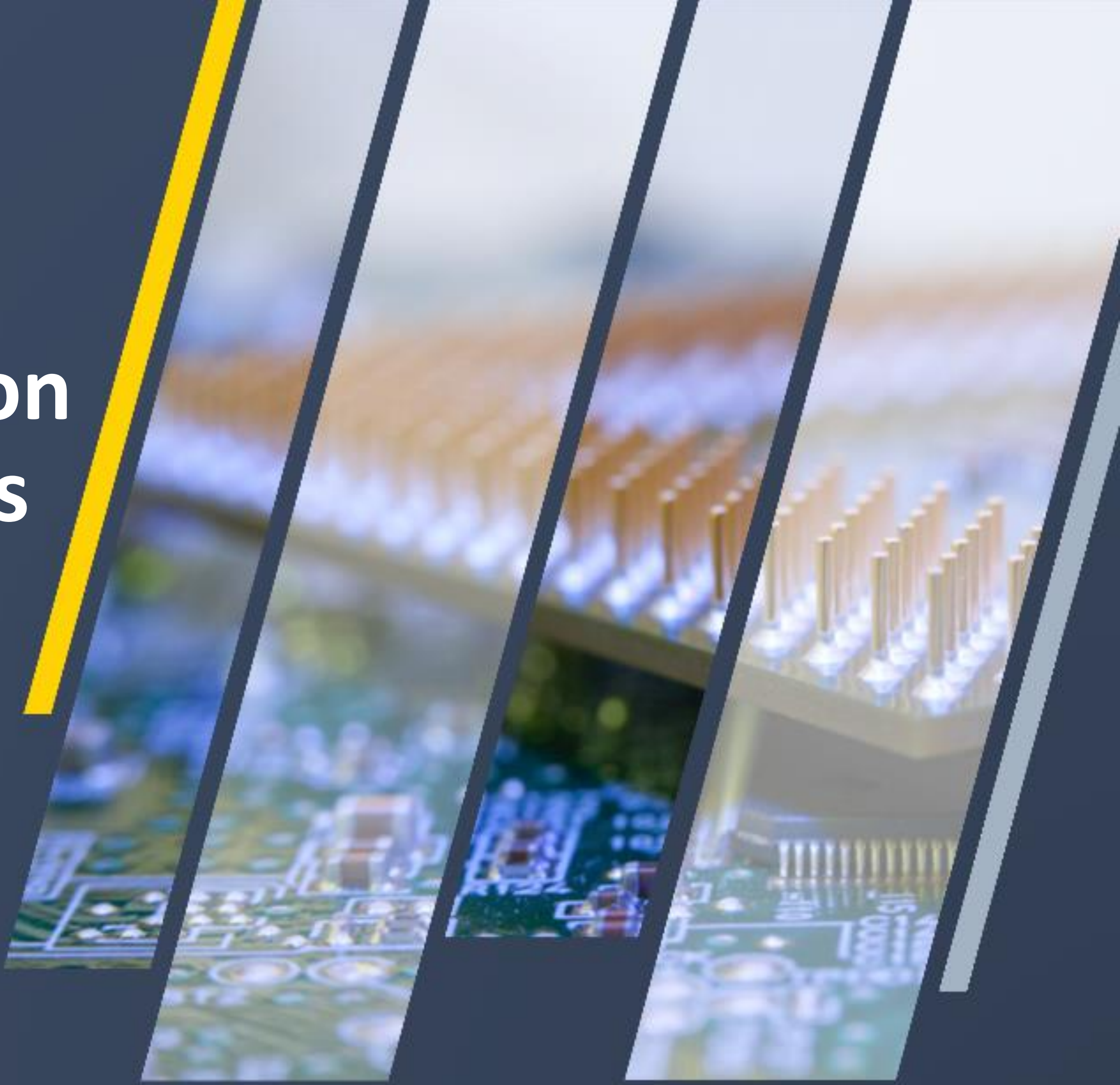
Electromagnetic Simulation Techniques for Connectors and PCBs



Bill McGinn

Ansys Sr. Application Engineer

ANSYS is the Simulation Leader

FOCUSED

This is all we do.
Leading product technologies in all physics areas
Largest development team focused on simulation

TRUSTED

96 of the top 100
FORTUNE 500 Industrials
ISO 9001 and NQA-1 certified

CAPABLE

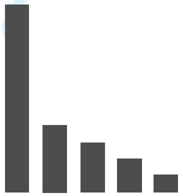
PROVEN

Recognized as one of the world's MOST INNOVATIVE AND FASTEST-GROWING COMPANIES*

INDEPENDENT

Long-term financial stability
CAD agnostic

LARGEST



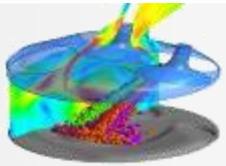
3x The size of our nearest competitor

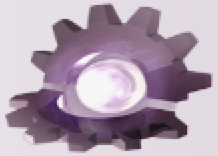
**BusinessWeek, FORTUNE*

Breadth of Technologies

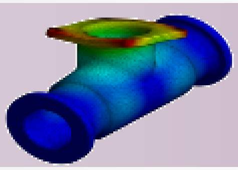
Fluid Mechanics:
From Single-Phase Flows

To Multiphase
Combustion

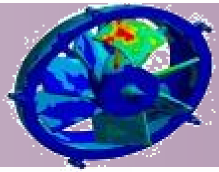


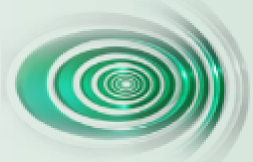


Structural Mechanics:
From Linear Statics

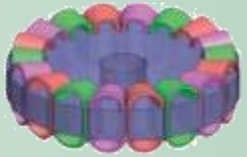


To High-Speed Impact

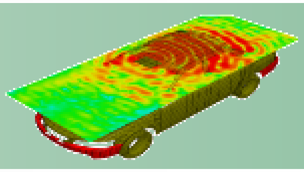


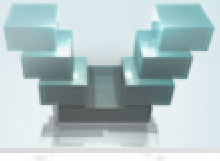


Electromagnetics: From
Low-Frequency Windings

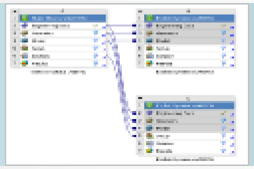


To High-Frequency
Field Analysis

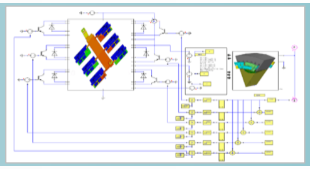




Systems:
From Data Sharing

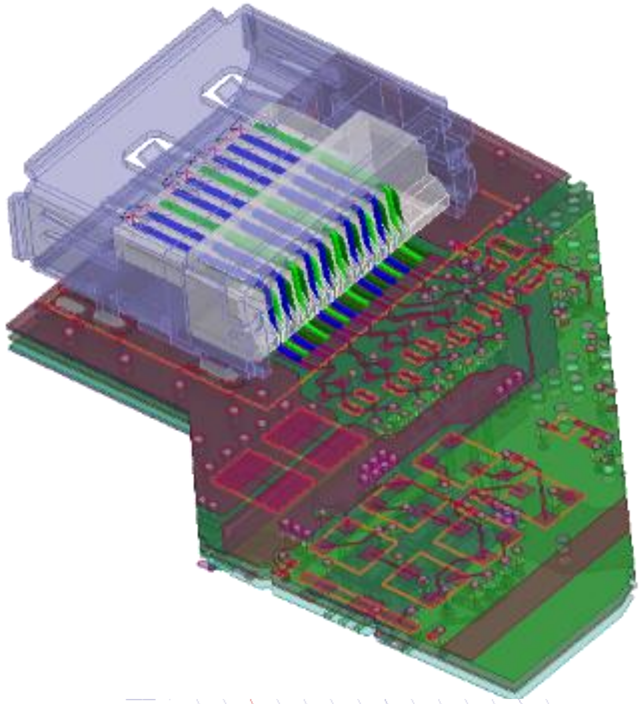


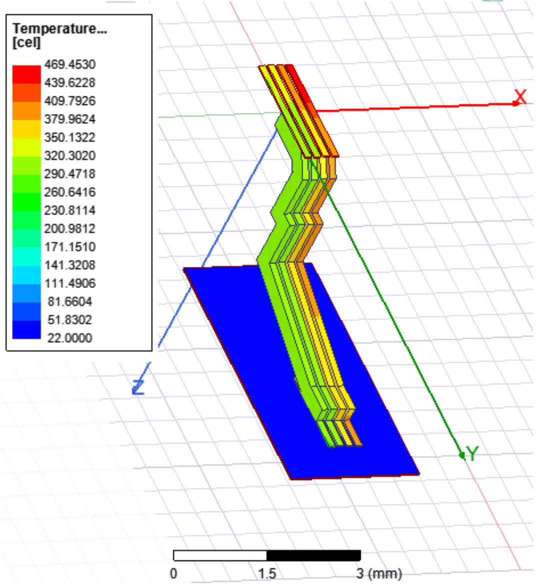
To Multi-Domain
System Analysis



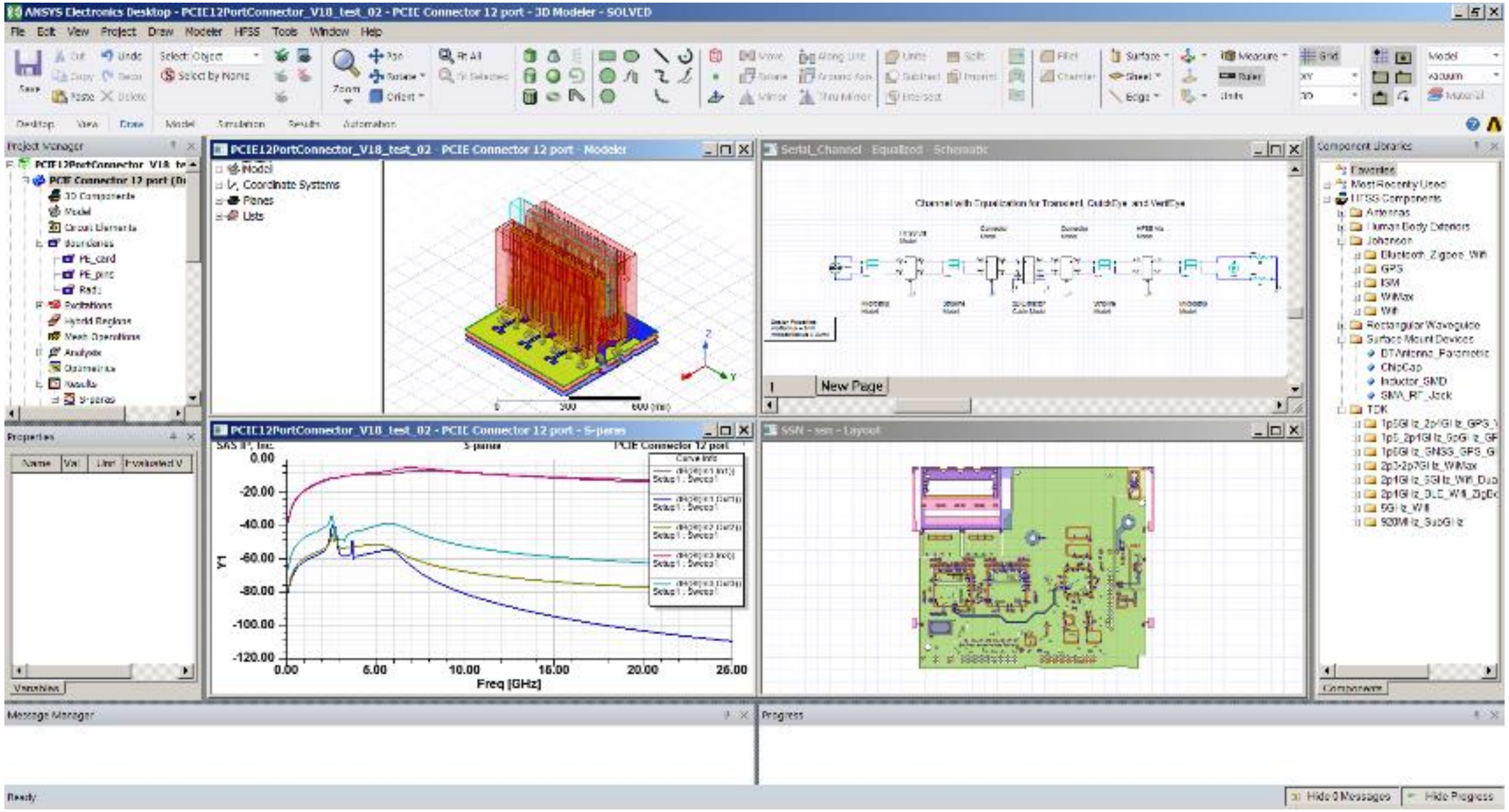
Summary

- Brief Overview of EM Techniques FEM and Transient
- Connector on Board "Assembly" Simulation
- HFSS 3D Components
- Thermal Simulation of EM Models
- EMI Analysis using HFSS
- EMI Scanner





AEDT: ANSYS Electronics Desktop

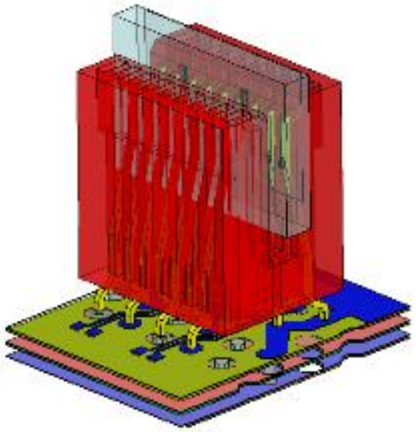


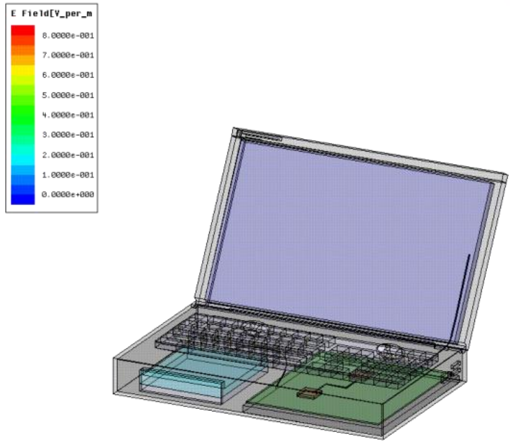
<u>Single Desktop for:</u>

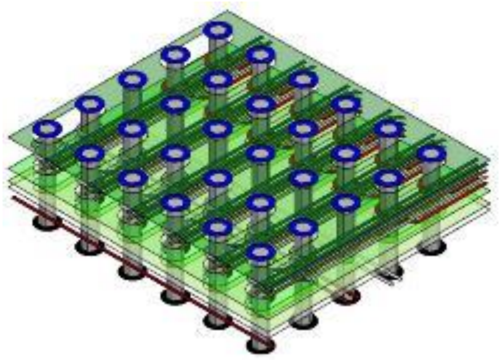
- ***HFSS***
- ***HFSS 3D Layout***
- ***Circuit***
- *Thermal*
- ***…***
- ***Tight integration between circuit and 3D EM simulation***

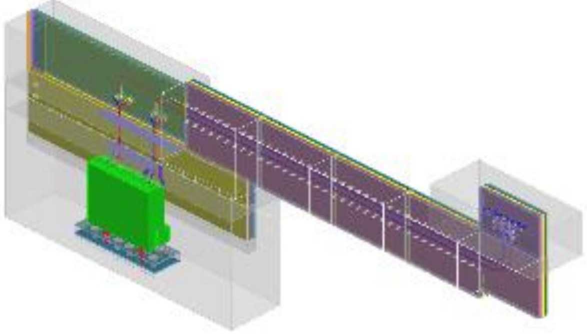
HFSS: High Frequency Structure Simulator

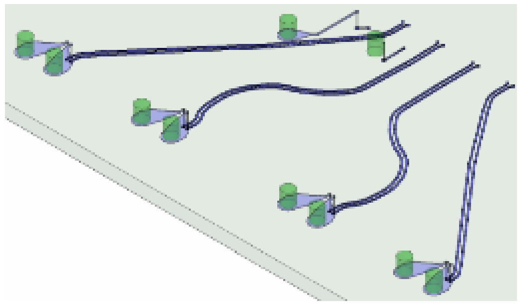
- Full-wave FEM 3D electromagnetic field solver
  - Computes electromagnetic behavior of high-frequency and high-speed components and systems
  - Extracts S-, Y-, and Z-parameters
  - Provides 3D electromagnetic fields
- Applications
  - RF/Microwave
  - Biomedical
  - Radiation: Antennas, EMI/EMC
  - Signal Integrity/High Speed Digital
    - ➢ Packages
    - ➢ PCB
    - ➢ Connectors
    - ➢ Transitions



