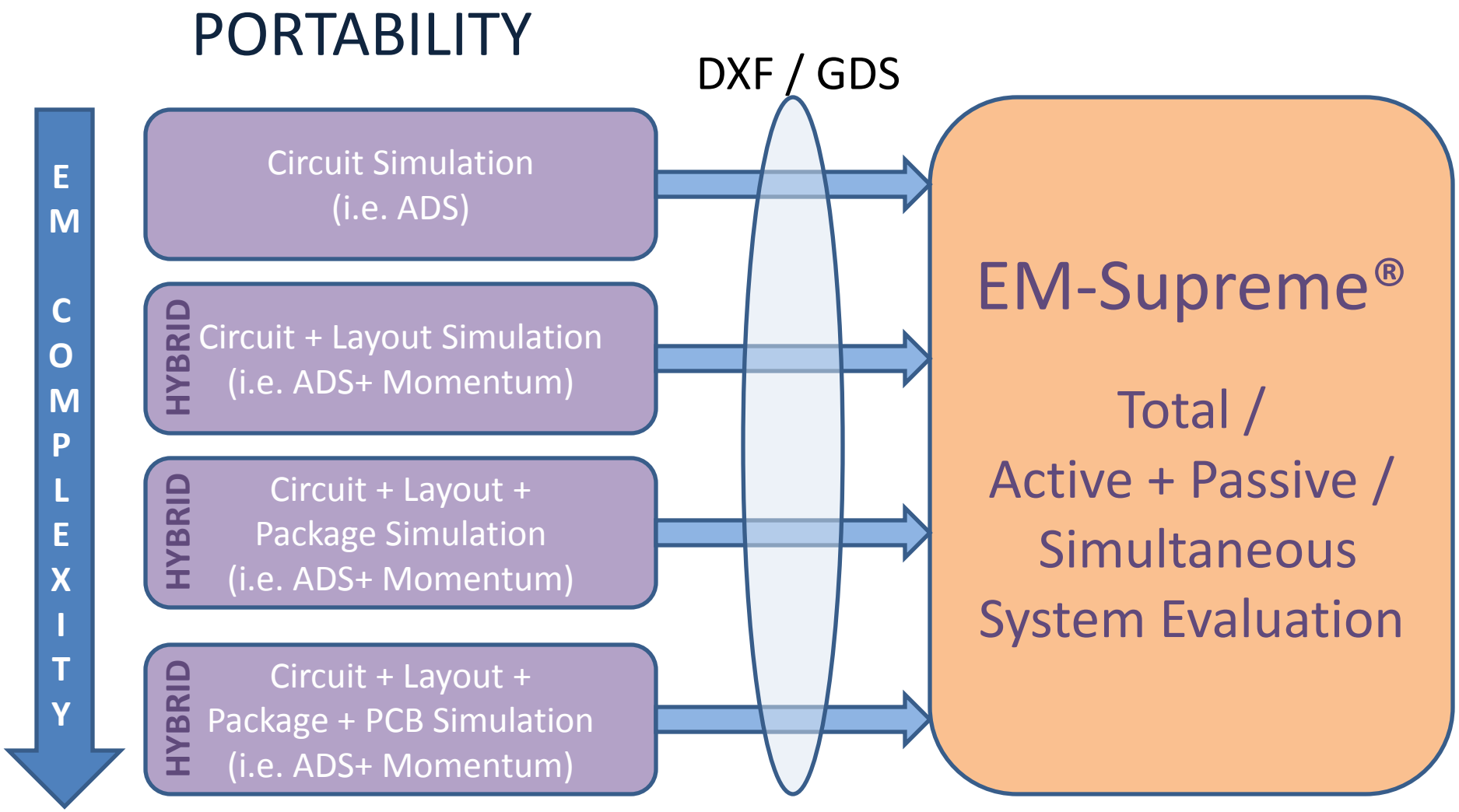
## EM-SUPREME®



- Finite Difference Time Domain (FDTD) model that uses no approximations.
- The tool models electromagnetic fields as they pass through the active and passive components to predict real circuit performance as it physically happens.
- IC, passives, substrate and package are all included in the model.
- Compatible with existing design tools to minimize learning curve.
- Two modes of operation:
  - Stand alone – Provides all necessary tools to completely model a given component or module.
  - Optimization – Adds on funtionality and its side by side to existing tools to improve prediction of the actual circuit performance.

# CONTENTS

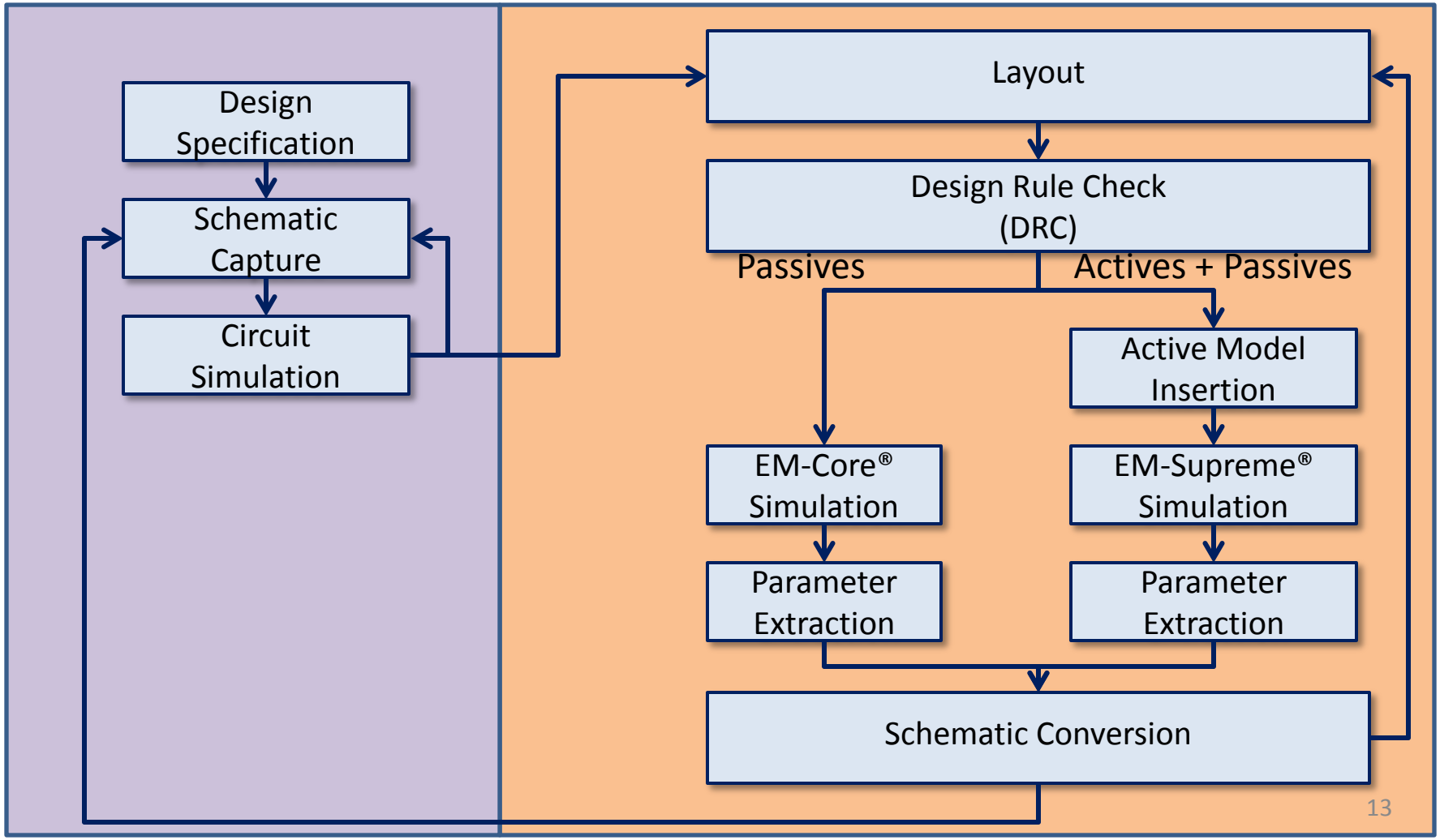
# DESIGN FLOW


PORTABILITY
DXF / GDS
EM COMPLEXITY
Circuit Simulation
(i.e. ADS)
HYBRID
Circuit + Layout Simulation
(i.e. ADS+ Momentum)
HYBRID
Circuit + Layout +
Package Simulation
(i.e. ADS+ Momentum)
HYBRID
Circuit + Layout +
Package + PCB Simulation
(i.e. ADS+ Momentum)
EM-Supreme®
Total /
Active + Passive /
Simultaneous
System Evaluation

