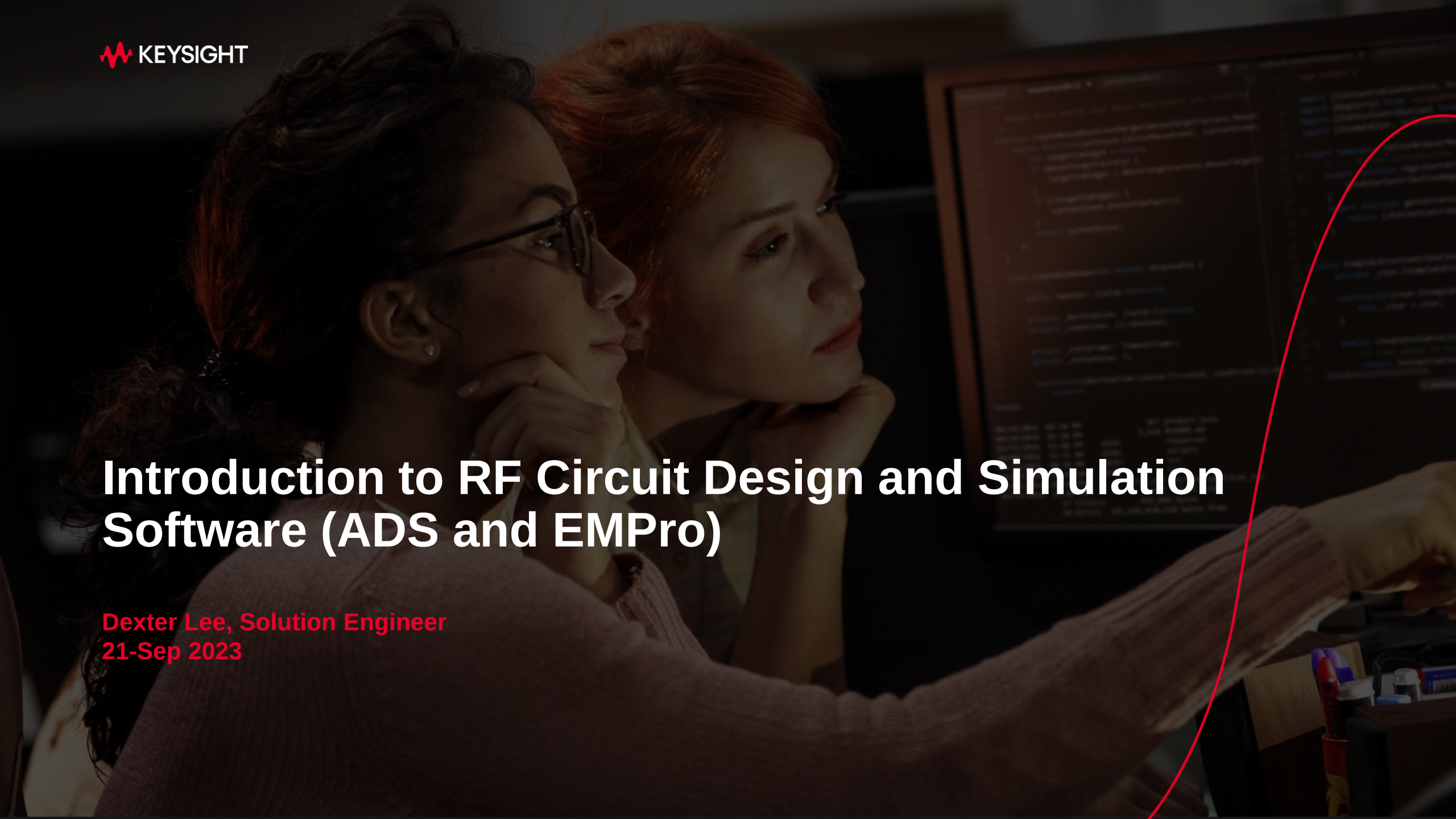


Introduction to RF Circuit Design and Simulation Software (ADS and EMPro)

Dexter Lee, Solution Engineer
21-Sep 2023

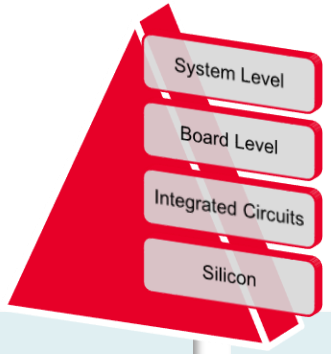
Keysight Offers End-to-End Solutions Across Workflows and Markets

MARKETS

WORKFLOW

Design → Emulate → Prototype → Test → Manufacture → Optimize

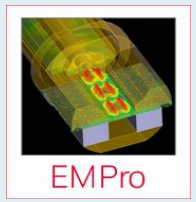
Keysight PathWave Design Solutions



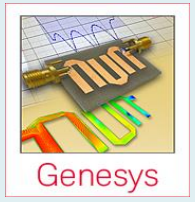
RF & Microwave

ADS
– MMIC, RF Board, SiP, HSD

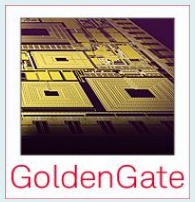
RFPro
– EM-Circuit analysis for circuit designers



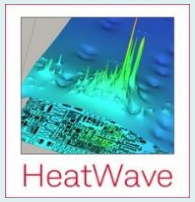
EMPro
– 3D EM



Genesys
– RF Board Circuit Synthesis

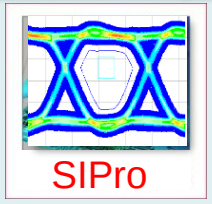


GoldenGate
– RFIC Mixed Signal

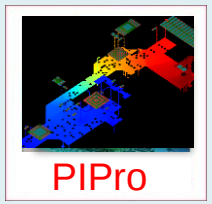


HeatWave
– IC electro-thermal analysis

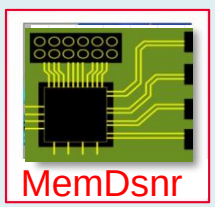
High Speed Digital



SIPro
– Signal Integrity design for High Speed Digital



PIPro
– Power Integrity design for DC power distribution network



MemoryDesigner
– Designs DDR4, DDR5 Memory modules

System Level Design

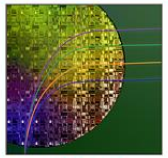
SystemVue
– Electronic System Level

Power Electronics

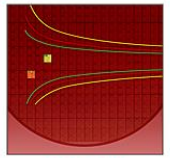
PEPro
- Power Electronics high speed switch mode power supply
–

Device Modeling

IC-CAP
– Device Modeling GaAs, GaN, Custom Models Measurement

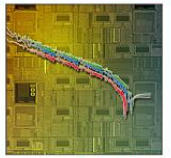


MBP
– Device Modeling Silicon



MQA
– Model Quality Assurance

WaferPro Express
– Wafer-level automated measurement



A-LFNA
– Advanced Low-Frequency Noise Analyzer

Agenda

1. IC Design Workflow with PathWave ADS (MMIC PA Design)

2. Rectenna Design with PathWave EMPro and ADS
   a) Patch Antenna Design with EMPro
   b) Rectifier Circuit with ADS
   c) Integration of Patch Antenna and Rectifier Circuit in ADS

3. General Introduction of EMI/EMC simulation with EMPro

4. Conclusion

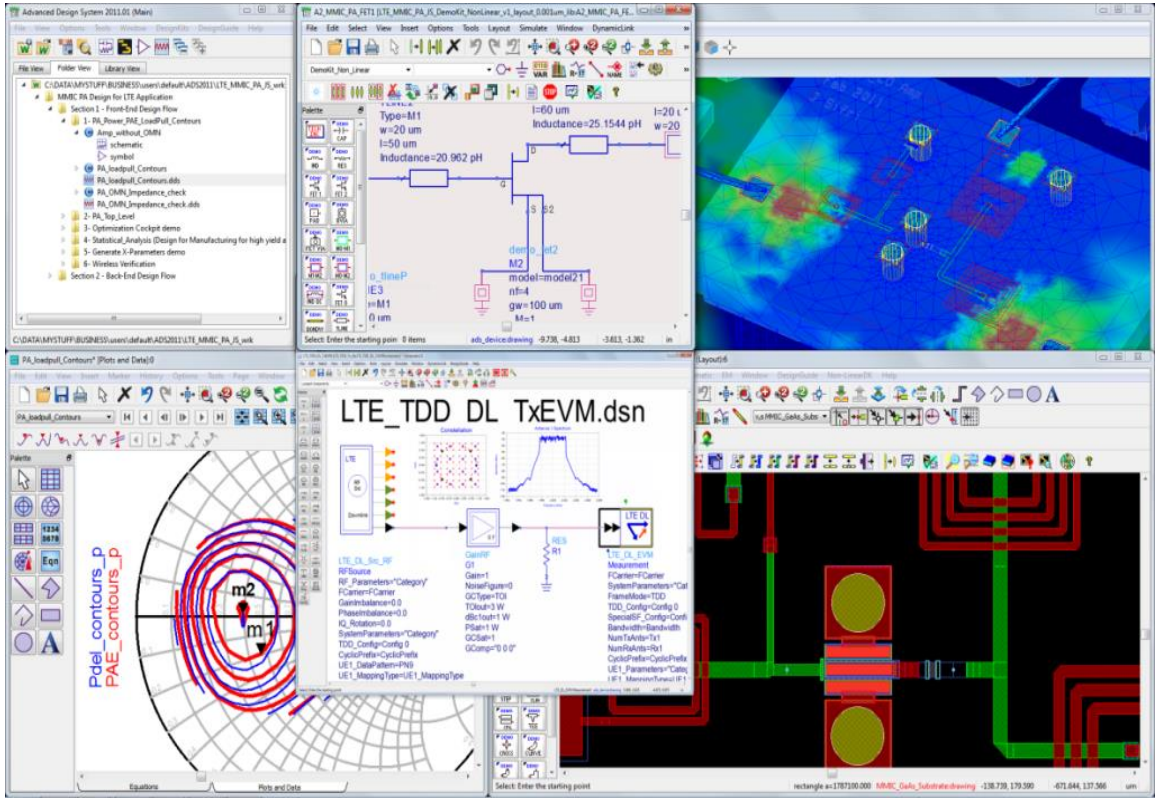
KEYSIGHT

IC Design Workflow with PathWave ADS (MMIC PA Design)

Keysight PathWave Advanced Design System (ADS)

Premier RF & Microwave Design Software

- Industry and Technology Leader Serving:
  - RFIC/MMIC
  - Module Design
  - RF Board Design
  - Silicon RFIC Design
  - High Speed Digital Design



Keysight Pathwave MMIC Solutions

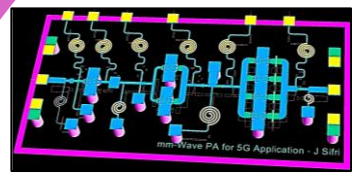
From Transistors to MMIC's to Modules

- ✓ Create Robust MMIC Designs with best-in-class tools
- ✓ Statistical Design Tools (including DOE)
- ✓ Non-Linear X-parameters modeling
- ✓ Cloud HPC

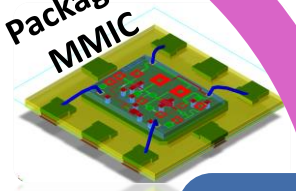
Best-in-class RF circuit simulators

- ✓ Seamless integrated EM/Circuit Co-Simulation
- ✓ Best-in-Class Non-Linear Stability Analysis / Winslow Probes
- ✓ Fast & Accurate "Design & Simulation with Modulation/EVM"
- ✓ Wireless Verification Testbenches (VTB) and Modulated Sources

MMIC



Packaged MMIC



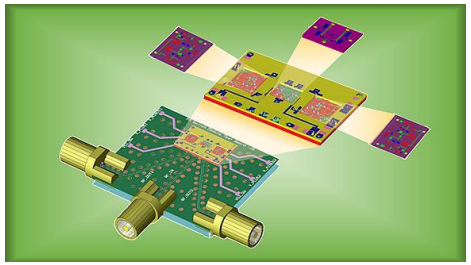
- ✓ Integrated Planar and 3D EM/Circuit Co-Simulation with RFPro
- ✓ Near and Far Field Plots
- ✓ EM with Circuit Excitation
- ✓ Cloud HPC

Integrated Planar and 3D EM/Circuit Co-Simulation with RFPro

Foundry Design Kits and Models from all major Foundries

- ✓ Design Kits from all major Foundries
- ✓ Full Front-to-Back ADS PDKs
- ✓ DRC / LVS with MMIC toolbar support
- ✓ GaAs, GaN, InP, HEMT, PHEMT, etc.
- ✓ New Front-to-Back mm-Wave DemoKit with Electrothermal capability

Integrated PA/Switch Module



- ✓ Electrothermal effect at chip and package/module levels
- ✓ Layout Thermal Floor-Planning
- ✓ Many foundry PDK's are Electrothermally enabled

Electrothermal Simulation

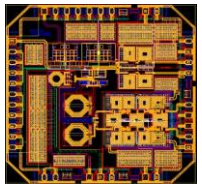
Back End Design Flow

- ✓ Layout / Electrothermal Simulation
- ✓ Integrated Planar and 3D EM/Circuit Co-Simulation with RFPro
- ✓ ADS Desktop and Third-Party DRC & LVS
- ✓ Multi-technology/Smart Mount for Packaging and Module Assembly and Simulation

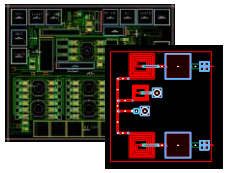
A Platform for Technology Assembly

PATHWAVE ADS

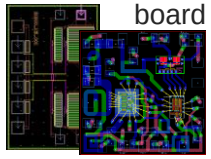
Silicon RFIC



GaAs/GaN/MMIC



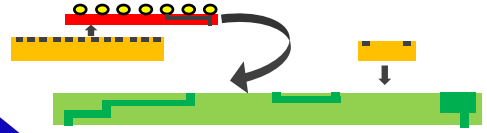
Silicon IC Pkg or board



Interoperable, OA-based designs

Native IC and package designs

Imported designs



Technology Assembly

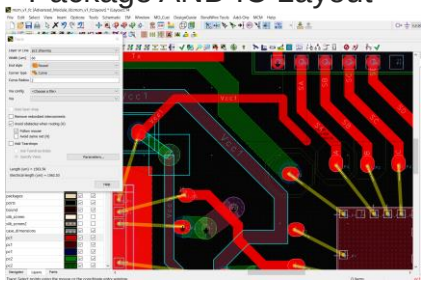
Layout, Verification

EM, Thermal

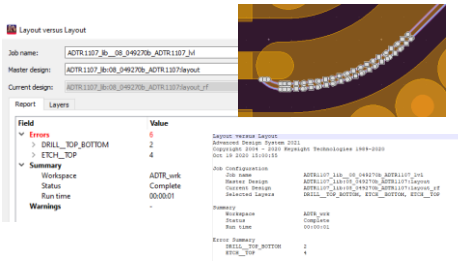
Simulation, Analysis

Models, Design Kits
Libraries, Database Management

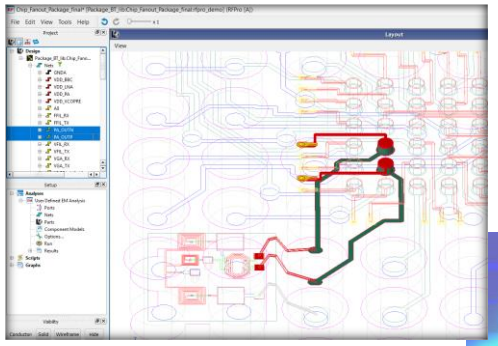
Package AND IC Layout



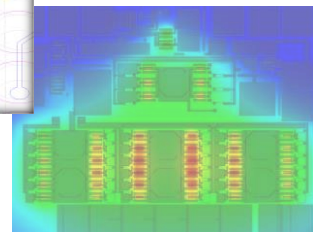
"Layout vs. Layout"



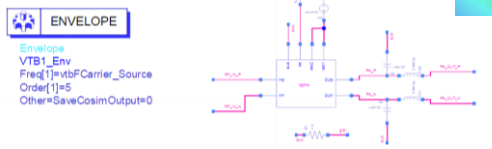
RF Pro



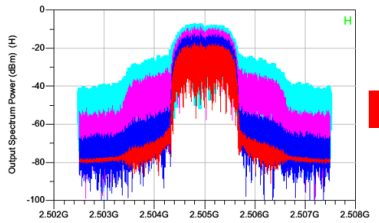
Heatwave



Circuit Envelope

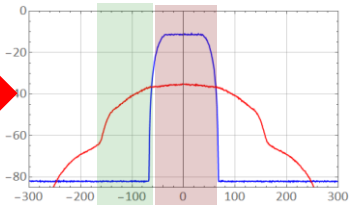


Data Display



X-Apps

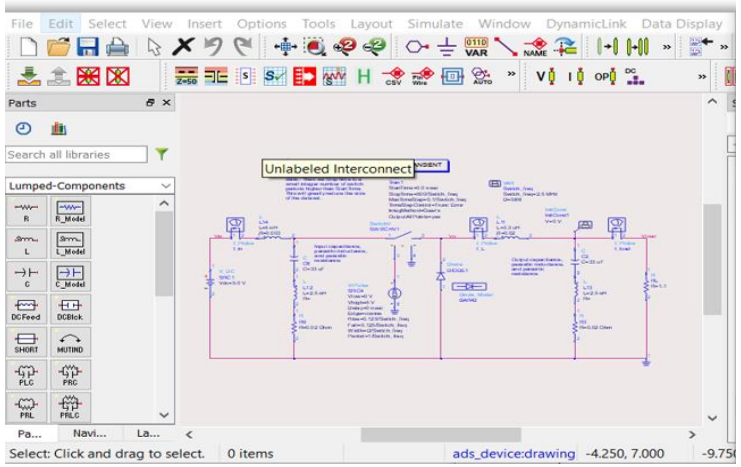
"Distortion EVM"



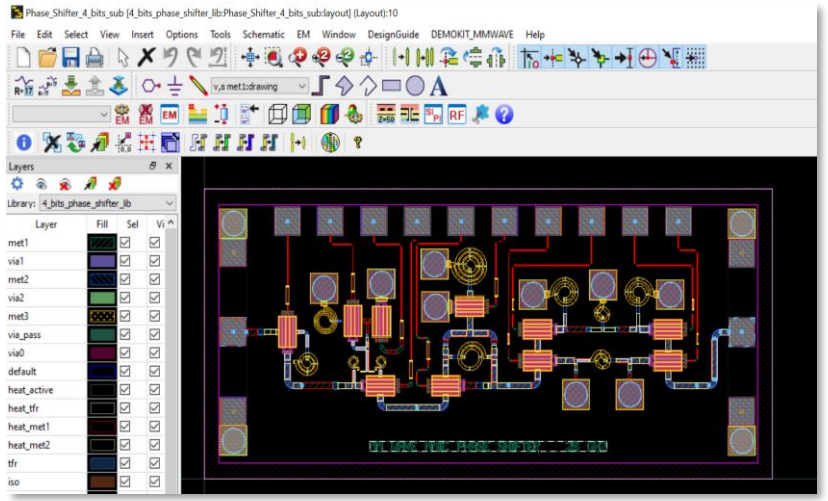
KEYSIGHT

Integrated Solution For Pre- And Post-Layout Analysis

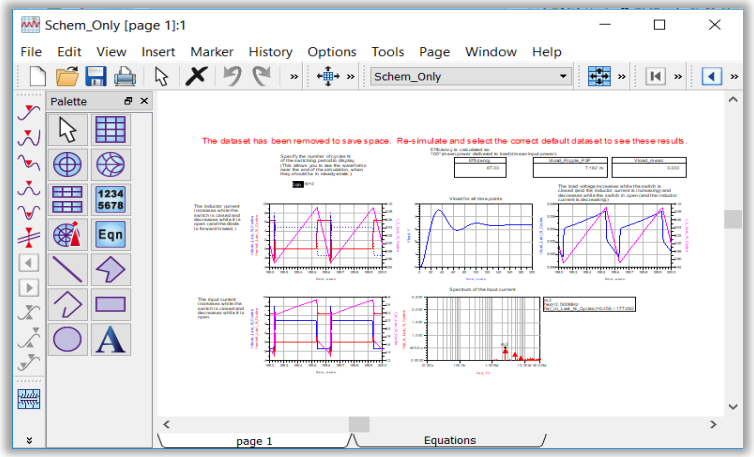
Schematic and Simulation



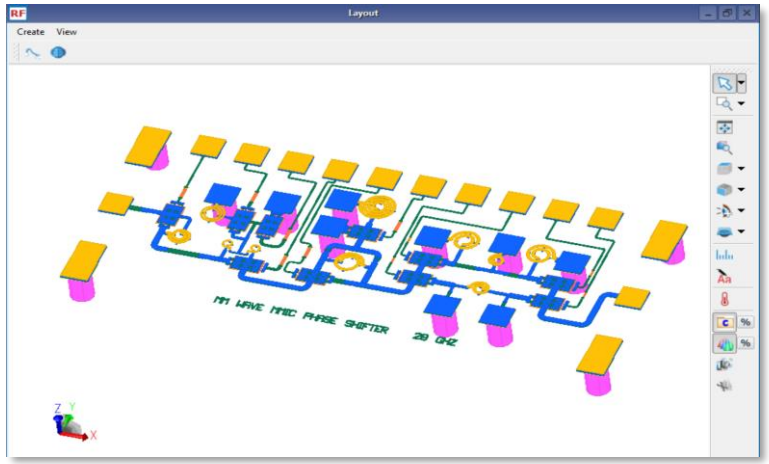
Layout



Post Processing

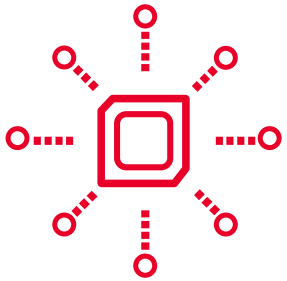


RFPro - 3DEM

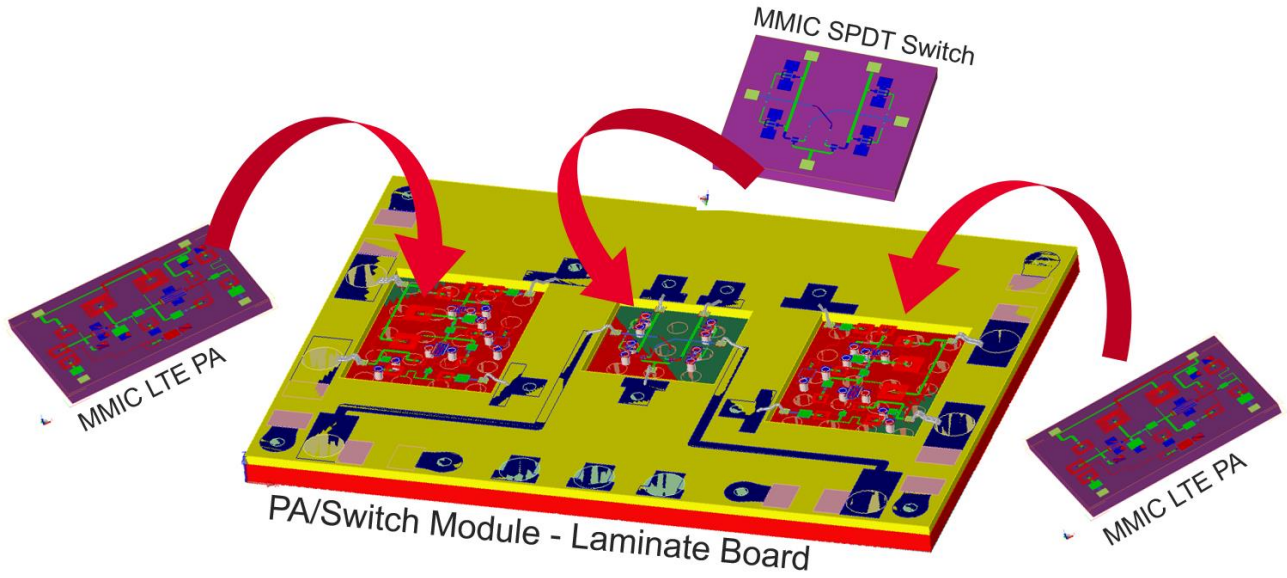


Demonstration: MMIC PA/Switch on Laminate Board

Design Flow



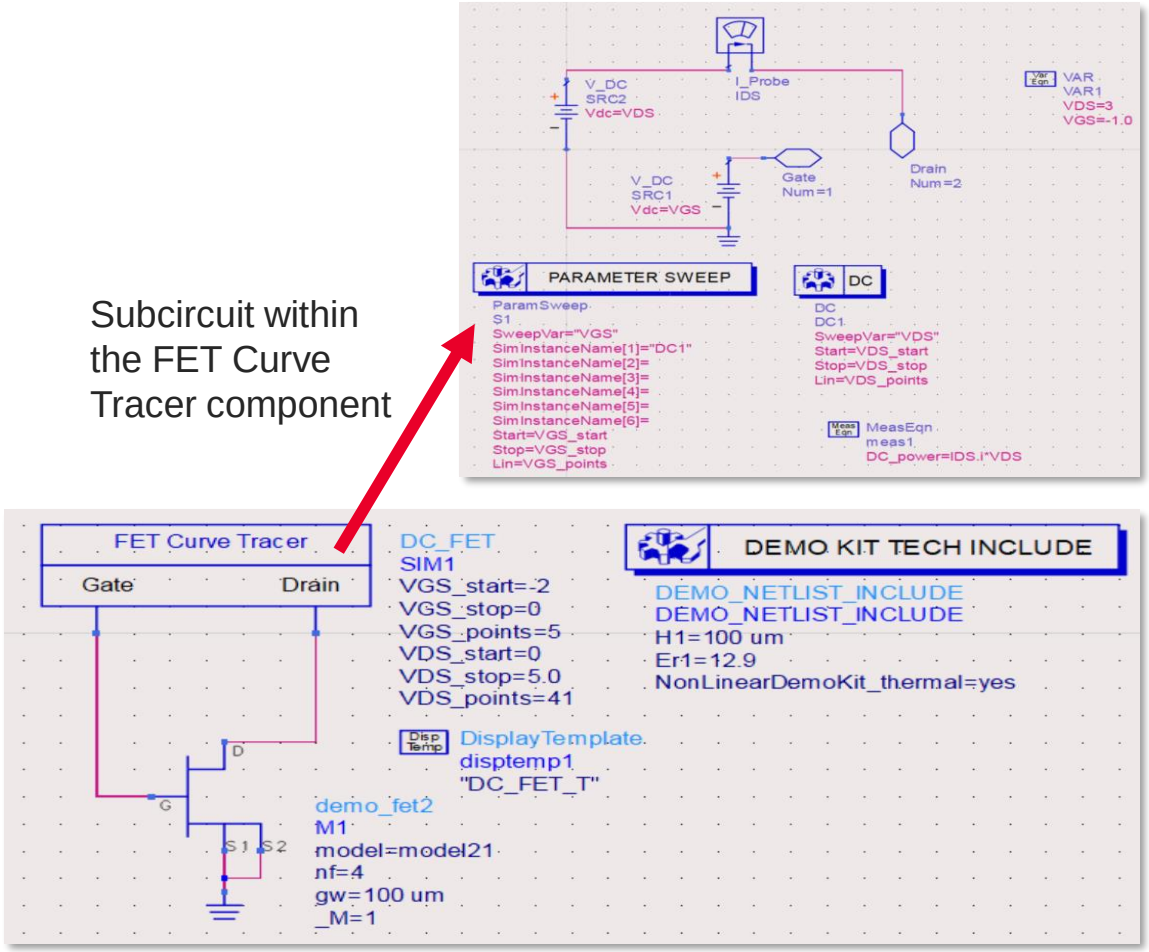
- DC Analysis of FET
- Optimization of Circuits for Stability/Impedance Matching
- Using of PDK Components
- Design Synchronization
- Substrate Definition
- EM Simulation with RFPro
- Smart Mount on Laminate Board
- Validation: Harmonic Balance/Virtual Test Bench

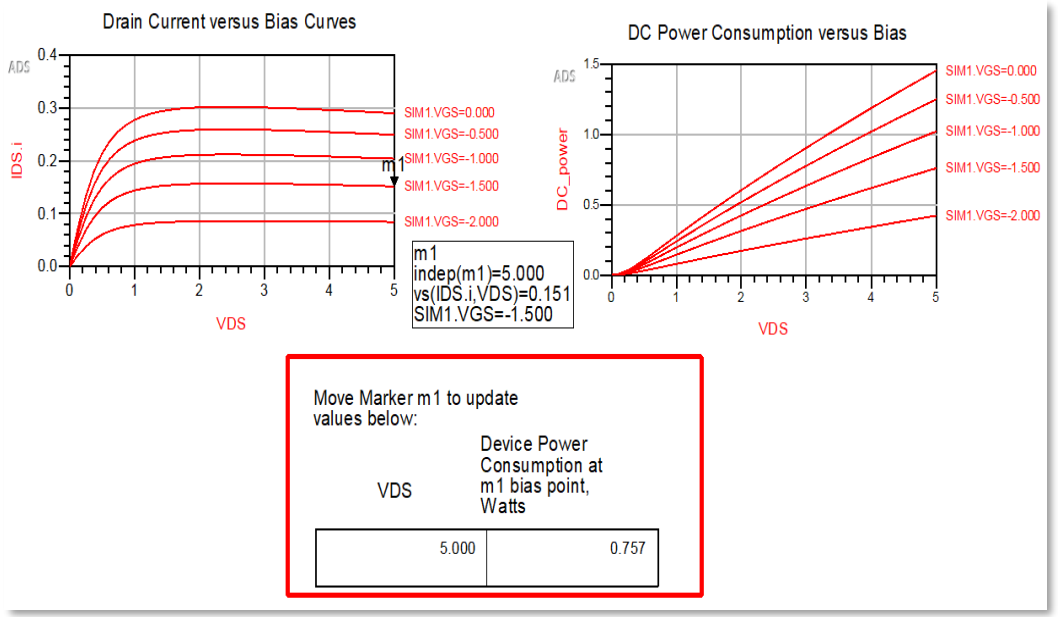


Schematic Design – DC Analysis of FET

- DC Analysis is usually performed at the start of amplifier design to understand the transistor performance
- ADS provides template that quickly helps designers to setup the simulation test bench.

Subcircuit within the FET Curve Tracer component

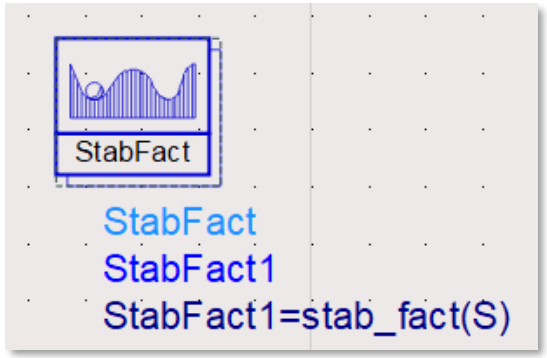


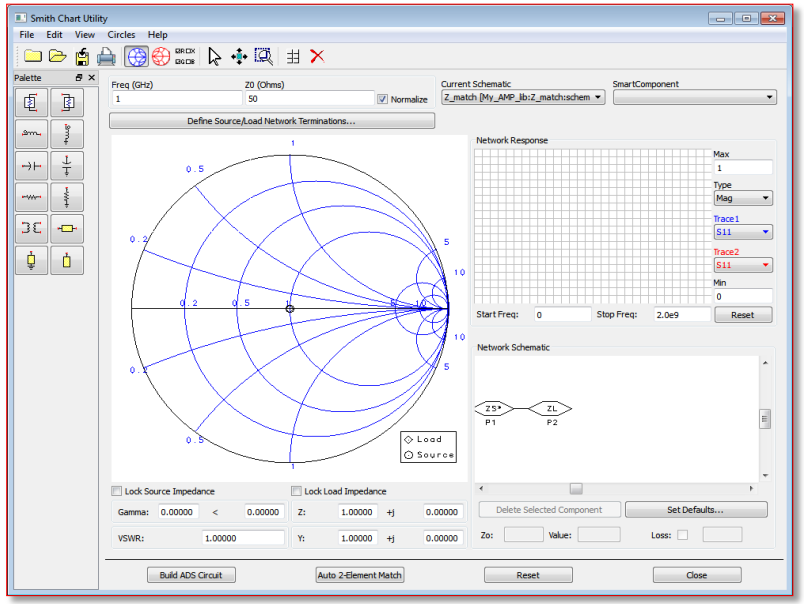


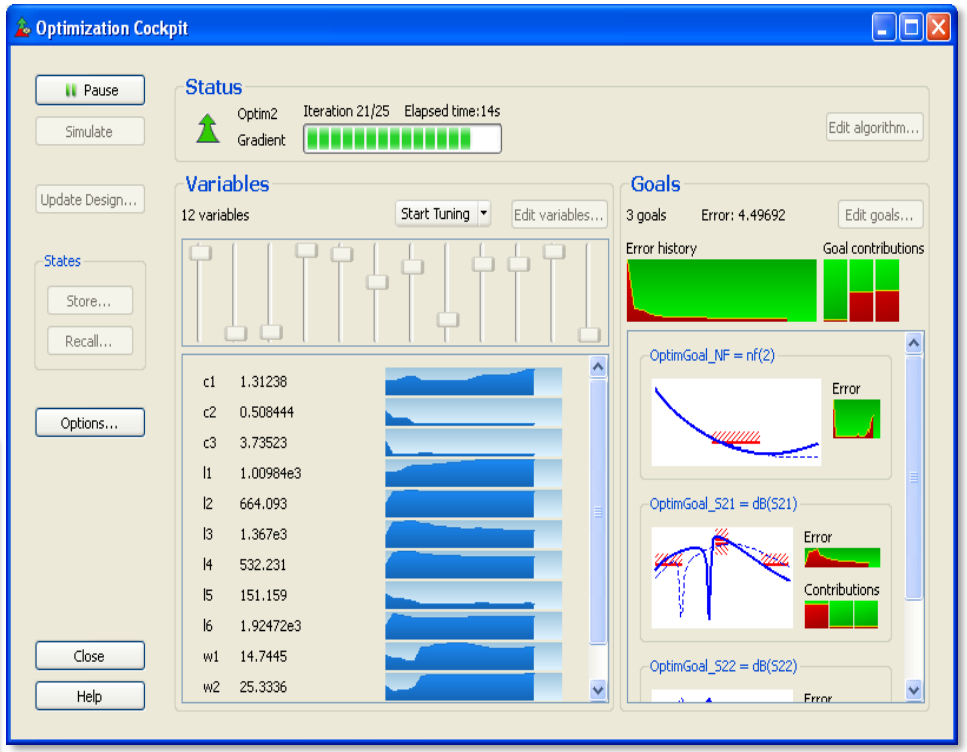
Schematic Design – Optimization of Circuits

- After understanding the transistor performance, designer will start to create the various circuit:
  1. Bias Circuit
  2. Stability Circuit
  3. Impedance Matching Circuit

- ADS Provides tools that helps designer to achieve their goals:
  1. Smith Chart Utility Tool for Impedance Matching
  2. StabFact component to measure stability quickly
  3. Optimization Cockpit



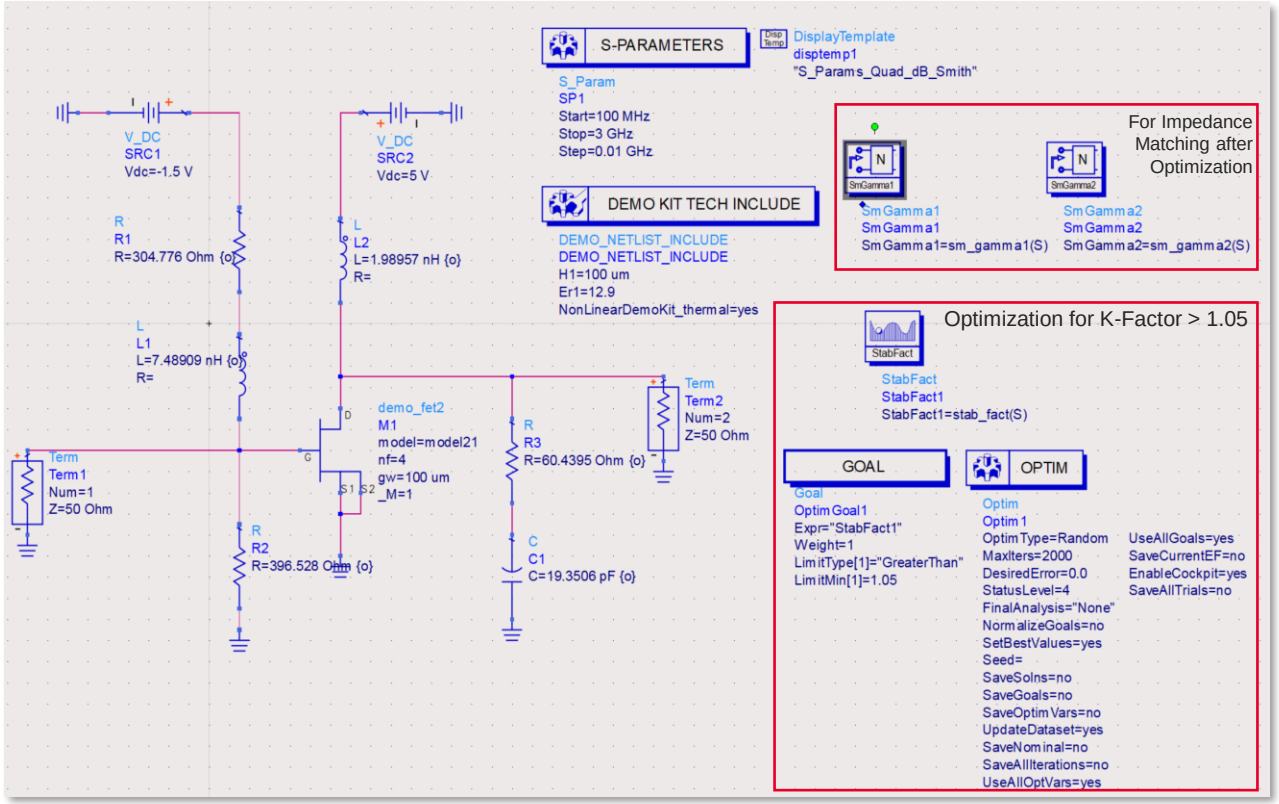


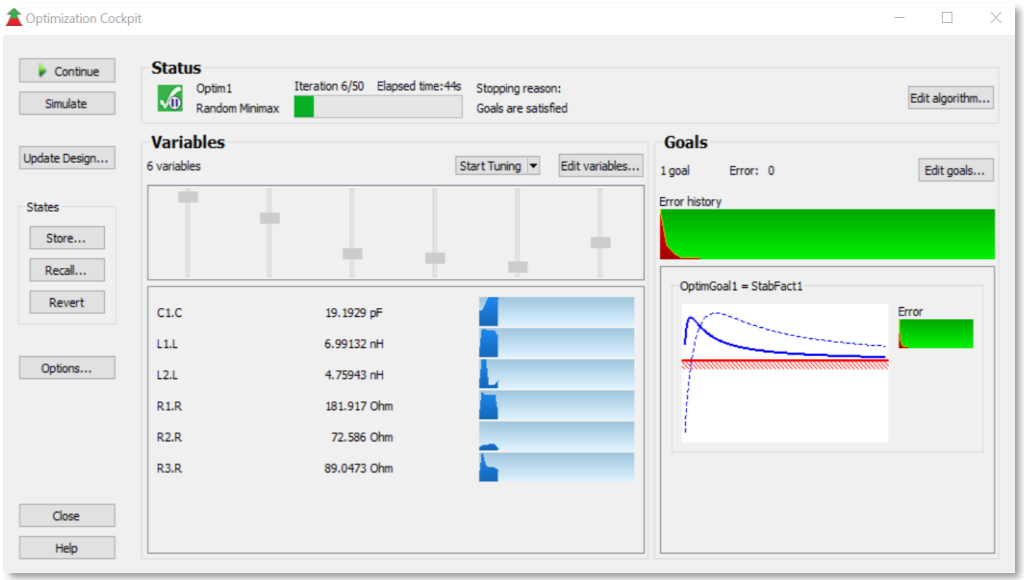


Schematic Design – S-Parameter Simulation

Stability Optimization

- Perform S-Parameter simulation for Stability and Impedance Matching purposes.
- Below schematic perform Optimization for Stability (K-Factor) > 1.05 at all frequencies.
- SmGamma1 and SmGamma2 to measure simultaneous-match input-reflection and output-reflection coefficient.

