FORCE Technology

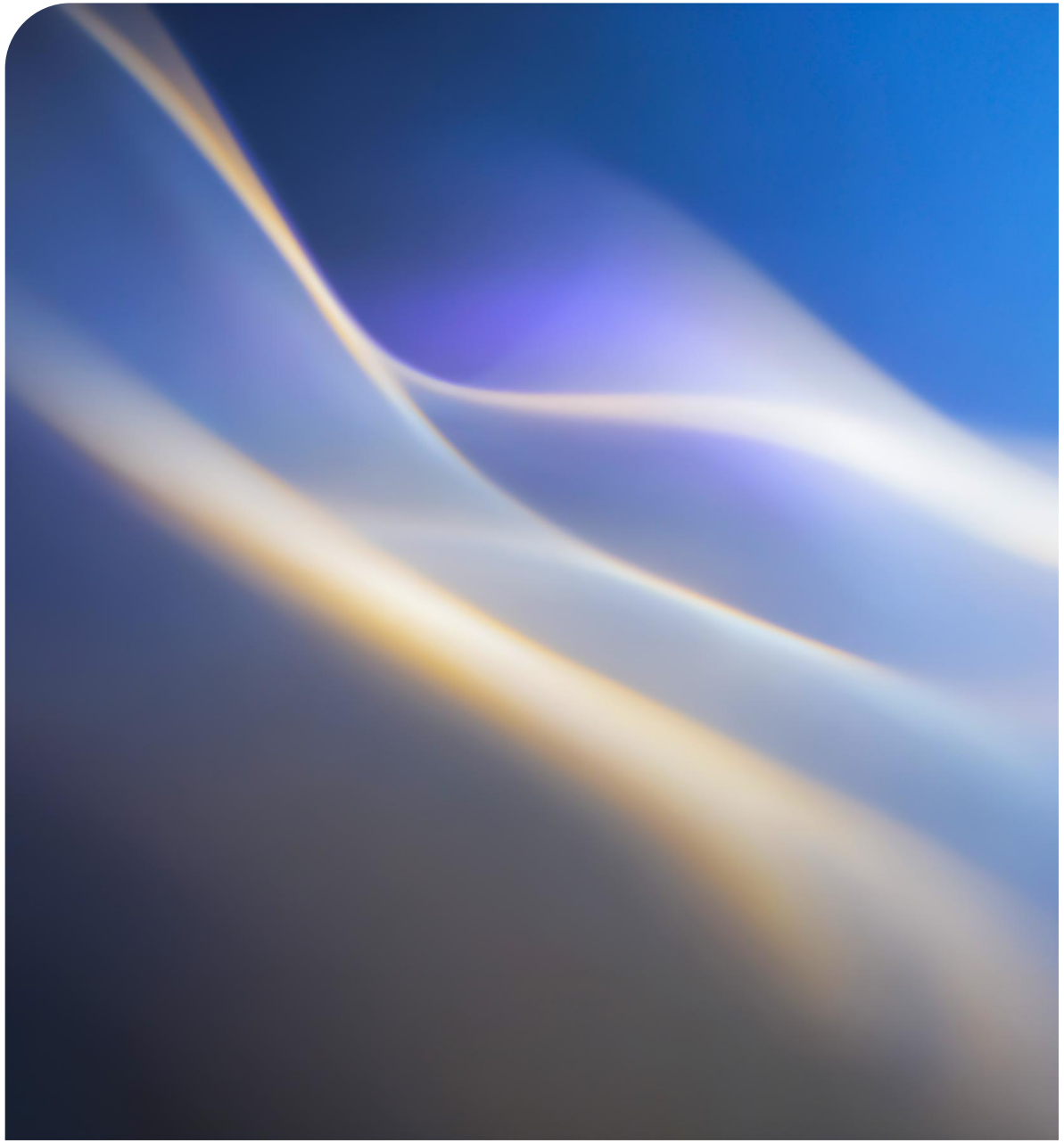
Derisking Tomorrow

3D Full-Wave Simulations in an Industrial Context

The Industry-Academic Forum on EMC

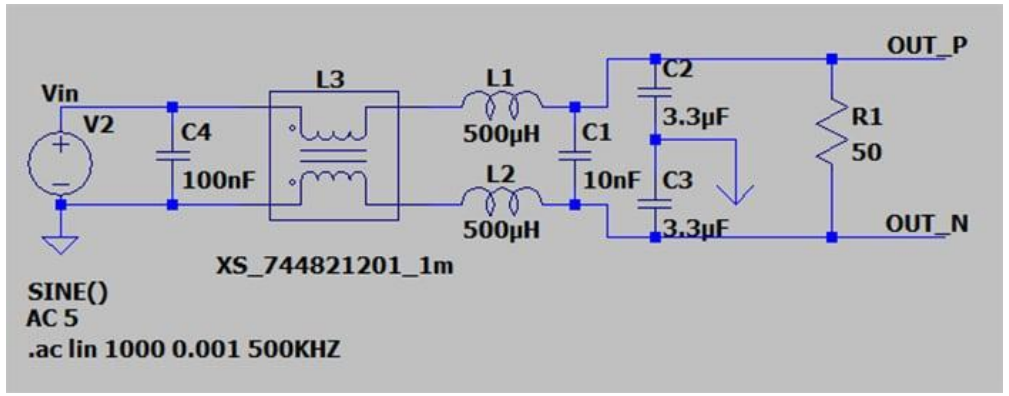
Morten Sørensen

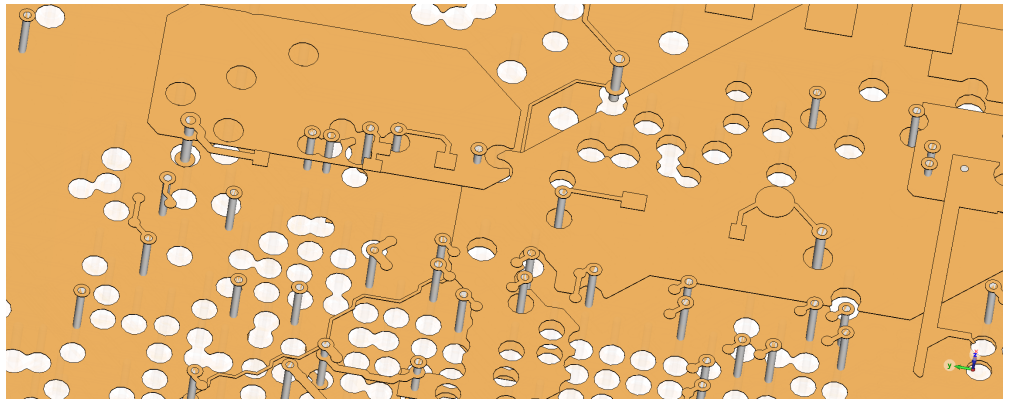
29 June, 2026



Morten Sørensen

- MSc in Physics, Aarhus University, PhD in electrical engineering, Aalborg University.
- 2006-17: Working with EMC and antennas at Bang & Olufsen a/s.
- 2017-19: Visiting Assistant Research Professor at EMCLAB Missouri University of Science & Technology and EMC research engineer at Amber Precision Instrument, San Jose.
- 2019-22: Assoc. Professor in the field of EMC at University of Southern Denmark.
- 2022: Senior Specialist, EMC, FORCE Technology.
- Competences: EMC, antennas, and propagation.





