RF/MW Module Design in ADS

CHEN, Jason Xue, Xin-Dong

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Keysight EEsof EDA

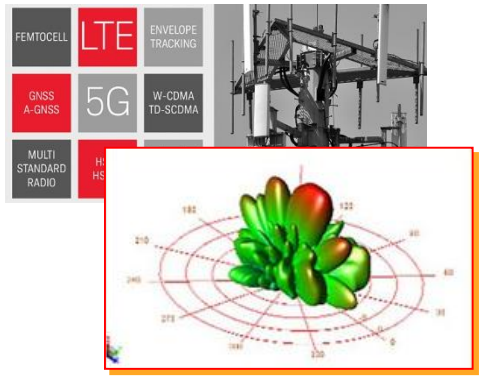
KEYSIGHT TECHNOLOGIES

Industry Trends, Challenges, & Solutions

RF/MW

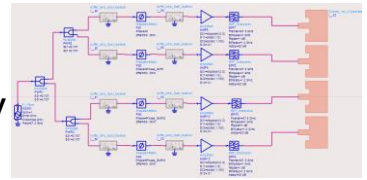
RF/MW new applications

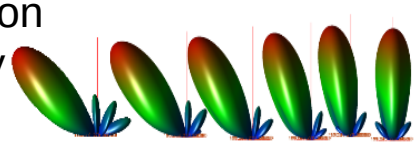
- mmWave: 5G & Automotive RADAR



KEYSIGHT TECHNOLOGIES

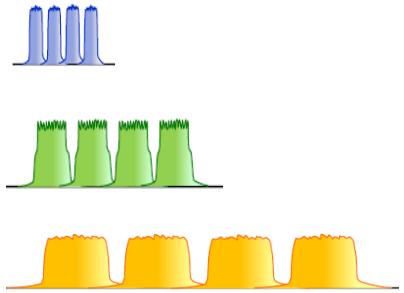
5G/Radar Phased Array & Phase Shifter design iPDK support & Silicon RFIC Interoperability





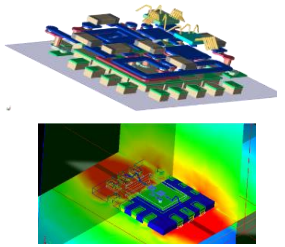
RF/MW Module Design

- Integration of multiple technologies:
  - RF PCB
  - GaAs, GaN
  - SiGe, SOI, …
  - Laminate/Package
- Transition from PA modules to **multi-band Filter modules**: BAW, SAW for MIMO, 5G



KEYSIGHT TECHNOLOGIES

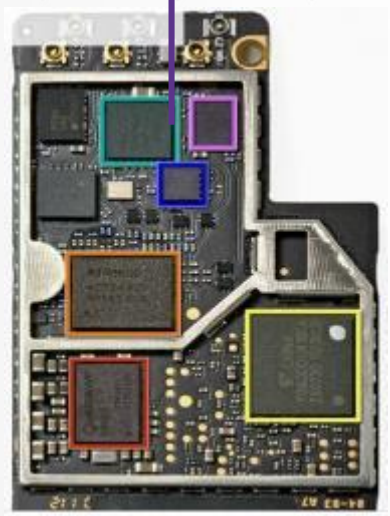
Multi-Technology circuit & Integrated 3DEM Simulation

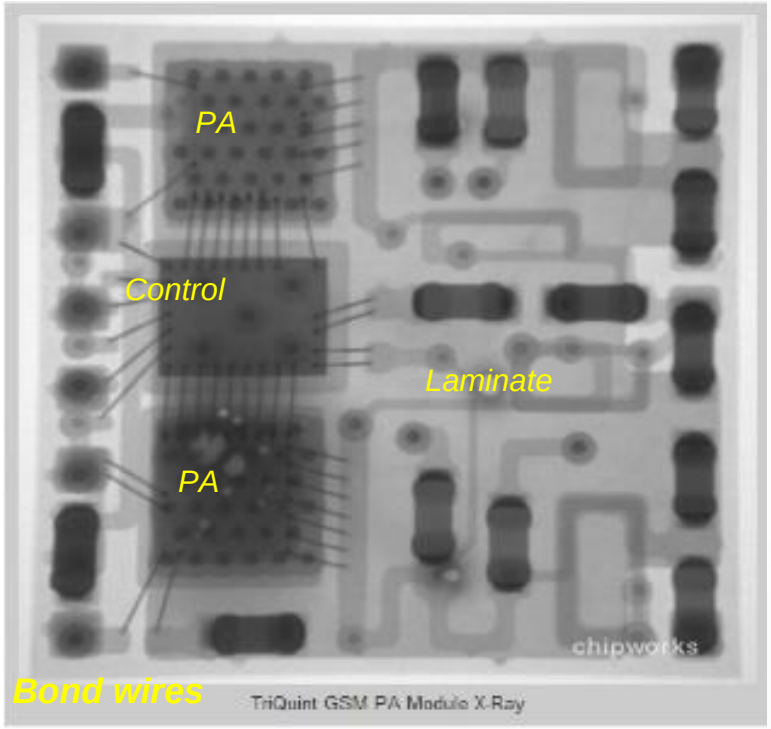


Multi Chip RF Modules

EXAMPLE – APPLE'S IPAD CELLULAR BOARD

TriQuint TQM7M5013





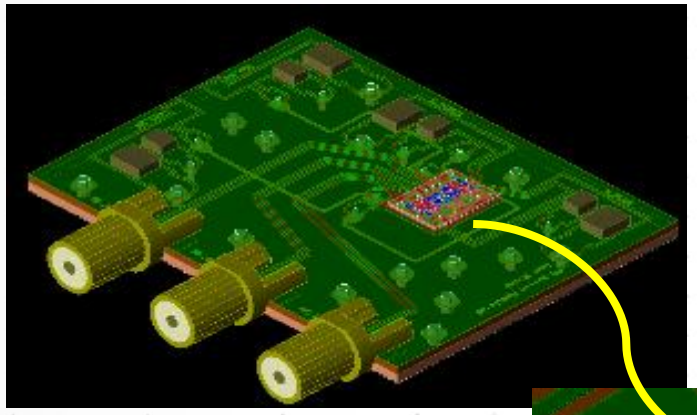
TriQuint GSM PA Module X-Ray

TriQuint GSM PA Module Side X-Ray

From Chipworks:
http://www.chipworks.com/
A recognized leader in reverse engineering and patent infringement analysis of semiconductors and electronic systems

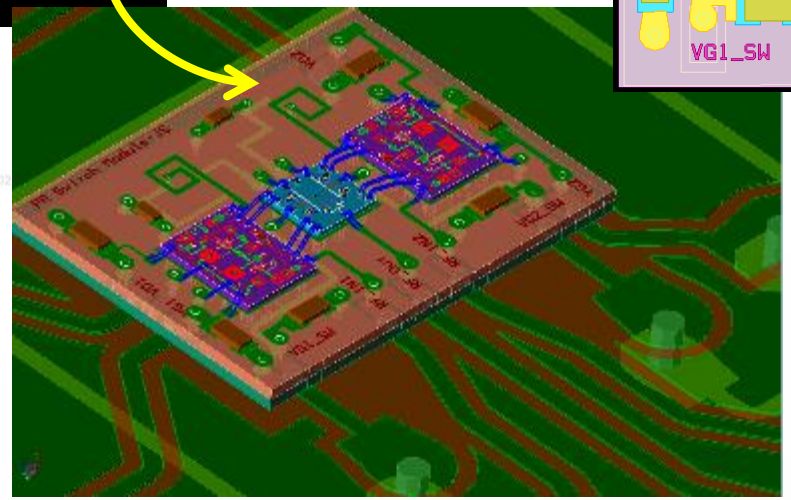
Multi Chip RF Modules

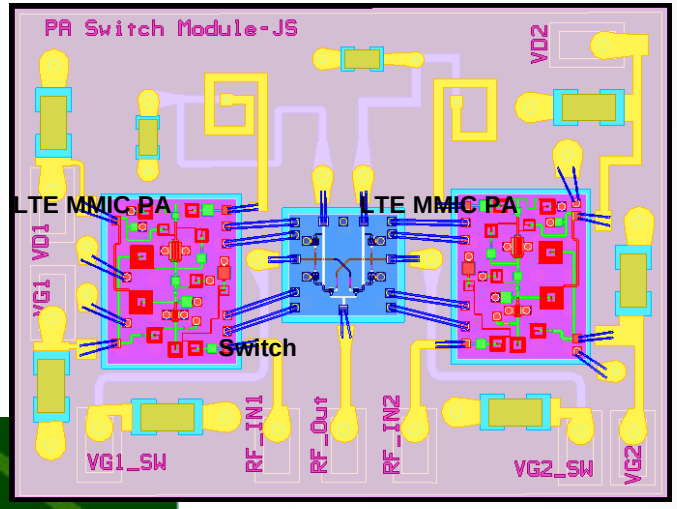
PA / SWITCH MODULE



The Complete PA / Switch Multi-Chip Module

- PA / Switch IC's
- Bond wires
- Laminate board
- Solder bumps
- PCB test board
- Connectors





Laminate Board with PA / Switch IC's

5G is A Game Changer For Packages

HIGH FREQUENCIES AND HIGH BANDWIDTH

Frequency Range 1: 400 MHz to 6 GHz	Frequency Range 2: 24.25 to 52.6 GHz	
Adds 1.5 GHz of new spectrum in frequency bands	Adds 8.25 GHz of new spectrum in frequency bands	Frequencies up to 90 GHz are currently being investigated for future releases.
n77: 3.3–4.2 GHz n78: 3.3–3.8 GHz n79: 4.4–5 GHz	n257: 26.5-29.5 GHz n258: 24.25-27.5 GHz n260: 37–40 GHz	

mmWave spectrum will be needed to meet 5G peak data rate goals of 20 Gbps in downlink (DL) and 10 Gbps in uplink (UL).

Source : Keysight (Top considerations for 5GNR device designers)

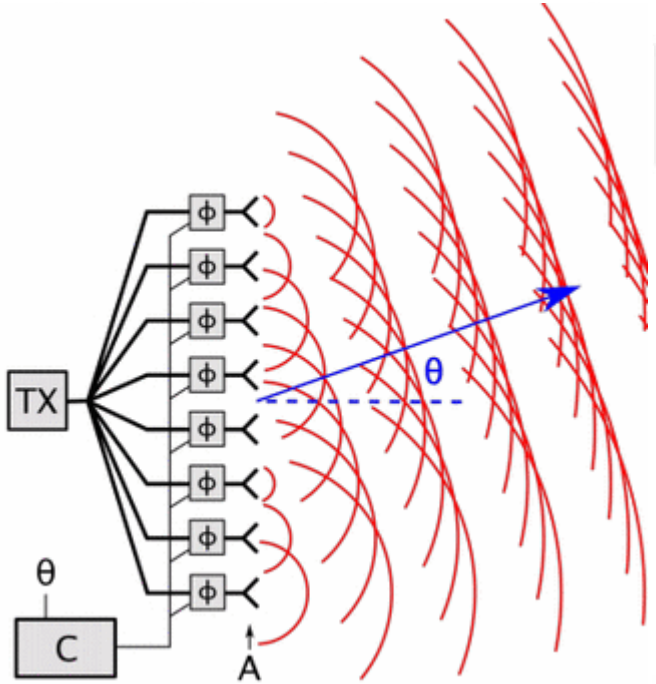
Modulation scheme for PDSCH	Required EVM
QPSK	17.5 %
16QAM	12.5 %
64QAM	8 %
256QAM	3.5 %

Figure 5: 3GPP TS 38.101-1 EVM requirements for different 5G modulation schemes

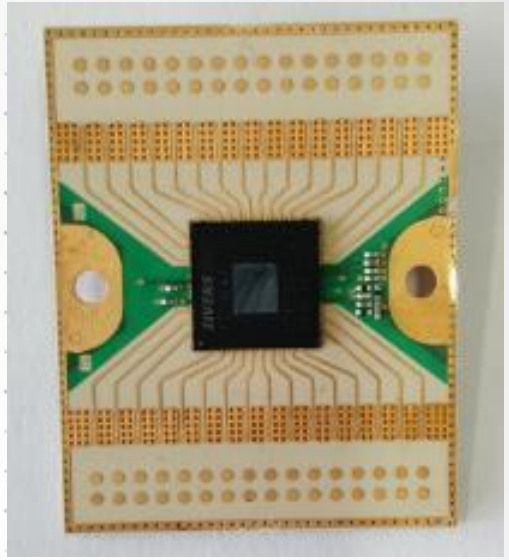
- Maintaining these high bandwidths at high frequencies have a direct impact on the design on every interconnection and then packages

One Slide Overview Of Phased Array

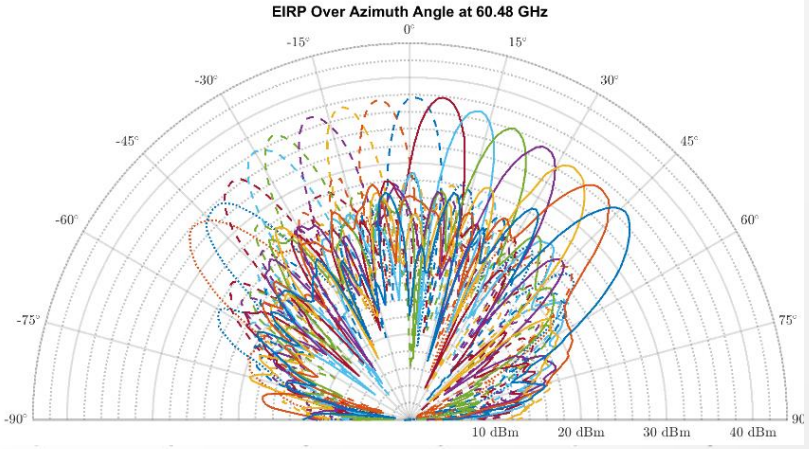
- Just basic physics of wave propagation
- Adjusting the time delay or phase difference between adjacent antennas results in maximum radiation in a specific direction



Source : [Wikipedia]

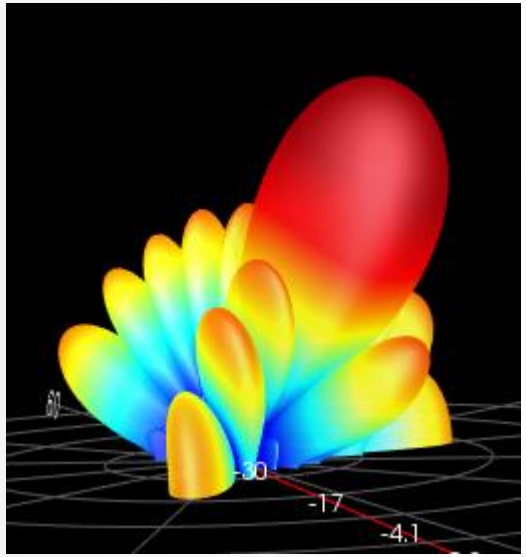


WLAN 802.11ad transceiver (courtesy of Sivers IMA)

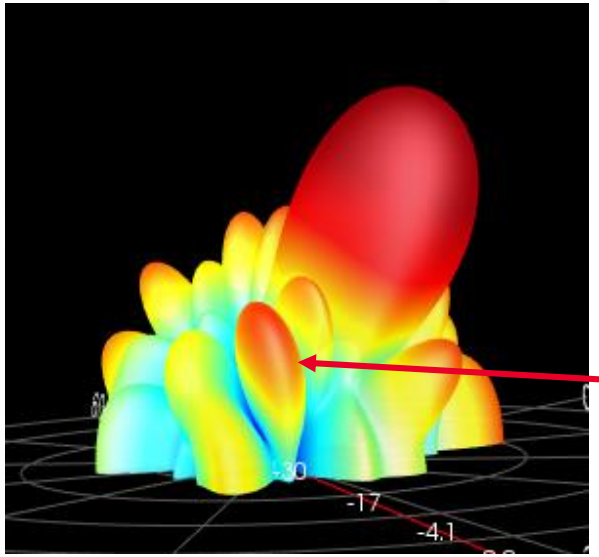


Phased Array And Packaging

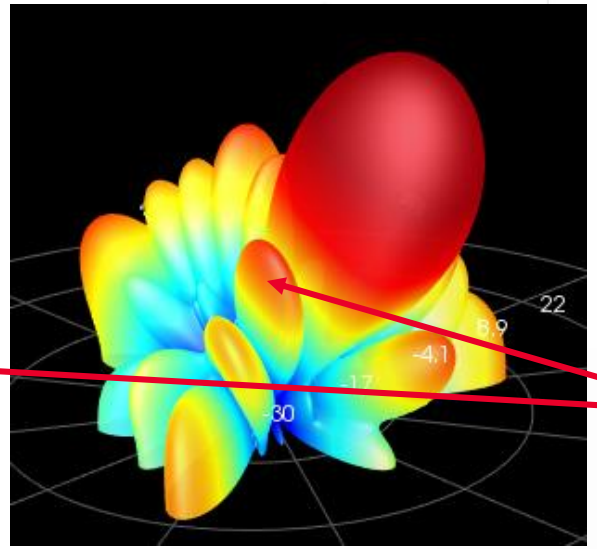
- As this is phase-driven, the group delay or amplitude loss in the package interconnection could be a bottleneck



No error



Phase error

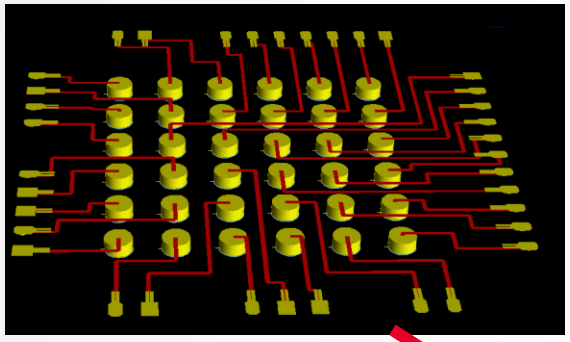


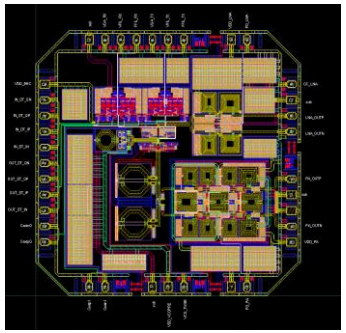
Amplitude error

Not co-designing can lead to several dBs of error in Side Lobes Level and then deteriorate the original antenna performances

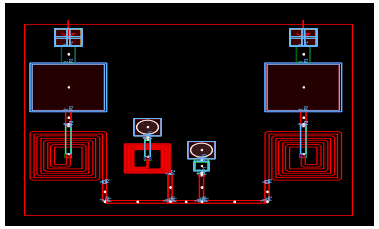
Higher Integration Needs Efficient Co-Design

DATABASES COME FROM DIFFERENT SOURCES



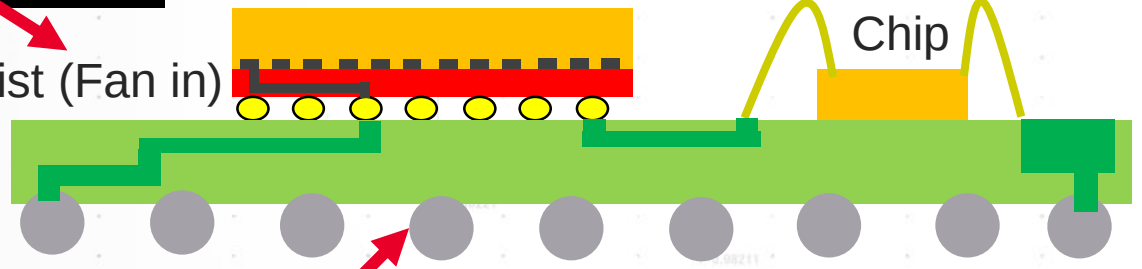


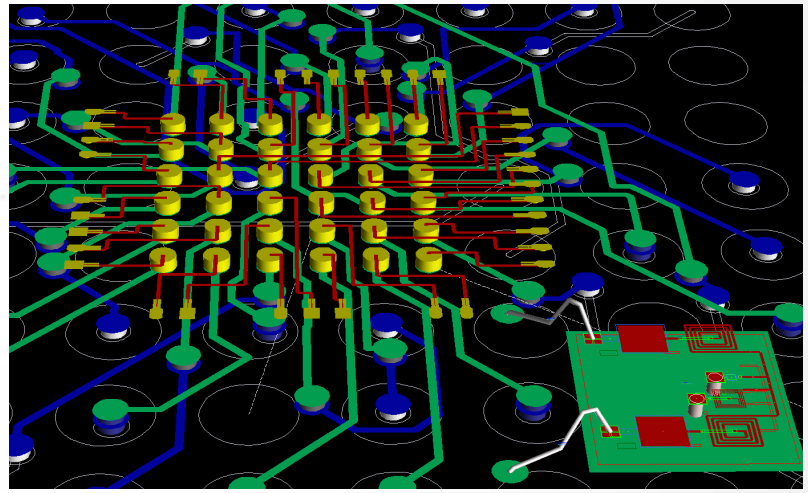
Si Transceiver



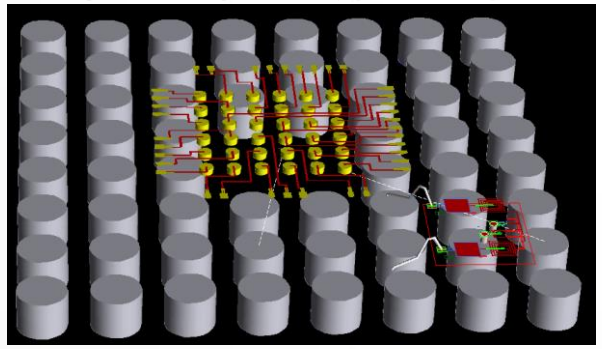
Filter Chip

Redist (Fan in)