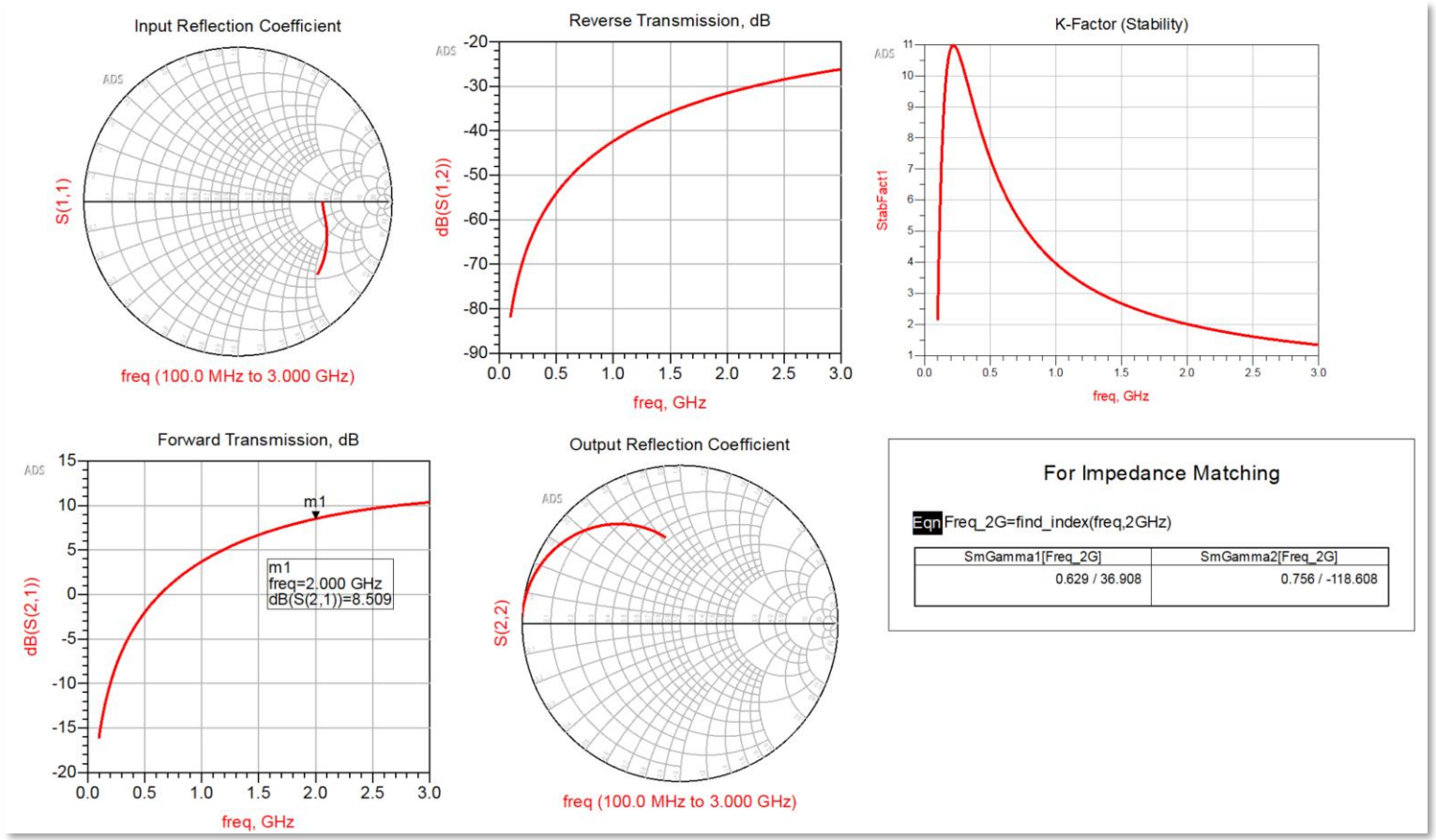




Schematic Design – S-Parameter Simulation

Stability Optimization

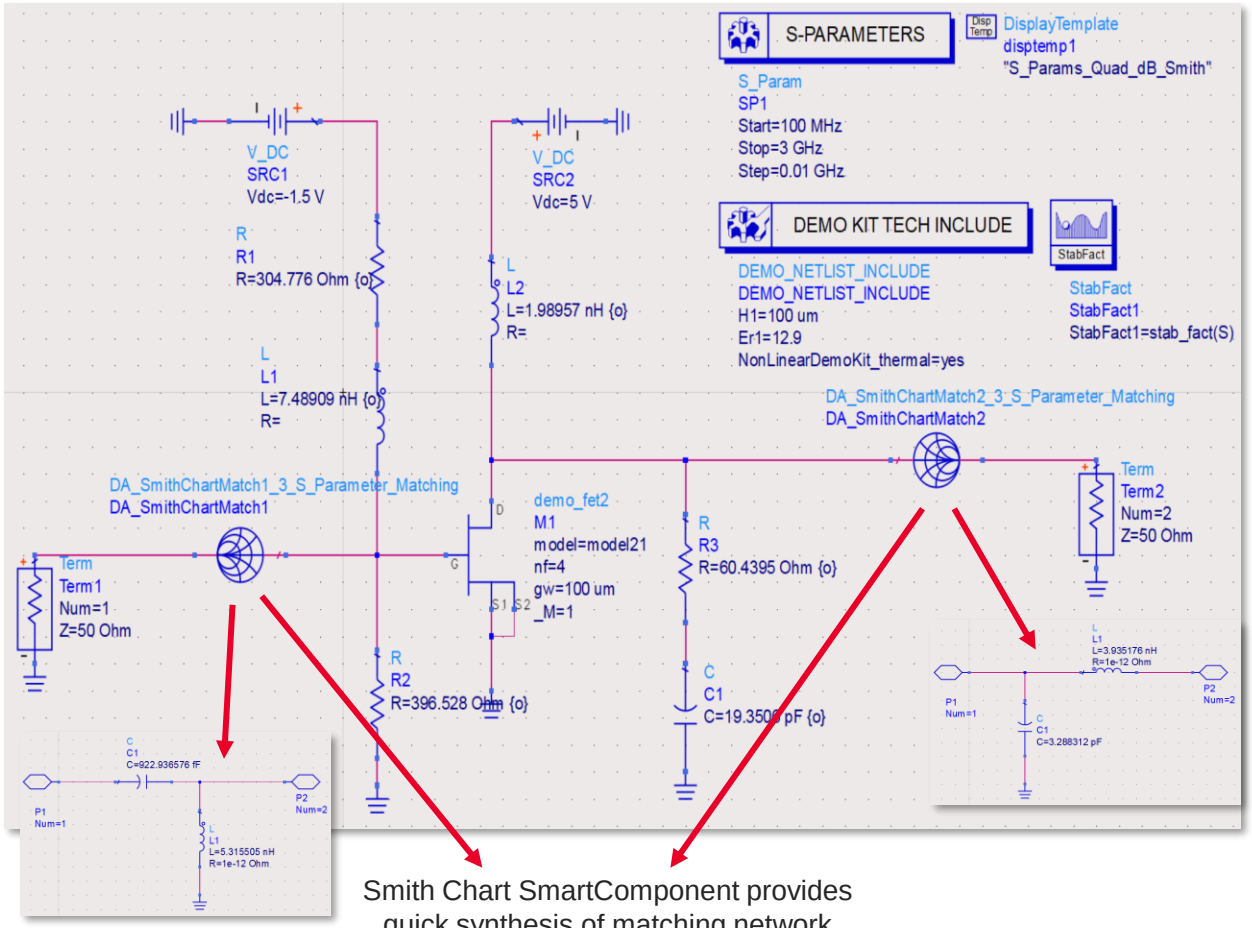
- Optimized K-Factor Results with S-Parameters being measured.
- SmGamma1 and SmGamma2 values are measured for impedance matching (@ 2GHz) for the next step.



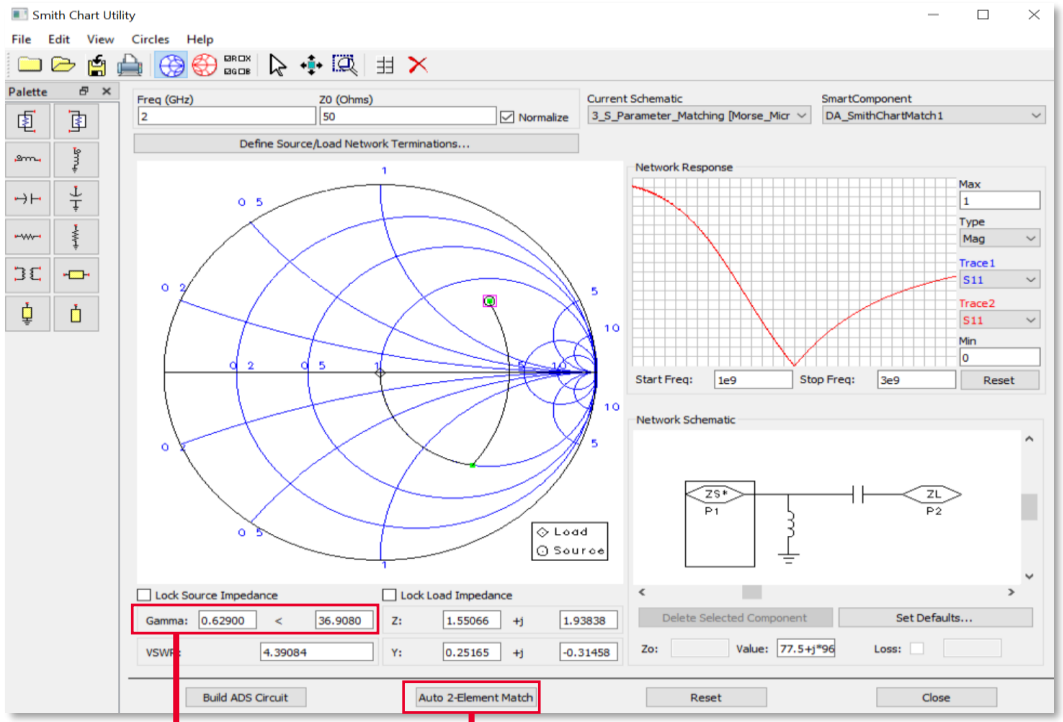
Schematic Design – S-Parameter Simulation

Impedance Matching @ 2GHz – Smith Chart Utility Tool

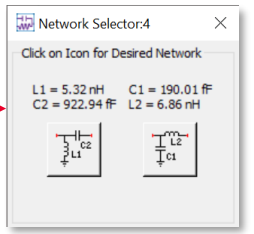
- Based on the measured SmGamma1 and SmGamma2, these values can be placed in the Smith Chart Utility Tool to creating matching network automatically.



Smith Chart SmartComponent provides quick synthesis of matching network together with Smith Chart Utility Tool



SmGamma1 and SmGamma2 values used for impedance matching

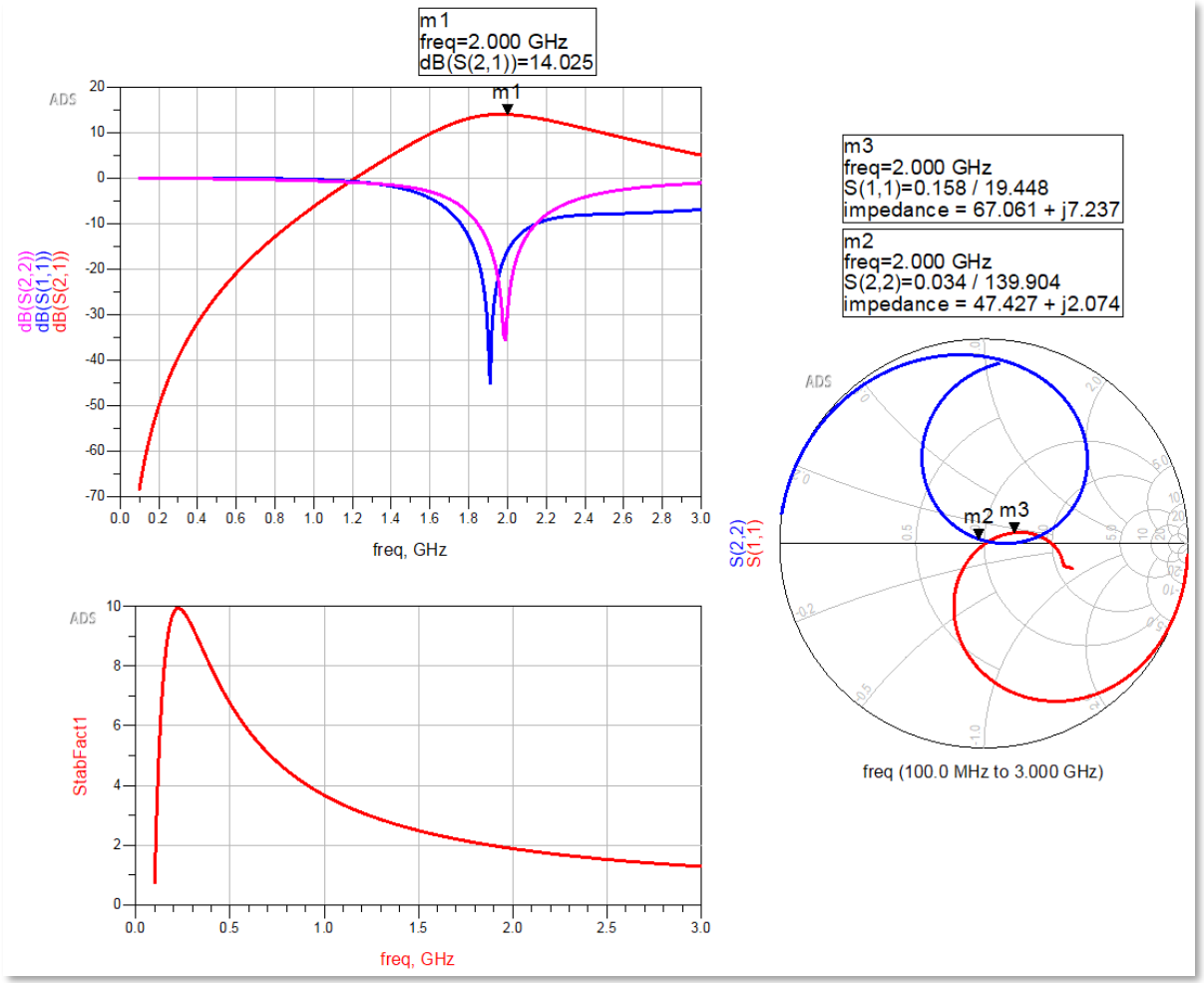


Quick automatic generation of matching network

Schematic Design – S-Parameter Simulation

Impedance Matching – Smith Chart Utility Tool

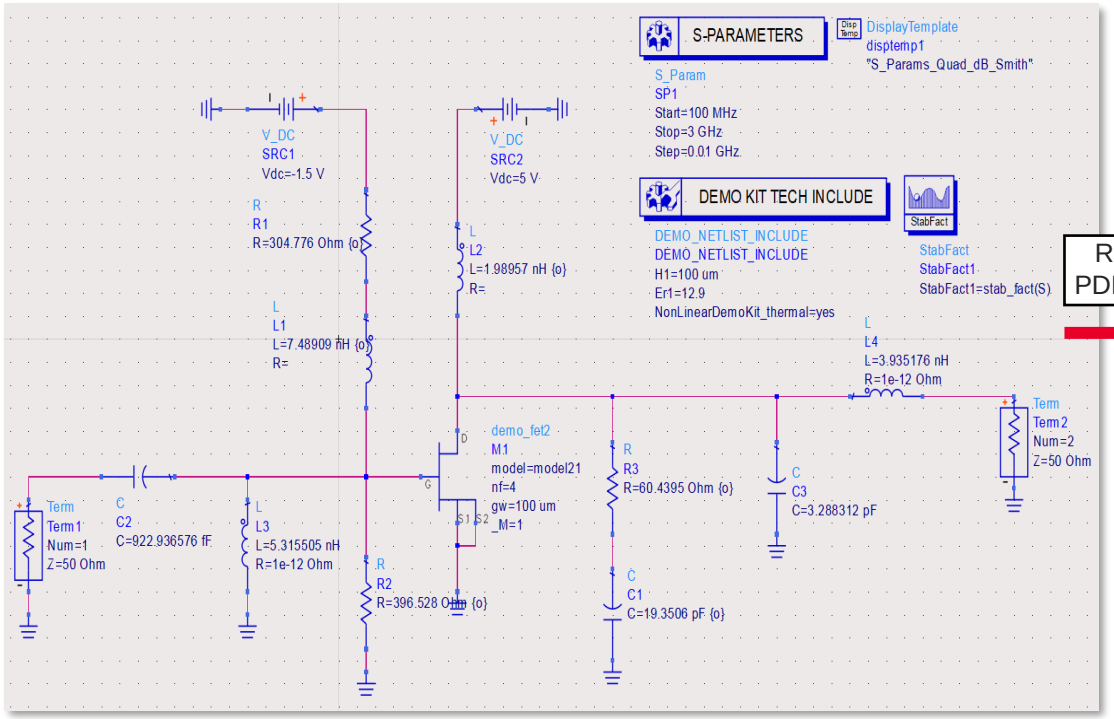
- Impedance Matched Results



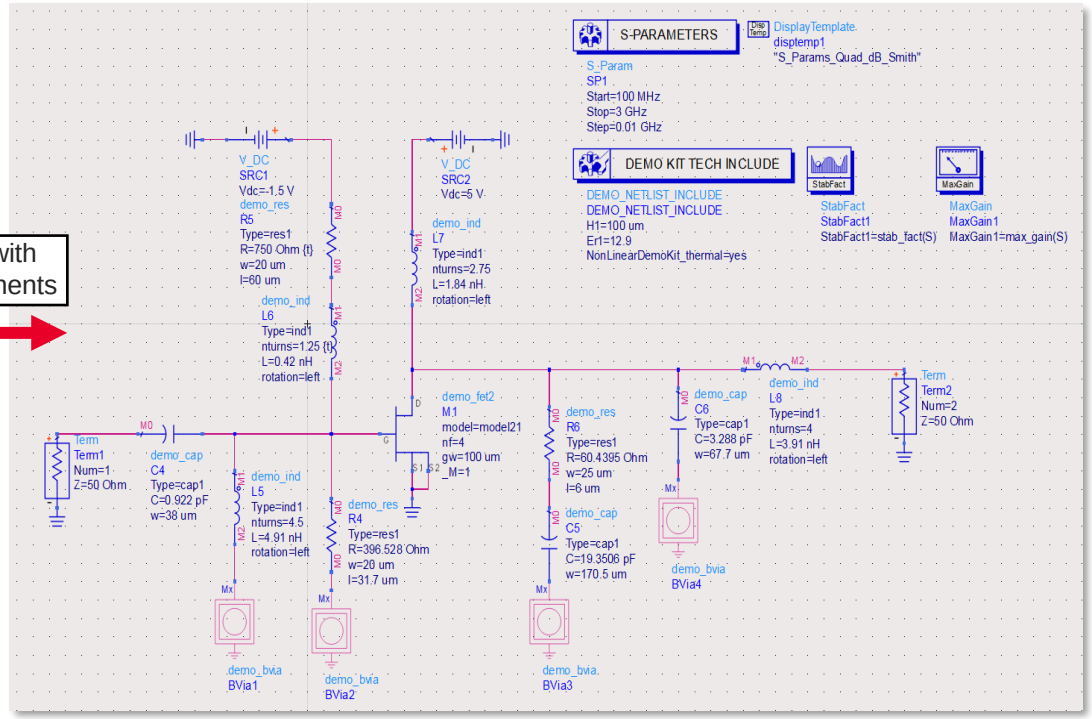
Schematic Design – S-Parameter Simulation

Using PDK Components

- To bring the results one step closer to the measurement results, Process Design Kits (PDKs) from Foundries or Vendors will be used to replace the ideal components.
- Due to the model creation depending on the Foundries or Vendors, ideal component values may not be exactly replaced with PDK component values – especially for inductor models.



Replaced with PDK components

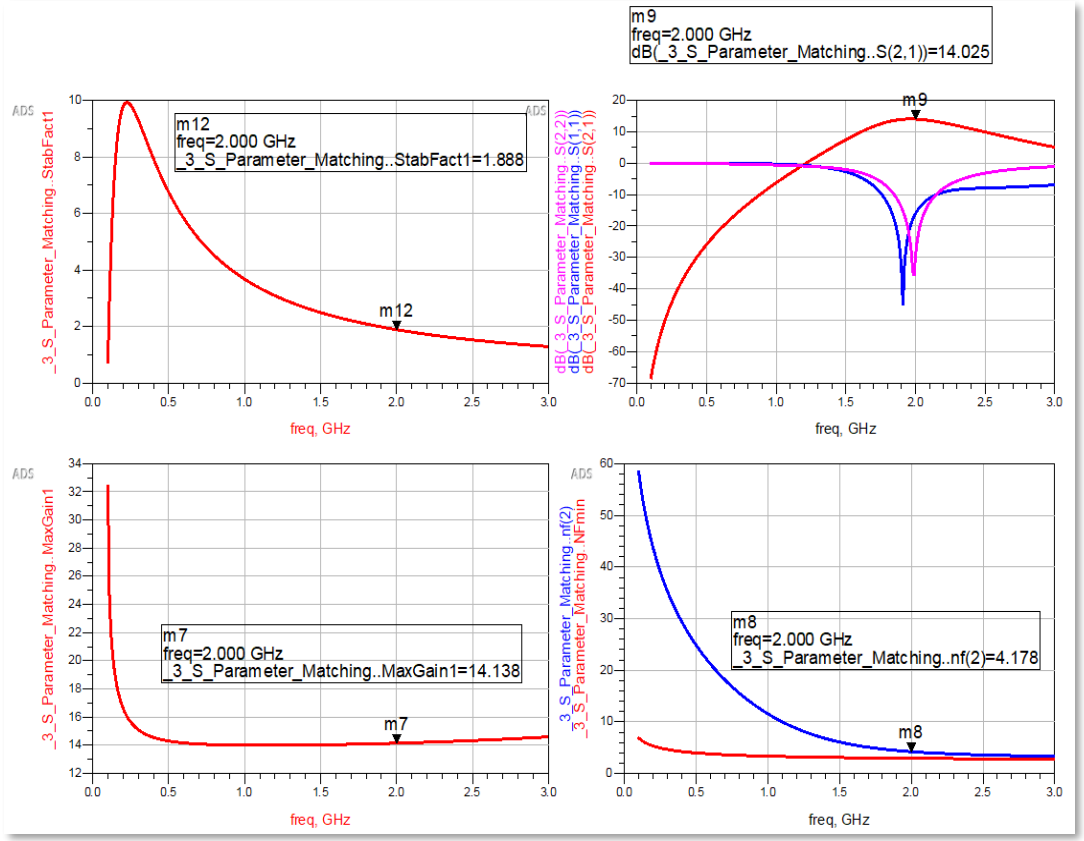


Schematic Design – S-Parameter Simulation

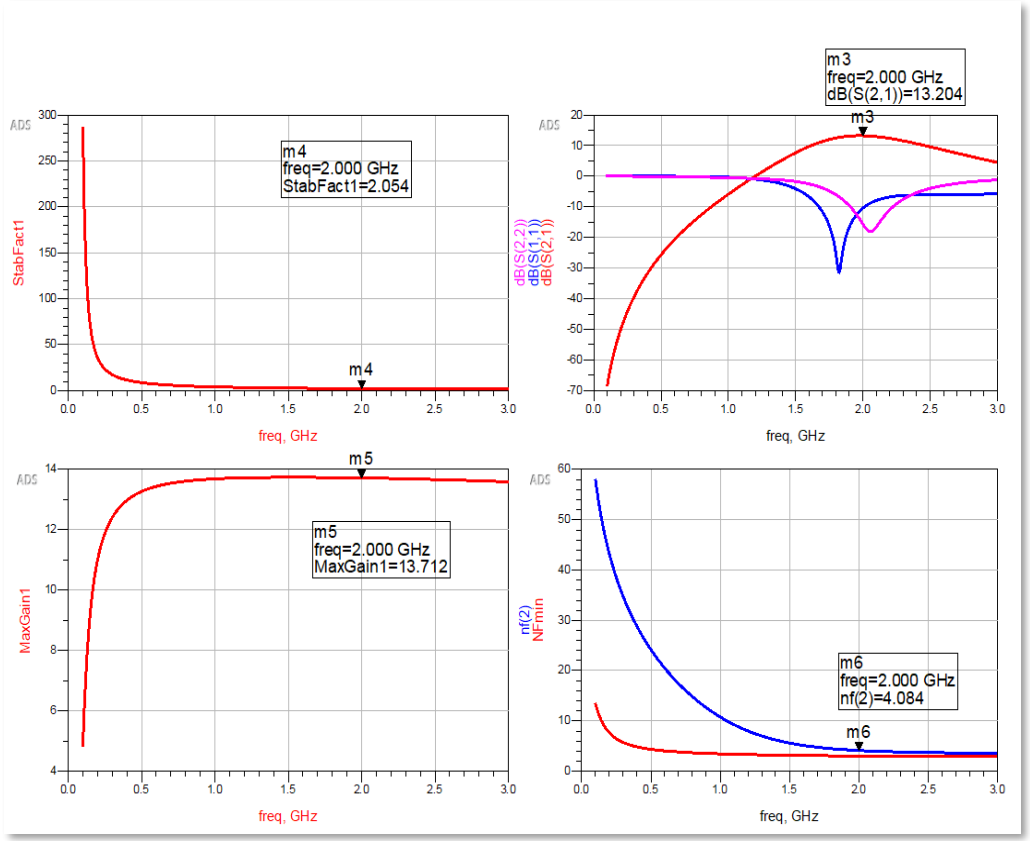
Using PDK Components

- Comparison of Results

Using Ideal Components



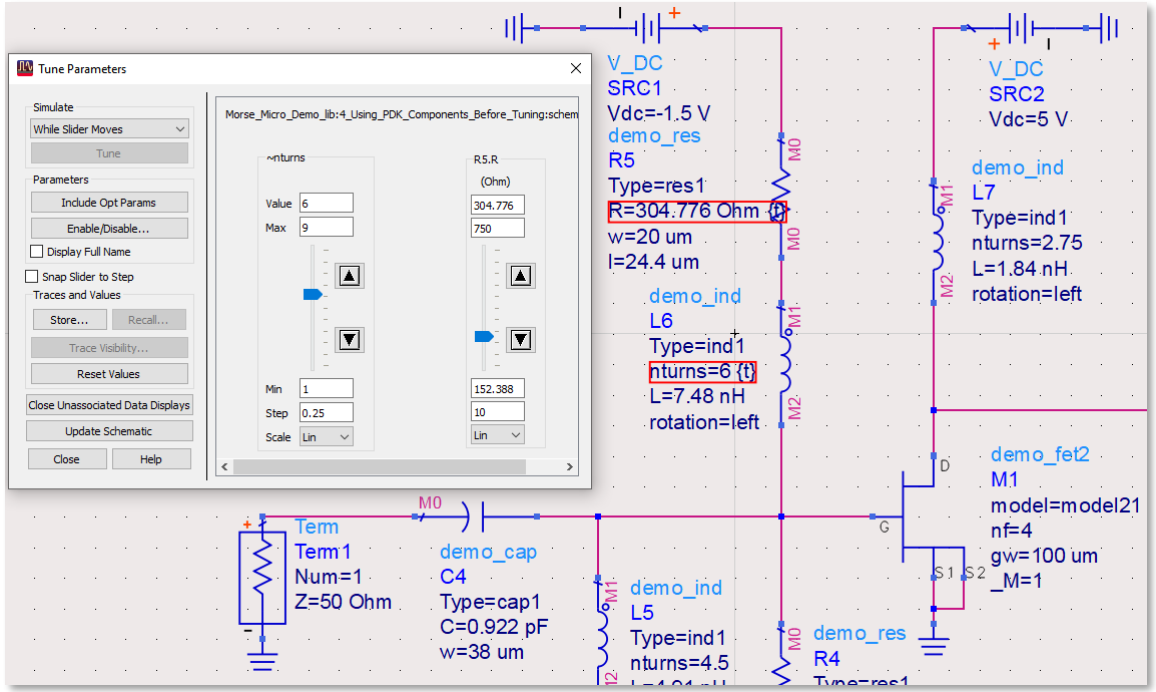
Using PDK Components



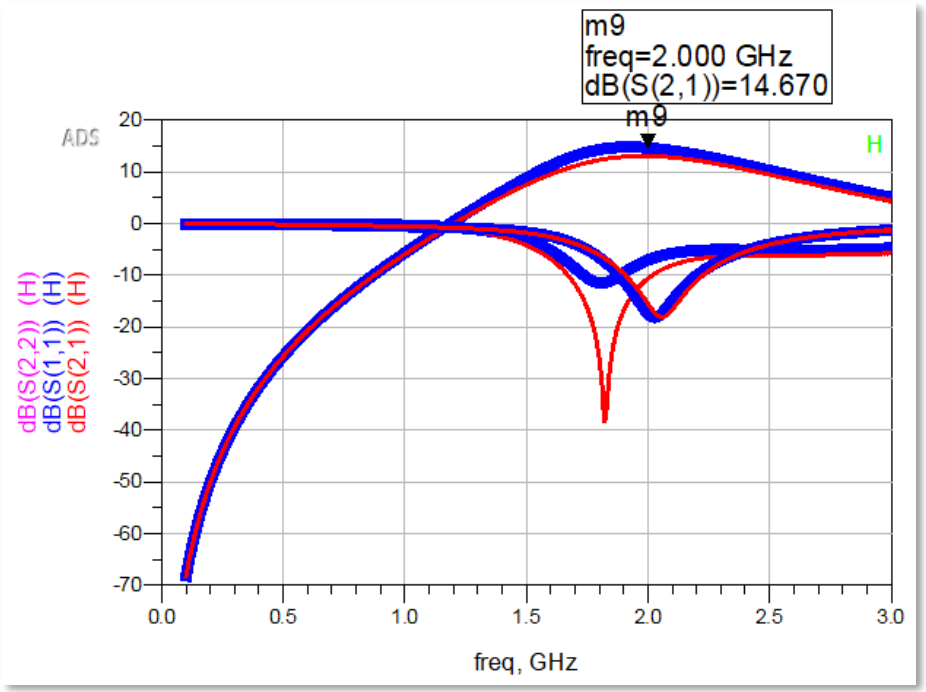
Schematic Design – S-Parameter Simulation

Using PDK Components - Tuning

- Tuning can help to fine tune the performance of the design.
- Tuning updates the results instantly – no need to re-run the simulation.



Blue plot shows updated results once components are being tuned.



Schematic Design – S-Parameter Simulation

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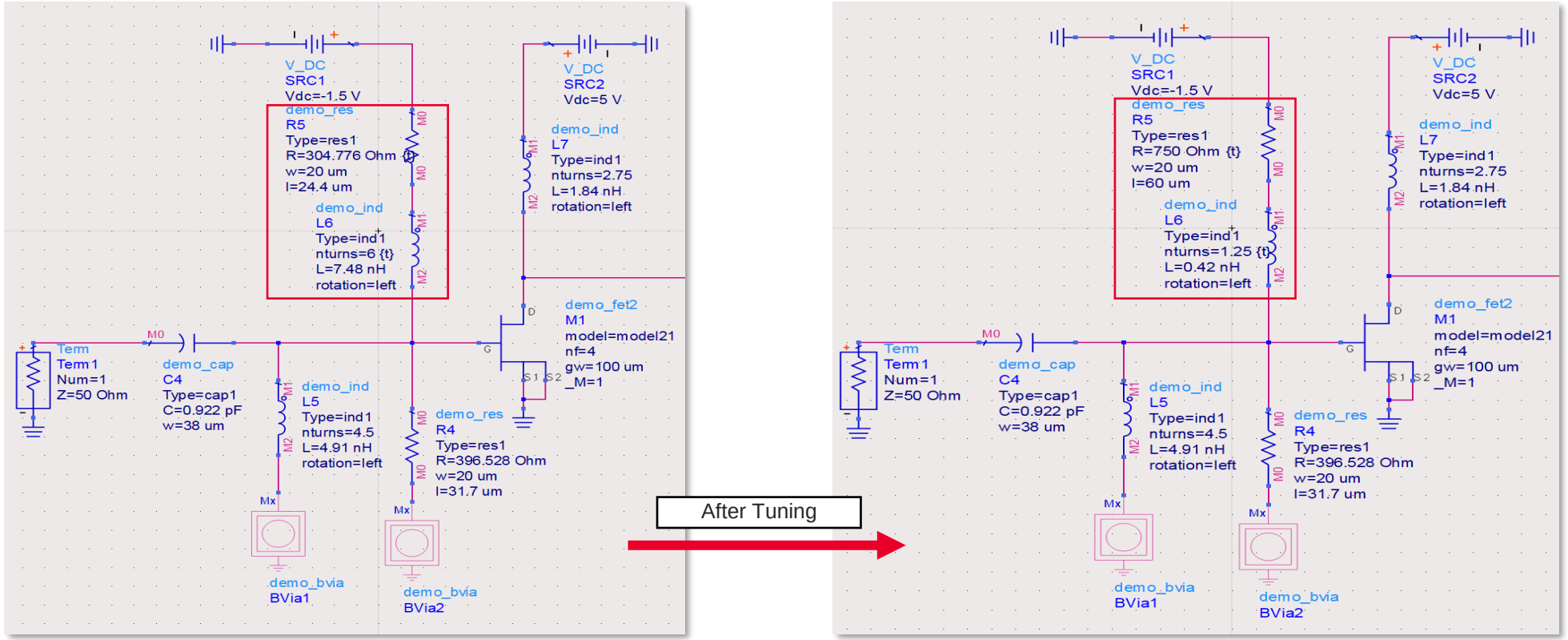
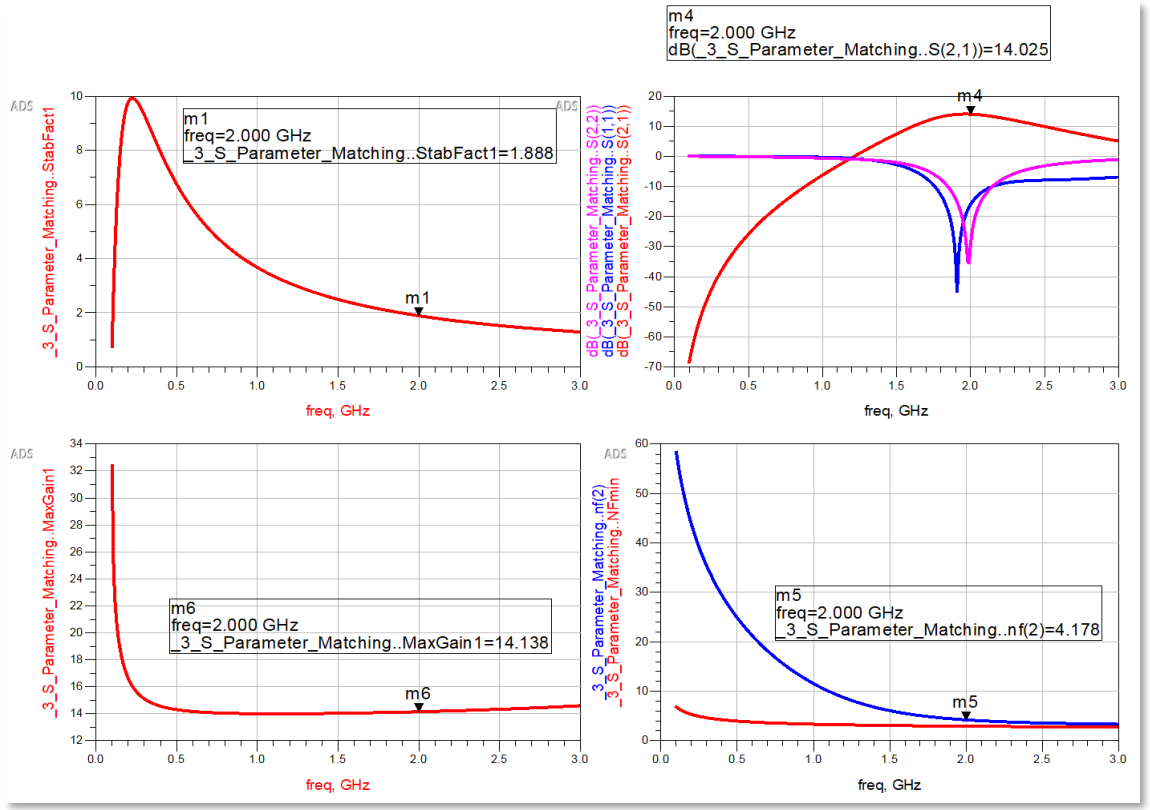
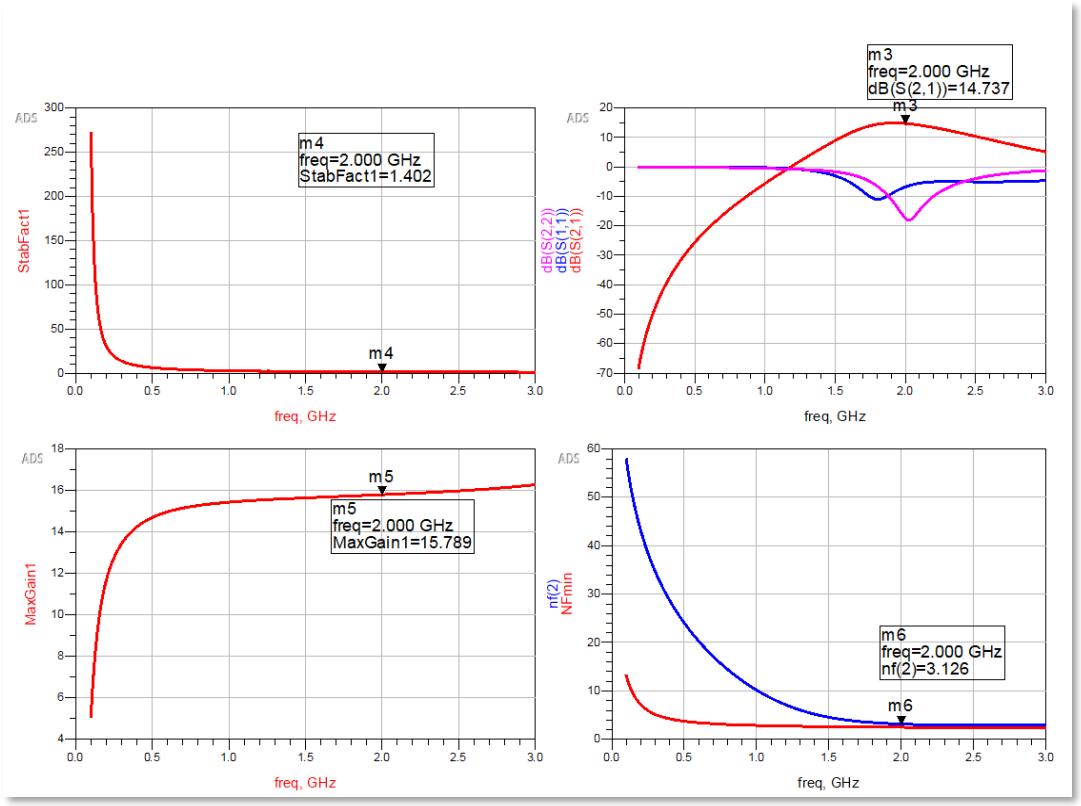


Schematic Design – S-Parameter Simulation

Using PDK Components - Tuning

- Tuning can help to fine-tune and improve the results.

