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Bending EM Tools to Your Will

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I'M HERE LIVE. I'M NOT A CAT.

Outline & Introduction

- So, you want to design a 112G system!
- Which of these tools is most important for a successful design?
  - Spreadsheet
  - Circuit Solver with S-parameter simulation capability
  - 2D Quasi-Static Electromagnetic Field Solver
  - 2D Quasi-Static PCB Signal Integrity Solver
  - 2.5D Fullwave Hybrid Planar PCB solver
  - 3D Fullwave Electromagnetic Field solver
  - Mass quantities of computational servers
  - Eyes and a brain
- All electromagnetic simulation tools have limitations.
- Understand your tools and work with/around them.

Simple Questions to Ask When Modeling Planar Structures

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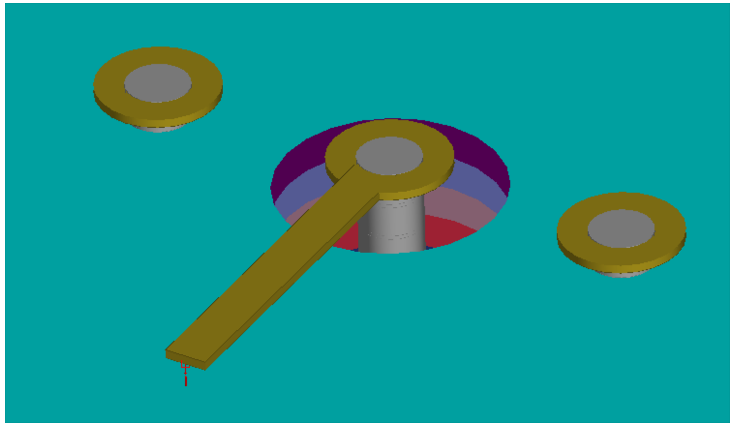
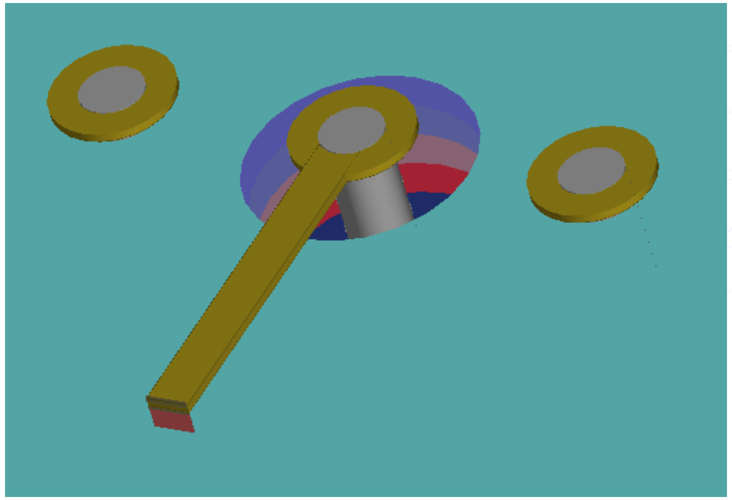
- What are you modeling?
  - Full board
  - Truncated structure
- How are ports modeled in your tool?
  - Circuit Port
  - Line or Sheet source
  - Wave source
- How are boundaries modeled in your tool?
  - Where is the boundary?
    - Touching the board
    - Away from the board
  - What is the boundary?
    - Absorbing or radiation boundary
    - Perfect Electric Conductor

Ports

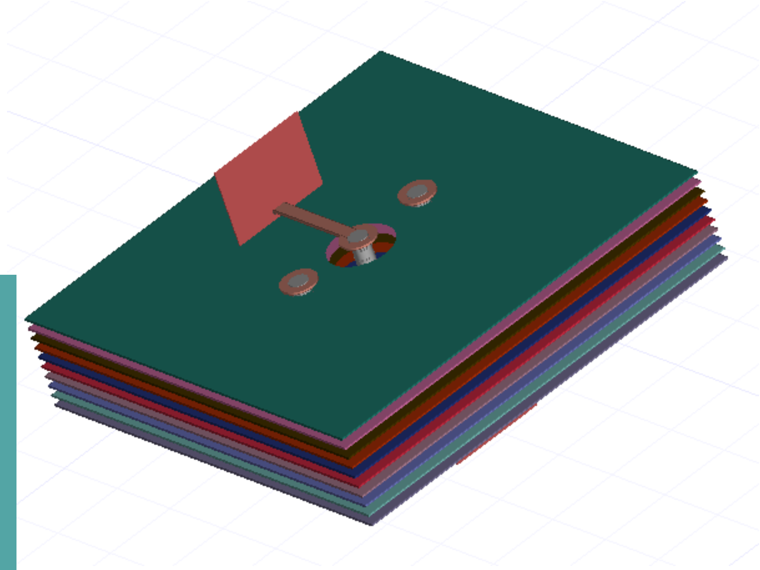
Port Types in 3-Dimensional Space



Circuit Port



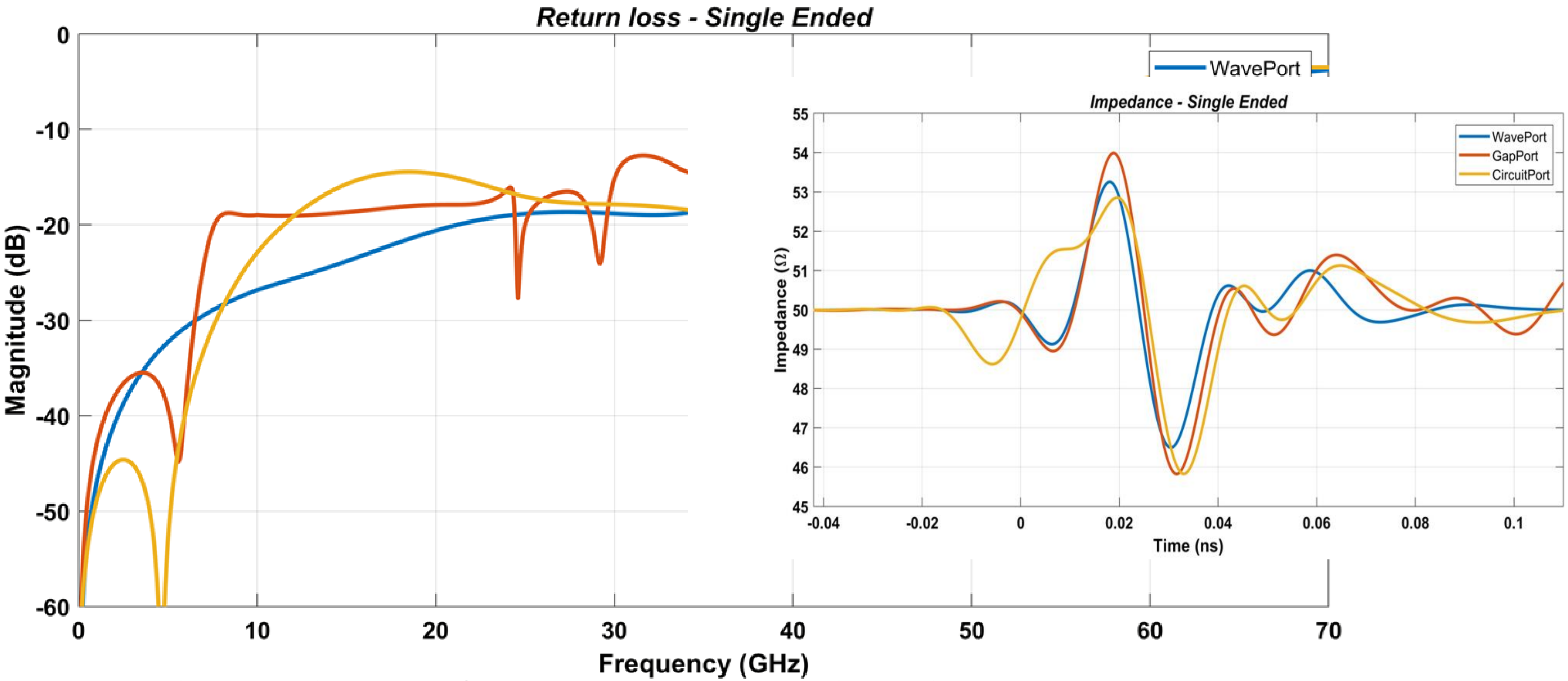
Gap/Lump Port



Wave Port

A wave port operates as a fully formulated 2D wave “portal” into the 3D trace space.
A gap, or lump, port acts as a current sheet that excites the 3D trace space.
A circuit port acts like a voltage line that excites the 3D trace space.