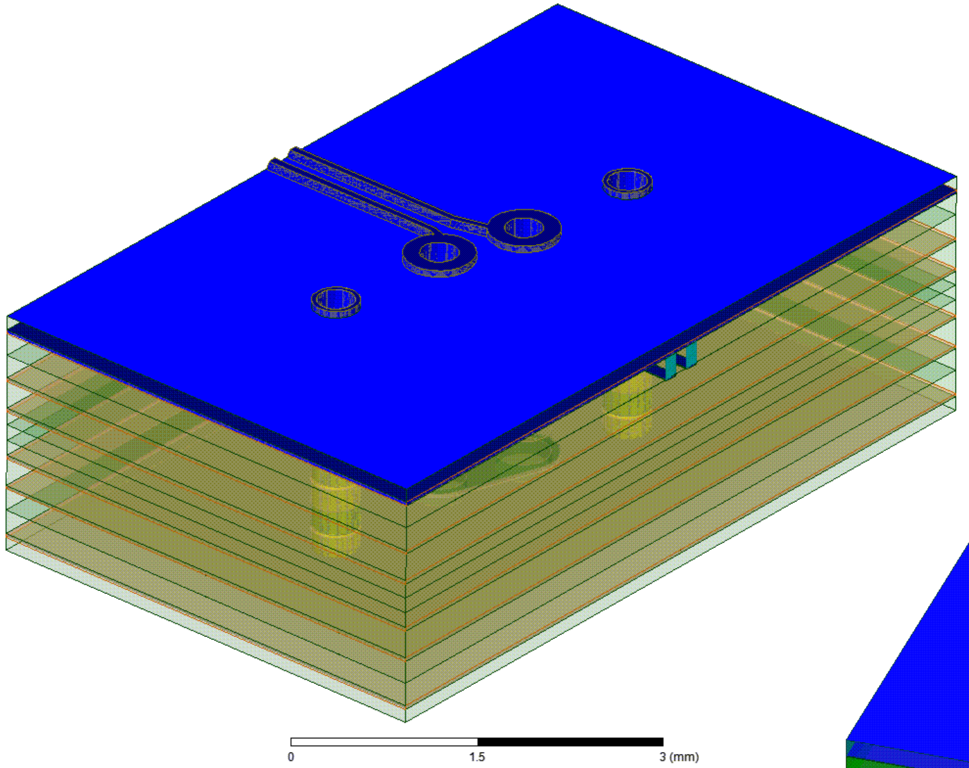


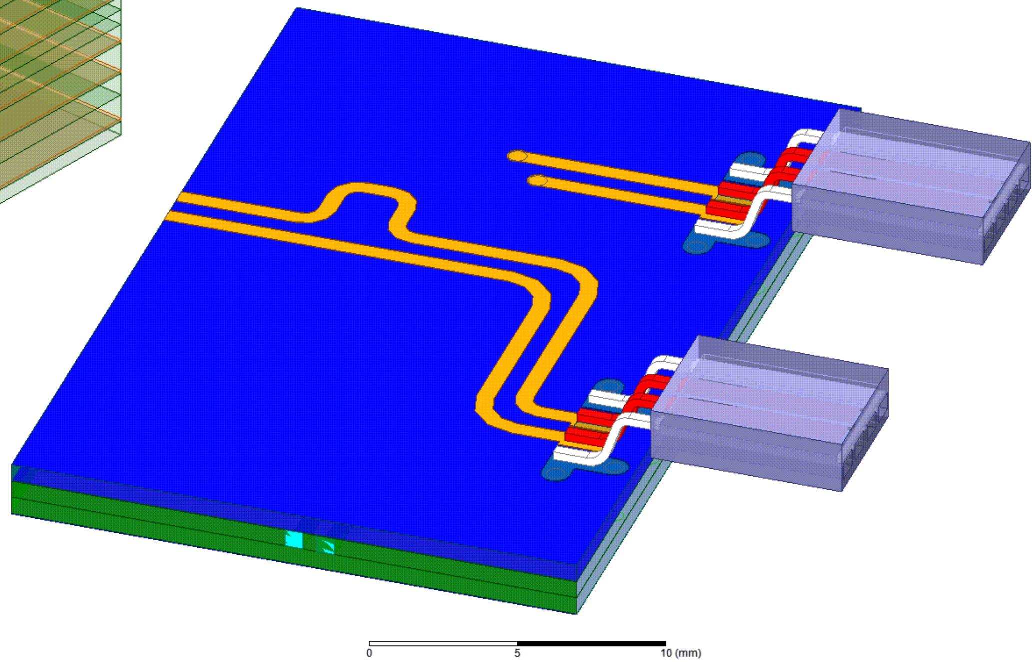






HFSS Transient Now Included with HFSS

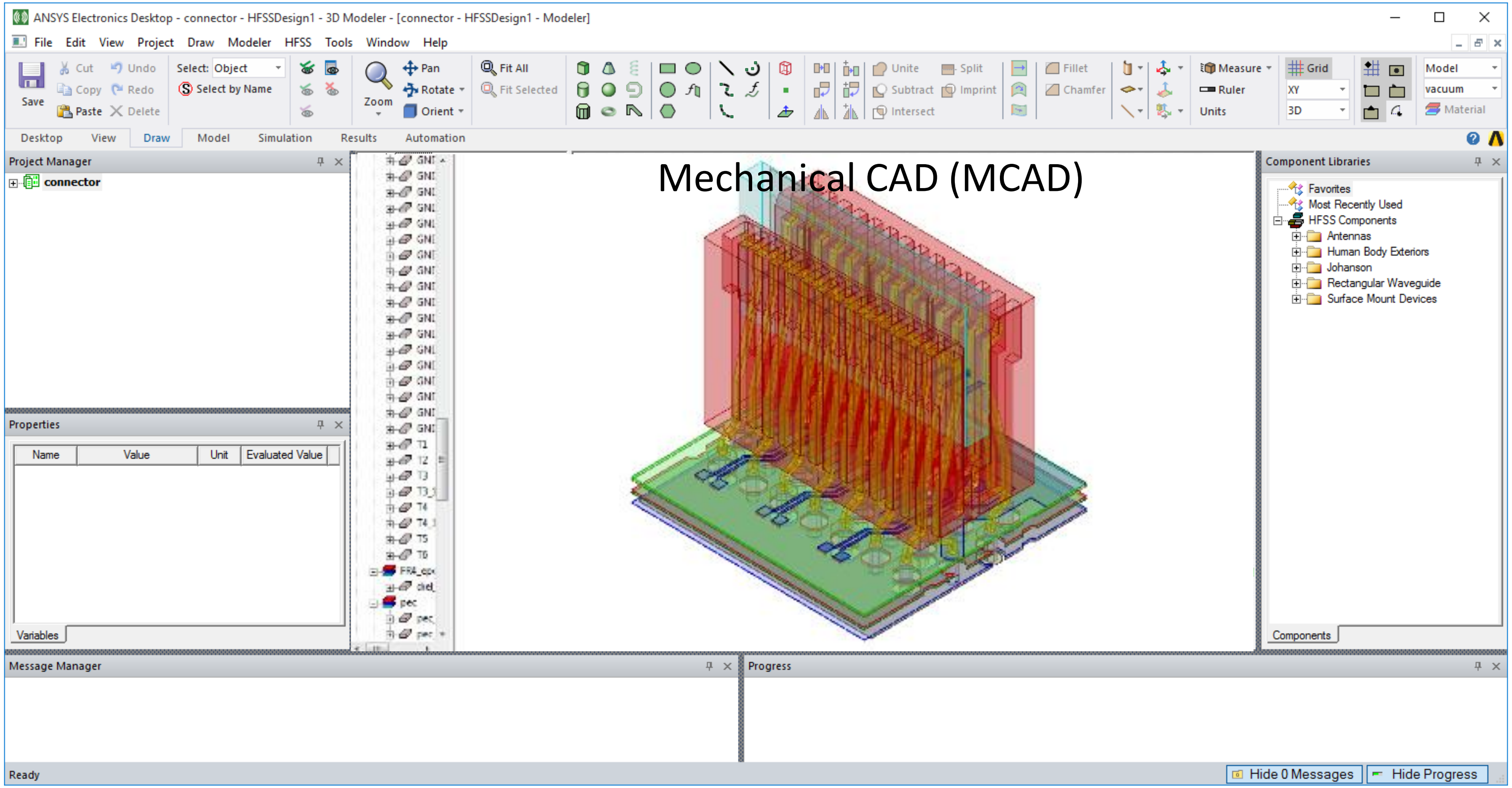




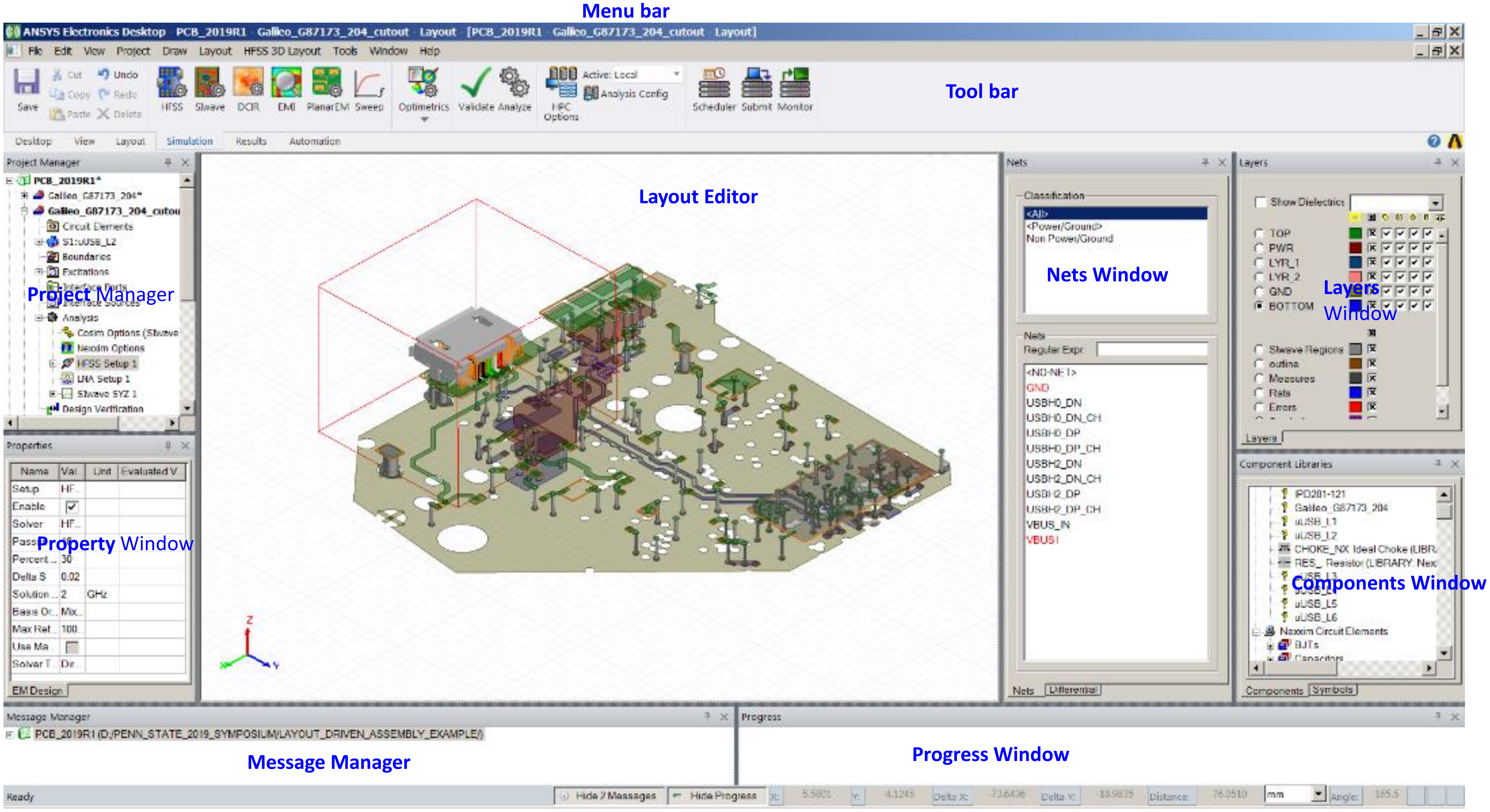
- **Time Domain Finite element solver**
- Faster implicit solver (New 2019)
- Improved Auto-HPC performance (New 2019)
- Unstructured FEM Mesh based on Tets (variable size, variable order, conformal)
- Adaptive meshing
- Local time stepping
- Waveform input flexibility (oblique angles)

HFSS 3D Layout

HFSS: Arbitrary 3D Geometry Editor



HFSS 3D Layout Desktop



Stackup Editor : Manufacturing Tolerances

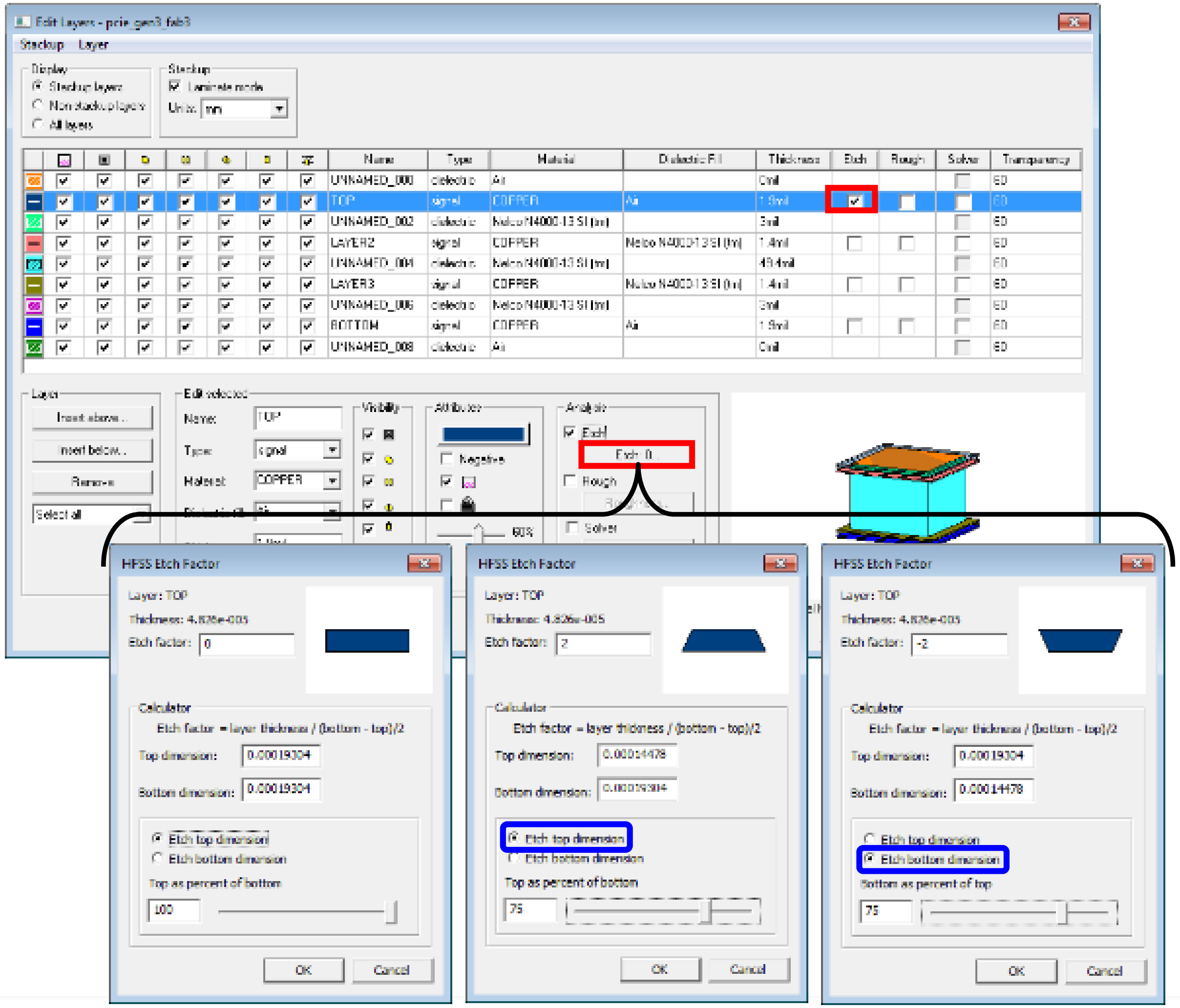
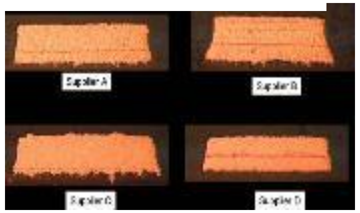


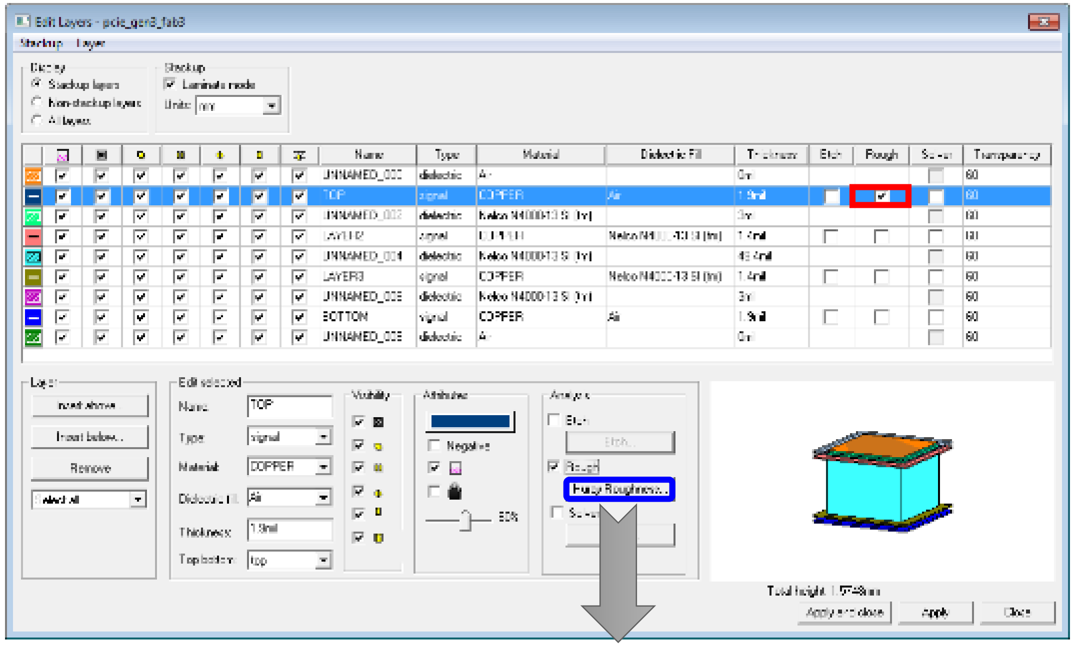
Image courtesy of AMKOR

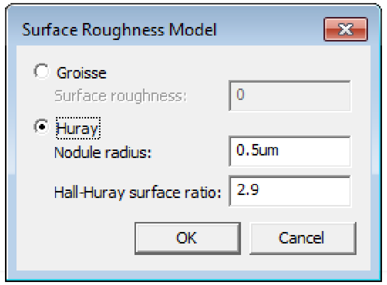


Stackup Editor : Surface Roughness

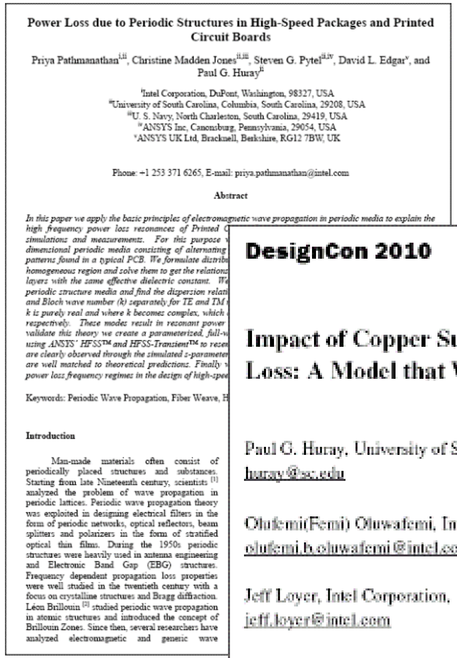
Stackup

- Surface Roughness
  - Huray or Groisse Roughness Models
    - ➢ Per Layer based
    - ➢ Per polygon based





Surface roughness

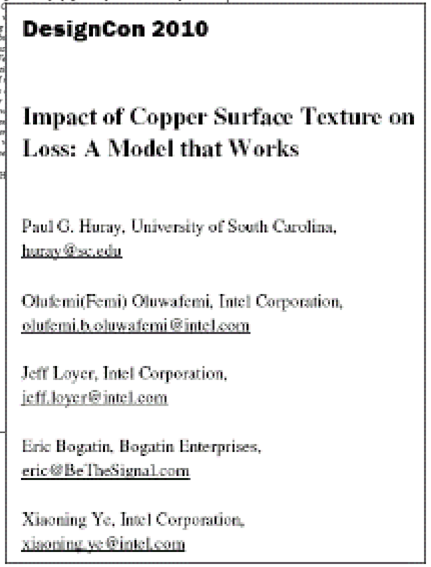


Power Loss due to Periodic Structures in High-Speed Packages and Printed Circuit Boards

Priya Pathmanathan, Christine Madden Jones, Steven G. Pytel, David L. Edgar, and Paul G. Huray

Abstract

Introduction



DesignCon 2010

Impact of Copper Surface Texture on Loss: A Model that Works

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Olufemi(Femi) Oluwafemi, Intel Corporation, olufemi.b.oluwafemi@intel.com

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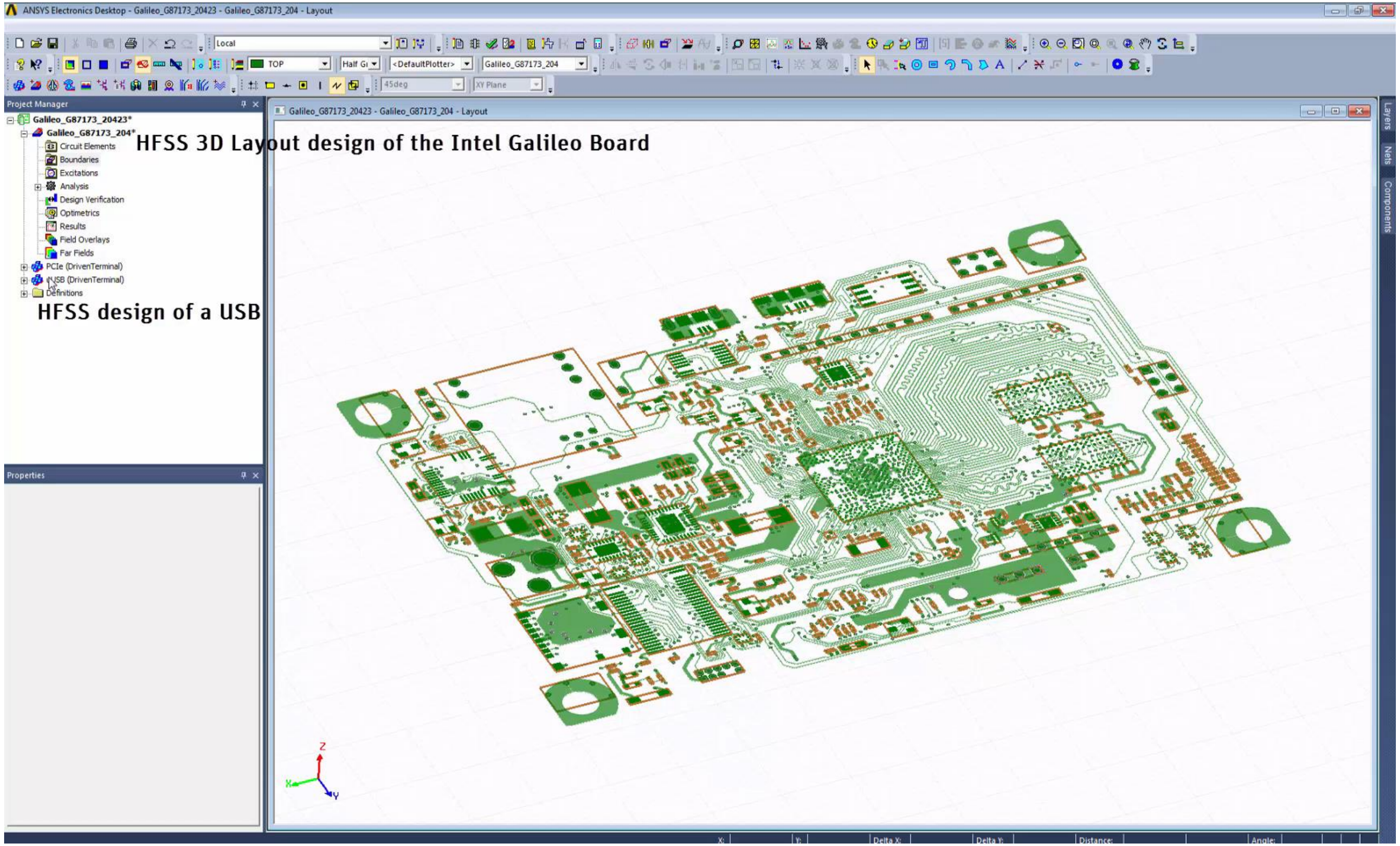
Eric Bogatin, Bogatin Enterprises, eric@BeTheSignal.com

Xiaoning Ye, Intel Corporation, xiaoning.ye@intel.com

HFSS 3D Layout: “Connector-on-Board”

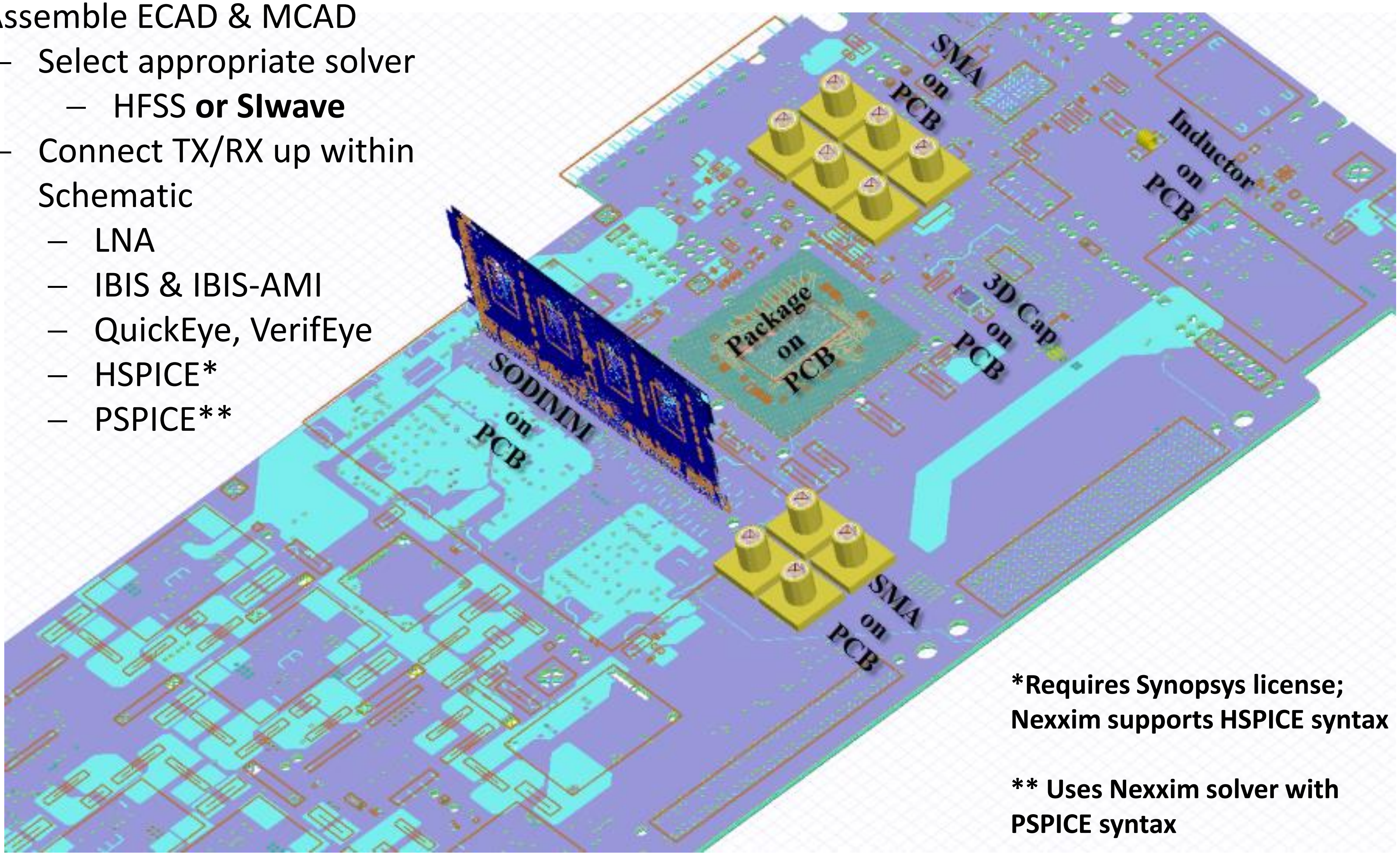
Combine ECAD (PCB, Package) and MCAD (Connector) in single design and simulation flow

Single 3D Mesh



System Analysis within HFSS 3D Layout

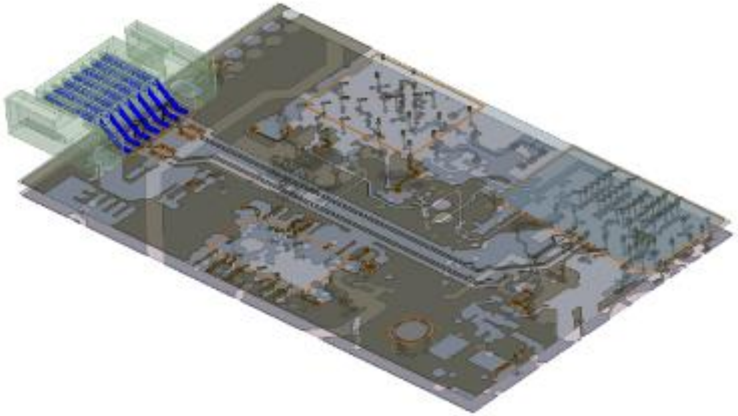
Assemble ECAD & MCAD
- Select appropriate solver
  - HFSS **or SIwave**
- Connect TX/RX up within Schematic
  - LNA
  - IBIS & IBIS-AMI
  - QuickEye, VerifEye
  - HSPICE*
  - PSPICE**