# DESIGN FLOW

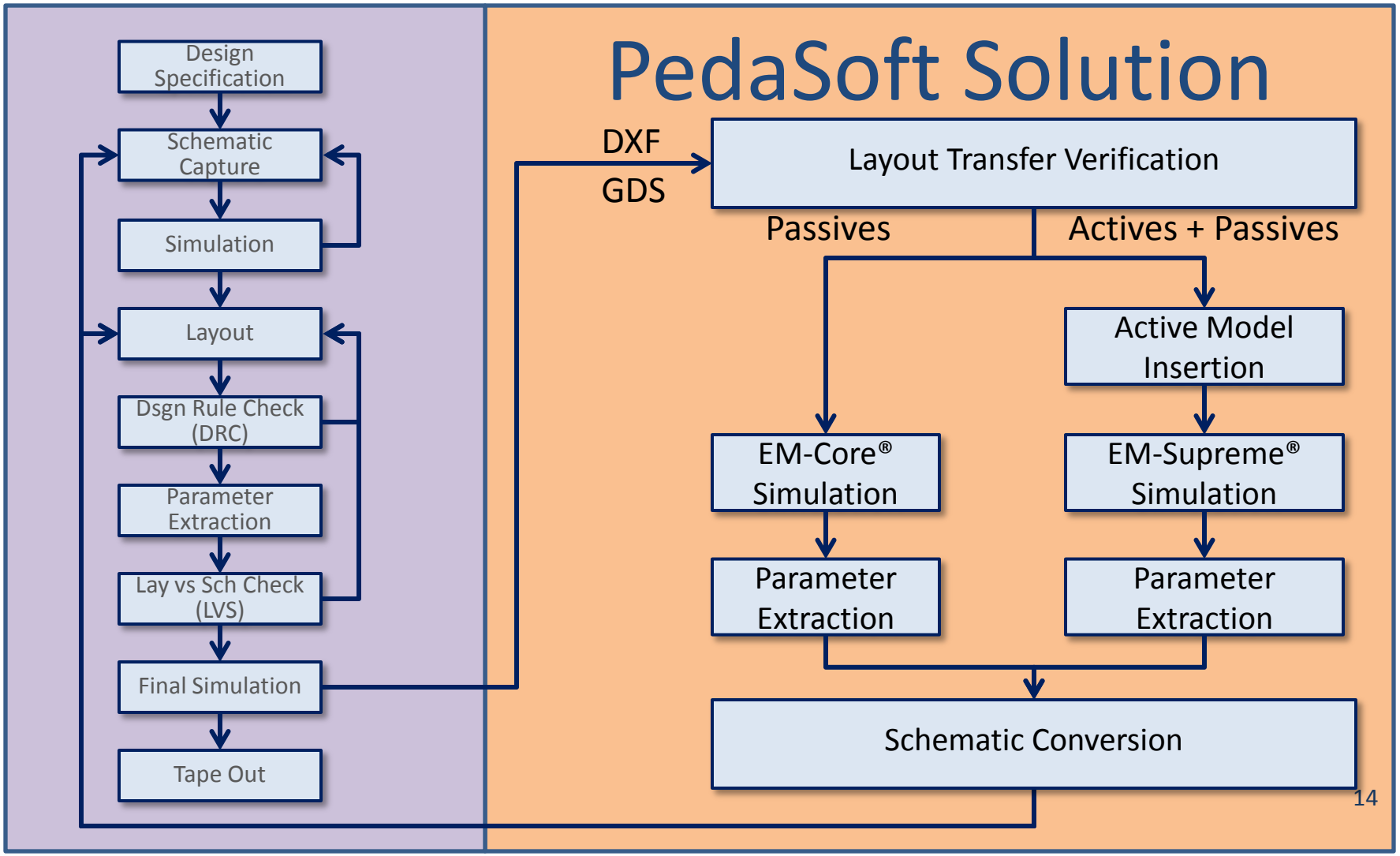
## STAND ALONE MODE

## PedaSoft Solution



# DESIGN FLOW

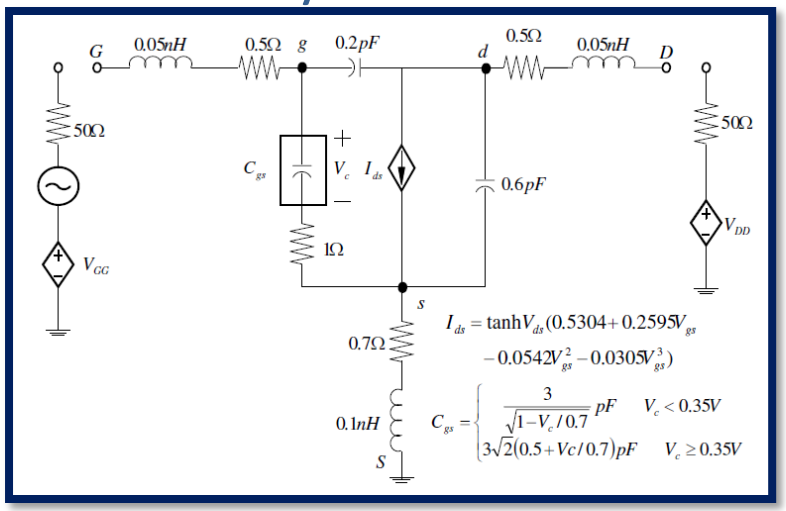
## OPTIMIZATION MODE



# DESIGN FLOW

## ACTIVE MODELS

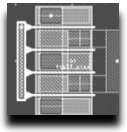
- PedaSoft's EM-Supreme® can accept any model:
  - Spice, Curtice, Angelov, Stats-Pucel, …
  - Foundry PDK, TOM, Customer proprietary, …
- PedaSoft customized
  - For optimal results PedaSoft will take any of the above models and work with the manufacturer / foundry to optimize the model for use in EM-Supreme®.

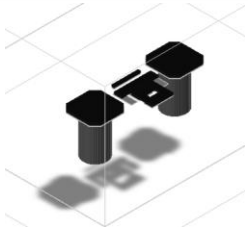


# Things Can Always Go Wrong!

## PA

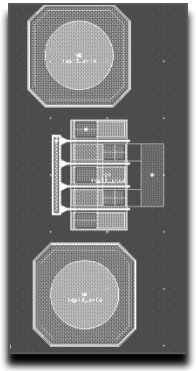
Transistor



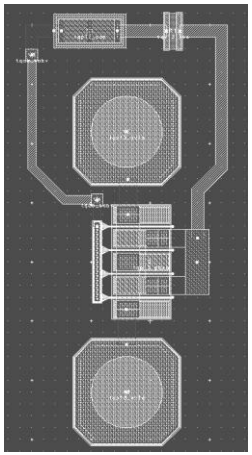


### Many potential sources of error

- New Dimensions results when EM Simulating the whole structure "i.e. feedback network and vias.
- The feedback line could EM-couple with the substrate, packaging layers, and neighborhood components
- The transistor along with feedback network exist on the top layer of a multilayer substrate with metallization underneath, adding possibilities of coupling that designer needs to account for.