Considerations About EMC-Simulations

The Industry-Academic Forum on EMC, 2026

Morten Sørensen

29.06.2024

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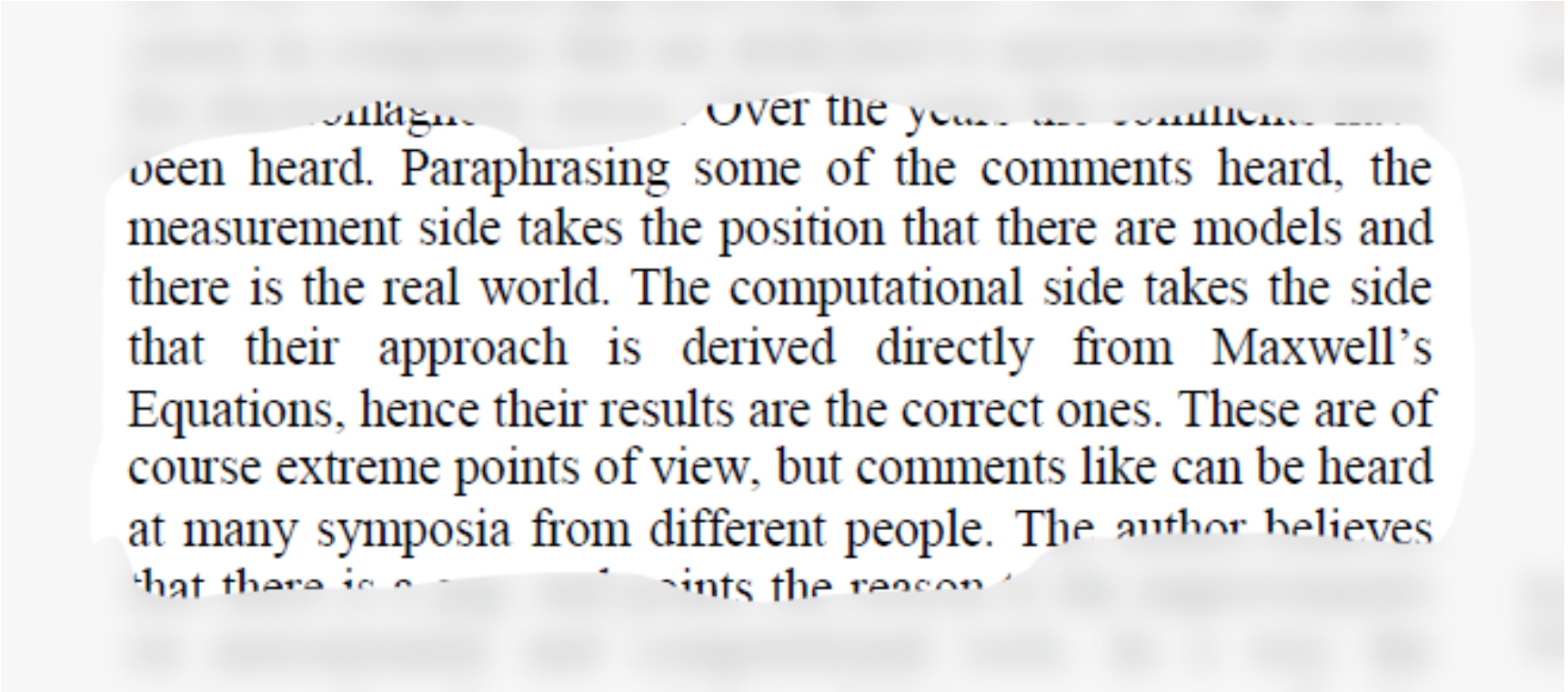
SPICE vs. 3D Full-Wave Simulations

	SPICE (Simulation Program with Integrated Circuit Emphasis)	**3D Full-wave Simulations**
Largest dimensions	< 1/10 wavelength where Kirchhoff's circuit laws are valid.	> 1/10 wavelength. Below, it often involves static/quasi-static solvers with fundamental approximations such as decoupled **E** and **H.**
Method	Takes a text netlist describing the circuit elements and their connections and translate this description into equations to be solved.	Solves Maxwell's equations for a physical representation of the circuit.

SPICE vs. 3D Full-Wave Simulations

	SPICE (Simulation Program with Integrated Circuit Emphasis)	**3D Full-wave Simulations**
PCB Layout, signal interactions, and effect of physical structures etc.	Non-ideal behavior must be estimated and included manually in the simulation.	Naturally included through the solution of Maxwell's equations.
Component behavior, e.g., MOSFET characteristic	Included in SPICE models.	Not included. Co-simulation possible.
Application	Predict the performance of electronic circuits.	Predict the electromagnetic behaviour of the complete system.

The Gap Between Measurements and Simulations

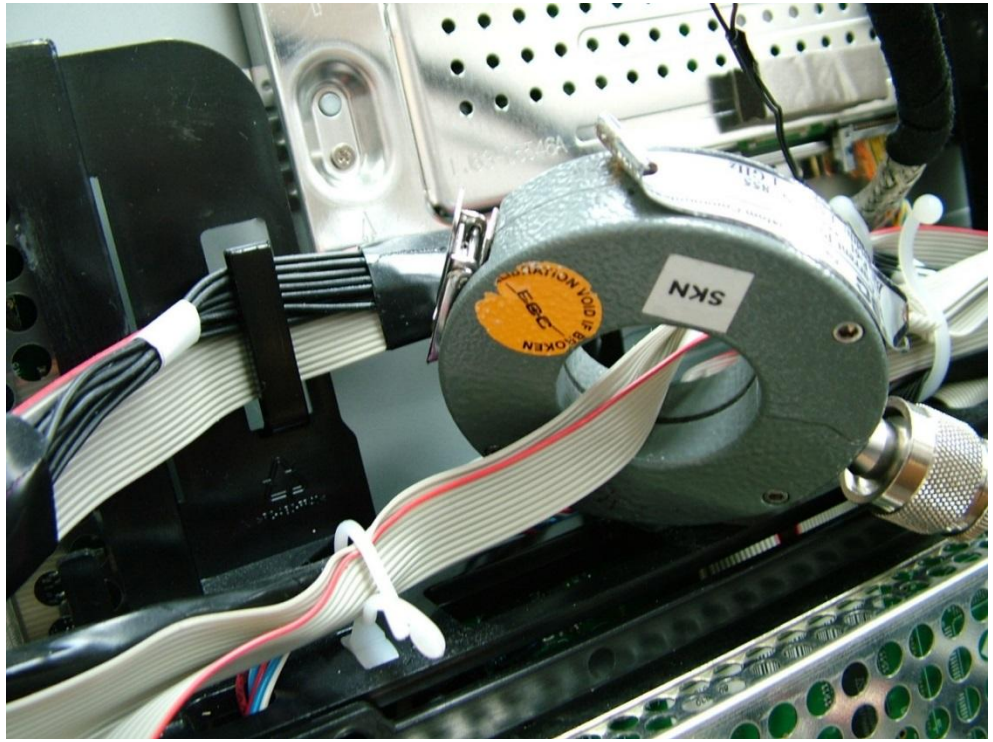


been heard. Paraphrasing some of the comments heard, the measurement side takes the position that there are models and there is the real world. The computational side takes the side that their approach is derived directly from Maxwell's Equations, hence their results are the correct ones. These are of course extreme points of view, but comments like can be heard at many symposia from different people. The author believes

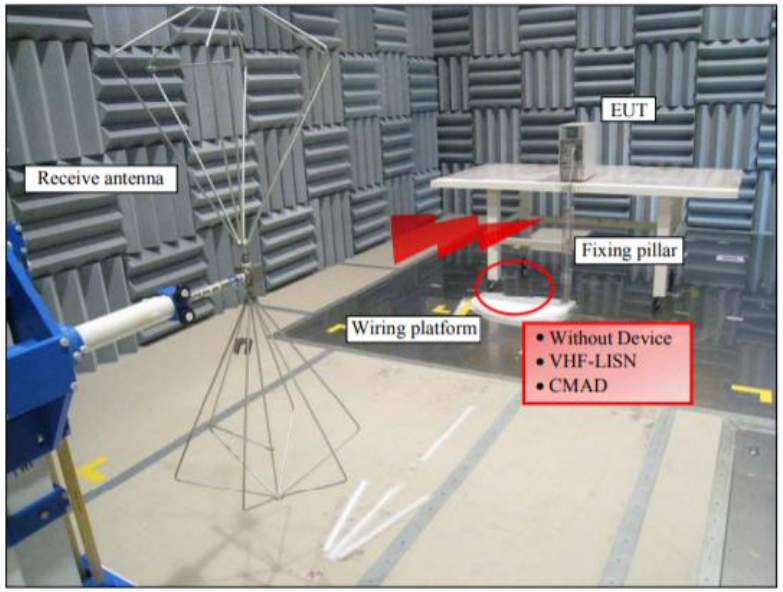
Bridging the gap: Bringing measurements and computational results together, *Antennas and Propagation (EuCAP), 2015 9th European Conference on,* Vince Rodriguez

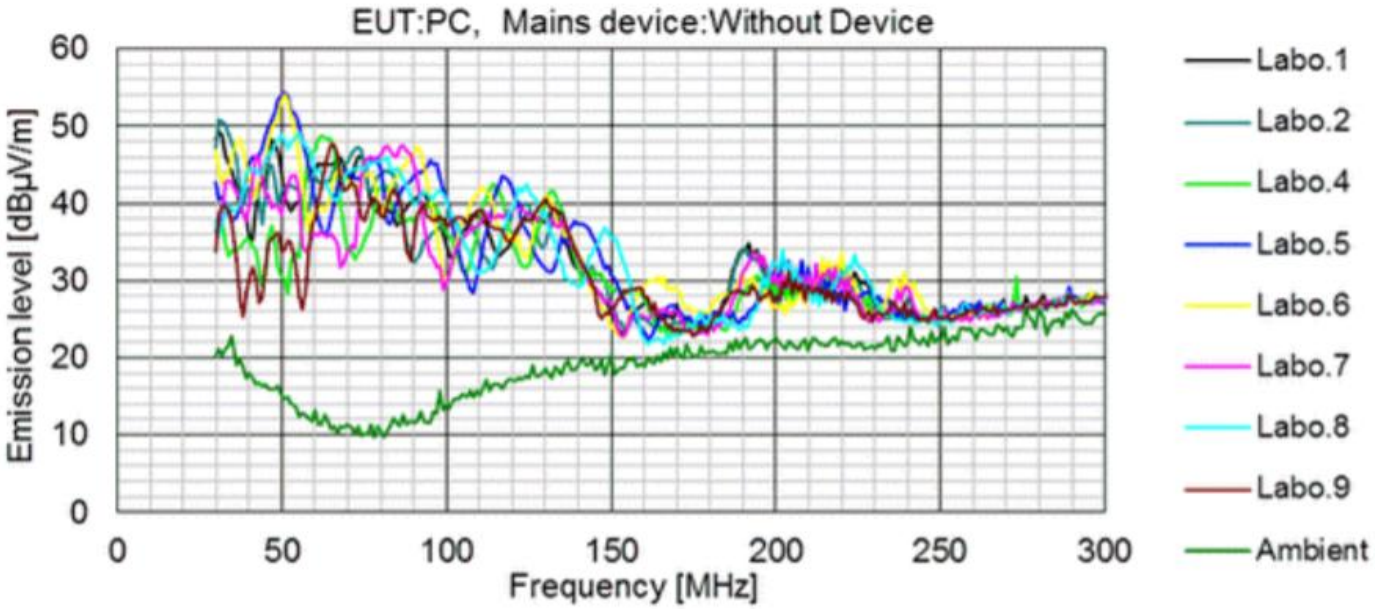
Are Measurements Correct?