RL/TDR of Various Port Types



A wave port excites a trace by mimicking an infinite transmission line. This is the most accurate port in any 3D simulator.
A gap/lump port mimics only the fields directly along the edge of the trace. As a result, it shows additional inductance.
A circuit port mimic a field voltage potential across a line to the middle of the trace. It is both capacitive and inductive.

Discussion of Ports

- The type of port chosen will determine the overall accuracy of the modeling.
  - A wave port has full fidelity to an infinite transmission line, if it is sized correctly
    - The outer perimeter of a wave port is a PEC line, or PEC solid. This can impact the modeling space.
  - A gap/lump port provides a matched impedance but does not fully formulate the field pattern around the trace. Thus it exhibits excess inductance that impacts the solution
  - A circuit port provides a simple line voltage across the terminal of a trace. It exhibits capacitance as the field "sees" the width of the trace, and inductance as the field spreads out. It will have the worst solution fidelity.
- 2D hybrid solvers generally utilize only circuit ports. As such, they have the lowest accuracy for characterization of small structures.
- For large boards, the launch point discontinuity of a circuit port is usually small compared to the remainder of the board.
- For small structure optimization, a wave port is usually the best choice.

Boundary impact on modeling

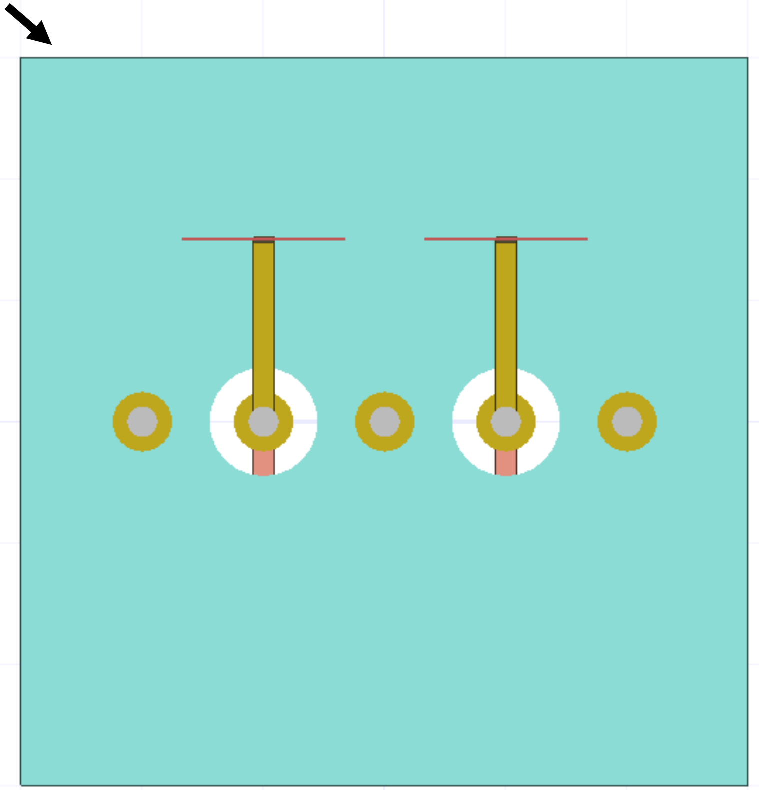
Boundary Types

- For general SI modeling, two boundary types are useful:
  - Perfect Electric Conducting (PEC) boundary
    - Provides a perfect metal conducting reflective bounding region
    - Think 0-ohm boundary that has a negative reflection coefficient
    - Useful to provide a full short across the side(s) of a design, or to place metal around dielectric structures.
      - This boundary is reflective and may interact with the design
  - Radiation or Absorbing boundary
    - Radiation boundary terminates the 3D space to the impedance of free space, 377-ohm for fields in the normal direction. Fields in the tangential direction may reflect off the boundary.
    - These boundaries can provide "infinite space" around the air surrounding a board.
    - They may also be used to "terminate" small planes, creating effective infinite plane simulations.