W/ VIAs

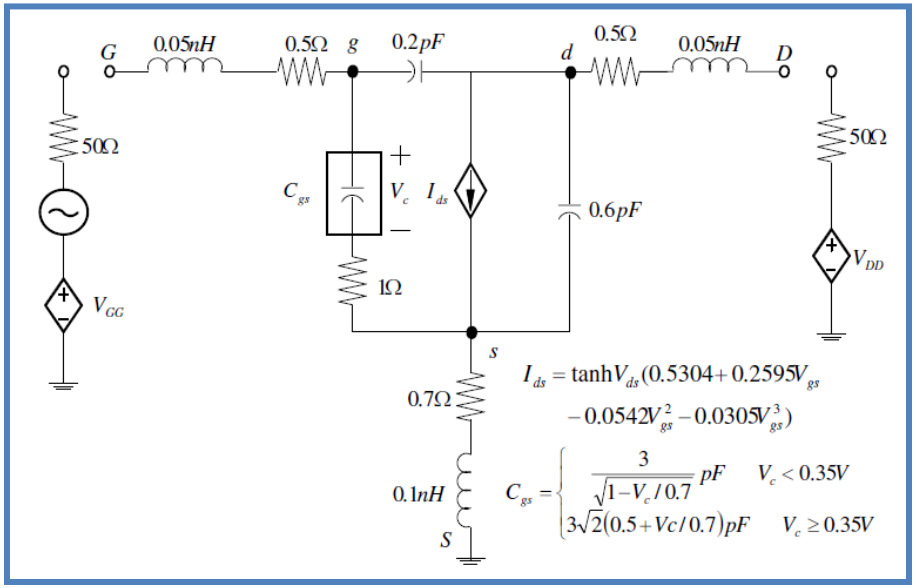


W/ Feedback Network

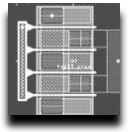
# EXAMPLES

## PA DESIGN

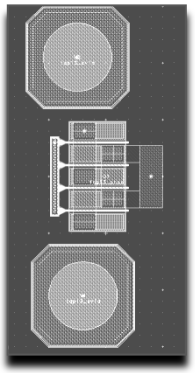
### 2 – 5 GHz flat gain target



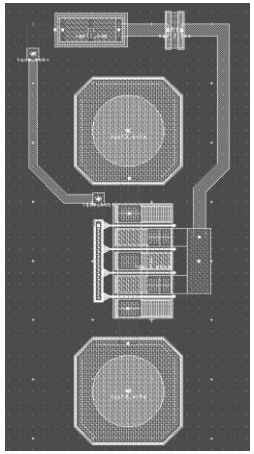

Transistor



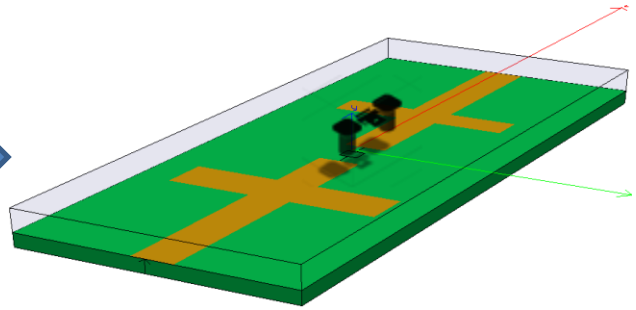
+ VIAs



+ Feedback Network

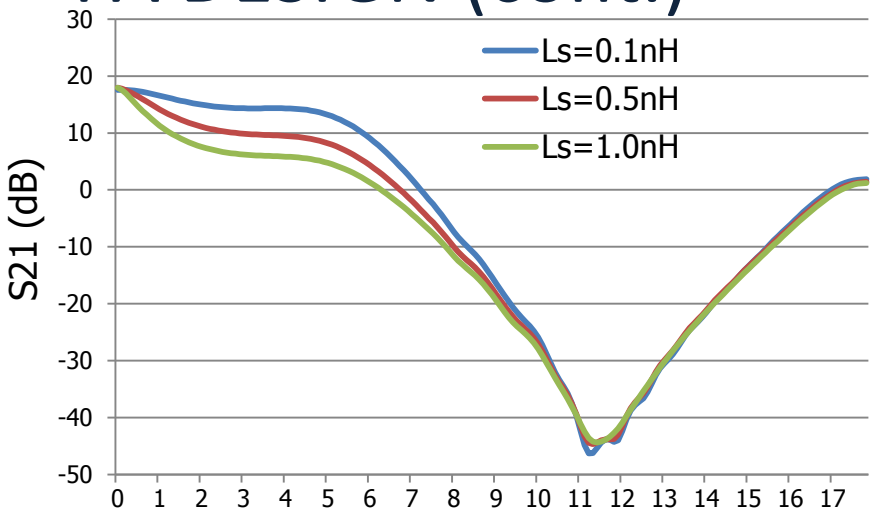


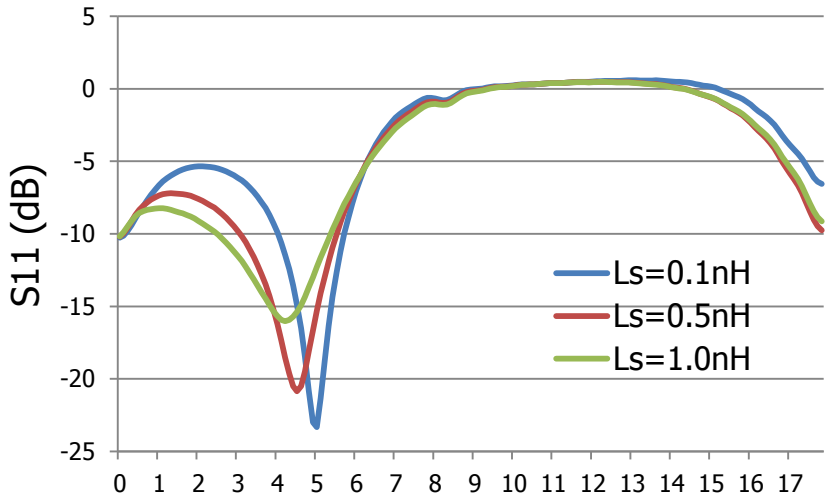
+ PCB

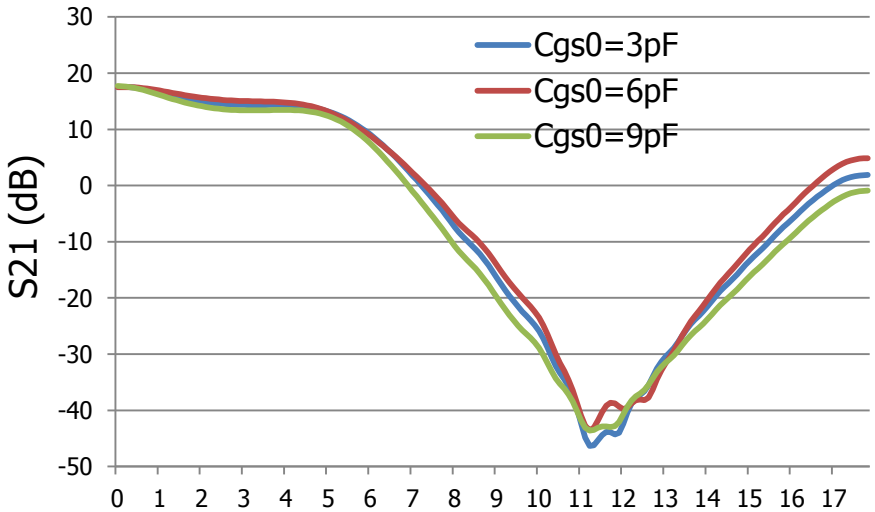


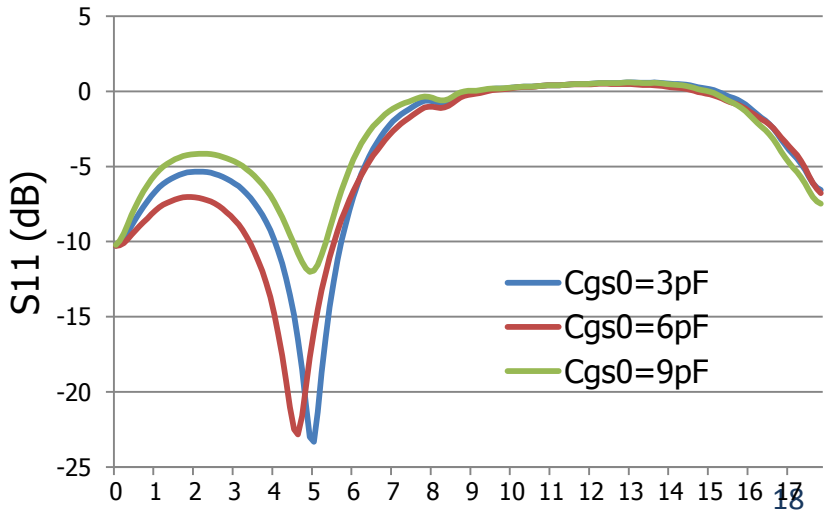
# EXAMPLES

## PA DESIGN (cont.)



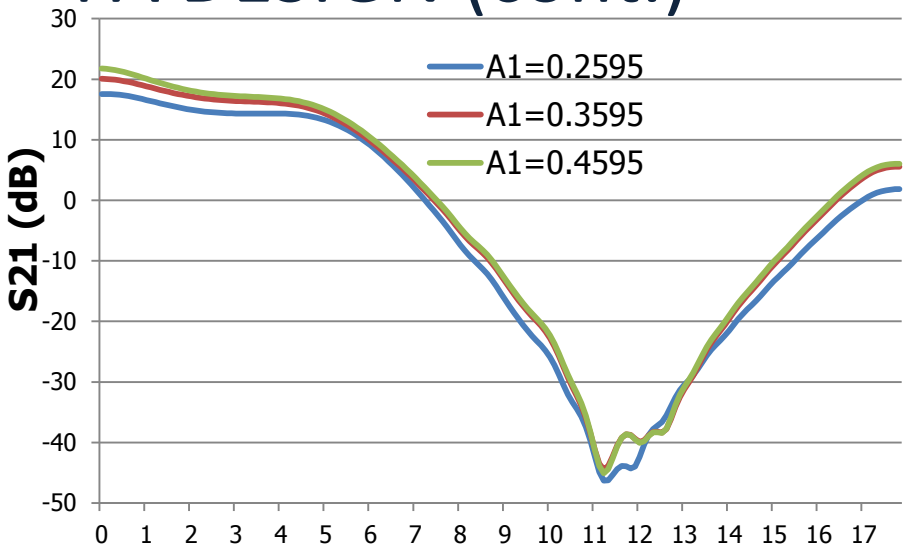



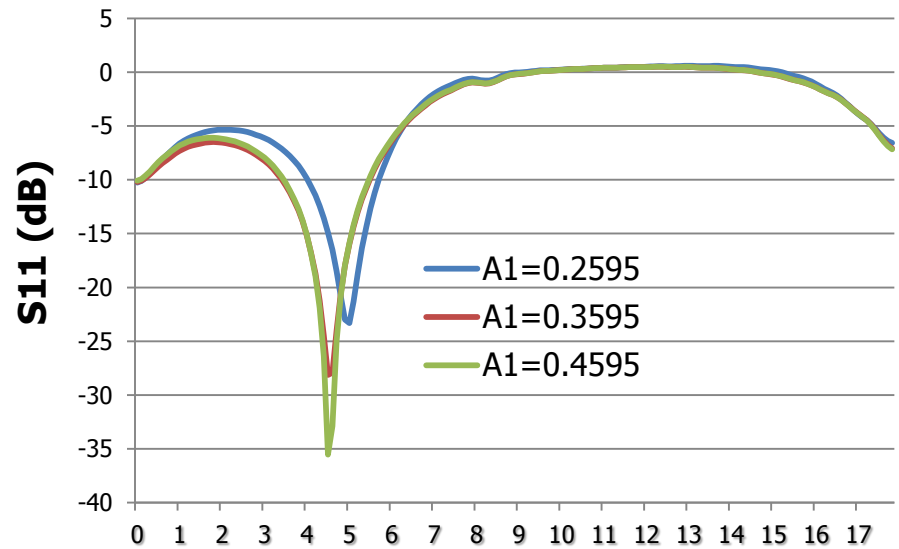



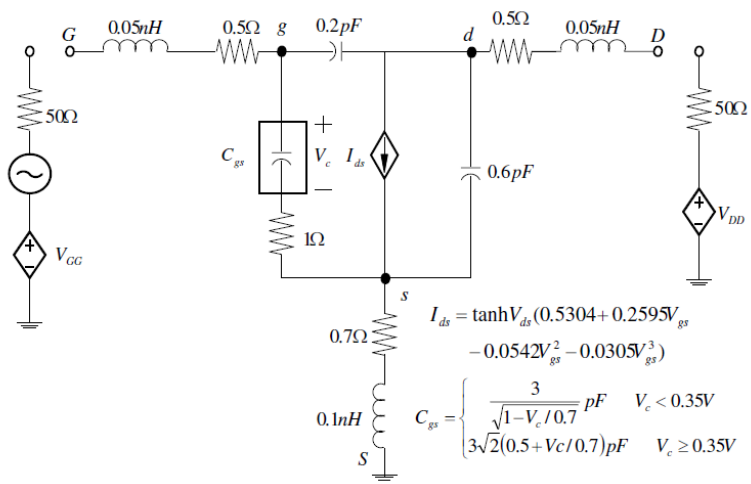
# EXAMPLES

## PA DESIGN (cont.)



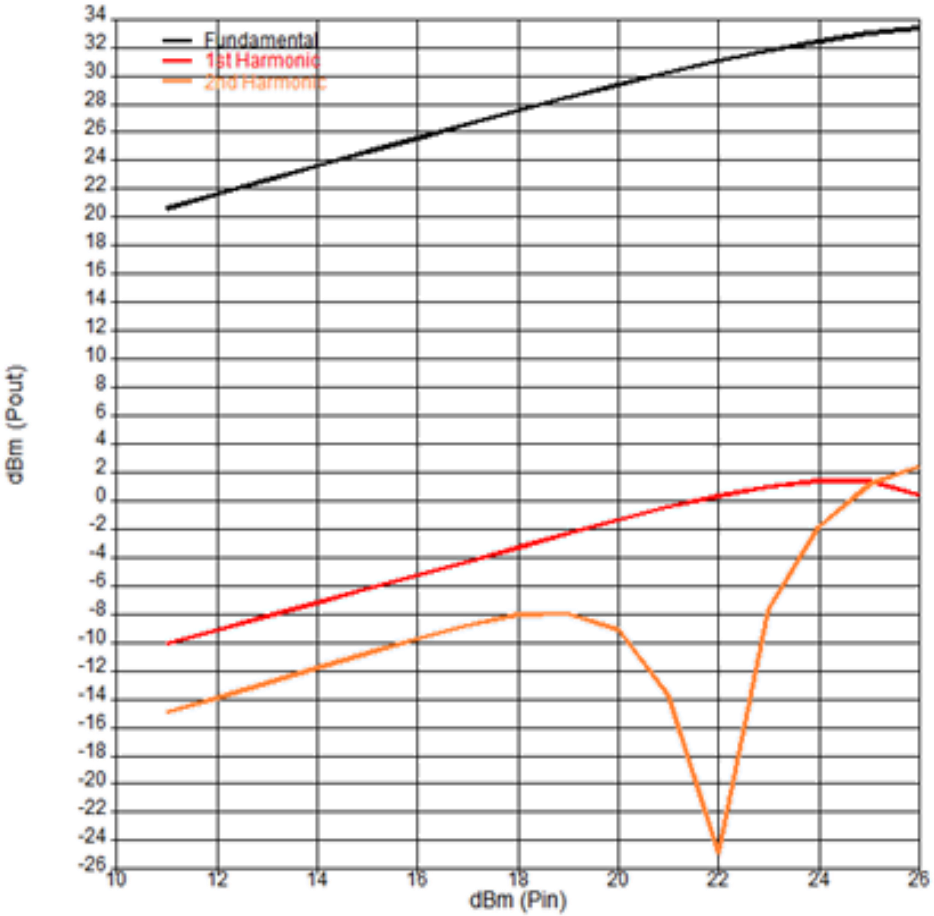