- Observer effect
  - From physics we know that the act of observation will affect the phenomenon being observed (observer effect).
  - Ammeter/voltmeter present an additional load to the circuit.
  - A current clamp changes characteristic impedance of the wire being measured because of mutual inductance.
  - Measurement uncertainty in general



Are Measurements Correct? – Round Robin Test





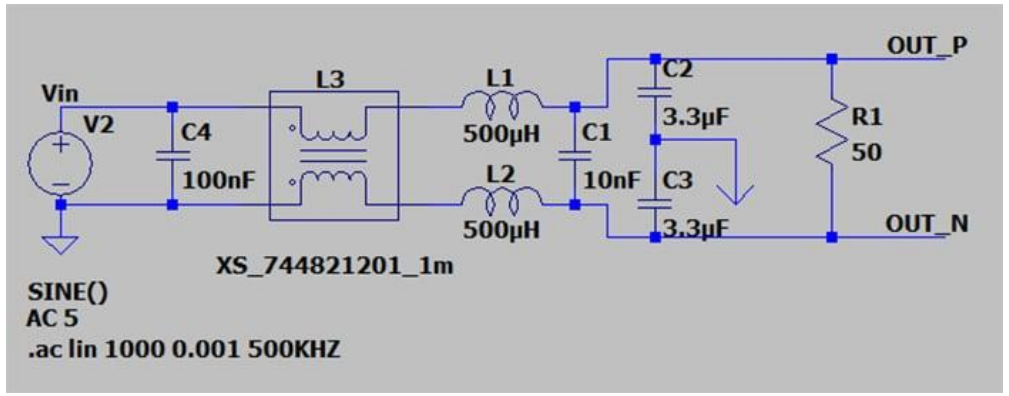
S. Okuyama, K. Osabe, K. Tanakajima and H. Muramatsu, "Investigation on effectiveness of very high frequency line impedance stabilization network (VHF-LISN) for measurement reproducibility," 2013 International Symposium on Electromagnetic Compatibility, Brugge, Belgium, 2013, pp. 174-179.

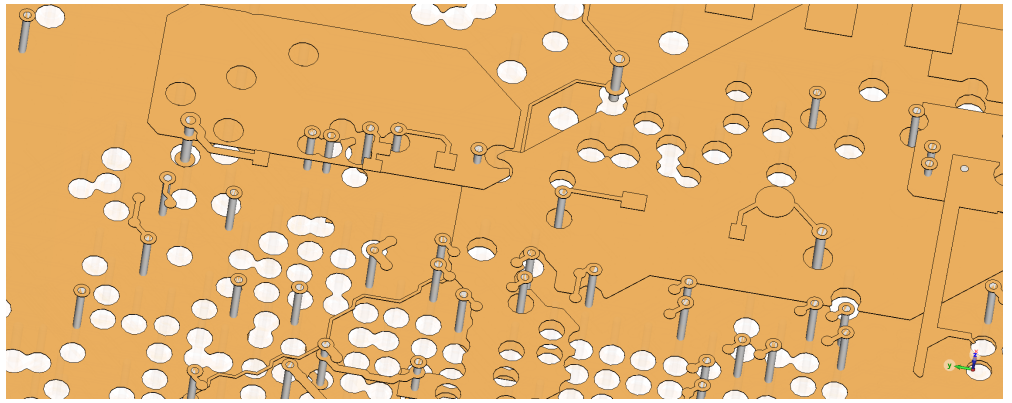
Are Simulations Correct?

- Simulations are no better than the input: Garbage in, garbage out (garbage in, Hollywood out).
- Unknown material properties.
- Physical simplifications.
- Simulation uncertainties: Meshing, numerical dispersion, truncation errors etc.

Measurements vs. Simulations

- There is a gap between measurements and simulations.
- **Neither simulations nor measurements represent the absolute truth.**
- (Measurements are per definition “correct” with respect to test and approval. What about the future?)
- When simulation and measurements agree, I am confident in both results.
- Measurements and simulations can benefit from each other.
- Understanding the results is important.





A few Examples From the Industry

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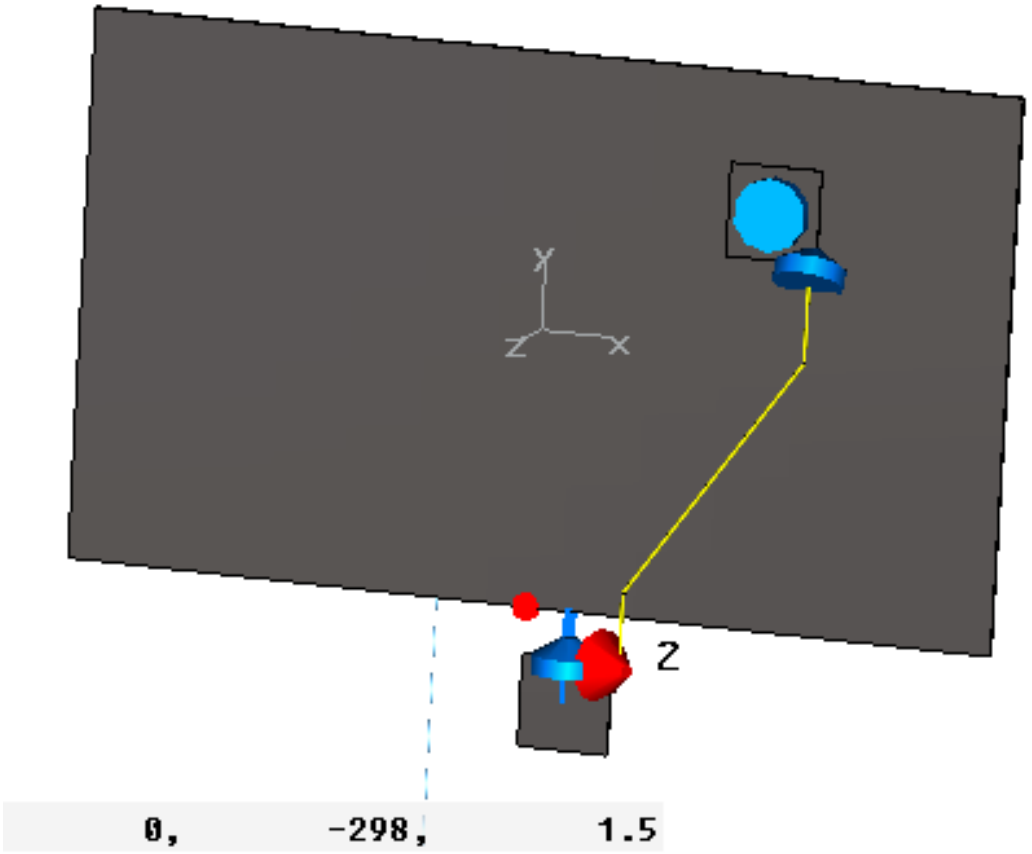
Opening Remarks