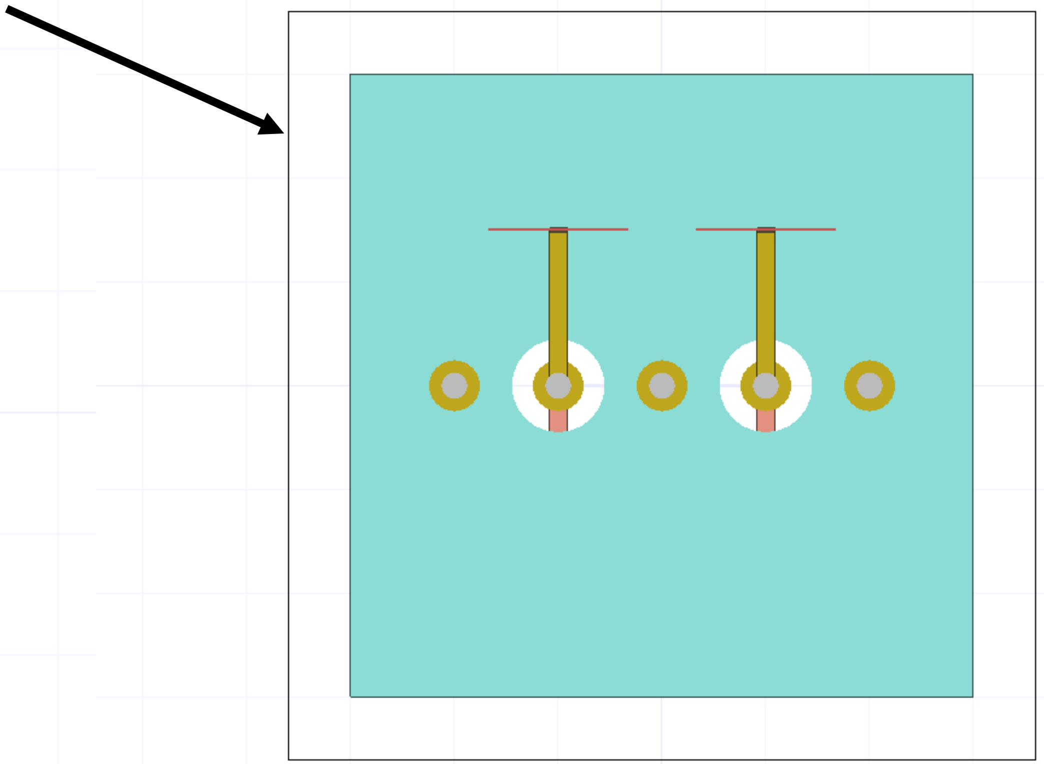
Simple Two SE Signal Via Design

Not Reflective

Reflective

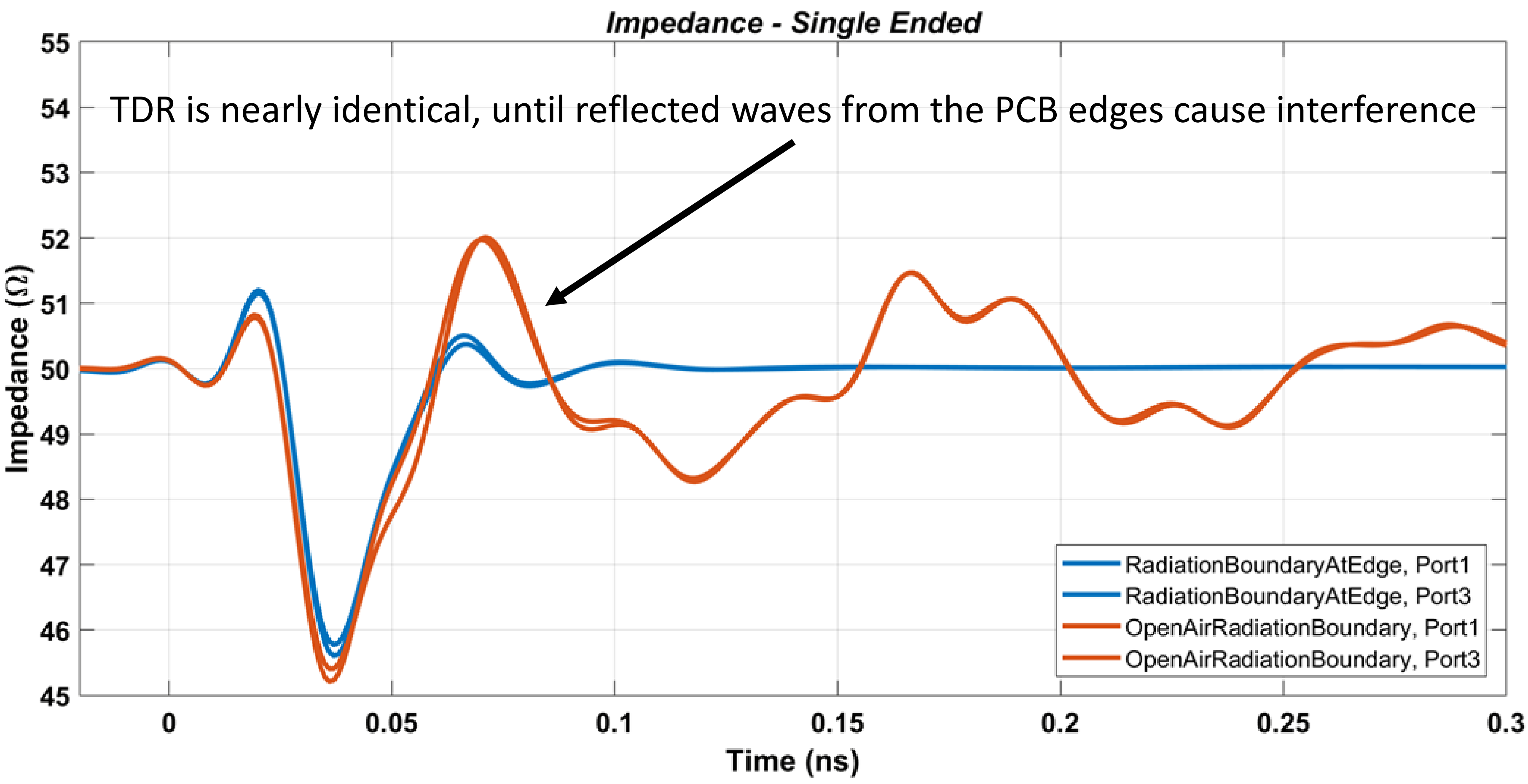


Design with radiation boundary at edge of planes.
Boundary absorbs fields

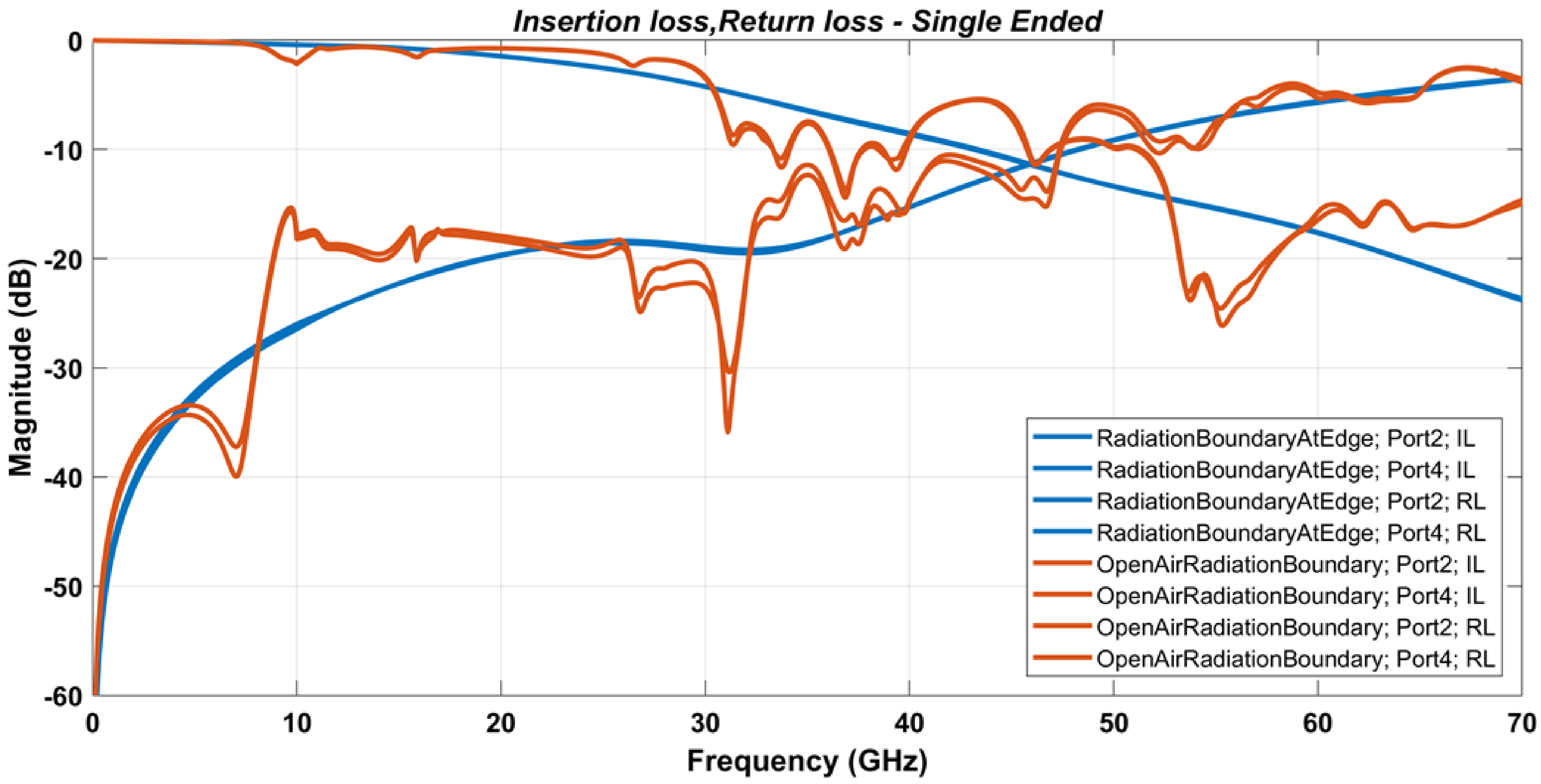


Design with radiation boundary at faces of air box surrounding planes.