Fanout Package

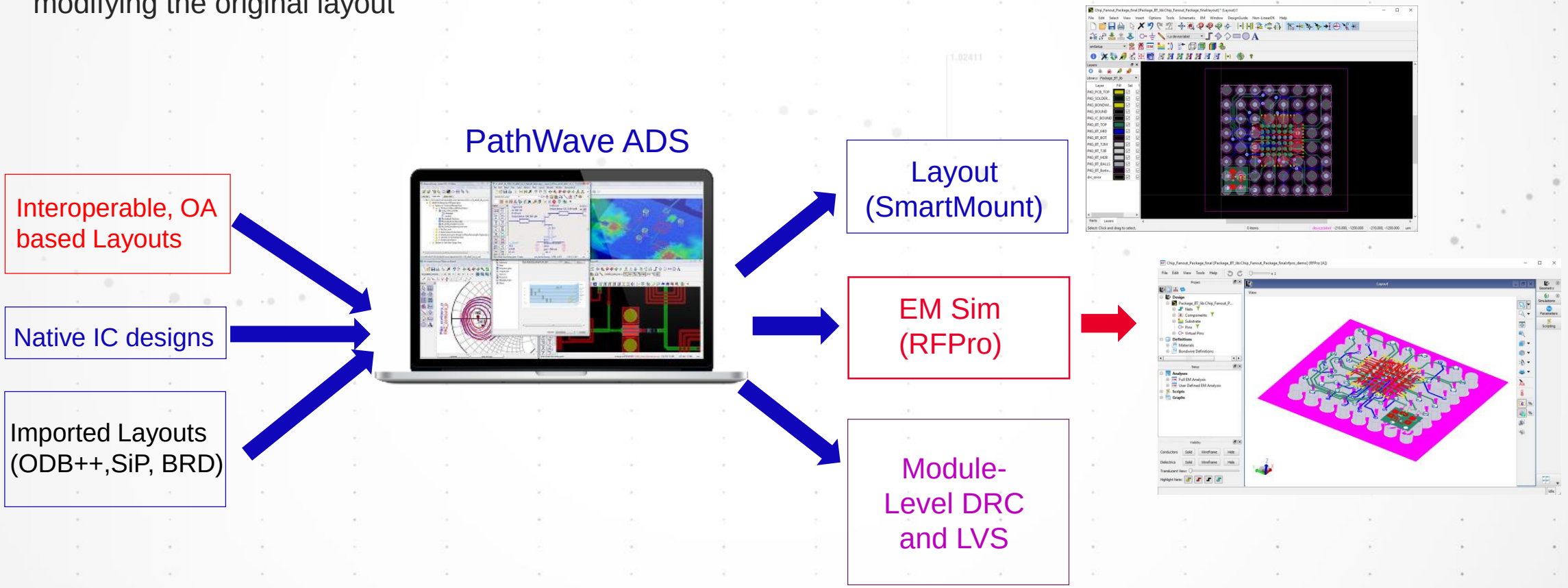


Goal:

- Assemble all the technologies keeping traceability
- Co-design the interconnections at EM level
- Incorporate the results into circuit simulation

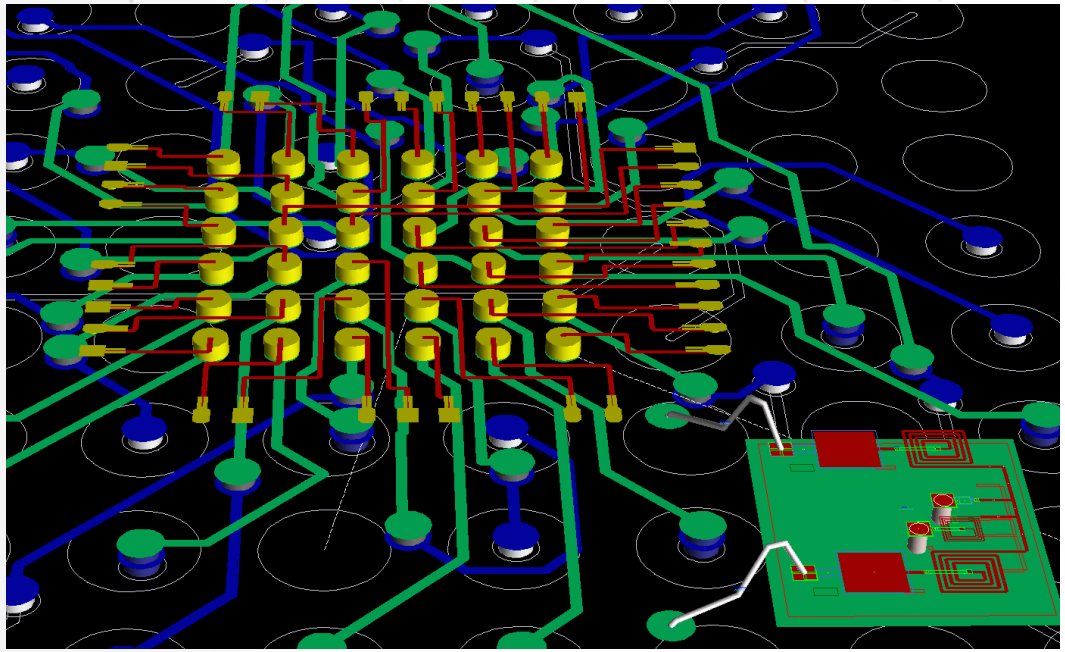
Using PathWave ADS As An Assembly Platform

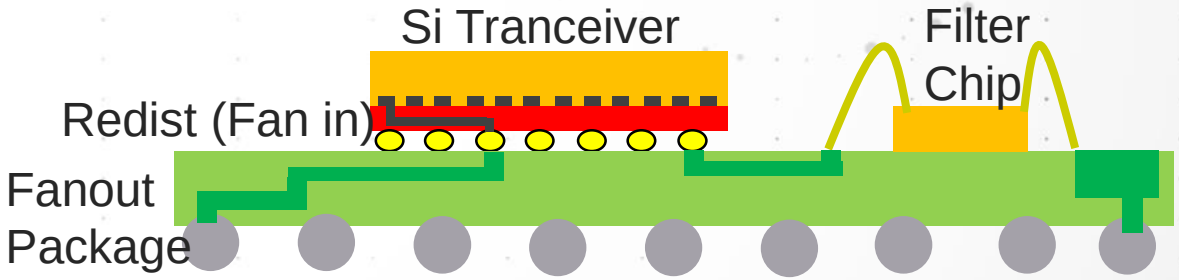
- **Goals:**
  - Build a multi-technology assembly and simulation flow which scales with the complexity of the products.
  - Build a user friendly capability to EM simulate pieces of this complex multi-technology design without cutting or modifying the original layout



Smart Mount Enables Complex Technology Assembly

- A new, unique, innovative way to assemble Multi-technology designs.
  - **Simple:** does not need layer mapping, does not require substrate modification
  - **Powerful:** user can write macros to do all sorts of custom mount configurations
  - **Versatile:** Supports read only and interoperable libraries, and scaled technologies (nm Si)
  - **Scalable:** works well for large scale assemblies and stacked technology





RFPro Vision: EM For Every RF Circuit Designer

ALLOWS USERS TO FOCUS ON DESIGN RATHER THAN SETTING UP EM

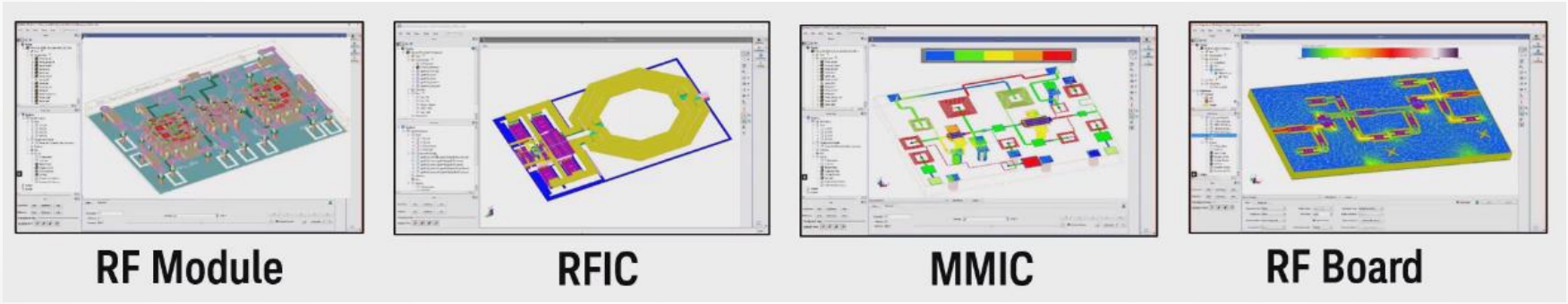
- Main customer requests for the EM flow

- Integration
  - ✓ 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

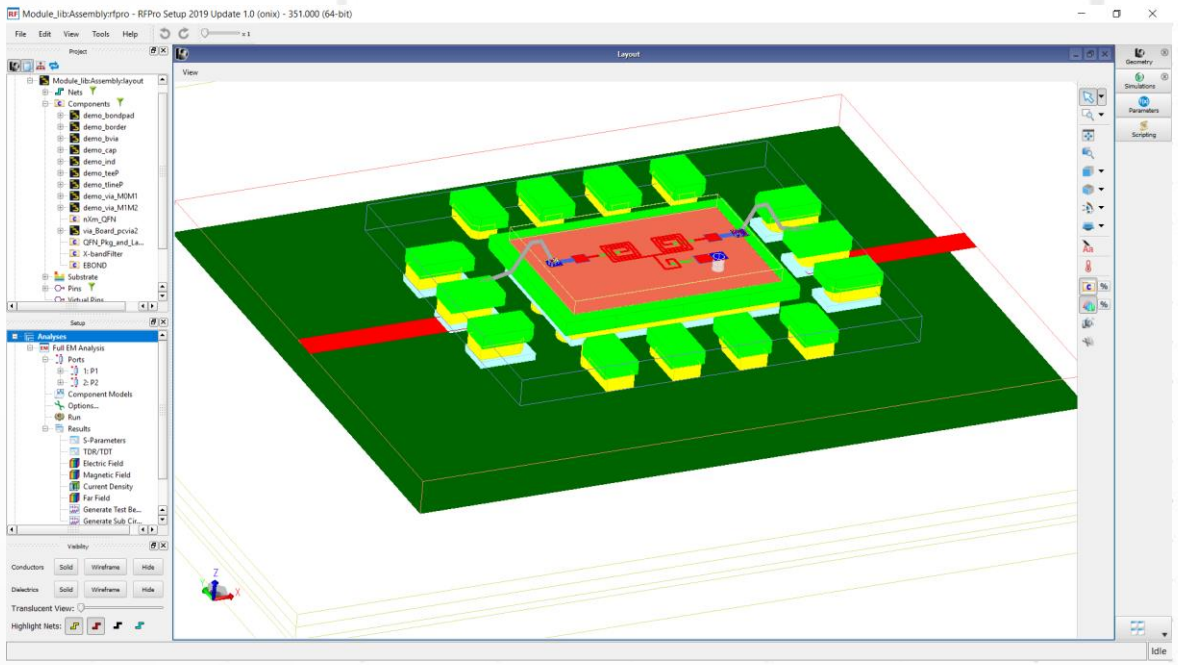
- Solver
  - ✓ No expert setup
  - ✓ Be confident in the setup of the simulation and accuracy of the results
  - ✓ Better automated defeaturing (via merging/dummy removal/hatched planes…)

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

RFPro



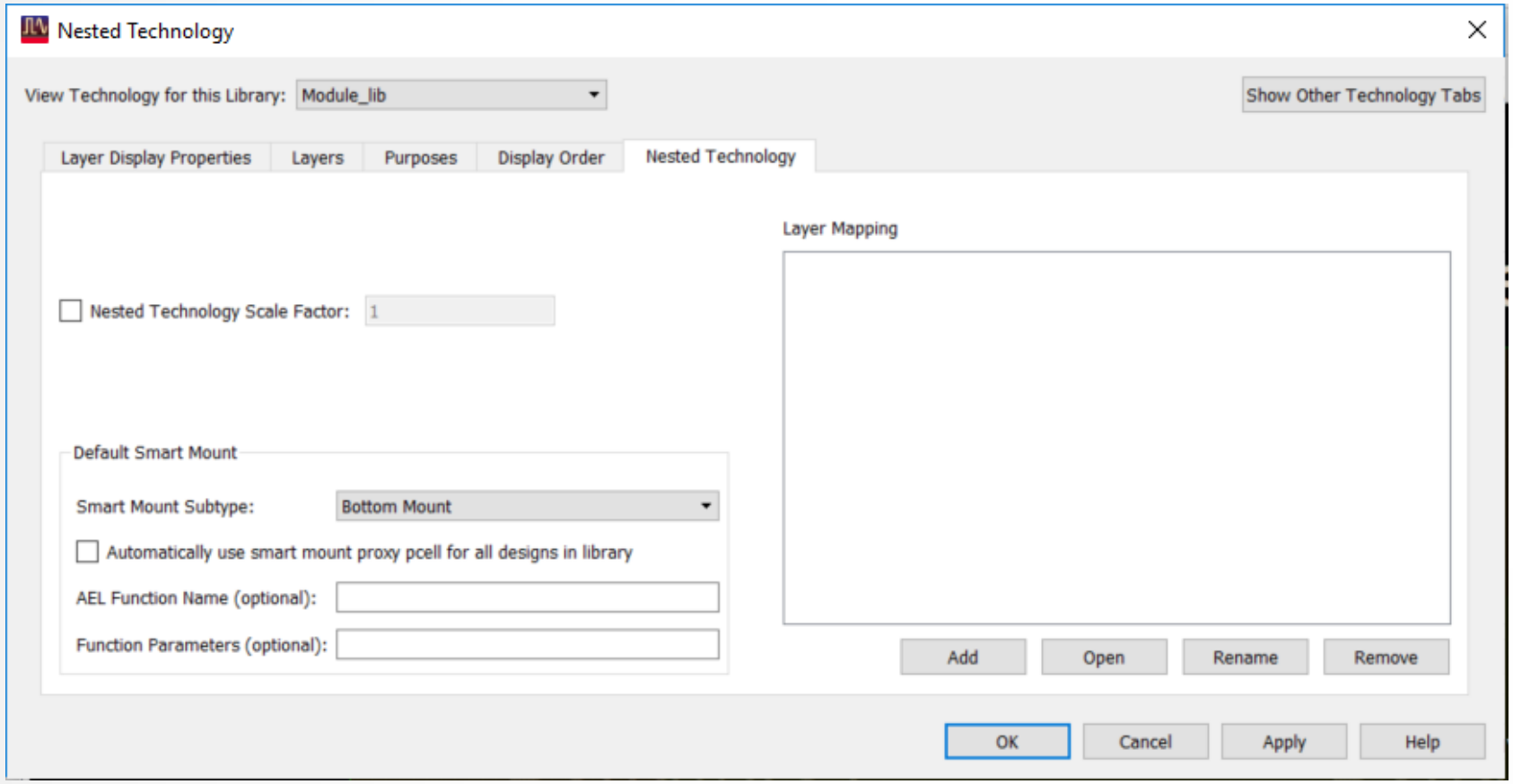
X-Band Filter IC in QFN Package Using Smart Mount (ADS 2019U1)



Steps using Smart Mount

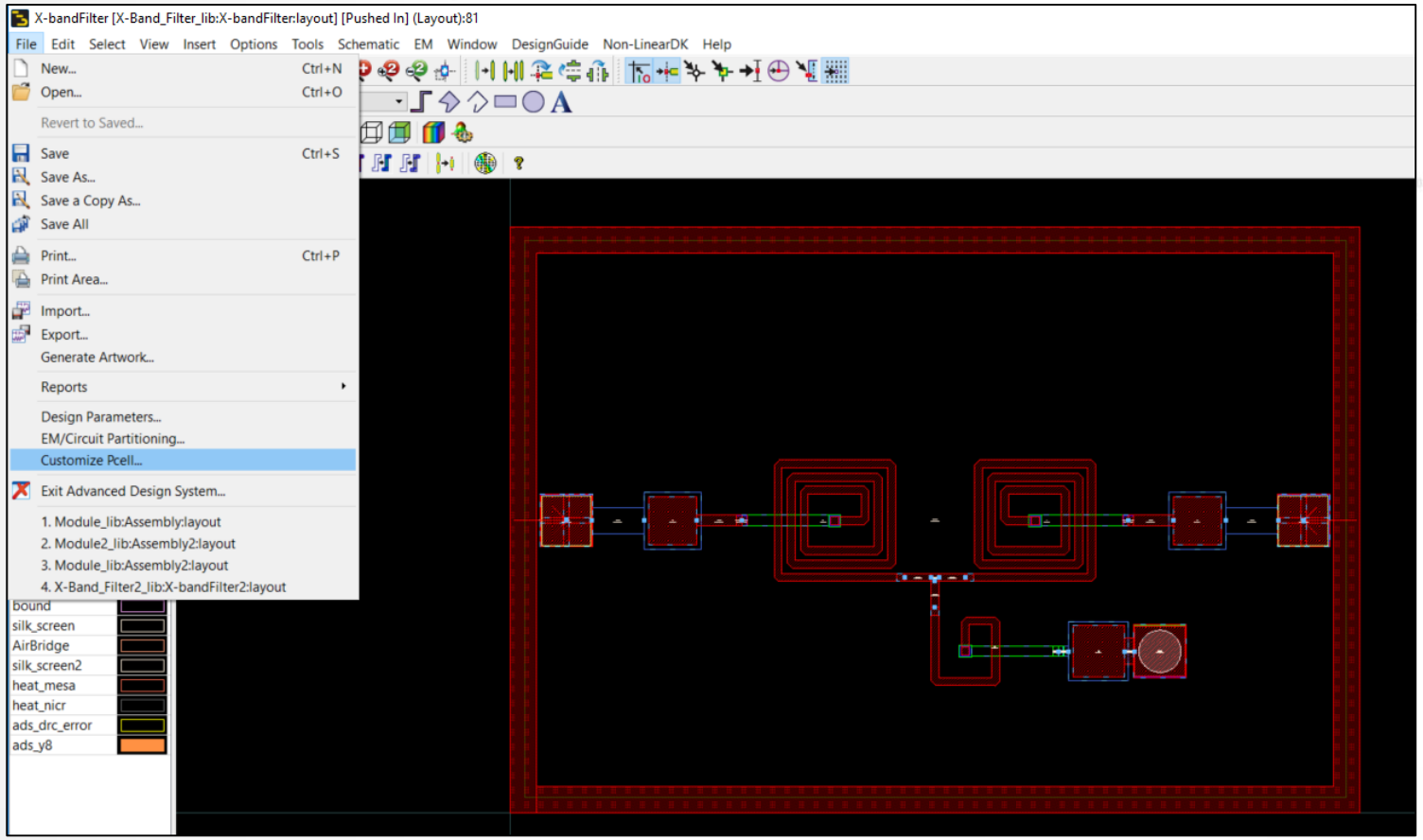
- Smart Mount Setup
- Building the Module Assembly
- Placing and Configuring the Bond Wires