***Requires Synopsys license; Nexxim supports HSPICE syntax**

**** Uses Nexxim solver with PSPICE syntax**

3D Layout Capabilities and Performance



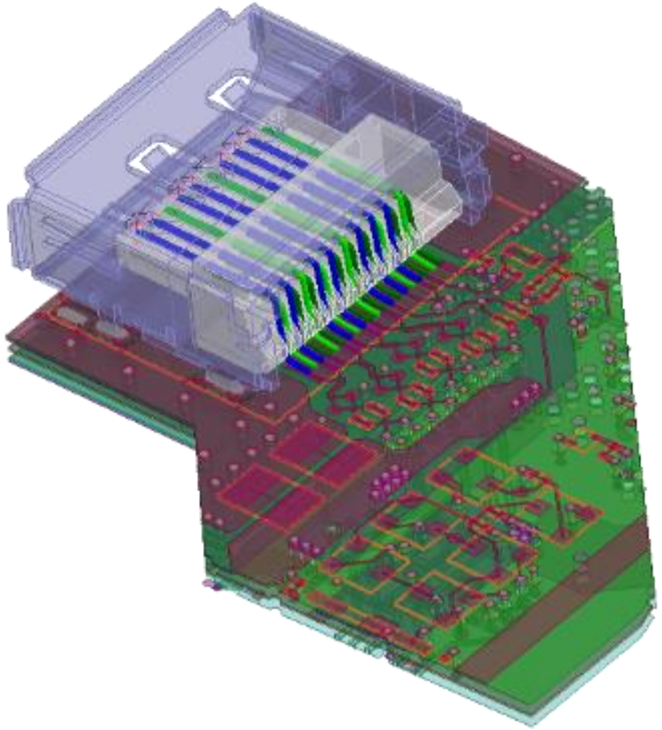
- MCAD Utilizes “TAU” Mesher
- ECAD Utilizes “PHI” Mesher
- New ECAD+MCAD mesh assembly process

Phi is used when appropriate

Material overrides supported

Parallel ECAD meshing

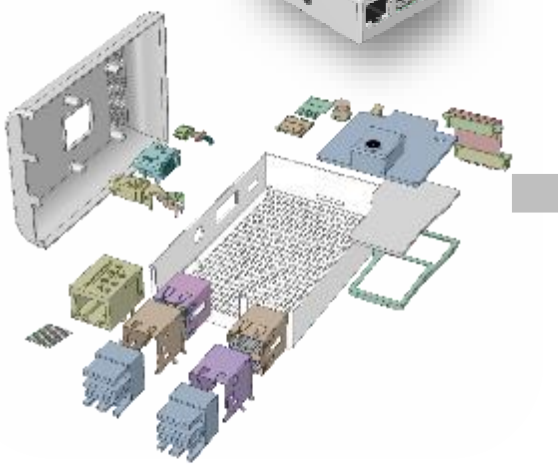
➢Faster mesh generation



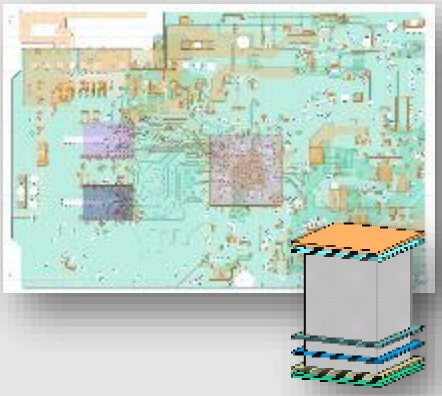
- Numerical de-embedding of non-rectangular lumped ports

New: Full Assembly - ECAD + MCAD Mesh Assembly

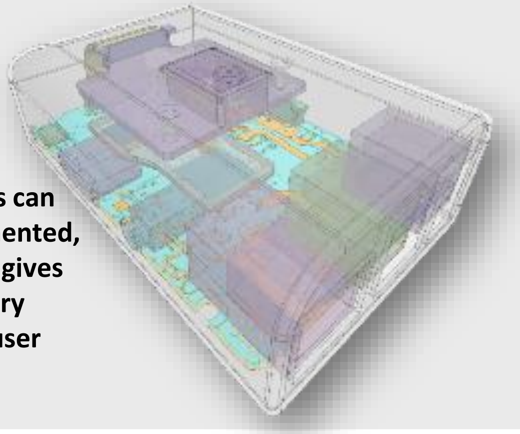
MCAD



3D Layout



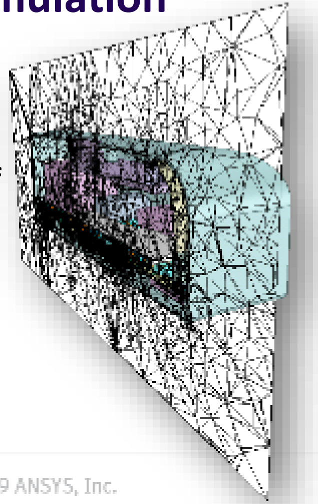
3D Layout: Full Assembly



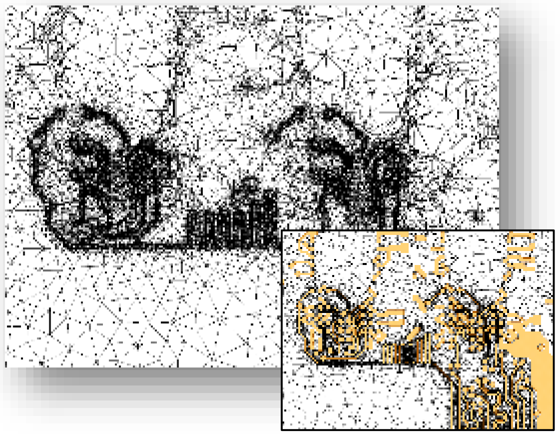
Geometry changes can quickly be implemented, adaptive meshing gives confidence on every solution without user interaction

HFSS Simulation

2D Cross section of mesh



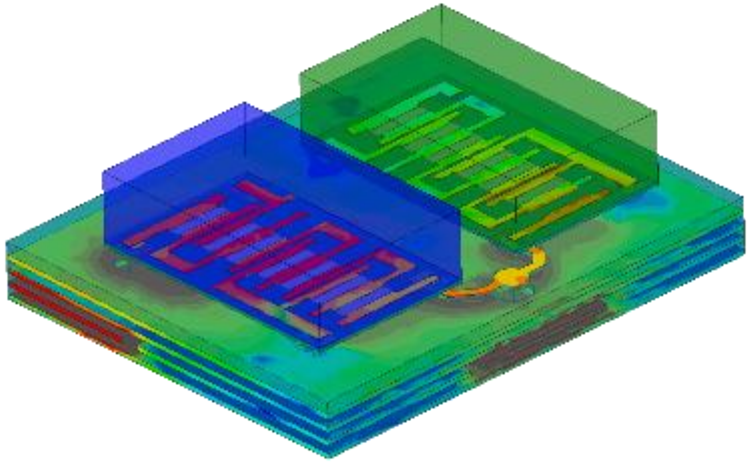
Automatically generated mesh shown on PCB



- **Automated Mesh Creation**
  - Accurate
  - Efficient
- **Solve time independent of port count**
  - Capture full network parameters for all nets simultaneously with low computational overhead
- **Captures small and large features efficiently**
  - Small pitch traces, meandering traces, accurate coupling and isolation

Simulation Setup Example: Multi-die Laminate

- Assembly and meshing technology significantly speeds up simulation setup time
- 12 Filters, two SMD (as HFSS 3D Components), one Laminate



Representative design only

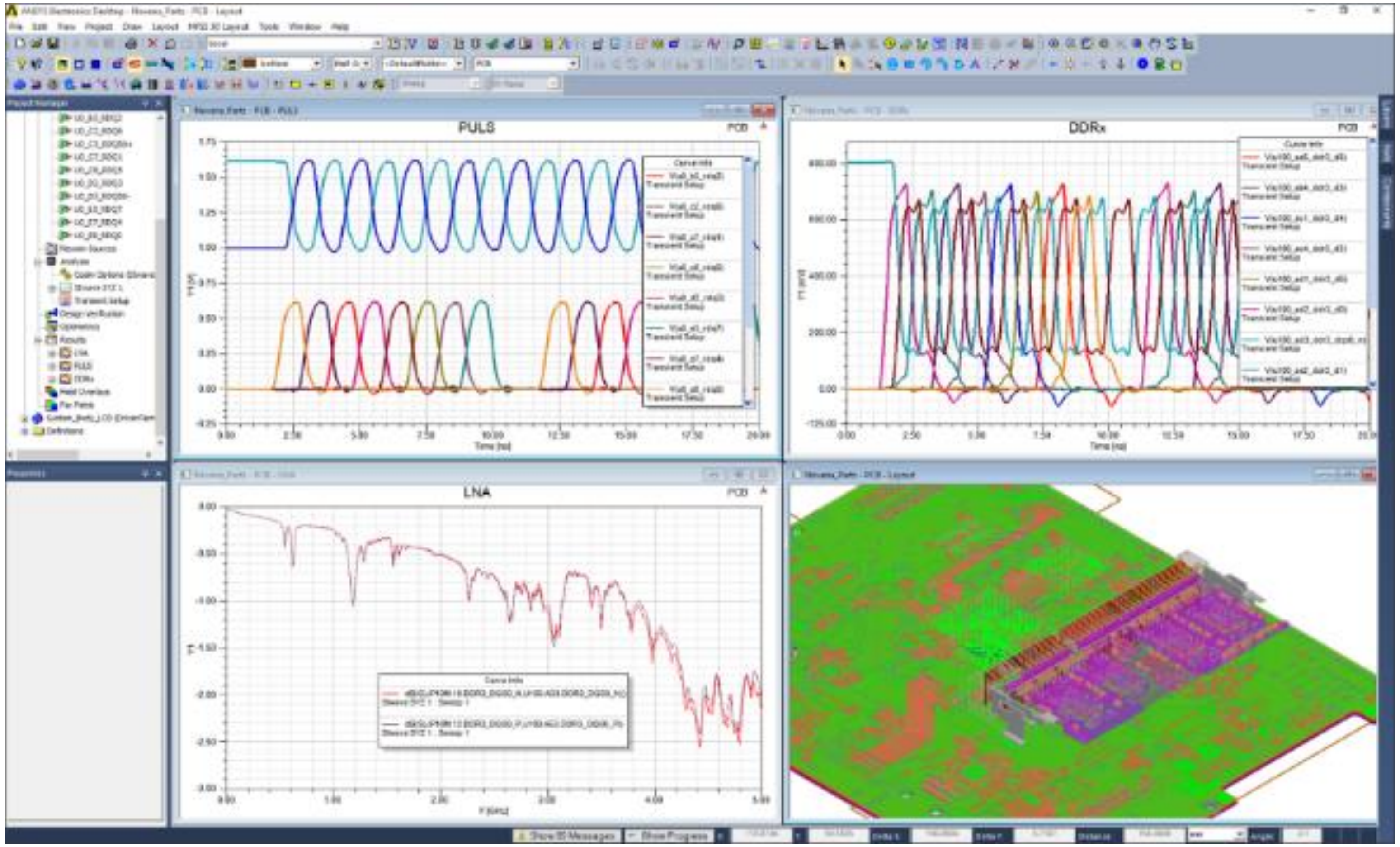
1. Component Creation via Scripted Automation – 7x faster
   - 3D: 21m
   - Layout w Mesh Assembly: 3m (Laminate/BAW + SMD)
2. Assembly Creation – 5x faster
   - 3D: 9m + Validation (~13m)
   - Layout w Mesh Assembly: 2m + Validation (<2m)
3. Project Opening – 5x faster
   - 3D: 4m
   - Layout w Mesh Assembly: 45s
4. Initial Mesh – 1.6x (~850k tets)
   1. 3D: 1h9m
   2. Layout w Mesh Assembly: 44m
5. Adaptive Mesh – 1.2x
   1. 3D: 186m (144GB RAM)
   2. Layout w Mesh Assembly: 156m

- **2019 R1 Flow Improvements**
  - **HFSS Layout 3D with Mesh Assembly**
    - **Faster initial mesh time**
    - **Faster user experience**
  - **Non-graphical Script Execution (Beta)**
  - **Reduction in 3D Component size-on-disk**
  - **Reduced 3D Validation Time**

Electromagnetics Highlights

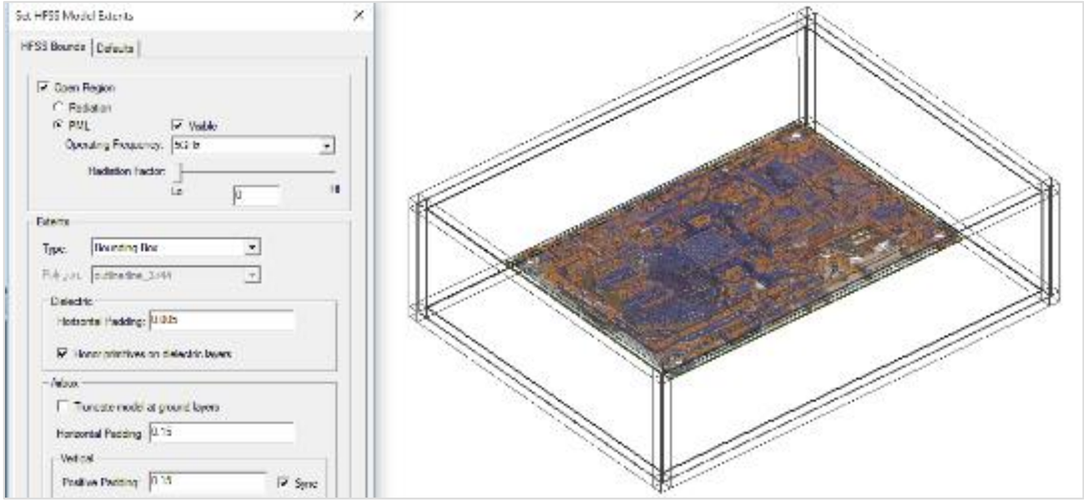
Integrated Transient Circuit Simulation

Assemble electronic system then perform electromagnetics plus transient circuit analysis system automatically

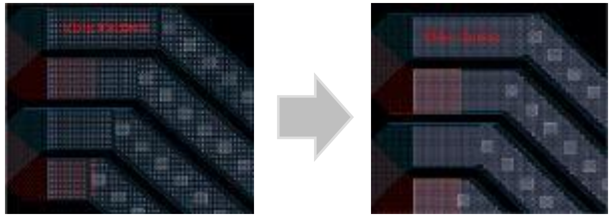


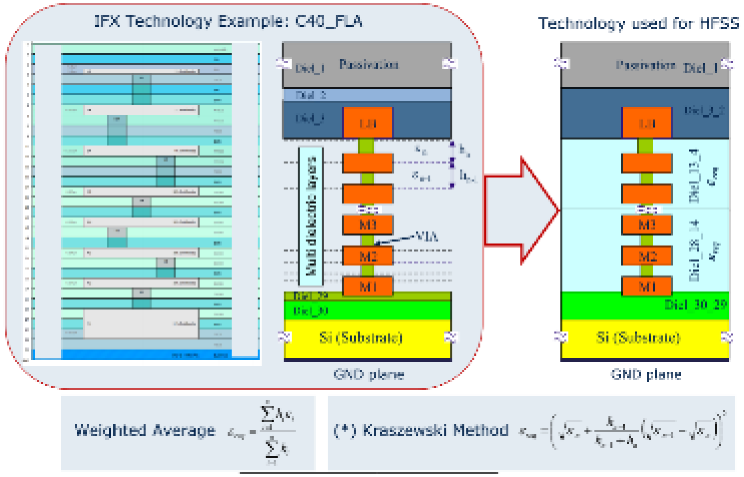
HFSS 3D Layout Improvements

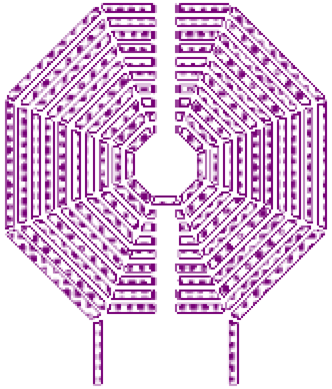
- Far Field + Post-Processing Enhancements
  - Consistent with HFSS 3D
  - PML Support



- Enhancements for on-chip inductor modeling
  - Dielectric Stackup Simplification
  - Via clustering

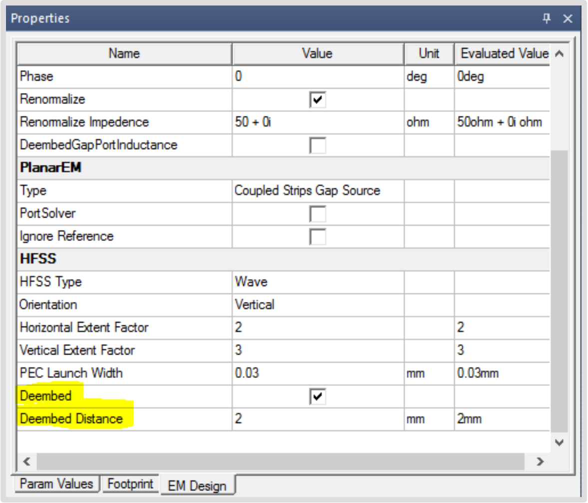


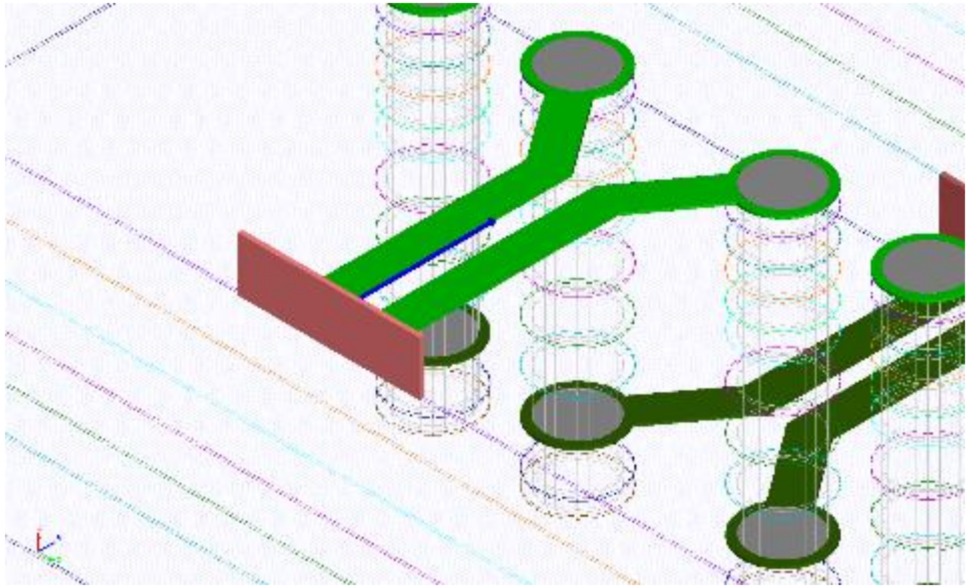




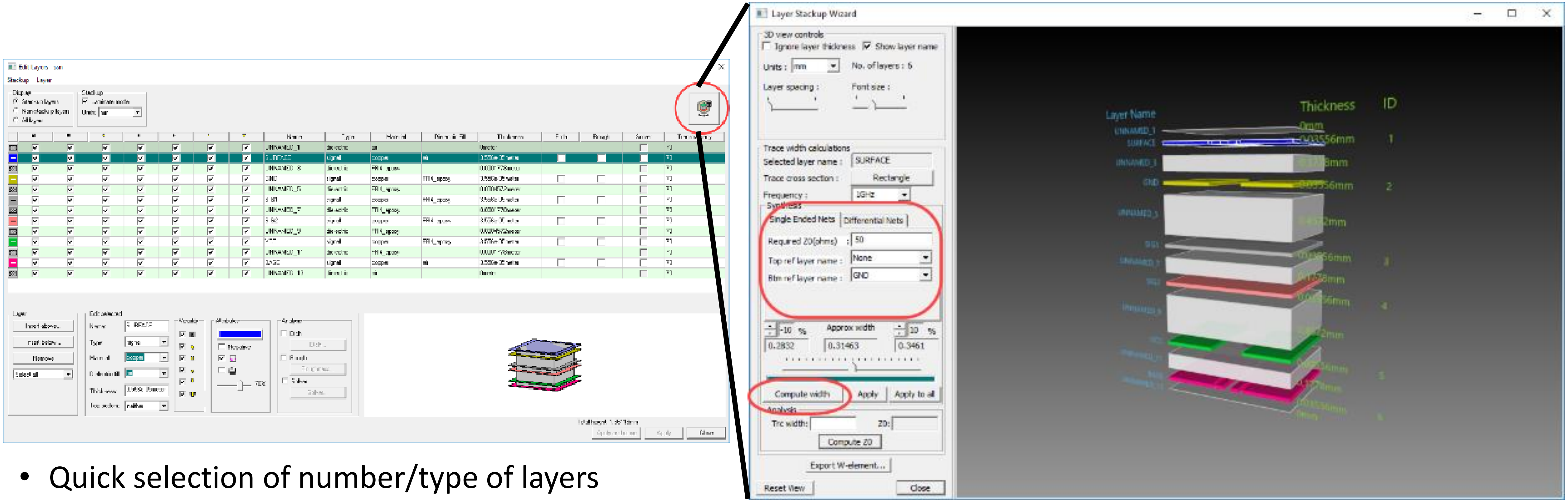
HFSS 3D Layout Port Configuration Enhancements

- Wave port support for mesh assembly
  - i.e. “connector-on-board”
- Usability improvements
  - Visualize wave port de-embed distance
  - Layer control for Pin-groups and internal/ref ports
  - Separate de-embedding/distance settings





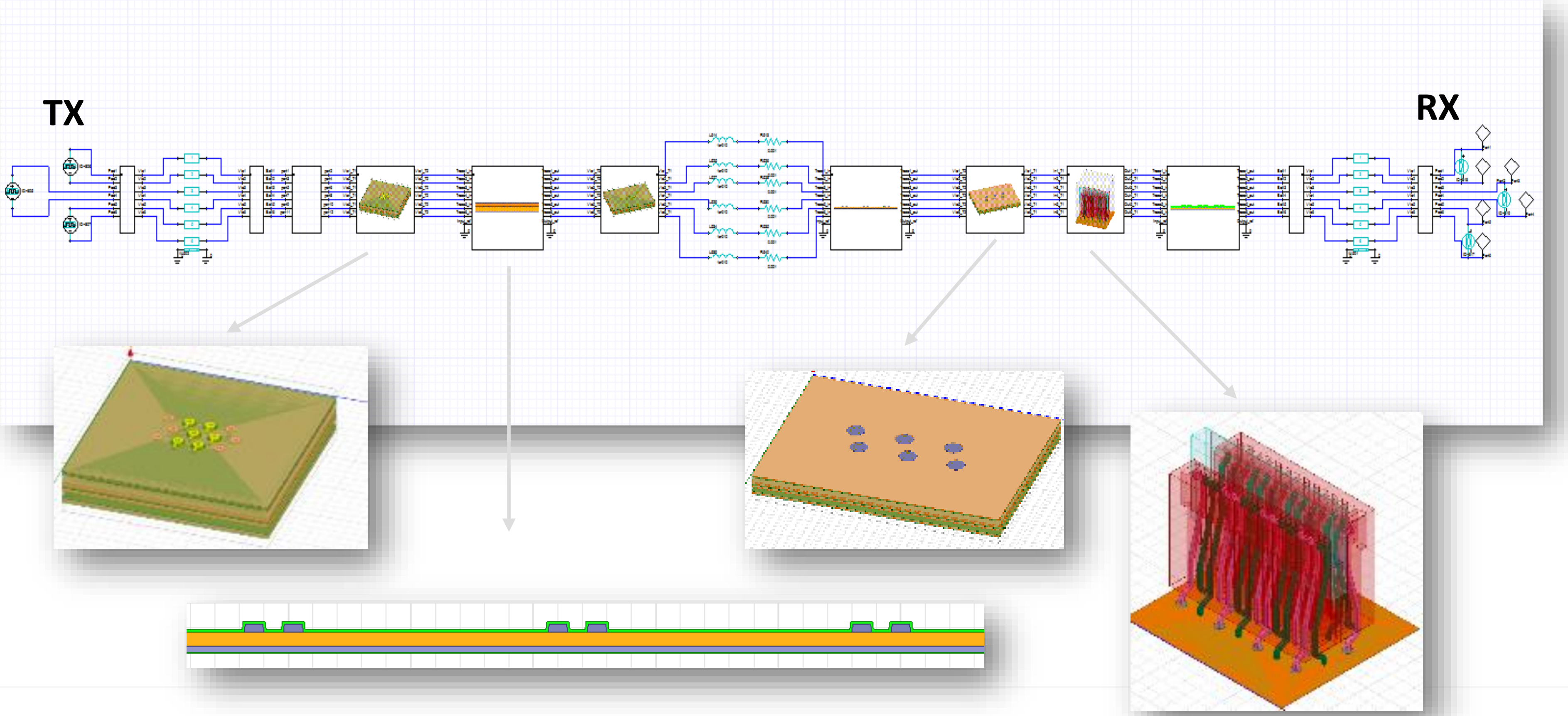
Stackup Wizard in 3D Layout Design



- Quick selection of number/type of layers
- Single-ended & Differential trace synthesis & analysis
- Etch factor considered in trace computations
- Convenient 3D viewer