| | |
|---|---|
| Endz | 510.000 |
| From Metal | Square5 |
| To Metal | Square6 |
| Source Impedance | 50.000 |
| Load Impedance | 50.000 |
| Cgs0 | 3.000 |
| Cgd | 0.200 |
| cds | 0.600 |
| Ls | 0.100 |
| Lg | 0.050 |
| Ld | 0.050 |
| A0 | 0.5304 |
| A1 | 0.2595 |
| A2 | -0.0542 |

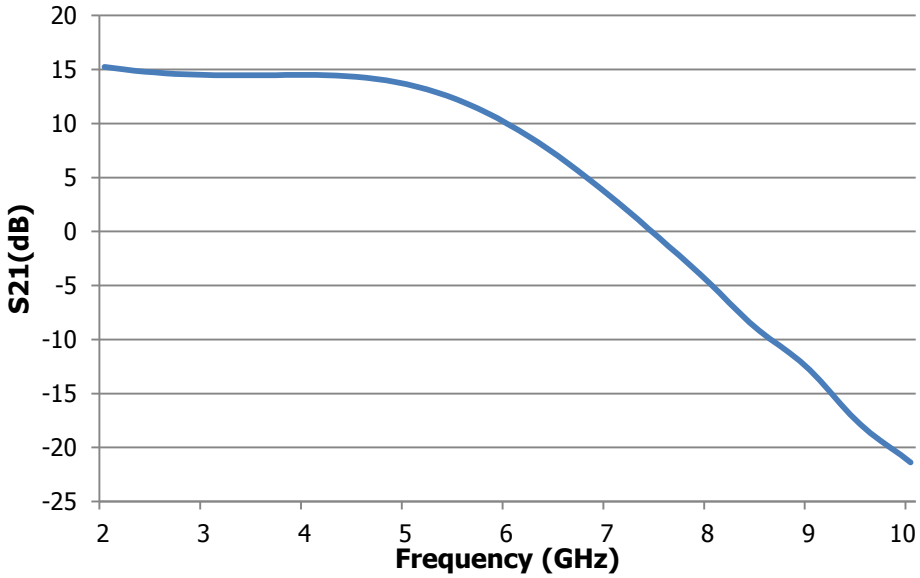


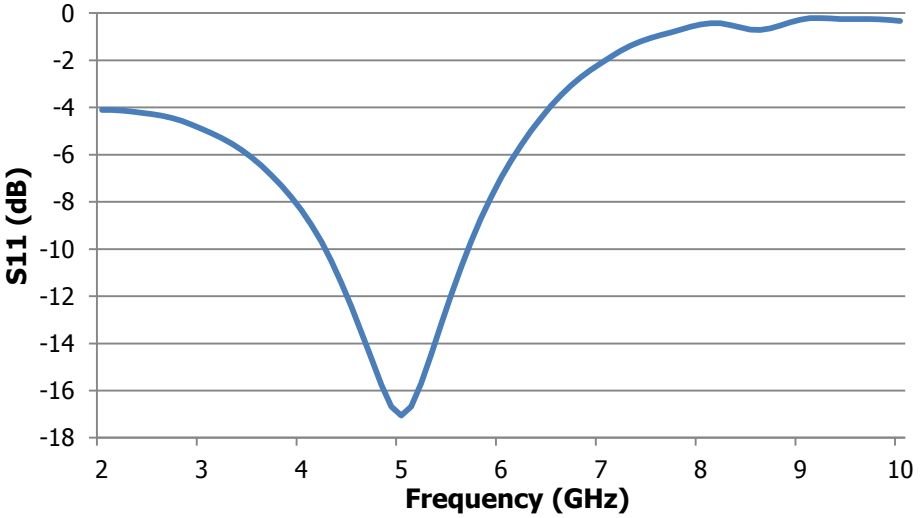

| | |
|---|---|
| A3 | -0.0305 |
| Alpha | 1.000 |
| Ri | 1.000 |
| Rs | 0.700 |
| Rg | 0.500 |
| Rd | 0.500 |
| VGG | -0.810 |
| VDD | 18.960 |
| Signal Simulations | Large |
| Temperature | 300.000 |
| Power Sweep (dbm) | 10.000 |
| Power Sweep Min (dbm) | 0.000 |
| Power Sweep Max (dbm) | 30.000 |
| Input Frequency (GHz) | 6.000 |