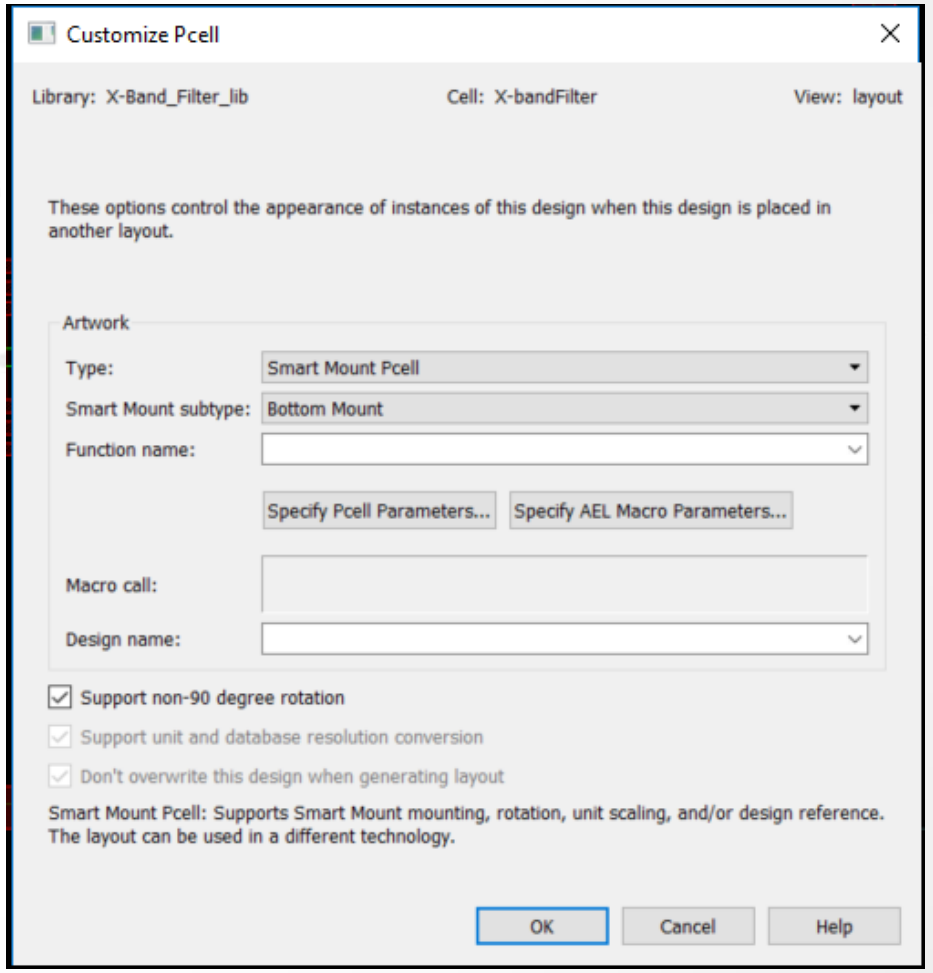
Smart Mount Technology Setup



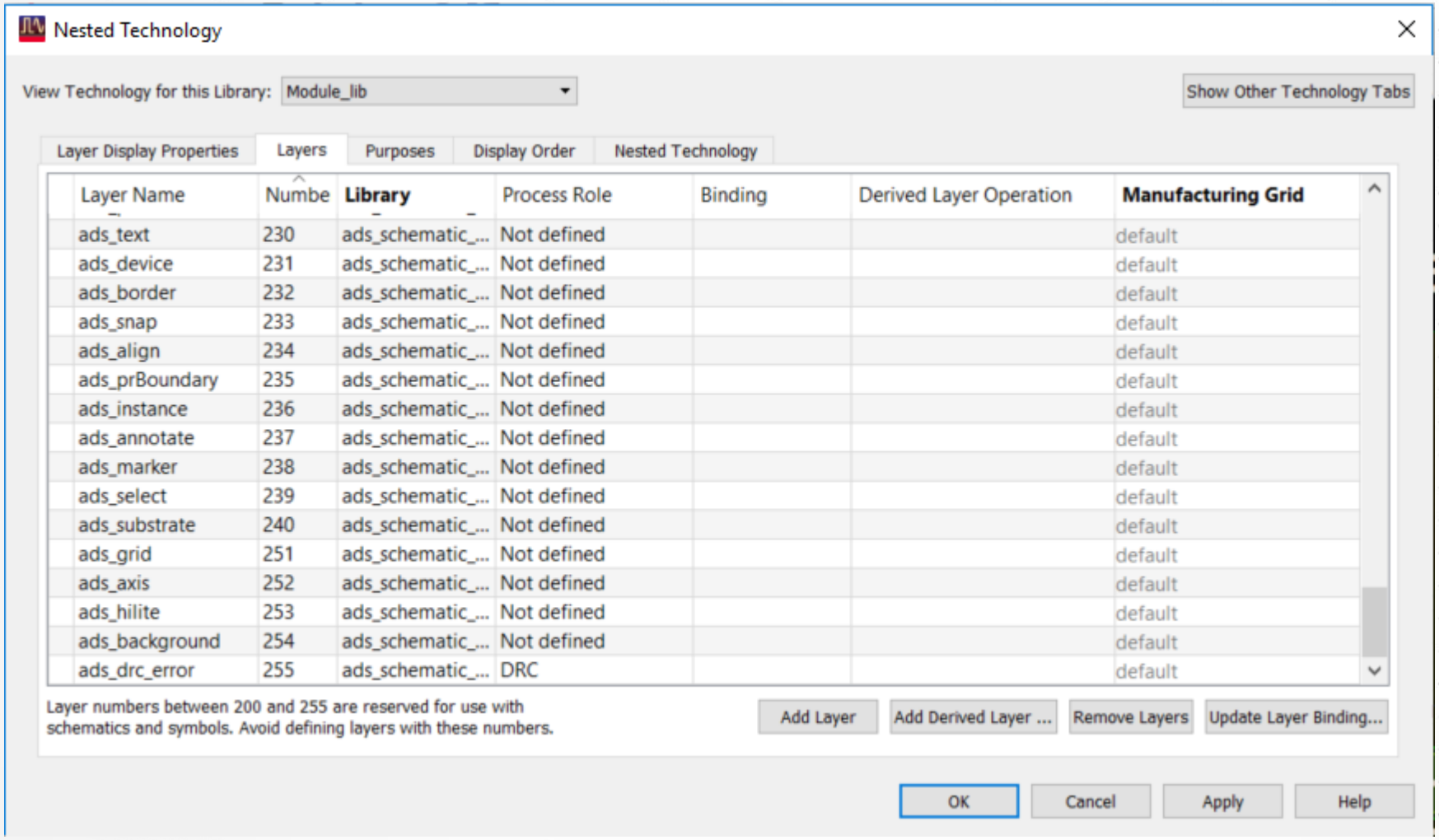
In Smart Mount we did not map the Layers of the IC to be in the Module Layers list

Smart Mount Technology Setup - Setup IC Pcell attribution





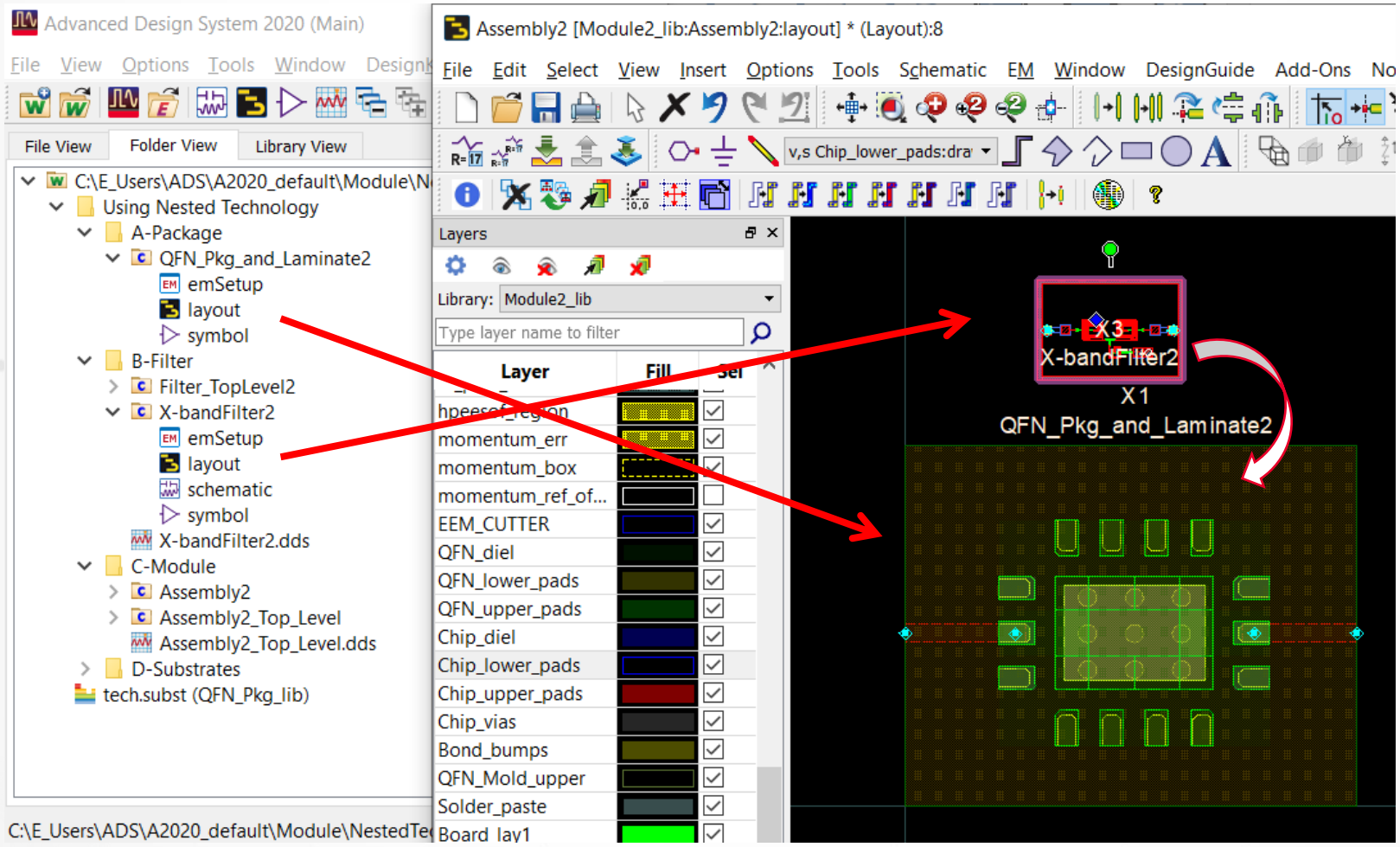
Check Layers



Building the Module Assembly

Drag and drop the package and the IC into the module layout page. The designs will be easily read along with their correspondent technologies (Layers and units)

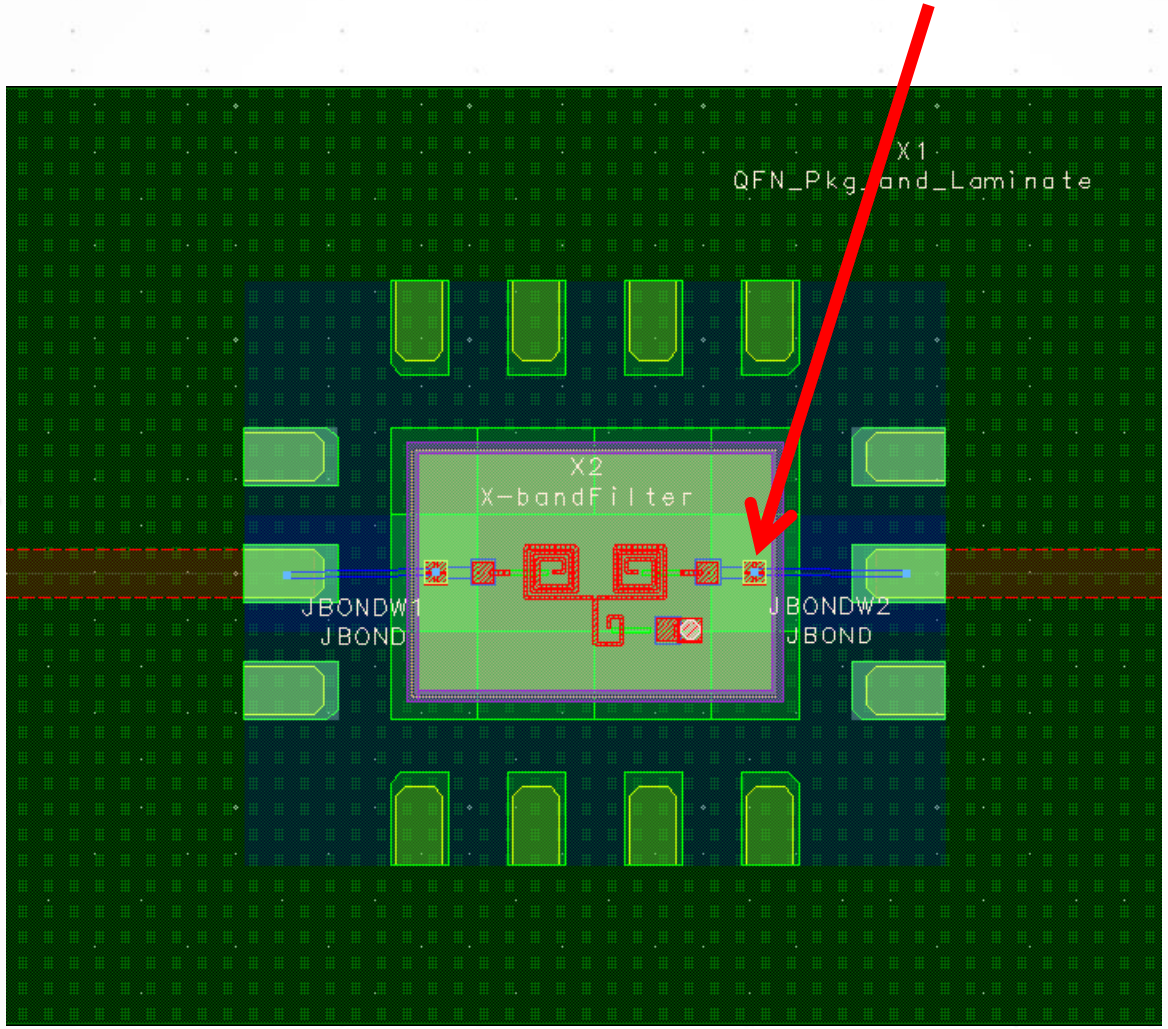
Insert QFN_Pkg_and_Laminate layout, followed by the X-bandFilter layout



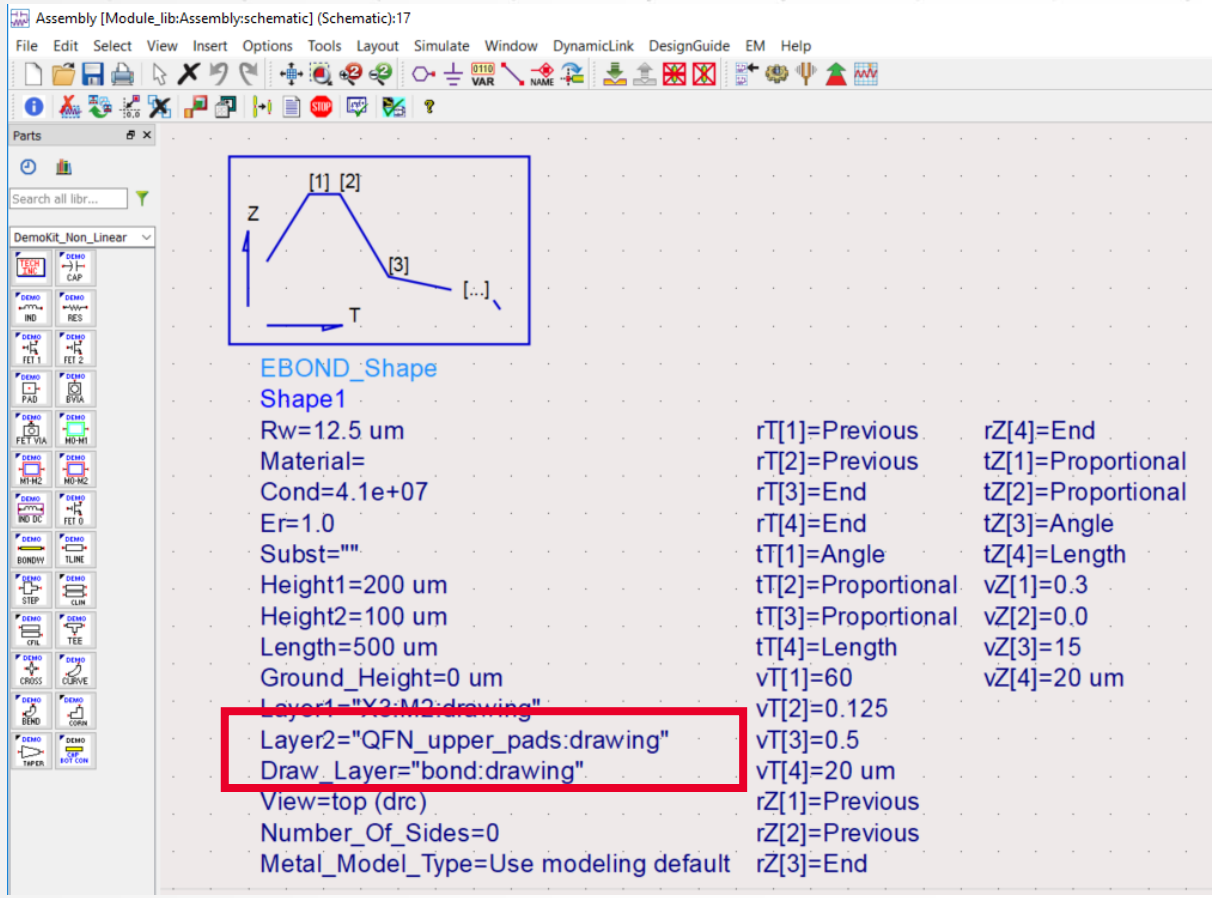
Next, drag and align the MMIC onto the package

Placing and Configuring the Bond Wires

Place bondwire starting on the MMIC pad and ending at the QFN upper pad.