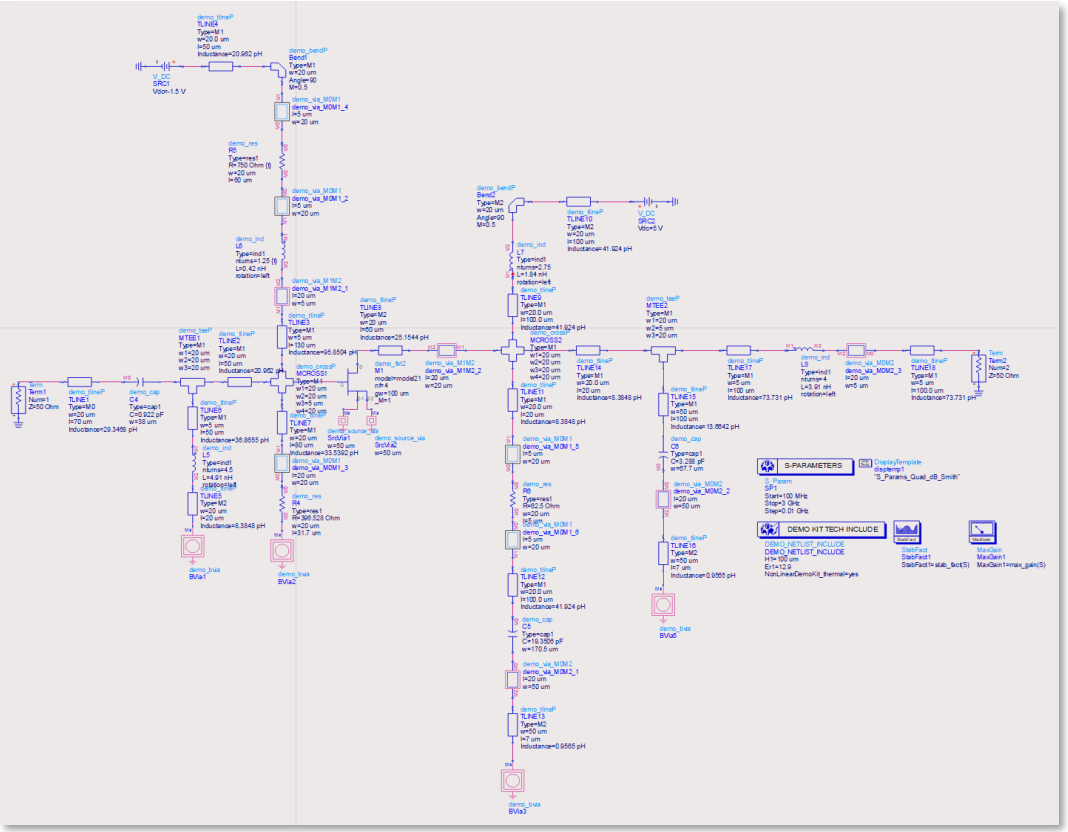


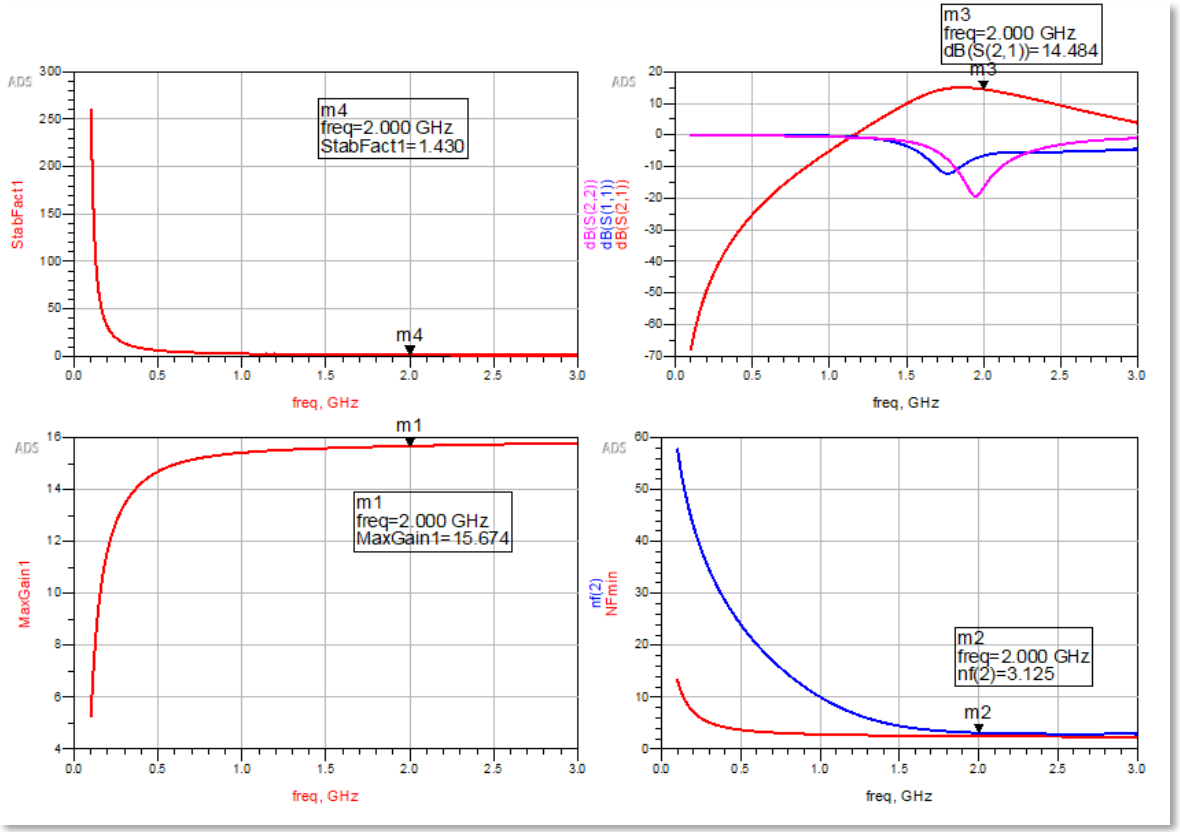


Schematic Design – S-Parameter Simulation

Using PDK Components – Microstrip Line

- To complete the simulation, PDK Microstrip line are used to complete the design.
- If the results shift too much, consider Tuning/Optimization to fine tune the results.

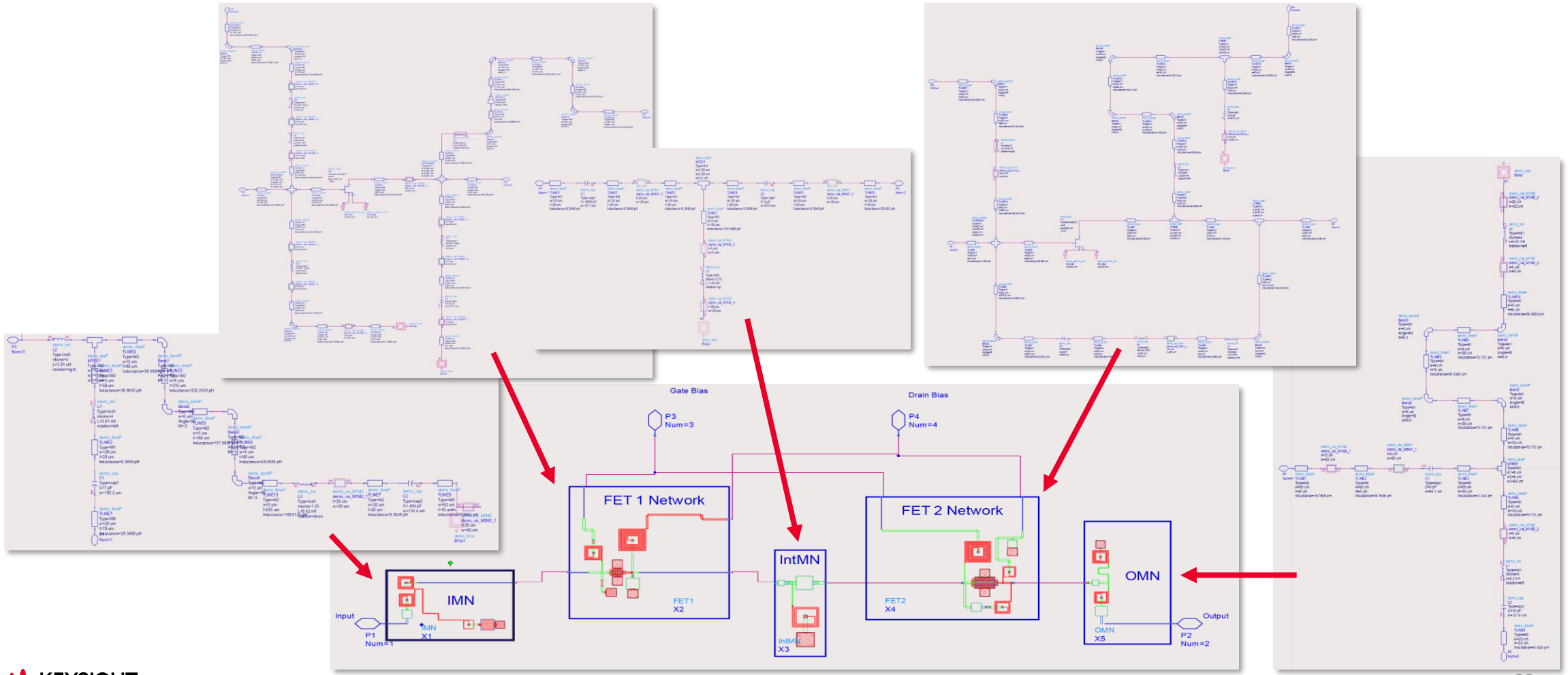




Schematic Design – S-Parameter Simulation

Complete Design: 2 Stage Amplifier Design

- The final demo design is a 2-Stage Amplifier and below are the schematic and results details.



Schematic Design – S-Parameter Simulation

Complete Design: 2 Stage Amplifier Design

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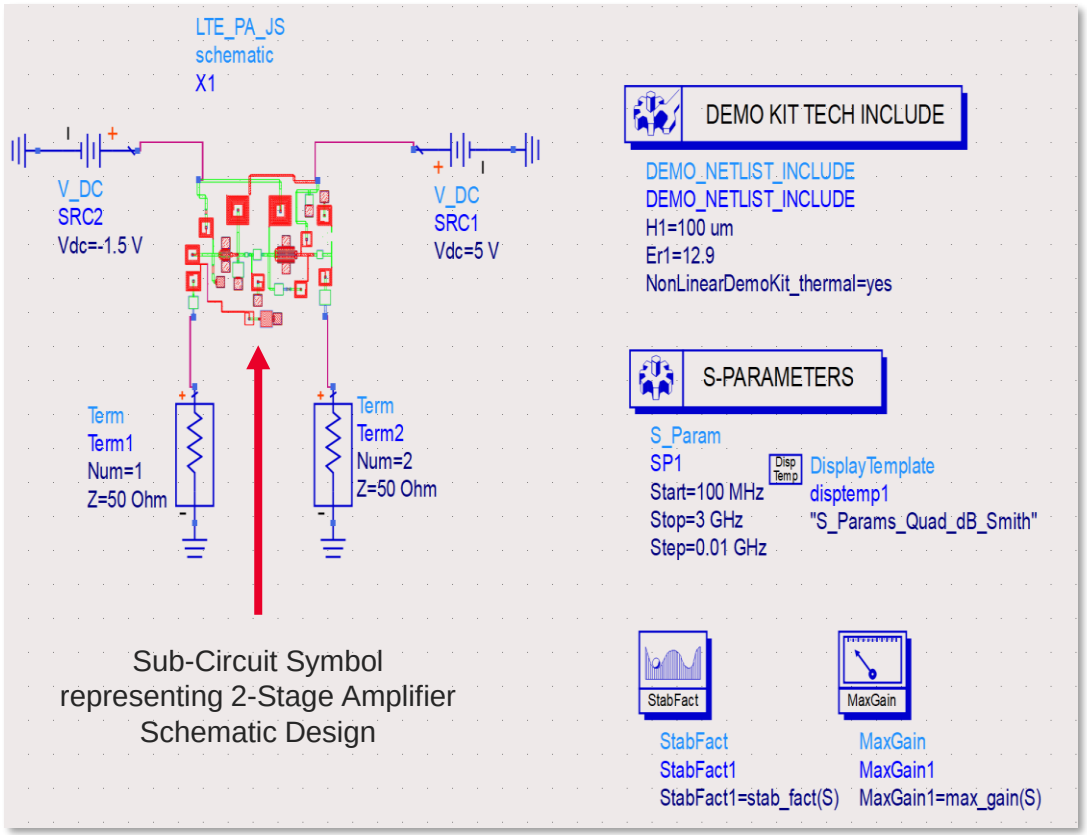
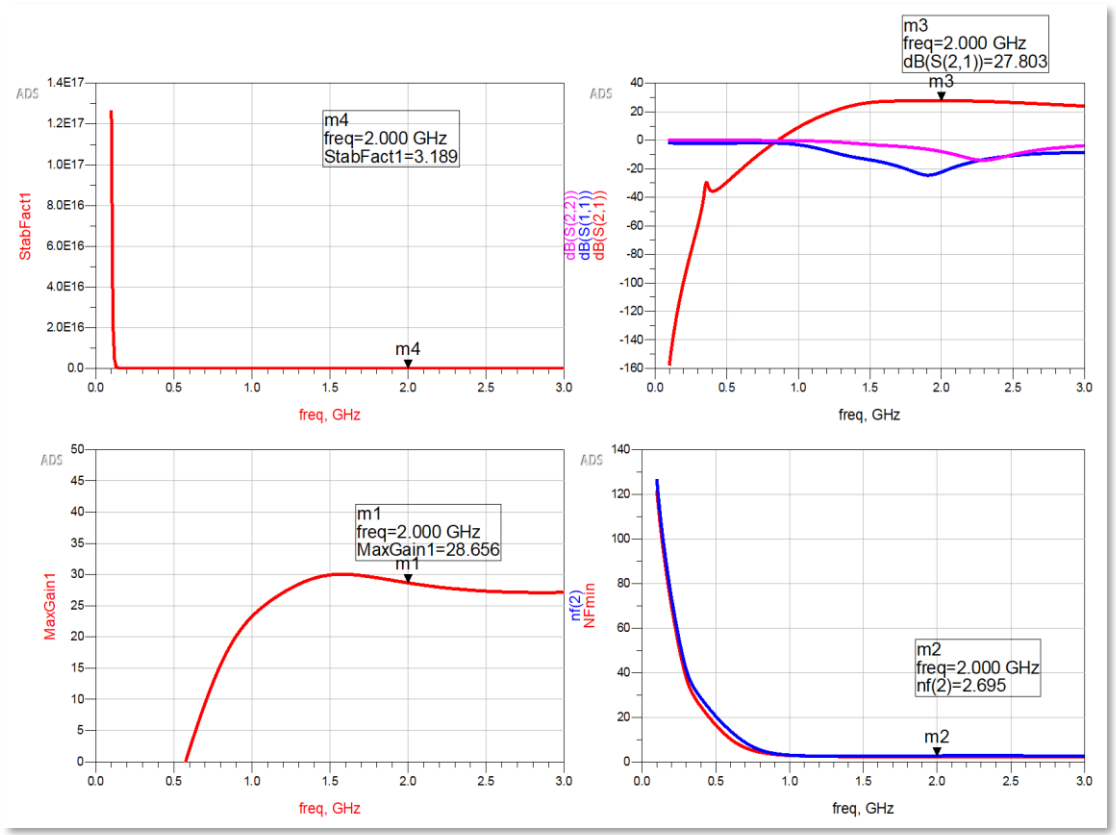


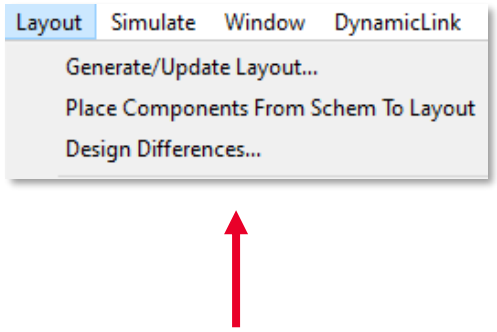
Sub-Circuit Symbol representing 2-Stage Amplifier Schematic Design



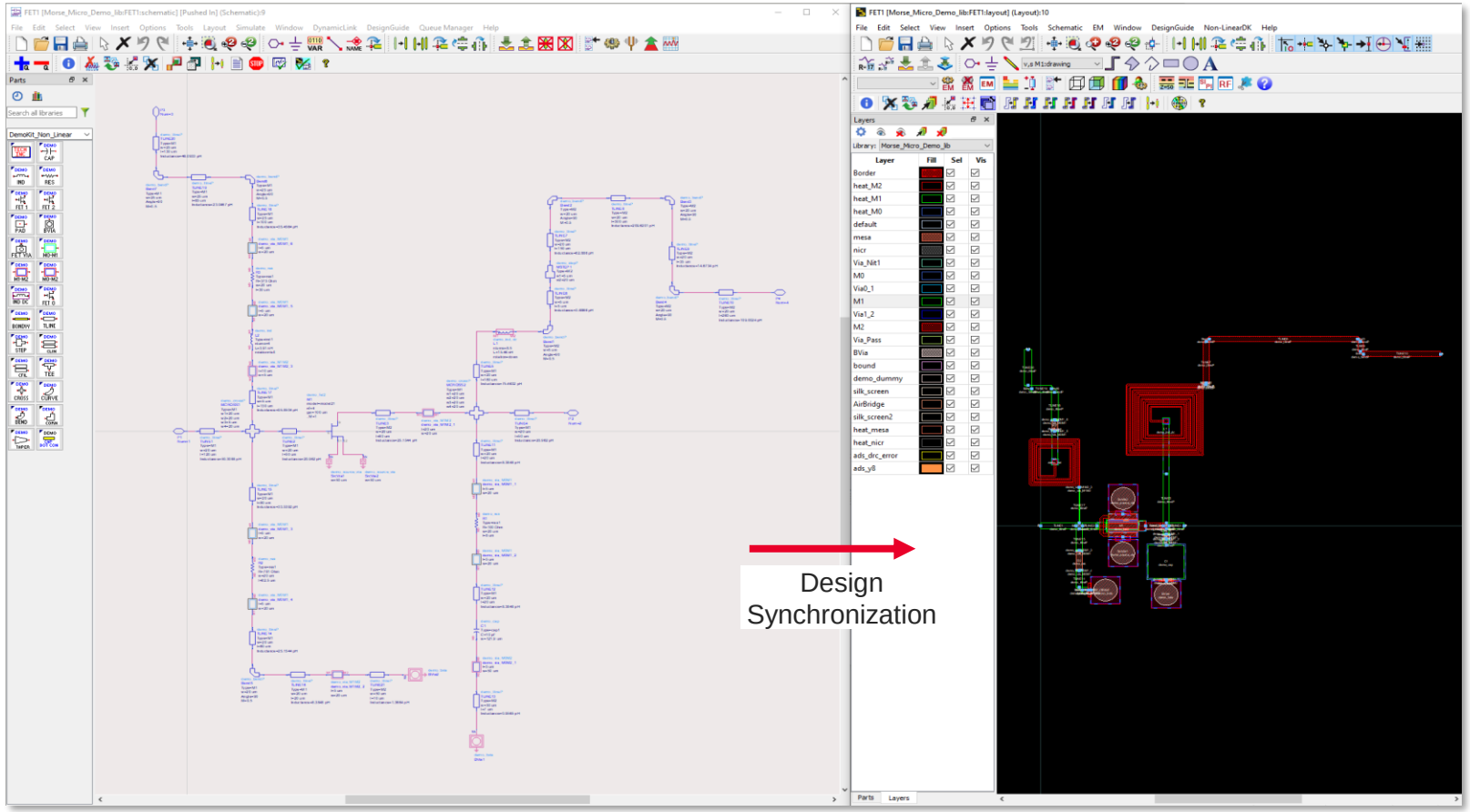
Layout Design – Design Synchronization

From Schematic to Layout

- Design Synchronization allows designs from schematic to be brought over to layout, while maintaining the schematic parameter such as component values, layout parameters (e.g Width, Length, No. of Turns, etc.) in layout.
- Valid for PDK Models/Components that has both schematic and layout components.



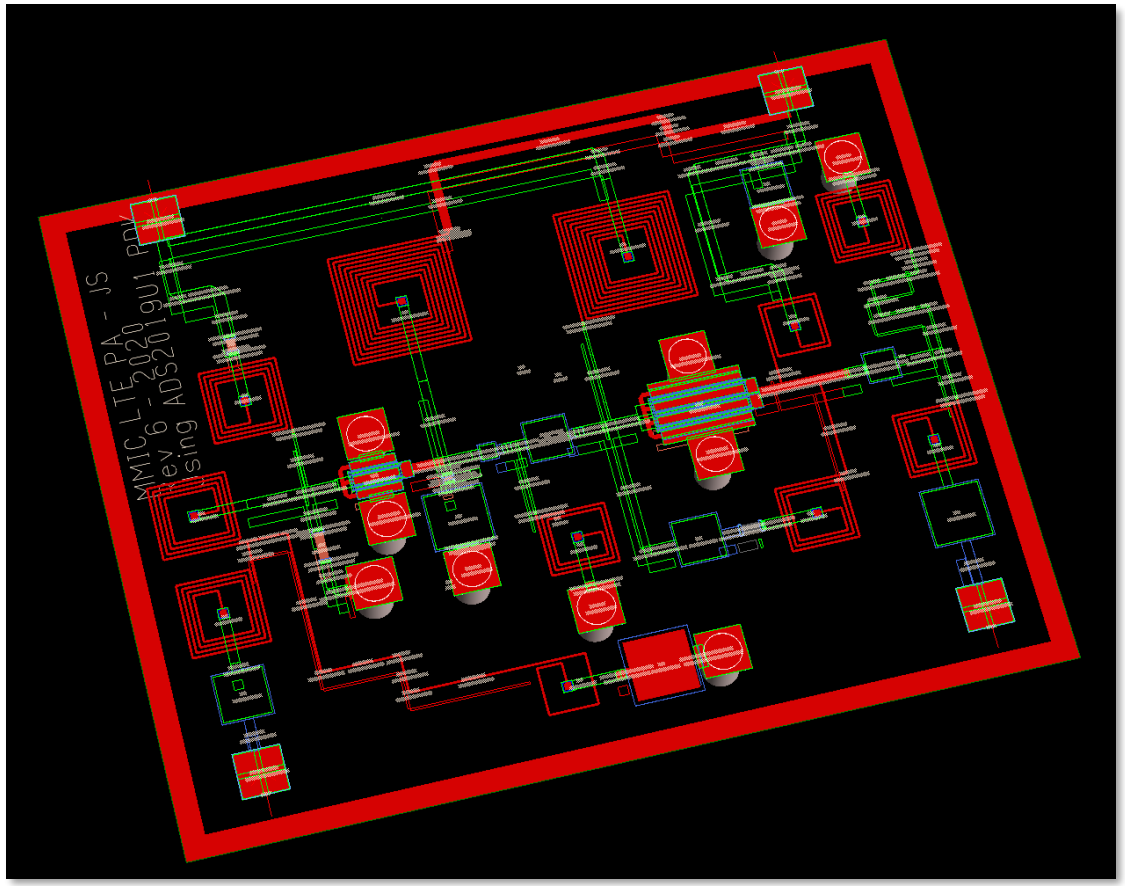
Design Synchronization options, to bring all schematic design into layout with a single import, or import the components into the layout individually.



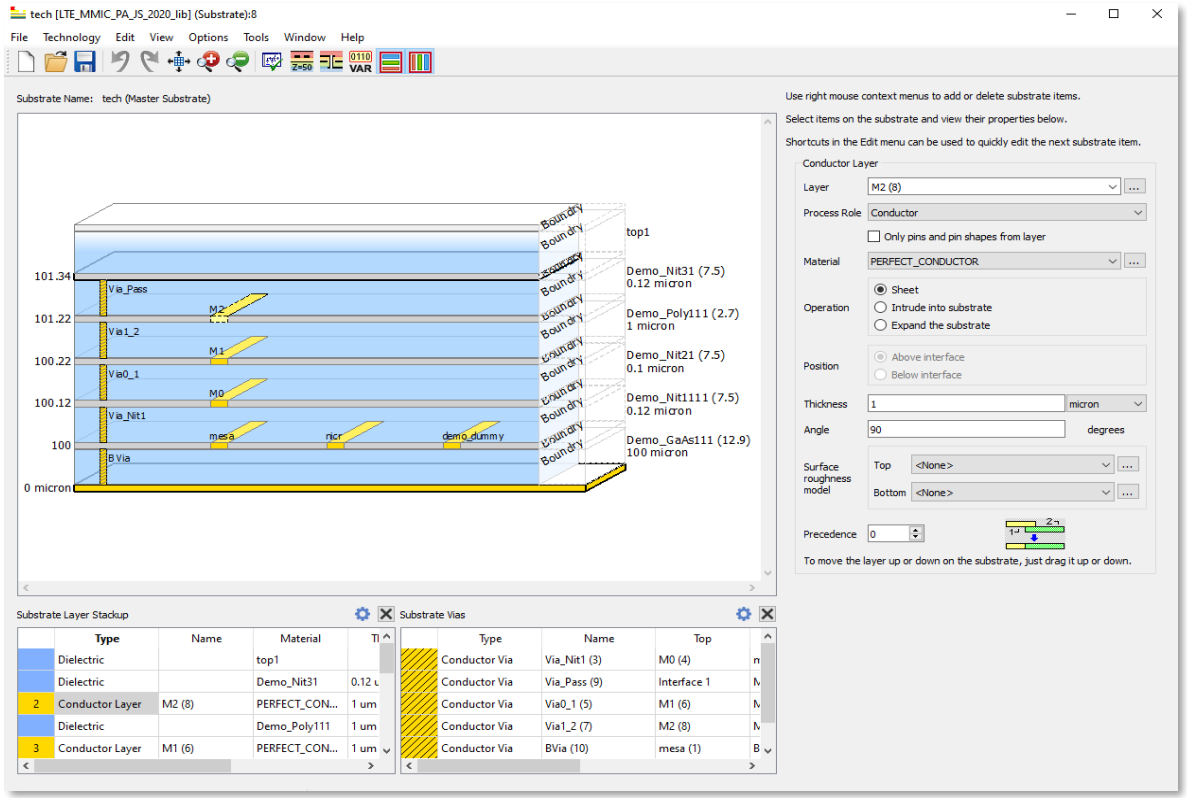
Layout Design – Design Synchronization

From Schematic to Layout

- Complete Layout Design for the 2-Stage Amplifier after design synchronization.

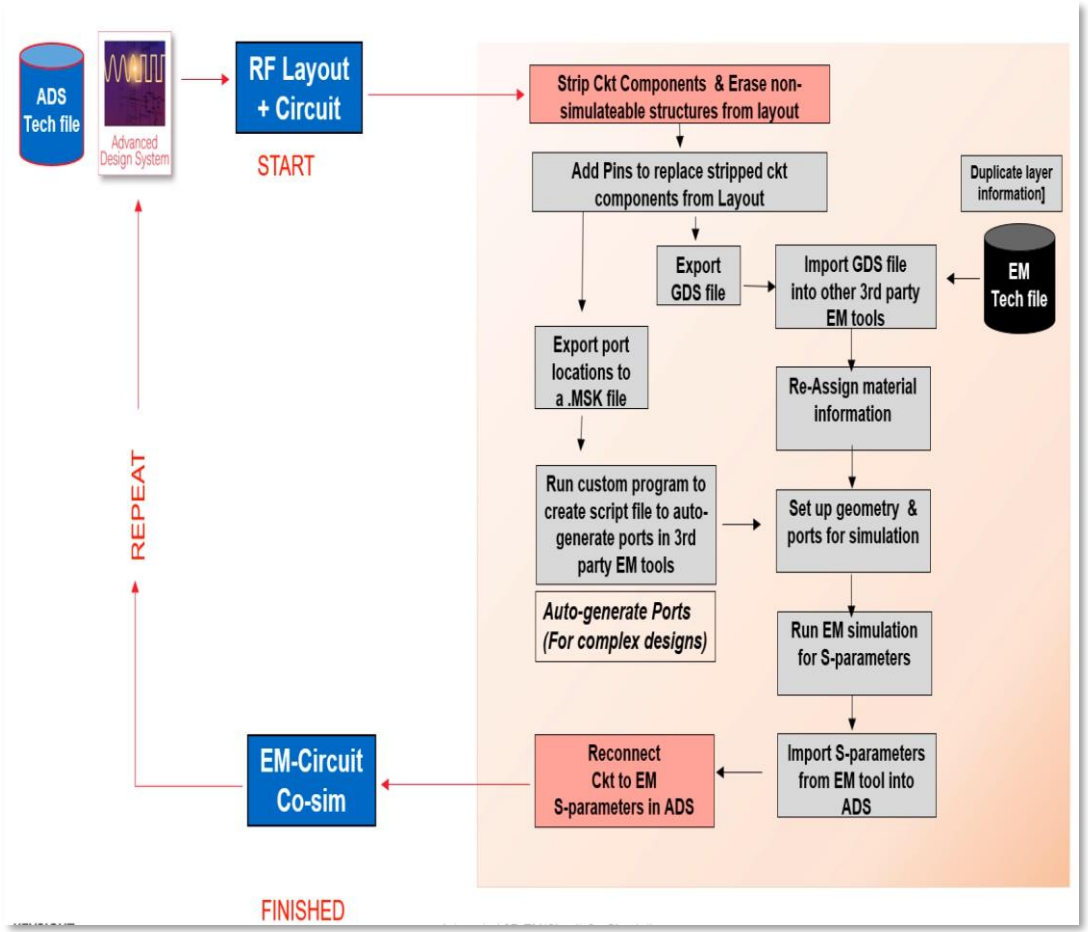


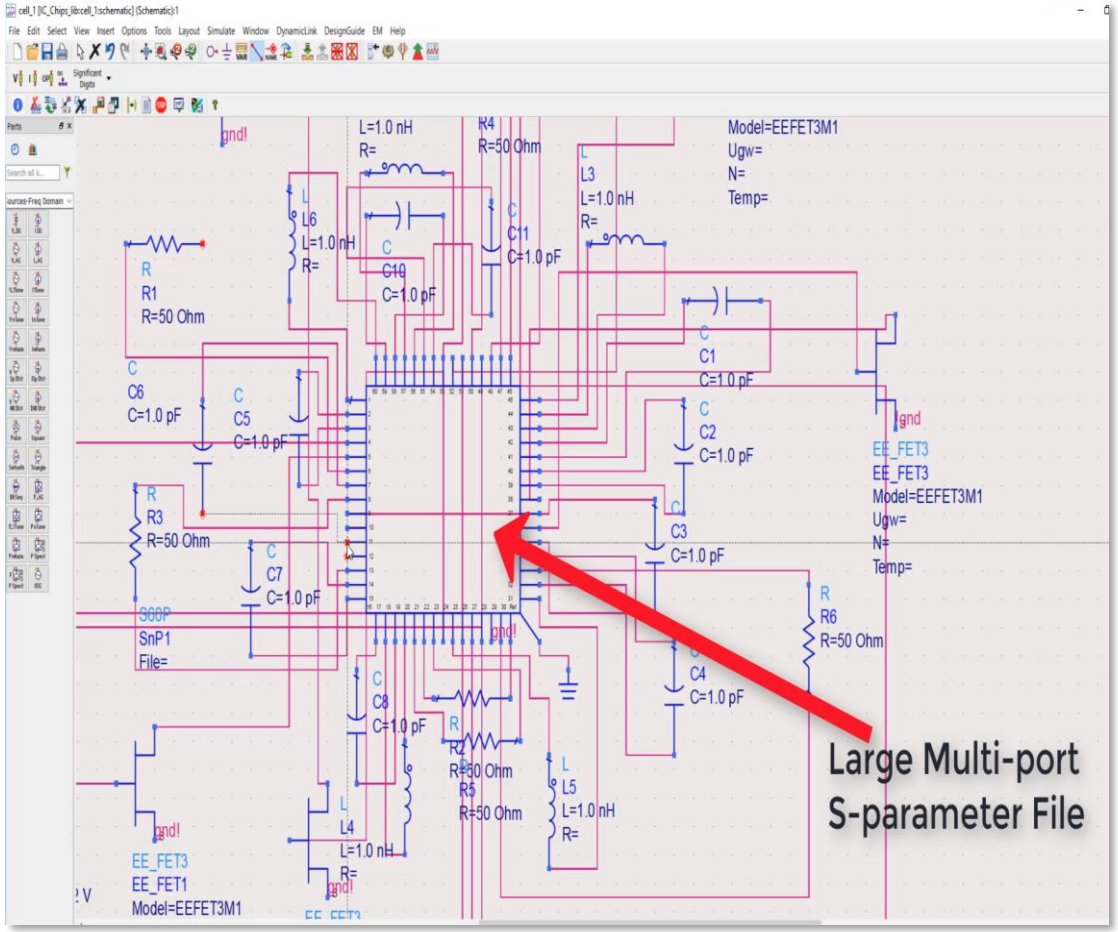
Substrate Stack-up are typically already defined by the PDK models.
Alternatively, create substrate stack-up using the ADS substrate editor



Layout Design – EM-Circuit Cosimulation

What we heard over the years

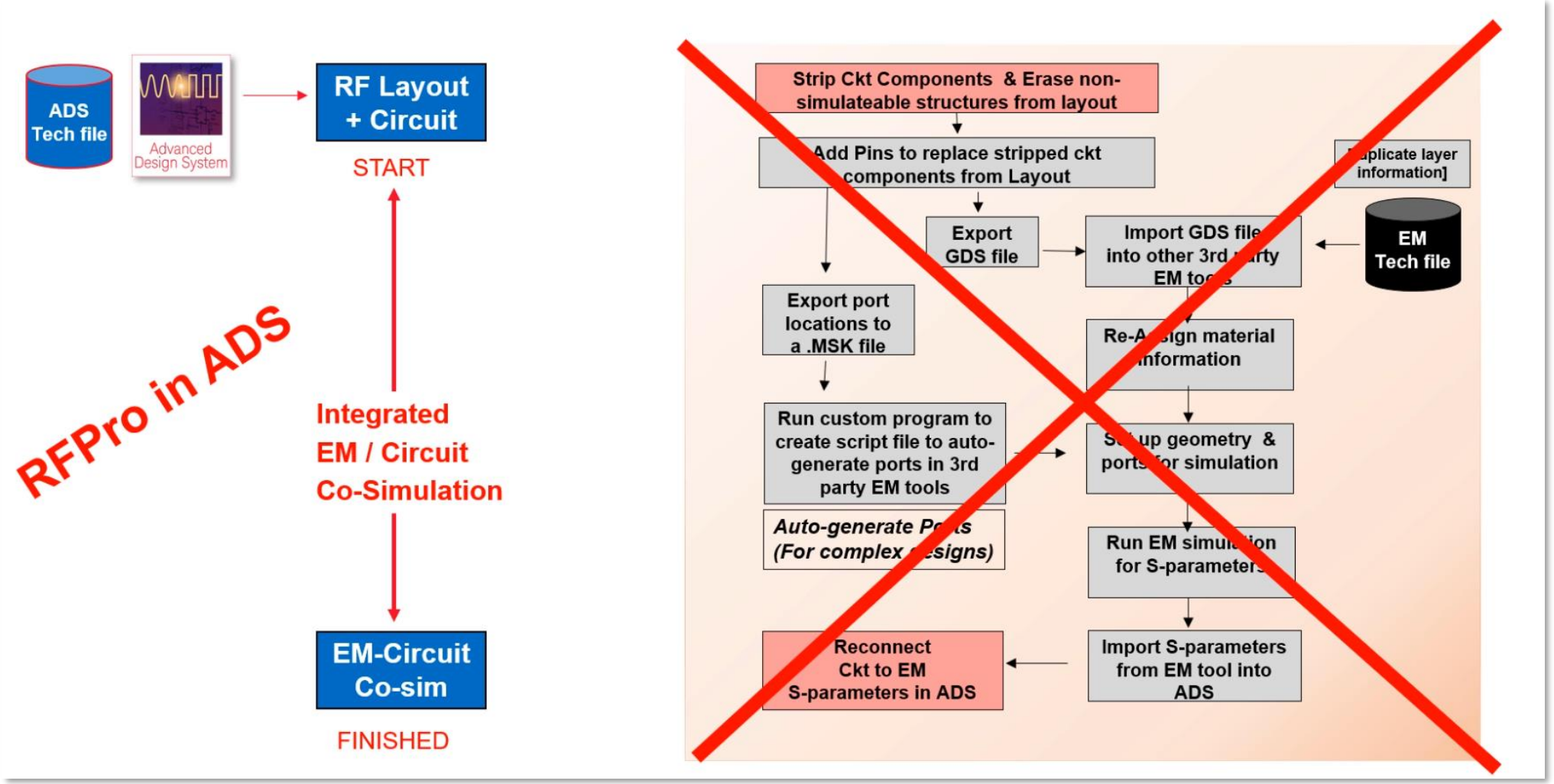




Tedious, Time-Consuming and Error Prone!