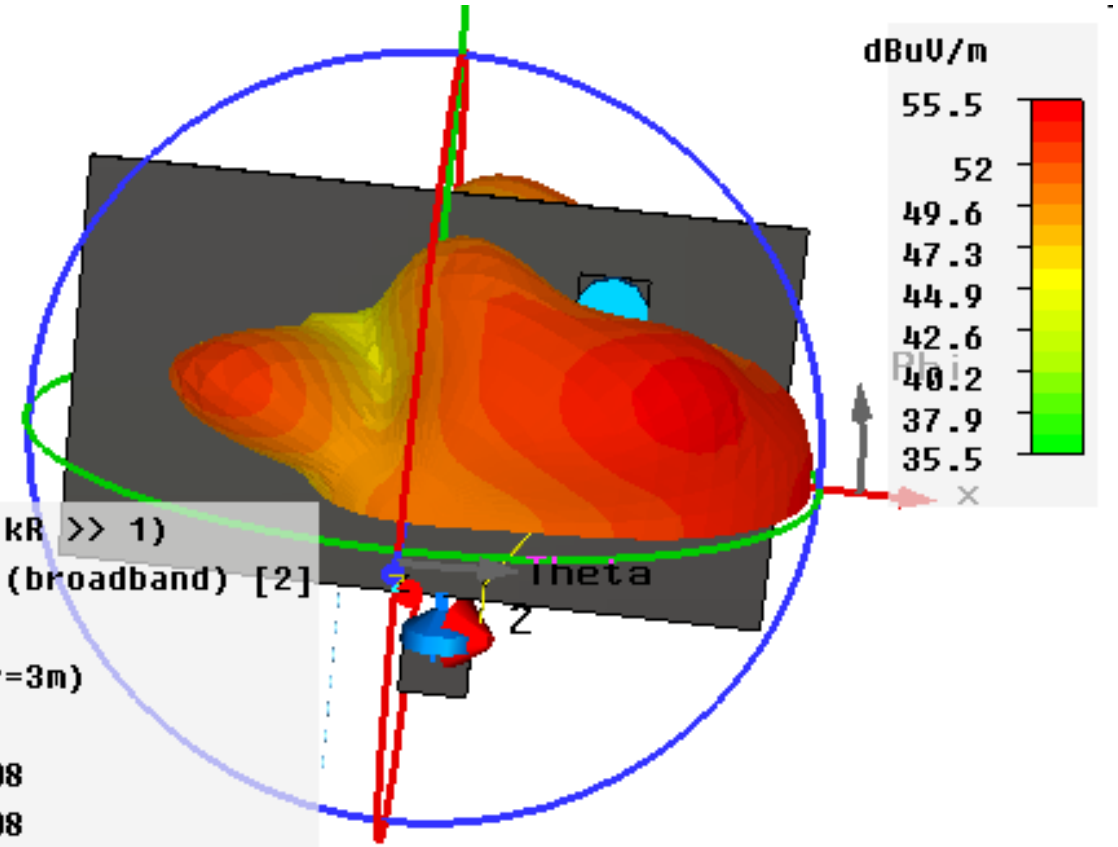
- A few examples from everyday engineering work.
- No common theme.
  - Purpose: To provide inspiration for how simulations can be used in industrial EMC.
  - Not fancy or deeply theoretical—just practical, everyday examples.
- The technical details will not be covered.

Radiated Emission from Long Cable in BeoVision 7



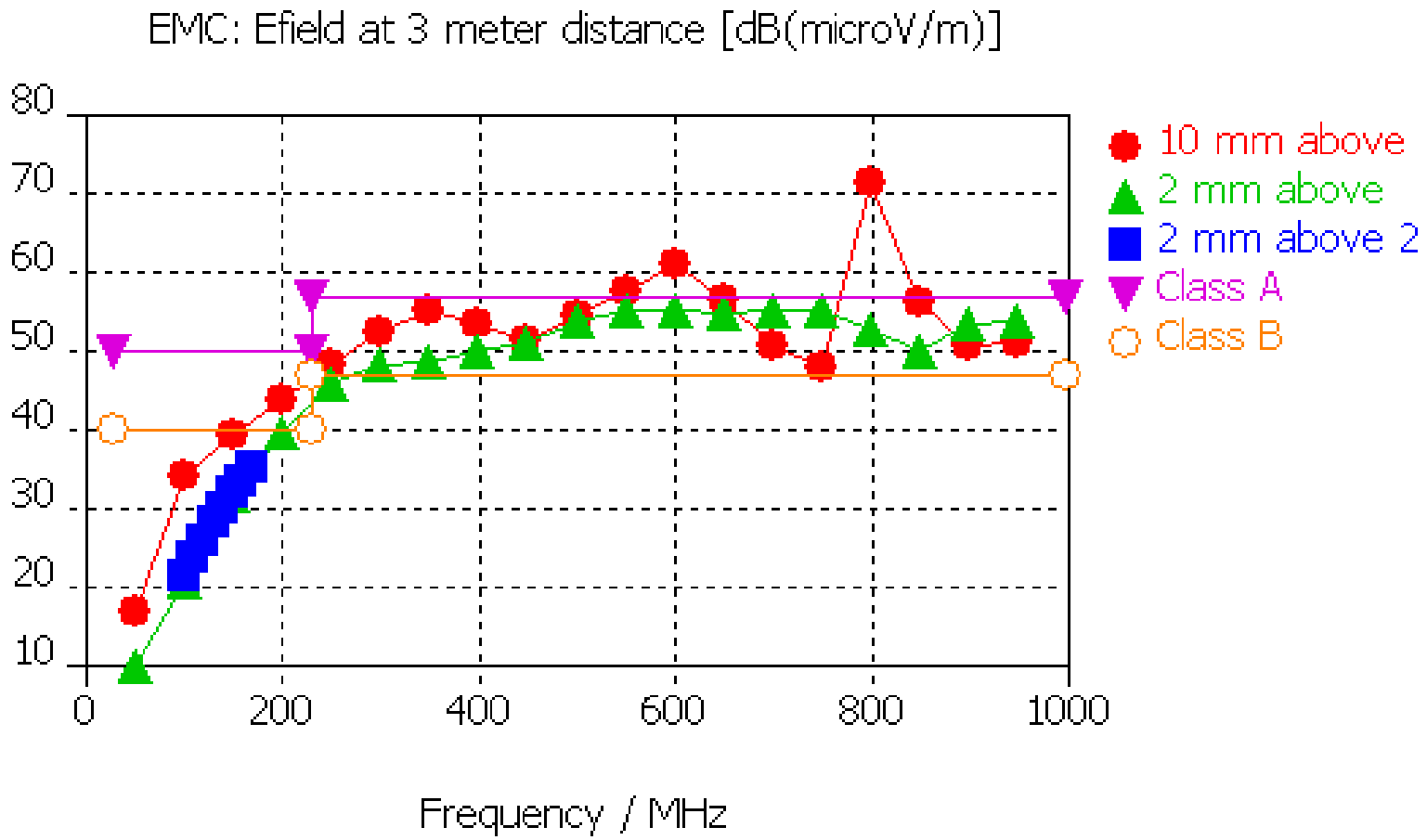
Current generator 10 µA. A few µA over common mode current requirements.

Farfield @ 500 MHz



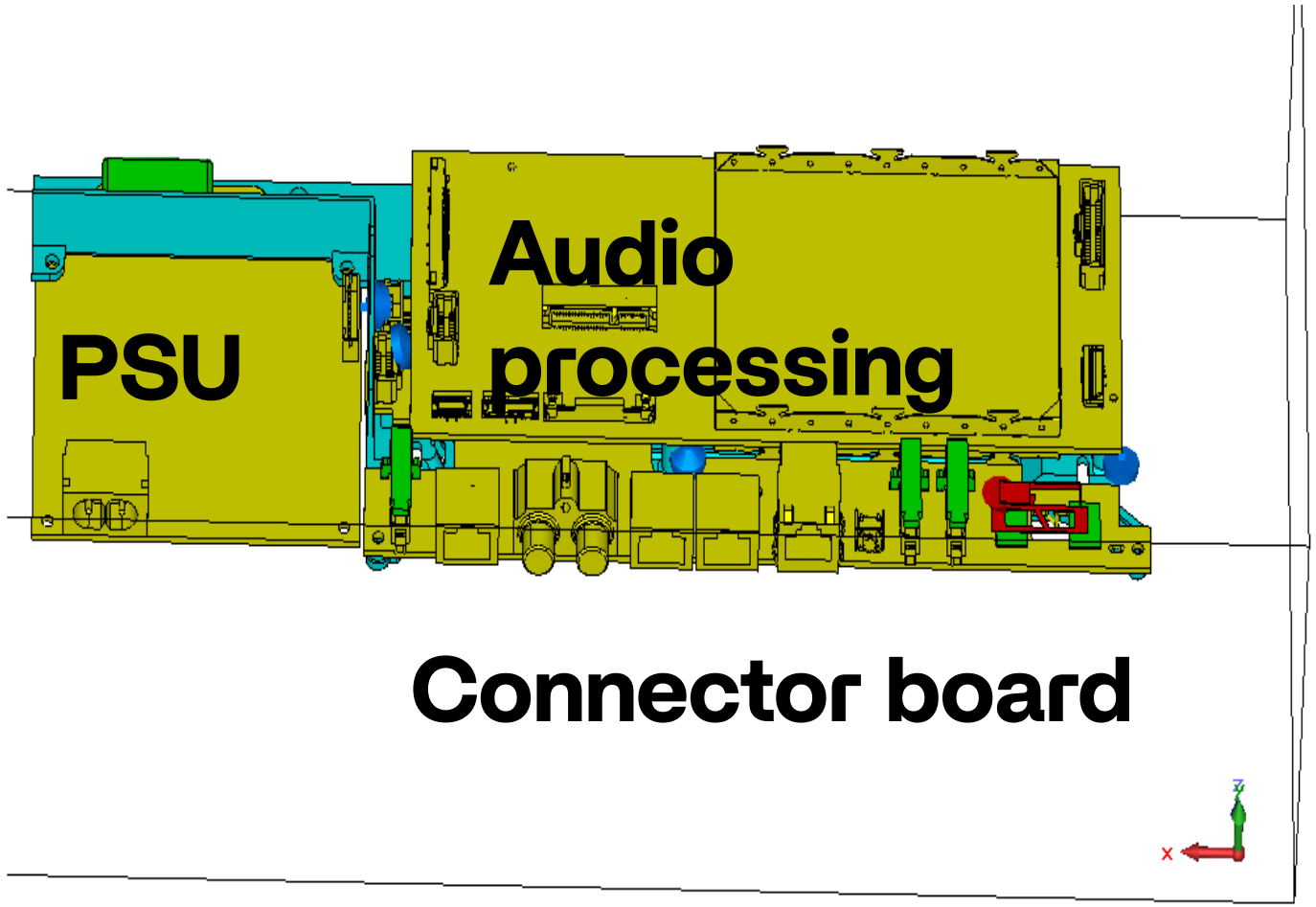
Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (broadband) [2]
Component	Abs
Output	E-Field(r=3m)
Frequency	500
Rad. effic.	1.640e-008
Tot. effic.	1.640e-008
Emax	55.52 dBuV/m