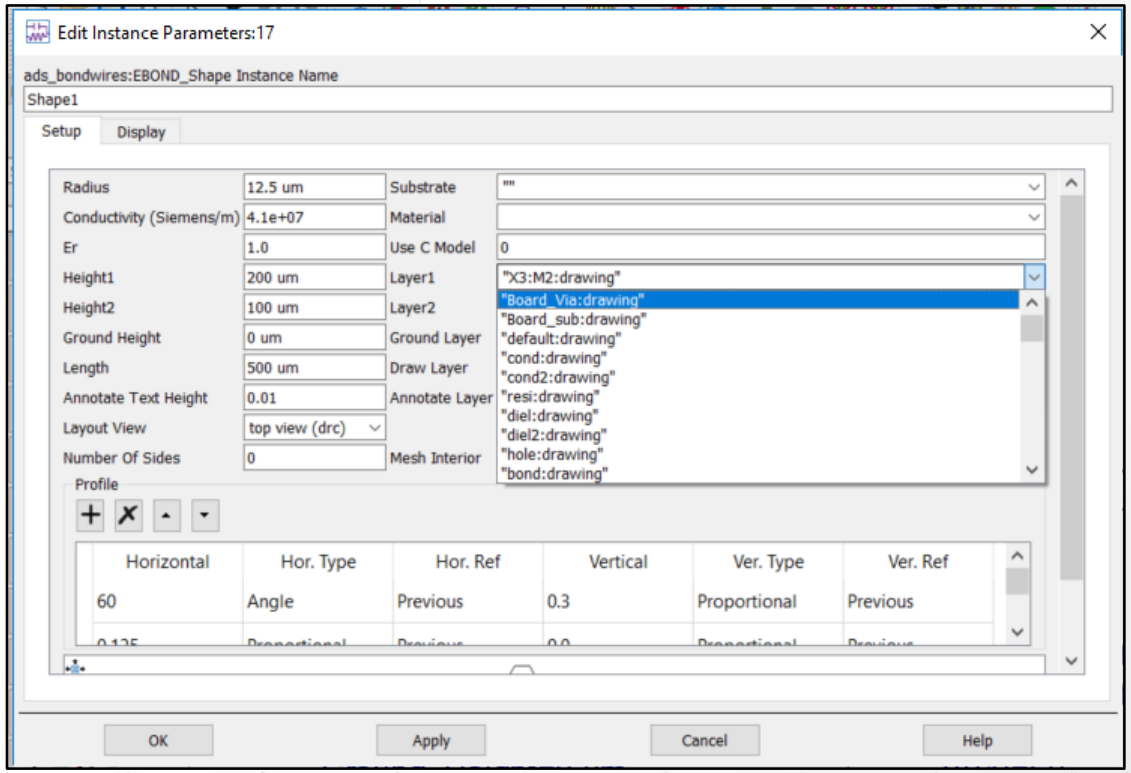


Configuring Bond Wires parameter and layers in Schematic



In Smart Mount we did not map the Layers of the IC to be in the Module Layers list

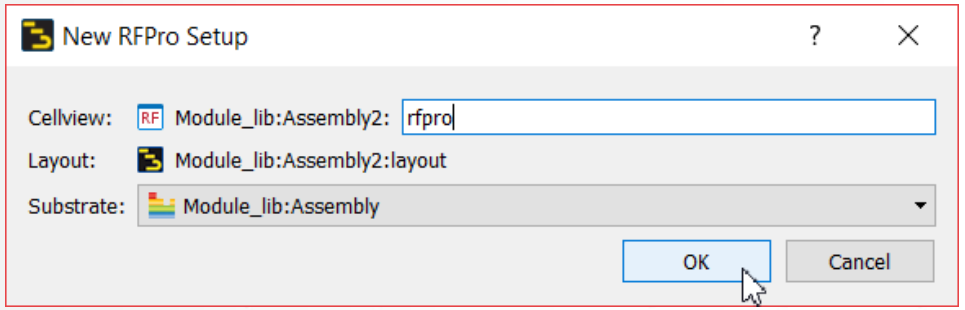
We must manually type it in: "X3:M2:drawings"

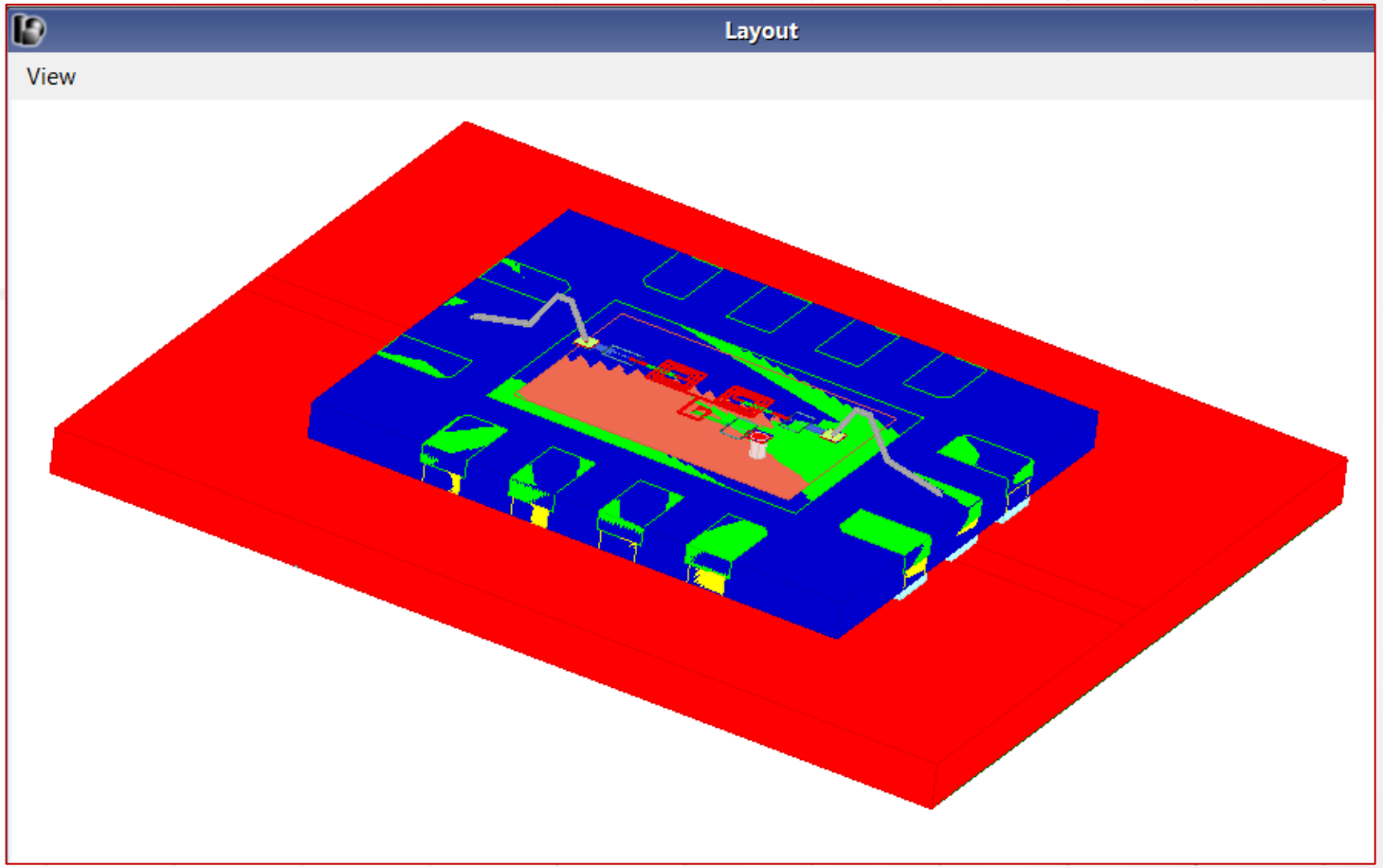


KEYSIGHT TECHNOLOGIES

Start RFPro for RF Module Simulation

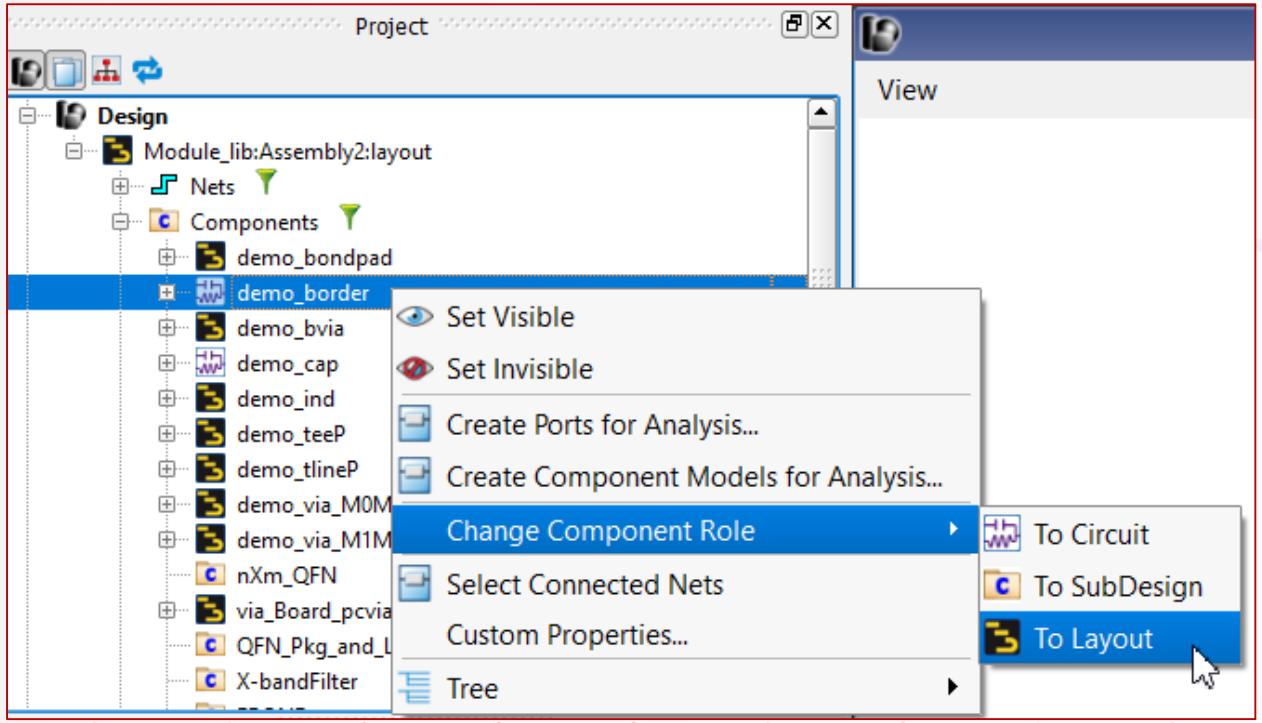
Launch RFPro from Layout window ***Tools*** -> ***RFPro*** -> ***New…***

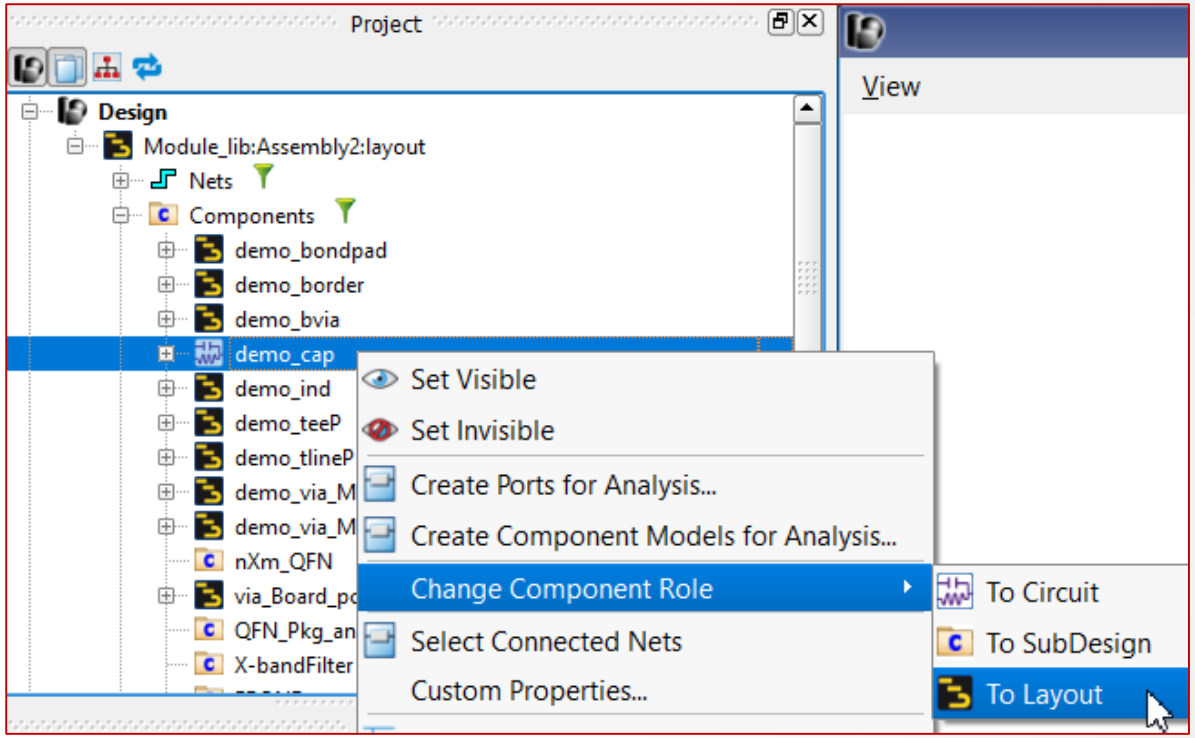




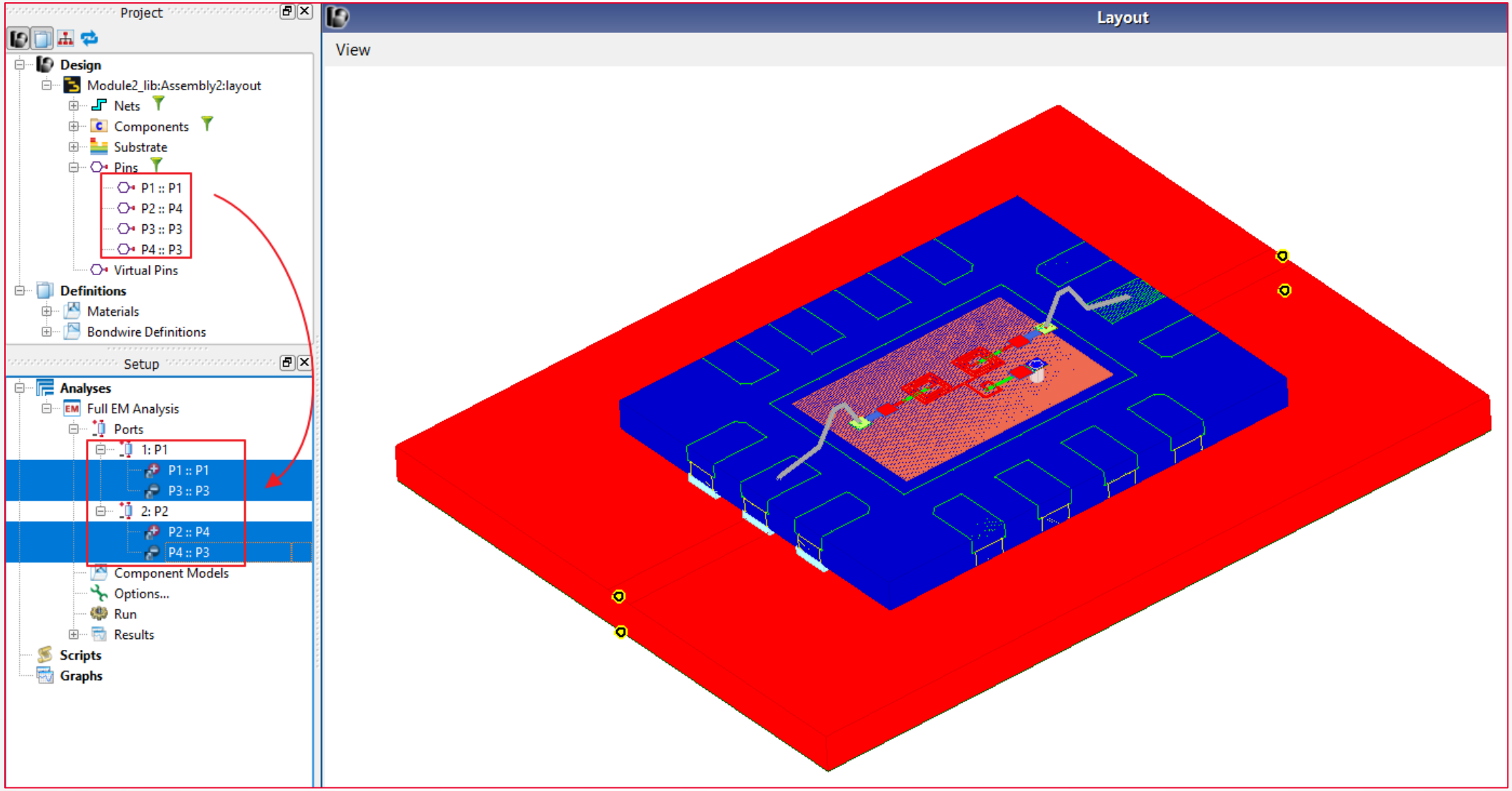
RFPro setup

Change Component's Role



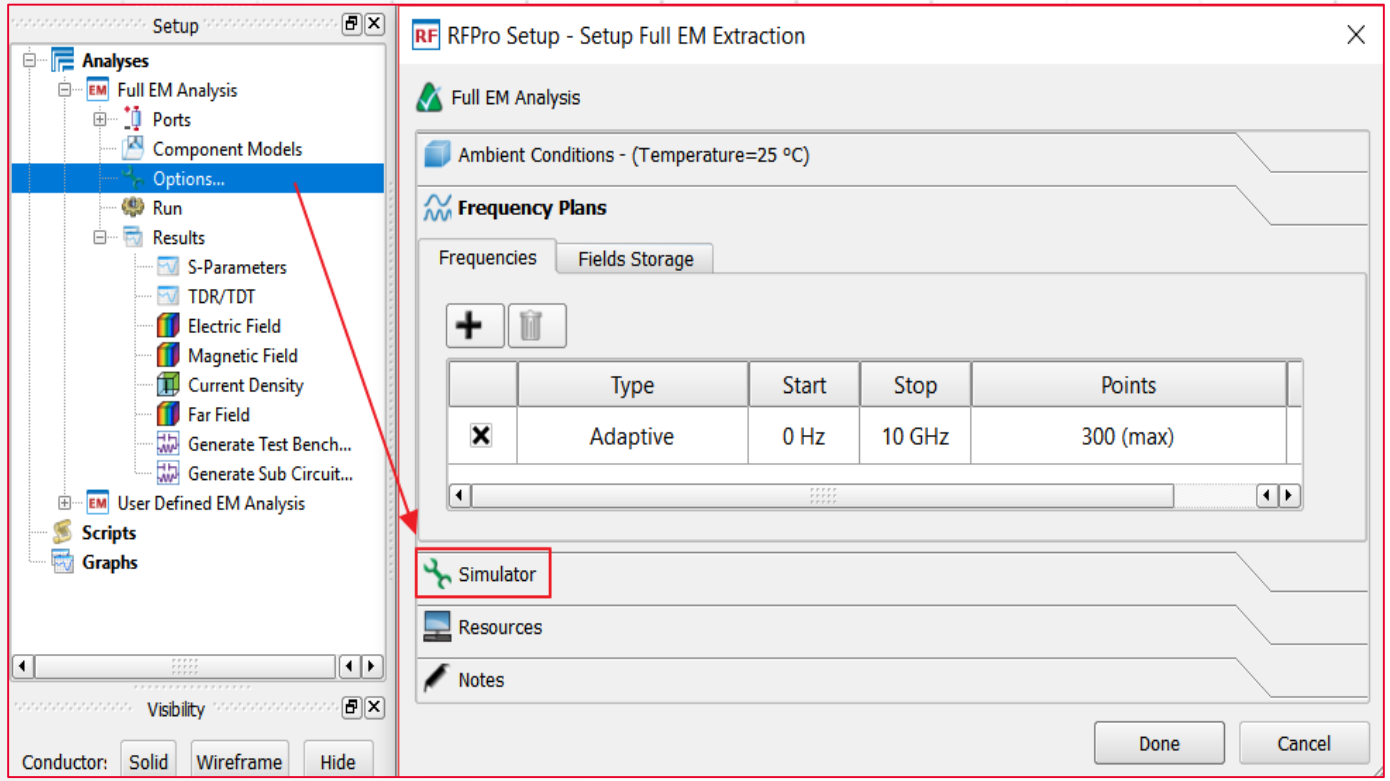


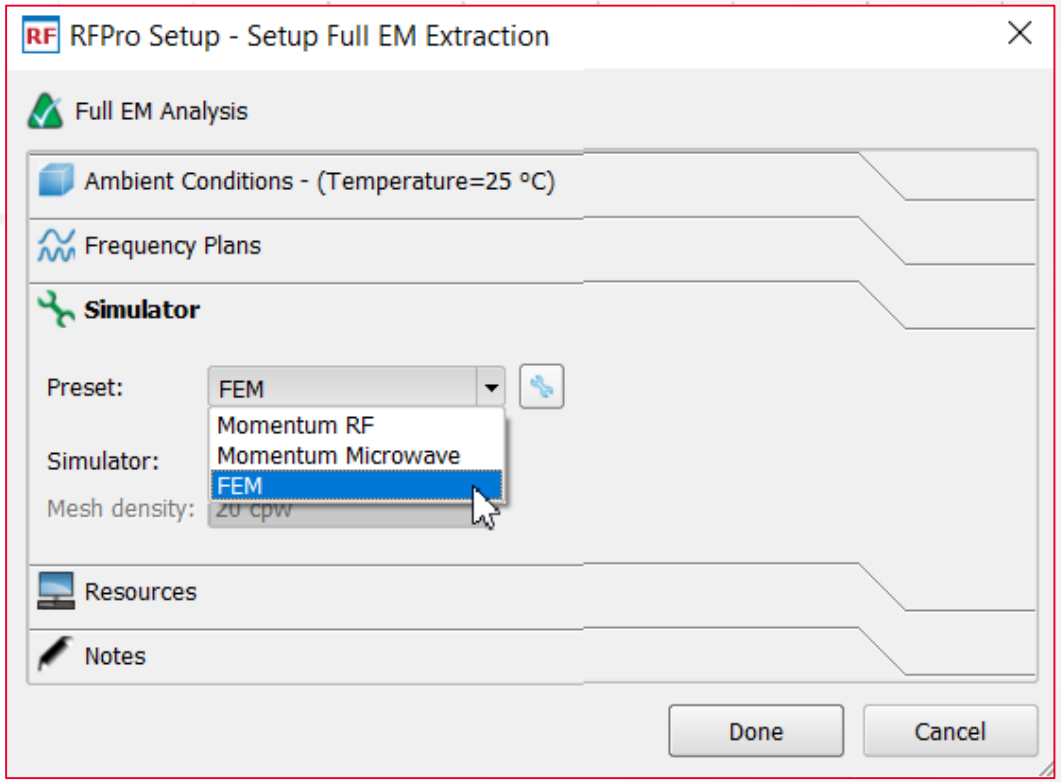
RFPro Ports Setup



RFPro Simulation Setup

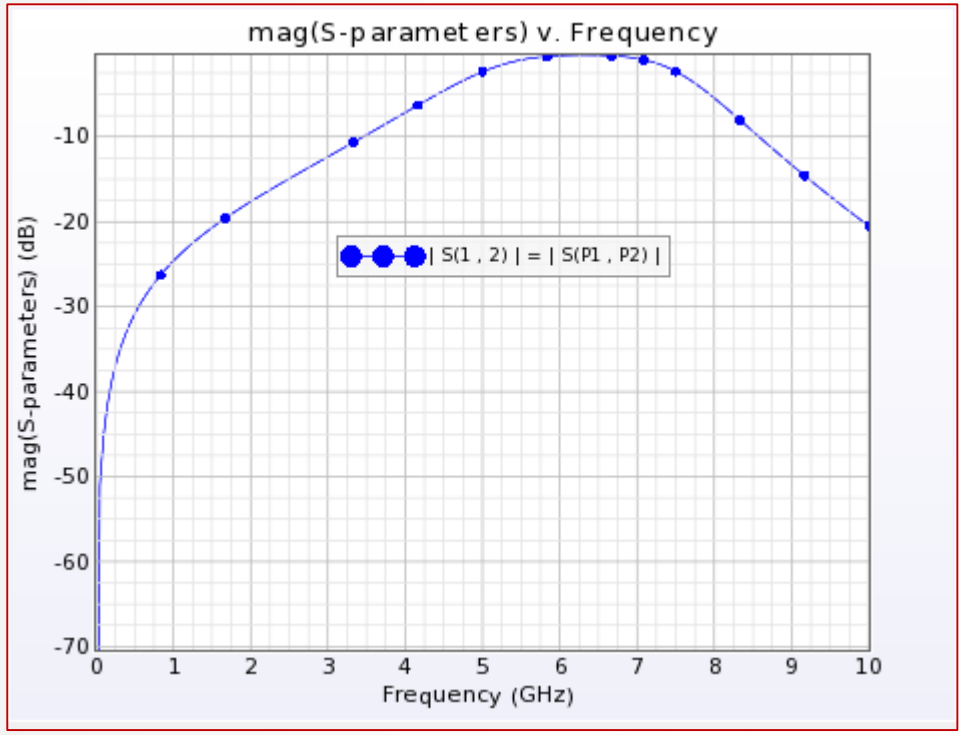
Double click ***Options*** , and select Simulator, change to FEM simulator:



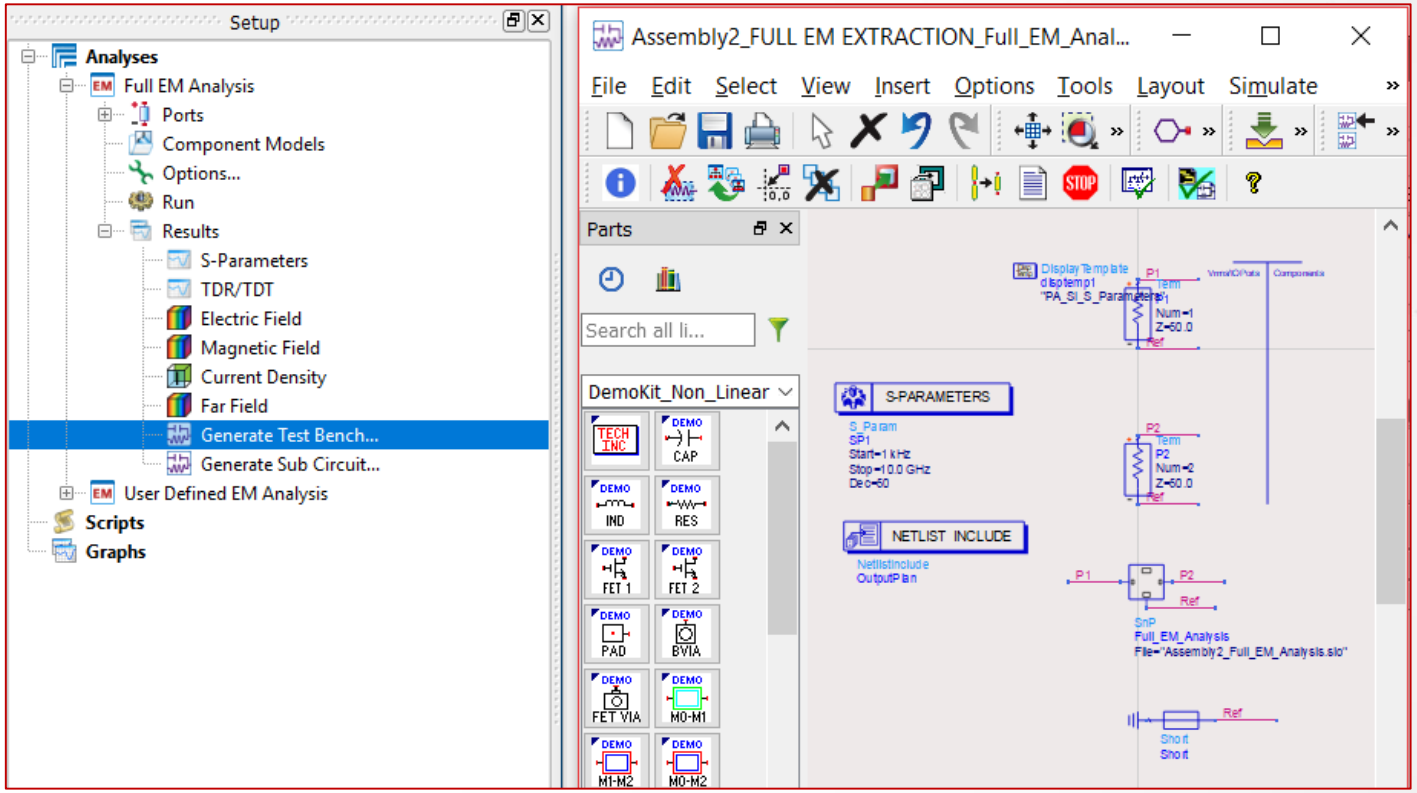


RFPro Simulation Results

Check result

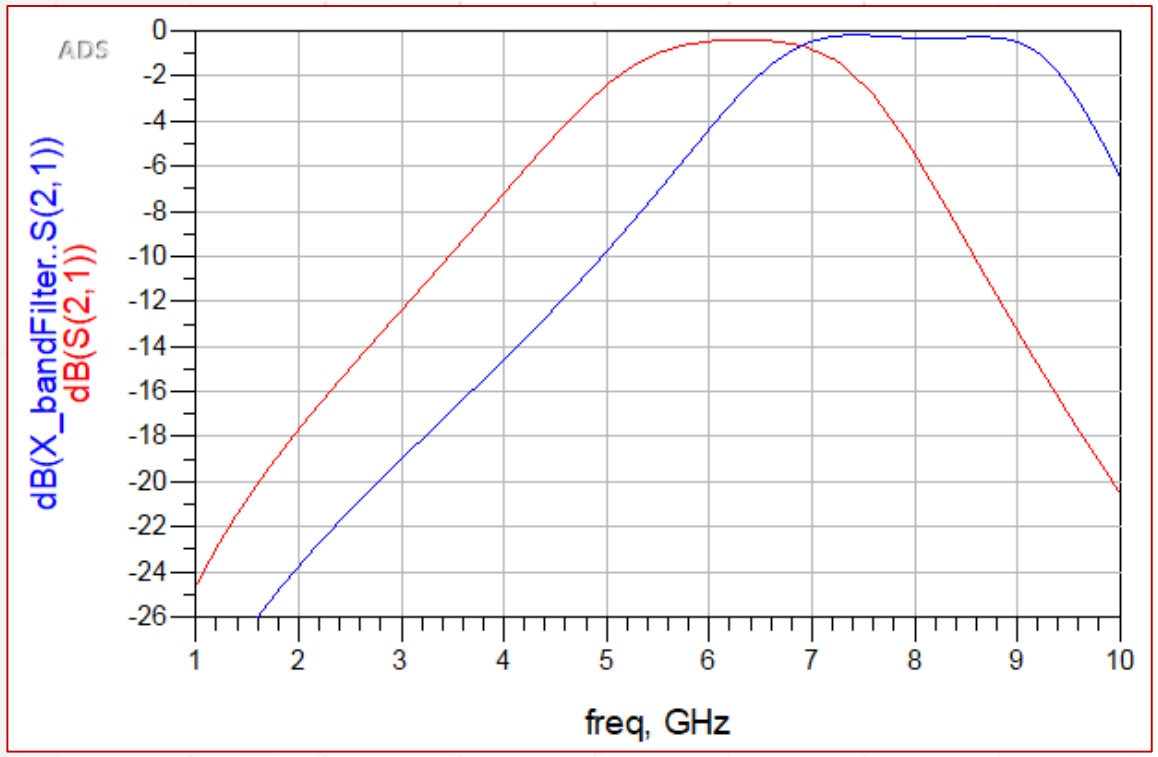


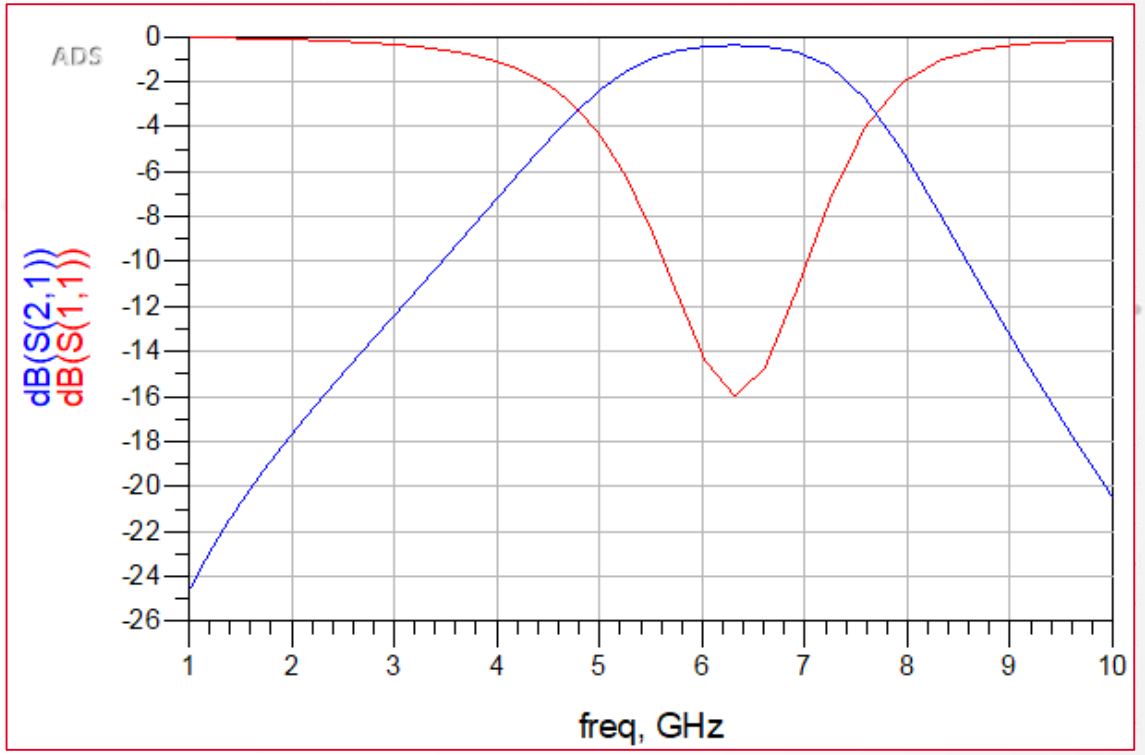
Generate Test bench and simulate in ADS



Smart Mount in ADS 2019_U1

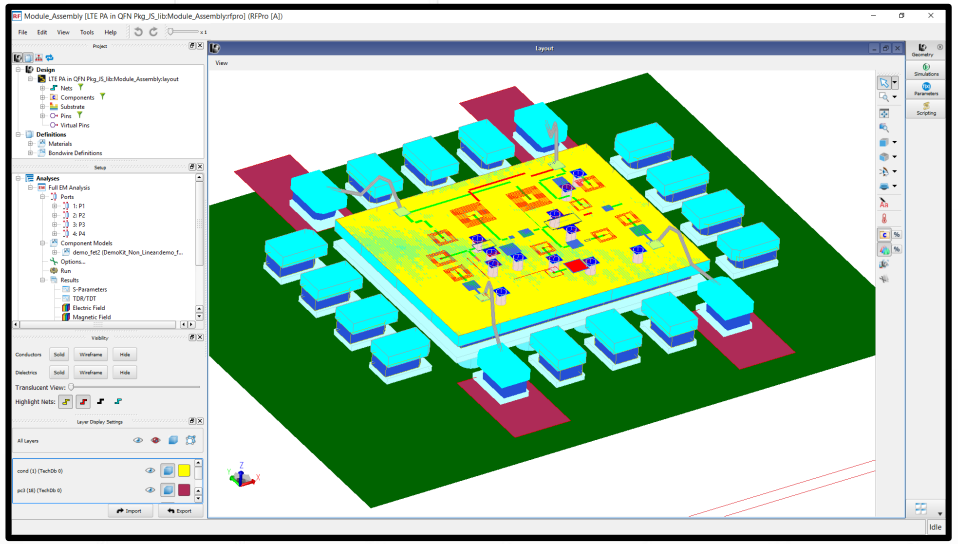
Compare results with X_bandFilter



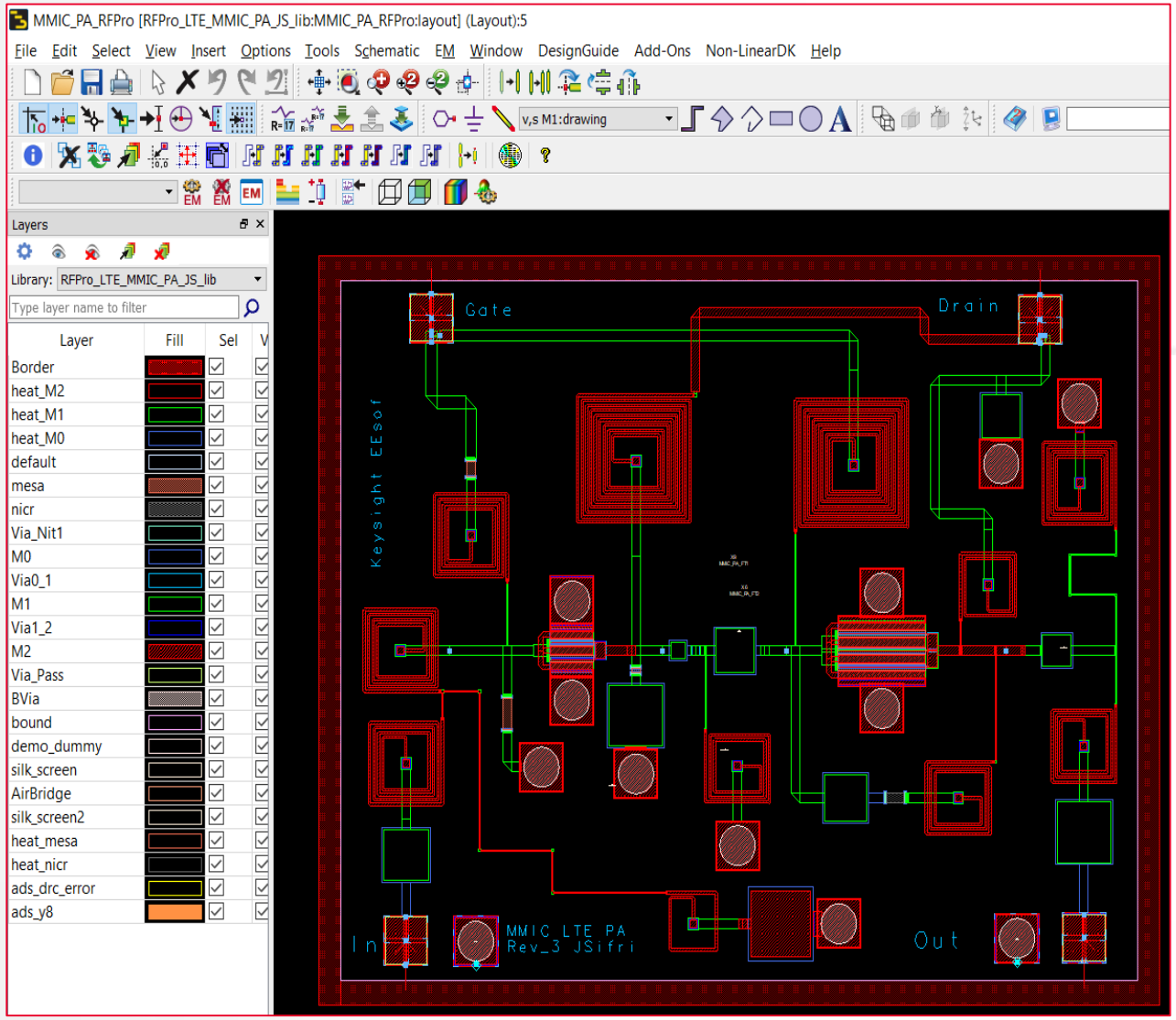


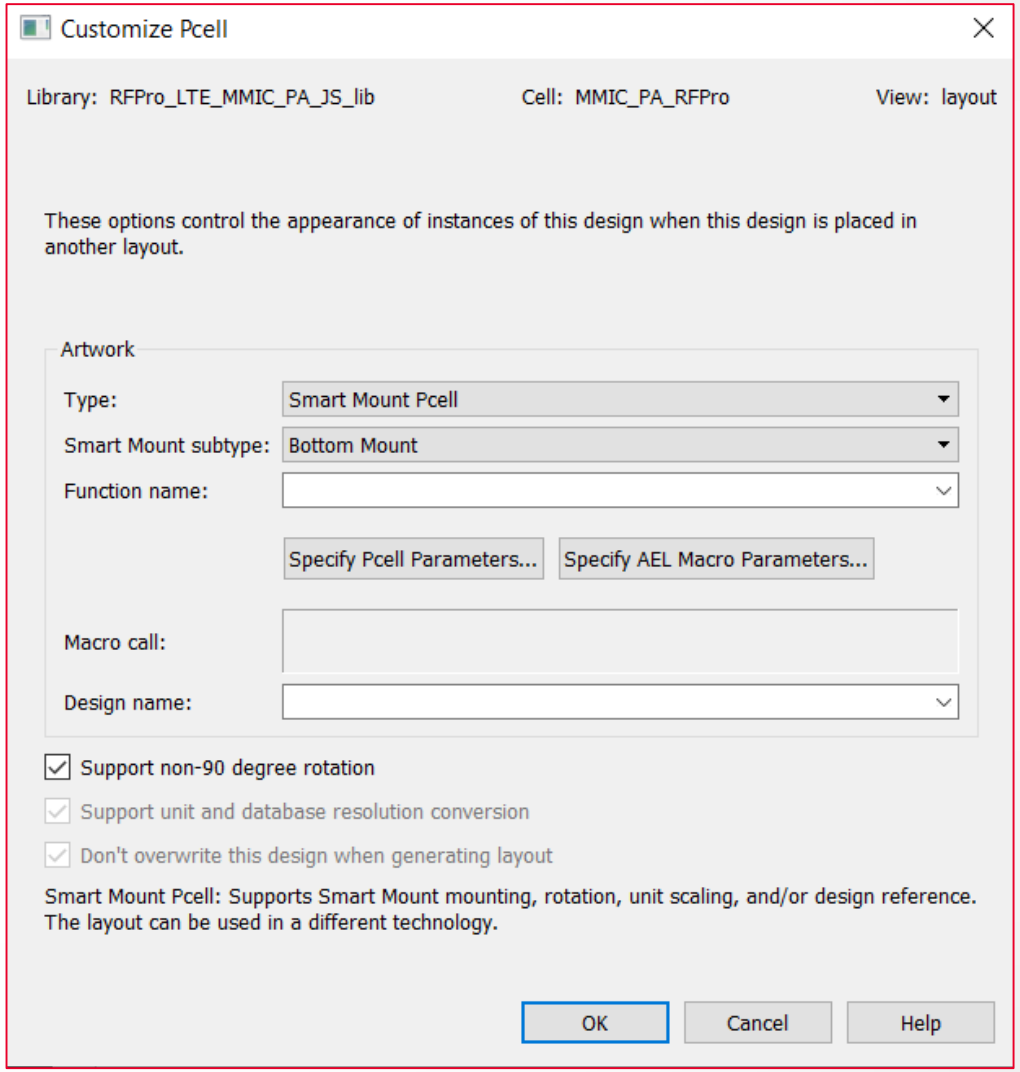
LTE PA in QFN Package / Laminate

Using Smart Mount Technology

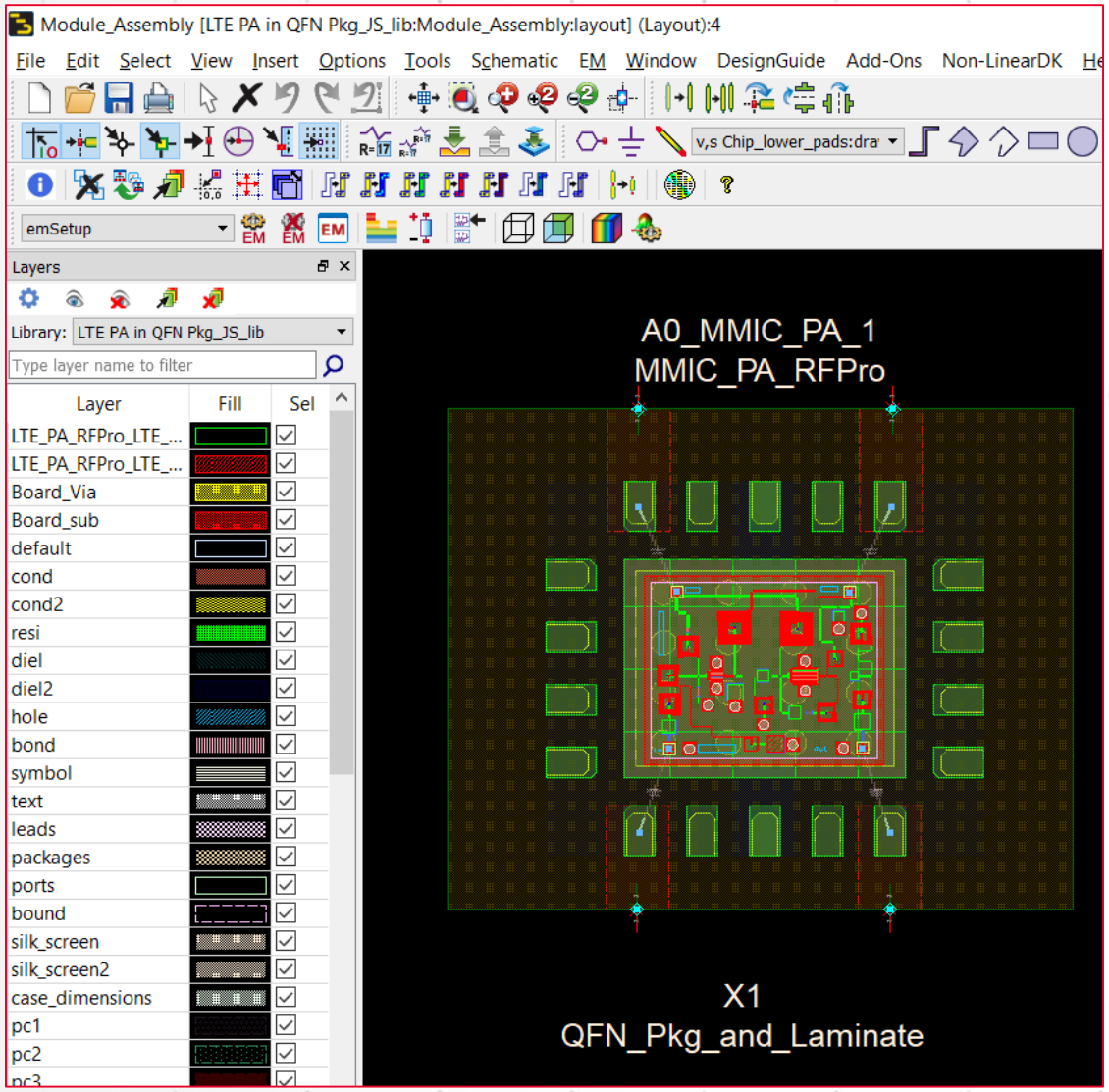


Smart Mount Technology Setup - Setup IC Pcell attribution

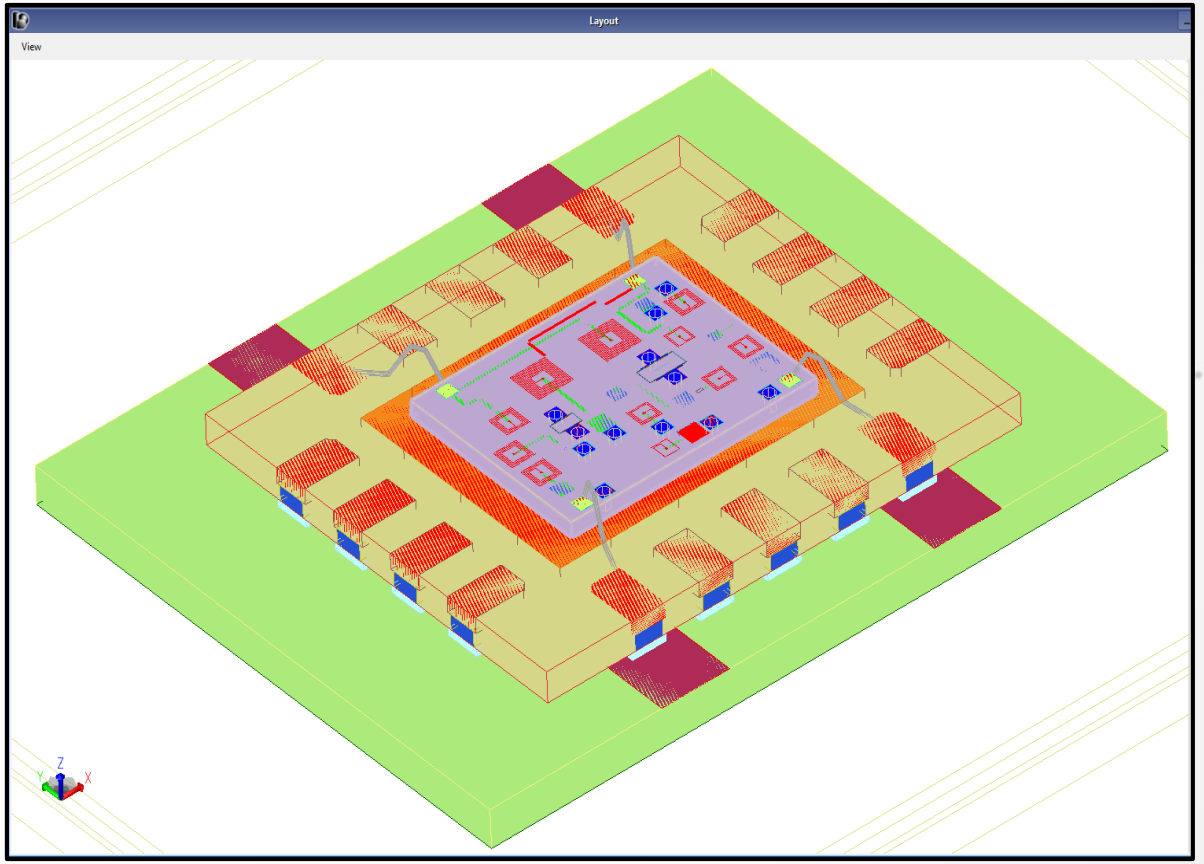