Layout Design – EM-Circuit Cosimulation

RFPro Simulation - Introduction



Layout Design – EM-Circuit Cosimulation

RFPro Simulation - Introduction

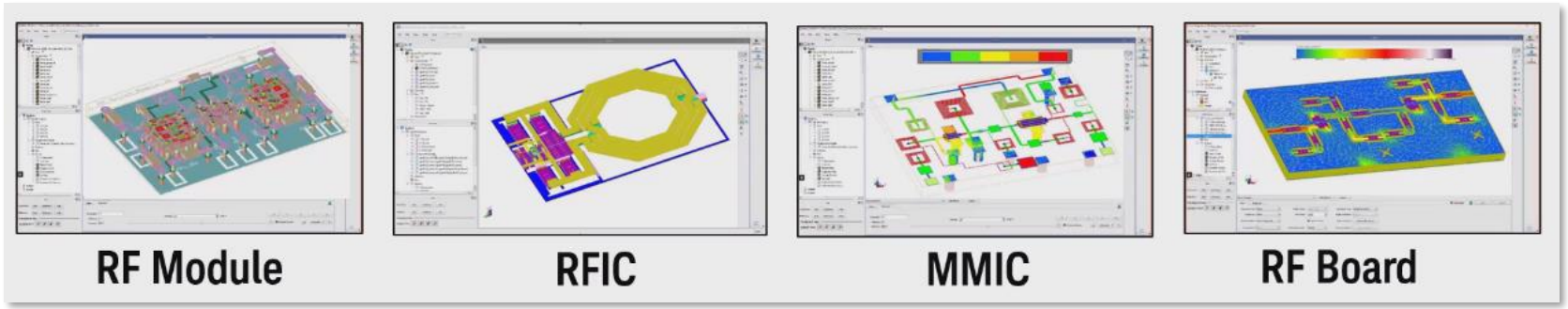
- RFPro in ADS Removes EM Setup Complexity

- Layout
  - ✓ No Cookie cutting
  - ✓ No exporting
  - ✓ No removing active devices and placing pins & ports
  - ✓ No reconnecting schematics to s-parameter files

- Solver
  - ✓ No expert setup
  - ✓ Be confident in the setup of the simulation and accuracy of the results
  - ✓ Better automated defeaturing (via merging/dummy removal/hatched planes…)

- Integration
  - ✓ Integrated EM and Circuit Co-Simulation
  - ✓ 3D view
  - ✓ Solution for RF PCB, RFIC, MMIC and RF Modules
  - ✓ Same user interface for ADS and Cadence Virtuoso
  - ✓ Same environment for FEM and Momentum

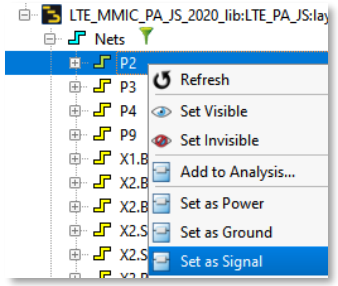
RFPro



Layout Design – EM-Circuit Cosimulation

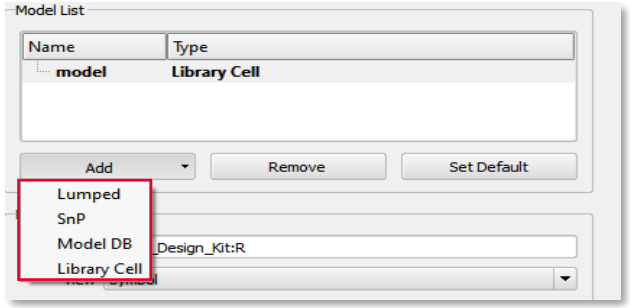
RFPro Simulation - Setup

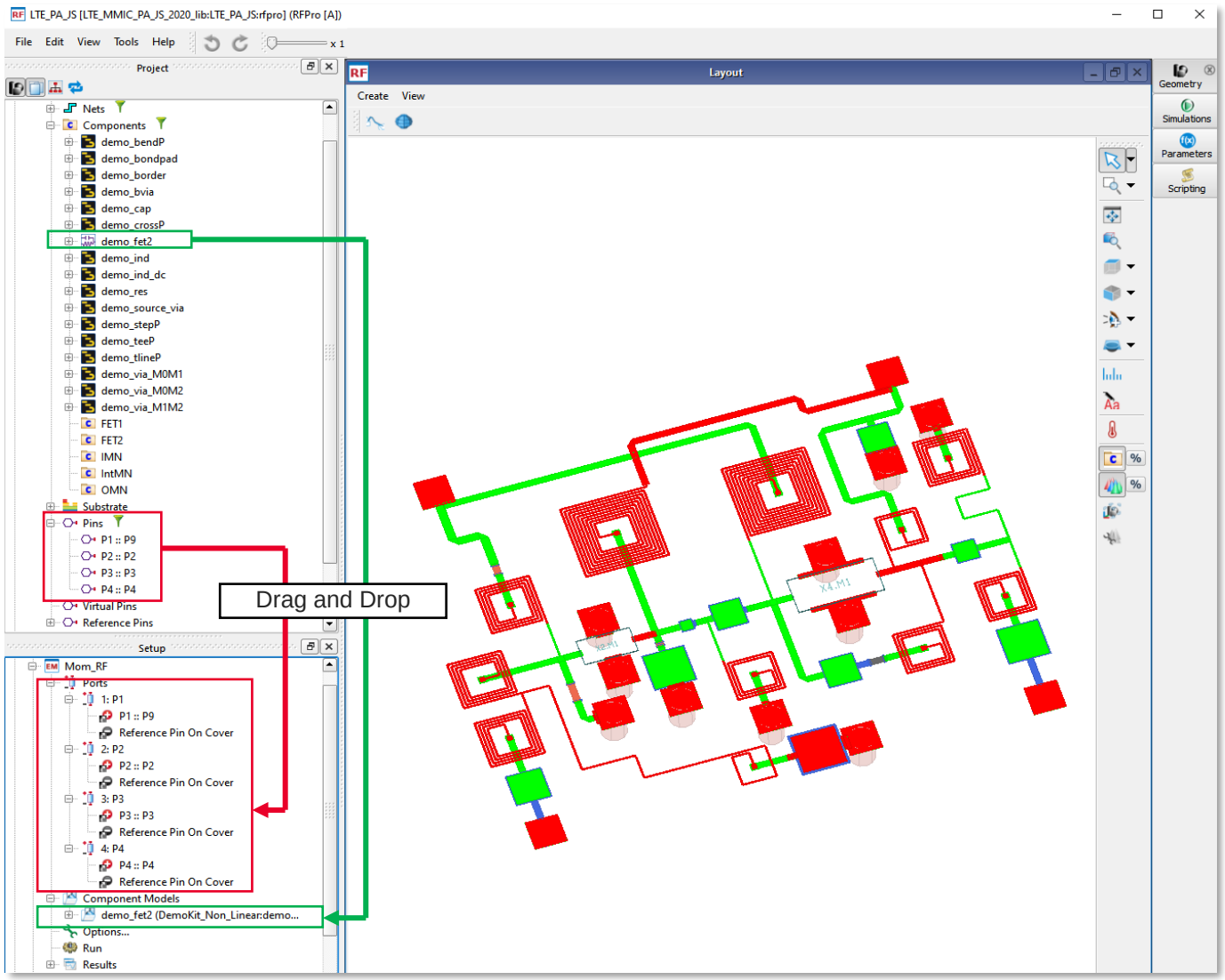
- Nets Assignment (Signal, Ground, Power) for automation in Ports Creation.



- Simple Drag-and-Drop for Ports and Component Creation

- Various options for model presentation – Lumped, SnP, Model DB, and Library Cell (PDK, SPICE)

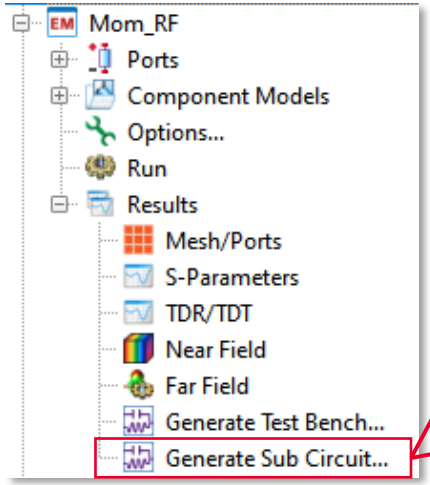


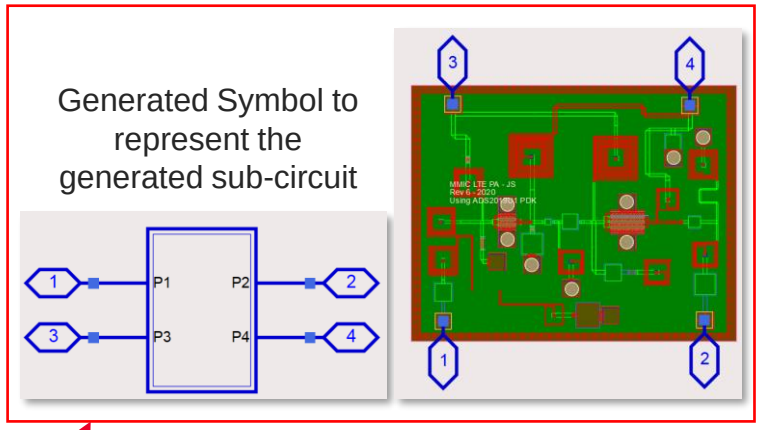


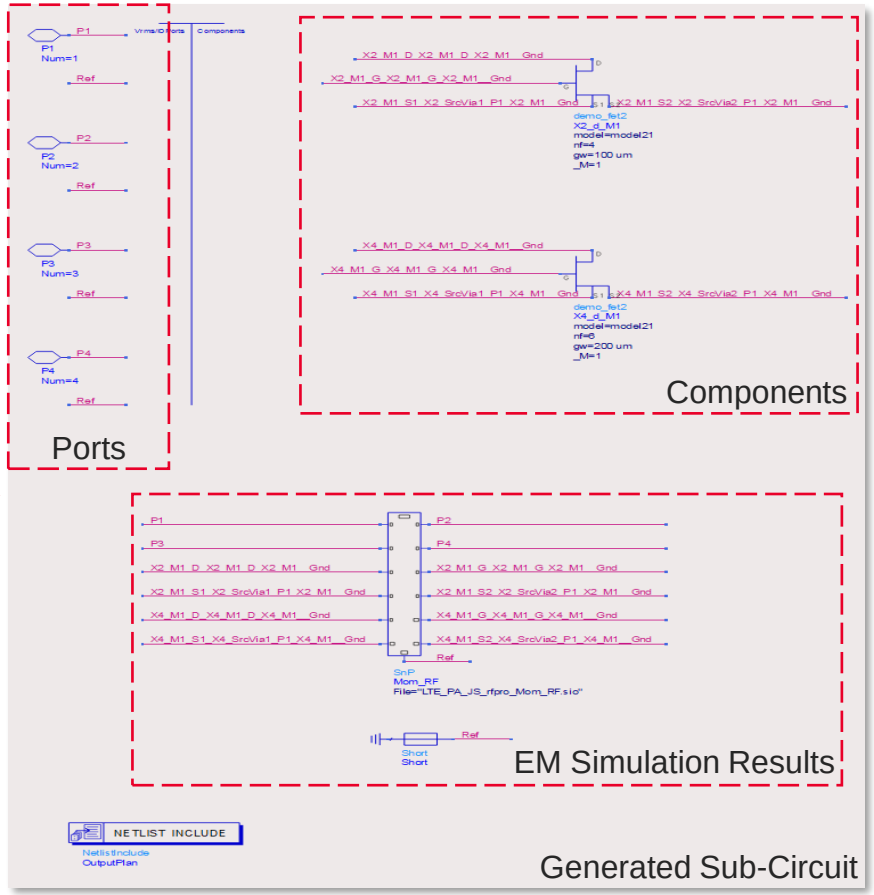
Layout Design – EM-Circuit Cosimulation

RFPro Simulation – Generated Sub-Circuit

- Quick sub-circuit generation for schematic use.
- Generated sub-circuit automatically connects Ports, Components, and EM simulation results together with Nets connections
- Circuit Components in the sub-circuit can be Tuned/Optimized with EM simulation results for Design Exploration



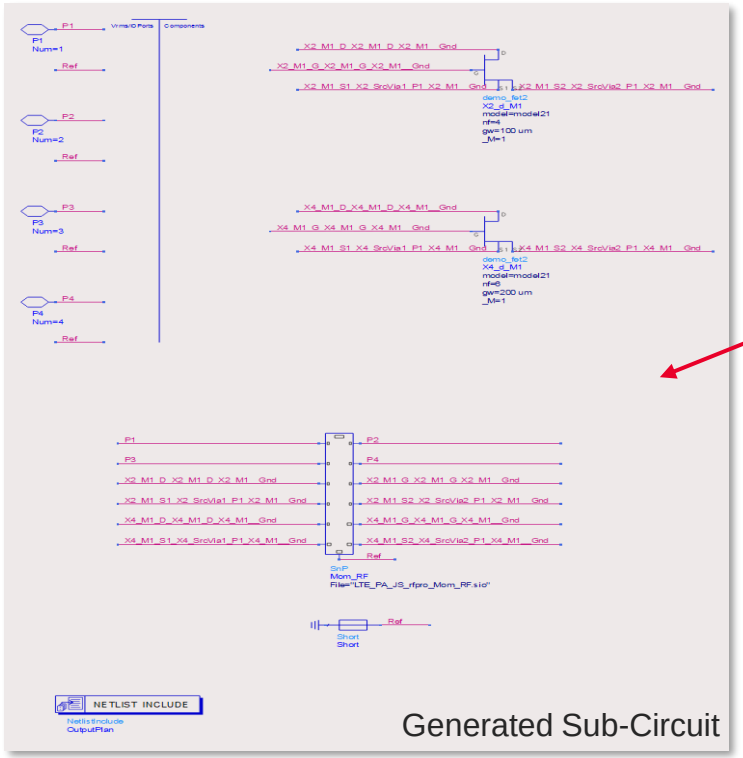




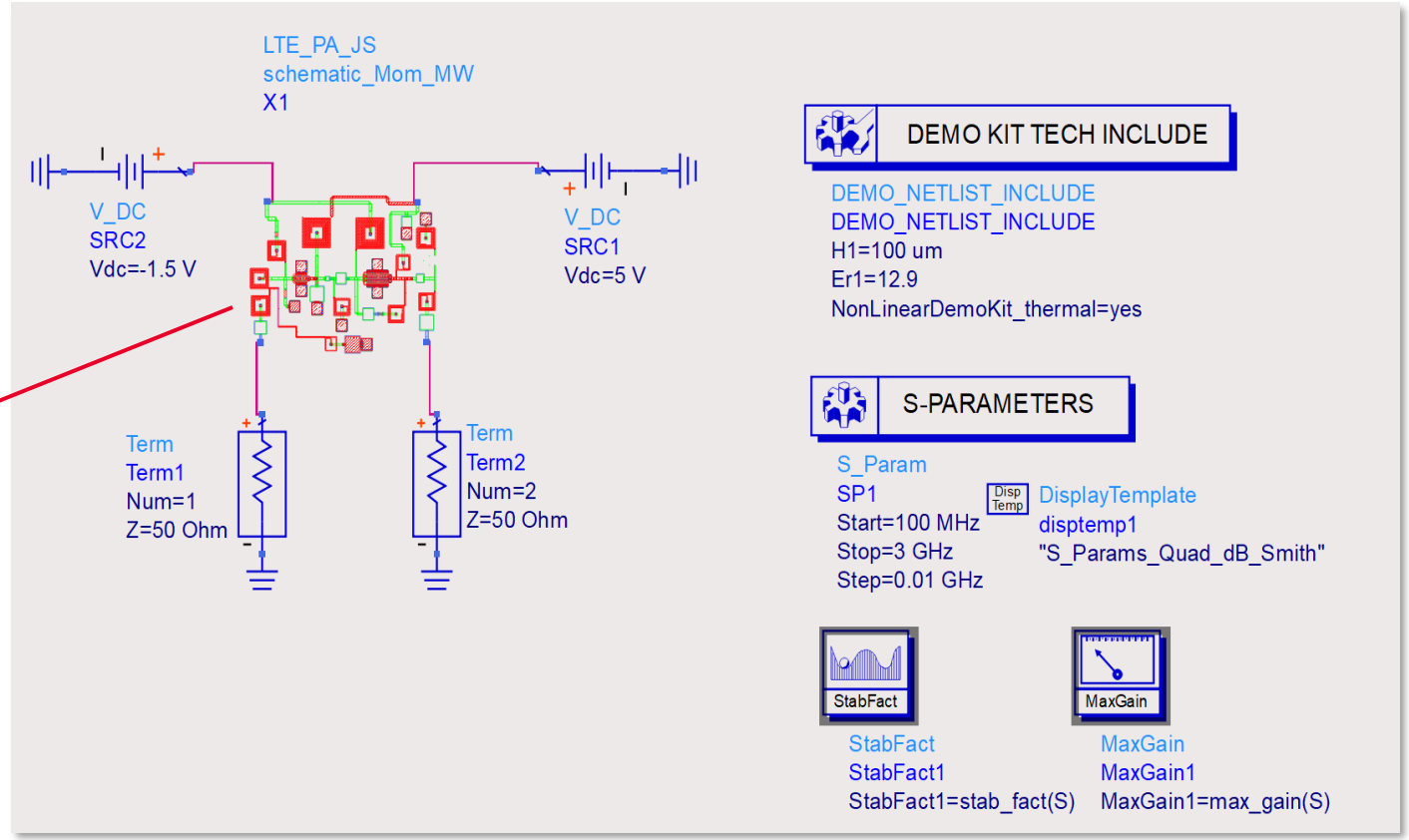
Layout Design – EM-Circuit Cosimulation

RFPro Simulation – Top Level Hierarchy Simulation

- Generated RFPro Sub-circuit results in comparison with Schematic simulation results.



Generated Sub-Circuit



Layout Design – EM-Circuit Cosimulation

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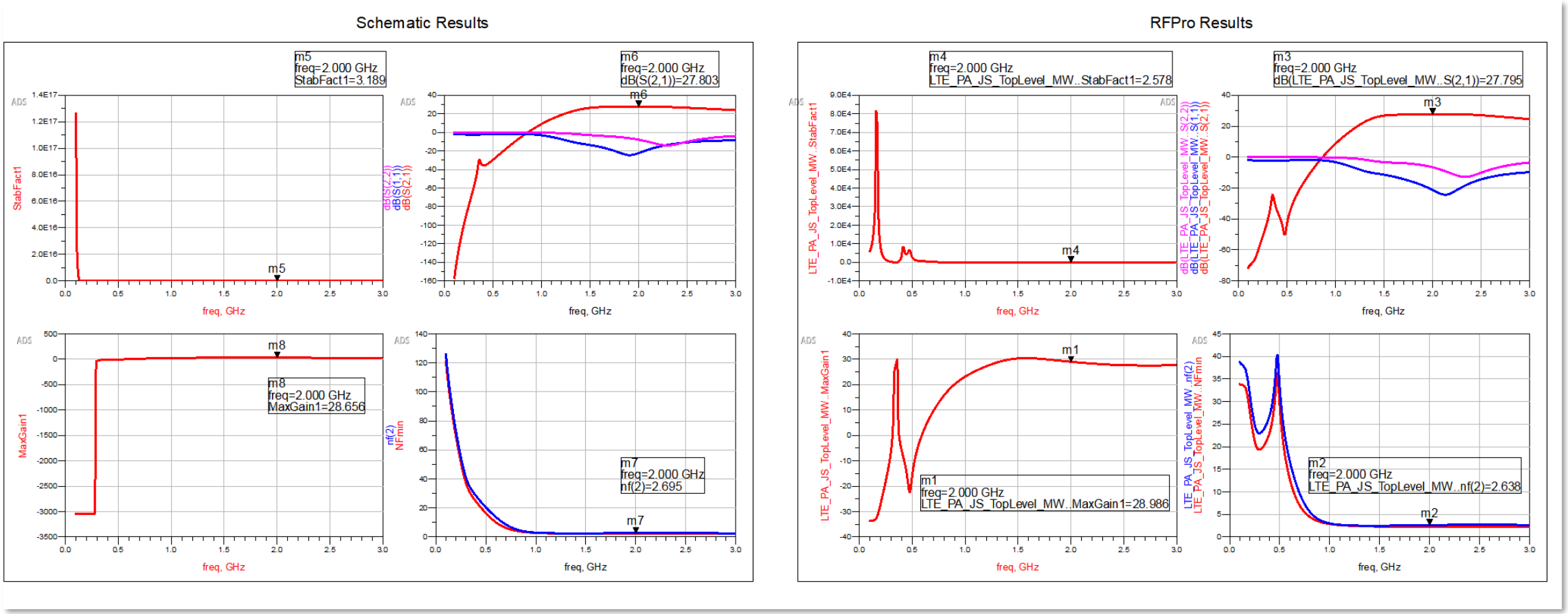


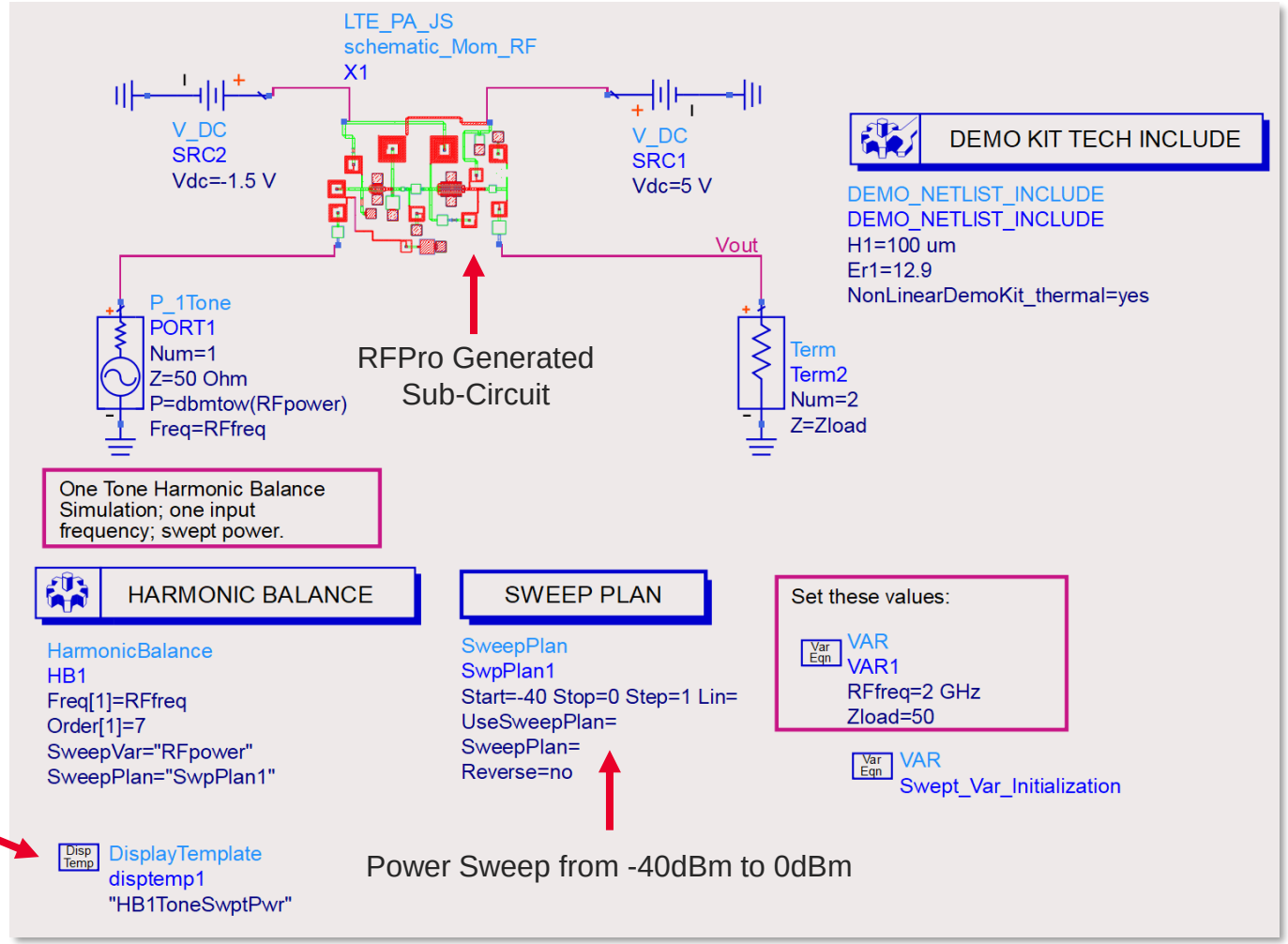
Further Validation of Design

Harmonic balance/modulated signals

- Non-linear performance of the LNA is critical
  - ➢ Designers leverage on ADS Harmonic Balance to analyze the non-linear performance
- Designer may also be interested how the LNA performed under Industry Standard Signals
  - ➢ Virtual Test Bench (VTBs) provides Industry Standard Signals that designers can use.

Validation: Harmonic Balance Simulation

1-Tone Non-Linear Simulation

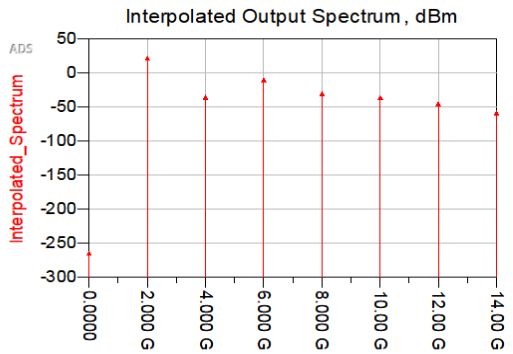


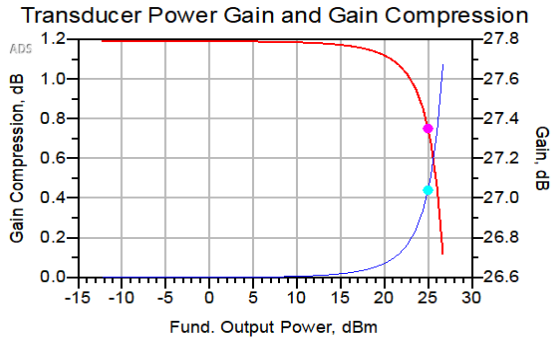
Schematic/Data Display templates for quick simulation setup and results display

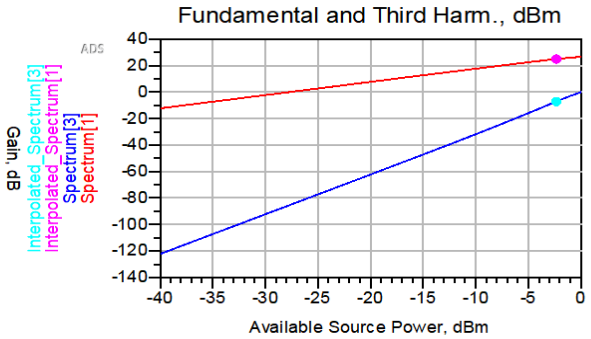
Validation: Harmonic Balance Simulation

1-Tone Non-Linear Simulation

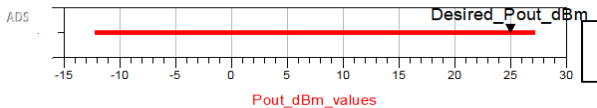
Use with HB1ToneSwptPwr Schematic Template







Set Desired_Pout_dBm = to desired output power in dBm. The gain, gain compression and spectral data will be interpolated to find the values that correspond to this output power.



Interpolated output power (dBm), gain (dB), and gain compression (dB)

24.990	27.350	0.440

Interpolated 2nd, 3rd, 4th, and 5th harmonics (dBc)

-57.284	-32.109	-51.900	-57.467

Fundamental Frequency
2.000 GHz

Available Source Power dBm	Fundamental Output Power dBm	Transducer Power Gain	Second Harmonic dBc	Third Harmonic dBc	Fourth Harmonic dBc	Fifth Harmonic dBc
-40.00	-12.21	27.79	-80.50	-110.1	-167.4	-216.7
-39.00	-11.21	27.79	-79.50	-108.1	-164.3	-212.7
-38.00	-10.21	27.79	-78.50	-106.1	-161.3	-208.7
-37.00	-9.210	27.79	-77.50	-104.1	-158.3	-204.7
-36.00	-8.210	27.79	-76.50	-102.1	-155.3	-200.7
-35.00	-7.210	27.79	-75.50	-100.1	-152.3	-196.7
-34.00	-6.210	27.79	-74.50	-98.07	-149.3	-192.7
-33.00	-5.210	27.79	-73.50	-96.07	-146.4	-188.7
-32.00	-4.210	27.79	-72.50	-94.07	-143.4	-184.7
-31.00	-3.210	27.79	-71.51	-92.07	-140.4	-180.7
-30.00	-2.210	27.79	-70.51	-90.07	-137.4	-176.7
-29.00	-1.210	27.79	-69.51	-88.07	-134.4	-172.7
-28.00	-210.5 m	27.79	-68.51	-86.07	-131.4	-168.7
-27.00	789.4 m	27.79	-67.52	-84.06	-128.4	-164.7
-26.00	1.789	27.79	-66.52	-82.06	-125.4	-160.7
-25.00	2.789	27.79	-65.53	-80.06	-122.4	-156.7

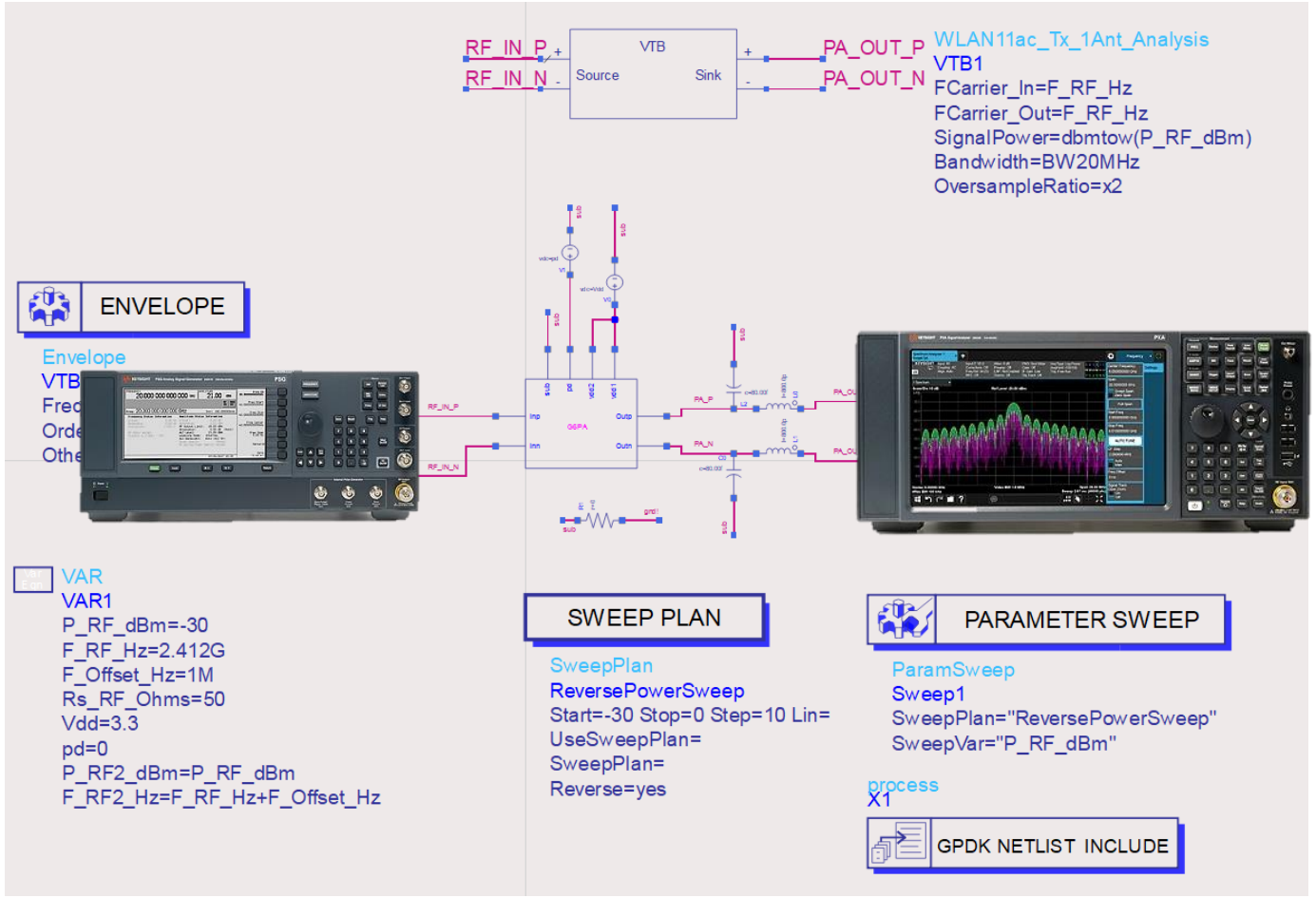
Available Source Power dBm	Gain Reduction dB	Delta Phase Shift degrees
-40.000	0.000	0.000
-39.000	-8.271E-6	-7.425E-5
-38.000	-1.869E-5	-1.677E-4
-37.000	-3.180E-5	-2.854E-4
-36.000	-4.831E-5	-4.335E-4
-35.000	-6.910E-5	-0.001
-34.000	-9.528E-5	-0.001
-33.000	-1.283E-4	-0.001
-32.000	-1.698E-4	-0.002
-31.000	-2.221E-4	-0.002
-30.000	-2.880E-4	-0.003
-29.000	-3.710E-4	-0.003
-28.000	-4.756E-4	-0.004
-27.000	-0.001	-0.005

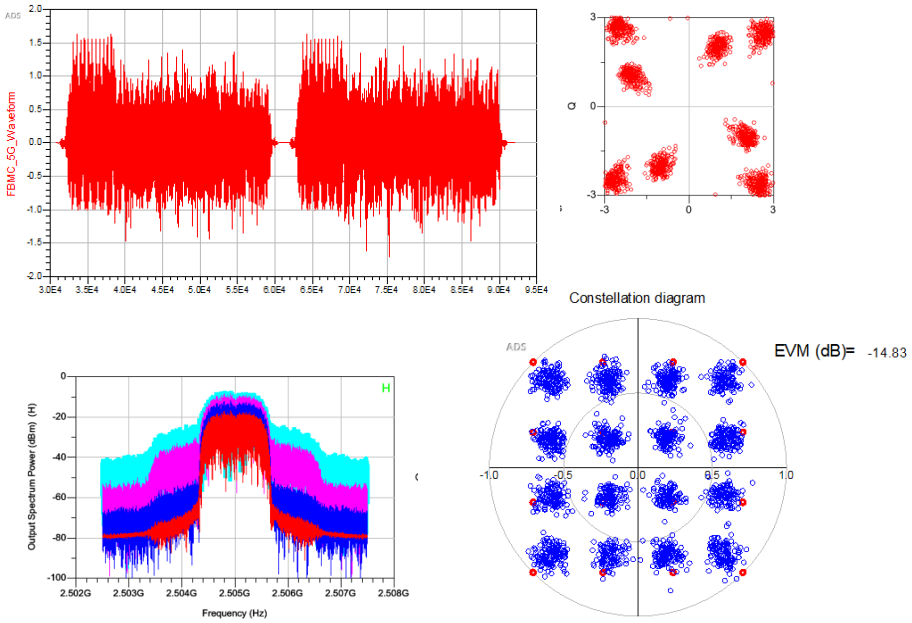
Use these values in GComp7 section of S2D data file, with option line:

AC(GHZ S DBM DB R 50.0)

Validation: Virtual Test Bench (VTB)