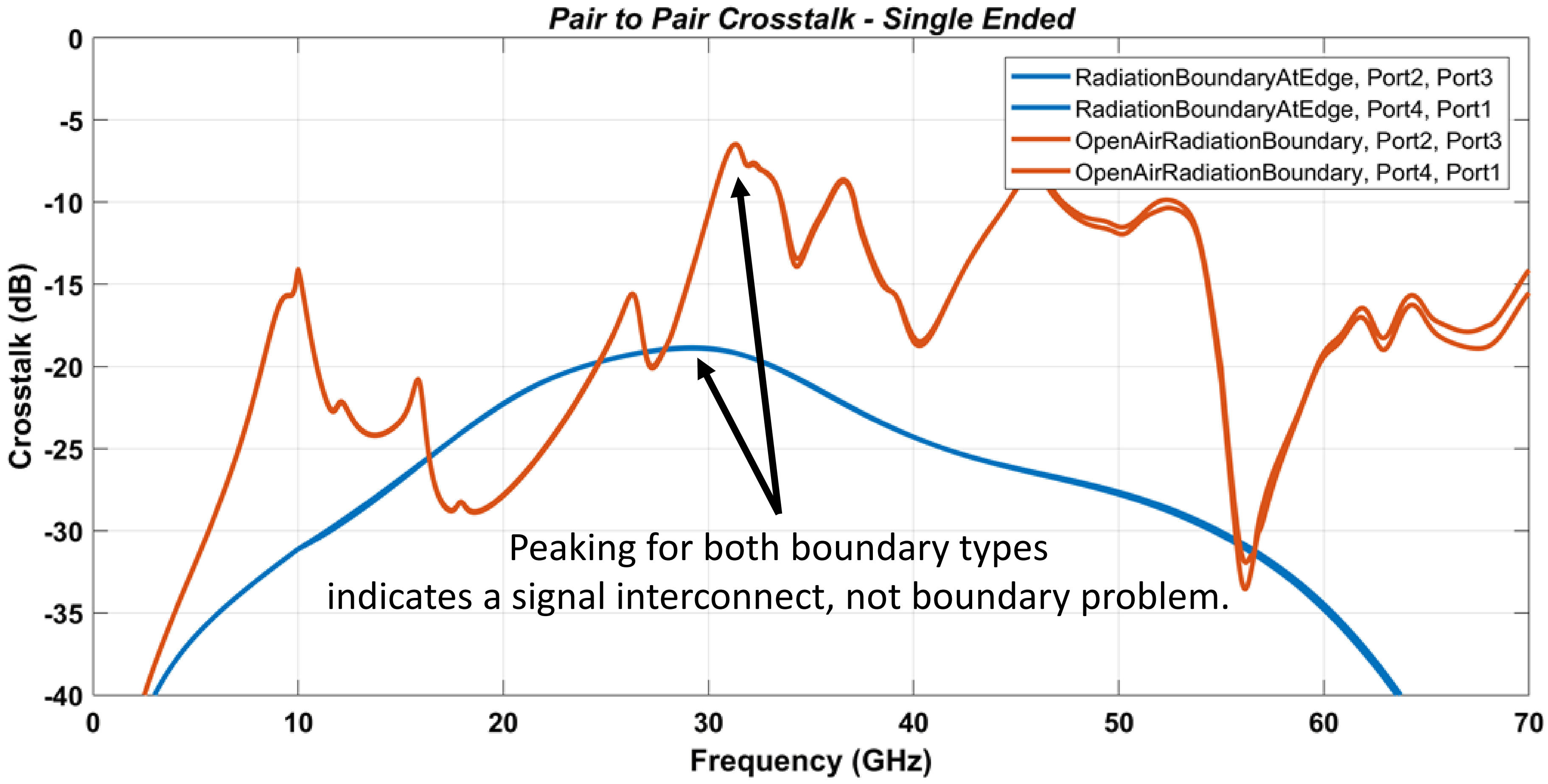
TDR Dependence on Boundary



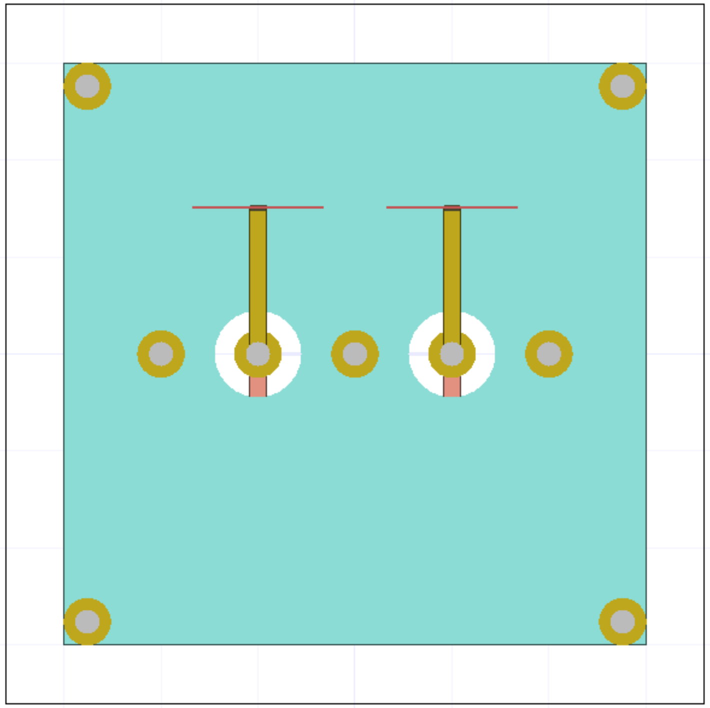
IL/RL Dependence on Boundary

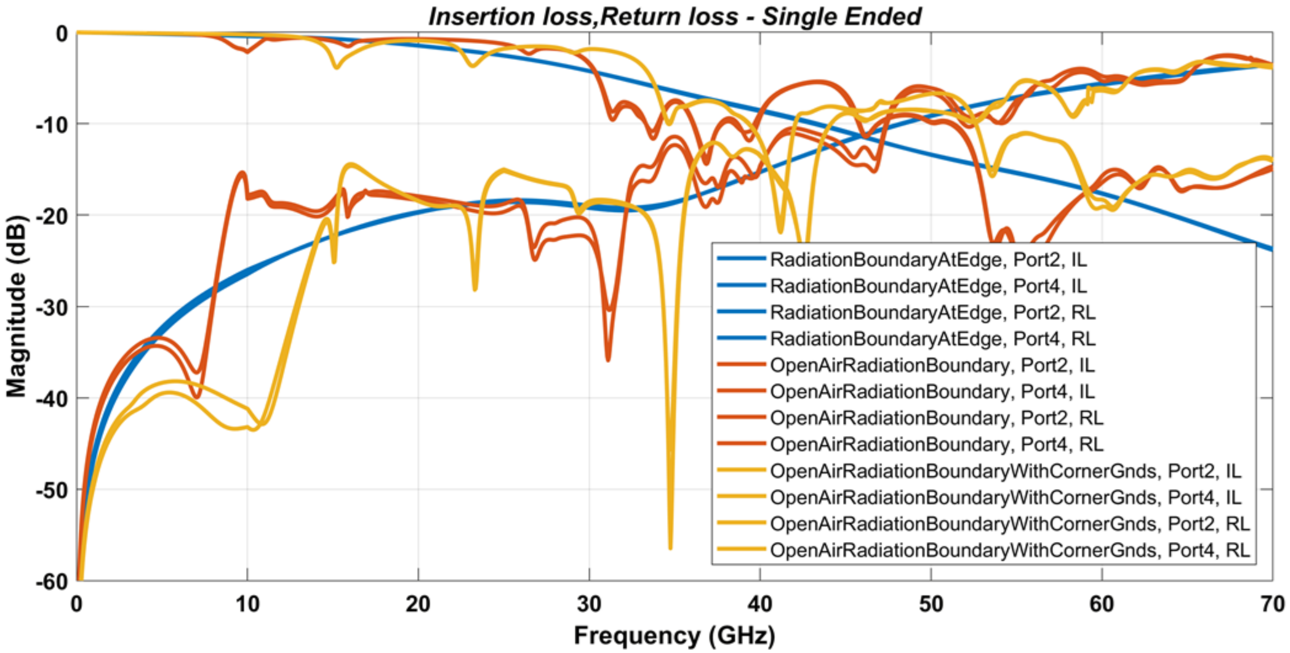


Crosstalk Dependence on Boundary



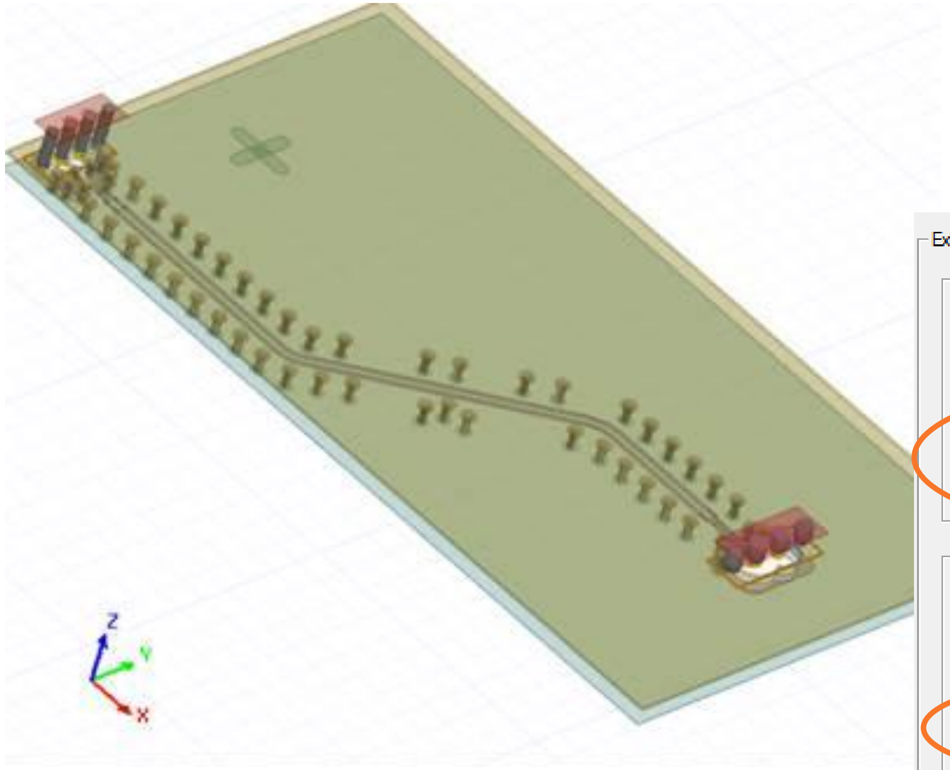
Add Corner Grounds

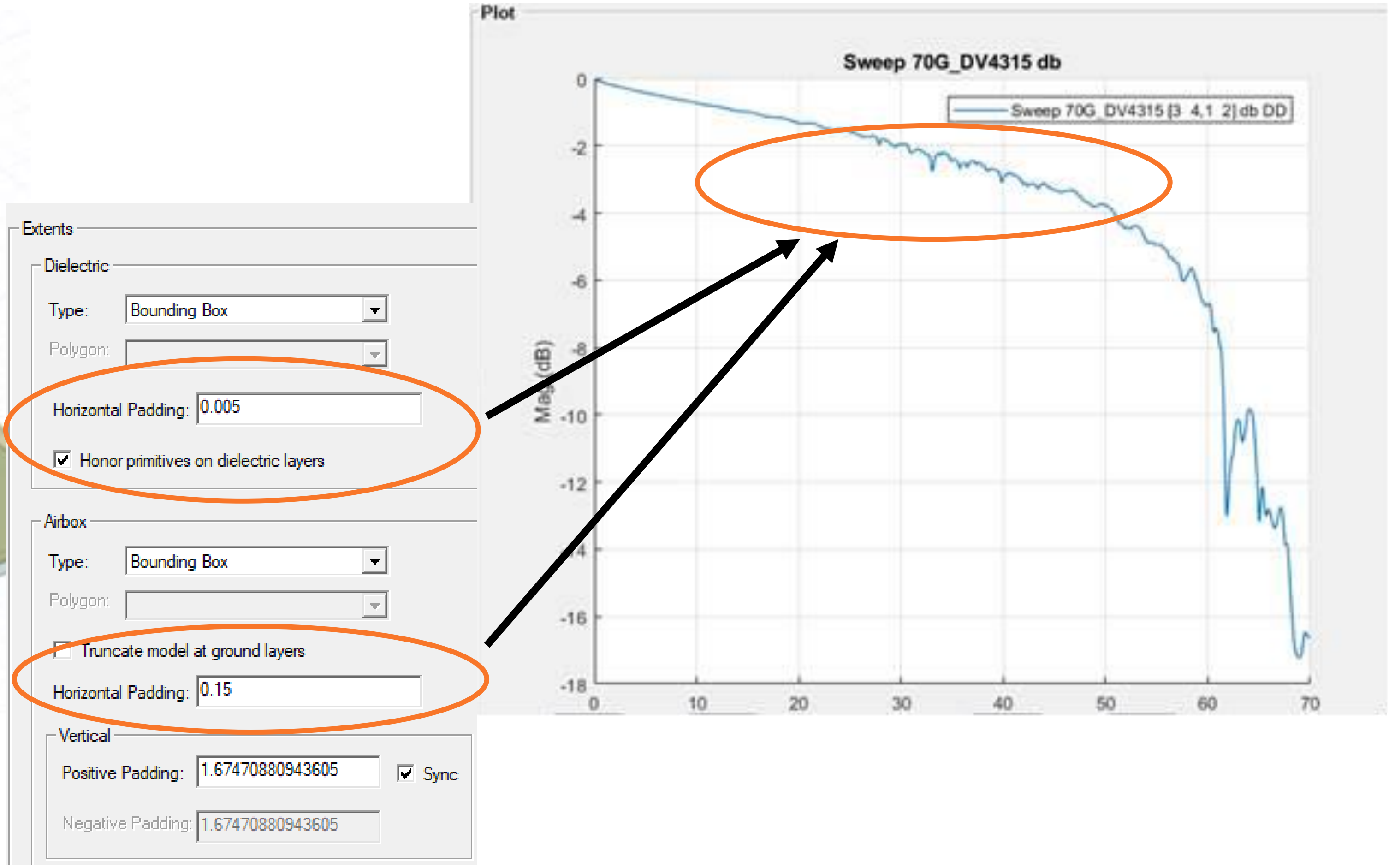




Adding additional ground vias in the design partially helps by moving resonances to higher frequencies.