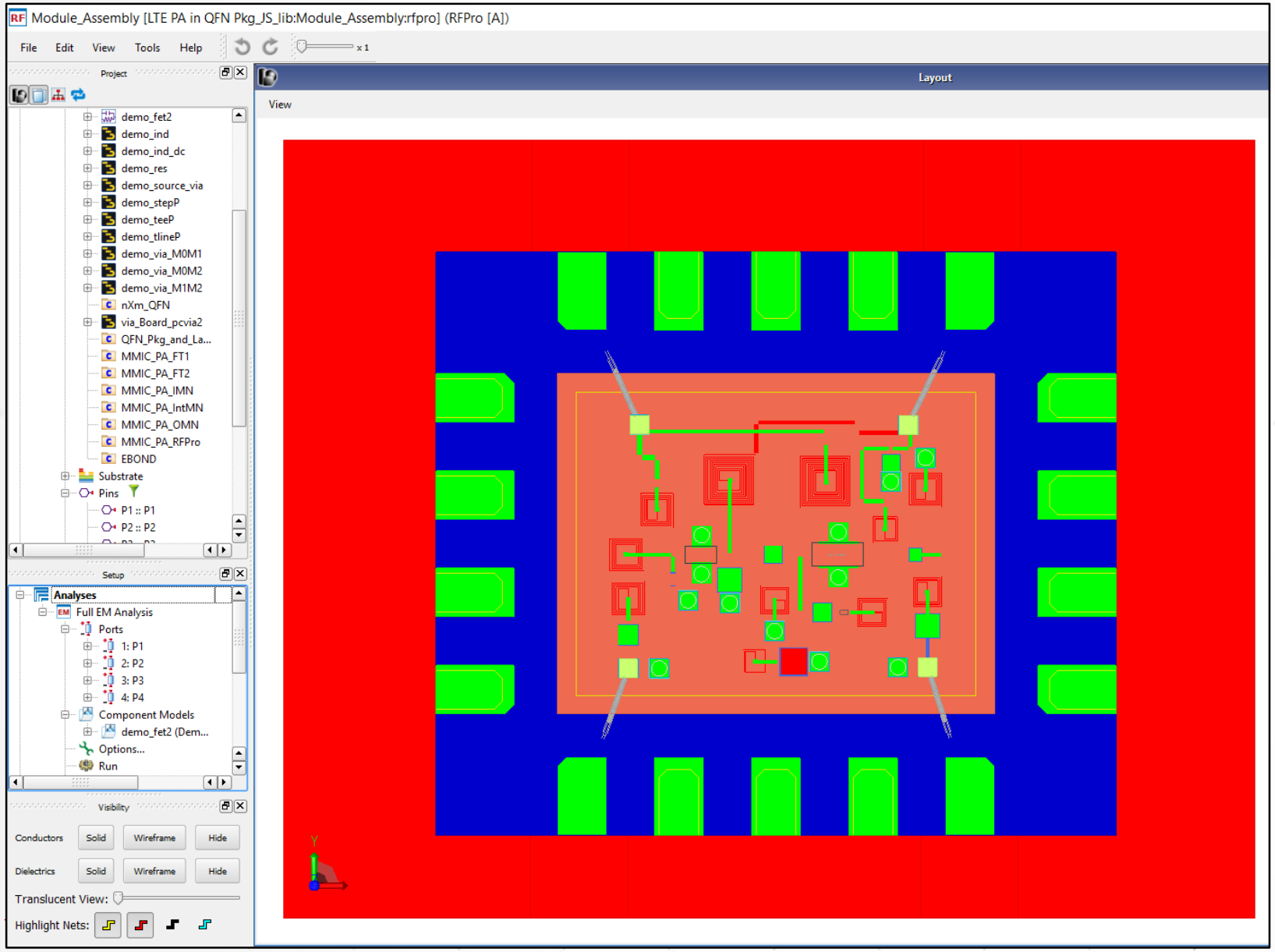
Building the Module Assembly

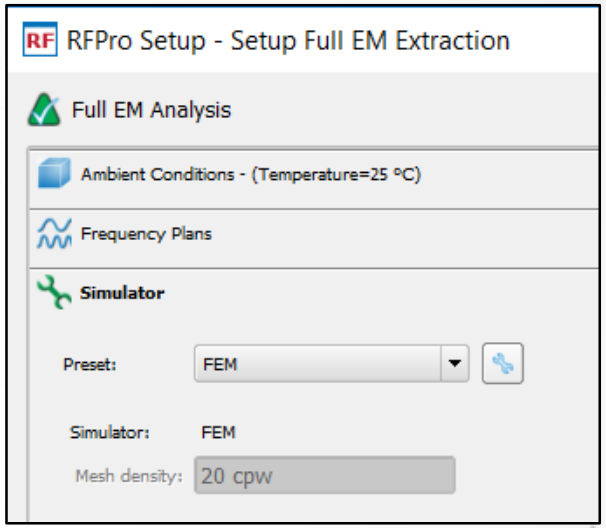


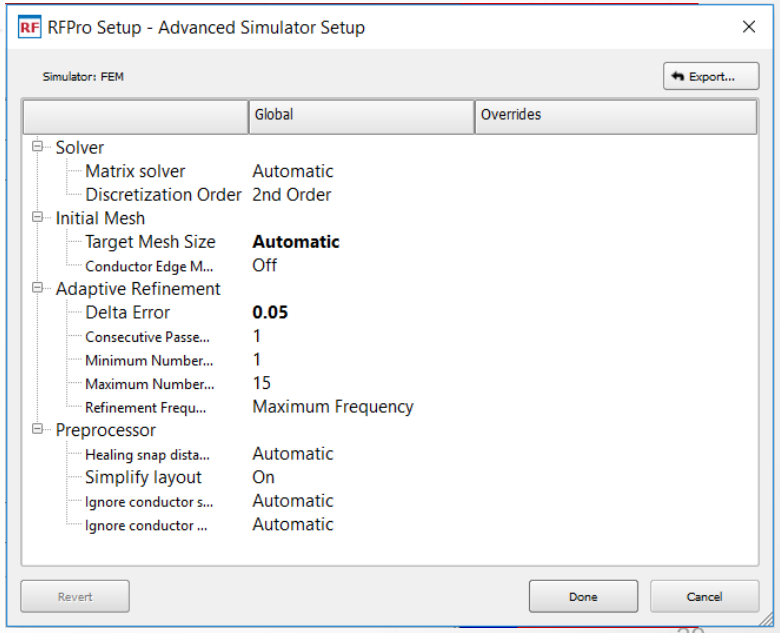
Module 3D View



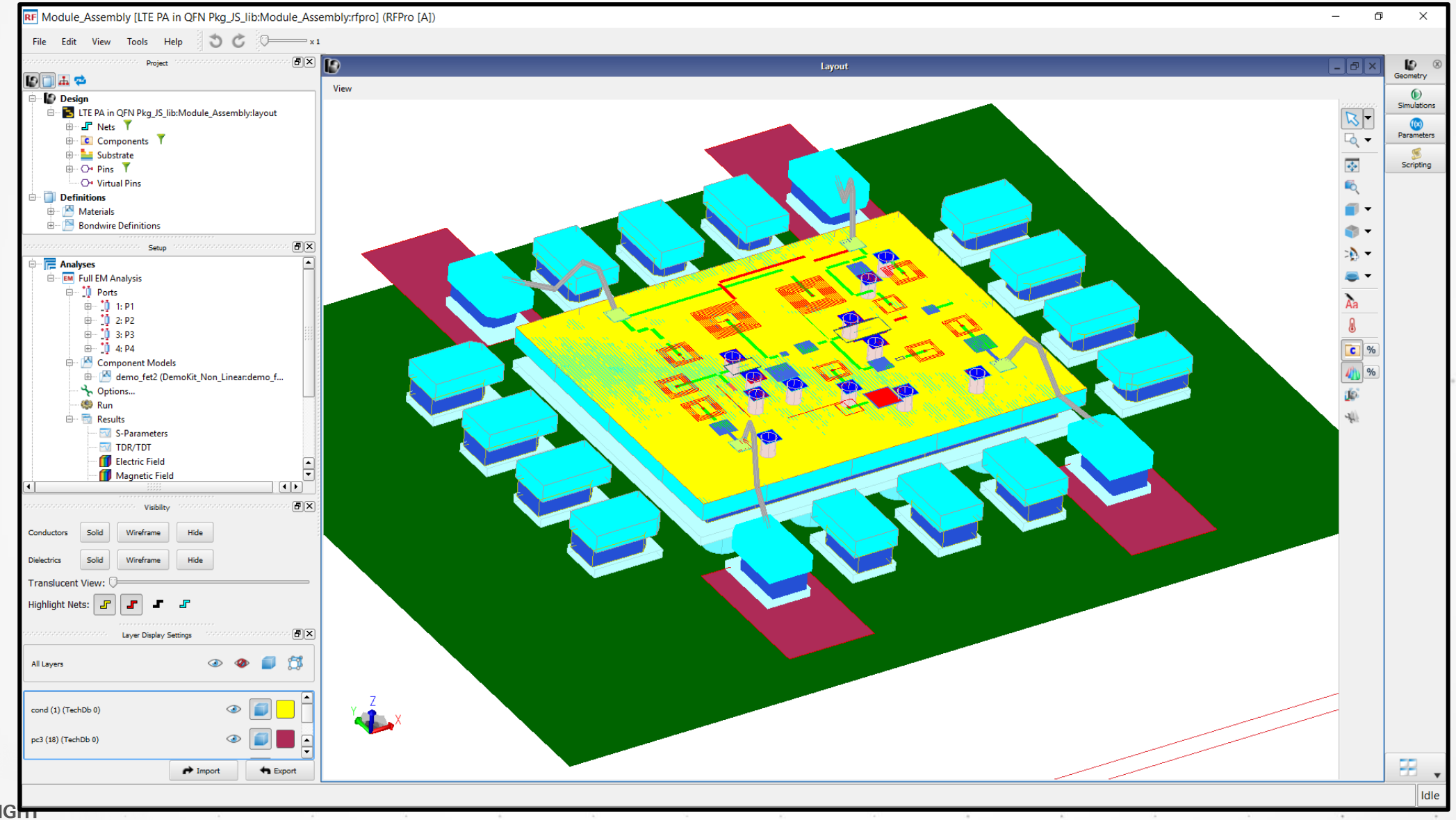
Module RFPro Simulation Setup



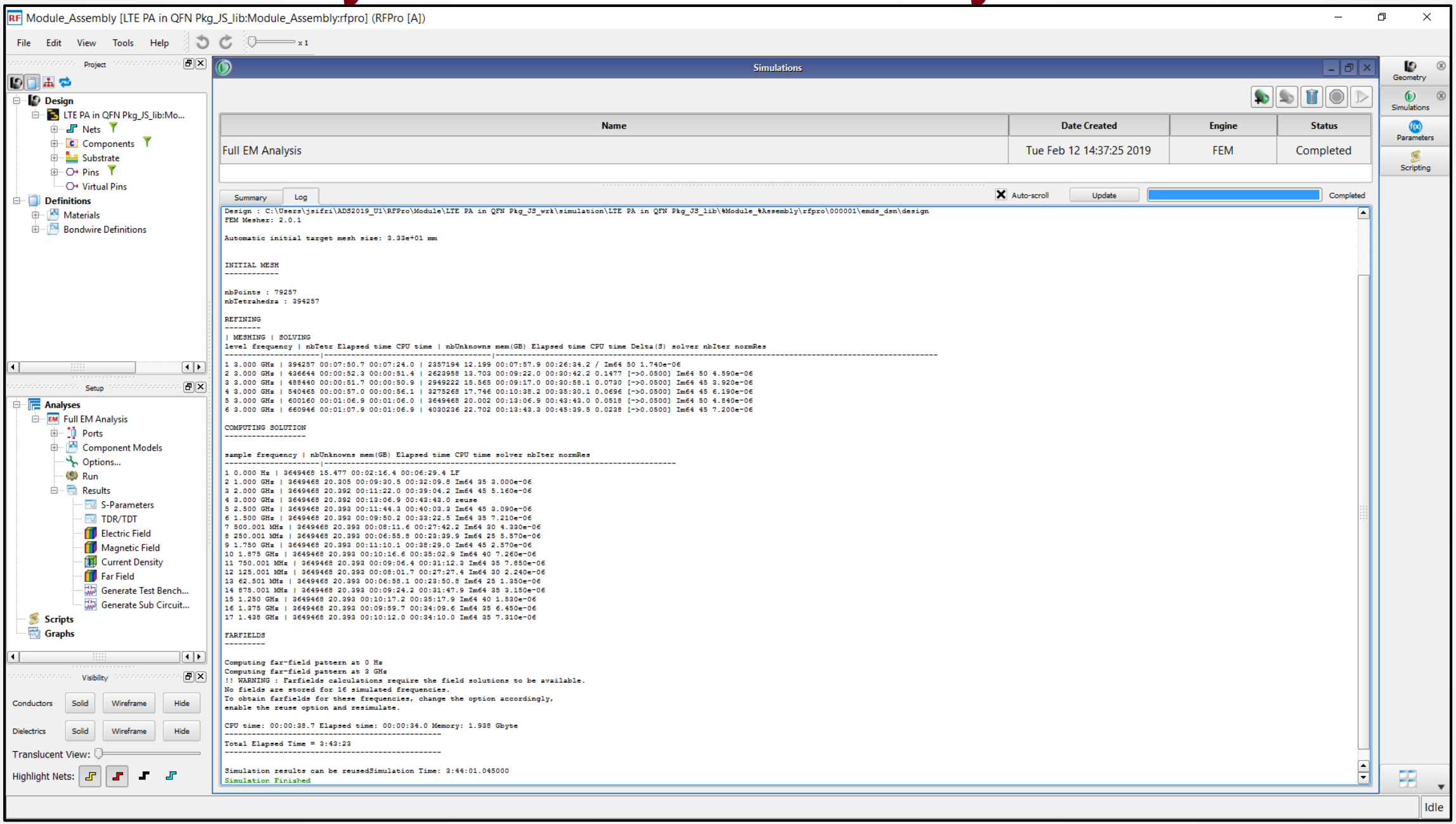




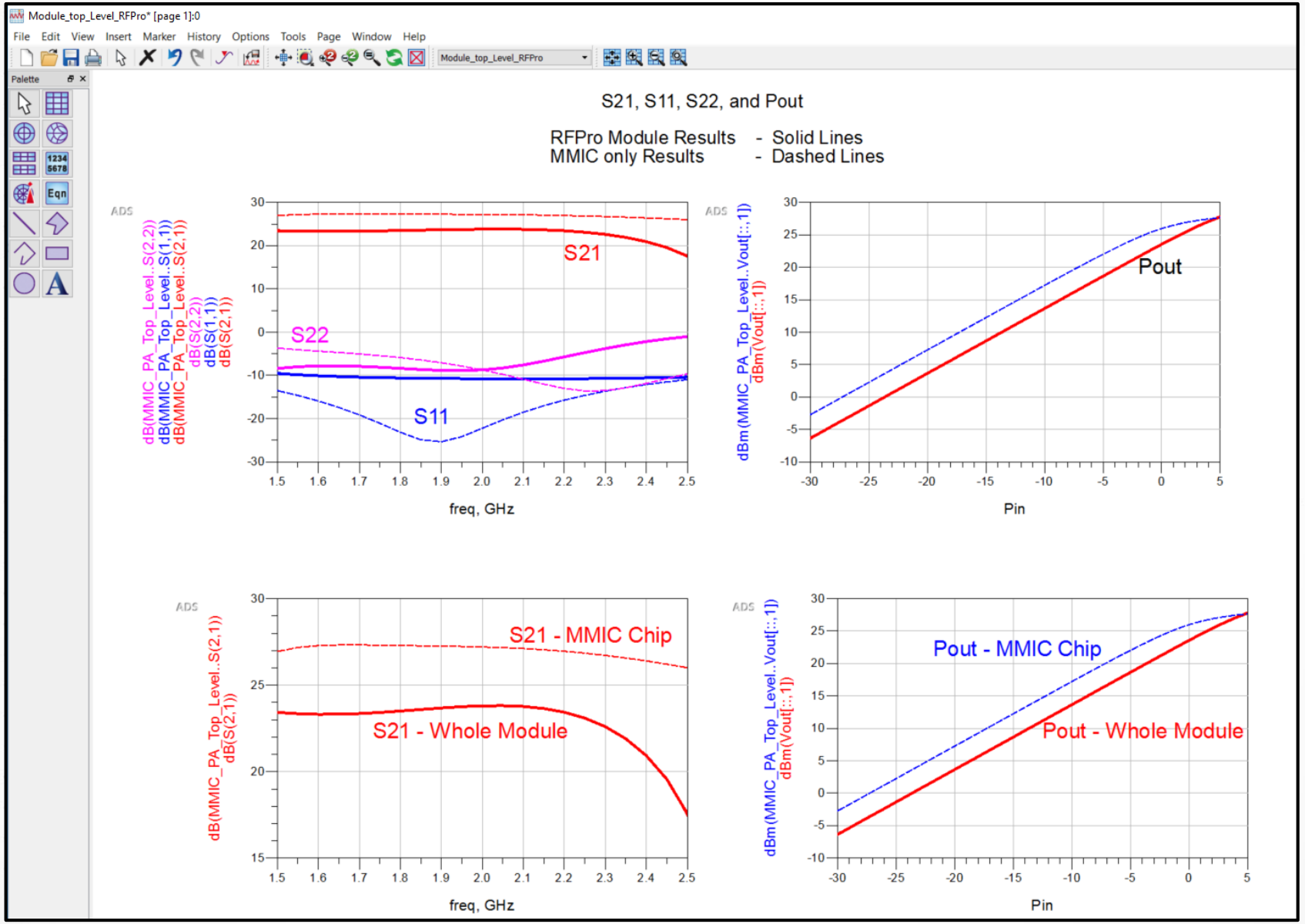
Module RFPro Simulation Setup



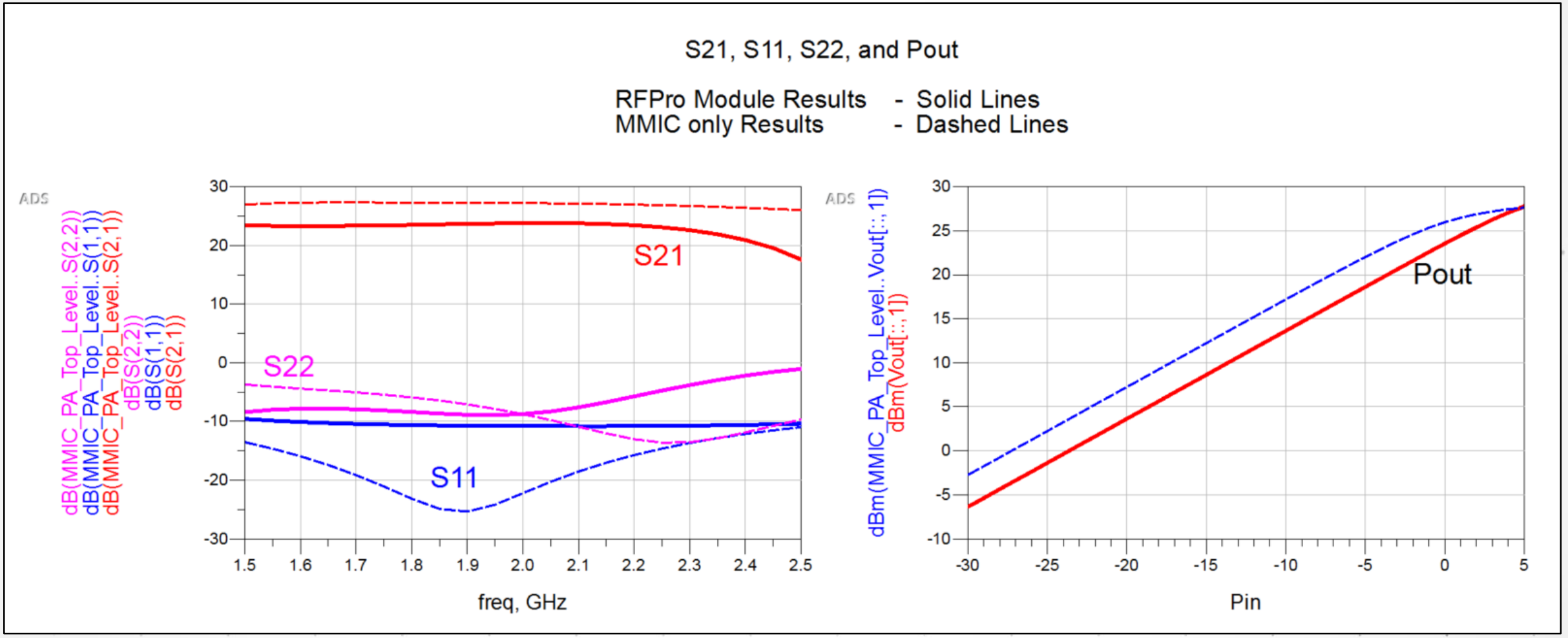
Full EM Analysis Simulation Summary



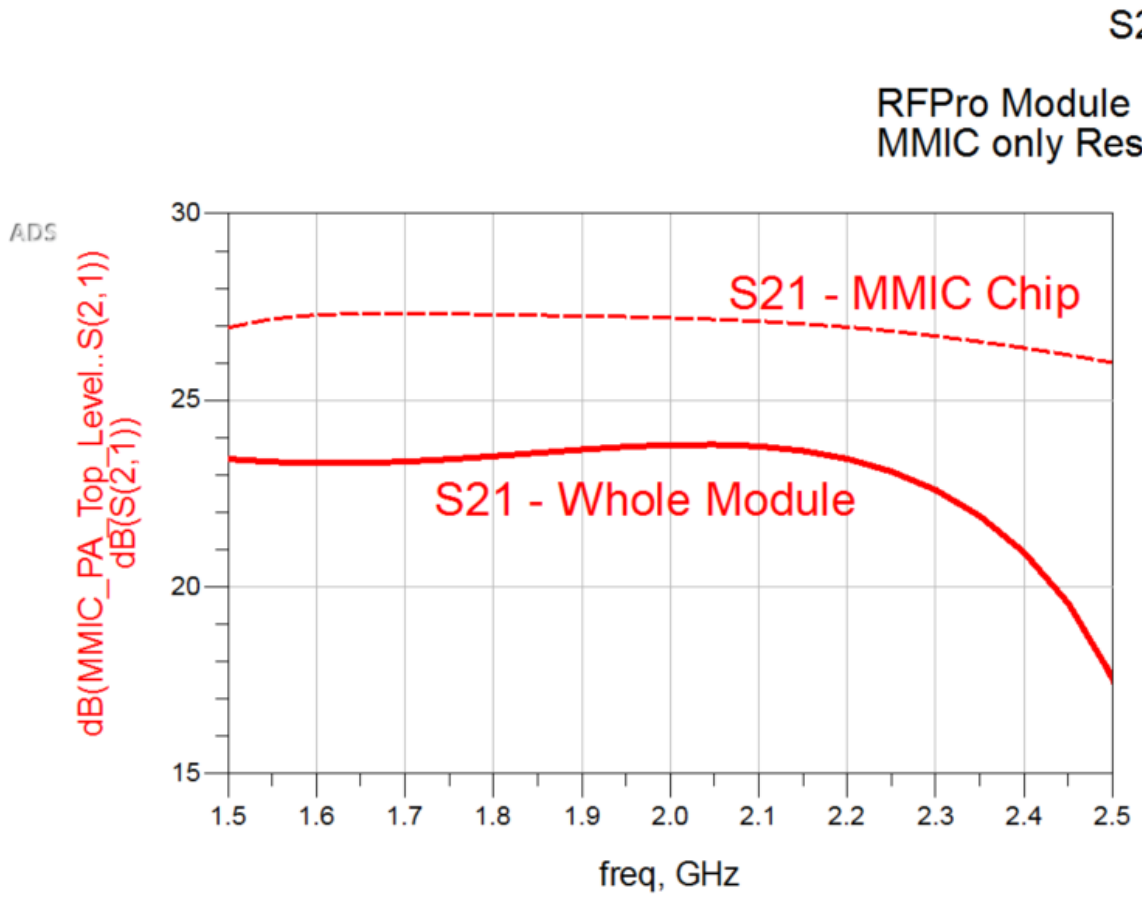
Simulation Results

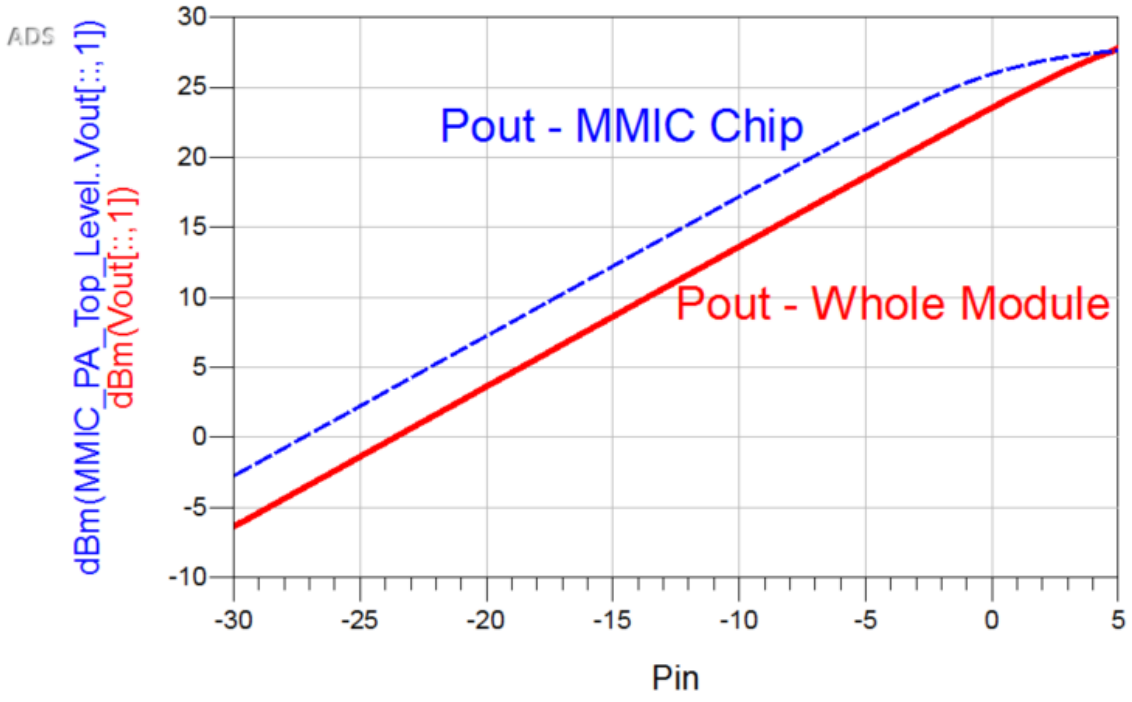


Simulation Results