High Frequency Signal Integrity

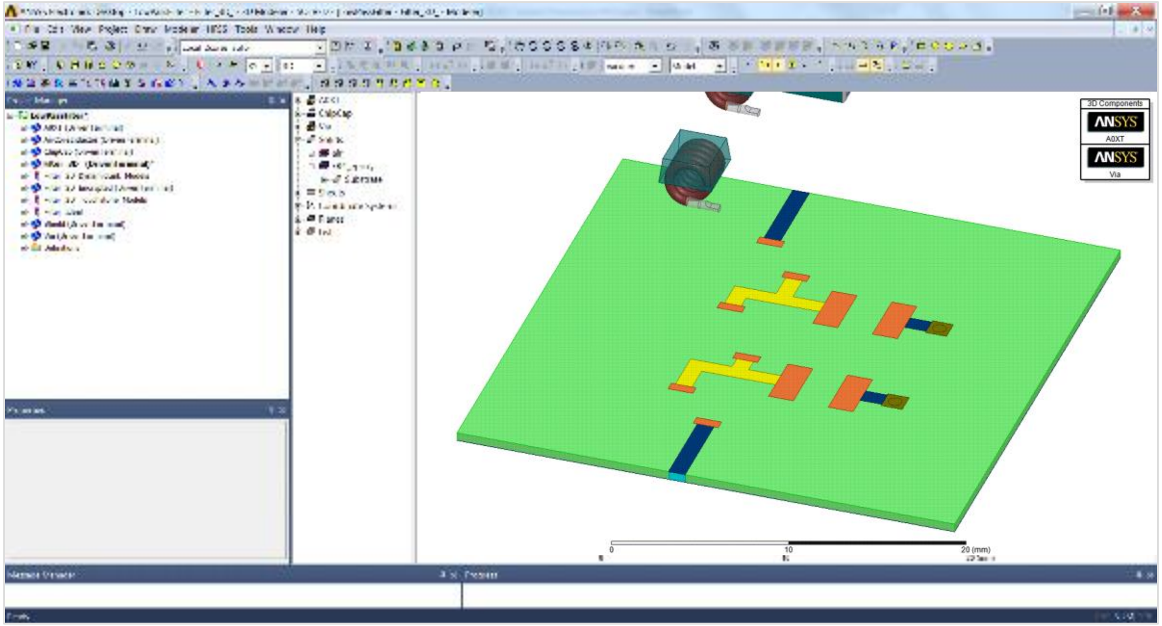
- Single environment allows extraction of component models such as vias, connectors, and transmission lines as well as concatenating these and other models into a channel schematic
- S-parameters, eye diagrams, and bit error rate of channel can be simulated
- Individual components can be optimized and channel results updated quickly

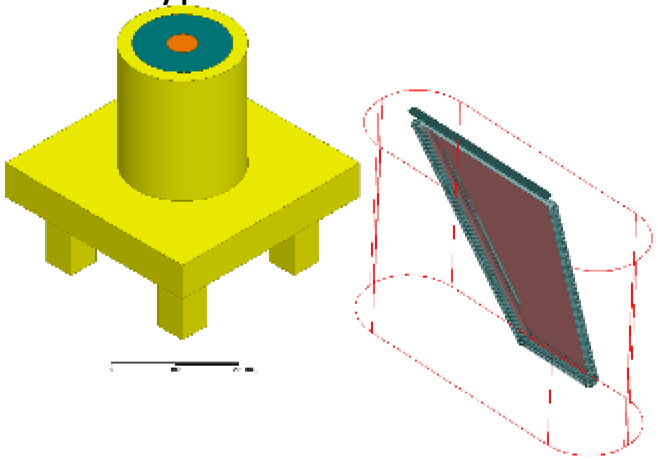


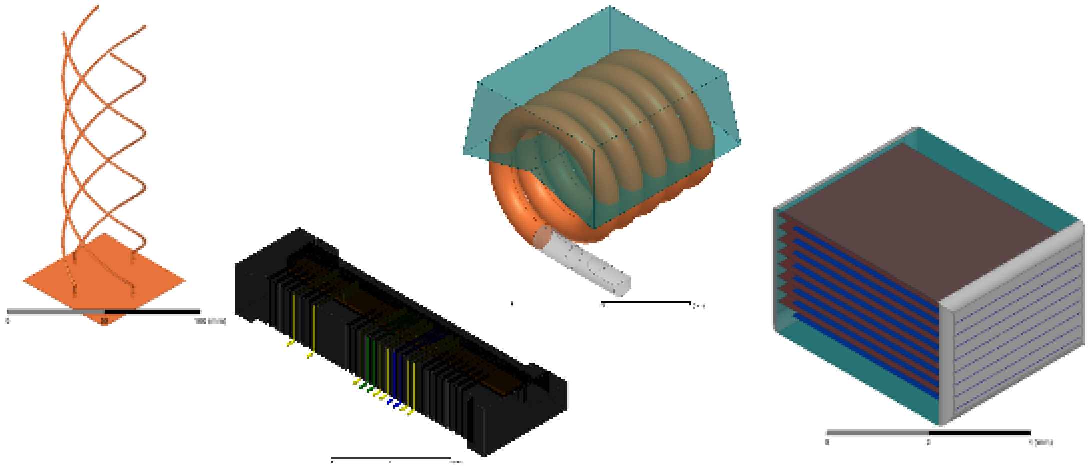
3D Components

3D Components

- ***3D Components***
  - Save and reuse designs
  - Share with partners, vendors and colleagues
- Contains
  - Geometries
  - Material properties
  - Boundary conditions
  - Excitations
  - Encryption

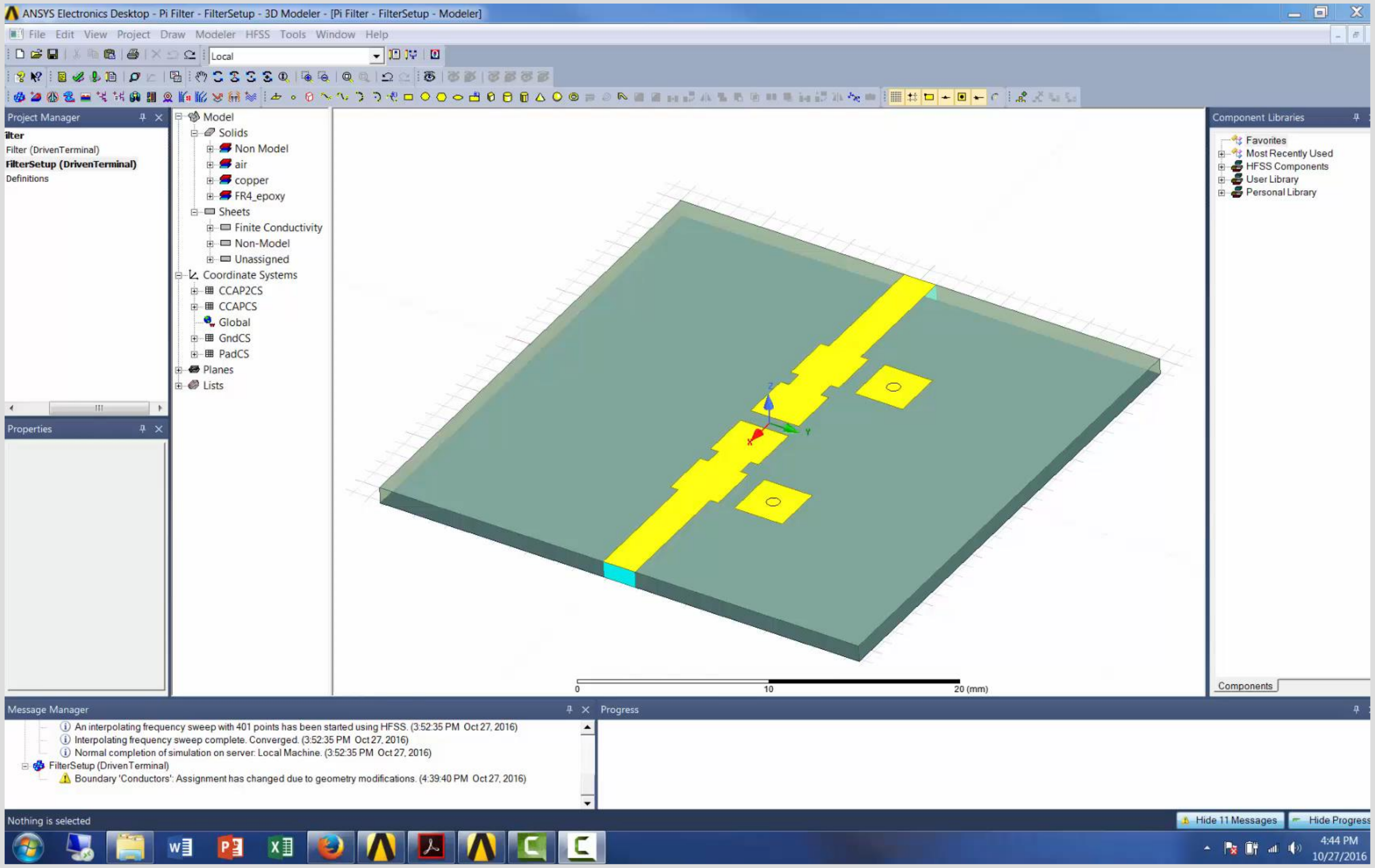






3D Components: Library Browser

- Easy availability of 3D Components
- Drag and drop of component geometry into modeler window

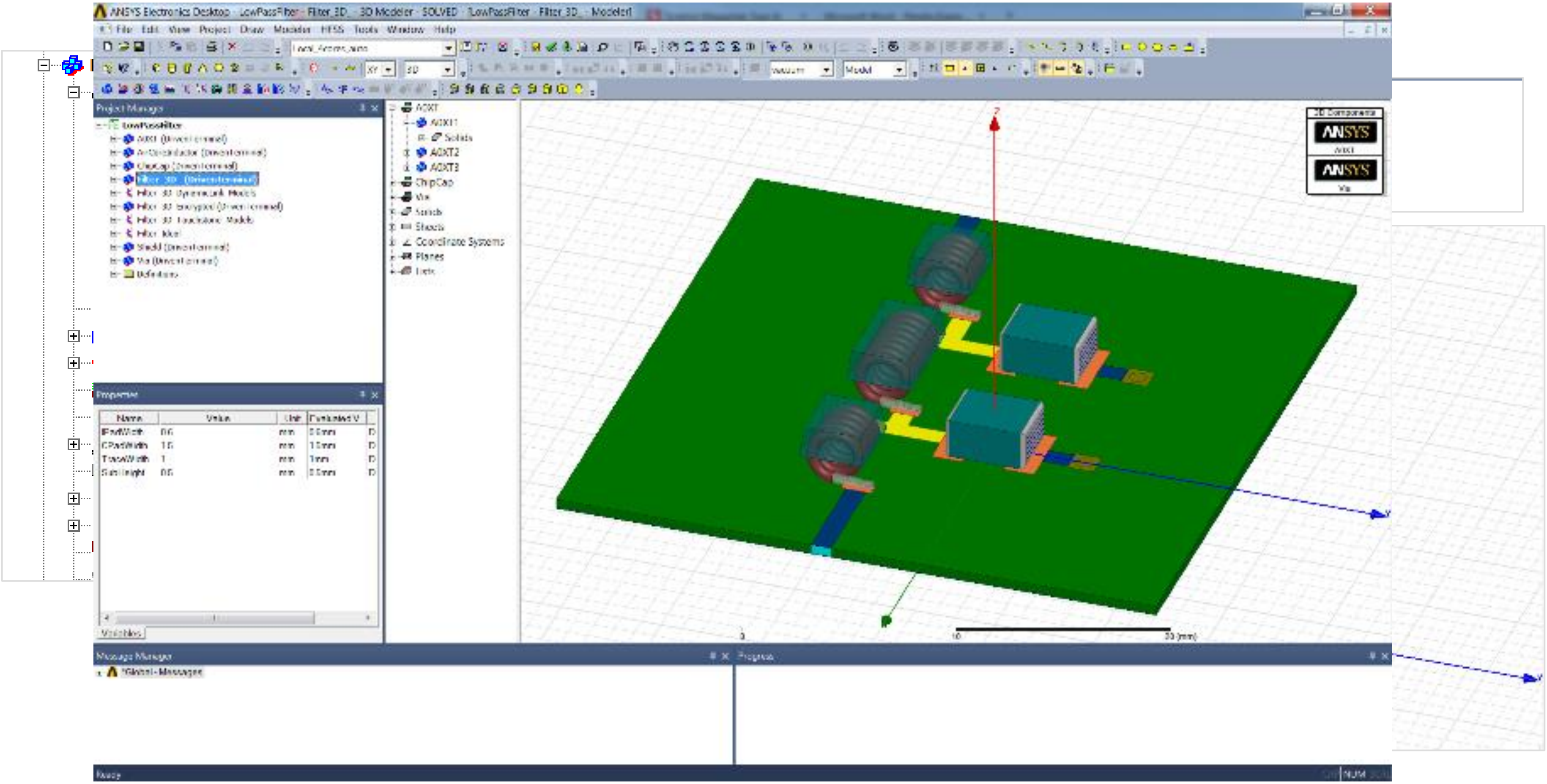


 ANSYS Confidential

3D Component: Edit Definition

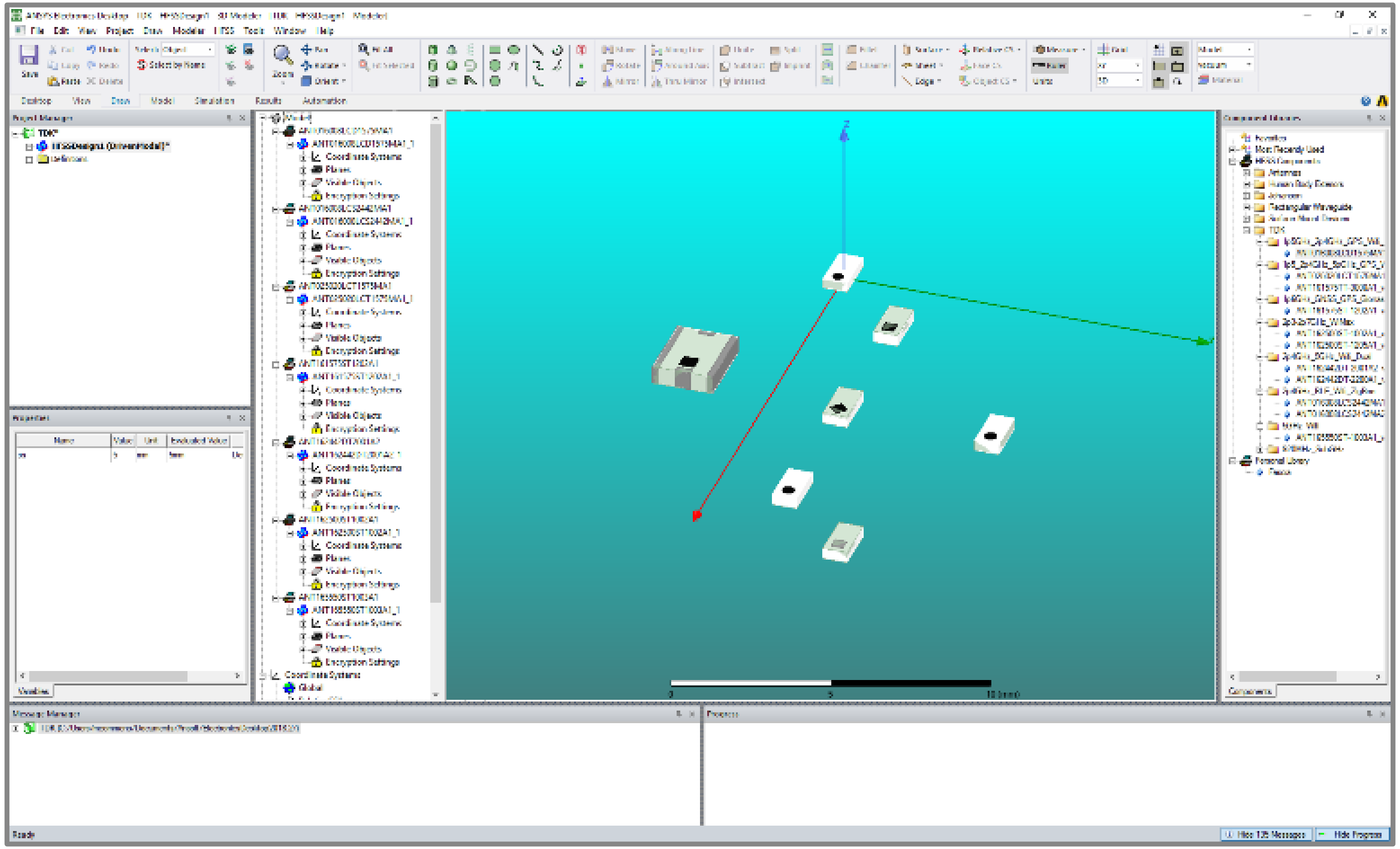
3D Component Edit

- An existing component can be flattened to a new design

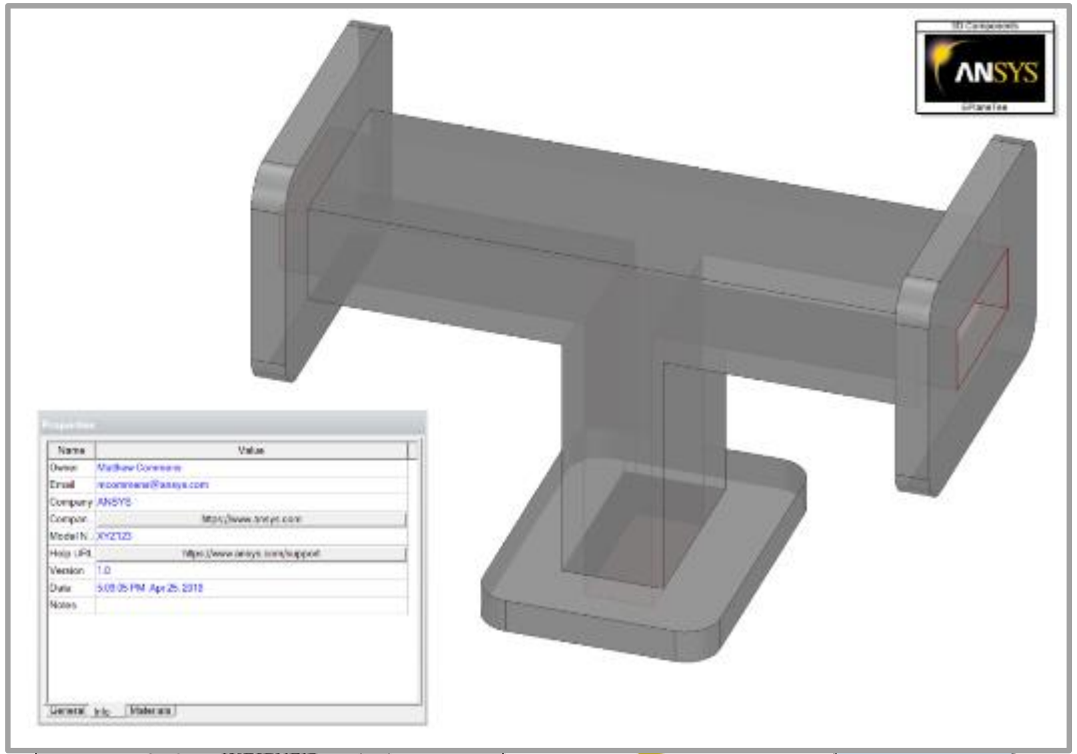


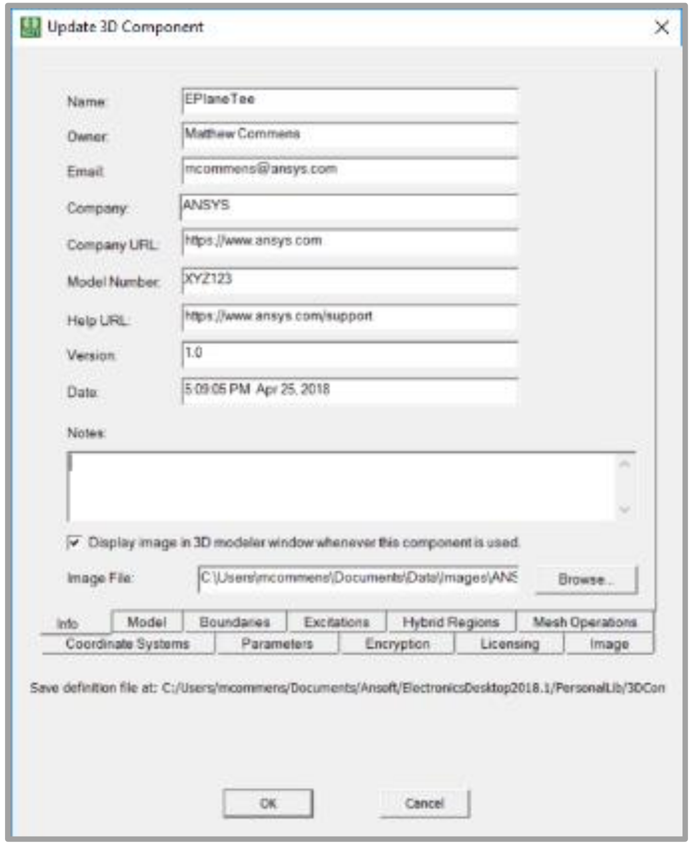
TDK Chip Antenna 3D Component Library

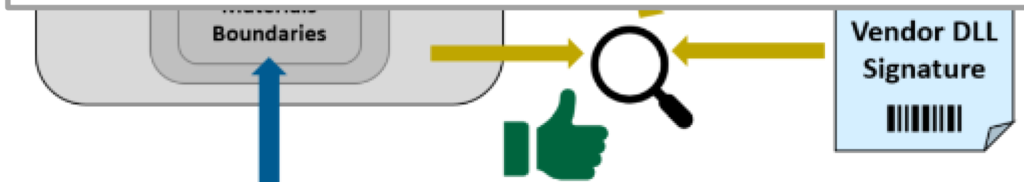
- **Library of TDK RF chip antenna 3D Components with encryption**