Problematic Architecture



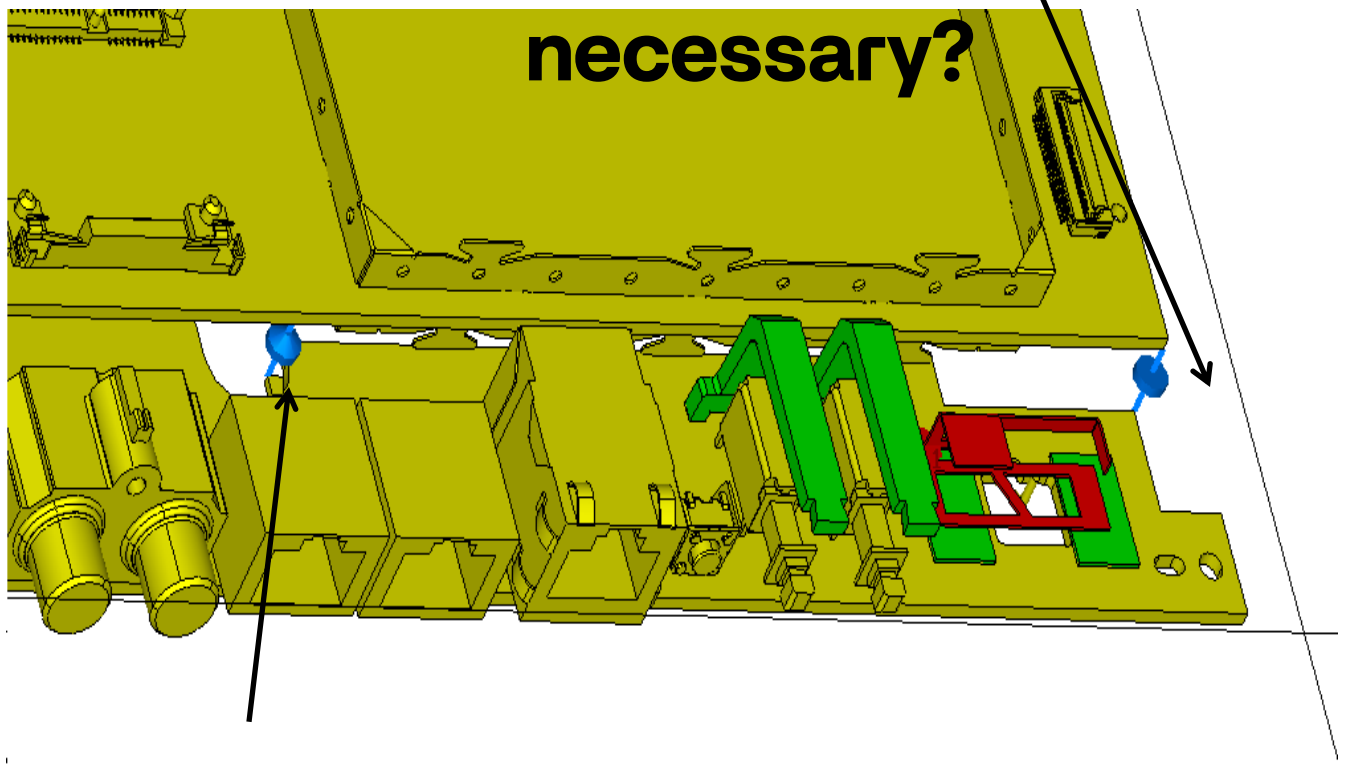
Keep cables close to chassis.

Plane Resonances Between two Modules



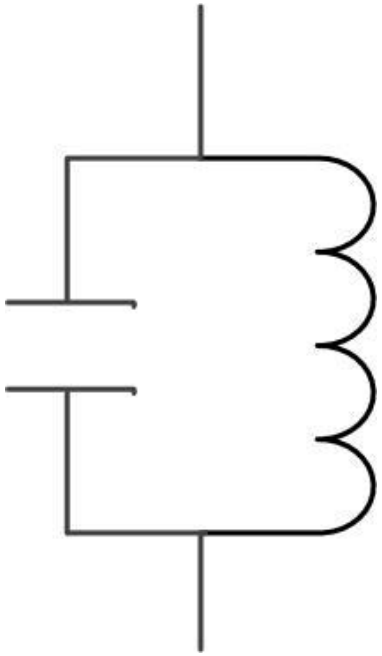
Plane Resonances Between two Modules

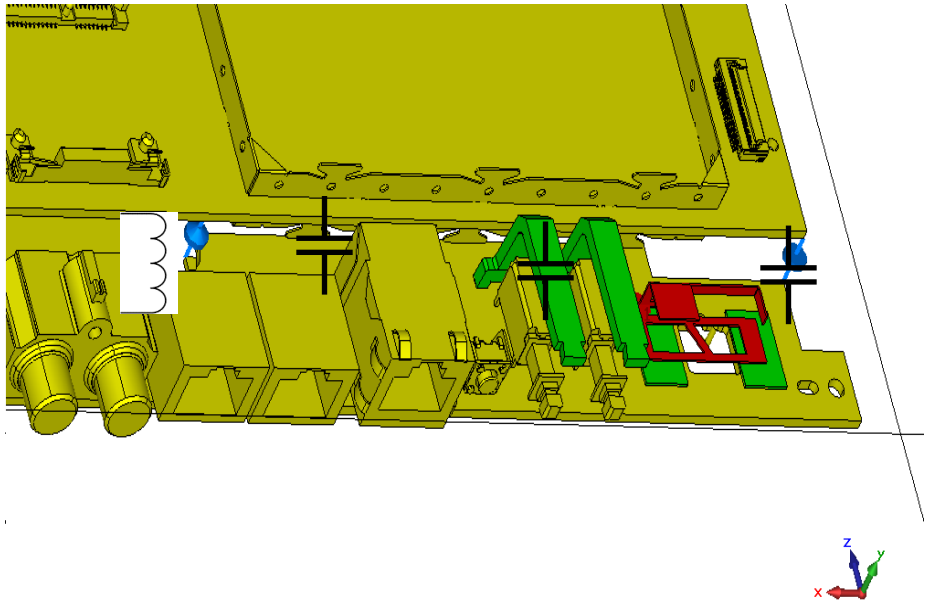
Is another screw necessary?