# EXAMPLES

## PA DESIGN (cont.)

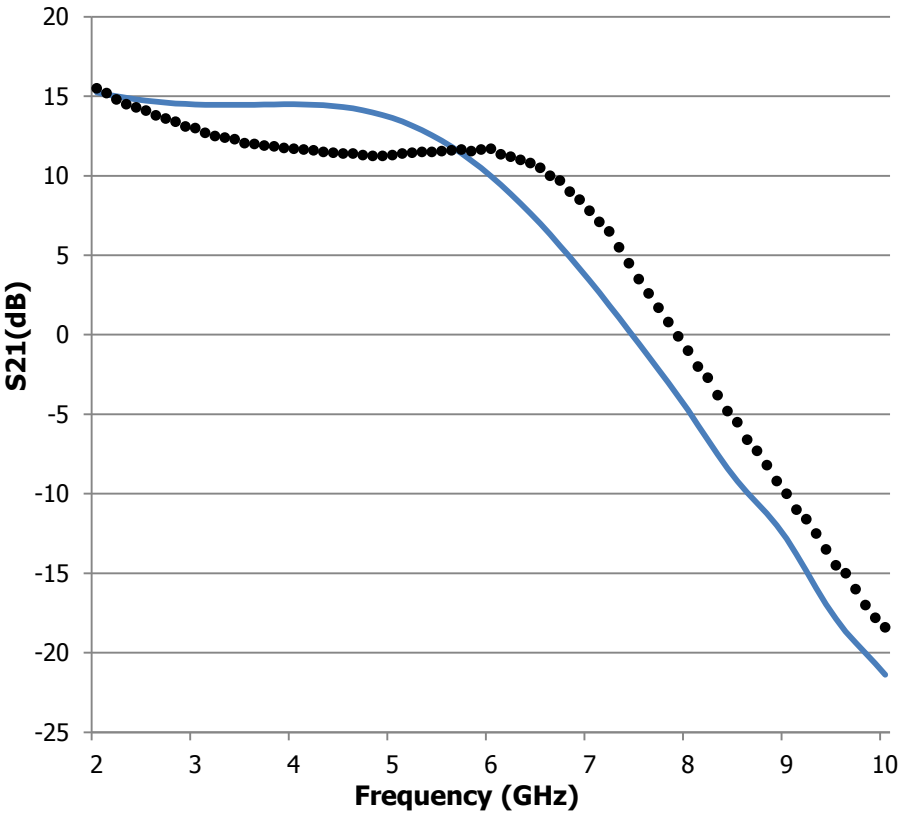


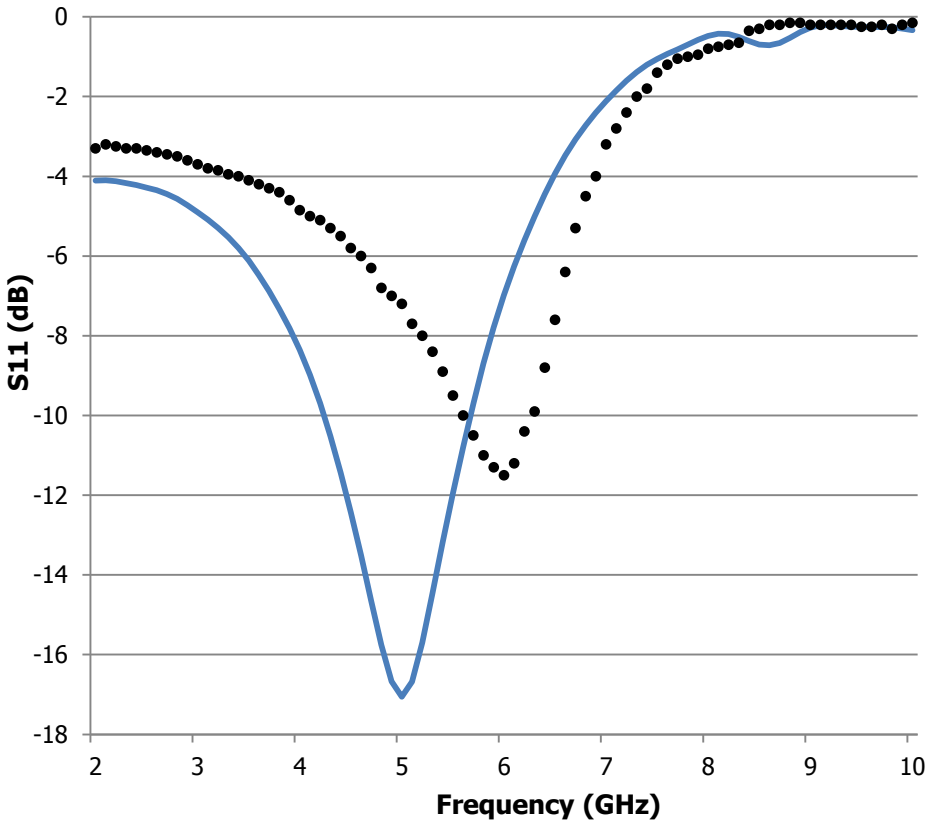



# PA DESIGN (cont.)

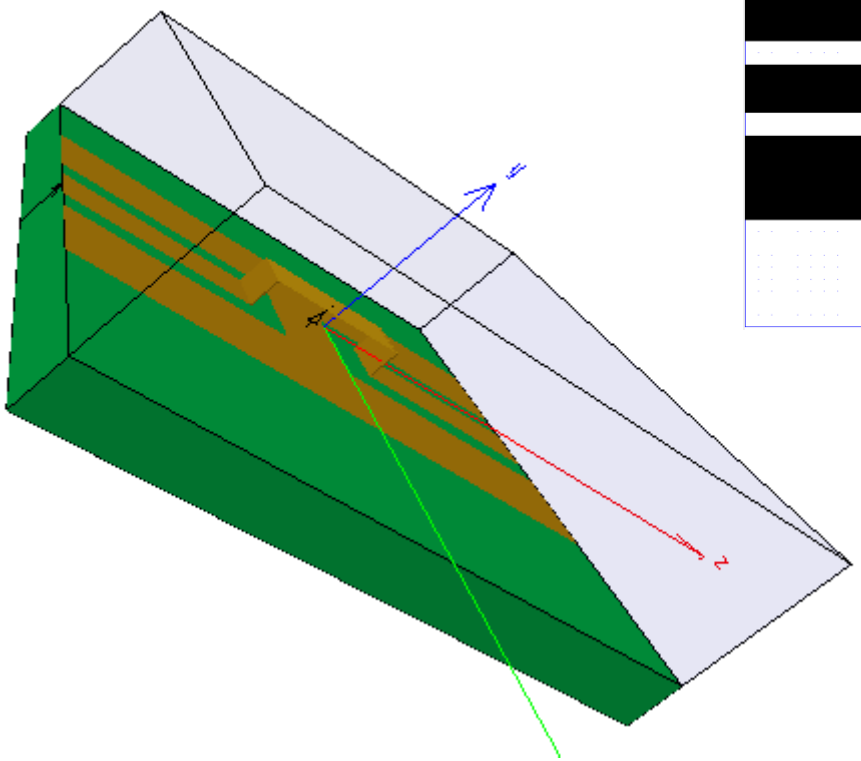
- Comparison of same circuit using co-simulation