This is like playing “Whack-a-Mole”. At 112 Gbps we need to Whack-a-Mole resonances beyond 28 GHz.
You have to add many more ground vias in order to “localize” the via transition. (Localization keeps fields from arriving at the edge of the board.

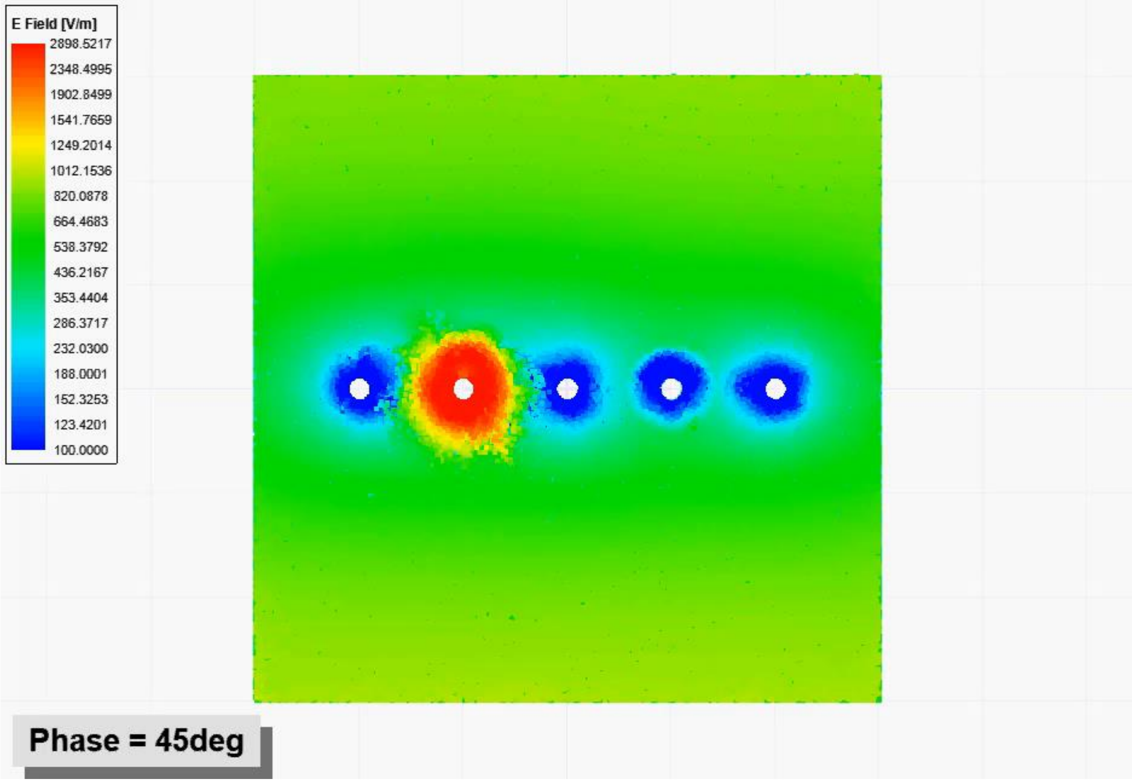
Well-Stitched Design With Out-Of-The-Box Boundary Settings (BGA to NovaRay Conn)