ANSYS HFSS 3D Components



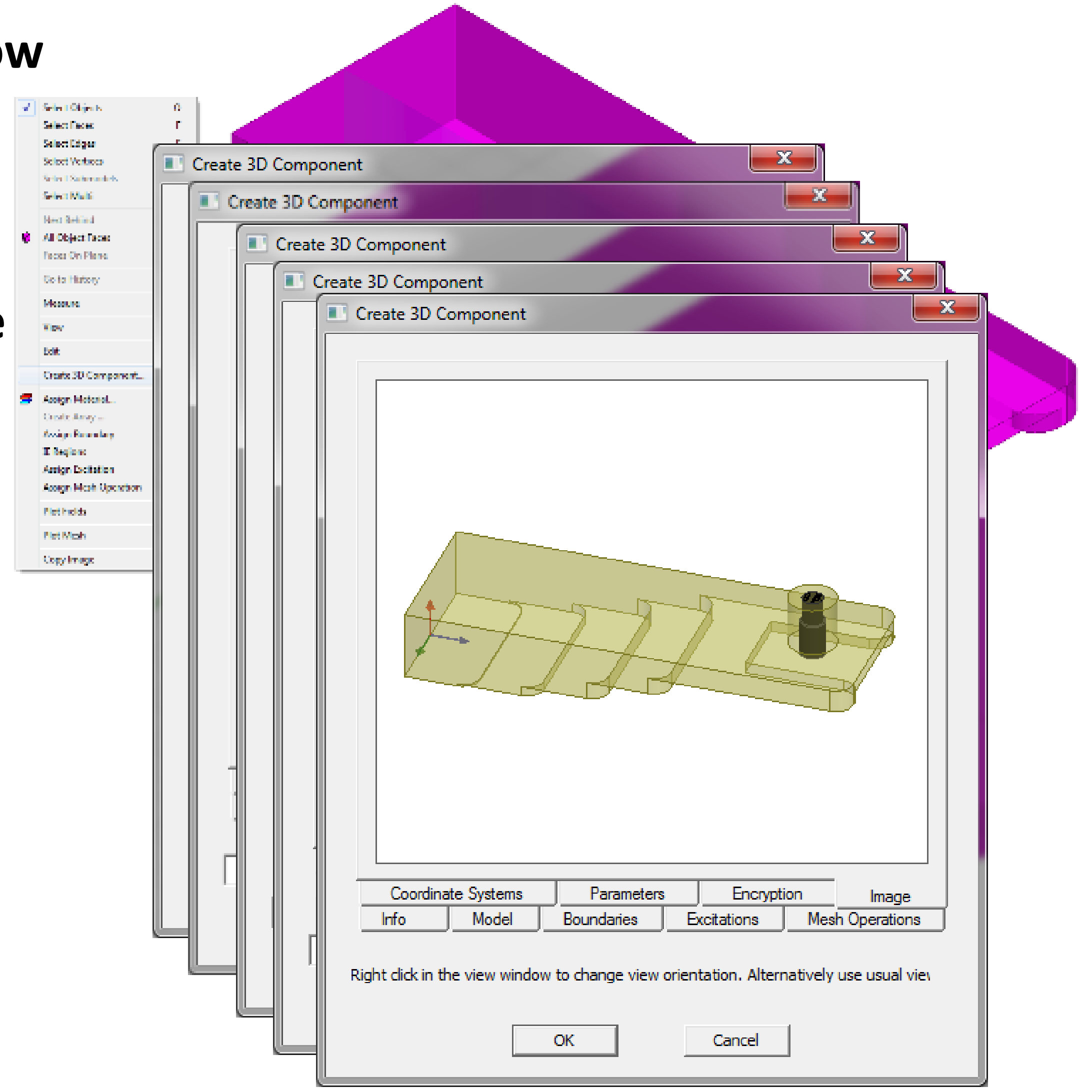




- Created by vendor using HFSS
- Imported into HFSS project
- Encrypted for security
- Includes vendor licensing info

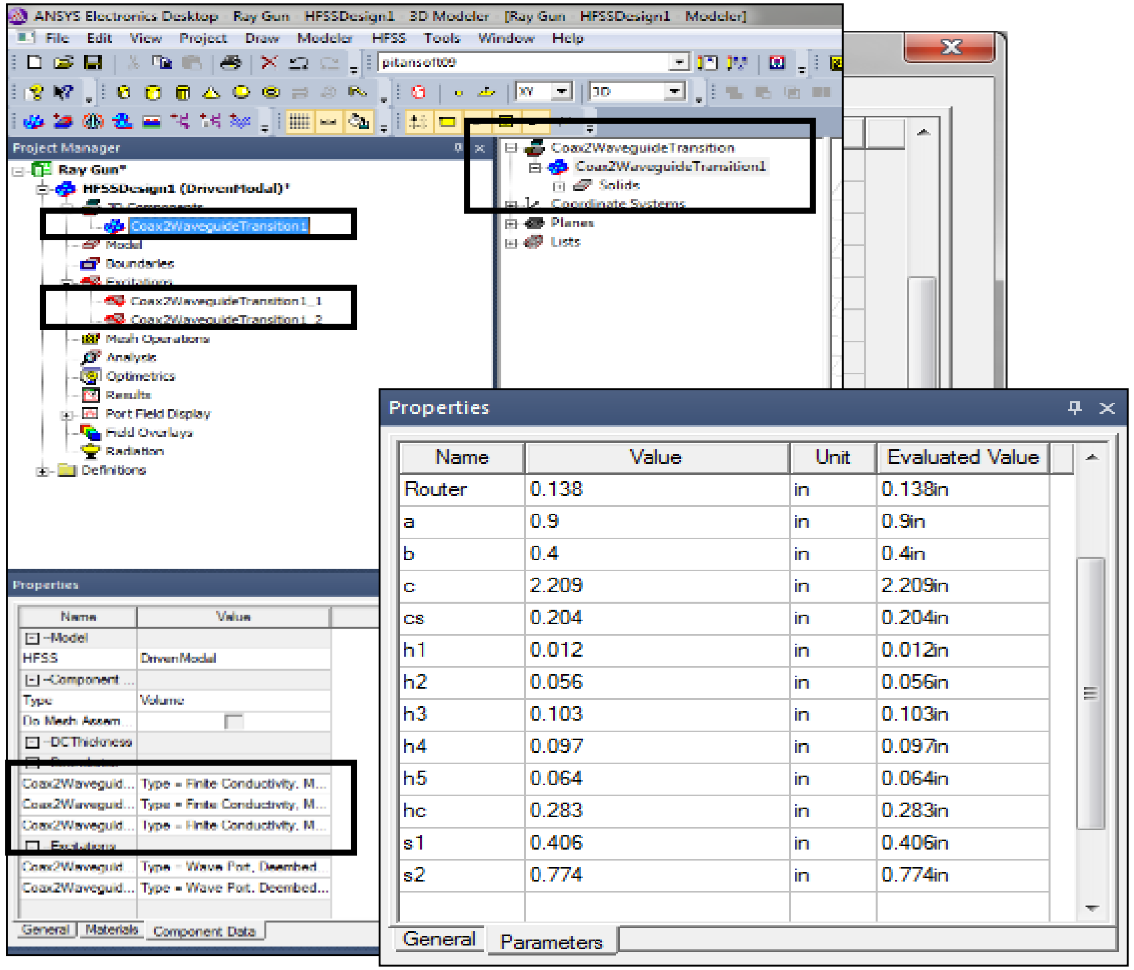
Creating a 3D Component

- To create component select objects from modeler window and go to
  - “Create 3D Component…”
- Enter Design information
- Select parameters to include
  - Objects
  - Boundary conditions and excitations
  - Design parameters
- Review image
- Save to system, user or personal library folders
  - Update menu



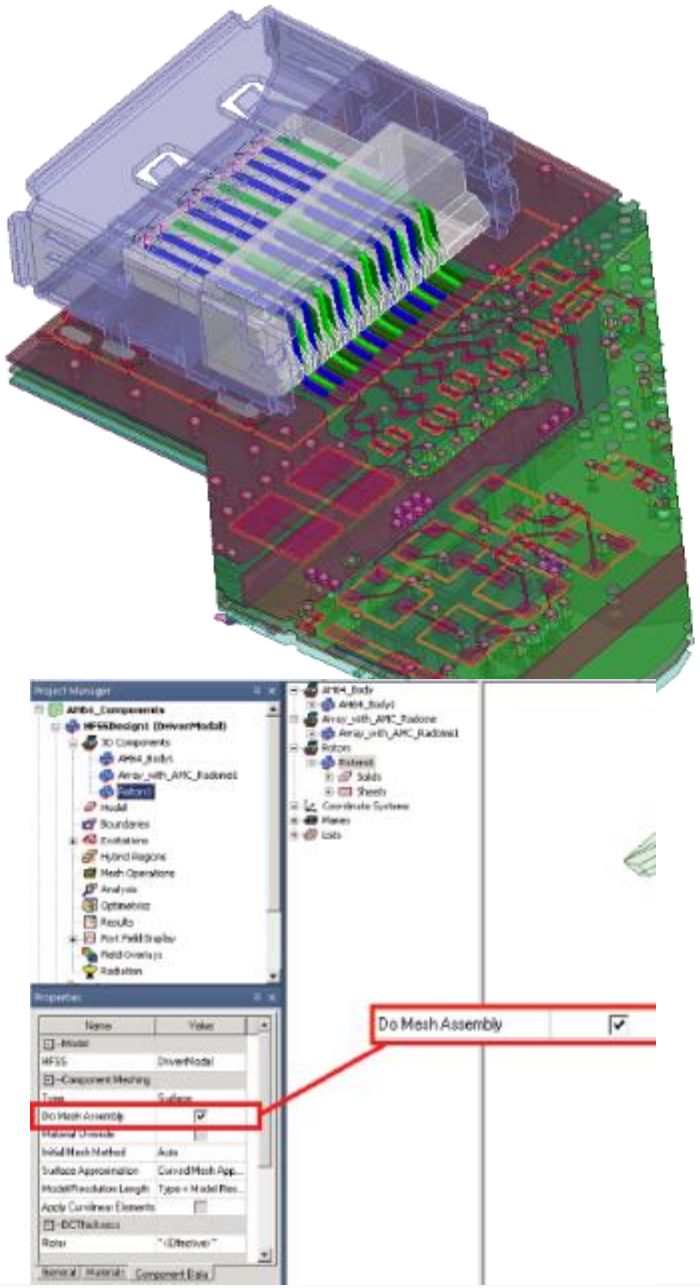
Inserting a component

- Insert 3D Component
  - Review Parameters
- Component in model and project trees
- Component design data in project tree
- Component parameters in the property box
- Treat as custom defined 3D primitive



3D Component Assembly Meshing

- Per-component model settings
- Per-component mesh
- Mesh in parallel
- ECAD+MCAD mesh assembly process
- Component based units
- Overcomes aspect ratio issues
- Multiple instances for same component
- Mesh re-use for parametric analysis

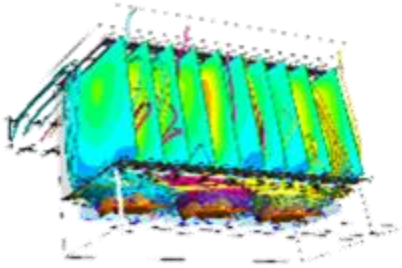


AEDT Thermal Analysis

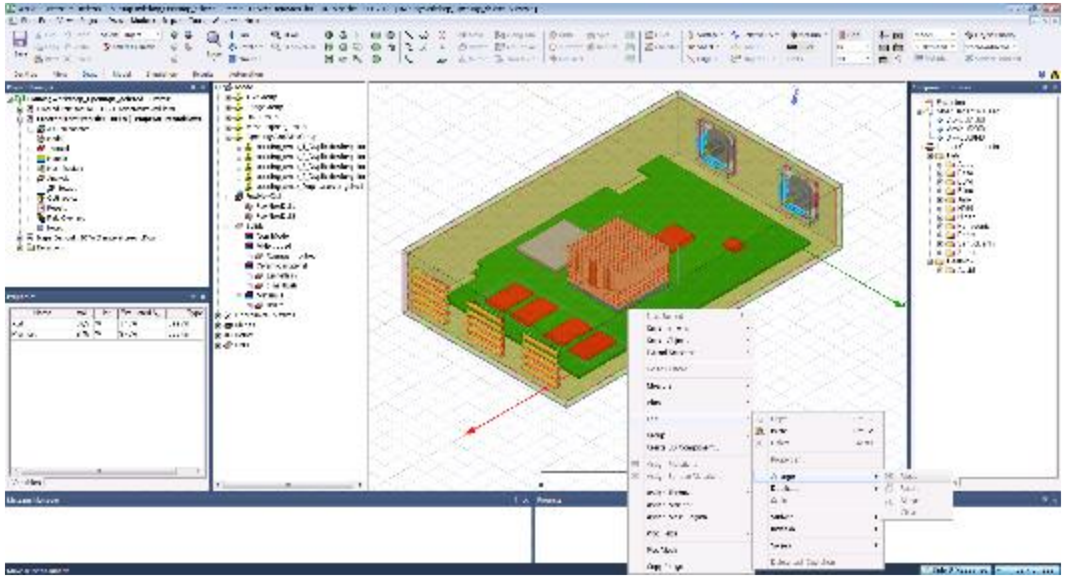
ANSYS Icepak – Computation Fluid Dynamics Solver

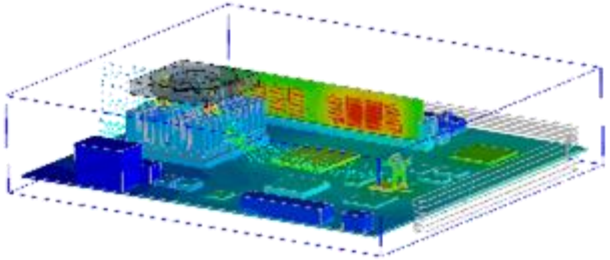
Icepak is an integrated “Electronics Cooling” solution for connectors, packages, printed circuit boards and electronic systems

- Fluid flow
- Conjugate heat transfer
- Steady-State Thermal
- Multi-physics coupling
- Single or multiple fluids
- Parametrics
- Optimization



Velocity streamlines and temperature contours for a card array in a VME box cooled by three axial fans

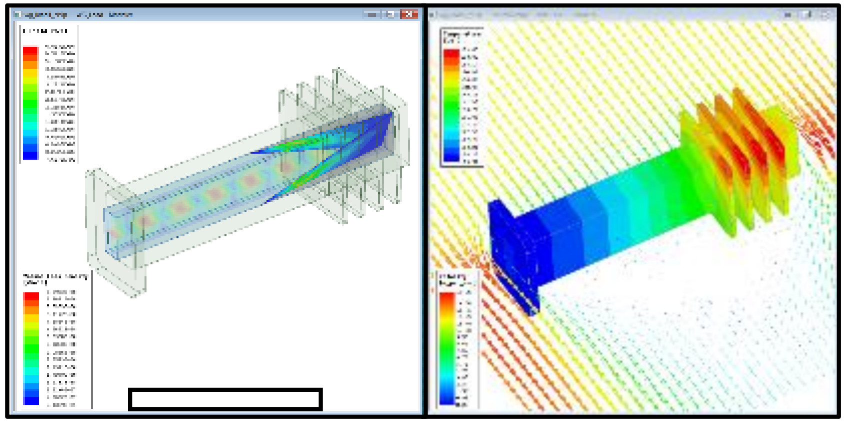


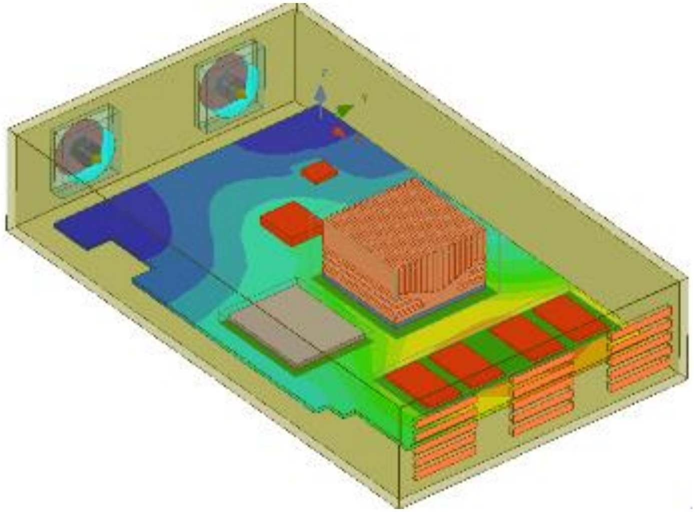


Temperature contours and fluid velocity vectors of a fan cooled rack mounted computer

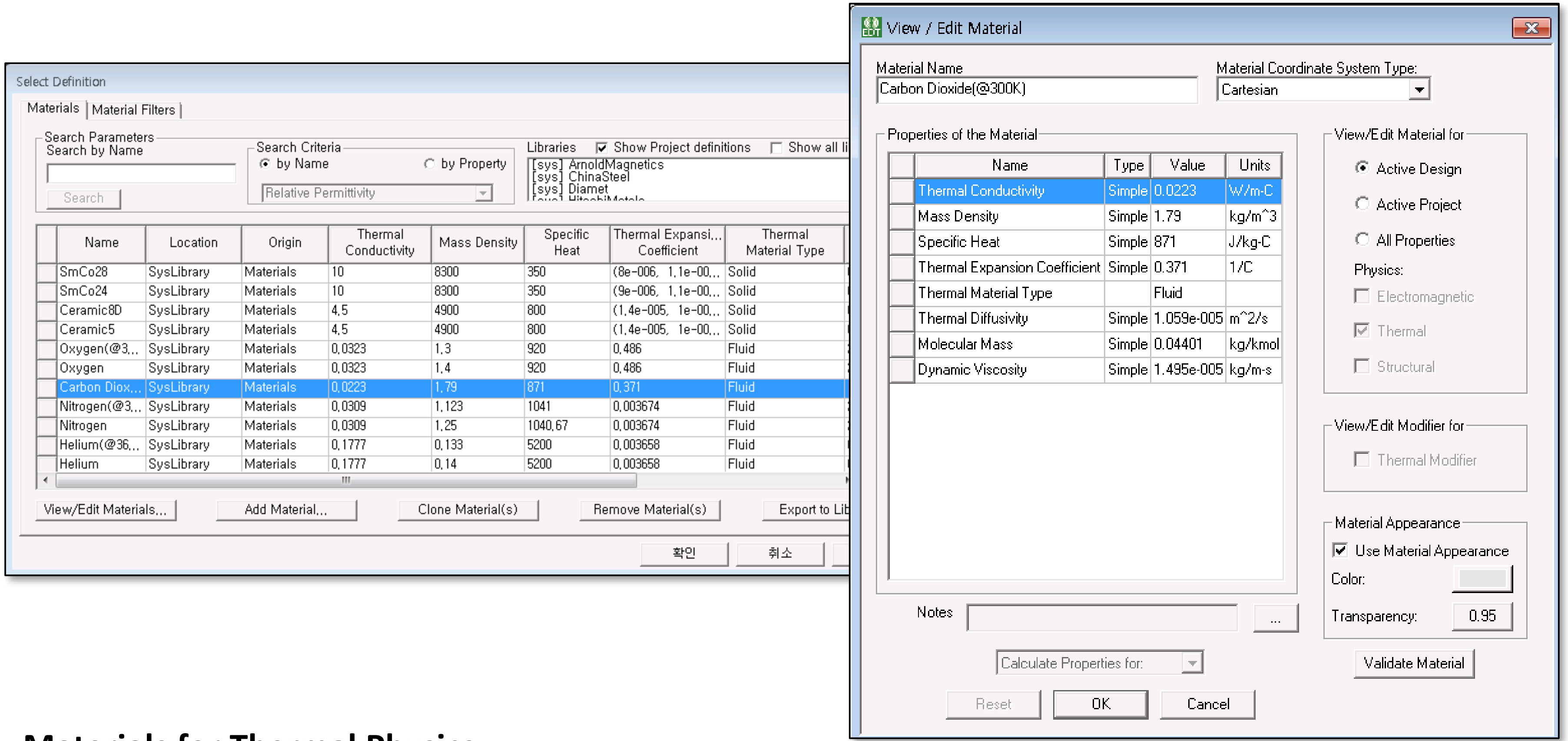
Icepak – ANSYS Electronics Desktop Integration

- Supported Workflows
  - MCAD Support
  - ECAD PCB workflow
  - EM loss coupling with HFSS, Maxwell and Q3D
  - Efficient Electronics Cooling CFD solution
    - Setup -> Meshing -> Solution (HPC)
    - Optimetrics and integrated post-processing
- Supported Thermal Physics
  - Steady-state flow and thermal
  - Conjugate heat transfer, including radiation
  - Laminar and turbulent flow modeling
- Modeling
  - Comprehensive thermal and flow boundary conditions
  - Native 3D Components : Fans (2D & 3D), Heatsinks, PCBs
- Libraries
  - Complete solid, fluid and surface materials library
  - Vendor component libraries: Fans, Heatsinks, BGA Components





Material Library for Electrical, Thermal, & Mechanical



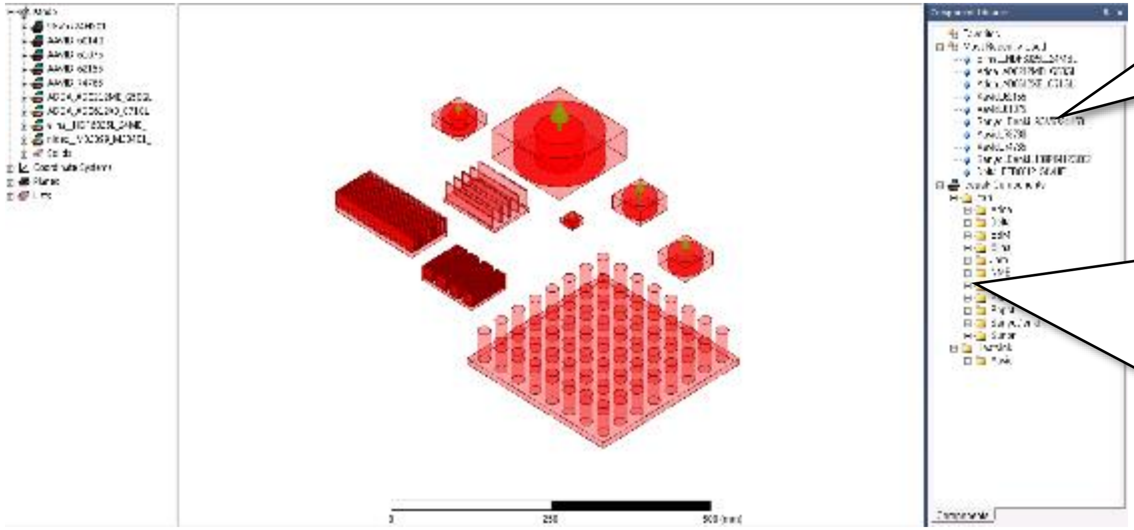
Materials for Thermal Physics

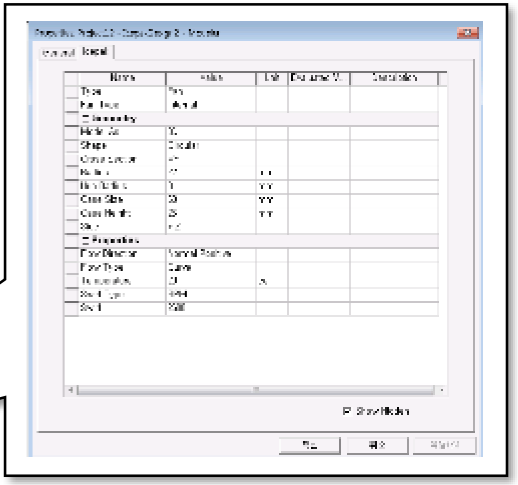
- **Surface materials :** Paint, metals, plastics etc.
- **Solid materials :** Insulations, epoxy, metals, Heat-spreaders, package materials, etc.
- **Fluid materials :** Liquid, gaseous materials relevant to electronics cooling applications

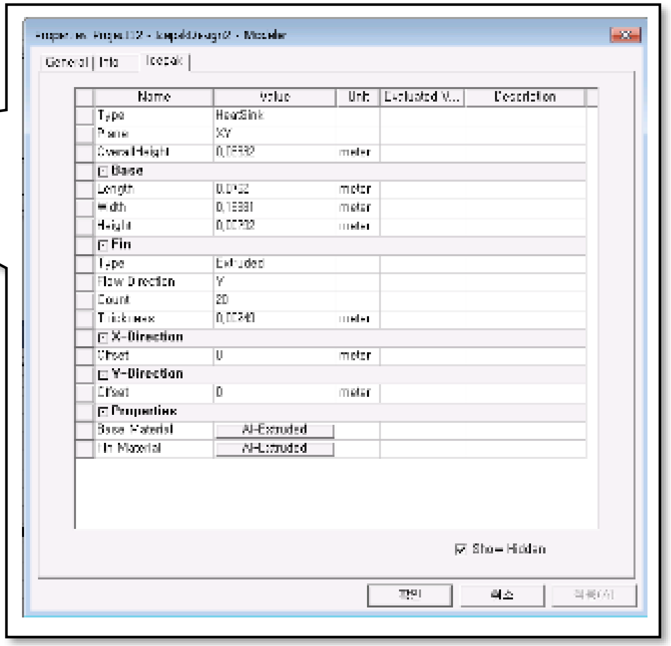
AEDT Icepak 3D Components Library

Support

- Variable Fan library
- Variable Heatsink library
- Customized Component
- Native 3D Components for Creating Fans, Heatsinks and PCBs