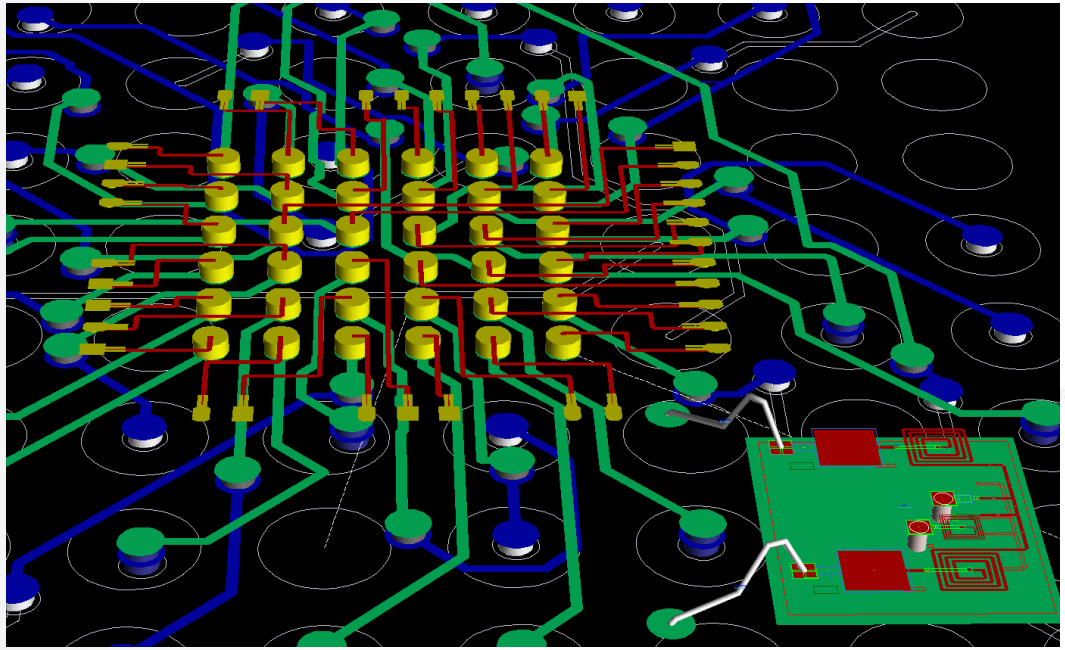


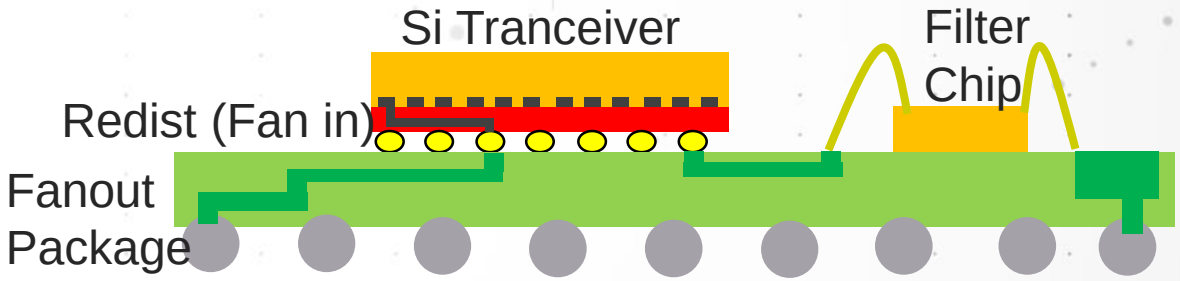
Simulation Results





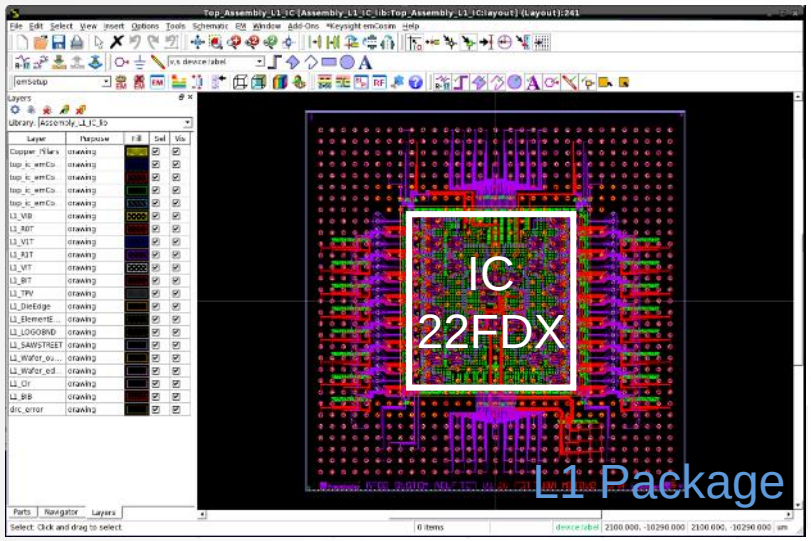
Connecting Different ICs In A FCBGA

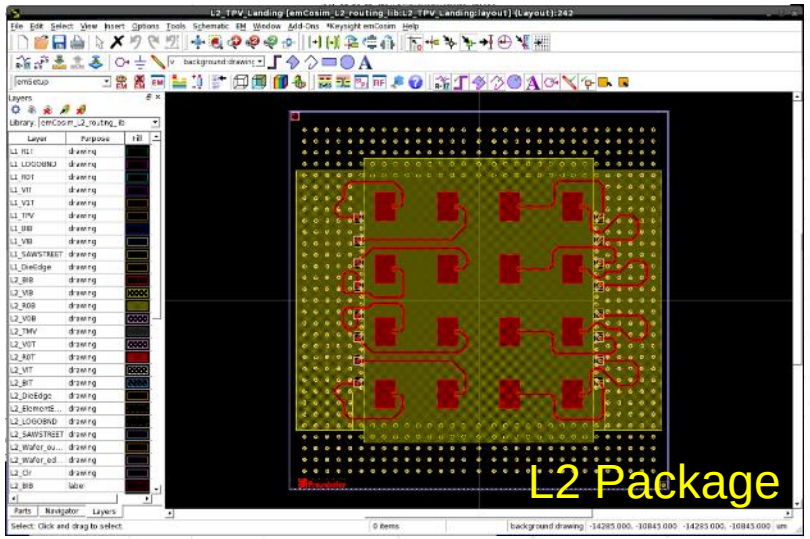


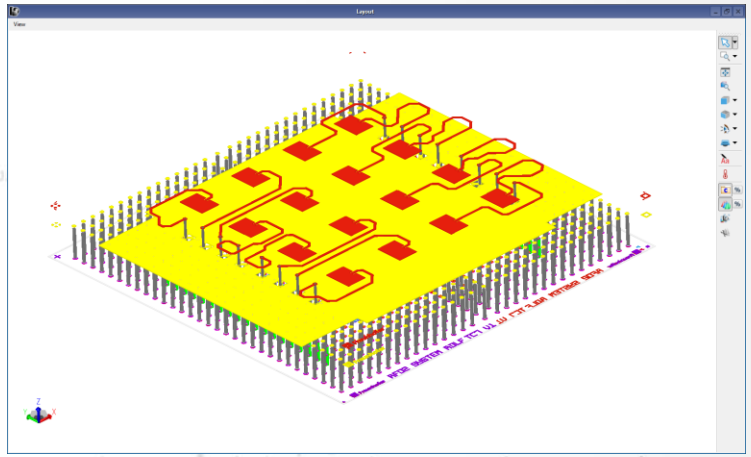


Application To a mmWave Example

Presented at EuMW 2018

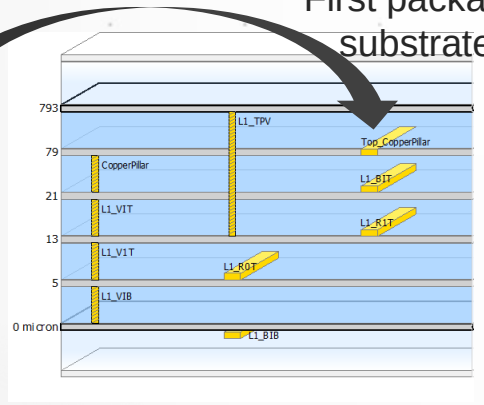






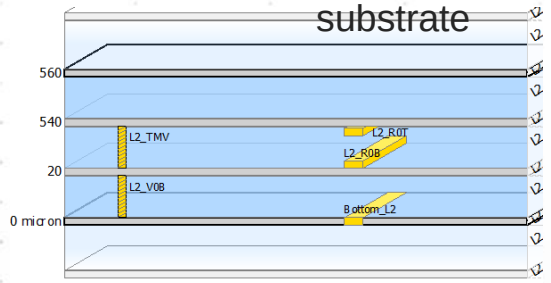
22FDX substrate

First package substrate



+

Second package substrate



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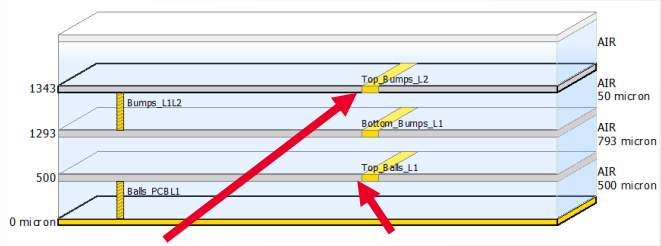
Overall substrate