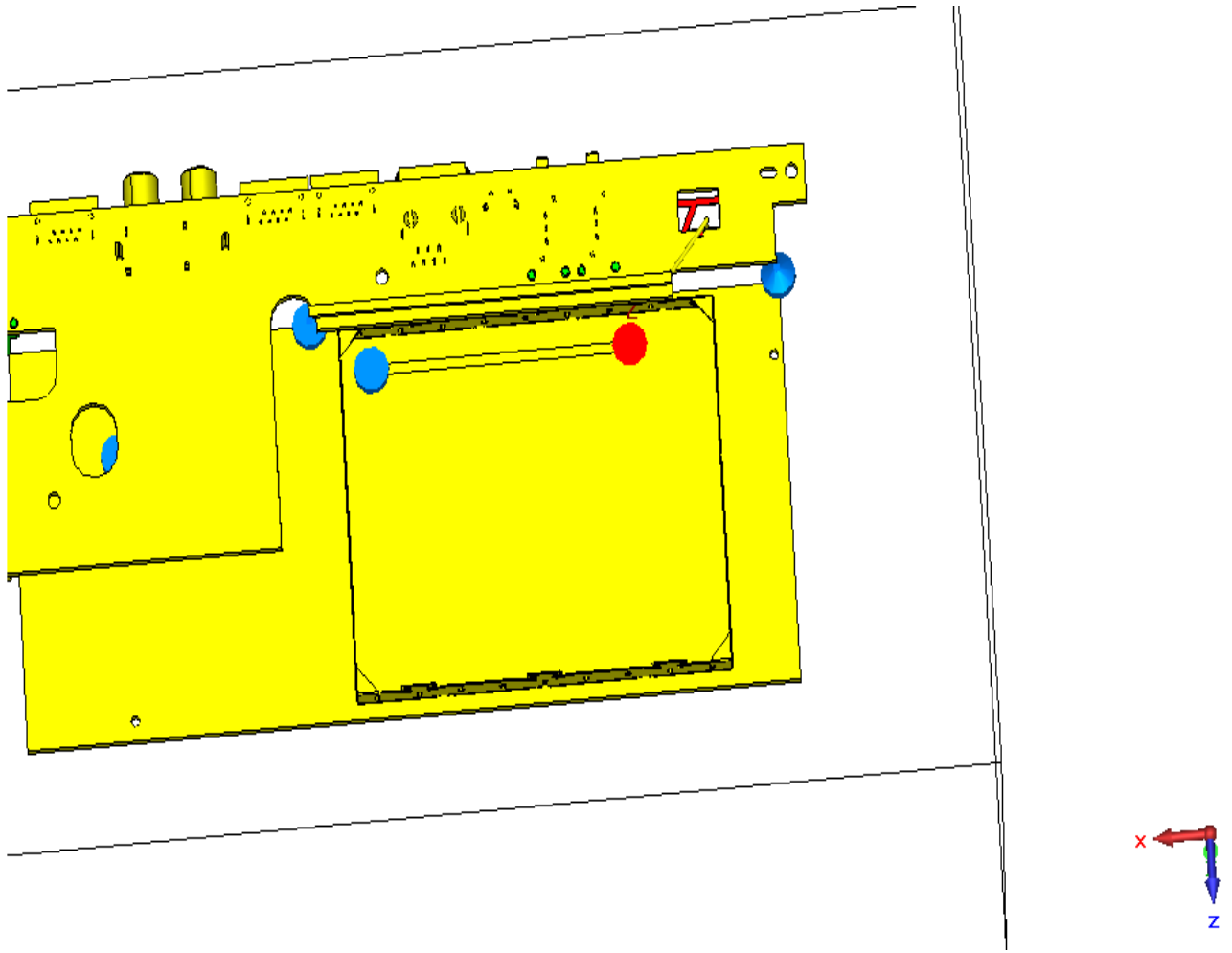
Screw with galvanic connection

Screw and Plane Capacitance can Form a Resonance

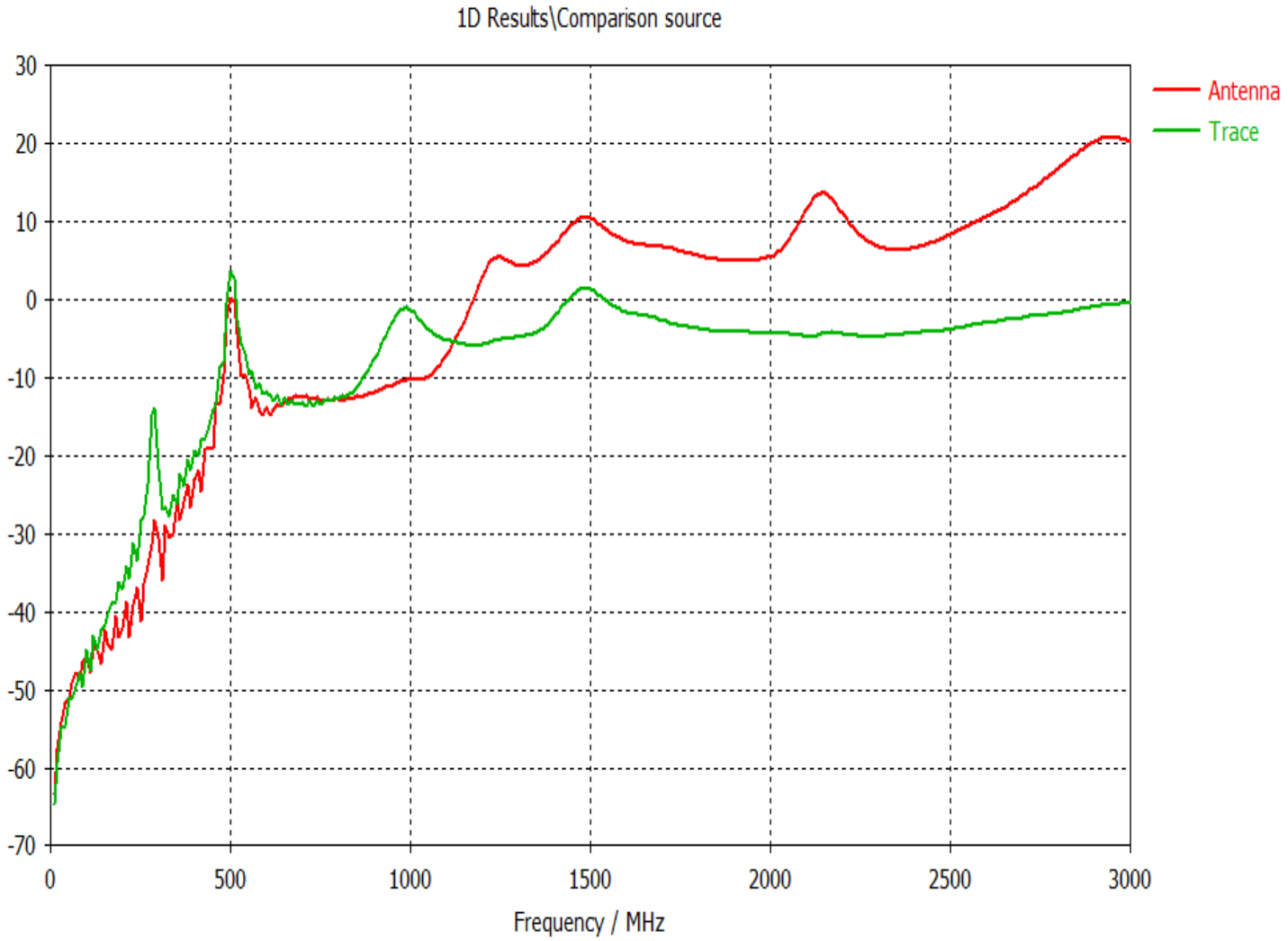


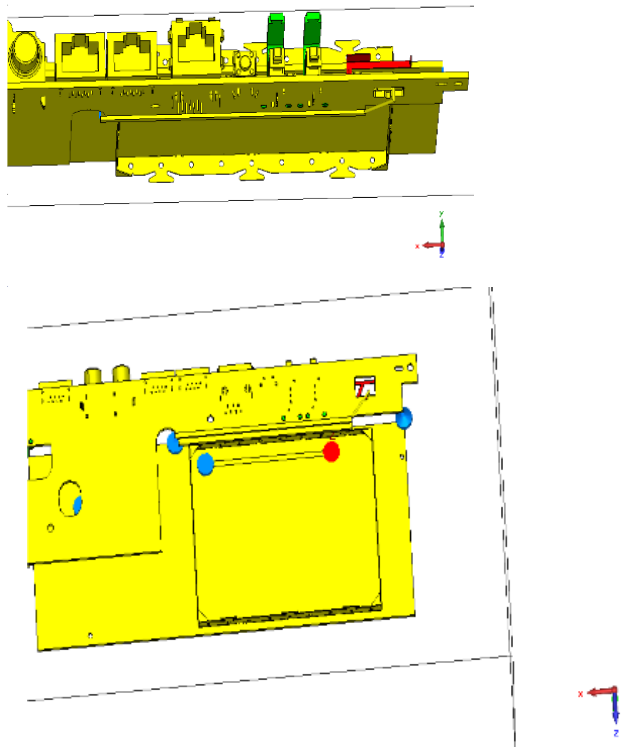