Simulate with industry standard signals

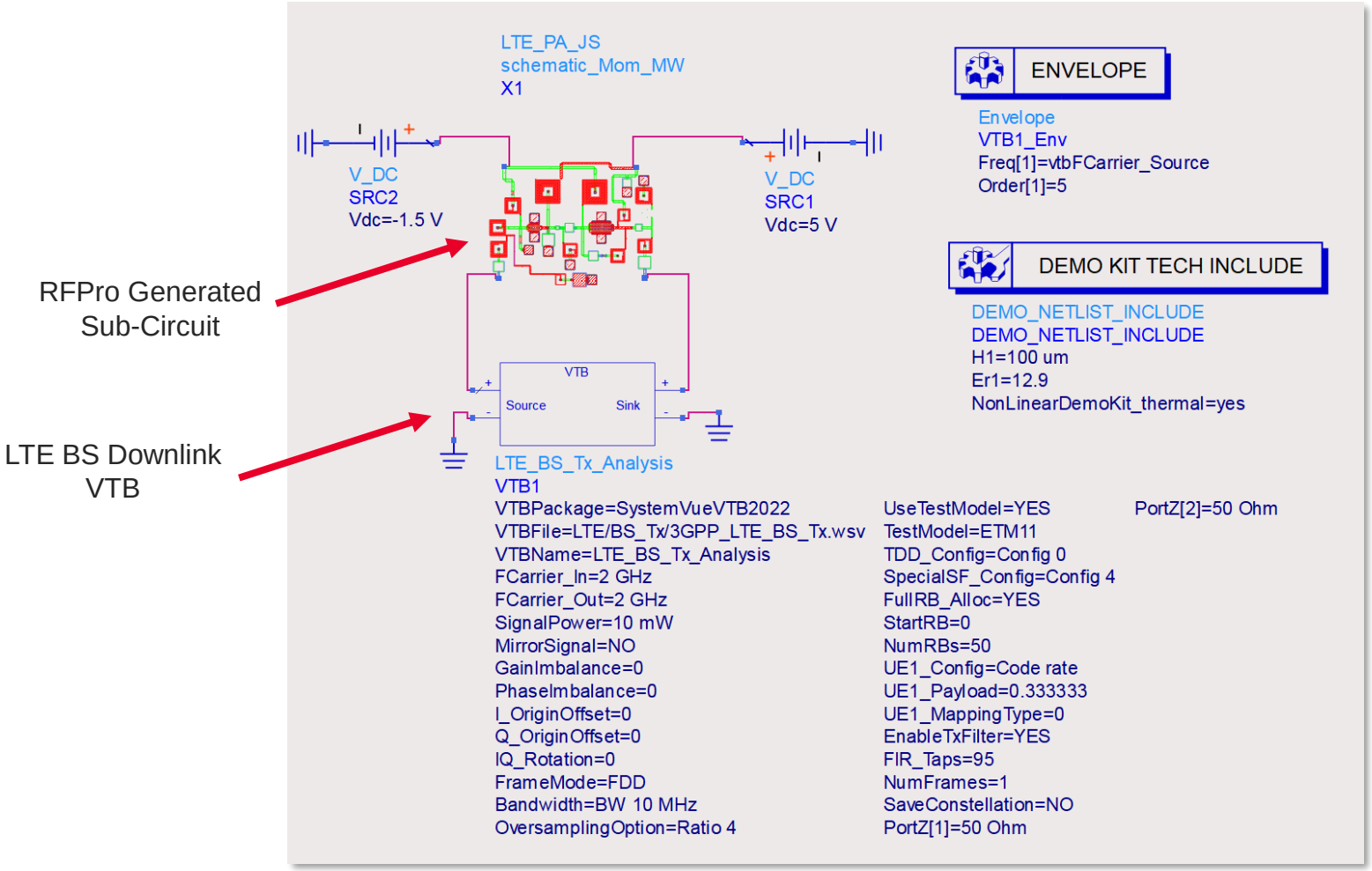




5G NR, Verizon, (U)F-OFDM, FBMC
3GPP / LTE, LTE Advanced
802.11 a/b/n/ac/ad/ah
802.15.3c, 802.15.4, 802.16e
Bluetooth (Basic, Enhanced and BLE)
GNSS/GPS
DVB-x2

Validation: Virtual Test Bench (VTB)

Simulate with industry standard signals



Validation: Virtual Test Bench (VTB)

Simulate with industry standard signals

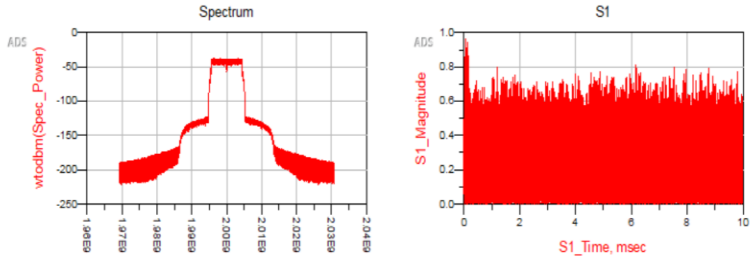
Input Power at -30dBm

Errors Summary

EVM =	0.187@0	%	at Max of EVM Window Start/End
EVM Peak =	1.086@0	%	at symbol 2@0, subcarrier 0@0
Data EVM =	0.189@0	%	
RS EVM =	0.174@0	%	
RS Tx. Power(Avg) =	-29.994@0	dBm	
OFDM Sym. Tx. Power =	-2.212@0	dBm	
Freq. Err =	0.000@0	Hz	
SyncCorr =	1.000@0		
Common Tracking Error =	0.000@0		
SymClk Err =	-0.000@0	ppm	
Time Offset =	0.010@0	sec	
IQ Offset =	0.000@0		
IQ GainImbalance =	1.000@0		
IQ QuadError =	0.001@0	deg	
IQ TimingSkew =	0.000@0	sec	

Frame Summary

Channel	EVM(%)	Power(dB)	Num.RB
P_SS	0.079@0	0.009@0	12@0
S_SS	0.102@0	0.009@0	12@0
PBCH	0.077@0	0.008@0	6@0
PHICH	0.222@0	0.000@0	40@0
PDCCH	0.166@0	1.065@0	480@0
PDSCH	0.189@0	-0.000@0	1000@0
PDSCH_User 1	0.189@0	-0.000@0	1000@0
PDSCH_User 2	-999.000@0	-999.000@0	-999@0
PDSCH_User 3	-999.000@0	-999.000@0	-999@0
PDSCH_User 4	-999.000@0	-999.000@0	-999@0
PDSCH_User 5	-999.000@0	-999.000@0	-999@0
PDSCH_User 6	-999.000@0	-999.000@0	-999@0



EVM_PassFailFlag	ACLR_PassFailFlag
TRUE	TRUE

ACLR_Lower1	ACLR_Lower2	ACLR_Upper1	ACLR_Upper2
90.419	138.501	90.183	138.370

L1_P_SSEVM_Frame	P_SSEVM	L1_S_SSEVM_Frame	S_SSEVM	L1_PBCHEVM_Frame	PBCHEVM	L1_PCFICHEVM_Frame	PCFICHEVM	L1_PHICHEVM_Frame	PHICHEVM	L1_PDCCHEVM_Frame	PDCCHEVM	L1_PDSCHEVM_Frame	PDSCHEVM
0	0.079	0	0.102	0	0.077	0	0.231	0	0.222	0	0.166	0	0.189

L1_EVM_Frame	EVM	L1_EVMPk_Frame	EVMPk	L1_FreqErr_Frame	FreqErr	L1_RSEVM_Frame	RSEVM	L1_RSTxPower_Frame	RSTxPower	L1_SyncCorr_Frame	SyncCorr
0	0.187	0	1.086	0	2.923E-5	0	0.174	0	-29.994	0	1.000

Validation: Virtual Test Bench (VTB)

Simulate with industry standard signals

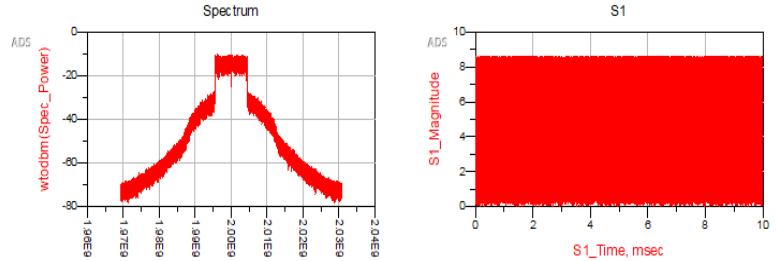
Input Power at 0dBm

Errors Summary

EVM =	16.278@0	%	at Max of EVM Window Start/End
EVM Peak =	56.645@0	%	at symbol 24@0, subcarrier 331@0
Data EVM =	16.386@0	%	
RS EVM =	16.327@0	%	
RS Tx. Power(Avg) =	-2.251@0	dBm	
OFDM Sym. Tx. Power =	25.524@0	dBm	
Freq. Err =	0.025@0	Hz	
SyncCorr =	0.960@0		
Common Tracking Error =	0.000@0		
SymClk Err =	0.070@0	ppm	
Time Offset =	0.010@0	sec	
IQ Offset =	0.000@0		
IQ GainImbalance =	1.000@0		
IQ QuadError =	0.032@0	deg	
IQ TimingSkew =	0.000@0	sec	

Frame Summary

Channel	EVM(%)	Power(dB)	Num.RB
P_SS	17.336@0	0.172@0	12@0
S_SS	17.734@0	-0.089@0	12@0
PBCH	17.257@0	0.009@0	6@0
PHICH	8.872@0	-0.118@0	40@0
PDCCH	14.583@0	1.039@0	480@0
PDSCH	16.386@0	-0.003@0	1000@0
PDSCH_User 1	16.386@0	-0.003@0	1000@0
PDSCH_User 2	-999.000@0	-999.000@0	-999@0
PDSCH_User 3	-999.000@0	-999.000@0	-999@0
PDSCH_User 4	-999.000@0	-999.000@0	-999@0
PDSCH_User 5	-999.000@0	-999.000@0	-999@0
PDSCH_User 6	-999.000@0	-999.000@0	-999@0



EVM_PassFailFlag	ACLR_PassFailFlag
TRUE	FALSE

ACLR_Lower1	ACLR_Lower2	ACLR_Upper1	ACLR_Upper2
23.166	46.257	23.106	46.342

L1_P_SSEVM_Frame	P_SSEVM	L1_S_SSEVM_Frame	S_SSEVM	L1_PBCHEVM_Frame	PBCHEVM	L1_PCFICHEVM_Frame	PCFICHEVM	L1_PHICHEVM_Frame	PHICHEVM	L1_PDCCHEVM_Frame	PDCCHEVM	L1_PDSCHEVM_Frame	PDSCHEVM
0	17.336	0	17.734	0	17.257	0	16.063	0	8.872	0	14.583	0	16.386

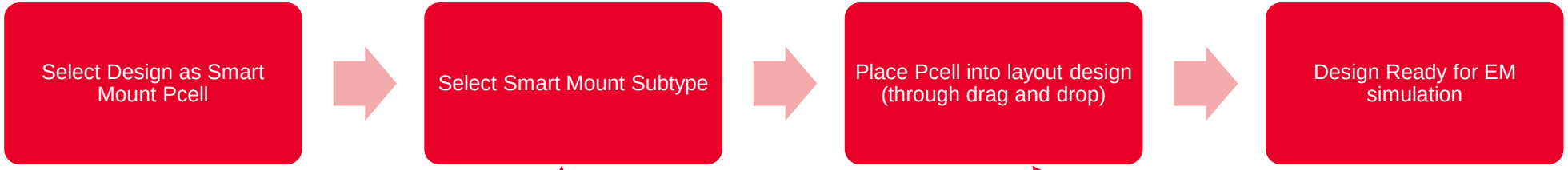
L1_EVM_Frame	EVM	L1_EVMPk_Frame	EVMPk	L1_FreqErr_Frame	FreqErr	L1_RSEVM_Frame	RSEVM	L1_RSTxPower_Frame	RSTxPower	L1_SyncCorr_Frame	SyncCorr
0	16.278	0	56.645	0	0.025	0	16.327	0	-2.251	0	0.960

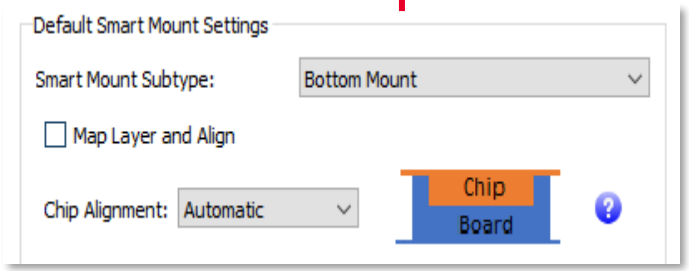
Smart Mount

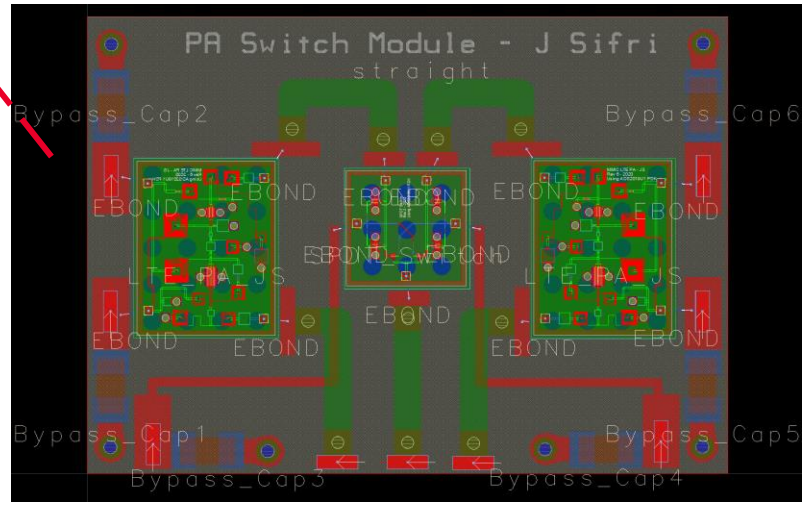
Multi-technology simulation

- SmartMount allows designs with different technology to be assembled into a single layout window
- This enables full design EM simulation together with Packages, Laminate, Connectors, etc.

SmartMount Flow

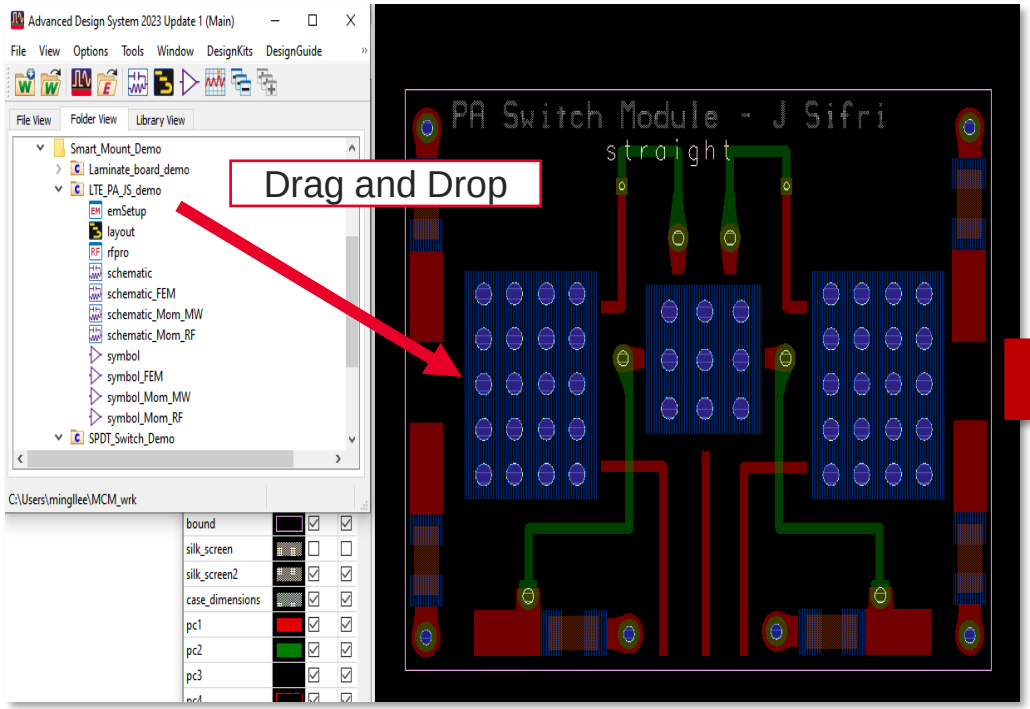


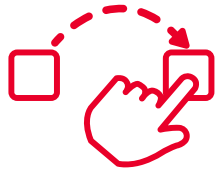




Smart Mount

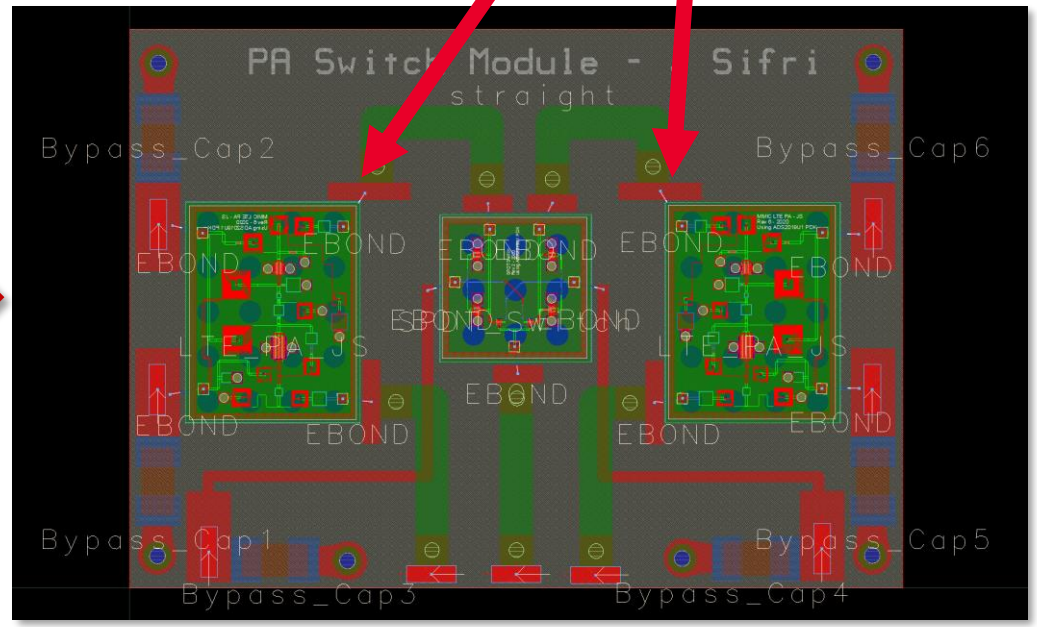
Mount PA onto Laminate Board





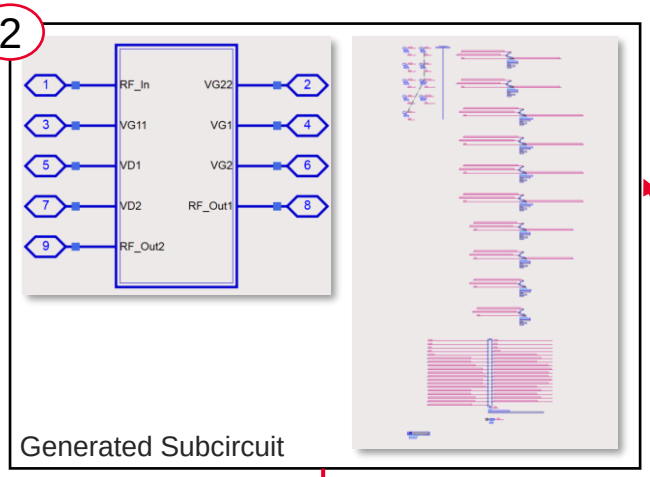
Mount PA/Switch onto Laminate Board

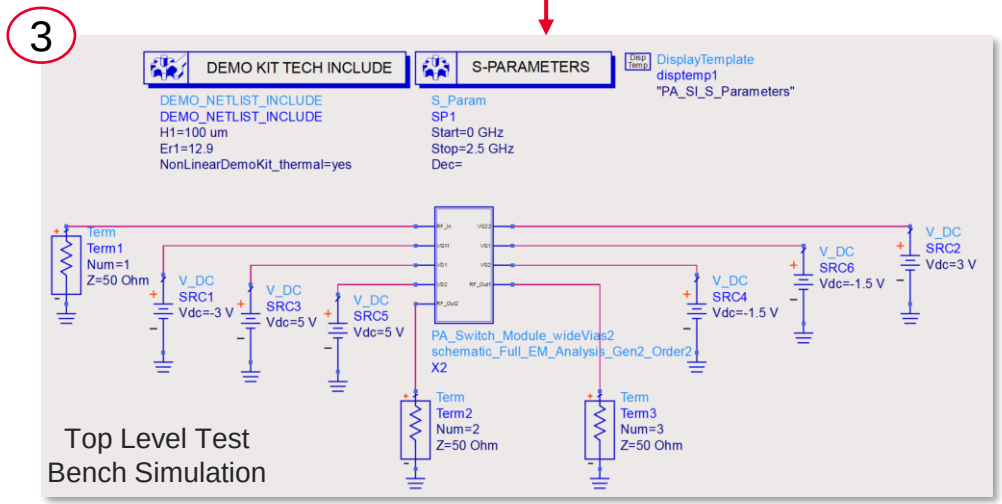
Bondwires drawn on layout to connect PA/Switch on Laminate Board

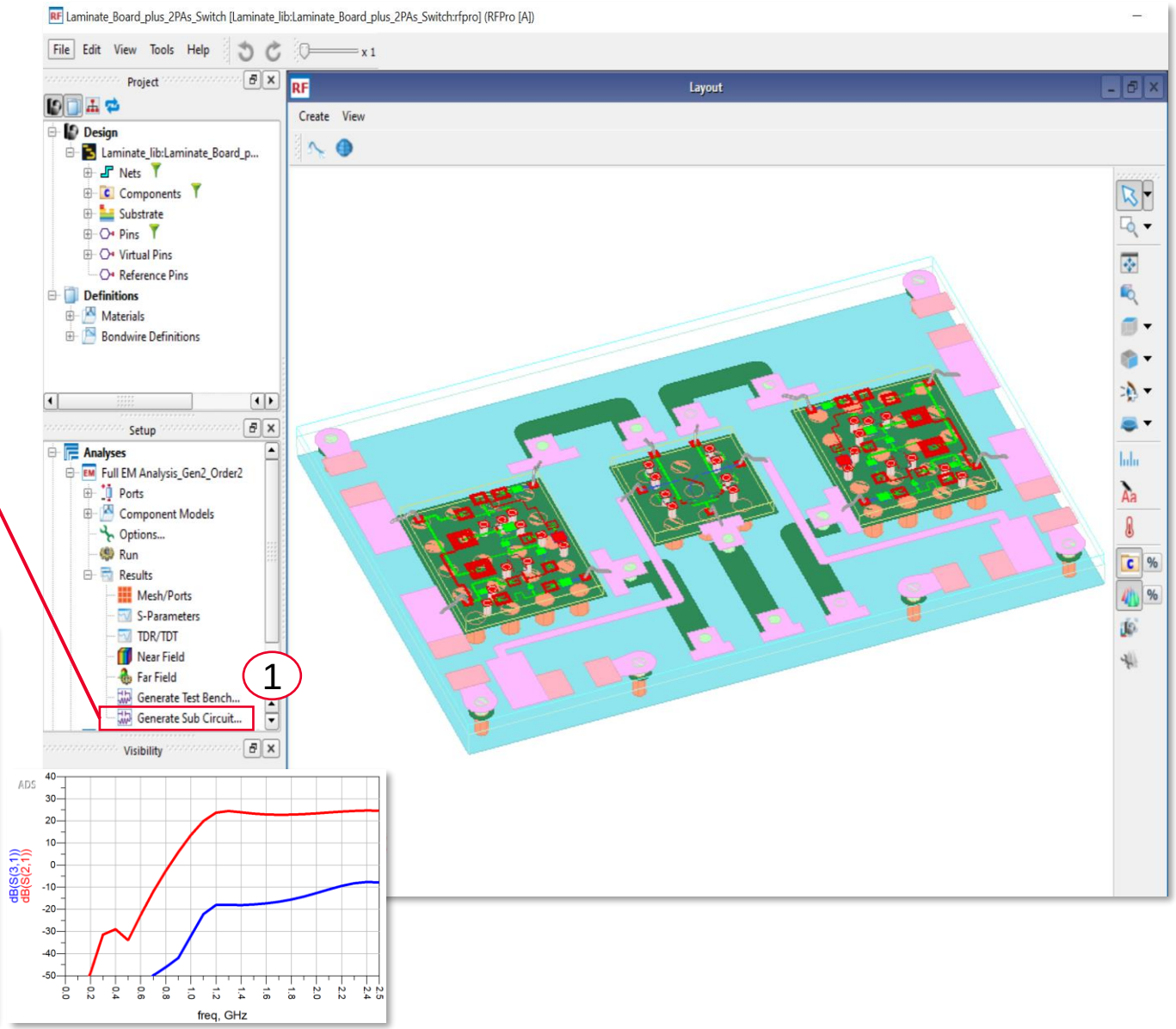


Smart Mount

Complete the design flow with RFPro







Smart Mount: DUT Test Board

Integrate design with DUT Test board

YouTube Videos

1. 3 Critical Requirements for RF Design Flow: PathWave ADS Overview
2. Integrated 3D EM/Circuit Co-Simulation for First-Pass Design Win

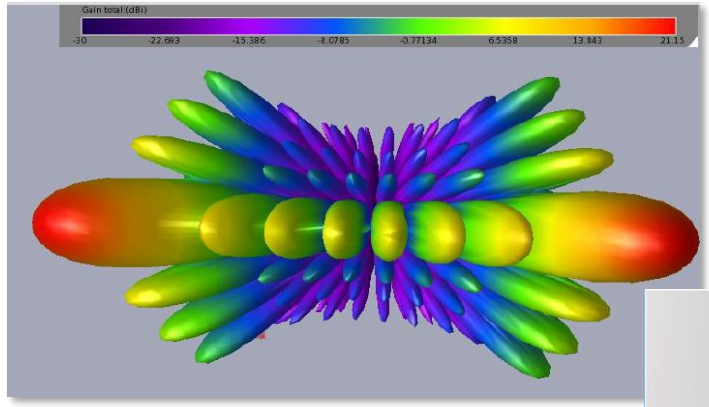
KEYSIGHT

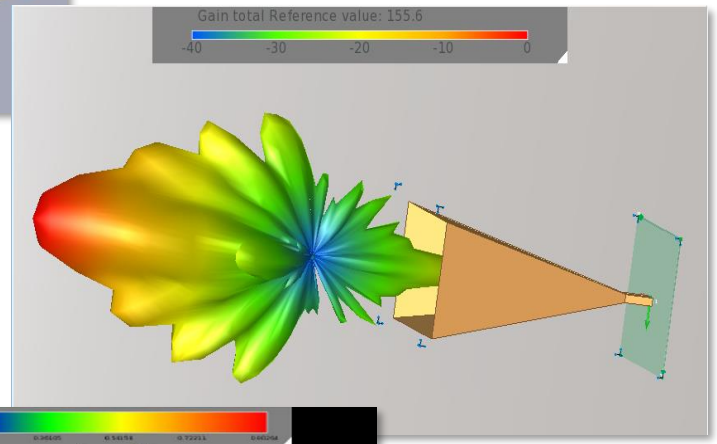
Rectenna Design with ADS and EMPro

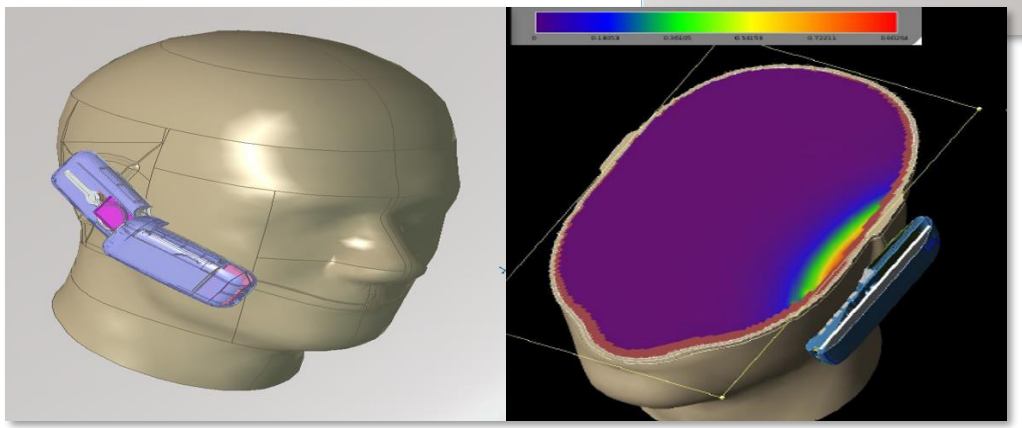
Keysight PathWave EM Design (EMPro)

3D EM Simulation Tool

- Modern, efficient 3D solid modeling environment
- Flexible choice of full wave 3D EM simulation technologies, FDTD and FEM
- Antenna Element and Array Designer for quick design generation
- Parameterize 3D EM components for co-simulation & optimization in ADS
- Transfer ADS Layouts to EMPro for additional 3D-EM simulation
- Full scripting (Python) and parameterization capability
- Windows & Linux

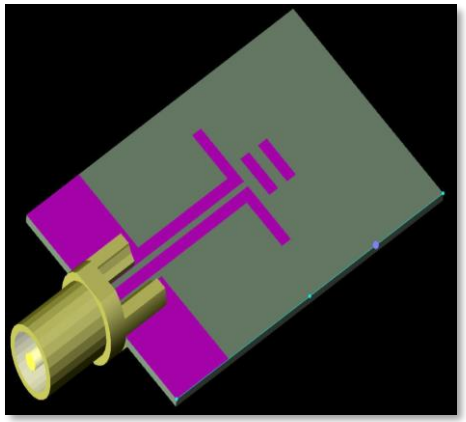


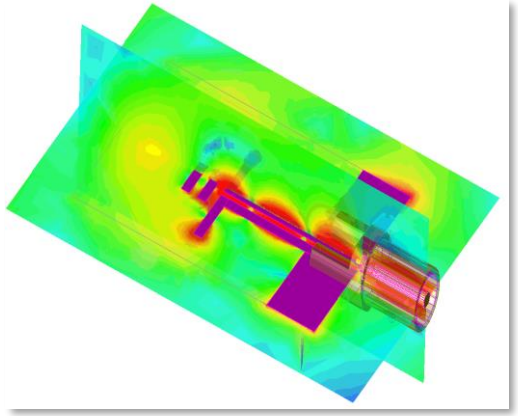




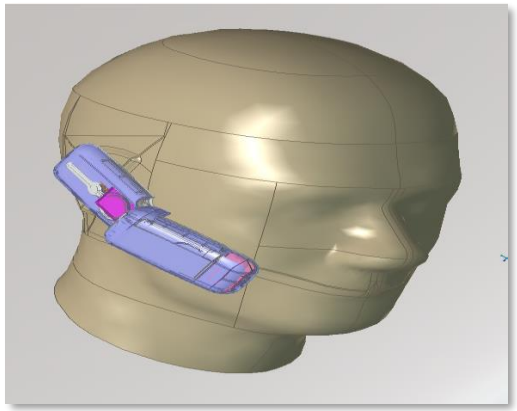
EMPro Application

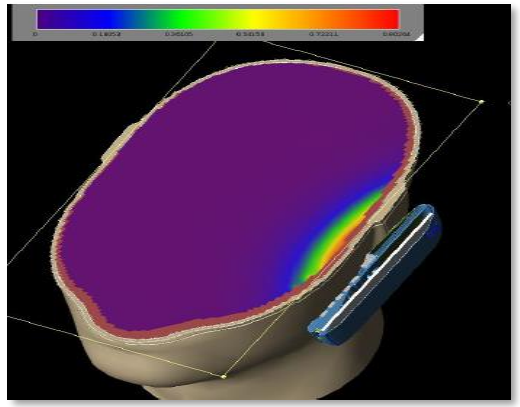
Microwave and RF
(E.g. Antenna, PCB Board, Waveguide)



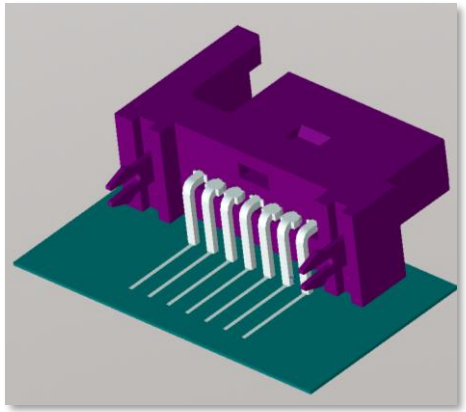


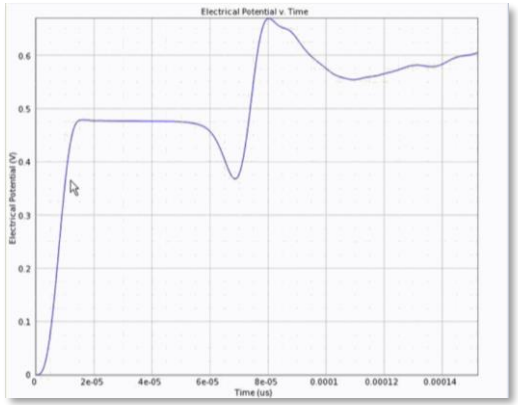
Specific Absorption Rate (SAR)



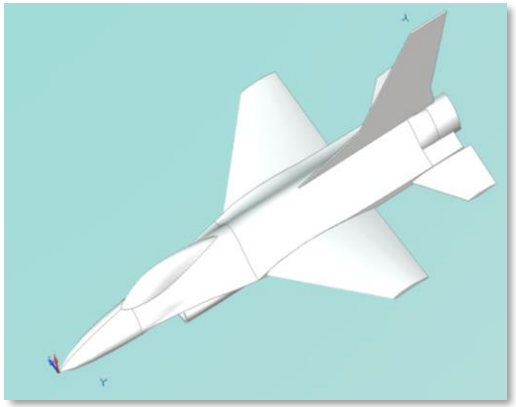


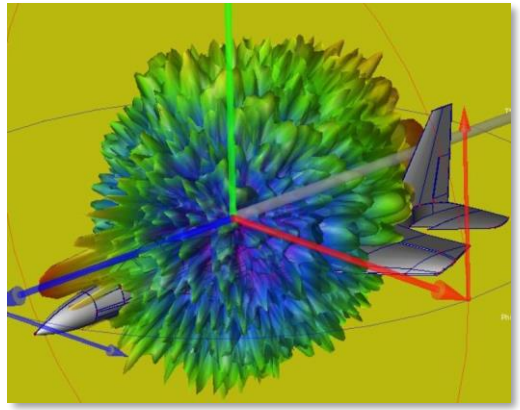
High Speed Digital
(E.g. Connector Models, etc)





Aerospace and Defence
(E.g. Radar Cross Section)





Antenna Design Toolkit

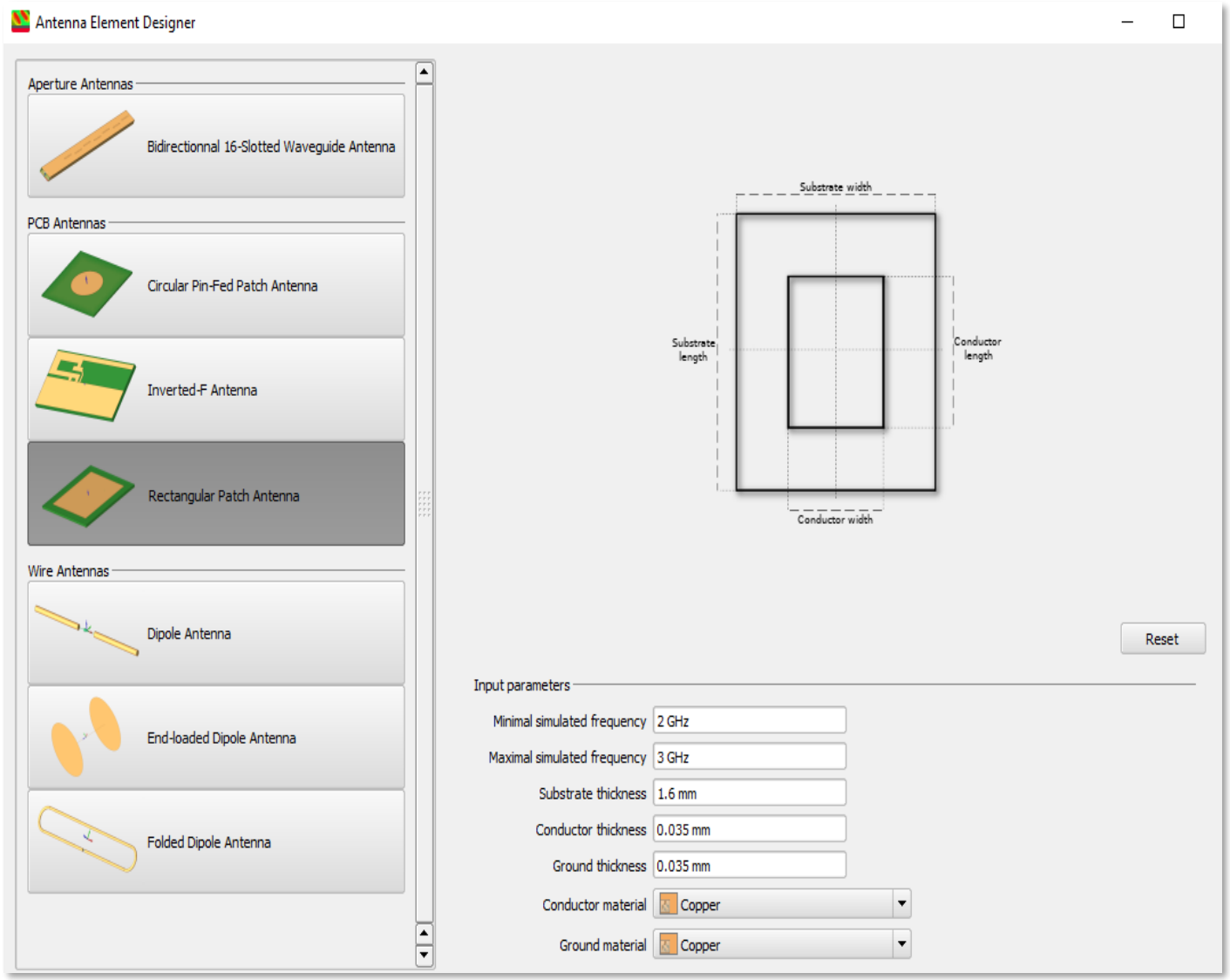
Element Designer

- Quick generation of desired antenna
- Support the following:

  ✓ Aperture Antennas
  - Bidirectional 16-Slotted Waveguide Antenna

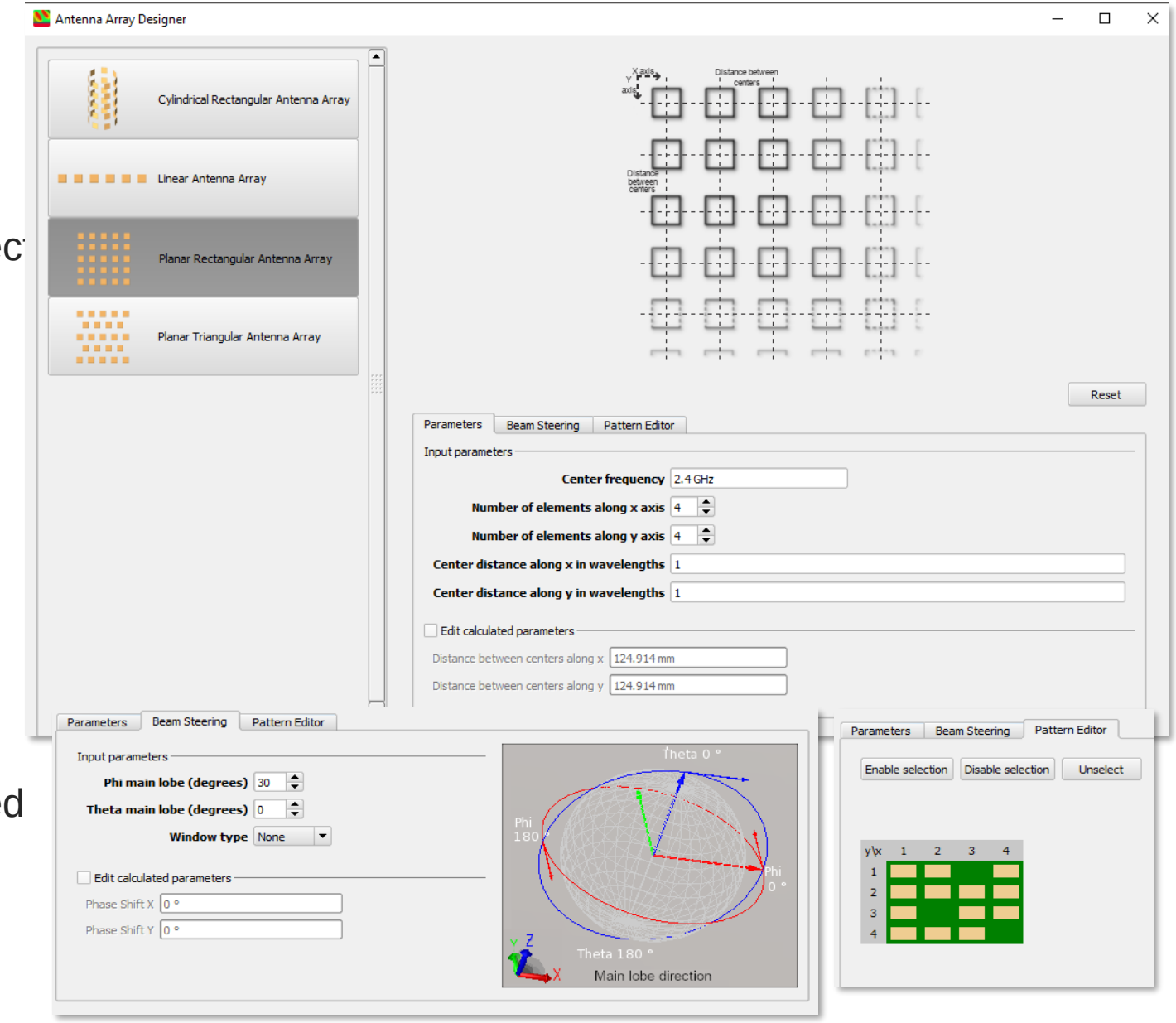
  ✓PCB Antennas
  - Circular Pin-Fed Patch Antenna
  - Inverted-F Antenna
  - Rectangular Patch Antenna

  ✓Wire Antennas
  - End-loaded Dipole Antenna
  - Folded Dipole Antenna
  - Dipole Antenna



Antenna Design Toolkit

- Quick generation of array from a single antenna element in the active EMPro projec
- Support the following:
  - ✓Cylindrical Rectangular Antenna Array
  - ✓Linear Antenna Array
  - ✓Planar Rectangular Antenna Array
  - ✓Planar Triangular Antenna Array
- Specify desired Beam Steering Operation
- Enable/Disable antenna element for desired pattern of array

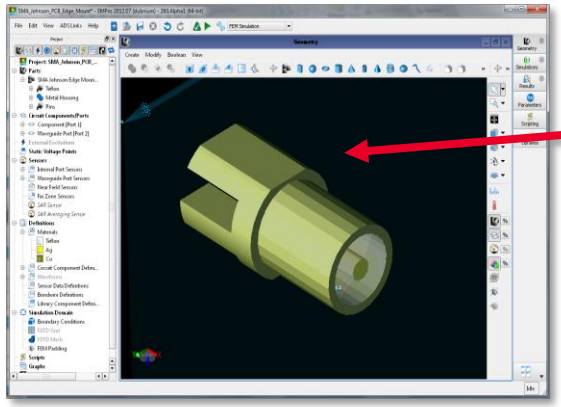


Keysight PathWave EM Design (EMPro)

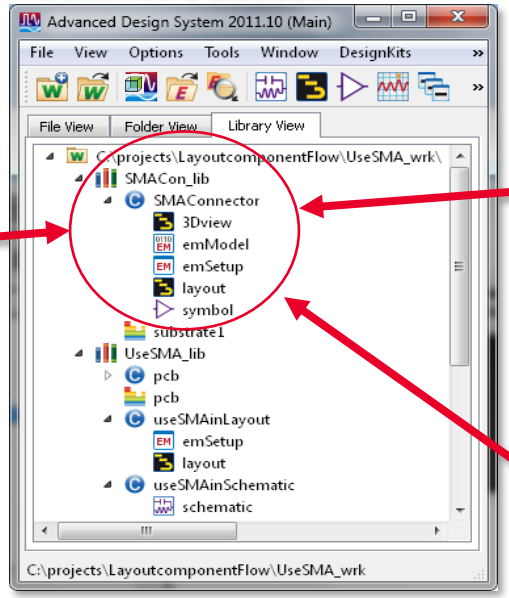
EMPro Standalone 3DEM integration with ADS

- EMPro 3D drawing environment shares common database with ADS
- Enables easy 3DEM –circuit cosimulation in ADS to account for full 3DEM effects on circuit performance, e.g. connectors, RF shields, antennas

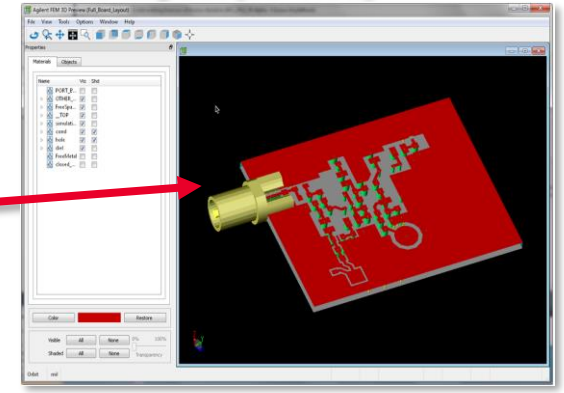
EMPro 3D Design



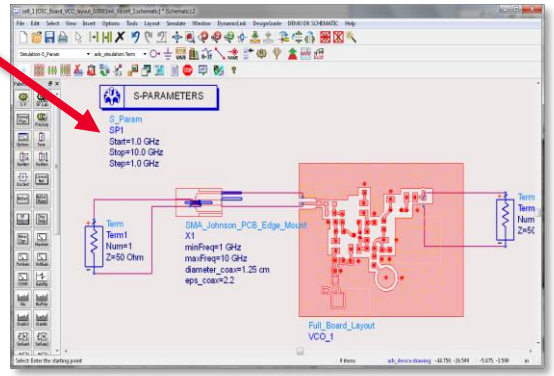
Common Database



ADS Layout (3D View)



ADS Schematic



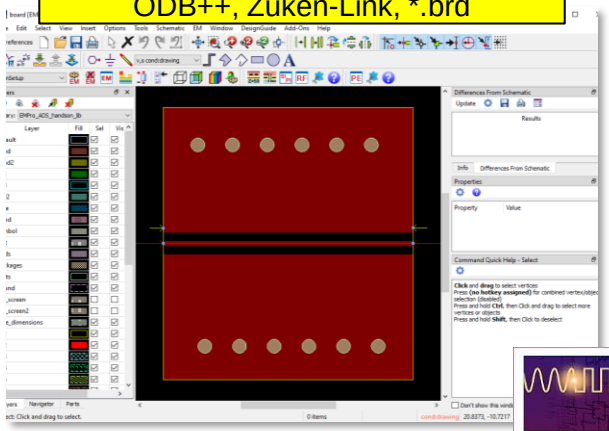
- EMPro projects now saved as ADS libraries
- 3D models now directly available in ADS as schematic and layout views
- Changes made in EMPro dynamically update in ADS
- Parameters created in EMPro available in ADS for EM sweep/optimization

Example: Design Flow with ADS - RFPro (Antenna)

Seamless EM-Circuit Cosimulation

*Note: Design is for Proof-of-Concept

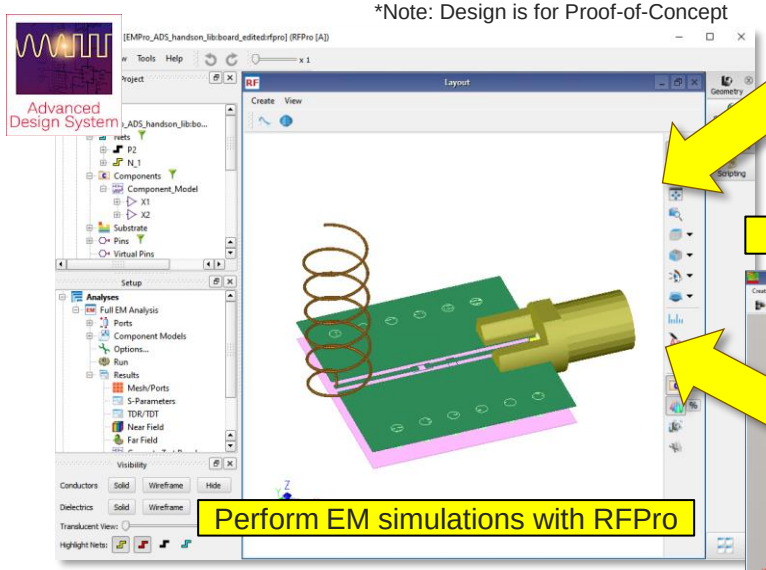
Design import from CAD-System
ODB++, Zuken-Link, *.brd

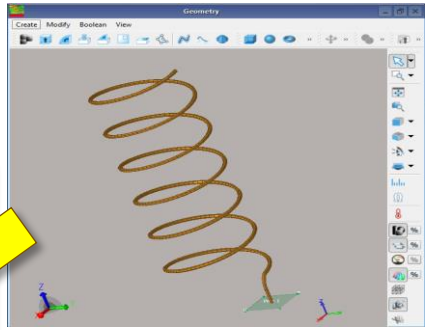


Advanced Design System

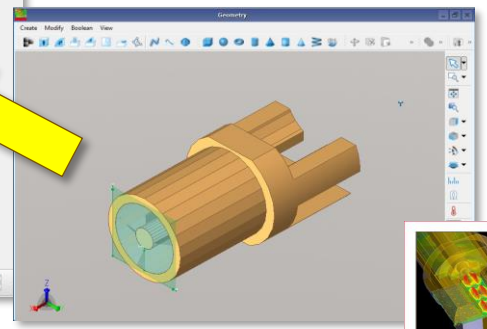
3D Design Import

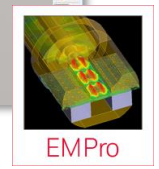
- Import 3D structures/design from Keysight EM Design (EMPro)
- Common shared library between ADS and EMPro





3D Design import from EMPro

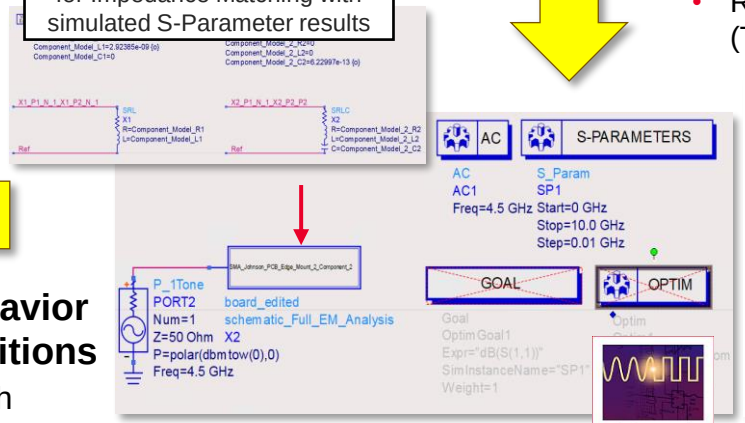


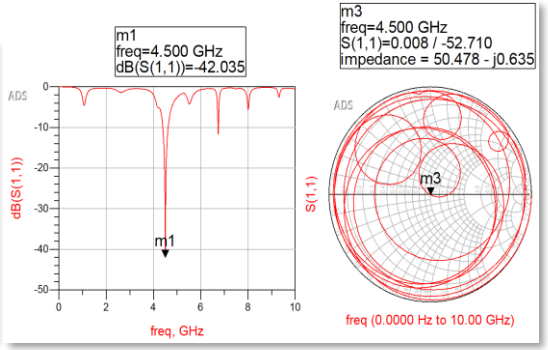


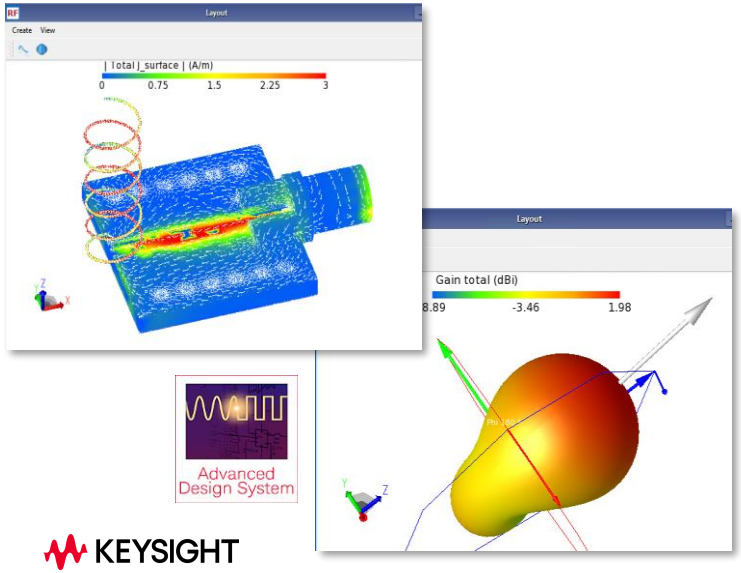
Verify under real conditions

- Assign SPICE/SMD component models
- Run Circuit Simulations (Transient/SP/HB/Optimization)

Optimization of Circuit Component for Impedance Matching with simulated S-Parameter results







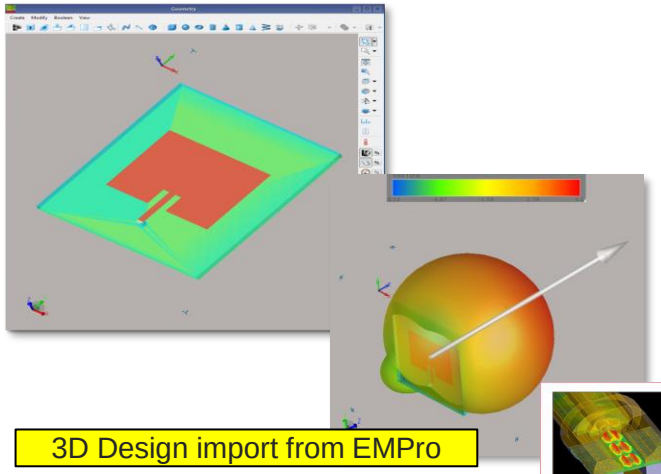
Check Antenna behavior with operating conditions

- Circuit Excitation with SMD/Circuit Components

KEYSIGHT

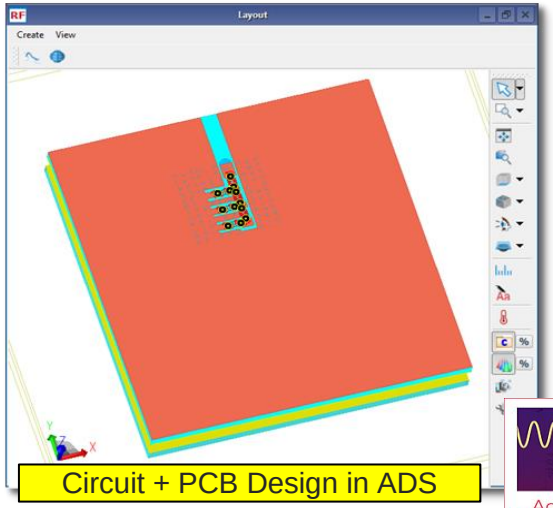
Demo: Rectenna Design

Antenna Design in EMPro, Rectifier PCB Design in ADS



3D Design import from EMPro

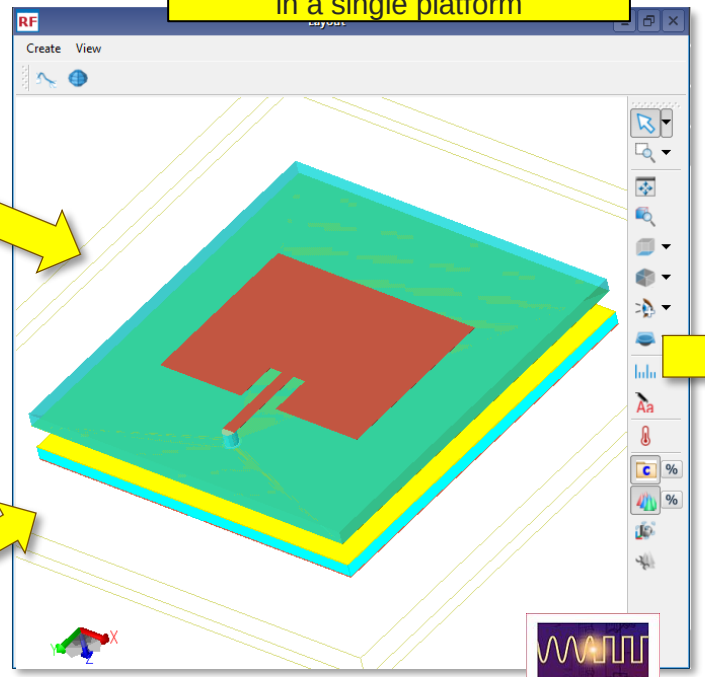
EMPro



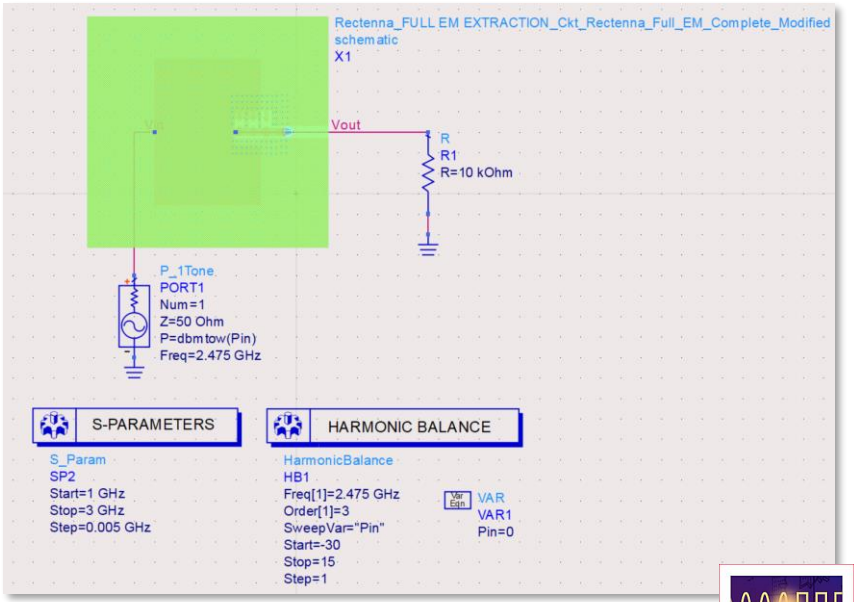
Circuit + PCB Design in ADS

Advanced Design System

Combine Circuit and EM Designs in a single platform

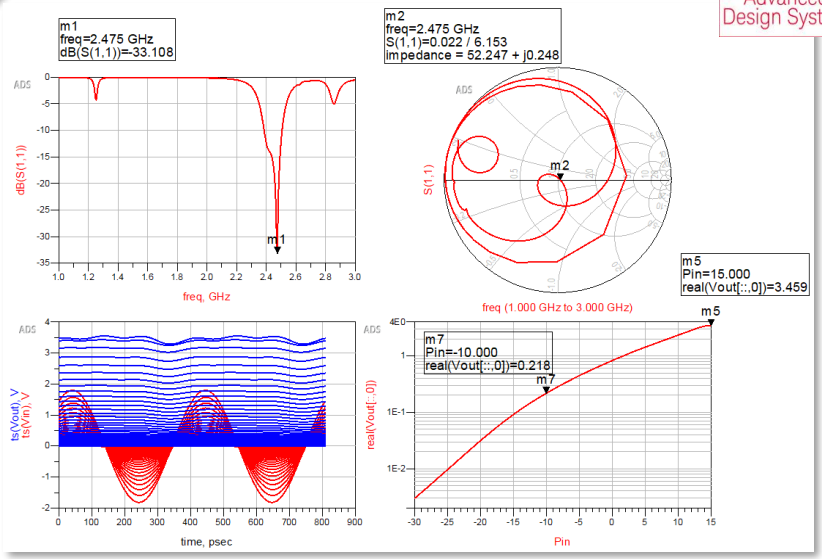


Advanced Design System



EM-Circuit Cosimulation that allows Tuning and Optimization

Advanced Design System

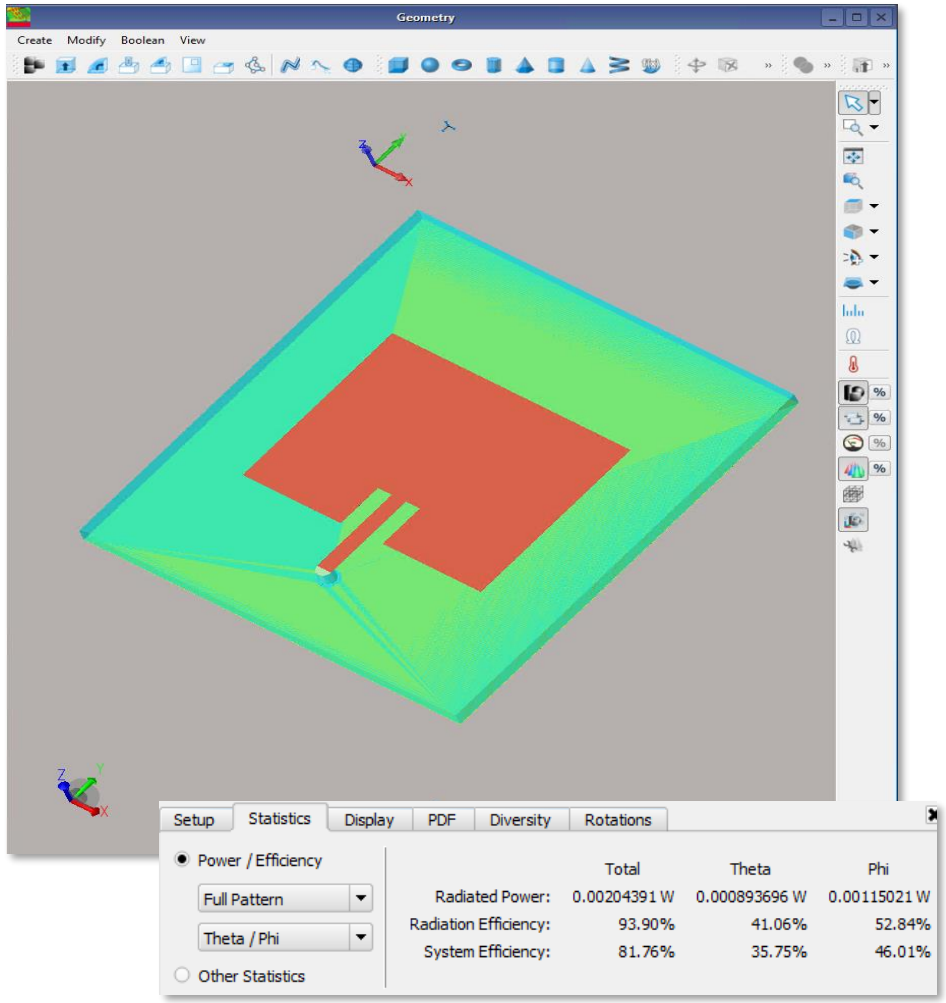


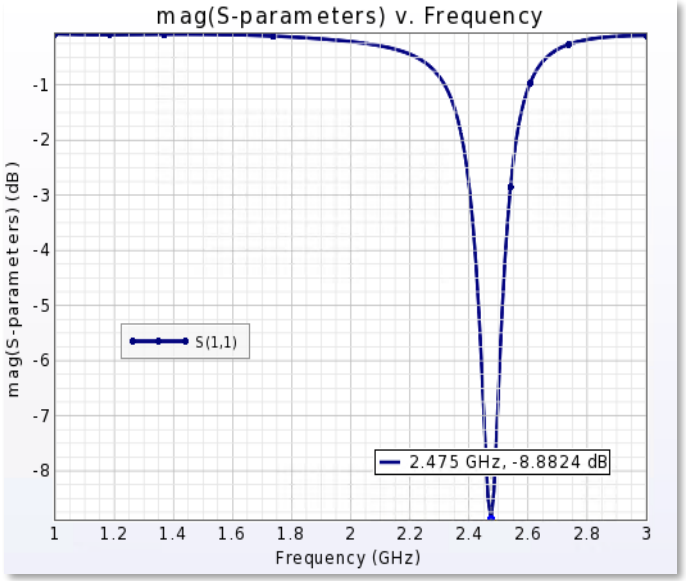
ADS + EMPro provides Design Insights.
Design still needs to be fine-tuned for a smoother DC output voltage!

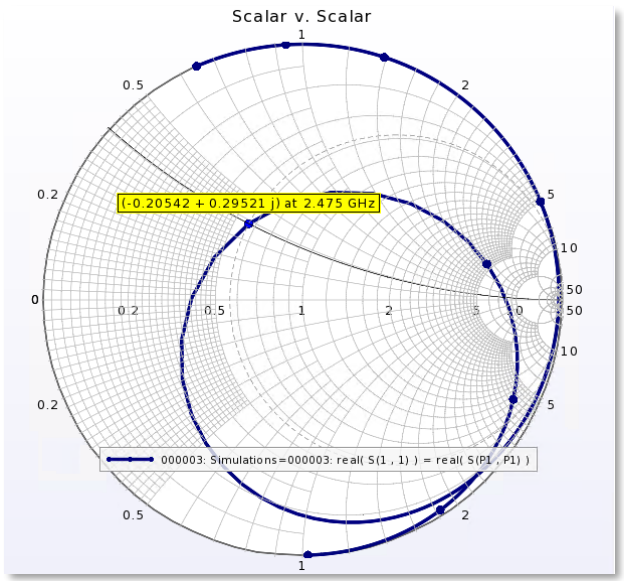
KEYSIGHT

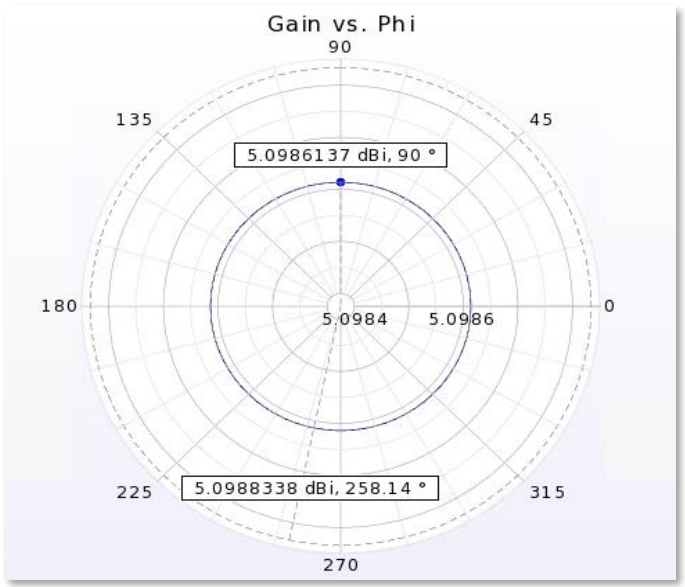
Demo: Rectenna Design

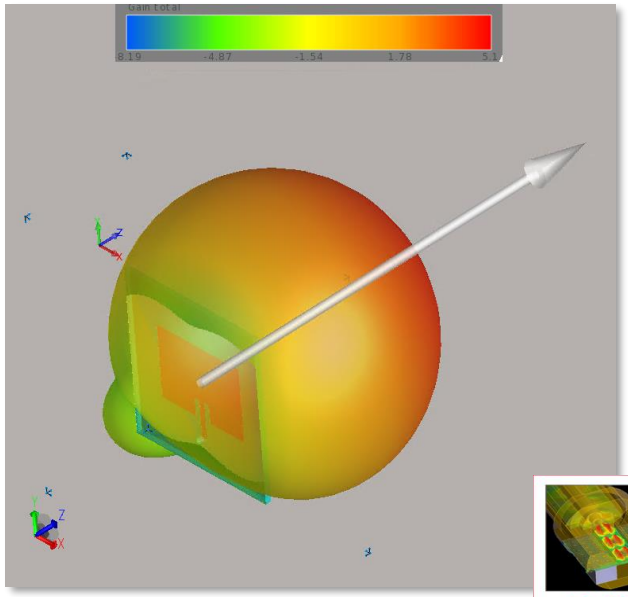
Antenna Design in EMPro

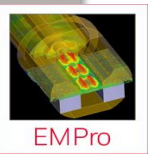






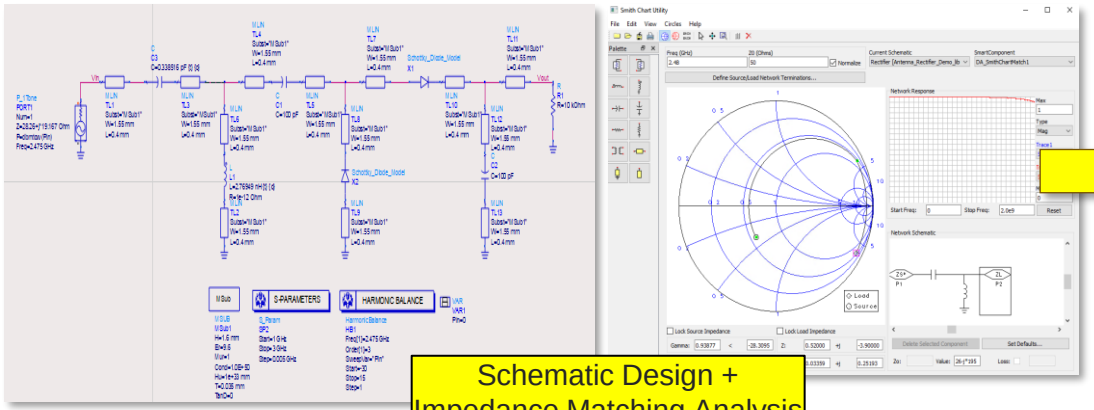




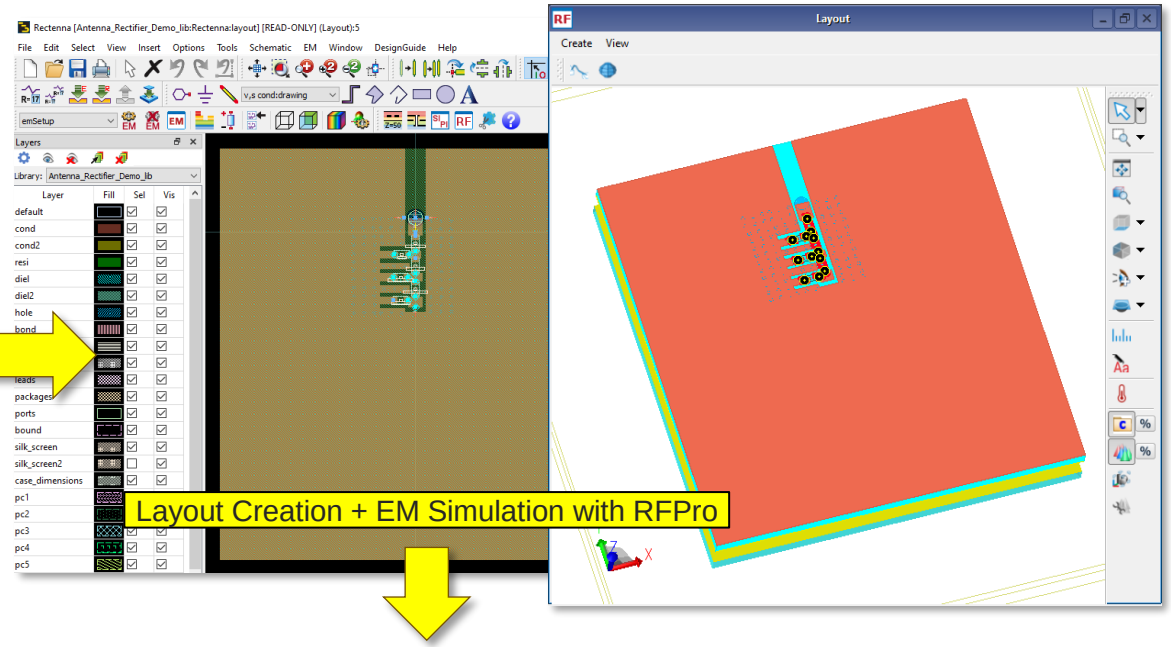


Demo: Rectenna Design

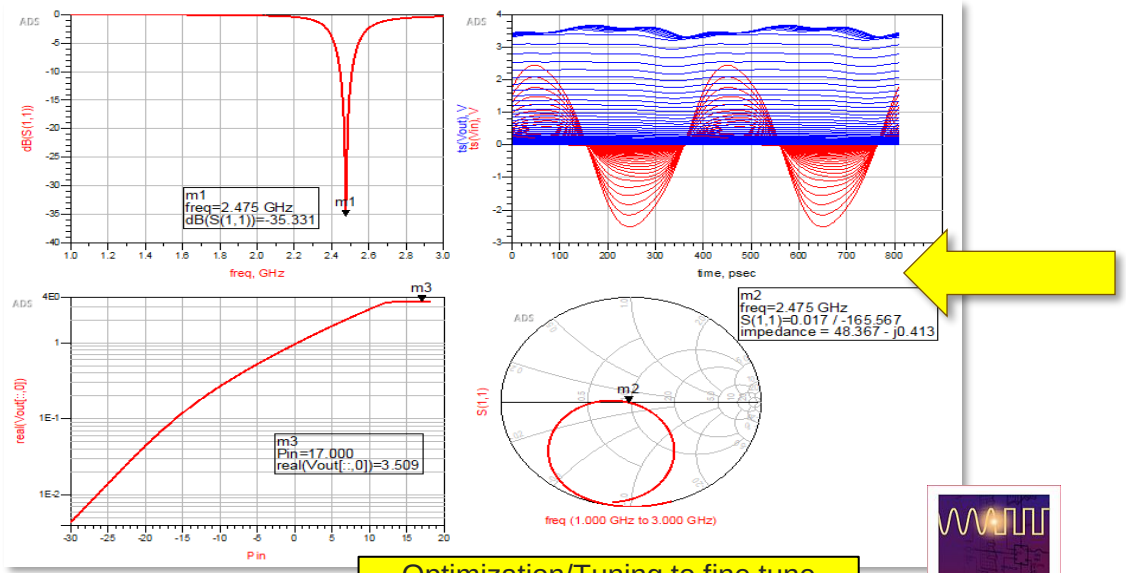
Rectifier PCB Design in ADS



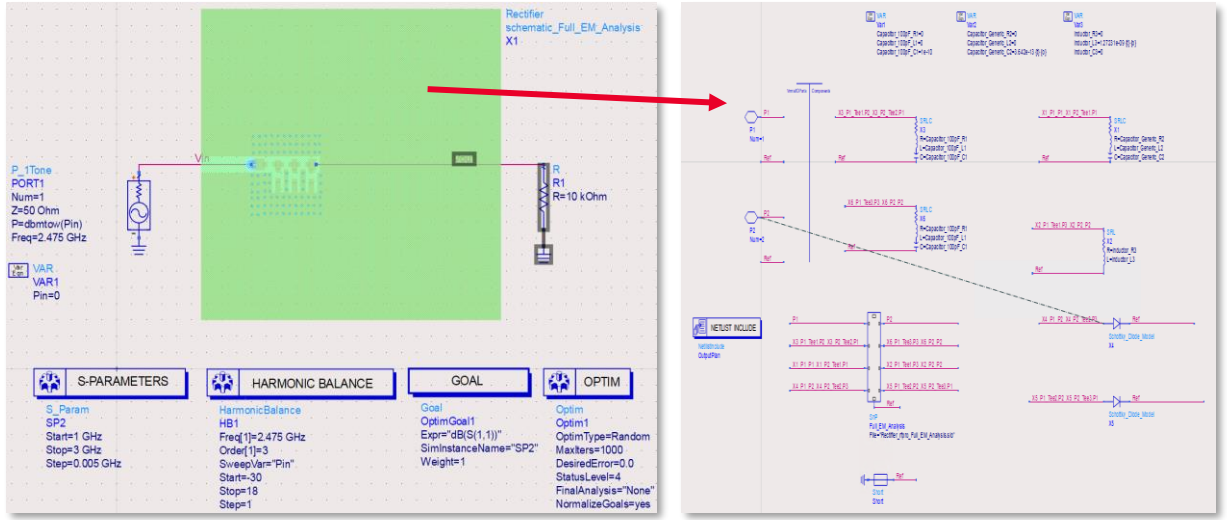
Schematic Design + Impedance Matching Analysis



Layout Creation + EM Simulation with RFPro



Optimization/Tuning to fine tune design performance



Test Bench simulation with RFPro Generated EM Sub-Circuit + Tuning

Advanced Design System

915MHz RF Energy Harvesting Variable Pitch Angle Helix Antenna Design

Integrating 3D Antenna and PCB Circuit Design

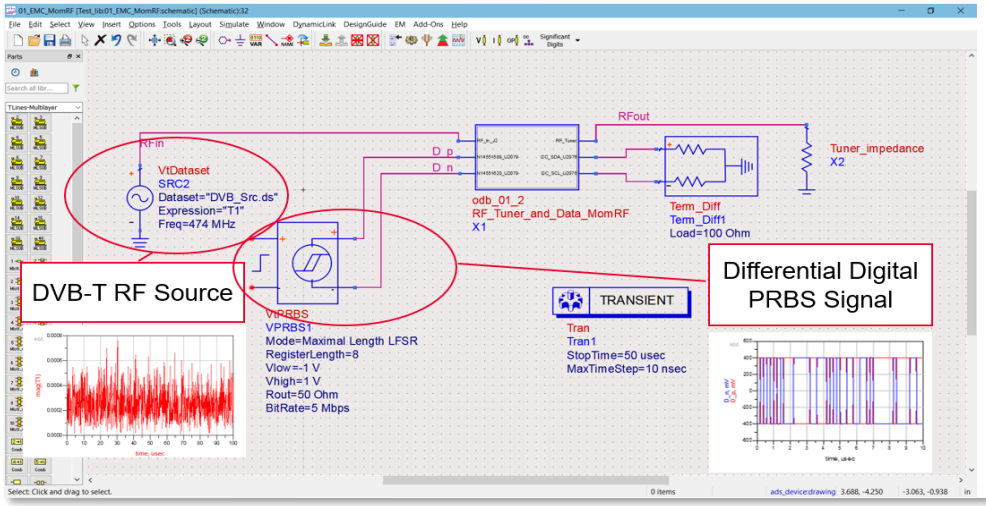
- Demonstration of Integrating 3D Antenna Design with PCB Circuit Design
- Antenna imported from 3rd party tool into EMPro, followed by into ADS
- RFPro simulation done with Antenna mounted on PCB Board
- Impedance matching with Modelithics component was done together with Antenna and PCB Board