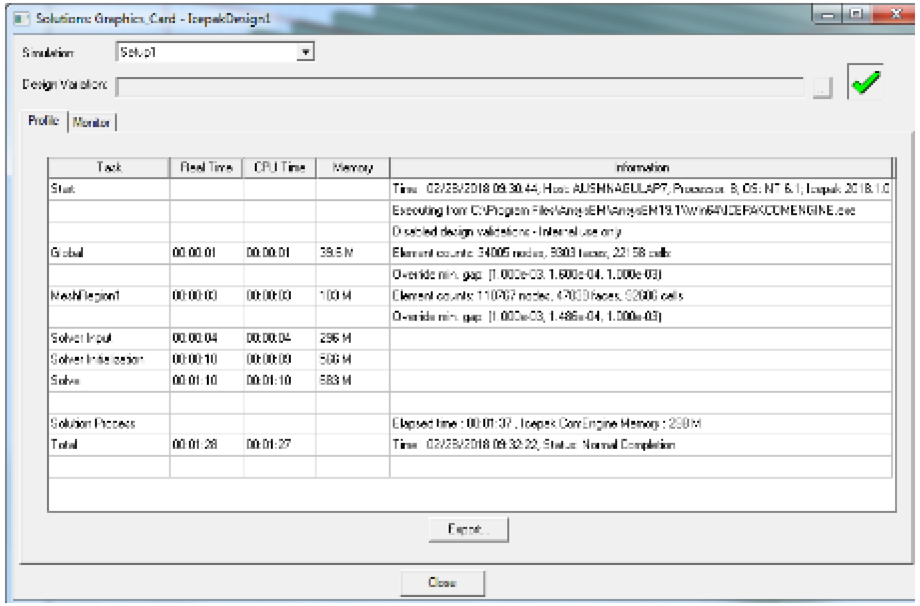
Component Library of Parts

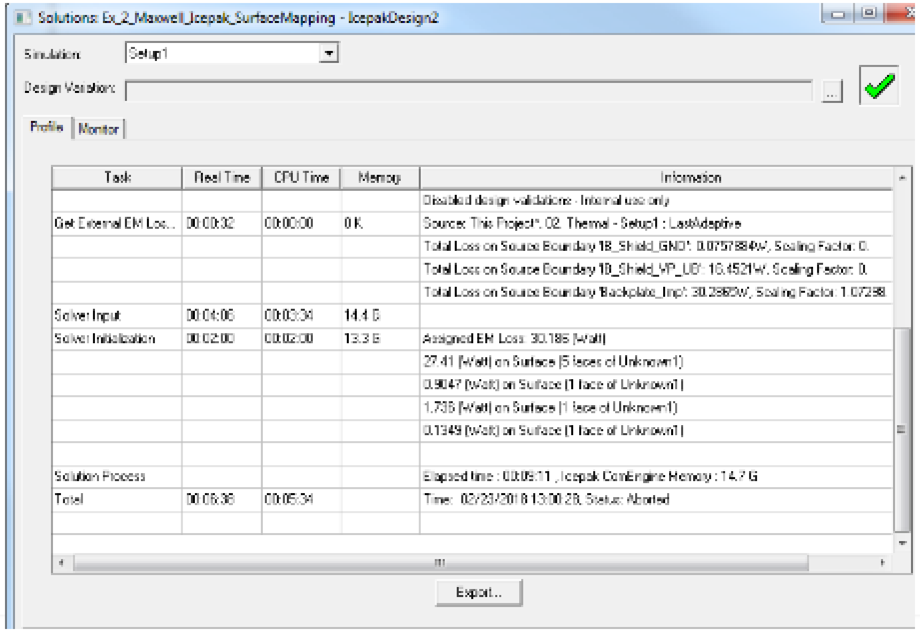
- Fans : Adda, Delta, EBM, Elina, Jaro, Nidec, NMB, Panasonic, Papst, SanyoDenki, Sunon
- Heatsinks : Aavid

Integrated with ANSYS Electronics Desktop

- **Leverage Electronics Desktop HPC Platform**
  - Easy to use
  - Includes Linux scheduler integration

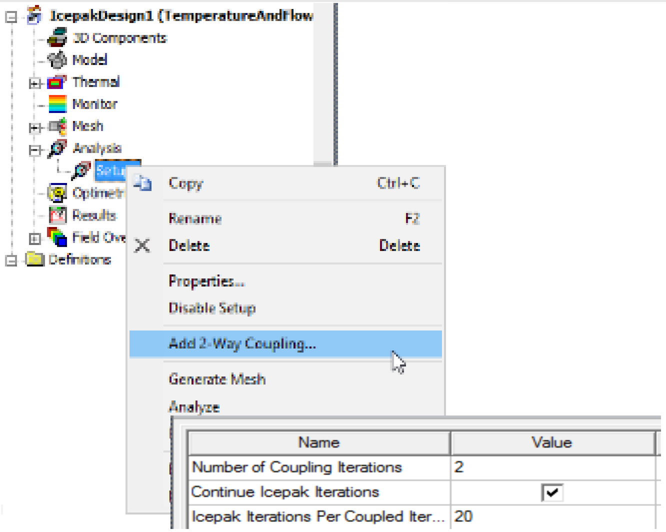
- **Progress and Profile Reporting**
  - Meshing and solution process
  - Enhanced profile reporting
  - EM loss assignment

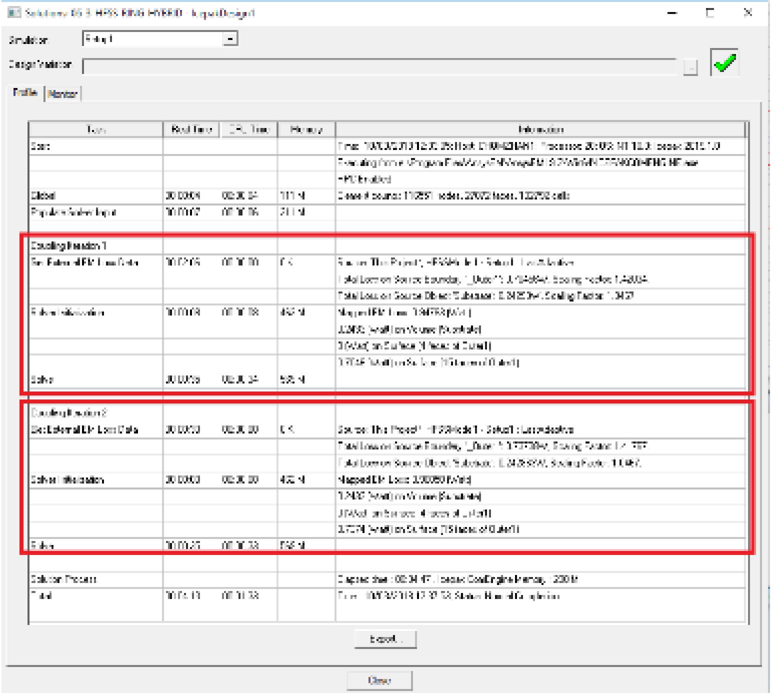


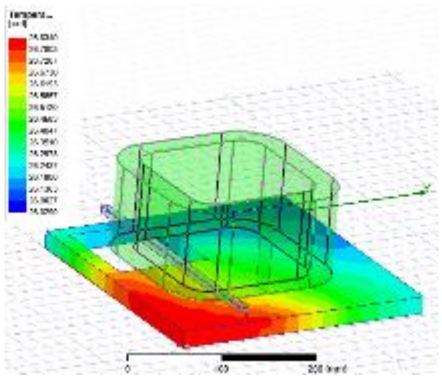


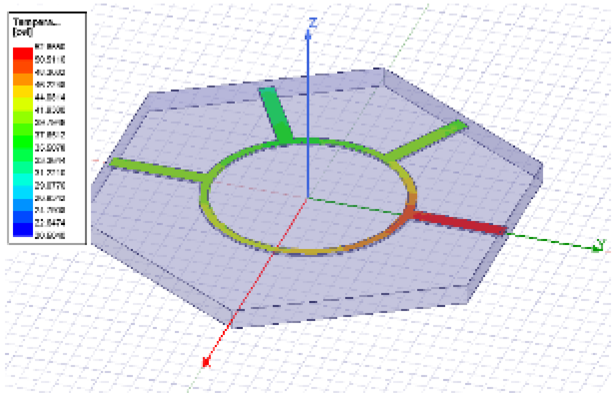
Icepak: Two-Way Coupling with HFSS, Maxwell, Q3D

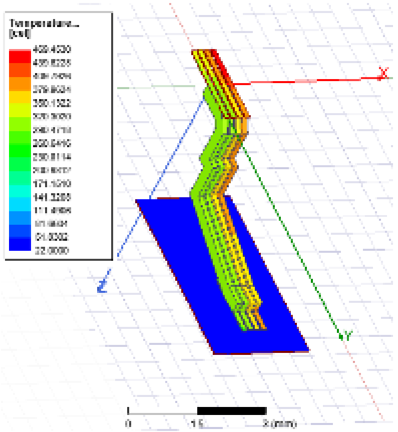
- New Coupled Simulation Controller in Icepak Design
  - ➢ User specified “Number of Coupling Iterations”
  - ➢ Options to “continue” Icepak iterations during coupling
  - ➢ Single controller per design
- Updates to EM losses in each coupling iteration
- Multiple EM Losses supported
- Icepak-Optimetrics Integration



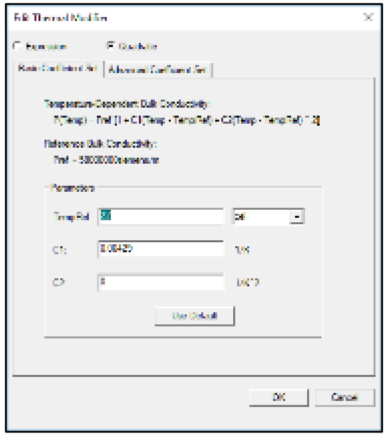




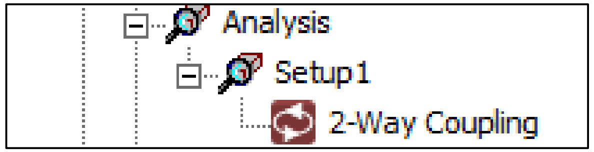




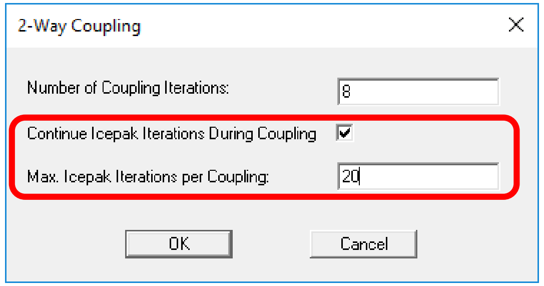
2-Way Electro-Thermal Coupling



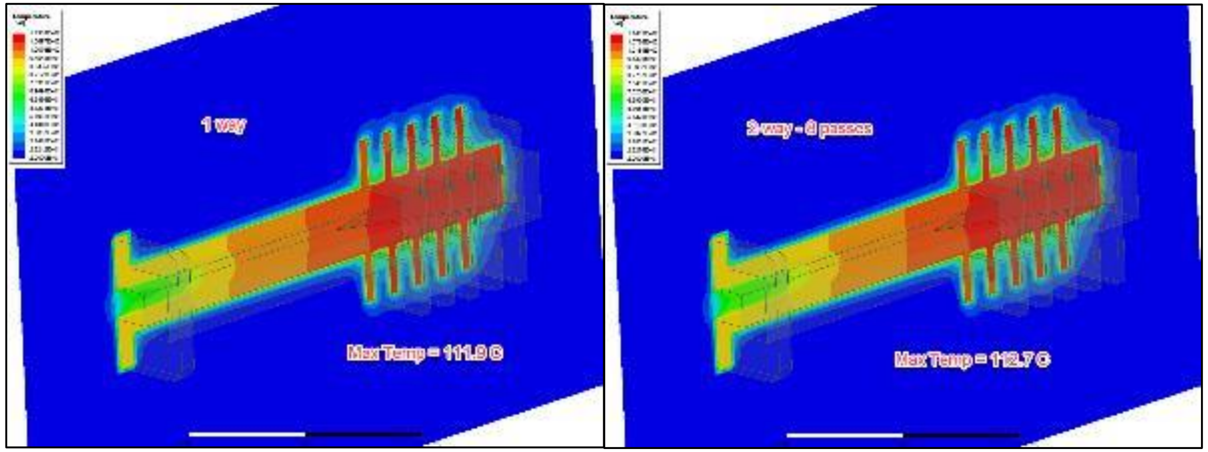
- Valid for HFSS, Q3D, and Maxwell design types
- Utilizes thermal modifier for materials and temperature feedback in electromagnetic design
- New 2-way Coupling controller in Icepak design



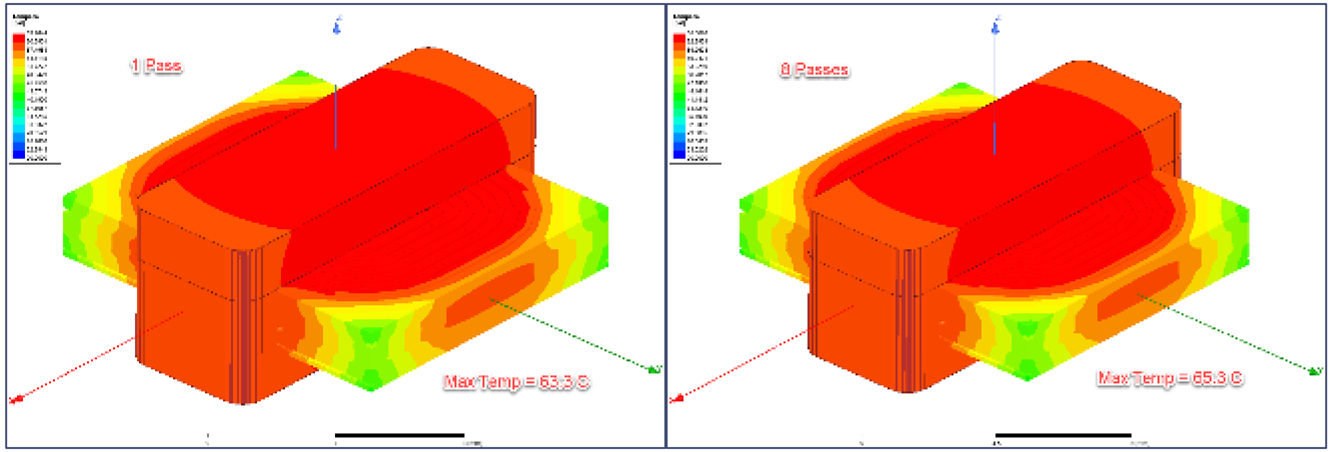
- Allows for additional Icepak iterations between material updates



HFSS Design of a High Power Waveguide Load

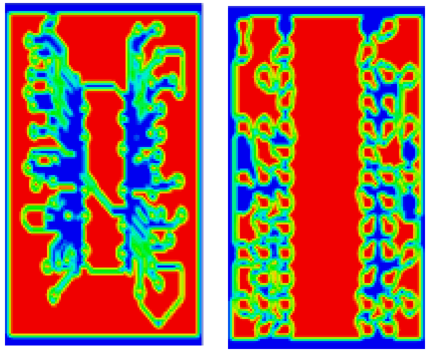


Maxwell Design of Planar Transformer

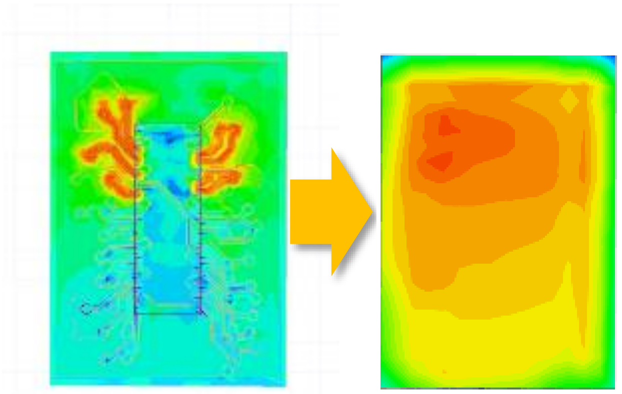


AEDT Icepak – Post-Processing

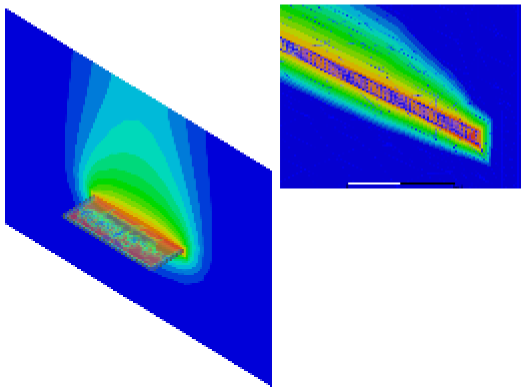
Thermal conductivity X



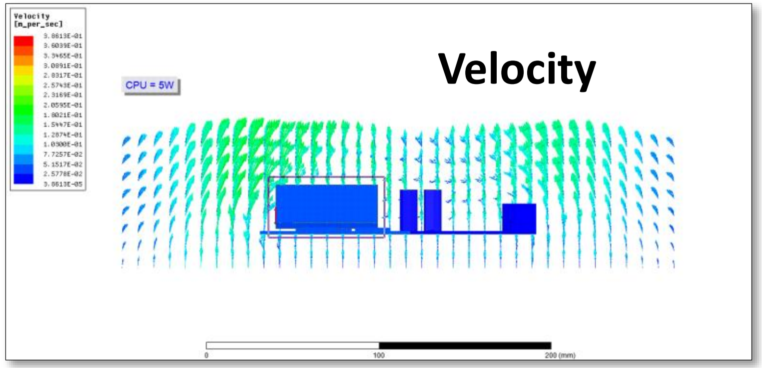
Top **Bottom**

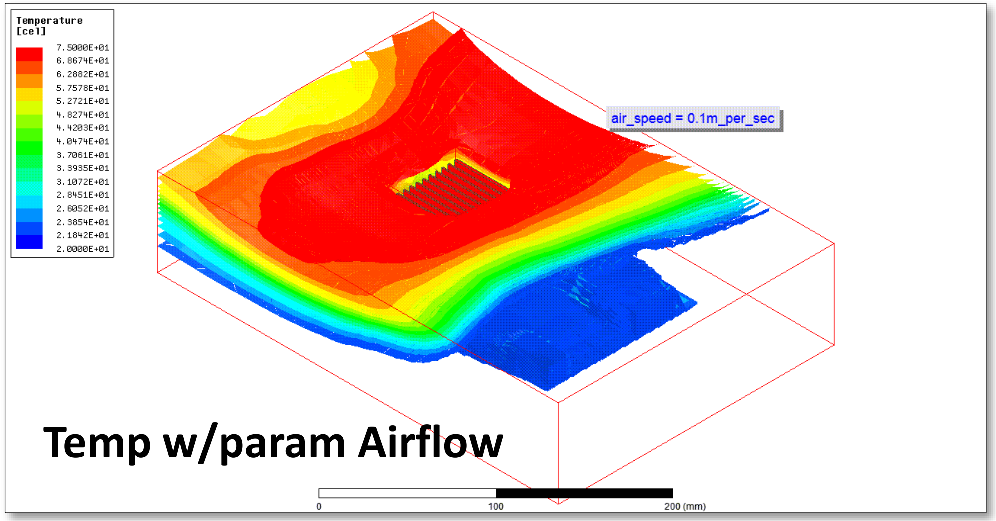


HFSS 3D layout Field **Temperature**



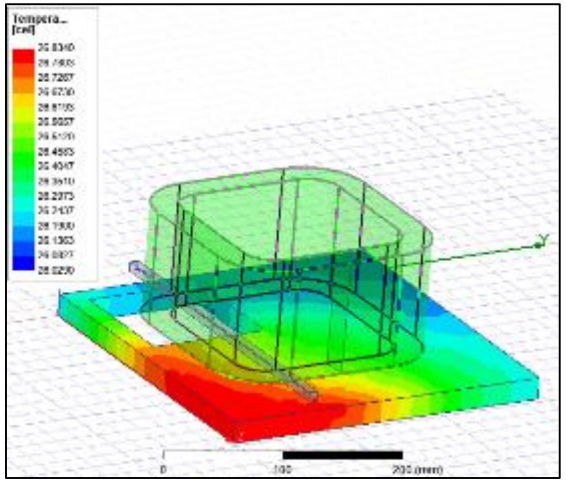
Thermal plot & PCB mesh

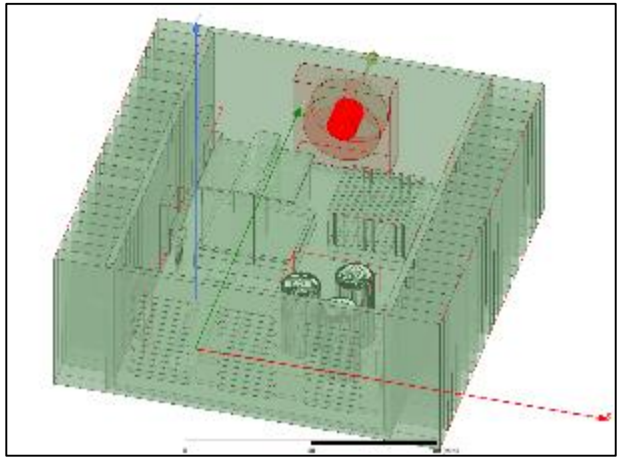




Highlights

- NEW 2-way thermal coupling to HFSS, Q3D, and Maxwell design types
- NEW 1-way thermal coupling to SIwave DC IR solver in AEDT
- NEW Import .tzr archive from Classic Icepak interface
- NEW 2D & 3D profile boundary conditions using datasets
- Workflow Improvements
  - Solution setup streamlined
  - Rotated PCB components
  - MCAD fan objects can be simplified into Icepak primitives
- Mesher Improvements
  - General mesh speed and quality improvements
  - Allow for simplified stair-step meshing
  - Control over uniform mesh sizing
  - Added the capability to enforce 2D cut cell meshing in a specified coordinate direction
- Classic Icepak Enhancements
  - Job submission to supported schedulers – within and across Windows/Linux platforms
  - Ability to export unencrypted ECXML files
  - Monte Carlo radiation model added (BETA)
  - Per Object meshing controls & Mesh re-use (BETA)

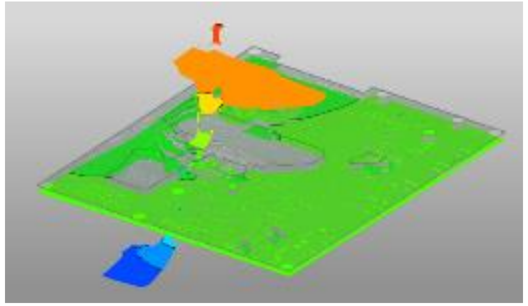
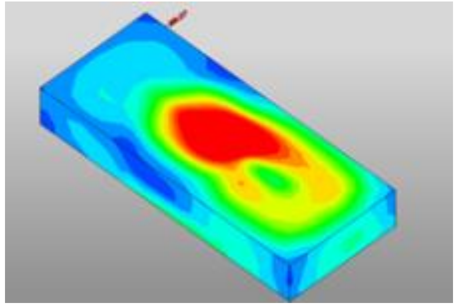
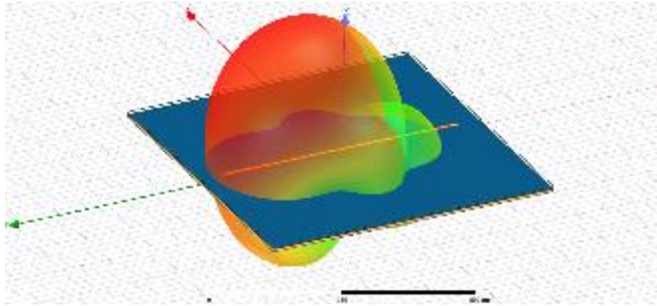
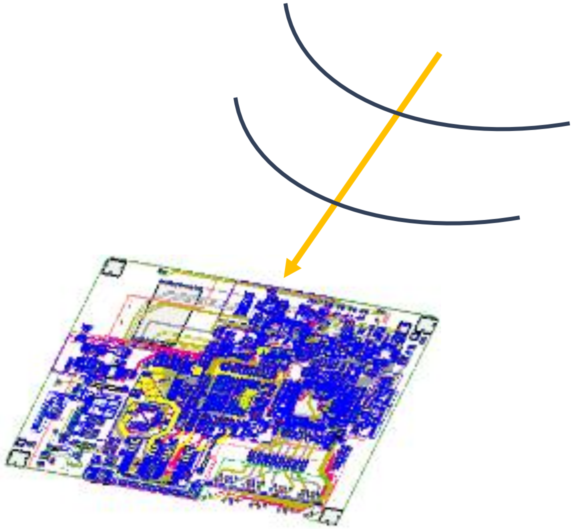