Resonance Can Possibly be Excited by Trace on Audio Module

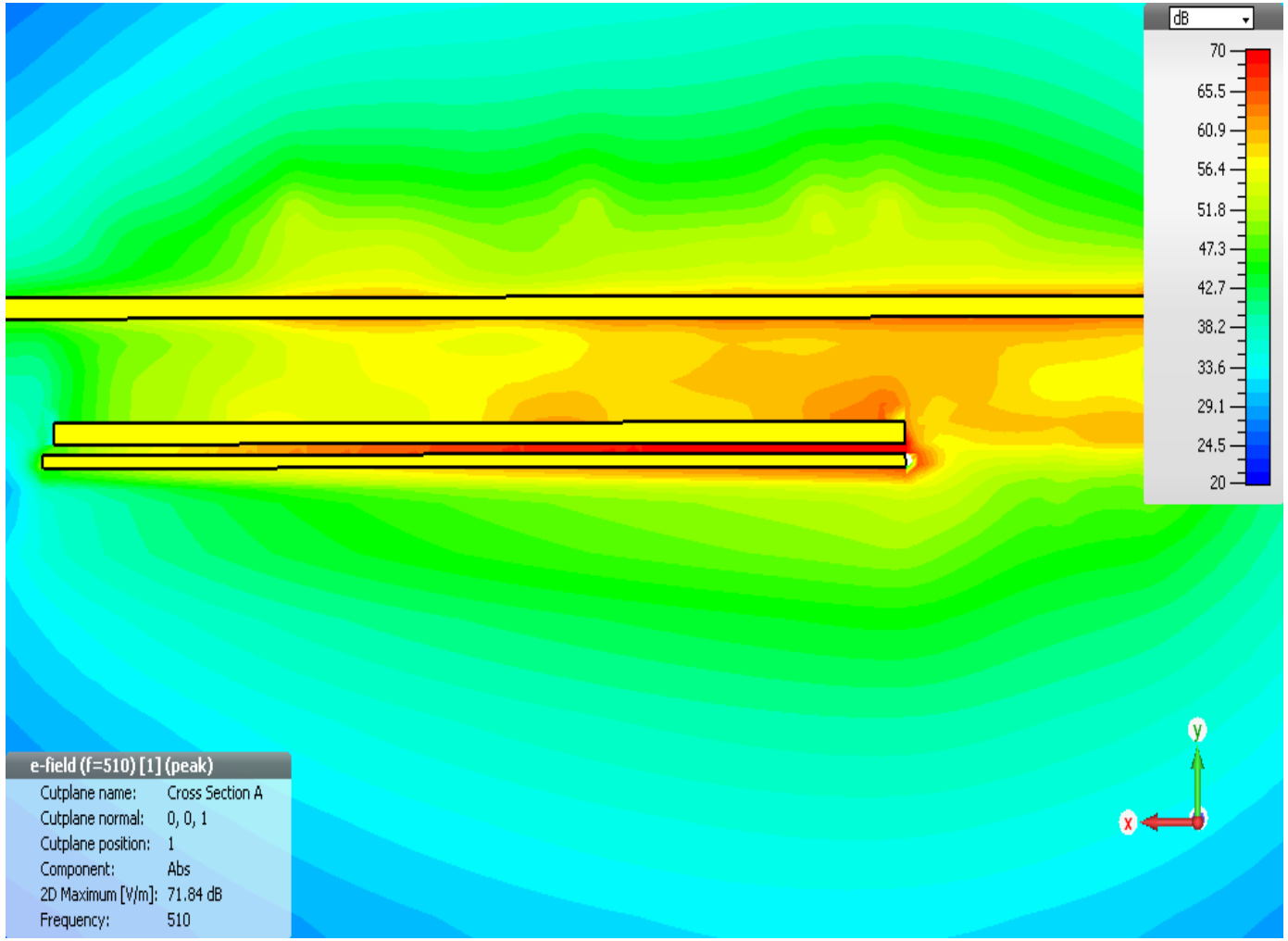


Comparison Source – no Extra Screw

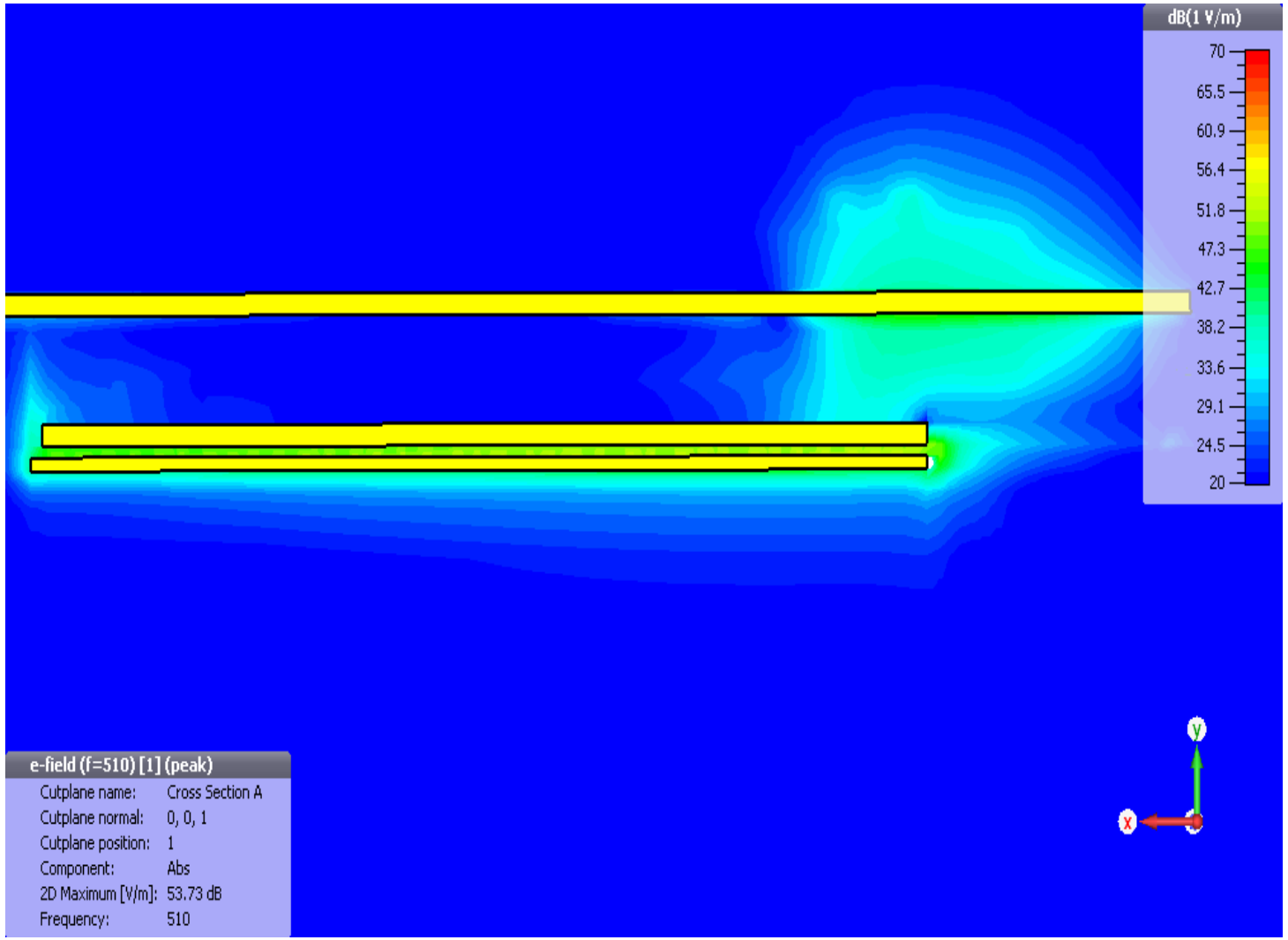




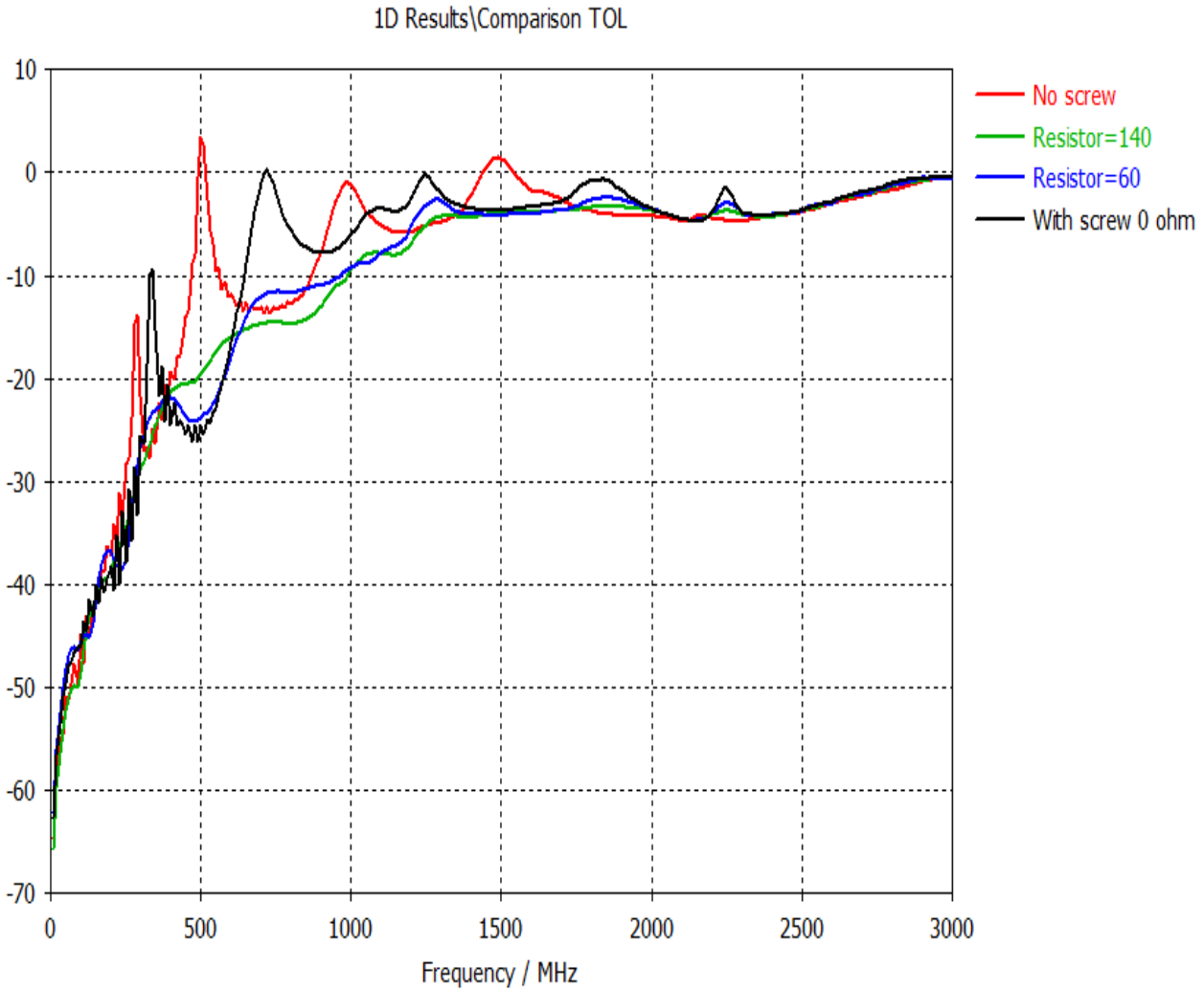
E-Field no Screw (F = 510 MHz)