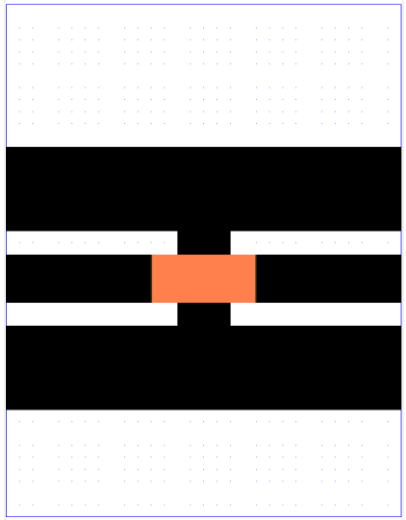


# EXAMPLES

## PIN SWITCH



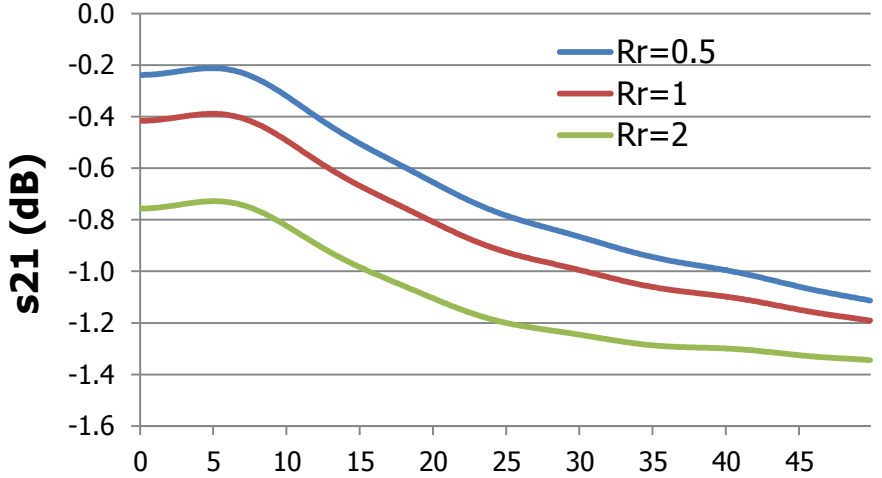


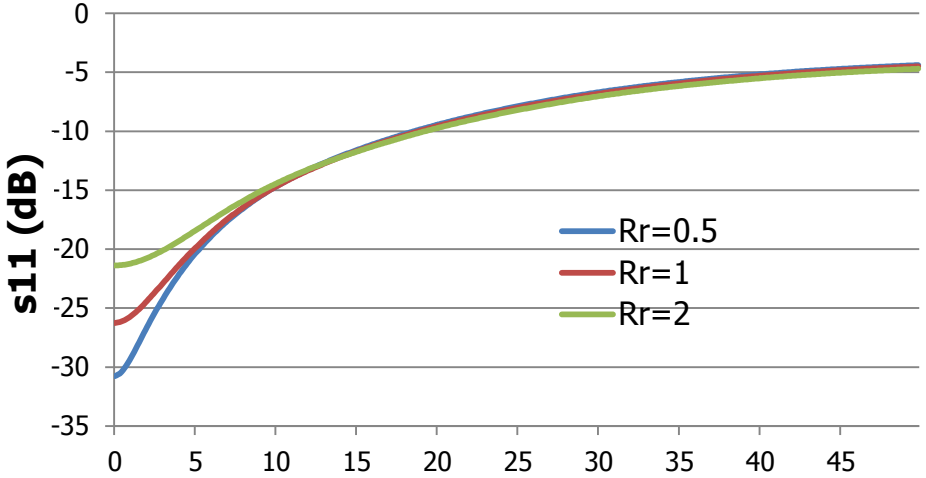
| | |
|---|---|
| Contact Resistance (Ohms) | 0.500 |
| Intrinsic Area (cm2) | 5.260e-006 |
| Int. Area Width (cm) | 2.000e-004 |
| Technology | GaAs |
| Bias_current (A) | 3.000e-002 |
| Doping_N (cm-3) | 1.000e+019 |
| Doping_P (cm-3) | 1.000e+018 |
| Reverse Voltage (V) | 10.000 |
| Power Sweep (dbm) | 1.000 |
| Power Sweep Min (dbm) | 10.000 |
| Power Sweep Max (dbm) | 20.000 |
| Input Frequency (GHz) | 40.000 |
| FoundryModel (On-State) | |
| FoundryModel (Off-State) | |

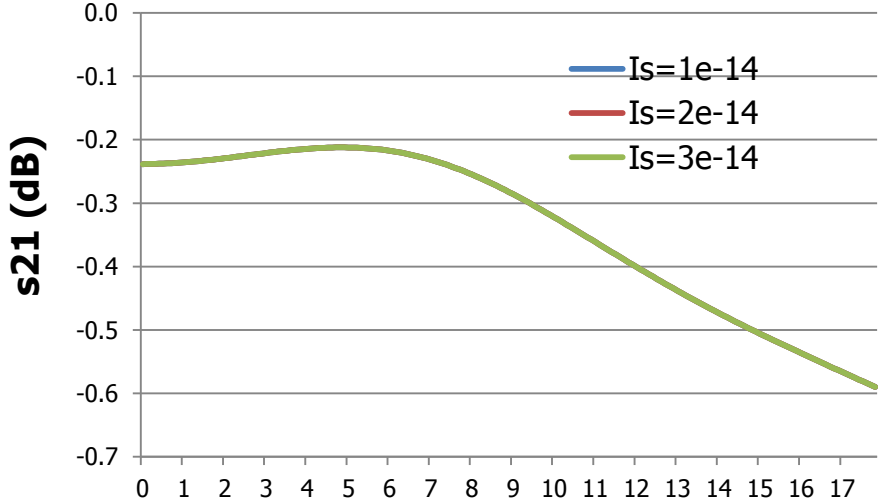
| | |
|---|---|
| Name | PinDiode1 |
| Startx | 300.000 |
| Starty | 100.000 |
| Startz | 150.000 |
| Endx | 300.000 |
| Endy | 166.667 |
| Endz | 150.000 |
| From Metal | Bridge1 |
| To Metal | Square10 |
| State | On |
| Signal Simulations | Small |
| Number of Contacts | 1.000 |
| Saturation Current (A) | 1.000e-014 |
| Turn-on Voltage (V) | 0.700 |