EMI EMC

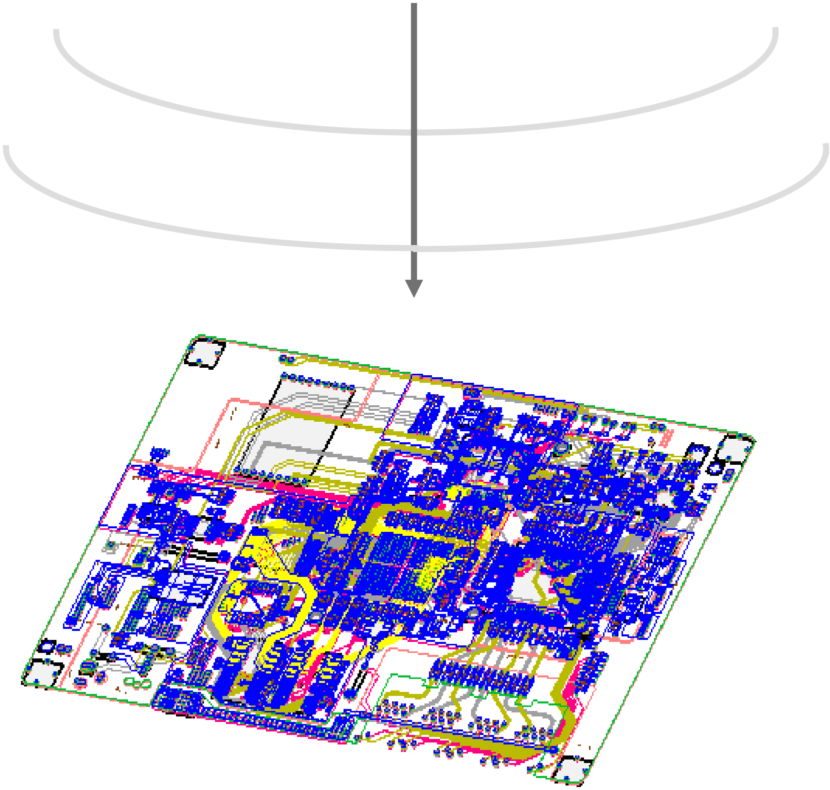
EMI Capabilities

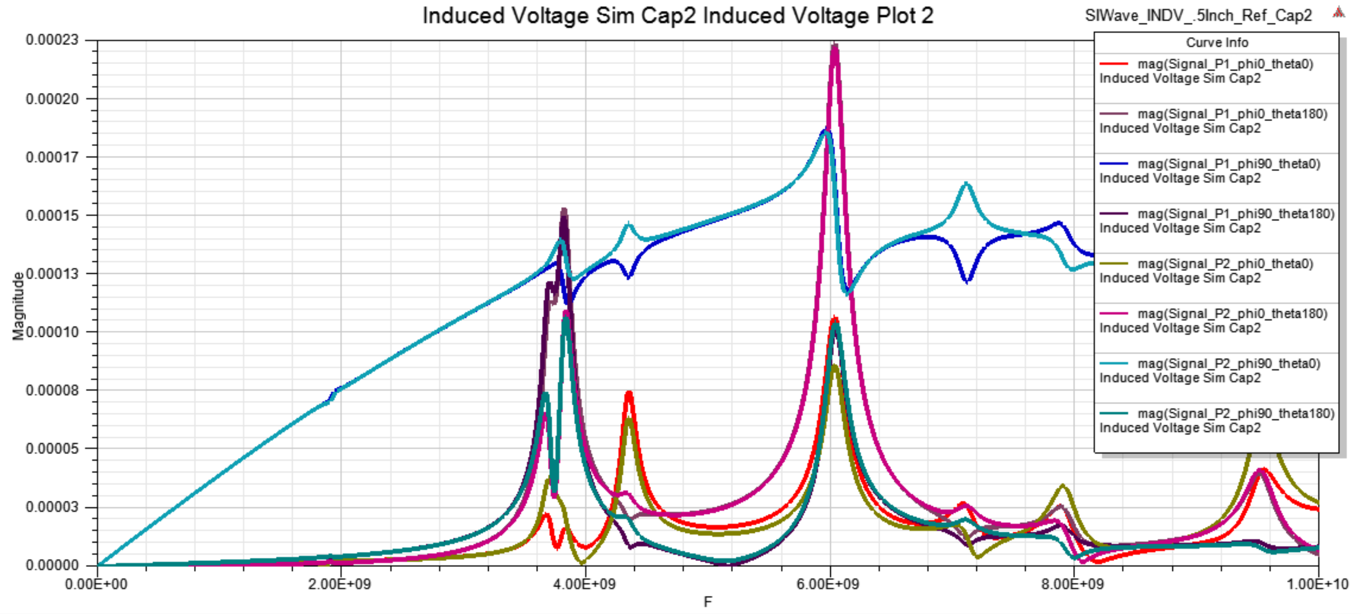
- Resonant Mode
  - Power and ground plane resonant mode solver.
- Induced Voltage (Susceptibility)
  - Models a plane wave incident to the PCB. Monitors voltages induced at port locations.
- Near-Field
  - Computes the near-field E- and H- fields close to the board.
- Far-Field
  - Computes the far-field radiation.

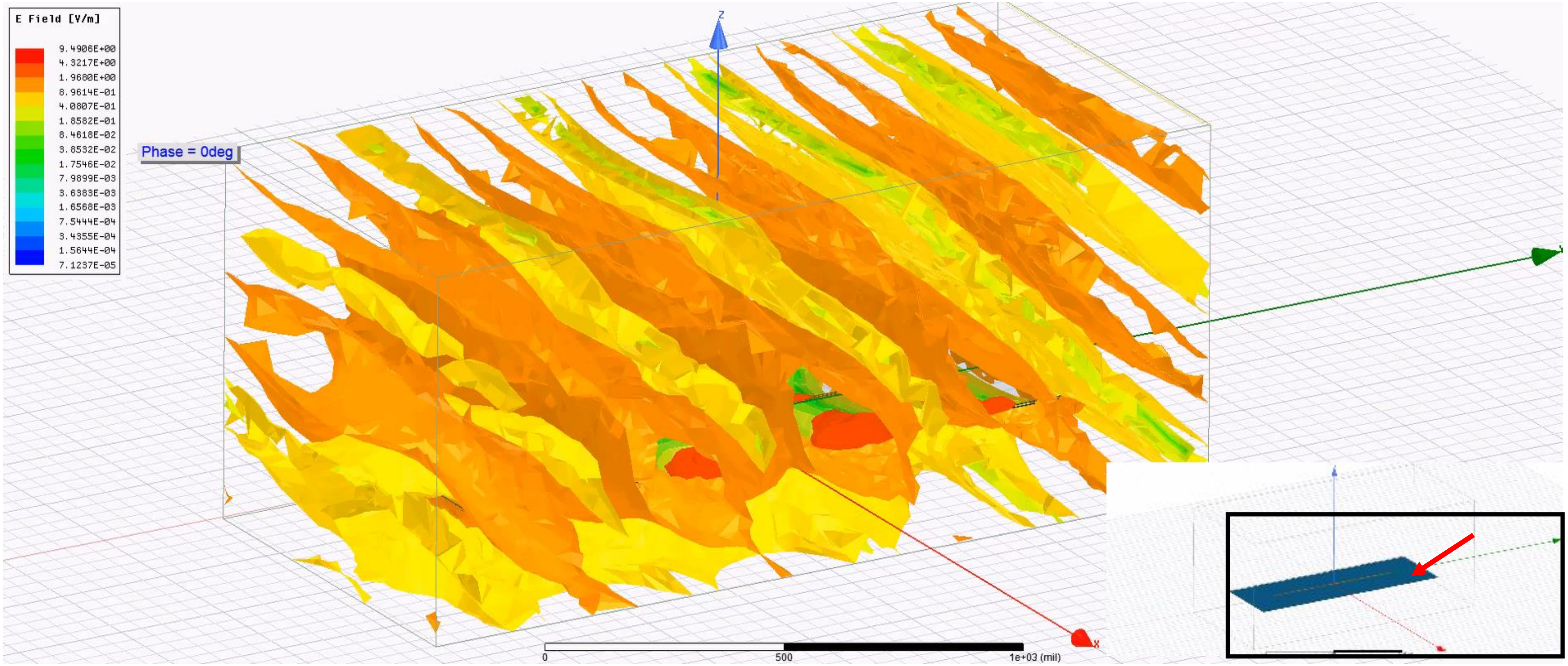
Induced Voltage (Susceptibility)

- **Models a plane wave incident to the PCB**
- **Monitors traces and planes for excitation**





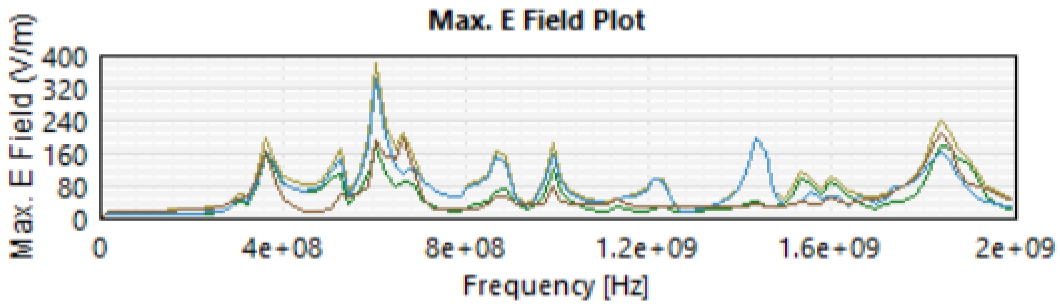
Induced Voltage – 10GHz Plane Wave Excitation

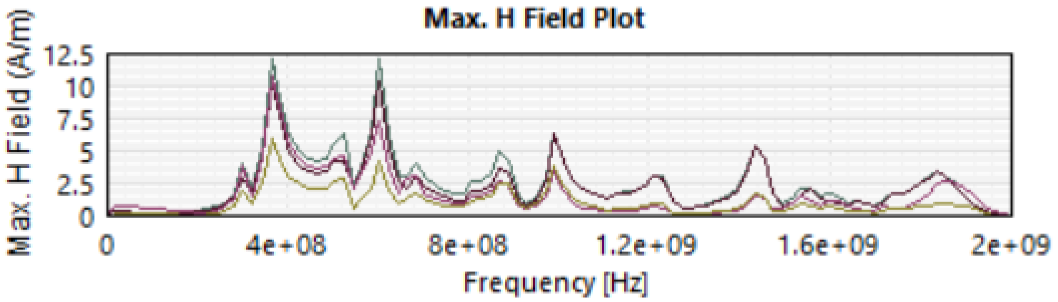


Animation

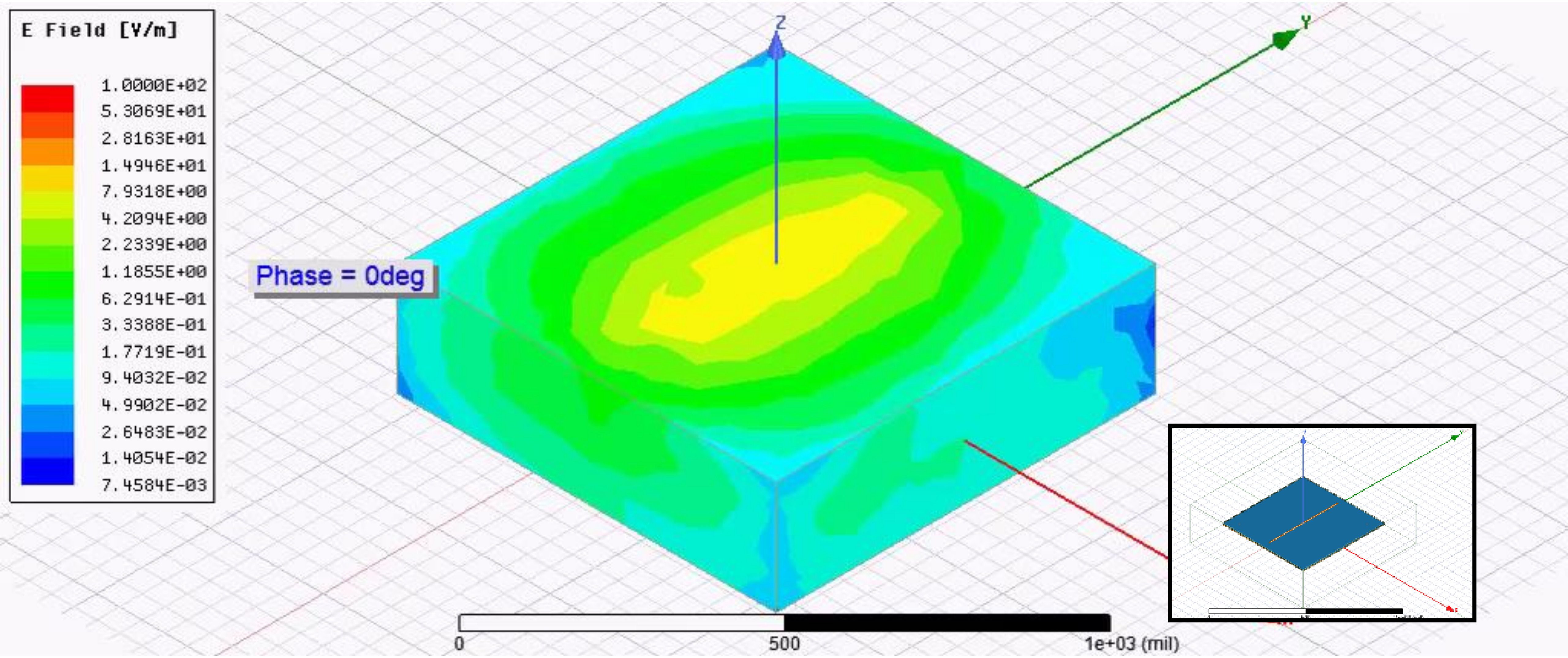
Near-Field

- **Computes the near-field E- and H-field at a specified distance from the model**
- **Mimics near-field probing that is commonly done with a spectrum analyzer to pinpoint localized sources of EMI**



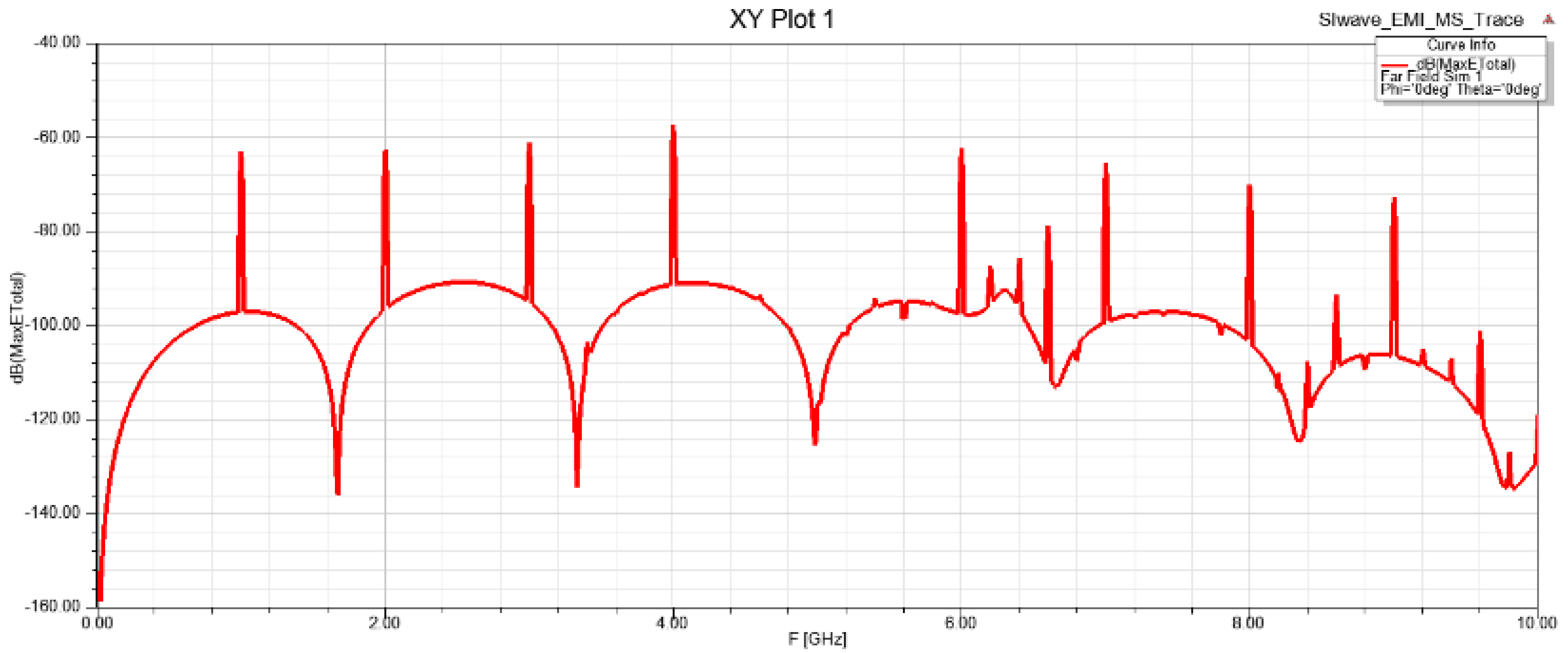


Near-Field E-Field Pattern

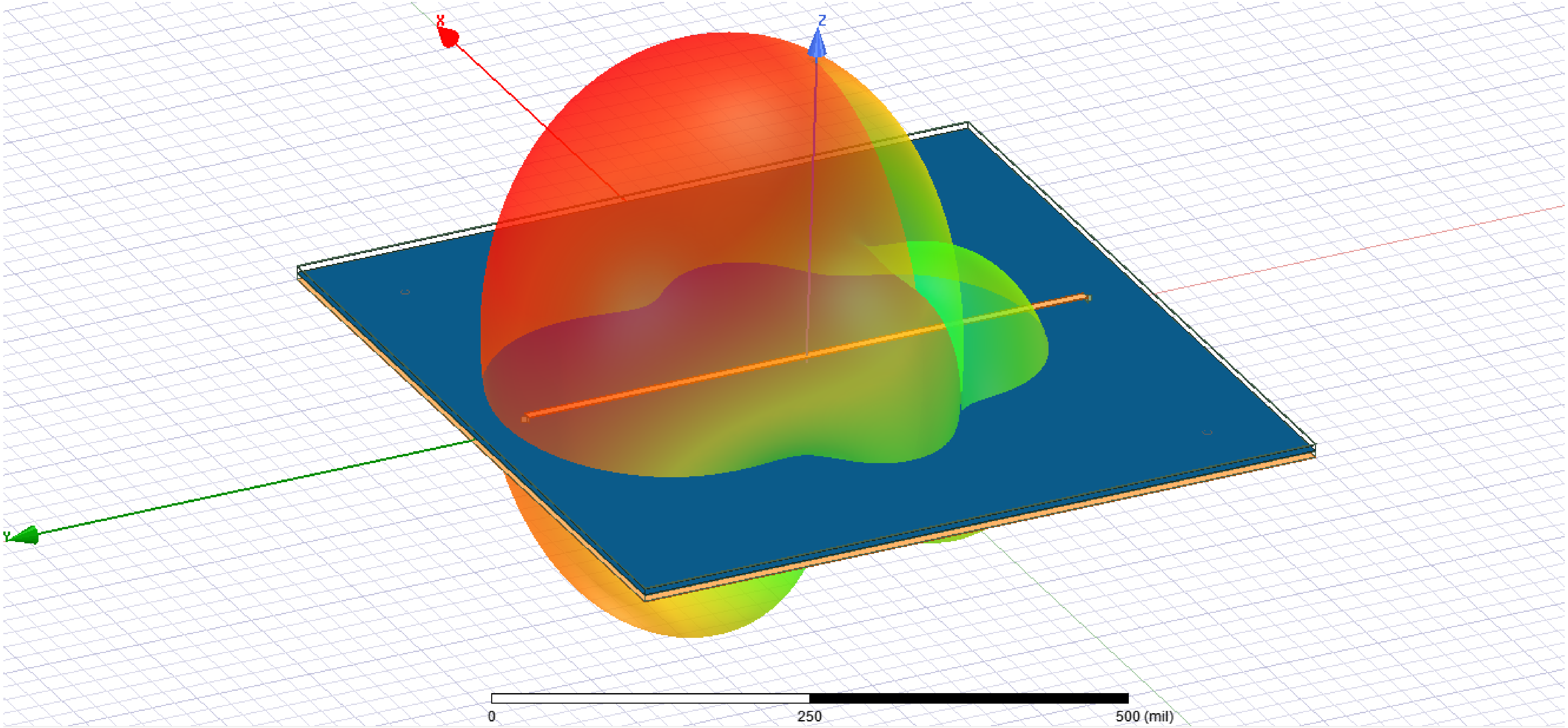


Far-Field

- Computes the radiation pattern and strength of the E-field in the far-field
- Mimics Radiated Emissions testing used for EMC Compliance
- Can be calculated for 3m, 5m, 10m testing



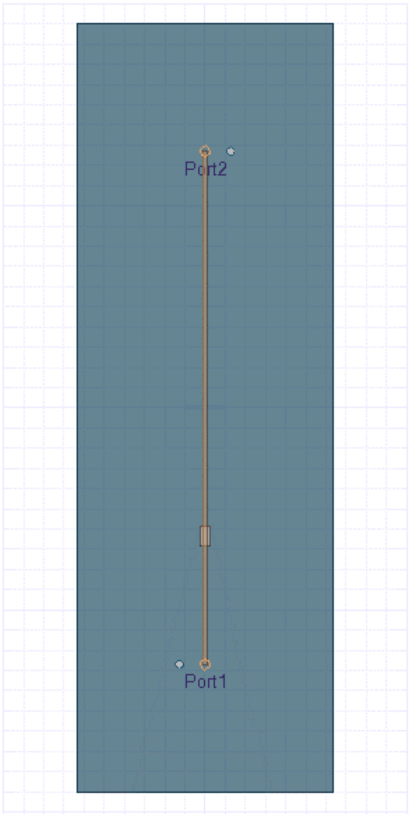
Far-Field Radiation Pattern

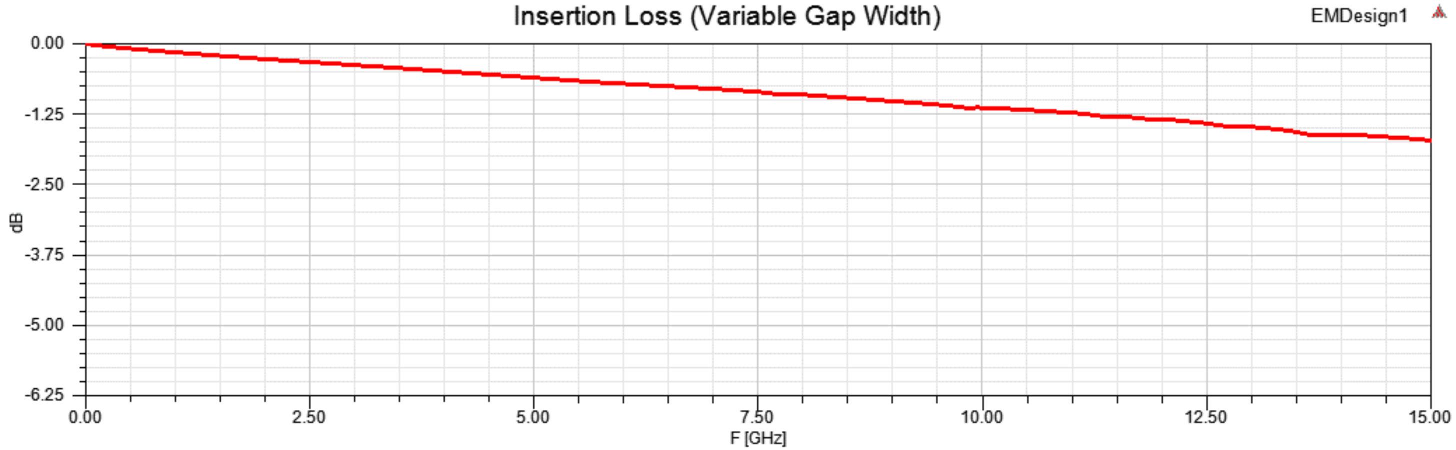


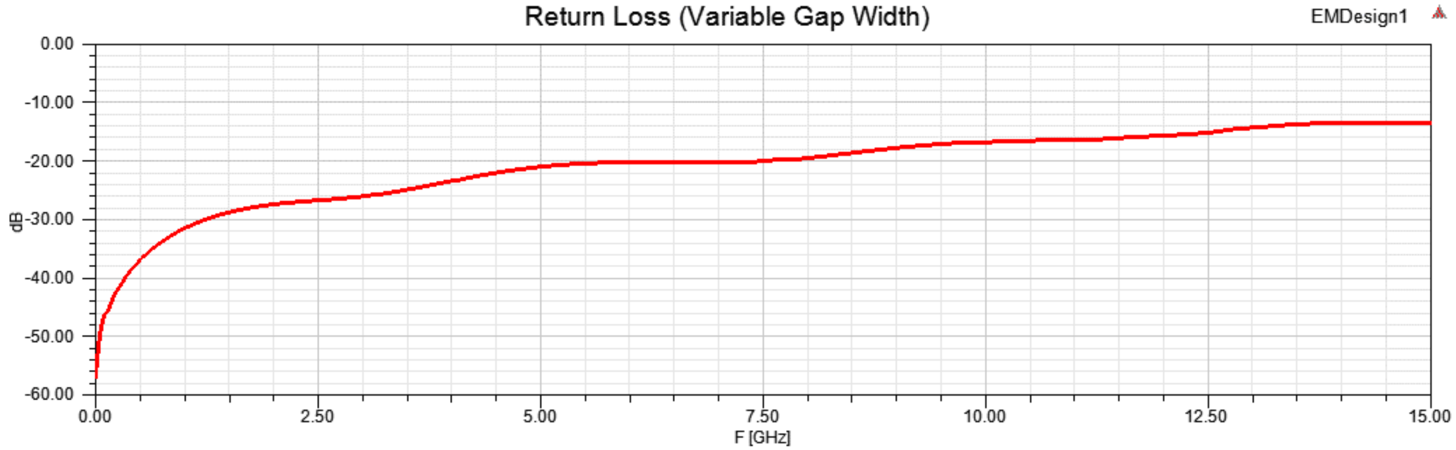
Microstrip w/ Slot – Varying Gap Width

Transmission Line models that assume perfect reference planes do not show the impact of non-ideal return paths

CM or DM radiation is proportional to the areas of the loops (s or h),which are set by the PCB/Connector technology and design strategies.