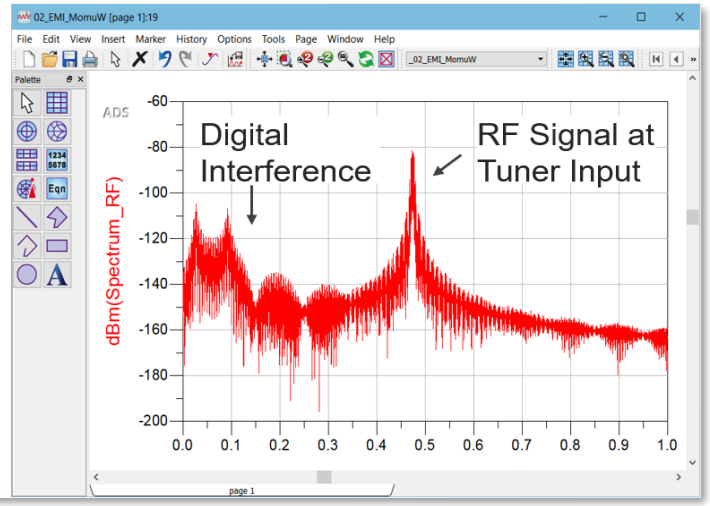
Tutorial 7: 915MHz RF Energy Harvesting Variable Pitch Angle Helix Antenna Design

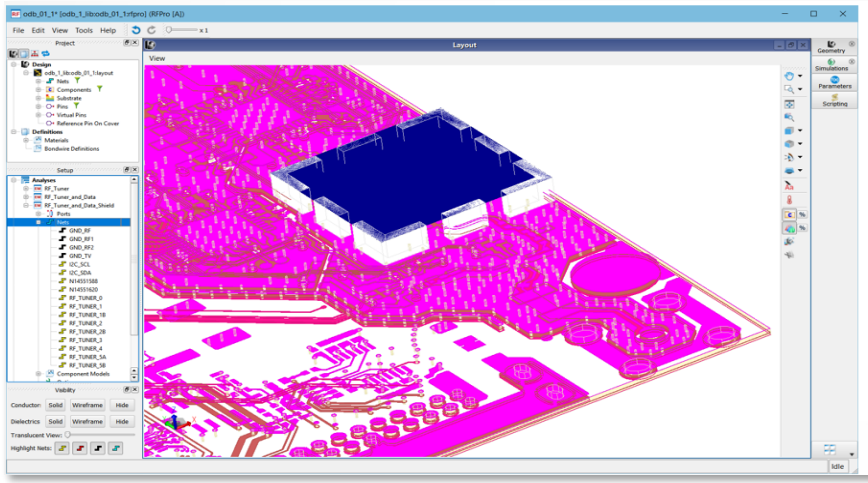
YouTube Link: https://www.youtube.com/watch?v=w6Ca52H__8k

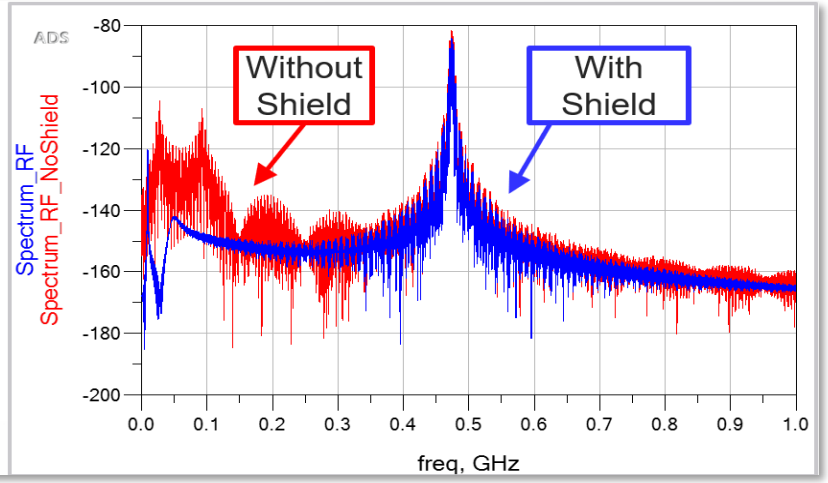
Another use case of EMPro and ADS Integration

Reference – RF PCB - HD TV Tuner with Embedded CPU









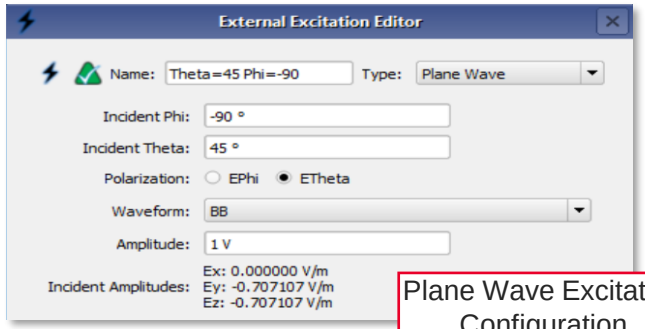
RF PCB - HD TV Tuner with embedded CPU Application Notes
https://edadocs.software.keysight.com/eesofapps/rf-pcb-hd-tv-tuner-with-embedded-cpu-577603432.html

KEYSIGHT

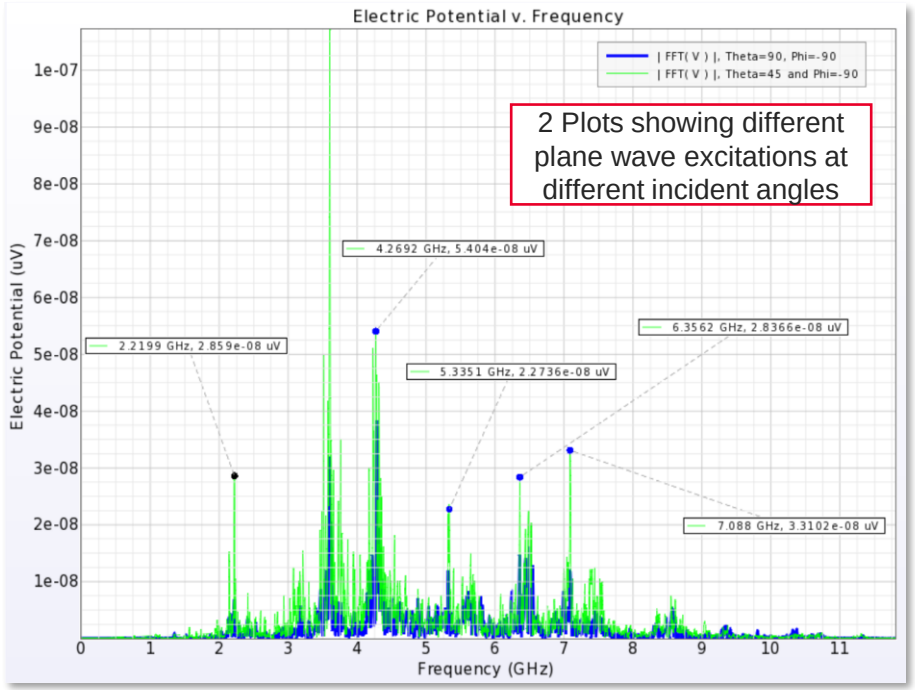
General Introduction to EMI/EMC simulation with EMPro

Demo: EMC Simulation with EMPro

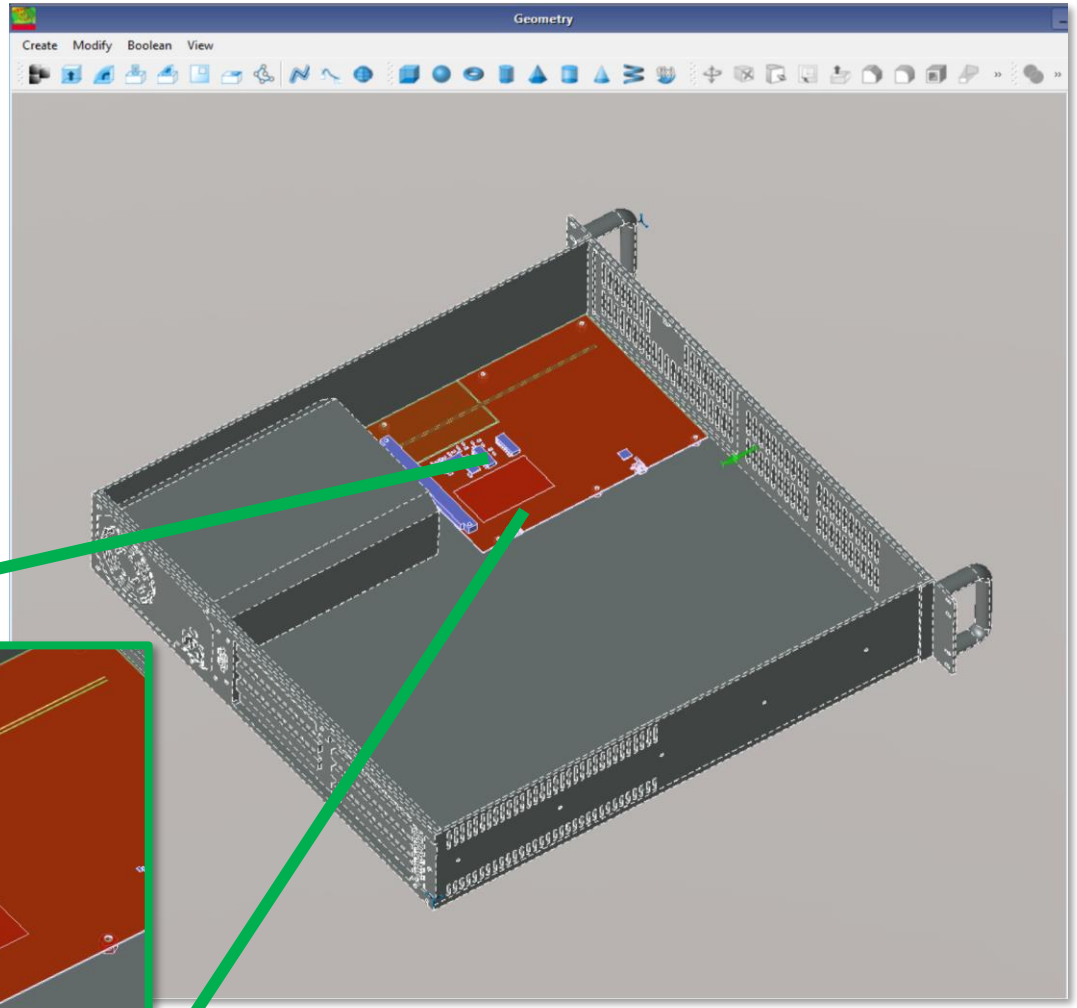
Plane Wave Excitation on Rackmount Chassis

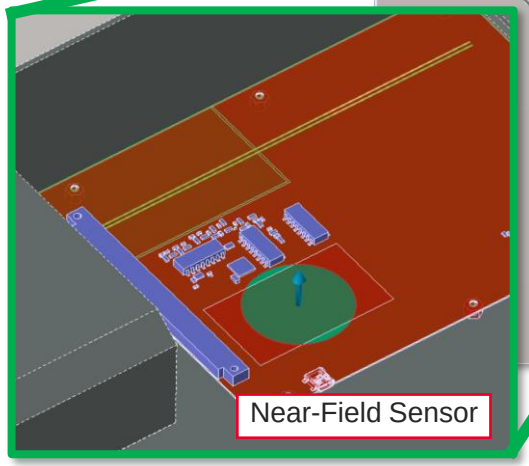


Plane Wave Excitation Configuration



2 Plots showing different plane wave excitations at different incident angles



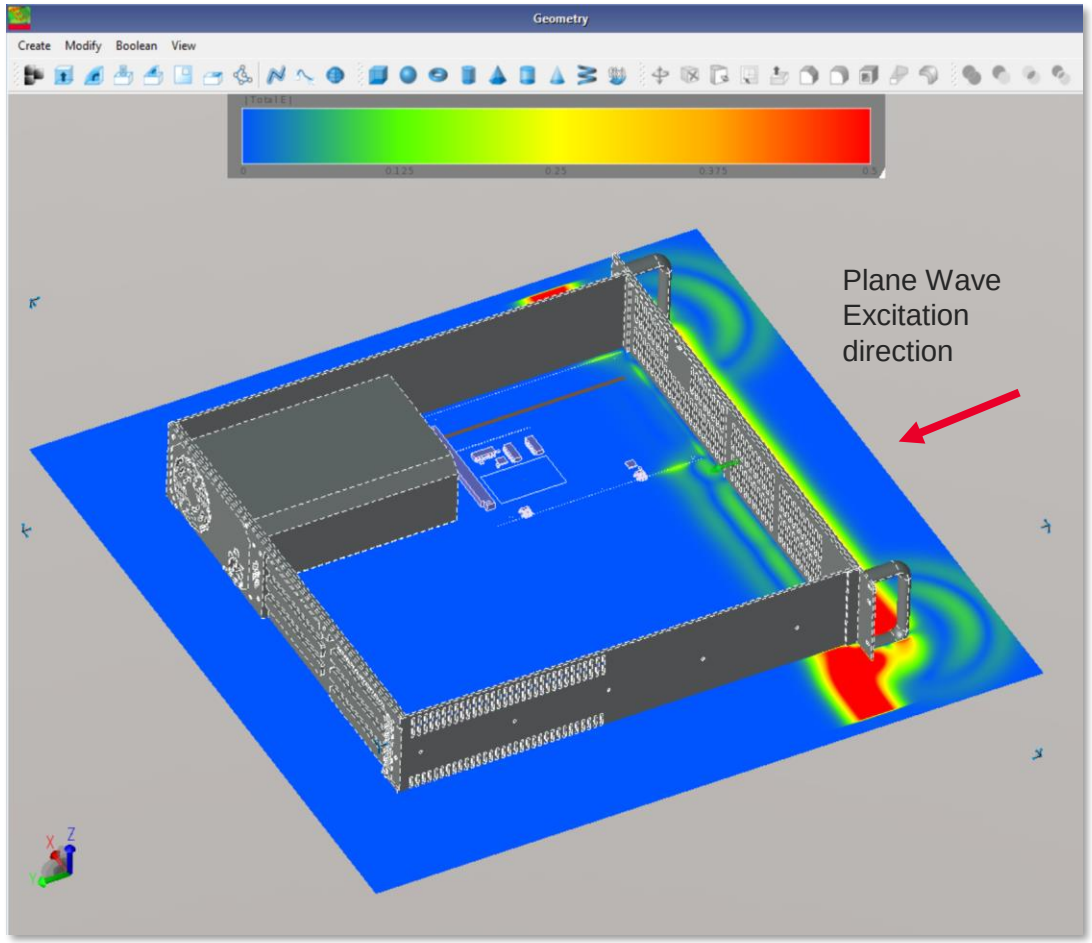


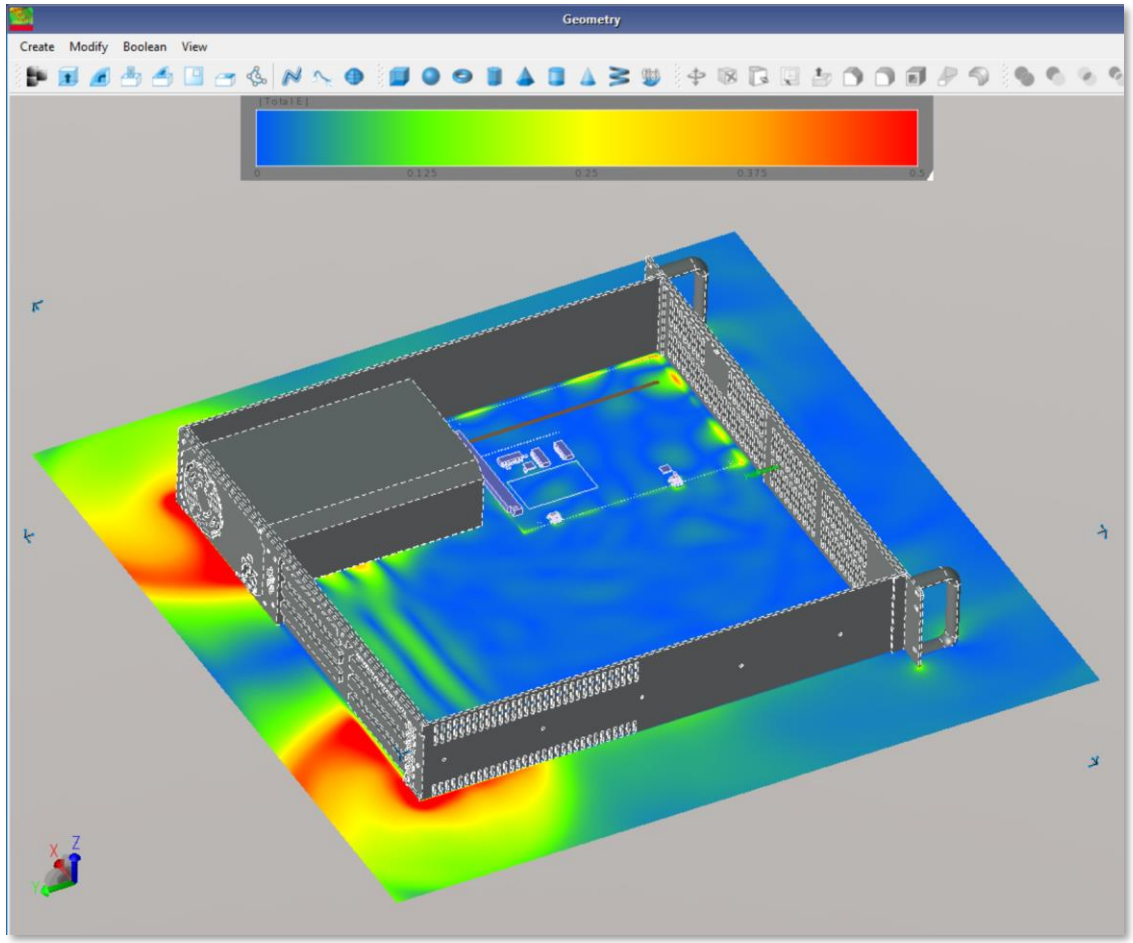
Near-Field Sensor

Demo: EMC Simulation with EMPro

Plane Wave Excitation on Rackmount Chassis

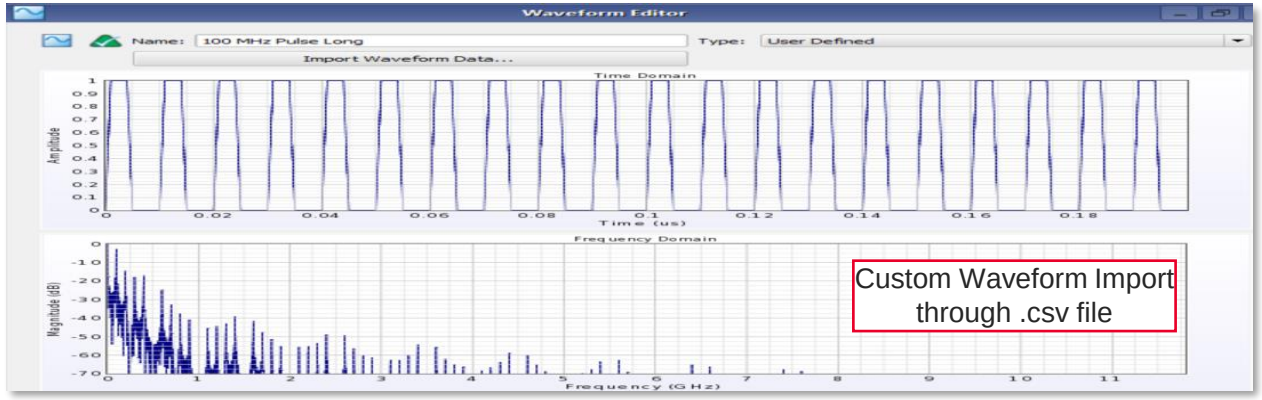
Transient E-Field Plot using Plane Wave Excitation

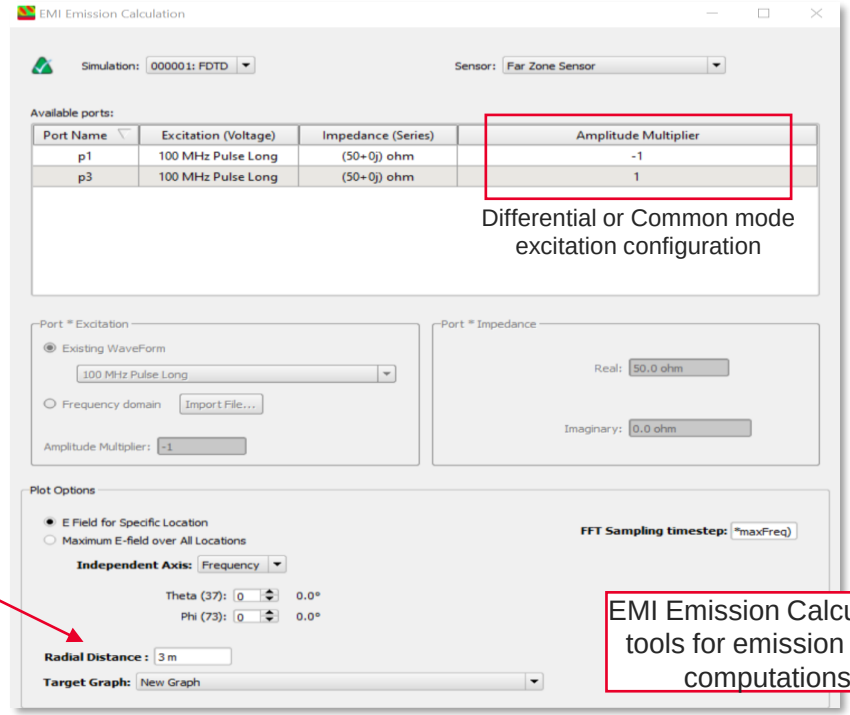


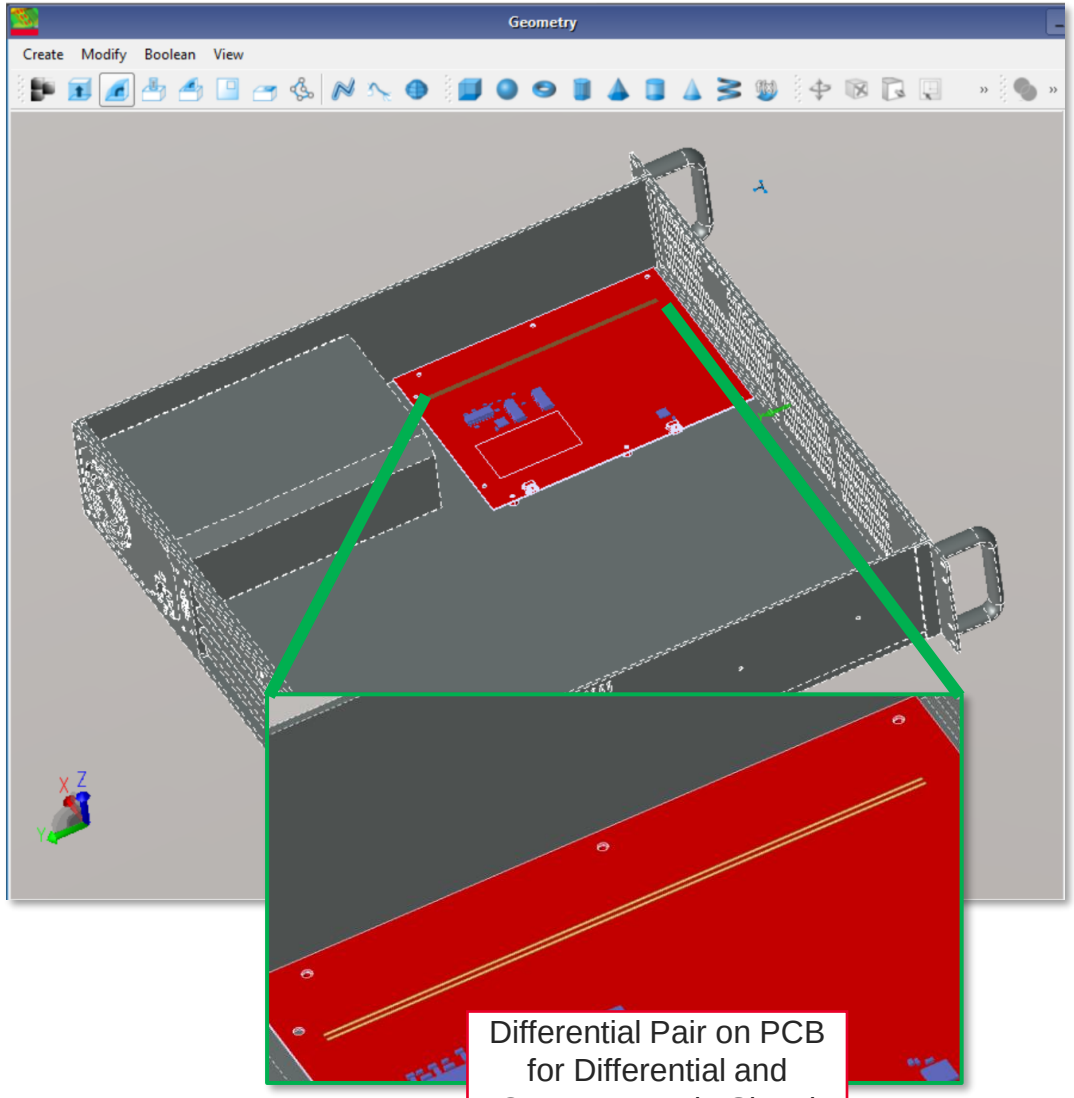


Demo: EMI Simulation with EMPro

EMI Emission

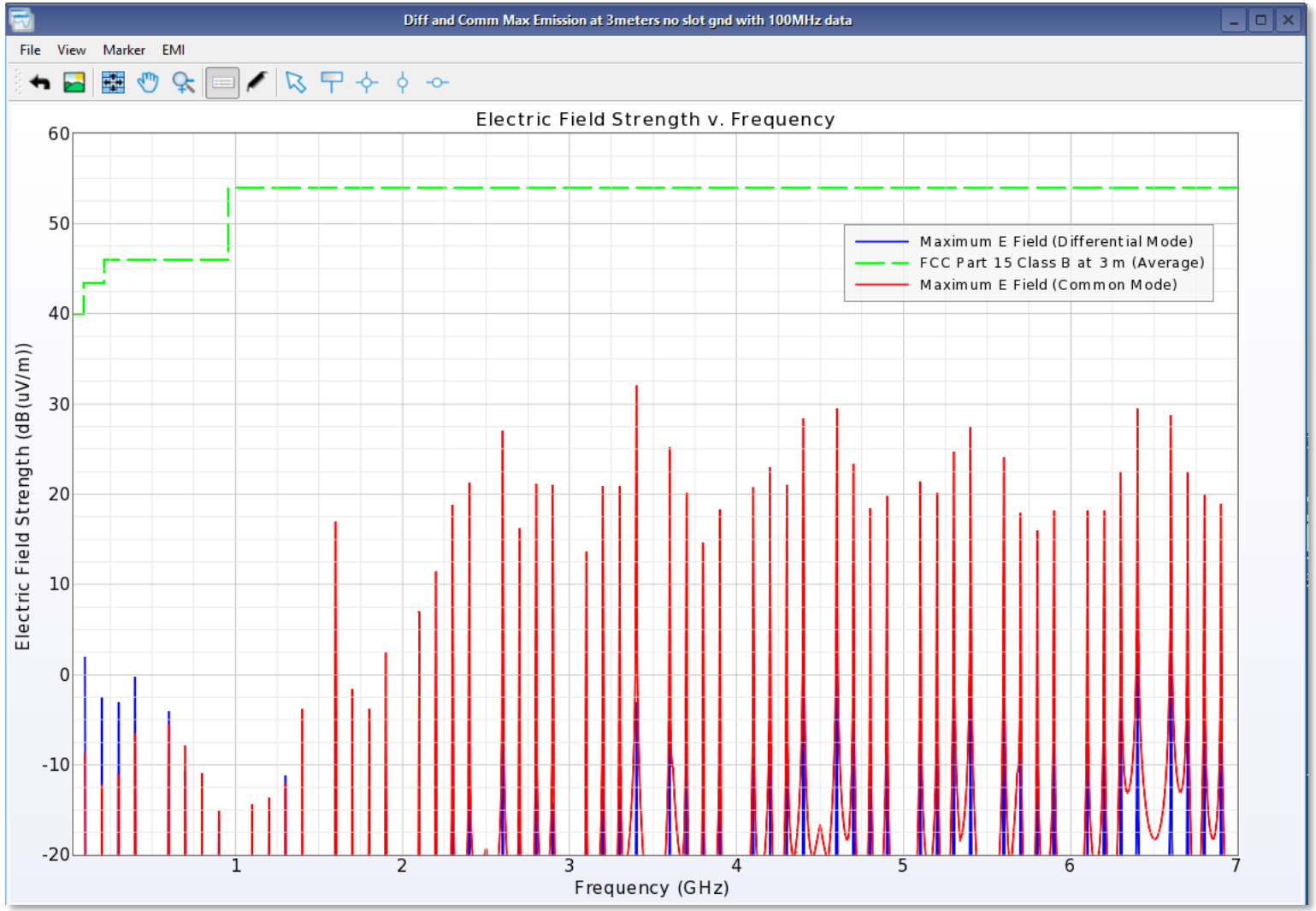






Demo: EMI Simulation with EMPro

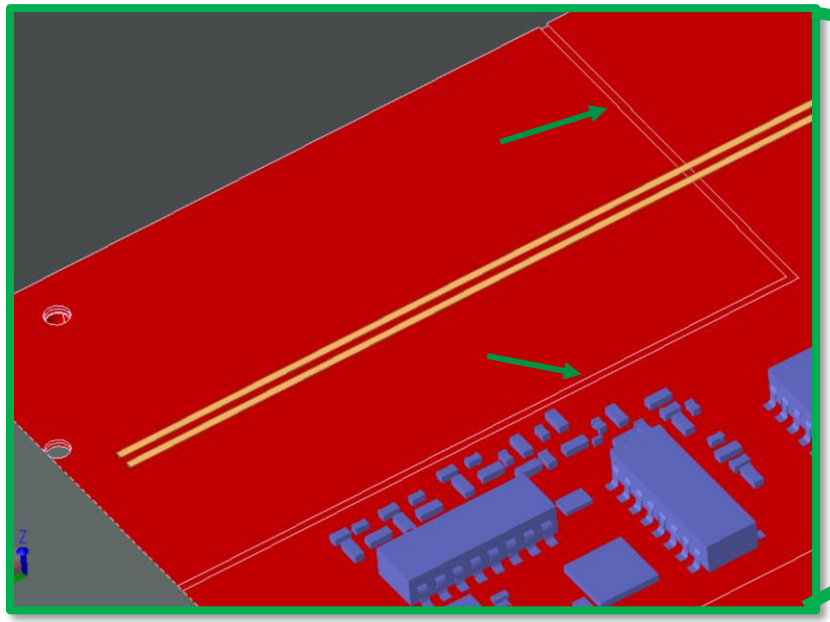
EMI Emission

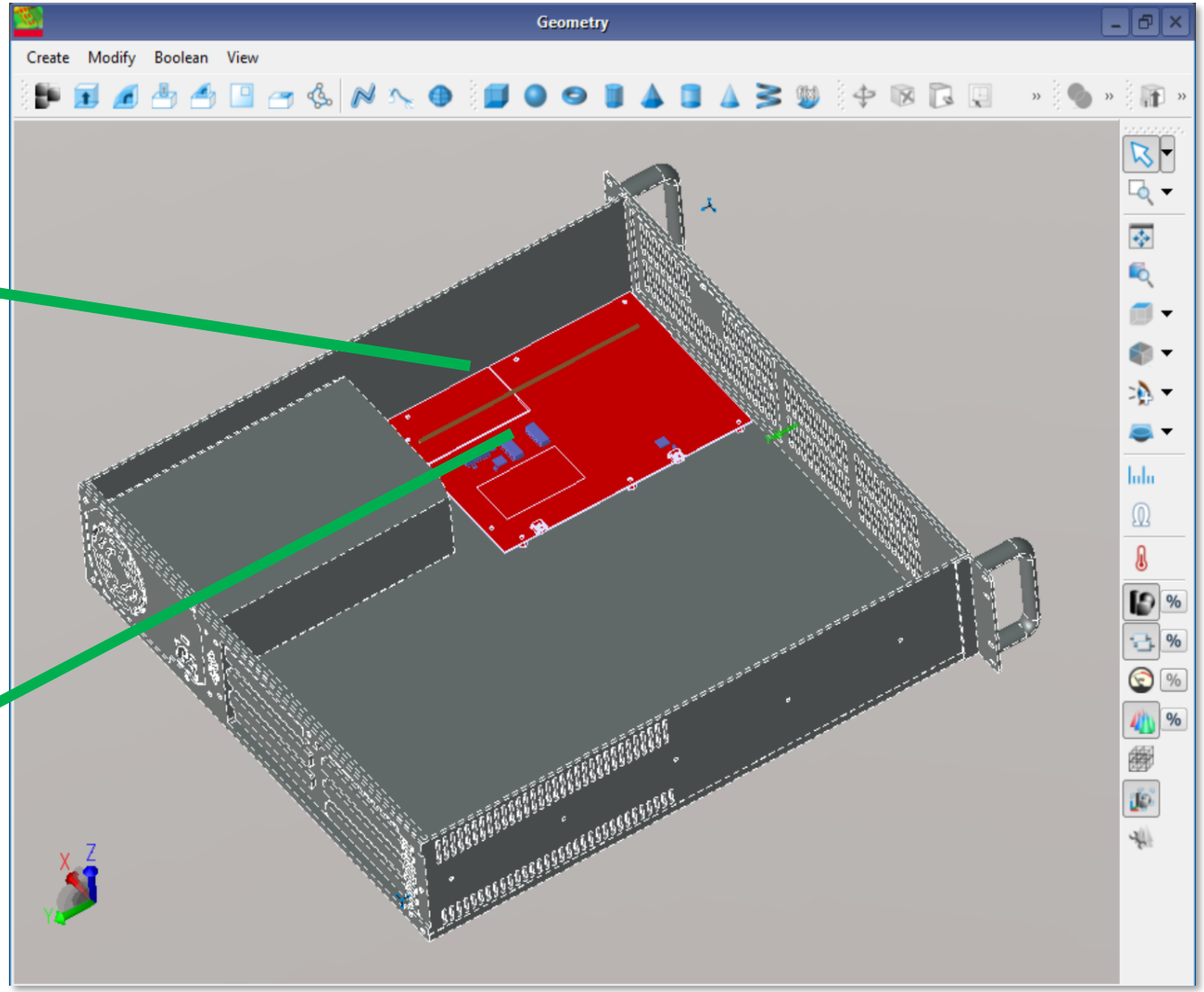


Demo: EMI Simulation with EMPro

EMI Emission (with Slot added)

Slot added under the differential pair to simulate the effects of discontinuities in the PCB Ground Plane (See Green arrows)

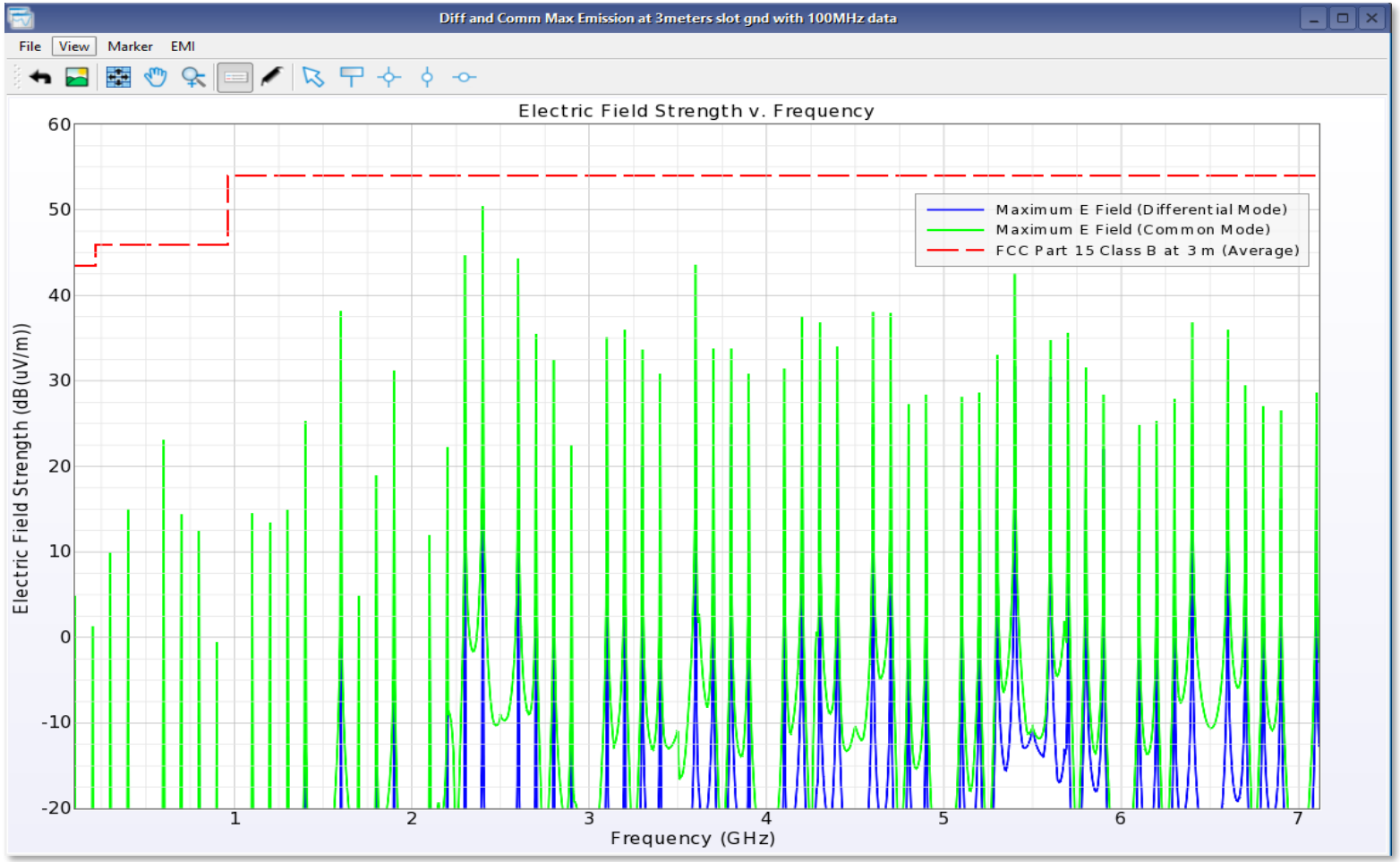




Demo: EMI Simulation with EMPro

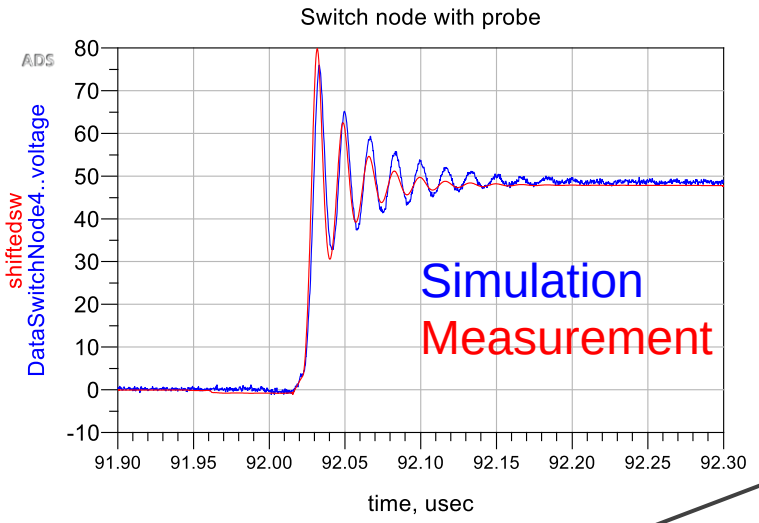
EMI Emission (with Slot added)