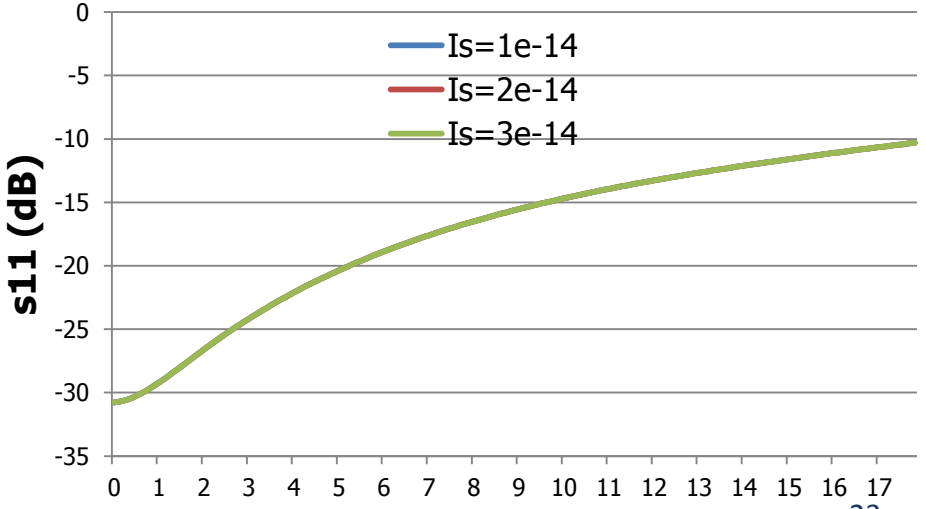
# EXAMPLES

## PIN SWITCH (cont.)



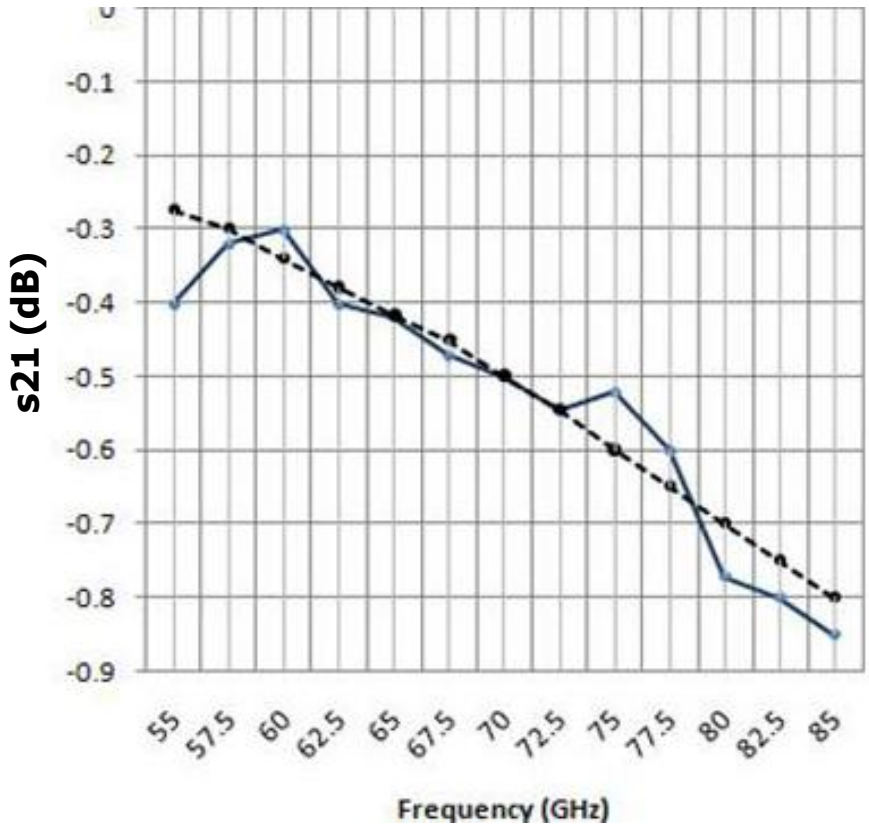



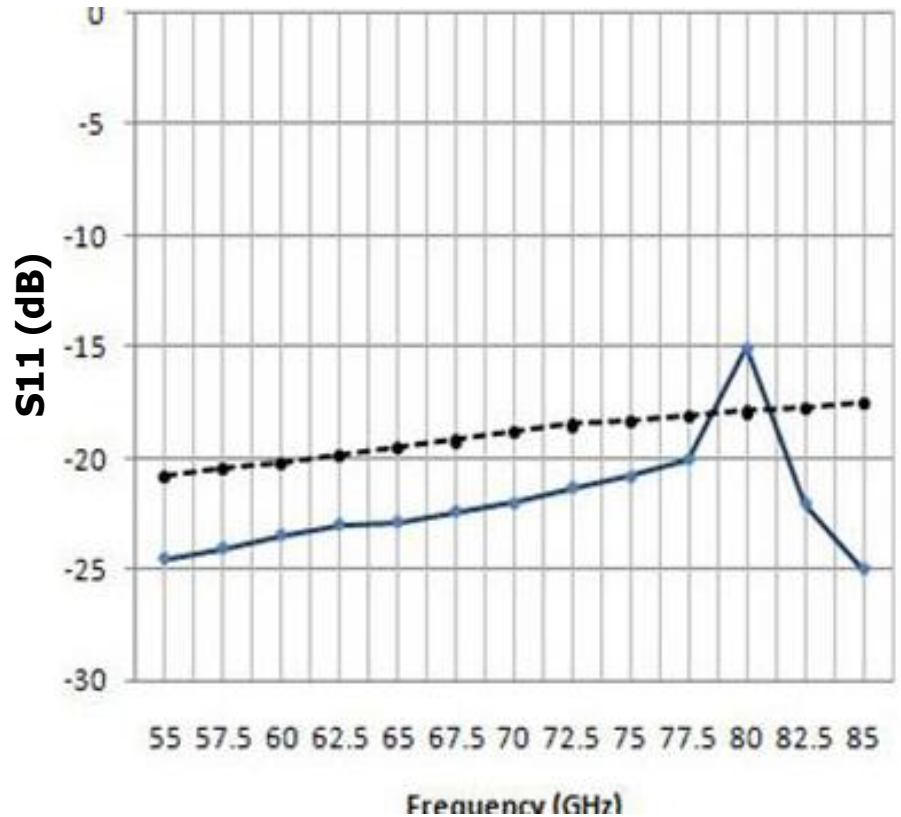
# EXAMPLES

## PIN SWITCH

- Diode only

EM-Supreme Simulation
Measurement

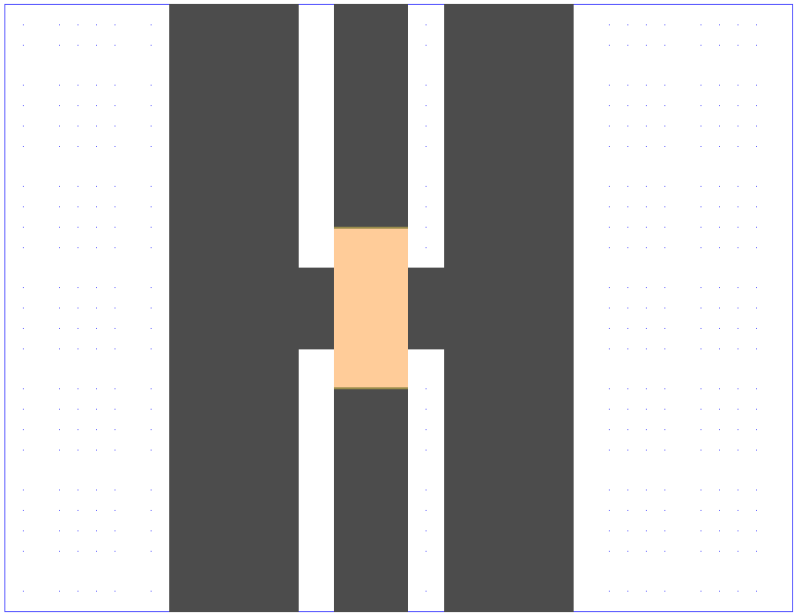


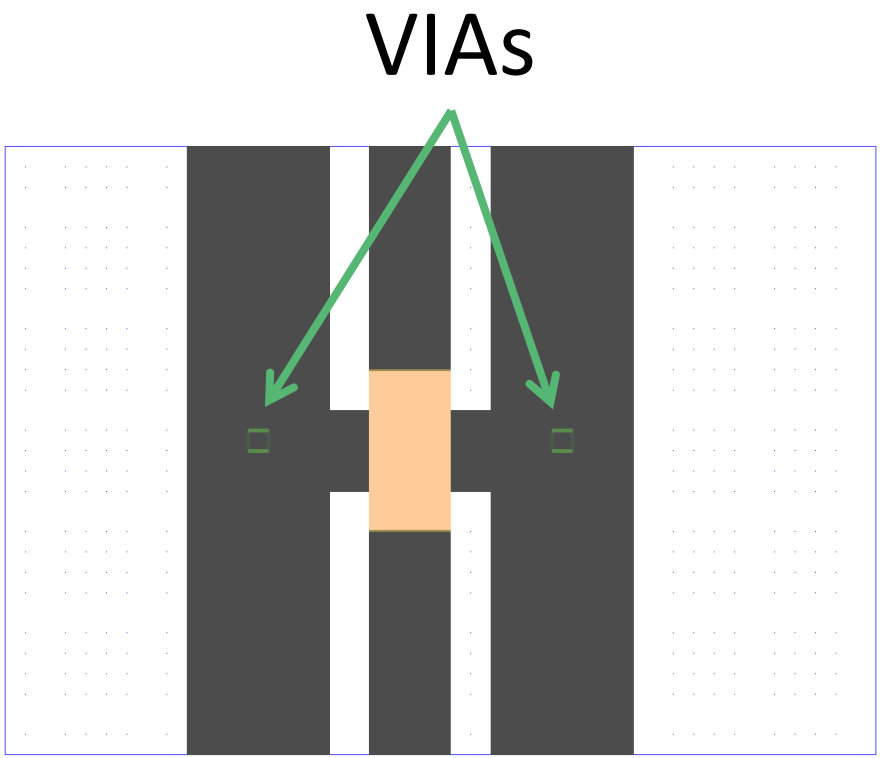



# EXAMPLES

## PIN SWITCH (cont.)

- Add VIAs



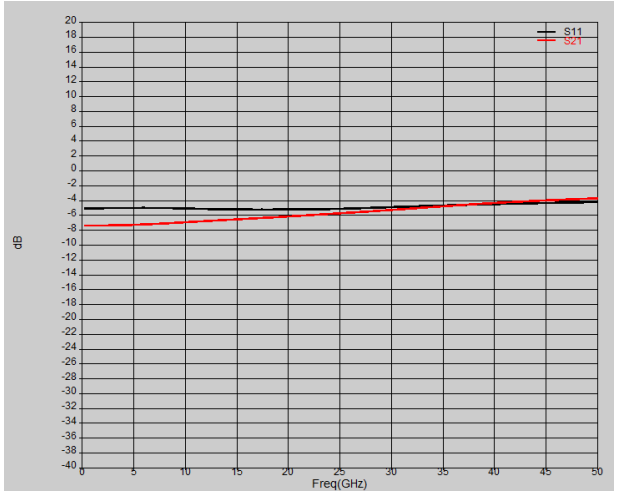


# EXAMPLES

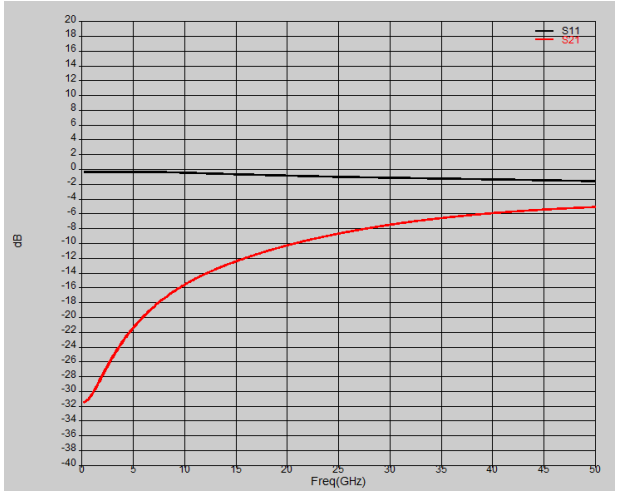
## PIN SWITCH (cont.)