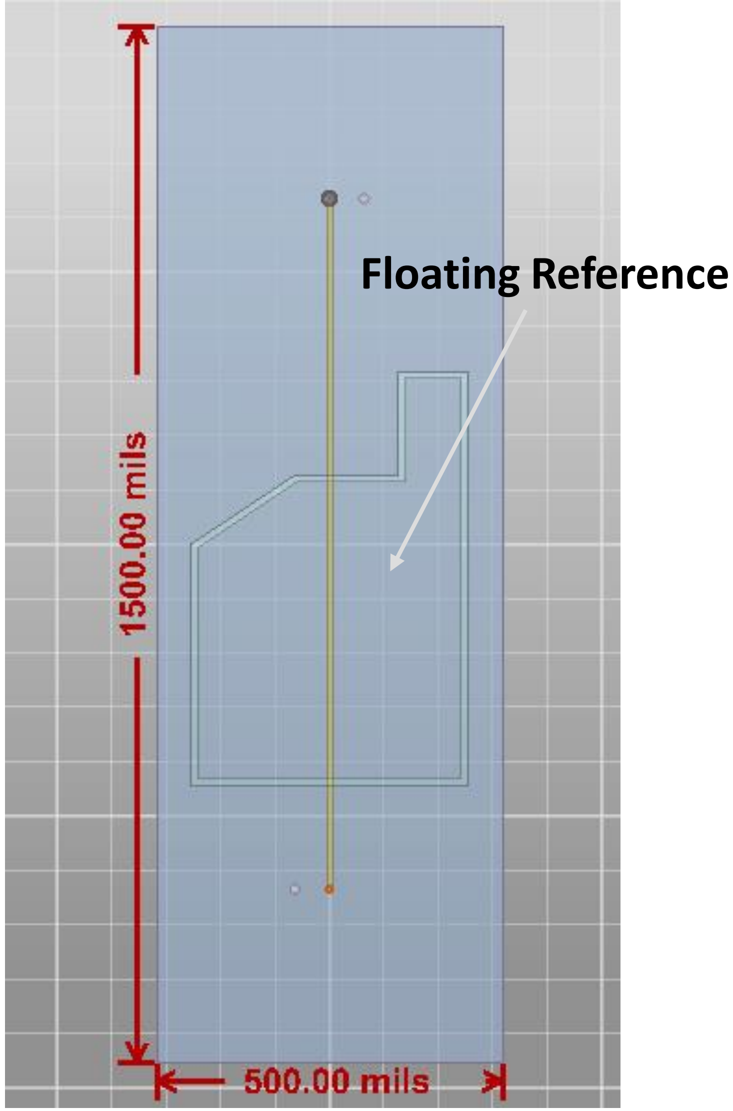


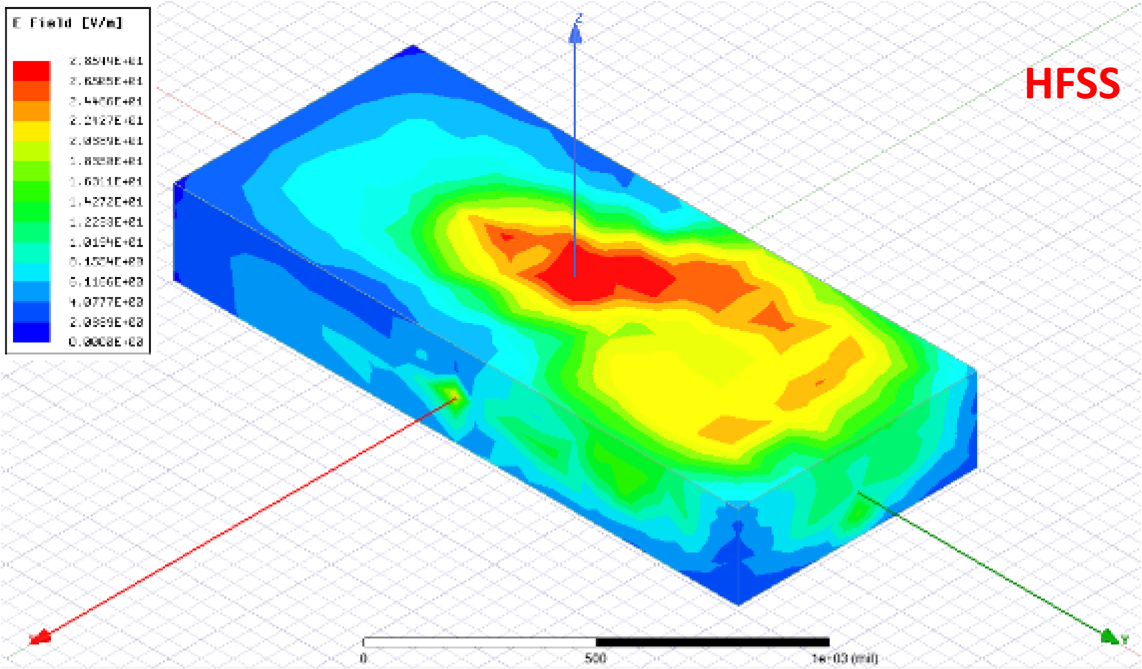


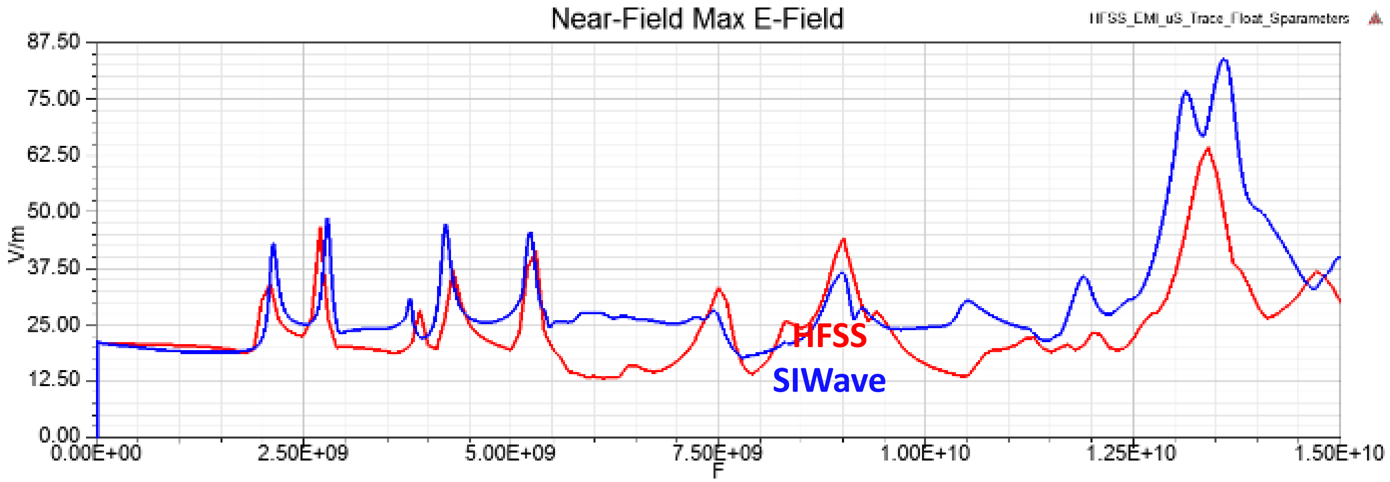


Animation

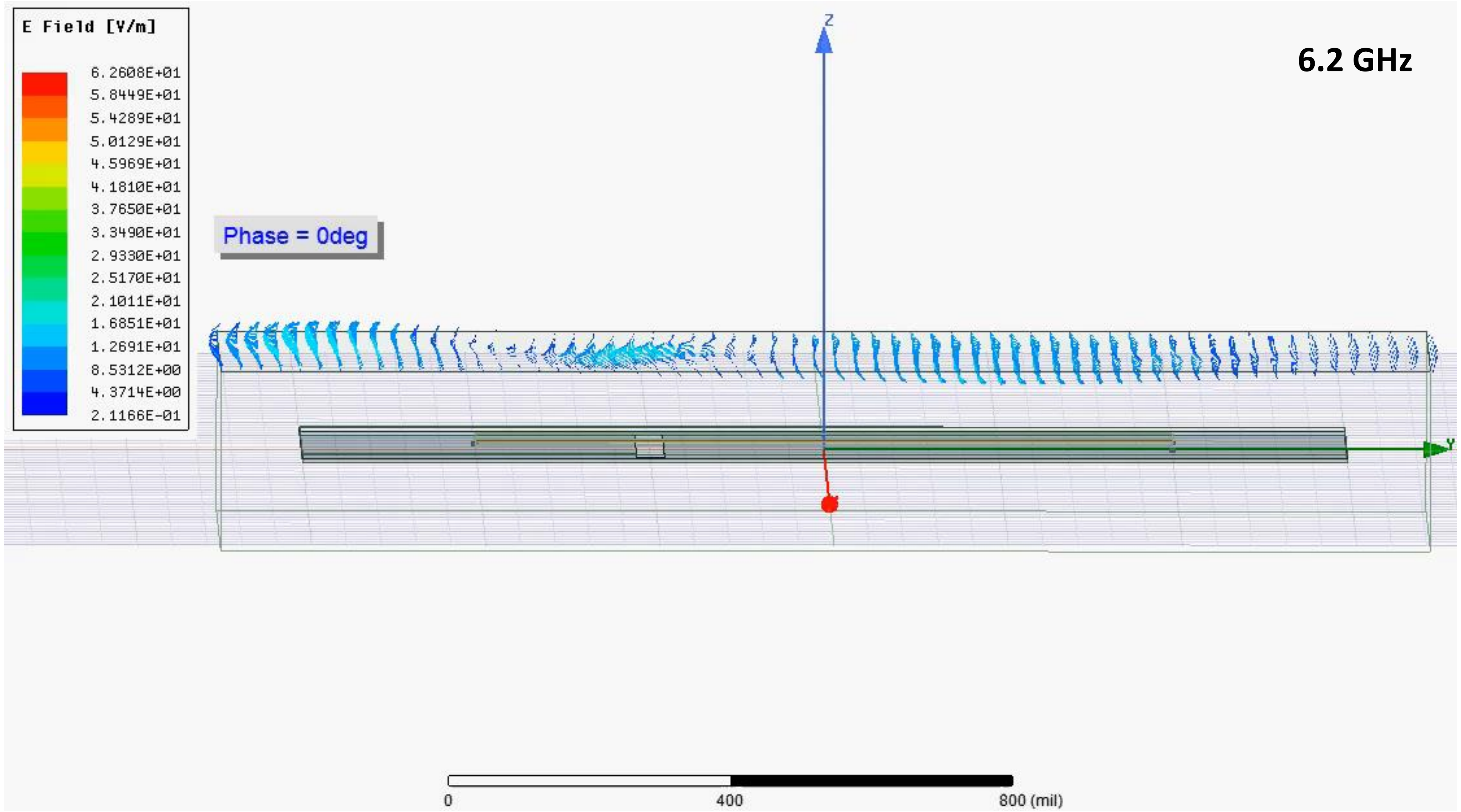
Near-Field E-Field – 2.1 GHz







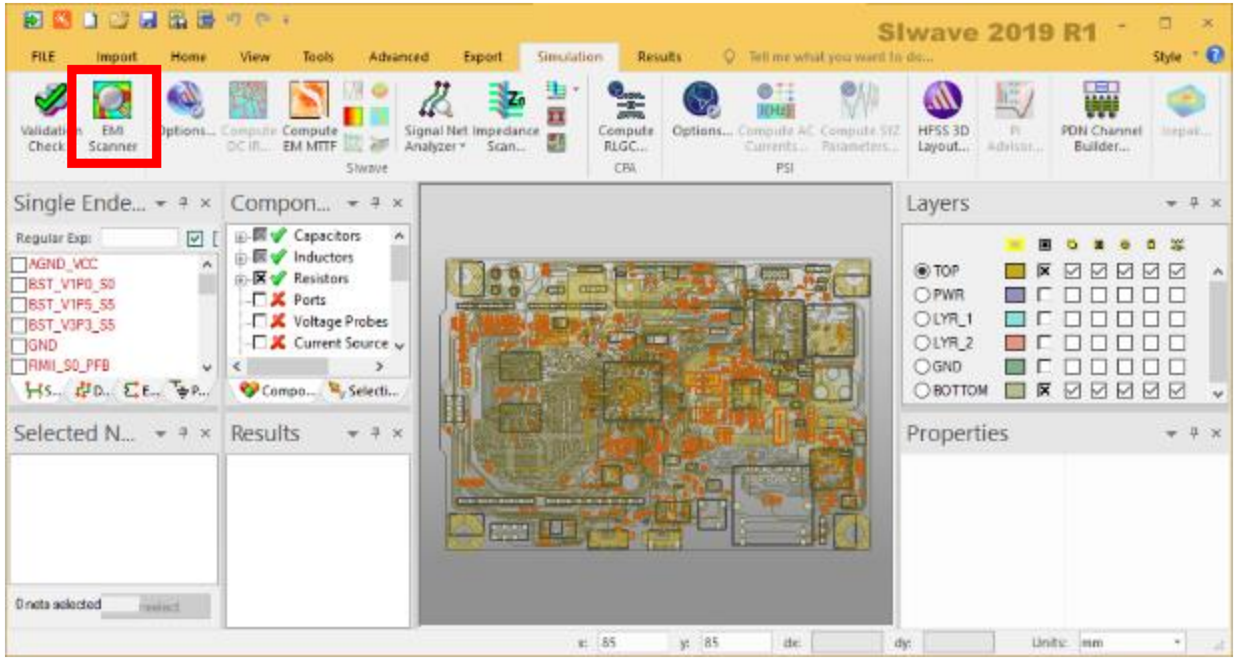
Microstrip w/ Slot - HFSS – Vector E-Field at 3mm above Slot

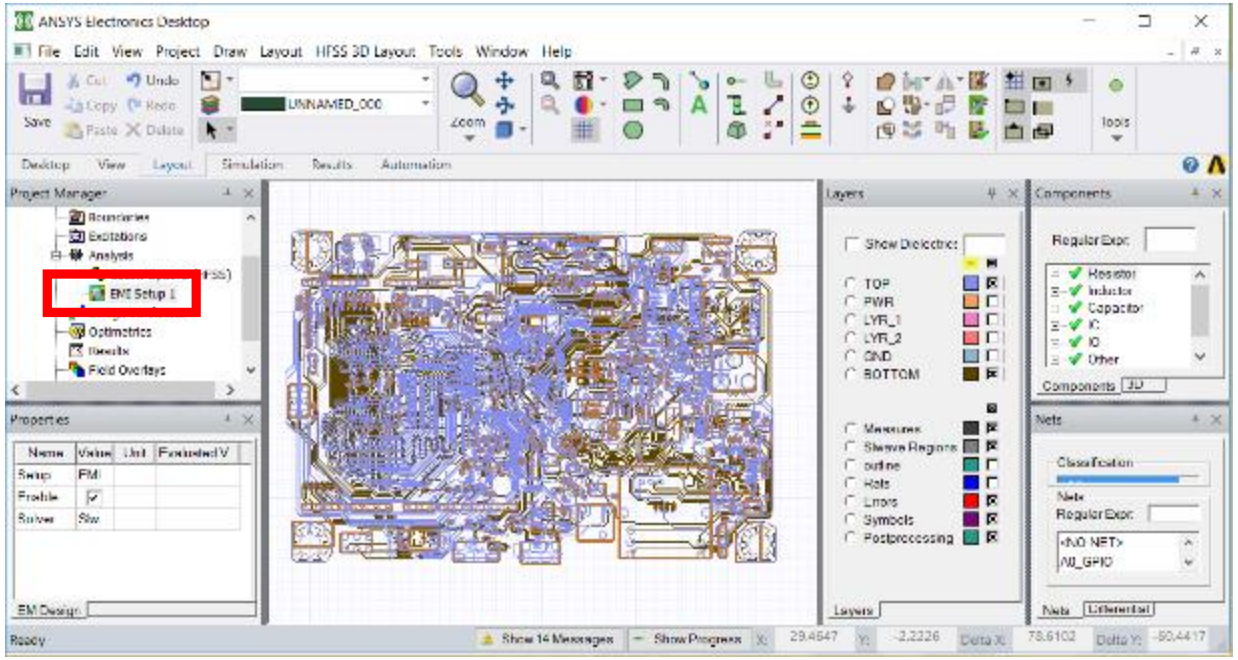


Animation

ANSYS EMI Scanner

- **Either HFSS or SIwave can utilize the EMI Scanner**
  - **No additional license needed**
  - **EMI Scanner runs directly in either tool**



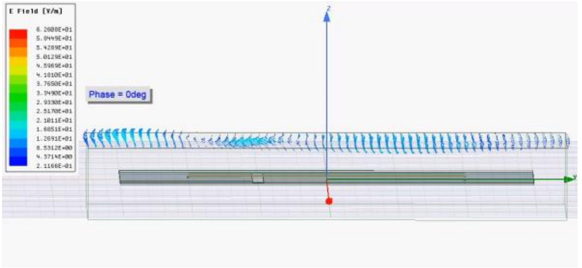


Electromagnetic Interference Rules

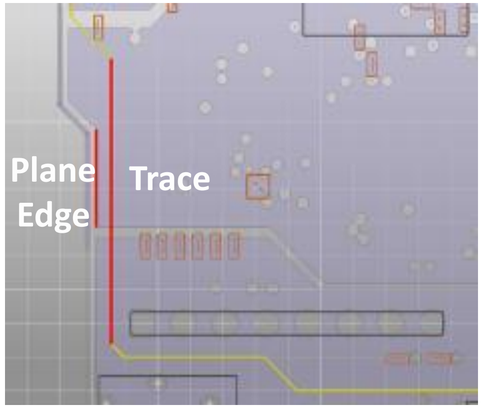
Signal Reference

- *Net Crossing Split*
- *Net Changing Reference*
- *Net Near Edge of Reference*

Example: Net Crossing Split



Example: Net Near Edge of Reference

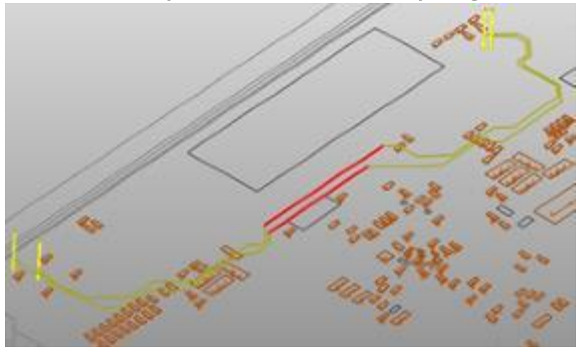


Wiring/ Crosstalk

- *Critical Net Near I/O Net*
- *Exposed Critical Trace Length*
- *Critical Net Isolation*
- *Critical Differential Net Matching*
- *Wide Power/Ground Traces*

Example: Via Stub Length

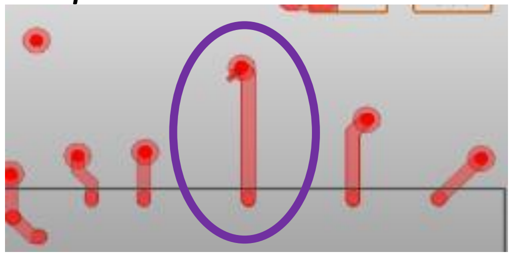
Example: Net to Net Coupling



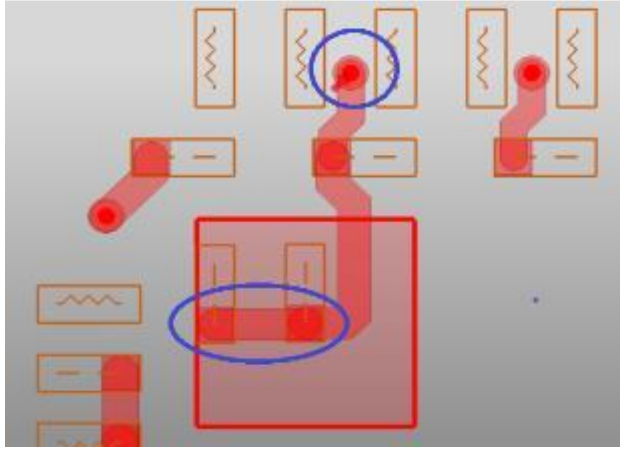
Decoupling

- *Decoupling Capacitor Density*
- *Power Pin to Capacitor Distance*
- *IC Power/Ground Pin to Via Distance*
- *Decoupling Cap Distance to Via*
- *Power/Ground Trace Decoupling*
- *Power Via Density*

Example: IC Power Pin to Via Distance



Example: Decoupling Capacitor Distance to Via



Summary

- Brief Overview of EM Techniques FEM and Transient
- Connector on Board “Assembly” Simulation
- HFSS 3D Components
- Thermal Simulation of EM Models
- EMI Analysis using HFSS
- EMI Scanner