Slot has increased emission levels

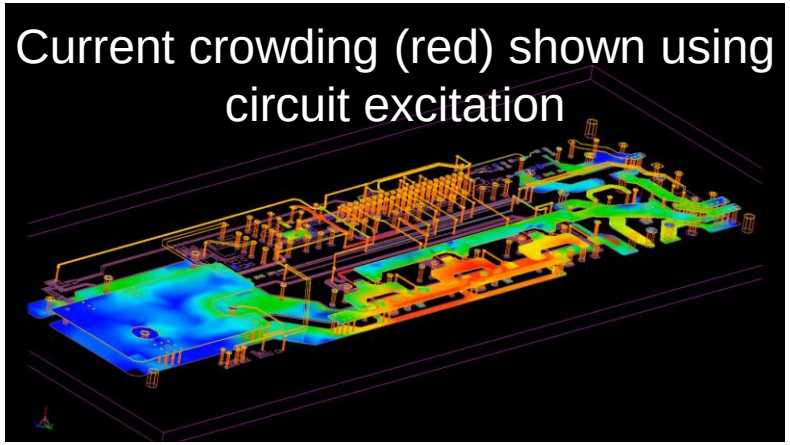


Keysight PathWave Design EMI Solutions

PEPro – Conducted and Radiated EMI for Power Electronics (DC-DC Converter, etc…)

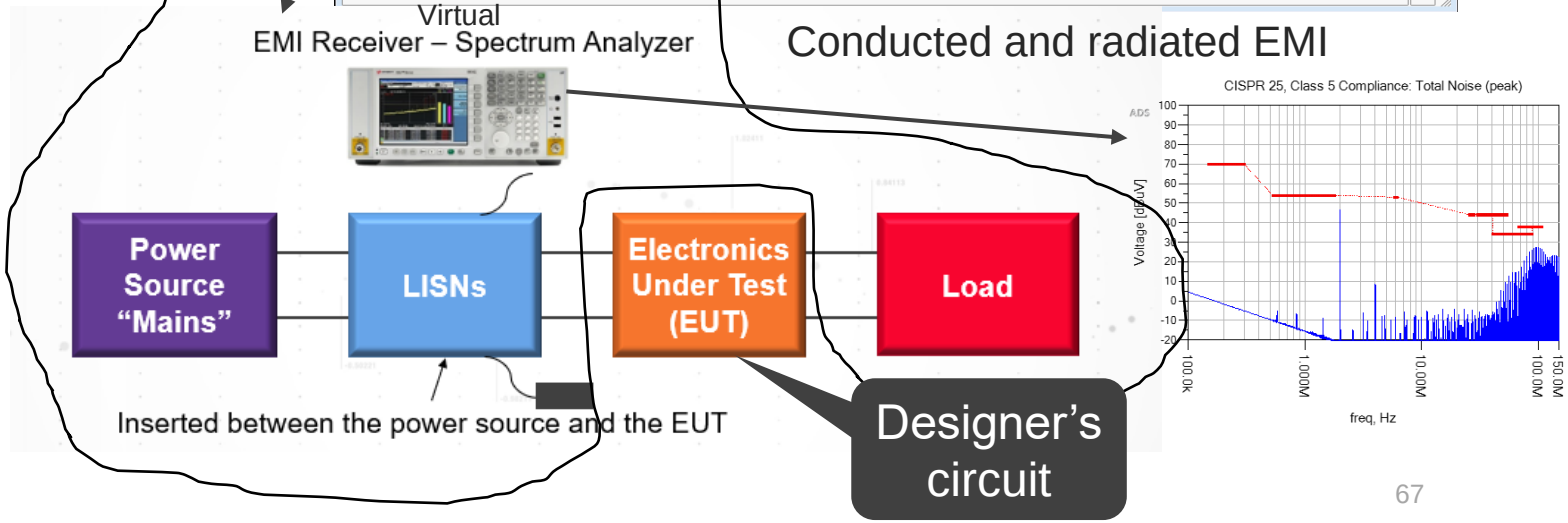


PEPro testbench



Virtual
EMI Receiver – Spectrum Analyzer

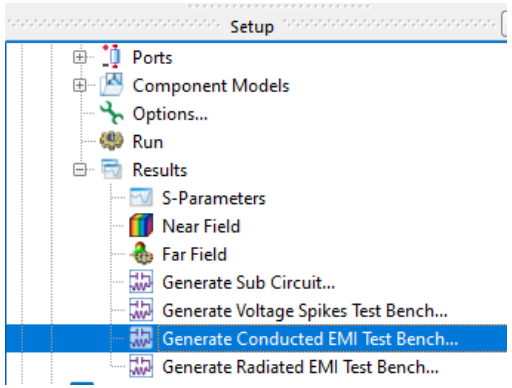
Conducted and radiated EMI



Designer's circuit

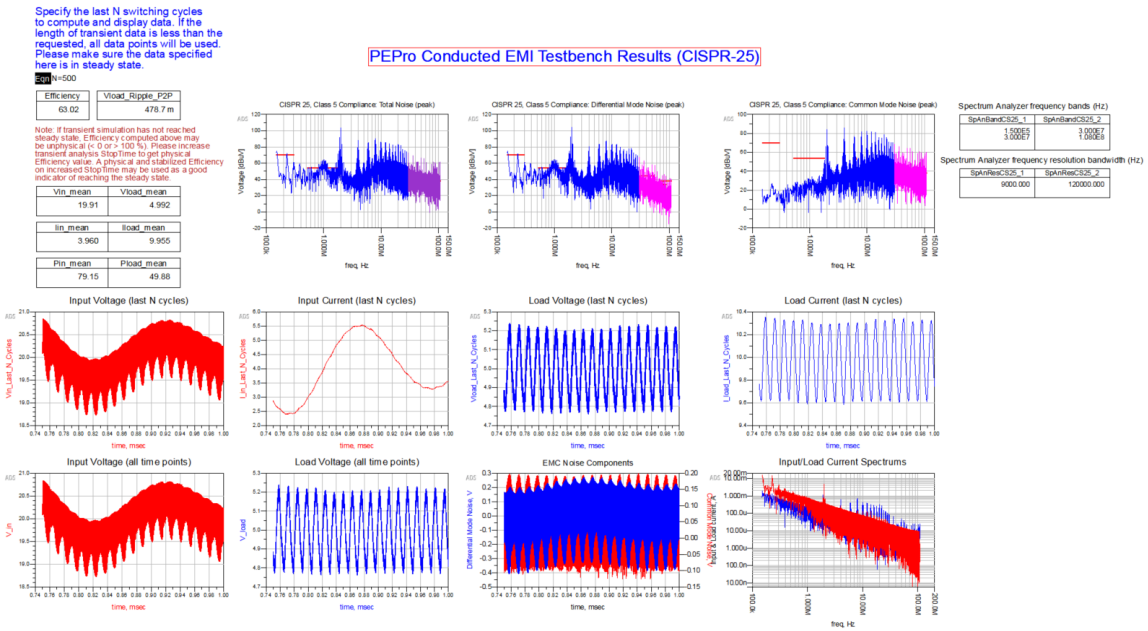
Keysight PathWave Design EMI Solutions

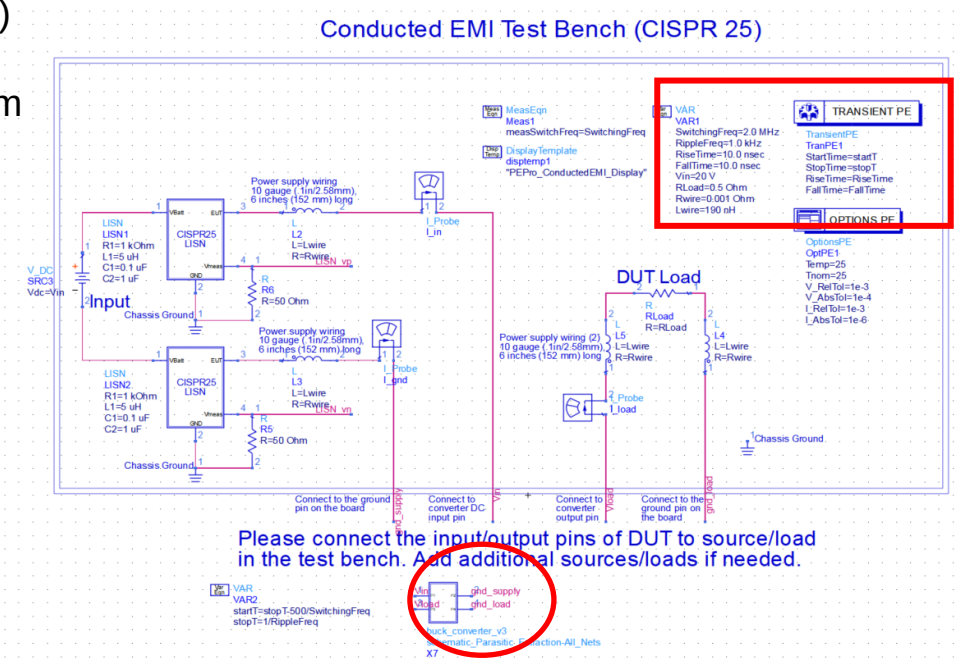
PEPro – Conducted and Radiated EMI for Power Electronics (DC-DC Converter, etc…)



- For this controller, the RiseTime and FallTime in Transient PE are from PEPro SMPS frequency plan.

- The Data Display shows the peak spectrum (total, differential / common mode noise) of SMPS noise calculated from the Linear Impedance Stabilization Network (LISN) output according to the CISPR-25 requirements of the frequency range and spectrum resolution RBW.



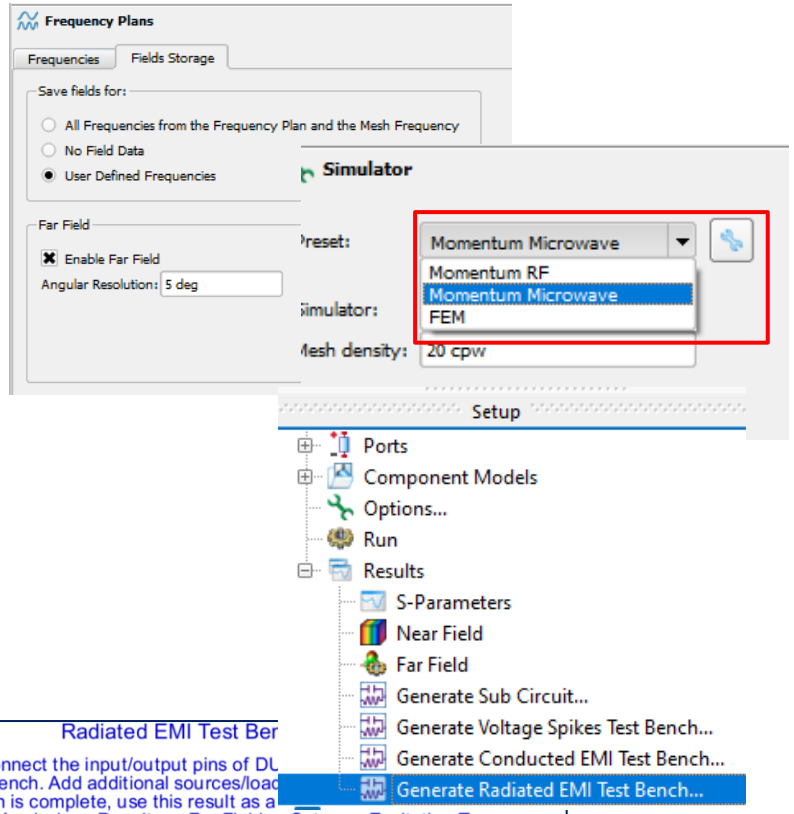


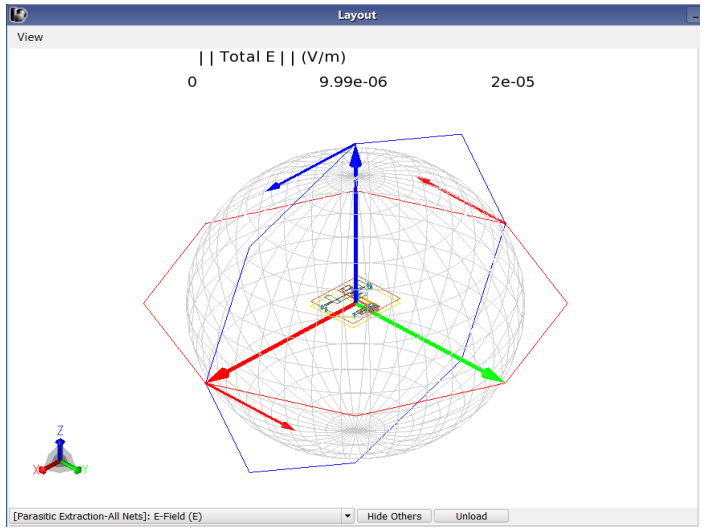
The EM analysis result of the board and the mounted parts are automatically placed as a sub circuit.

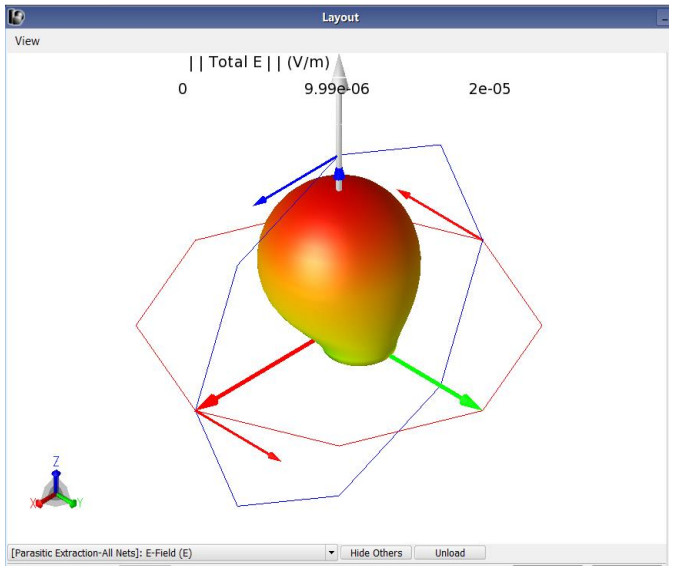
Keysight PathWave Design EMI Solutions

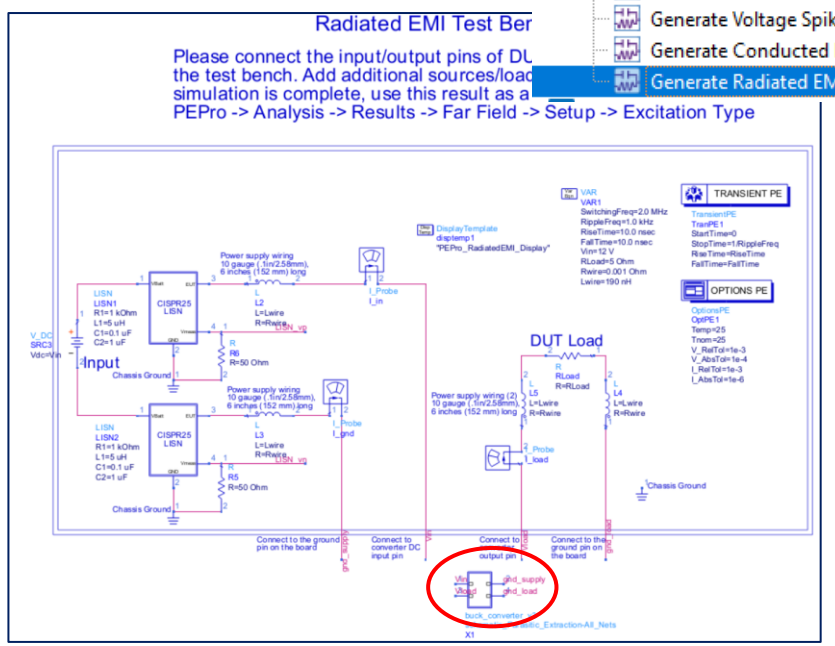
PEPro – Conducted and Radiated EMI for Power Electronics (DC-DC Converter,

- You need to check Enable Far Field in the Field Storage tab of Frequency Plans in Options and select Momentum Microwave or FEM in Preset of Simulator.
- The built-in far-field solver in PEPro can help user obtain far-field radiation patterns under specific excitation. The far-field data, including electric field strength and radiation power, can be examined directly in PEPro.





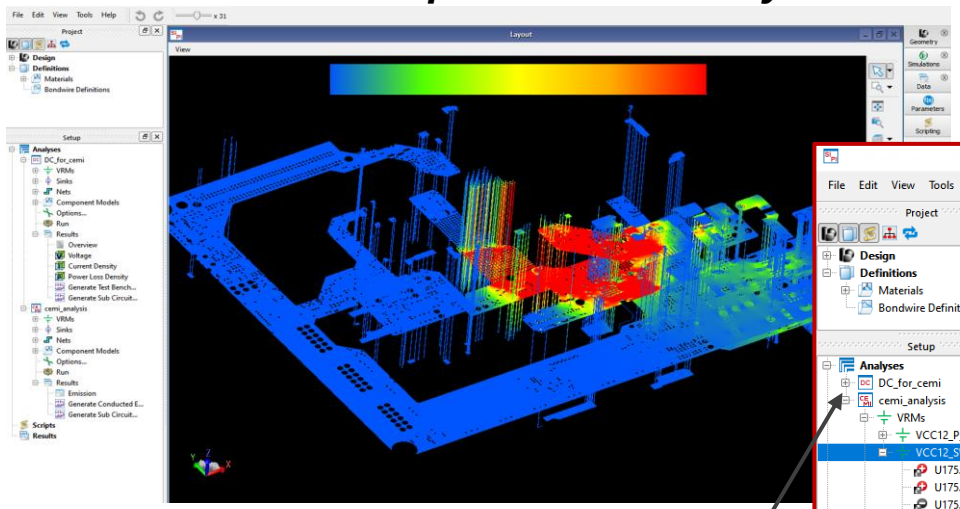




Keysight PathWave Design EMI Solutions

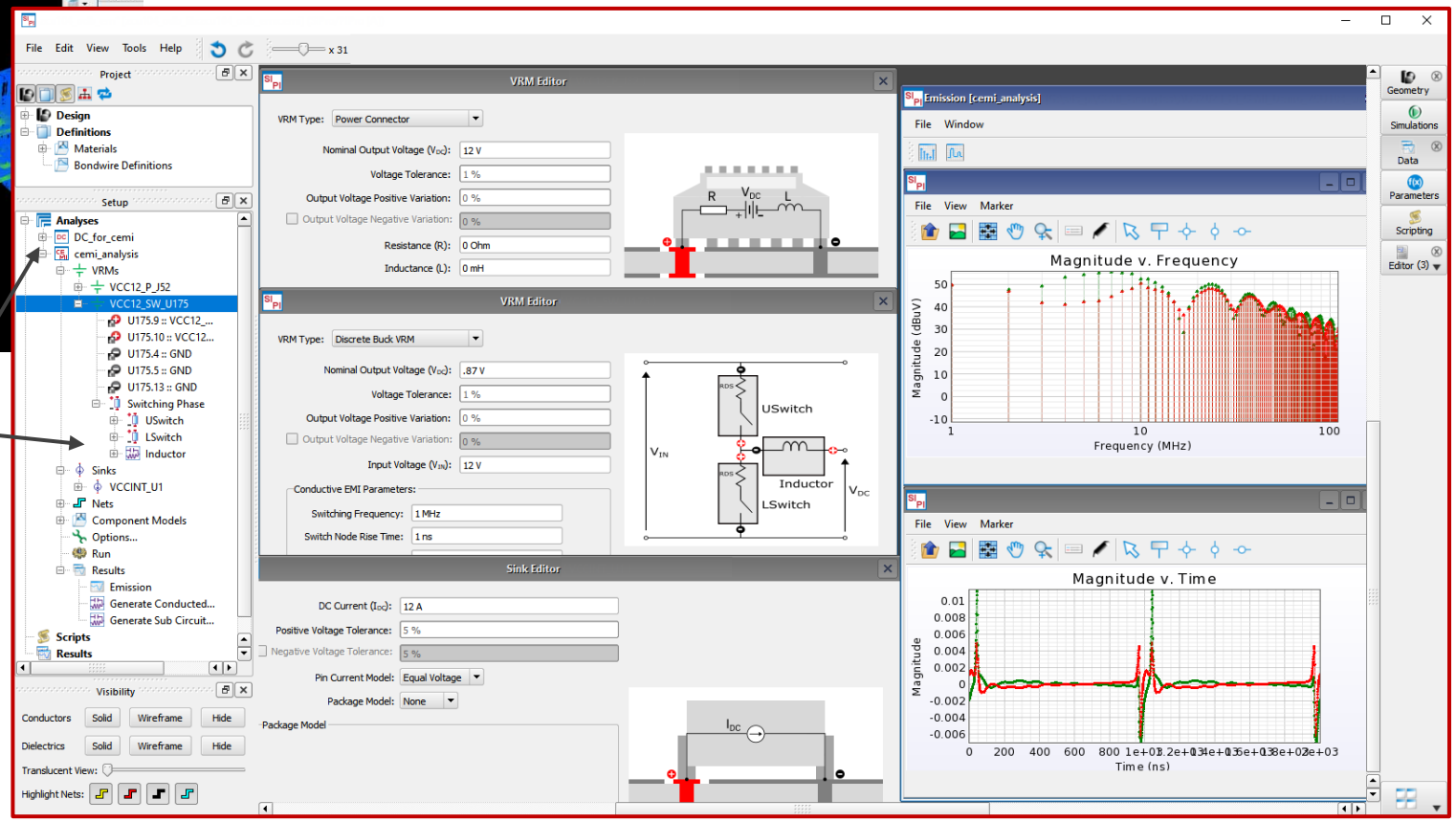
PIPro – Conducted EMI and Radiated EMI for High-Speed Digital Boards

DC IR Drop Current Density



CEMI EM Analysis automates ground plate reference ports. Populates a generic switching model for large signal switching noise. HB simulator for fast steady state frequency and time domain results.

Copy DC/IR Drop Analysis for switching regulator to CEMI Analysis

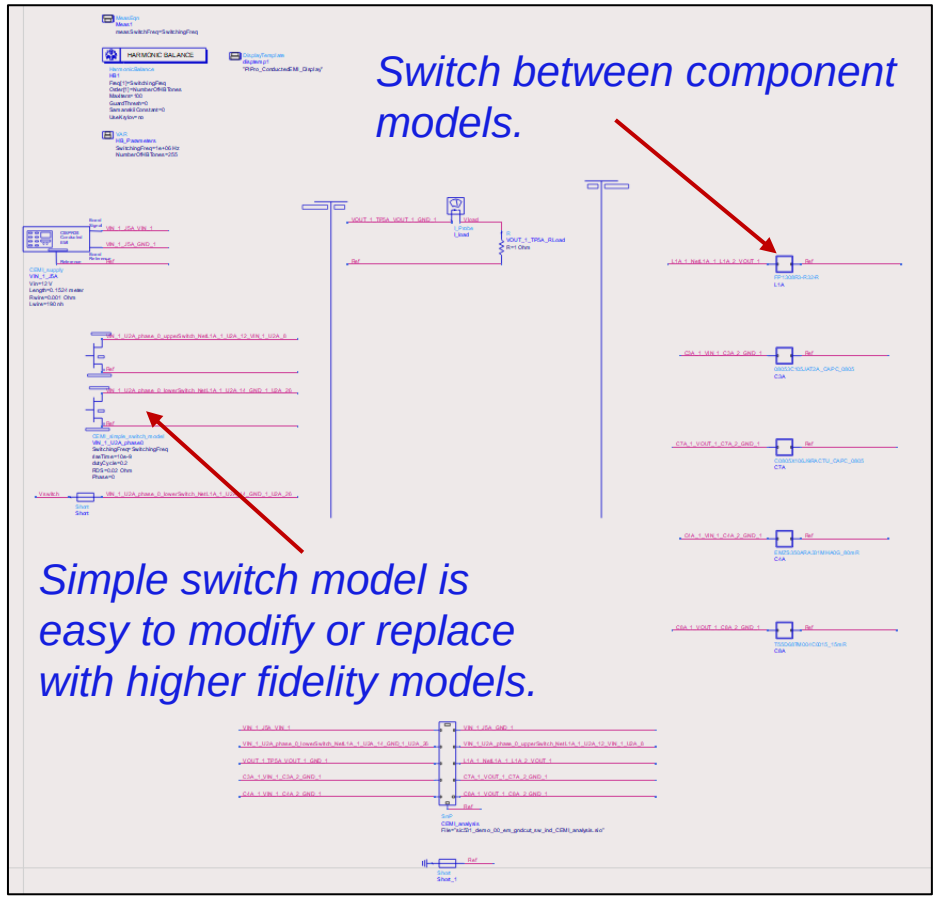


PIPro CEMI Analysis automates the differential setup and generic large signal switching model.

Keysight PathWave Design EMI Solutions

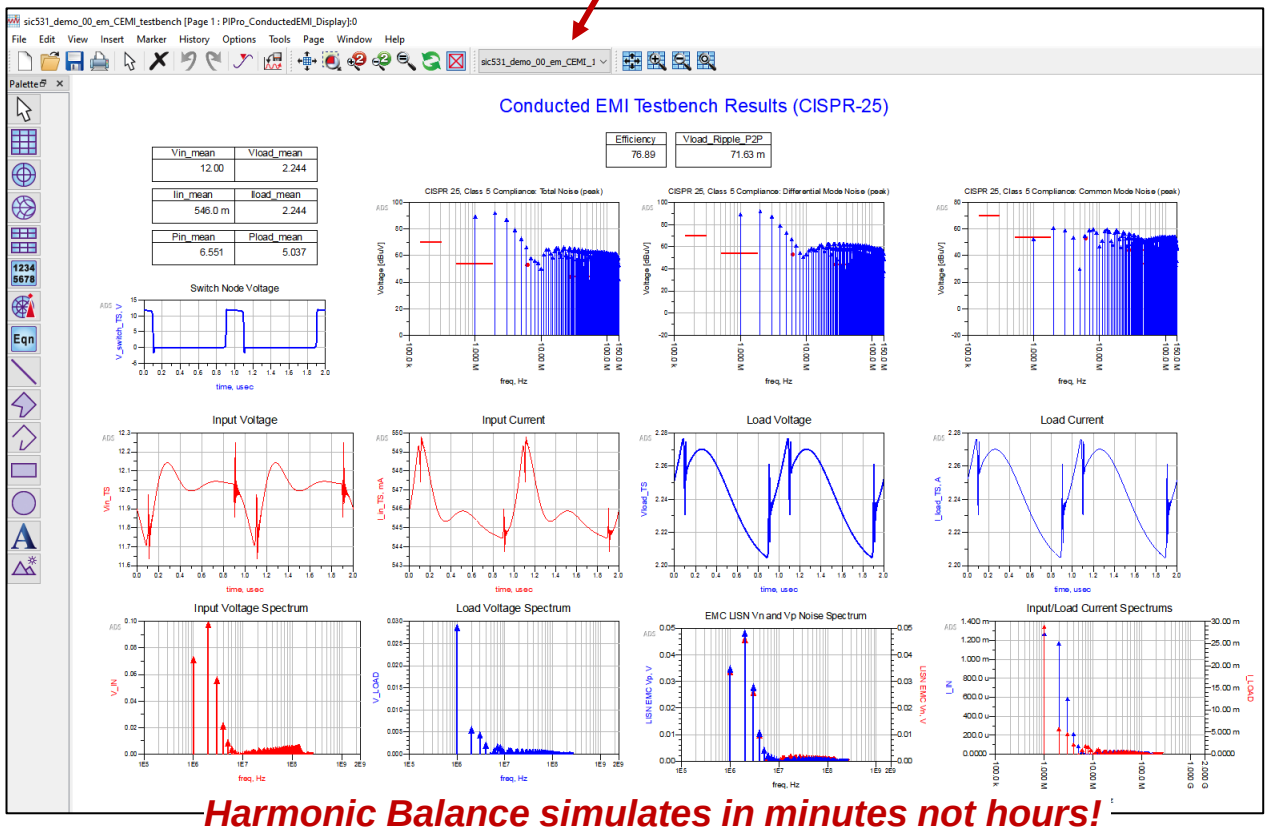
PIPro – Conducted EMI and Radiated EMI for High-Speed Digital Boards

CEMI Export to ADS Test Bench Schematic



Data Display Results

1) Toggle between data sets.

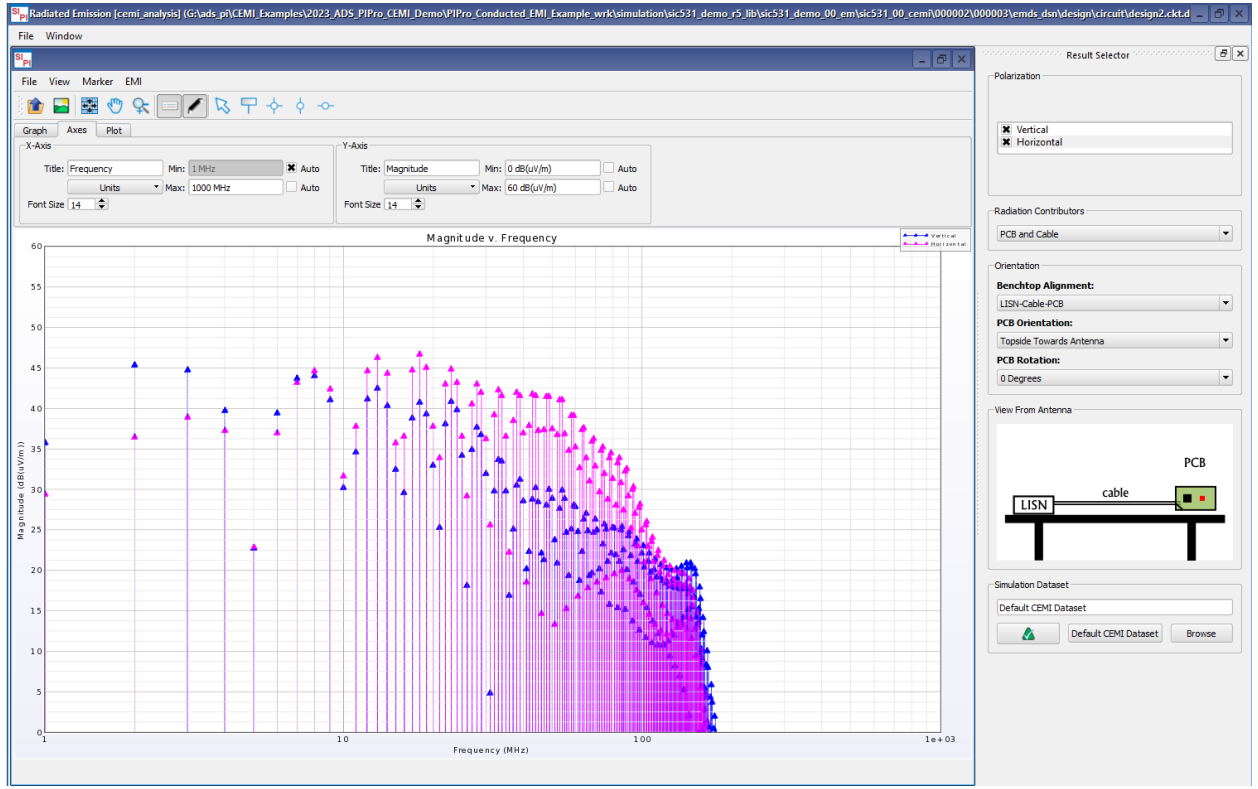


Harmonic Balance simulates in minutes not hours!

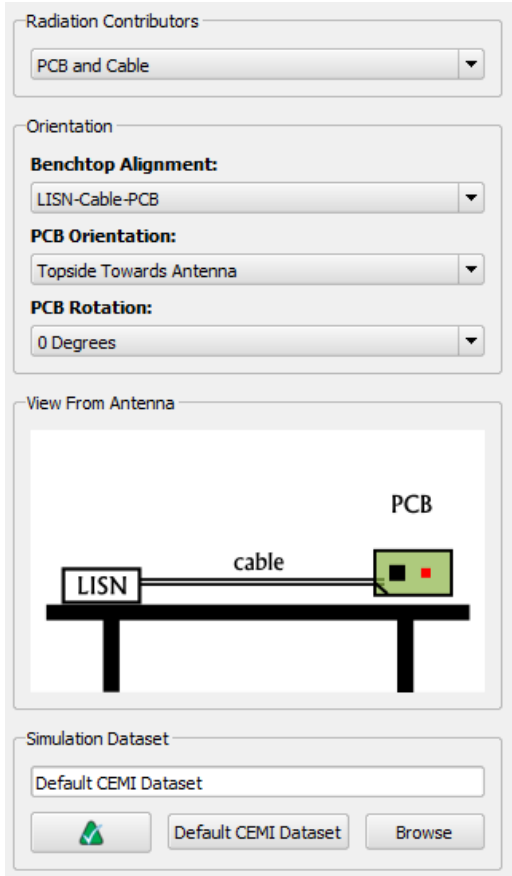
Keysight PathWave Design EMI Solutions

PIPro – Conducted EMI and Radiated EMI for High-Speed Digital Boards

Radiated Spectrum Vertical and Horizontal



Orientation and Setup Options



Common mode currents on a cable can radiate. PIPro Radiated EMI shows results with and without the cable.

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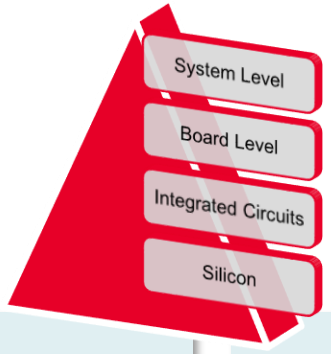
Conclusion

Conclusion

- ✓ADS provides efficient and accurate EM-Circuit simulation workflow for design covering ICs, Modules and PCB Designs
- ✓EMPro provides great insights for 3D Modeling EM simulation
- ✓Integrate PCB and 3D component design with both ADS and EMPro

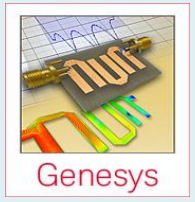
Keysight PathWave Design

Leading communication product design

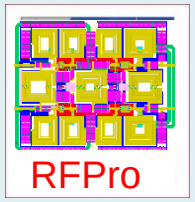


RF & Microwave

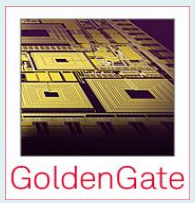
ADS
– MMIC, RF Board, SiP, HSD



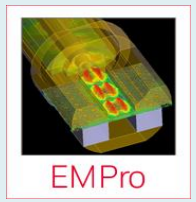
Genesys
– RF Board Circuit Synthesis



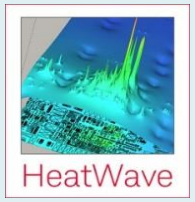
RFPro
– EM-Circuit analysis for circuit designers



GoldenGate
– RFIC Mixed Signal

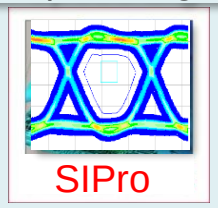


EMPro
– 3D EM

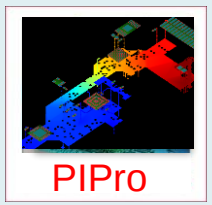


HeatWave
– IC electro-thermal analysis

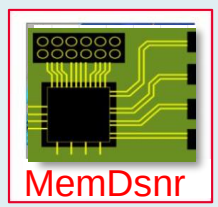
High Speed Digital



SIPro
– Signal Integrity design for High Speed Digital



PIPro
– Power Integrity design for DC power distribution network



MemoryDesigner
– Designs DDR4, DDR5 Memory modules

System Level Design

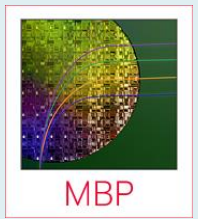
SystemVue
– Electronic System Level

Power Electronics

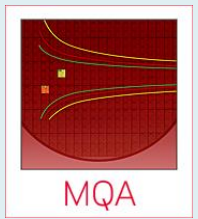
PEPro
- Power Electronics high speed switch mode power supply
–

Device Modeling

IC-CAP
– Device Modeling GaAs, GaN, Custom Models Measurement

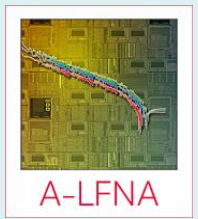


MBP
– Device Modeling Silicon



MQA
– Model Quality Assurance

WaferPro Express
– Wafer-level automated measurement



A-LFNA
– Advanced Low-Frequency Noise Analyzer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