L2 L1 and IC

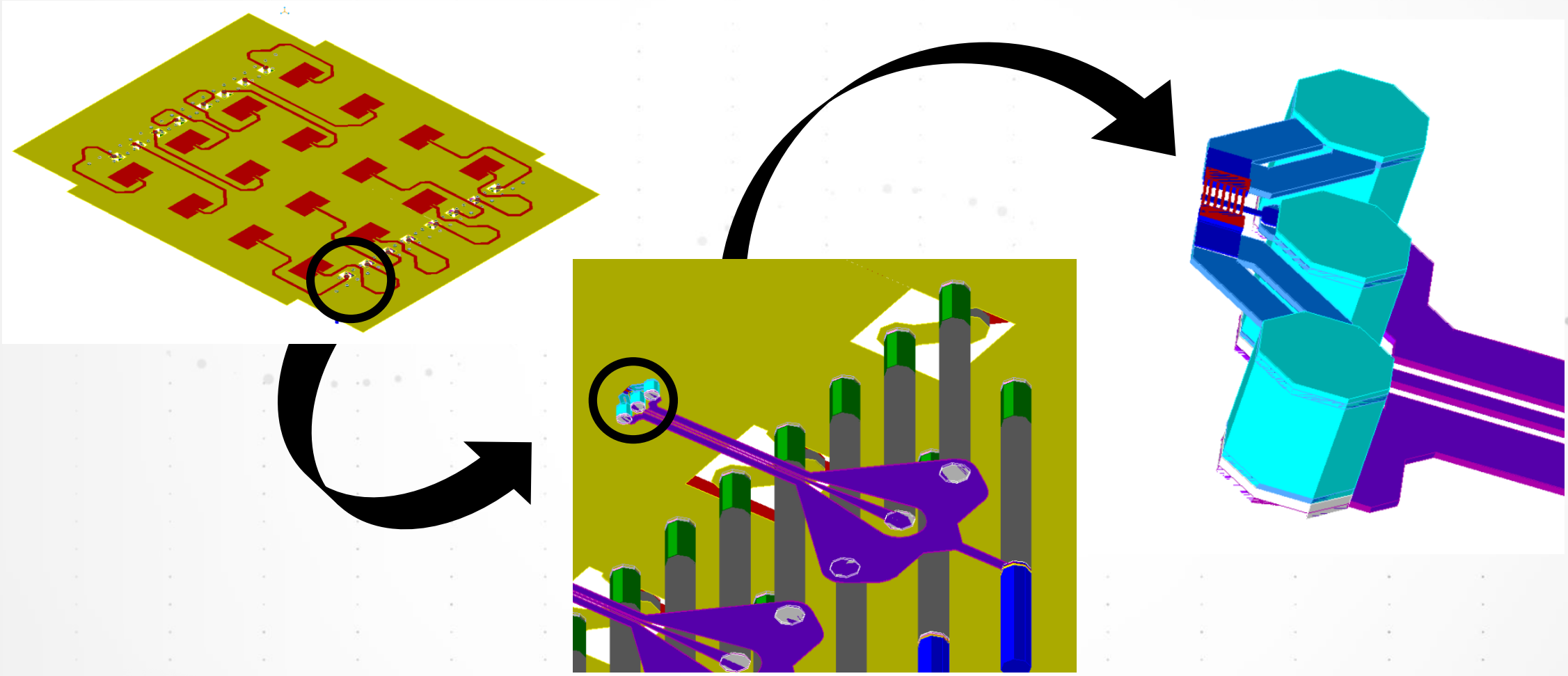
Application To a mmWave Example

MMW PATH FROM IC TO PATCH ANTENNA

GLOBALFOUNDRIES

Fraunhofer IIS

Presented at EuMW 2018



Application To a mmWave Example

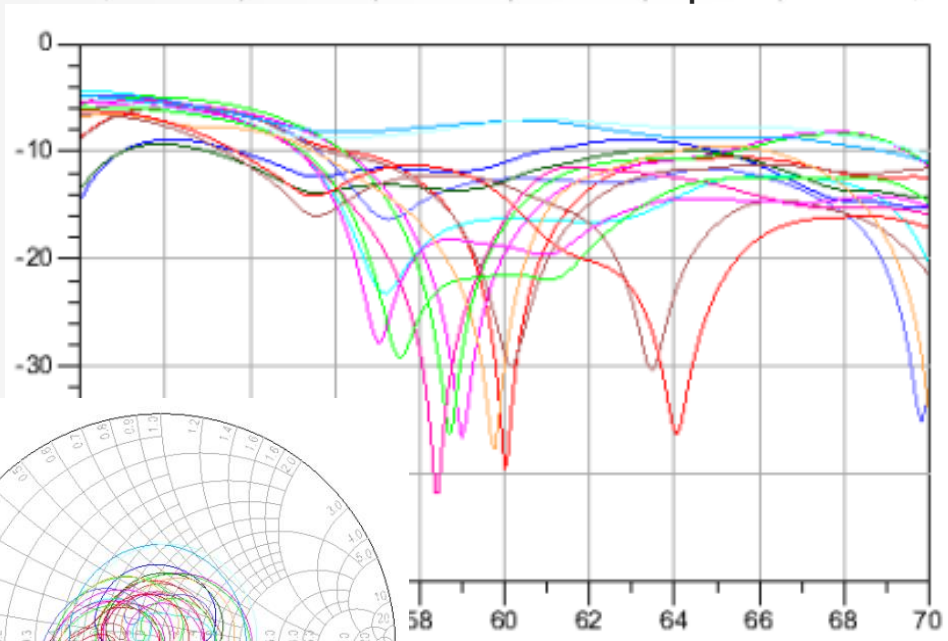
FEED-CIRCUIT-INTEGRATED PATCH ARRAY ANTENNA

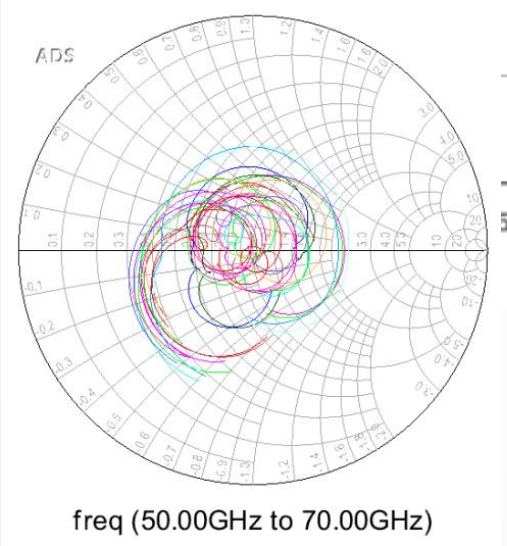
GLOBALFOUNDRIES

Fraunhofer IIS

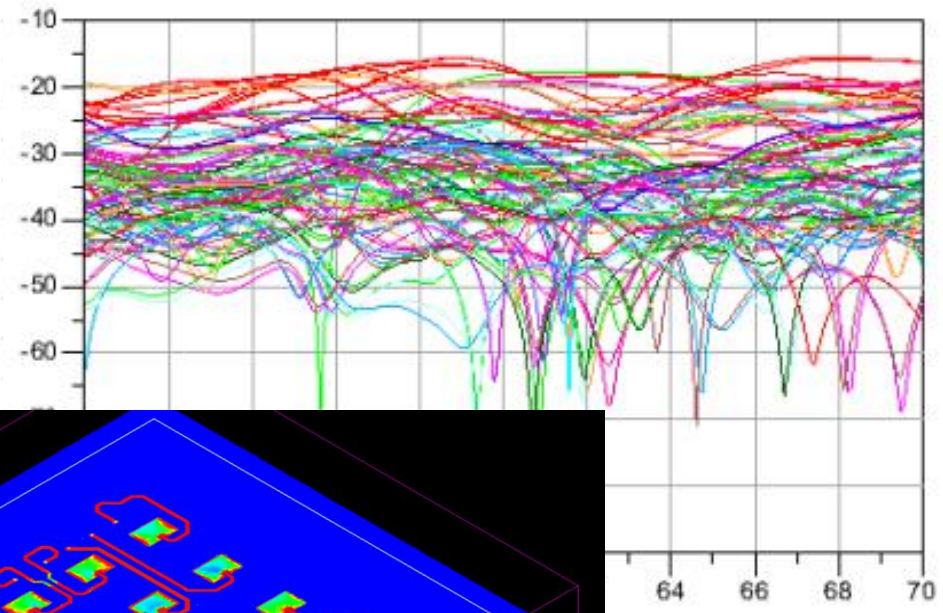
Presented at EuMW 2018

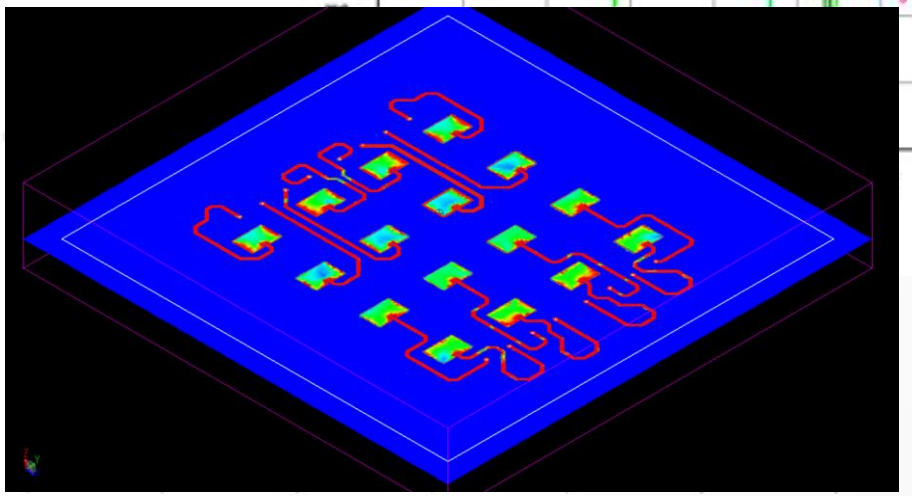
Return losses at antennas input





Coupling between antennas





KEYSIGHT TECHNOLOGIES

Application To a mmWave Example

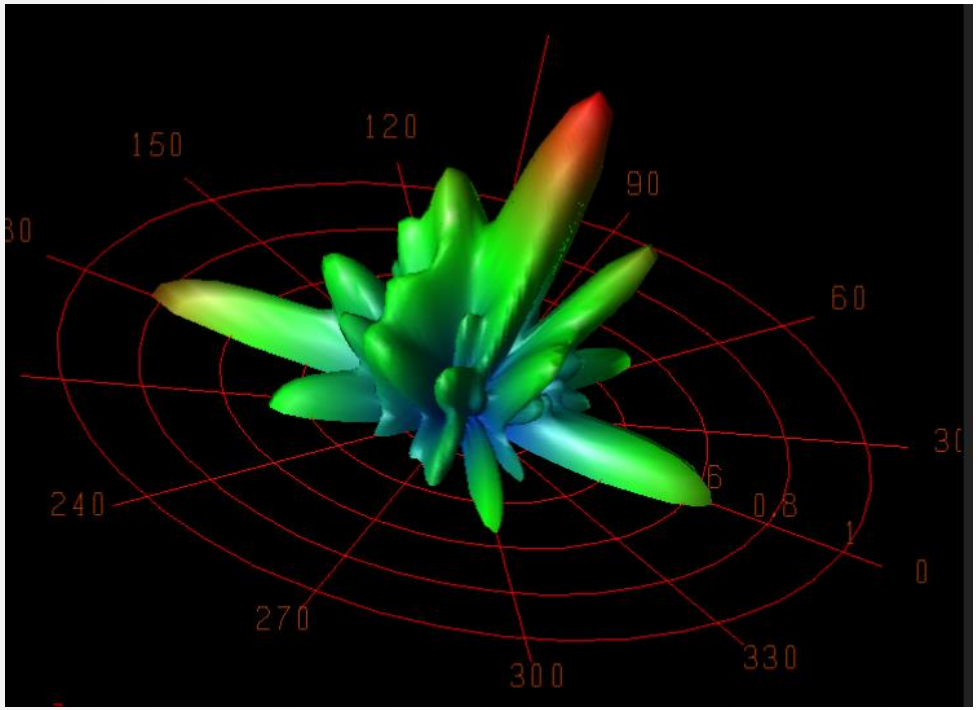
RADIATION PATTERN OF 4×4 PATCH ANTENNA ARRAY

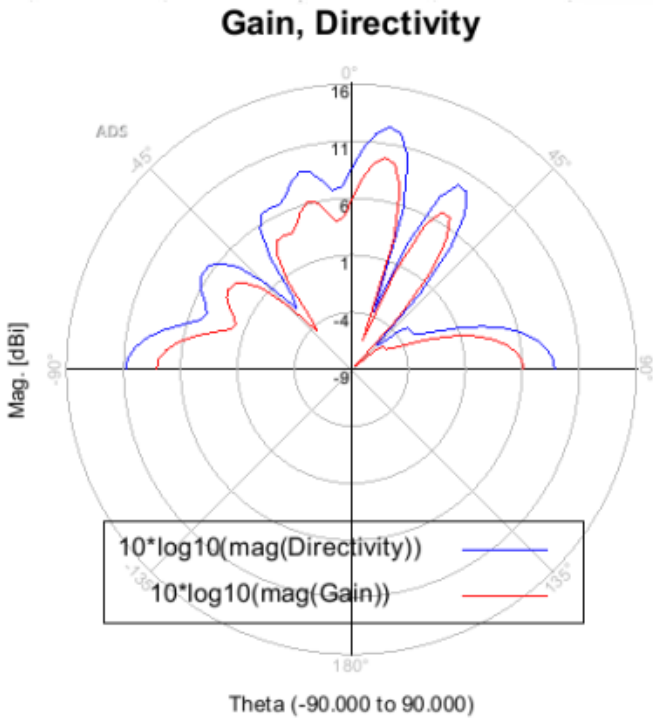
GLOBALFOUNDRIES

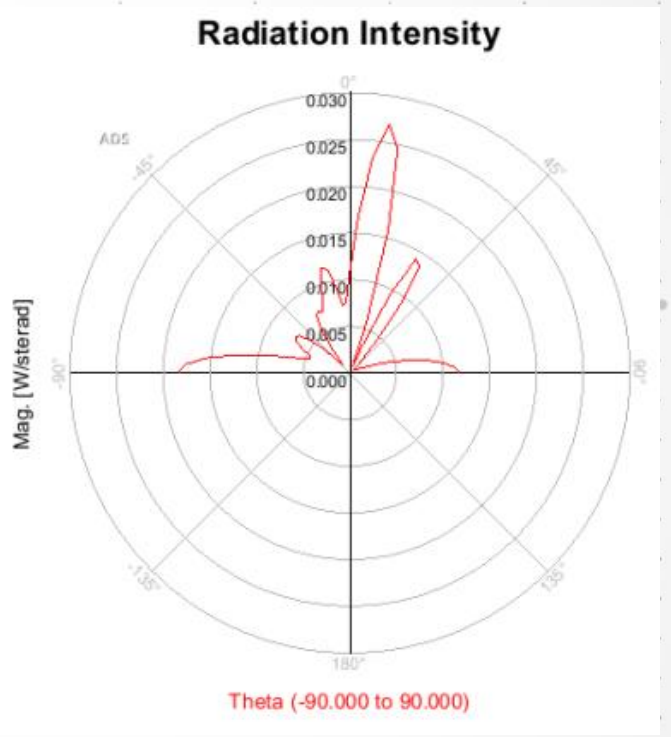
Fraunhofer IIS

Presented at EuMW 2018

0° phase at all inputs



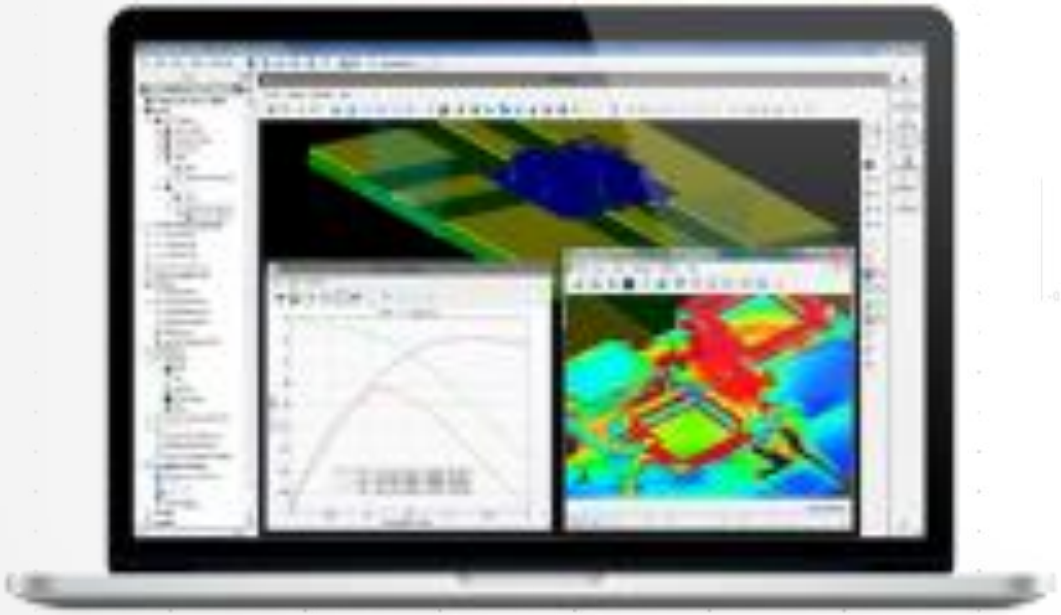


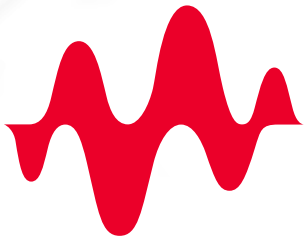


Gain : 9.7 dBi
Directivity : 12.4 dBi
Radiation Efficiency : 54%

Summary

- PathWave ADS allows to read databases coming from different tools
- The focus is made to swiftly assemble all the pieces
- The EM tools have been simplified to enable circuit, antenna and package designers to perform simulations seamlessly





KEYSIGHT
TECHNOLOGIES