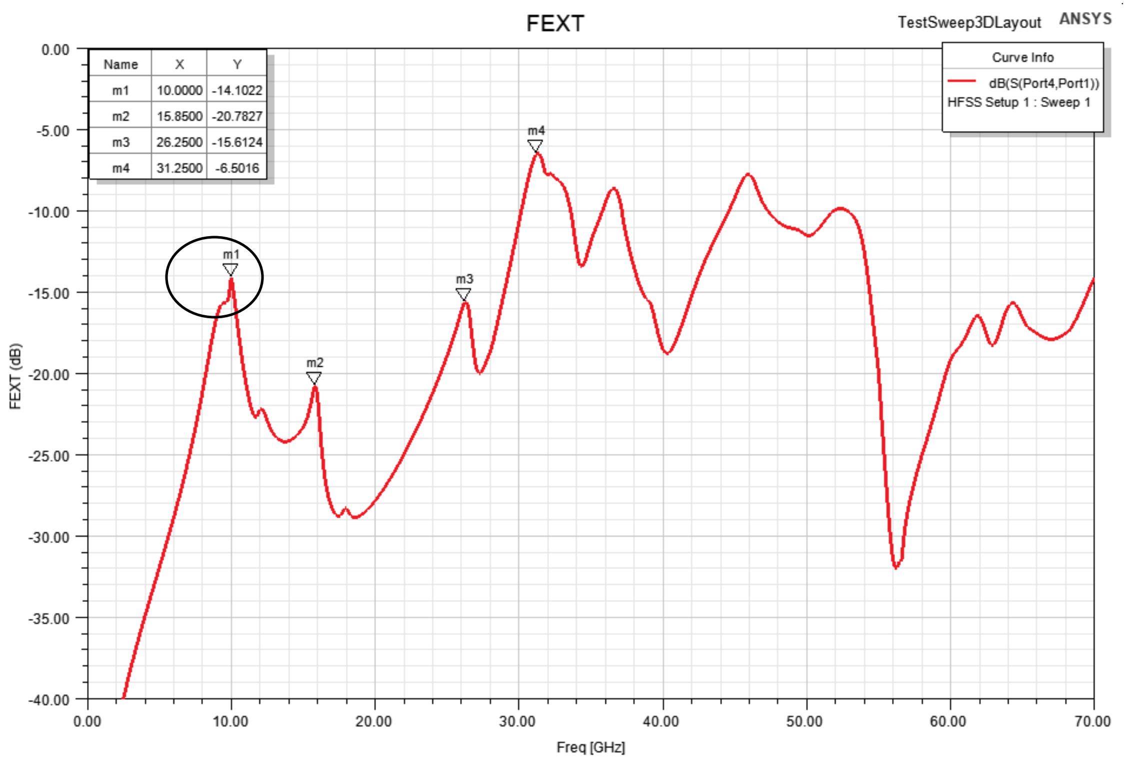




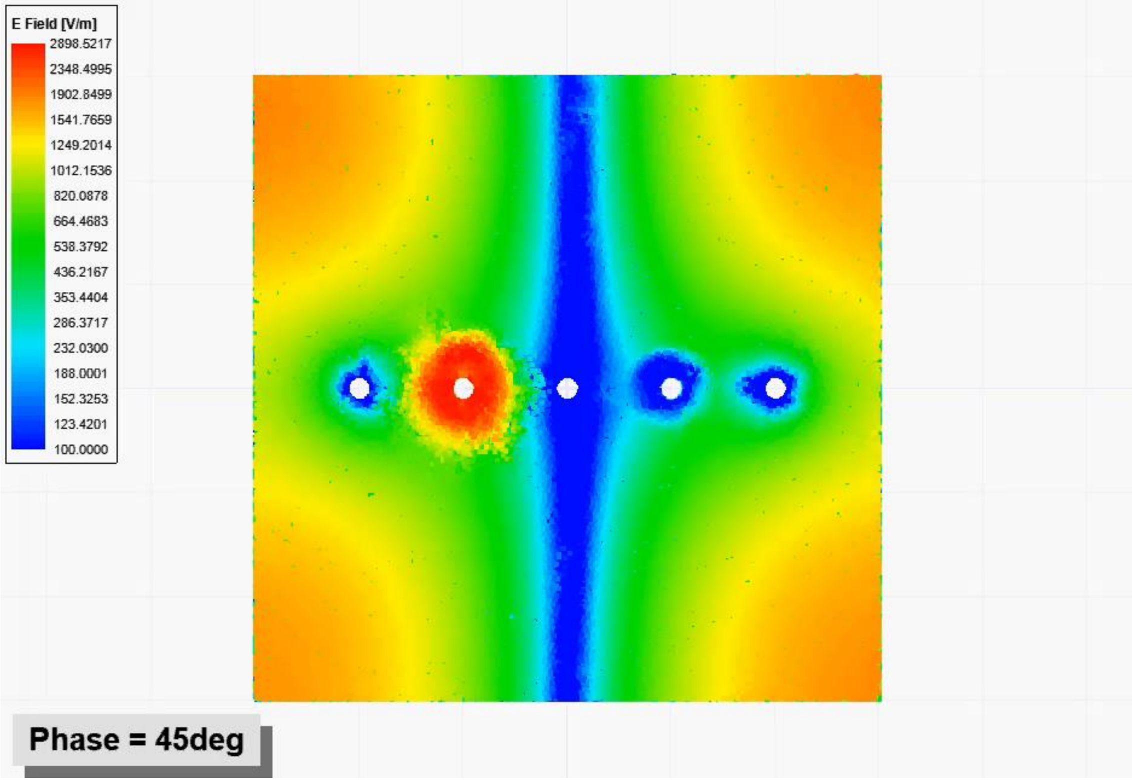
Resonance visualization

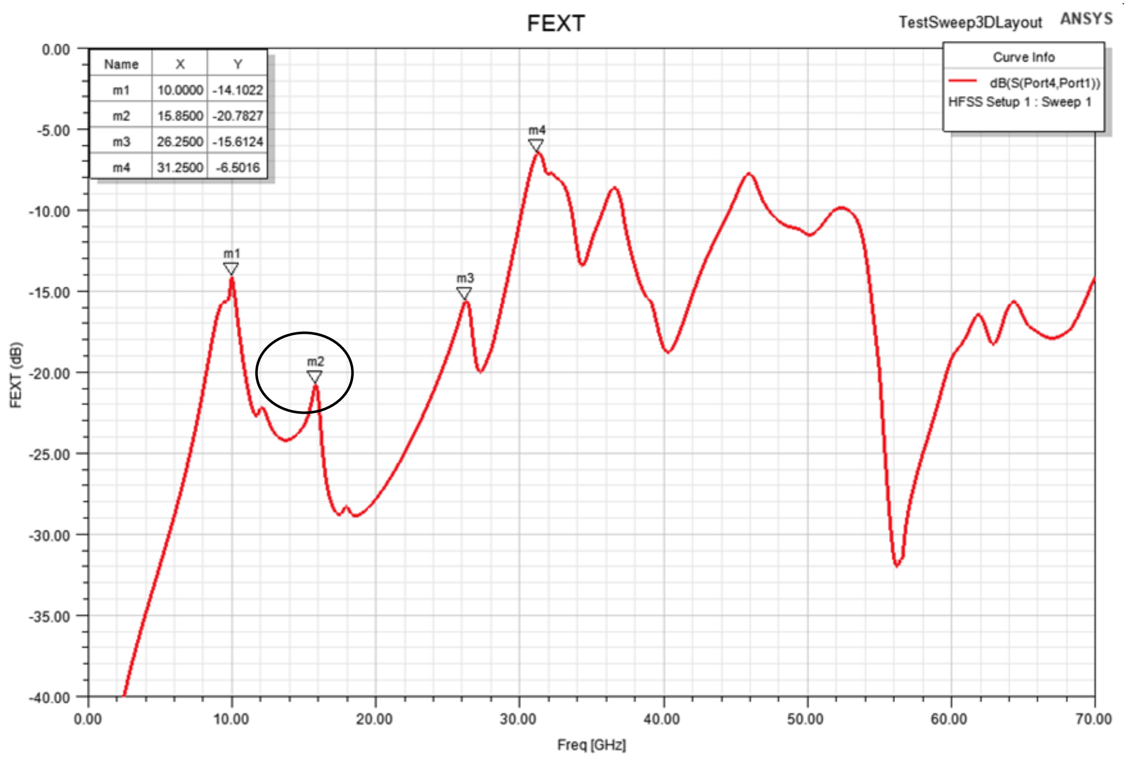
10 GHz Resonance





15.85 GHz Resonance





26.3 GHz Resonance