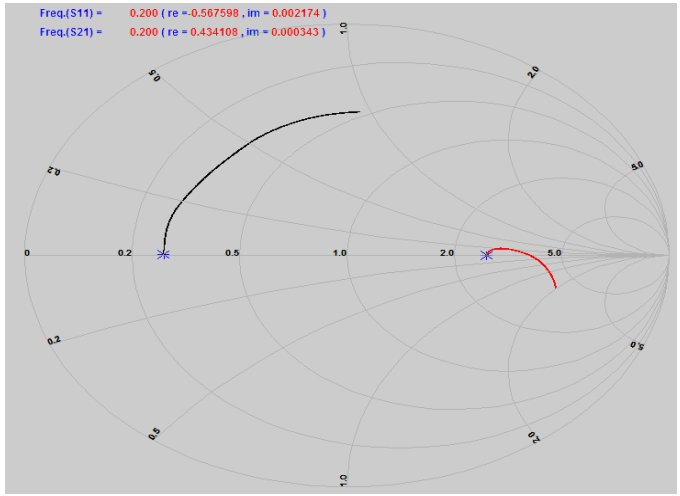
s21
s11

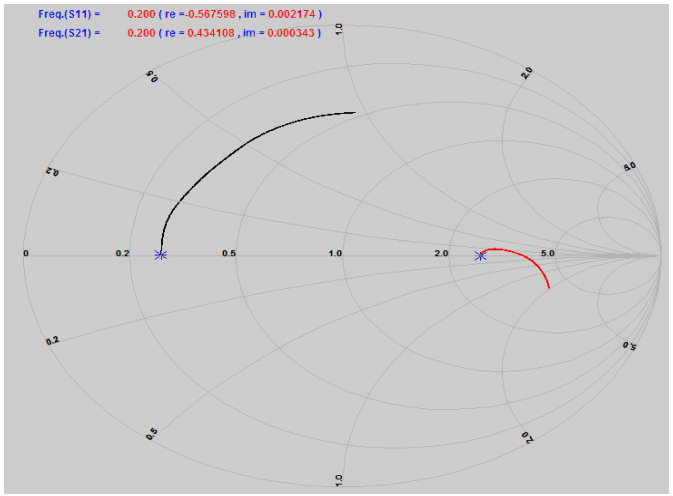
W/O VIAS




W/ VIAS

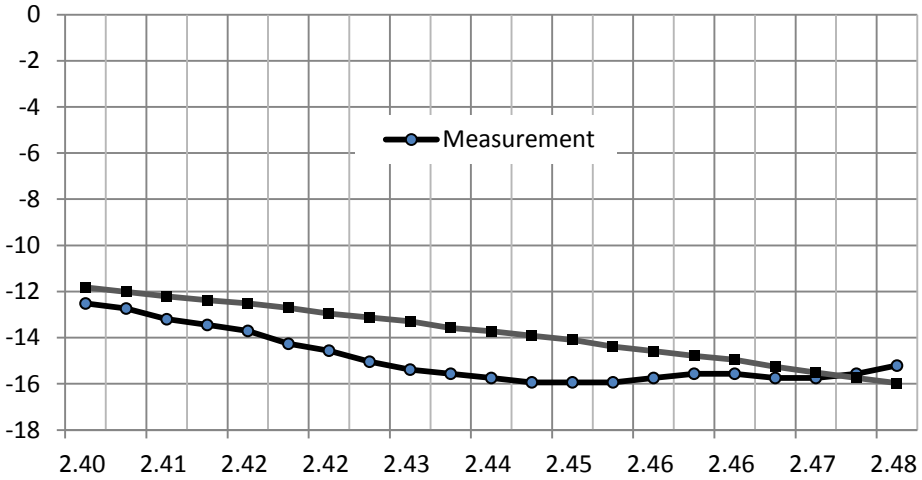


# Integrated Switch/Antenna Module

## Measurements versus EM-Supreme

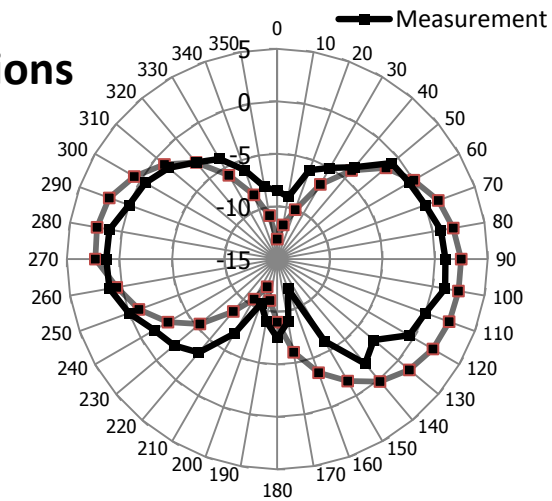


# Integrated Switch/Antenna Module

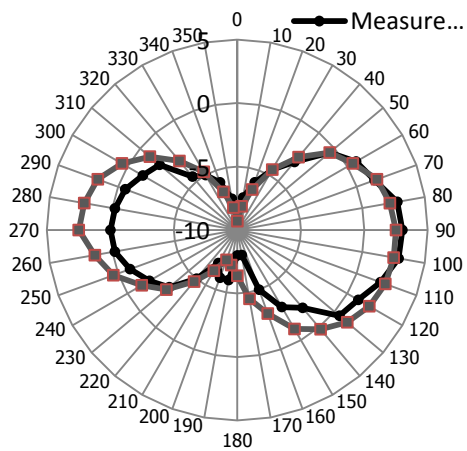
## Measurement versus EM-Supreme

**Radiated Emissions**

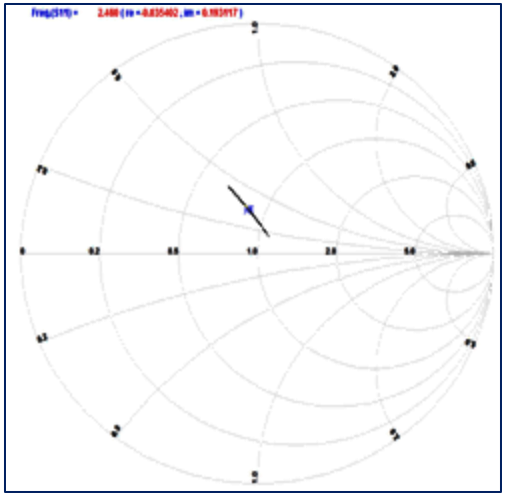
E-Field

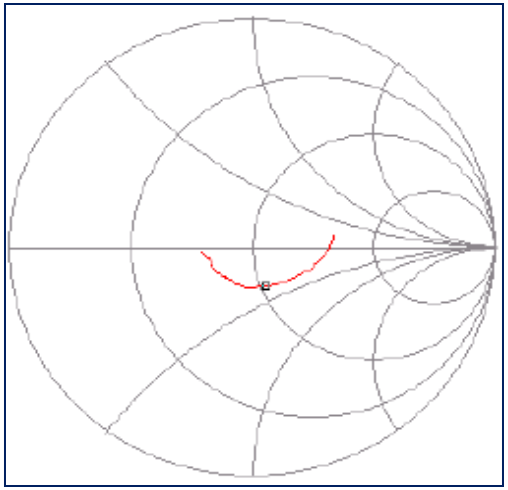



H-Field




**Two EVB Xmission Line Lengths**





# SUMMARY & CONCLUSION

- EM-Supreme includes electromagnetics to model field distributed-effects, coupling, radiation, as well as parasitic effects at RF and millimeter-wave bands; for active, passive, and complete RF modules.
- Technology supported includes, but not limited to,: PHEMTS, Silicon Germanium, Gallium Arsenide, Aluminium Gallium Arsenide, Indium Gallium Phosphide HBT's and PIN diodes. With the method, RF designer can model CMOS as well as Gallium Arsenide and Gallium Nitride FETs.
- EM-Supreme ***eliminates*** excessive design cycles (typically 3 to 4) and/or inefficient designs which would translate into high costs and ultimately lost time-to-market opportunities.

# SUMMARY & CONCLUSION

- EM-Supreme is the first EM simulator for the whole chip “transistors plus passives” to including all parasitic effects, radiation coupling and inference in a single software tool.
- The tool is fully customized. The tool comes as a stripped or customized version based on special foundry or active models “i.e. cost effective and flexible“
- Easy to Use “just import the layout in DXF and then insert active components”
- We have a very well established team "programmers, GUI's, RF engineers, and packaging designers”
- The current version is very stable version that has been used by dozens of RF engineering teams
- Windows compatible “can run efficiently on any windows operating system including windows 7.0”

PEDASOFT

# Thanks You

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