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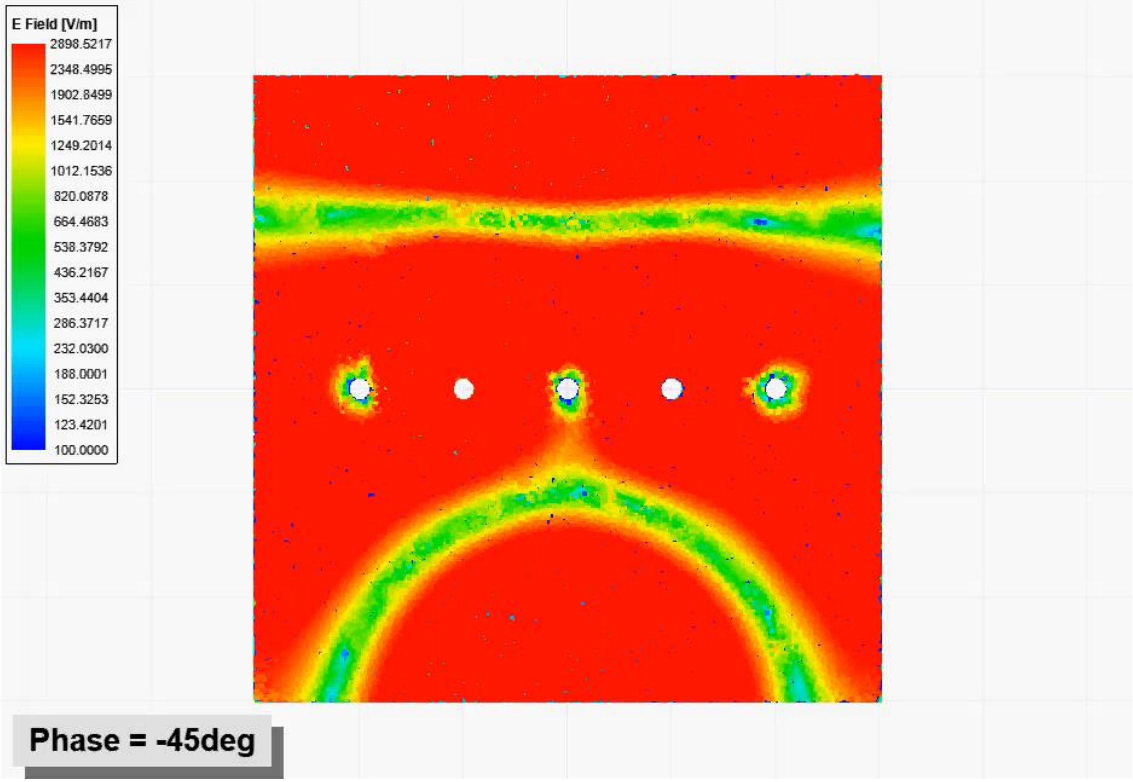
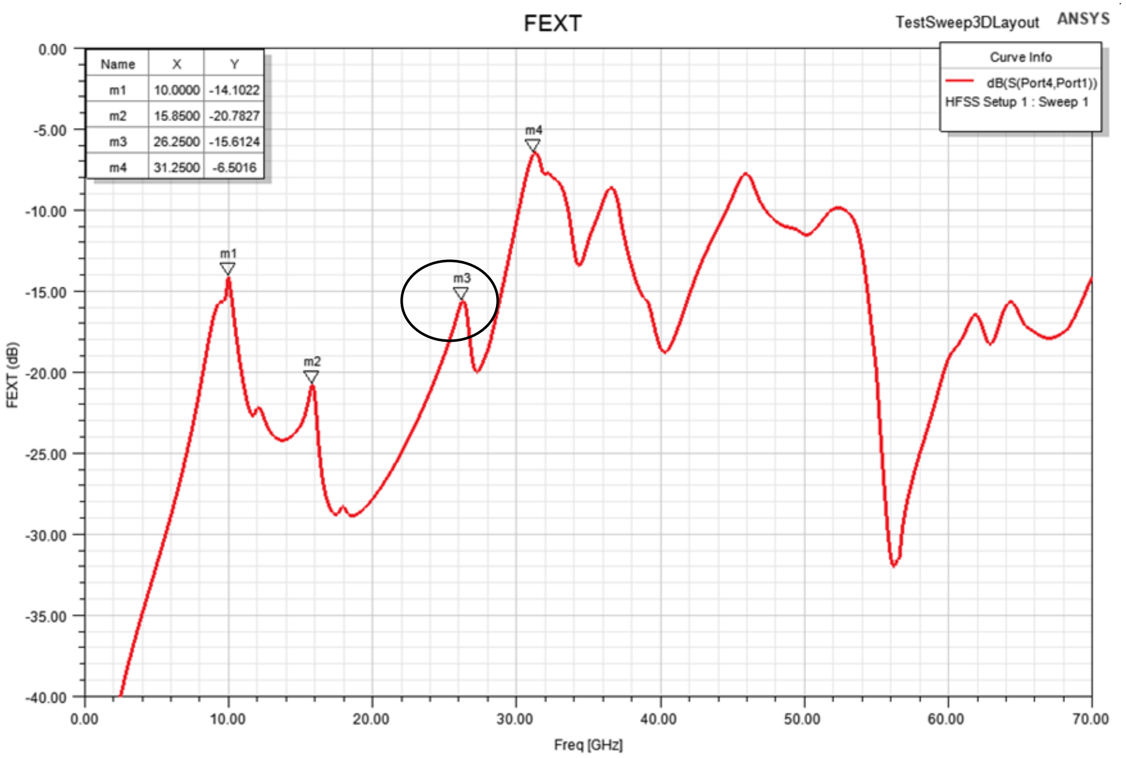
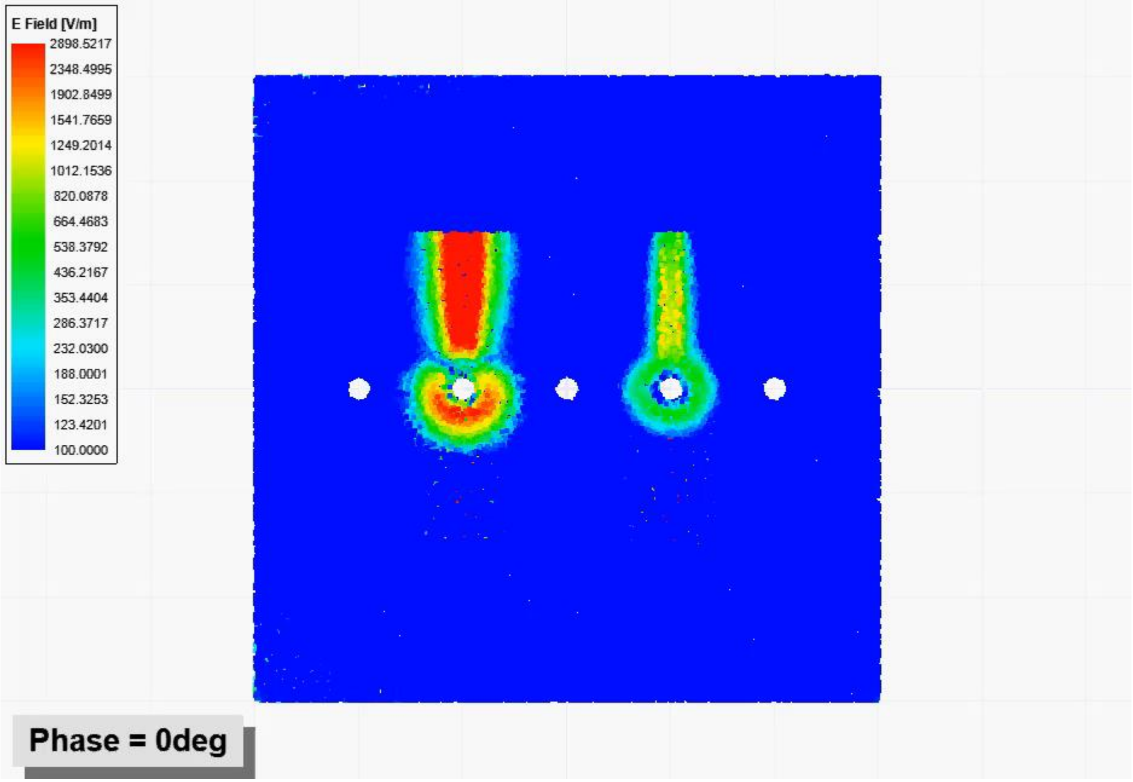
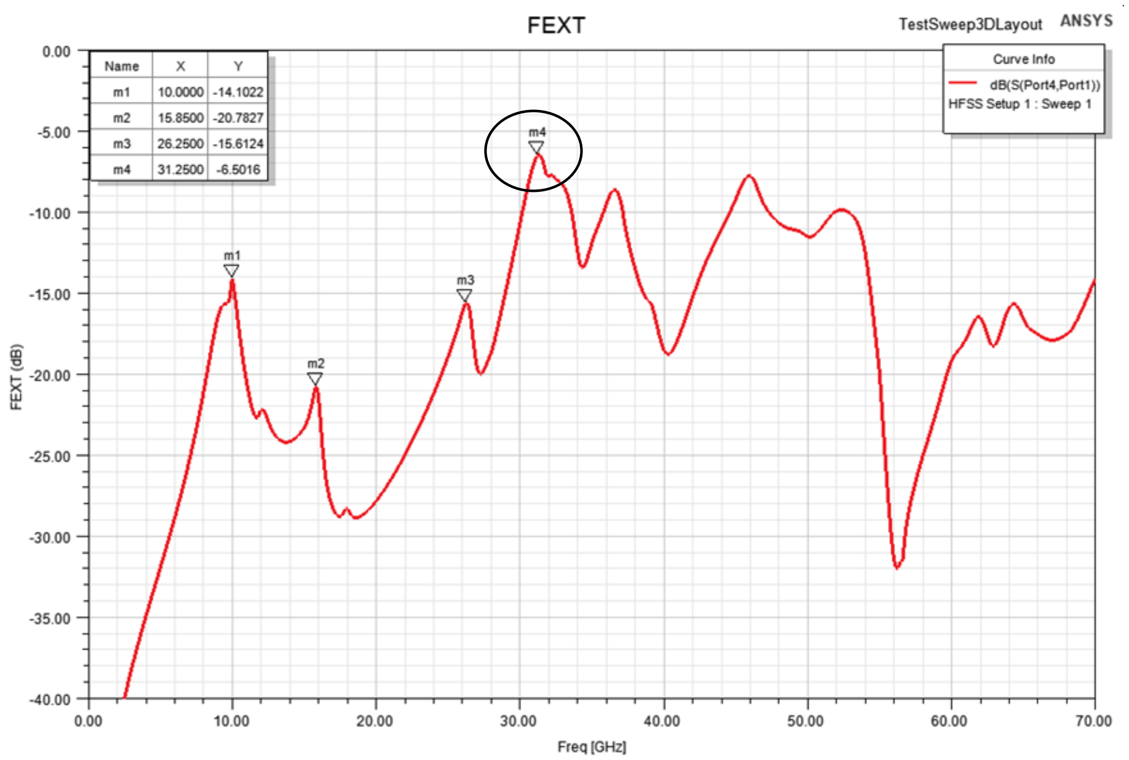


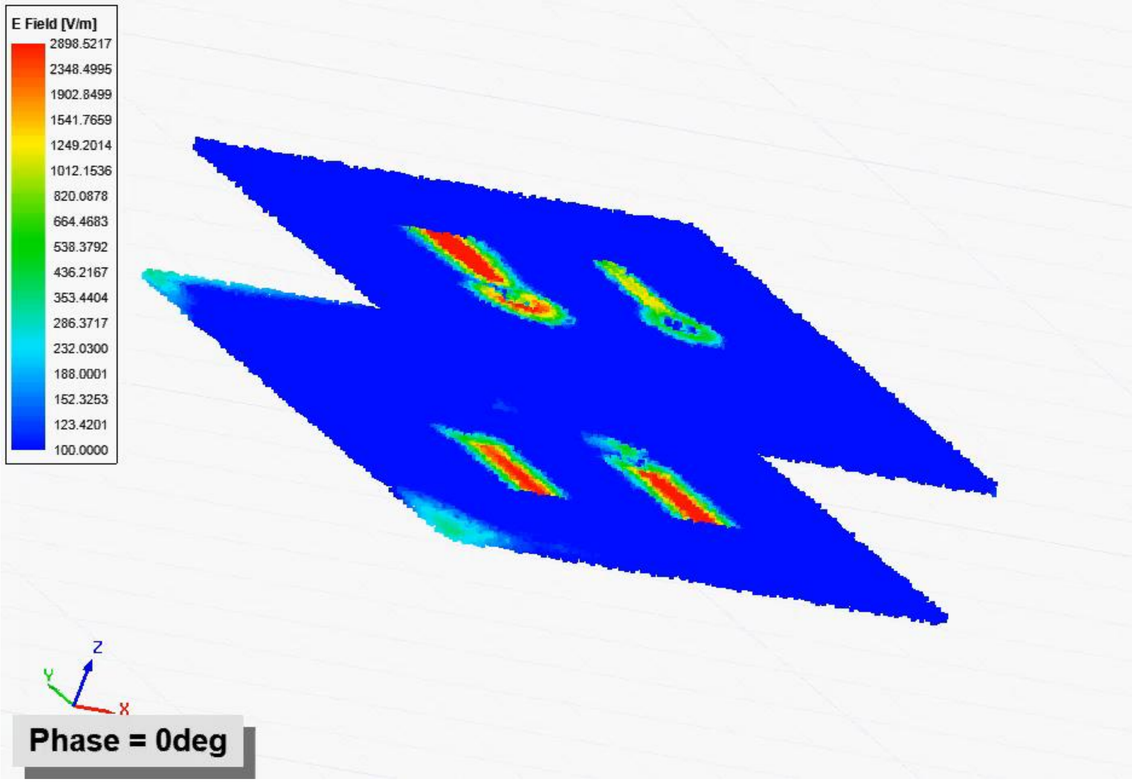


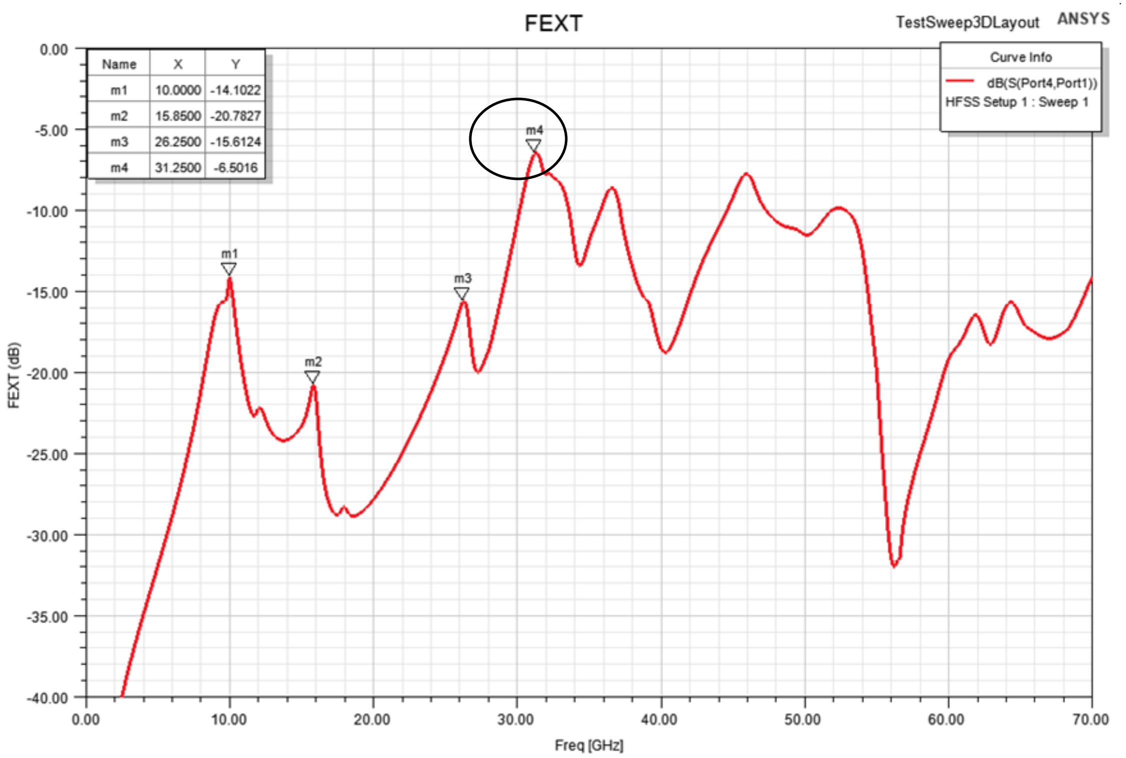
31.35 GHz Resonance
Top View





31.35 GHz Resonance Full View





Name	X	Y
m1	10.0000	-14.1022
m2	15.8500	-20.7827
m3	26.2500	-15.6124
m4	31.2500	-6.5016

Summary

- Optimization of 112 Gbps interconnect structures in EM solvers strongly depends on the types of ports and boundaries used.
- Use 3D EM wave ports to eliminate errors at the structure interface.
- Terminate PCB/Package planes to mimic infinite planes and remove planar resonances from the simulation.
- Remember that energy is lost from a via transition. Plane termination is merely a "trick" to eliminate it from consideration during optimization.
- But do not forget that this lost energy will convert to crosstalk somewhere.
- Your job as a 112 Gbps SI engineer is to
  - Optimize for impedance control and return loss
  - Then optimize for crosstalk containment and shielding.

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