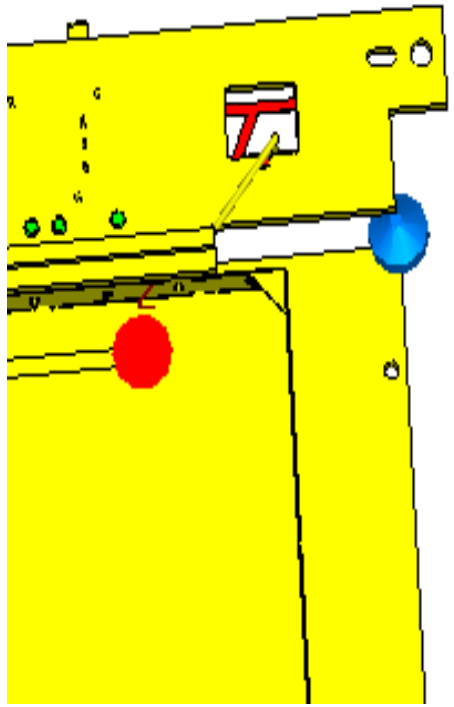


E-Field with Screw (F = 510 MHz)

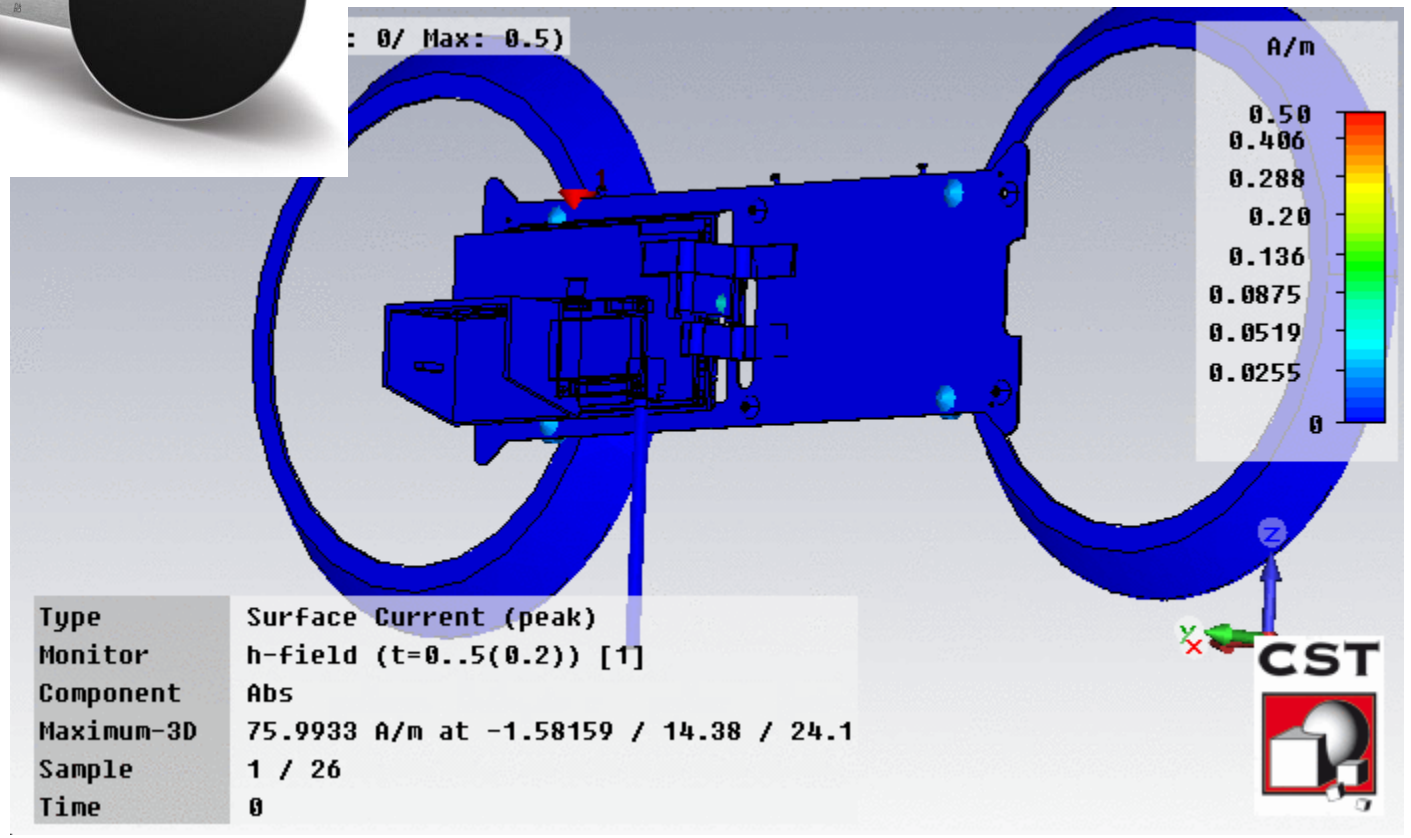


The Screw Just Moved the Resonance - Kill the Resonance





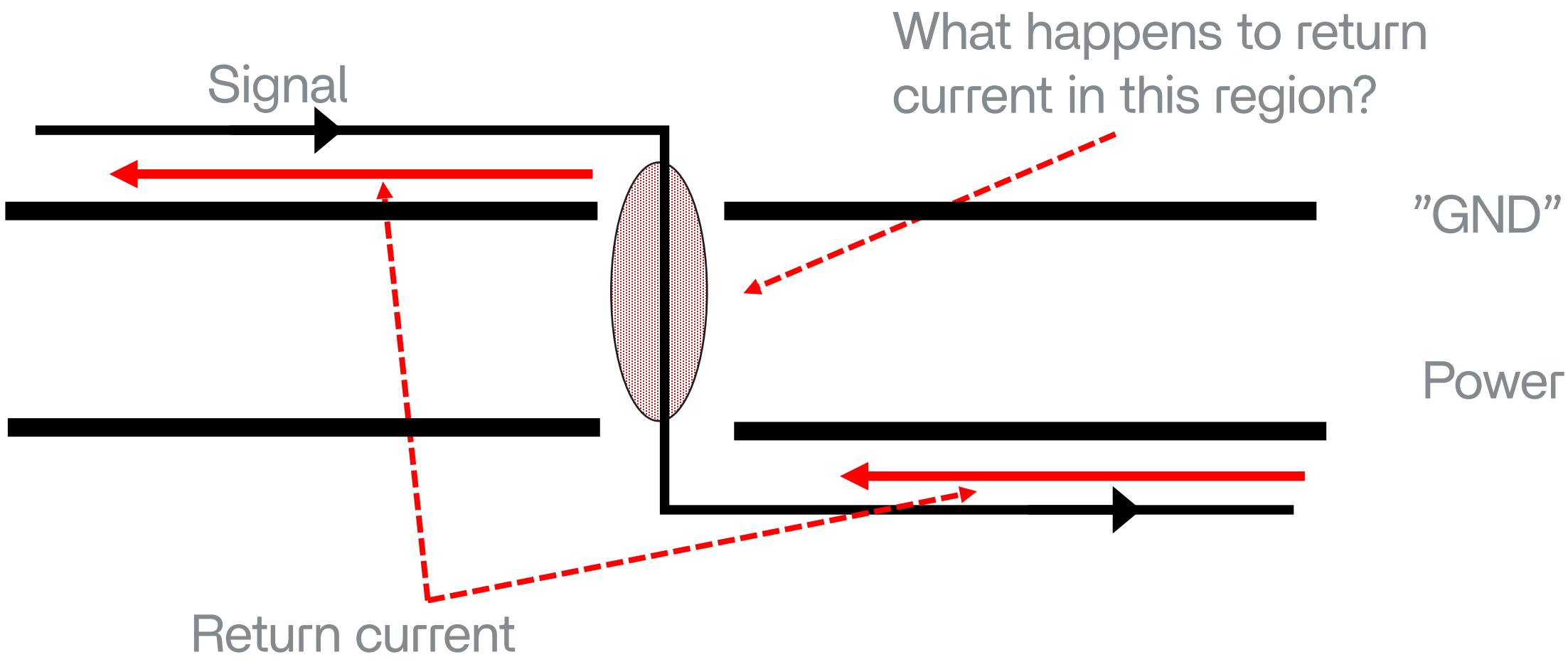
ESD design of BeoPlay A8



The Three Most Important EMC PCB Layout Rules

1. Critical signal must not change reference.
2. Critical signal must not change reference.
3. Critical signal must not change reference – but if you really must do it you must provide a return path.

How can the Return Current Flow When Signal Line Goes Through Via?



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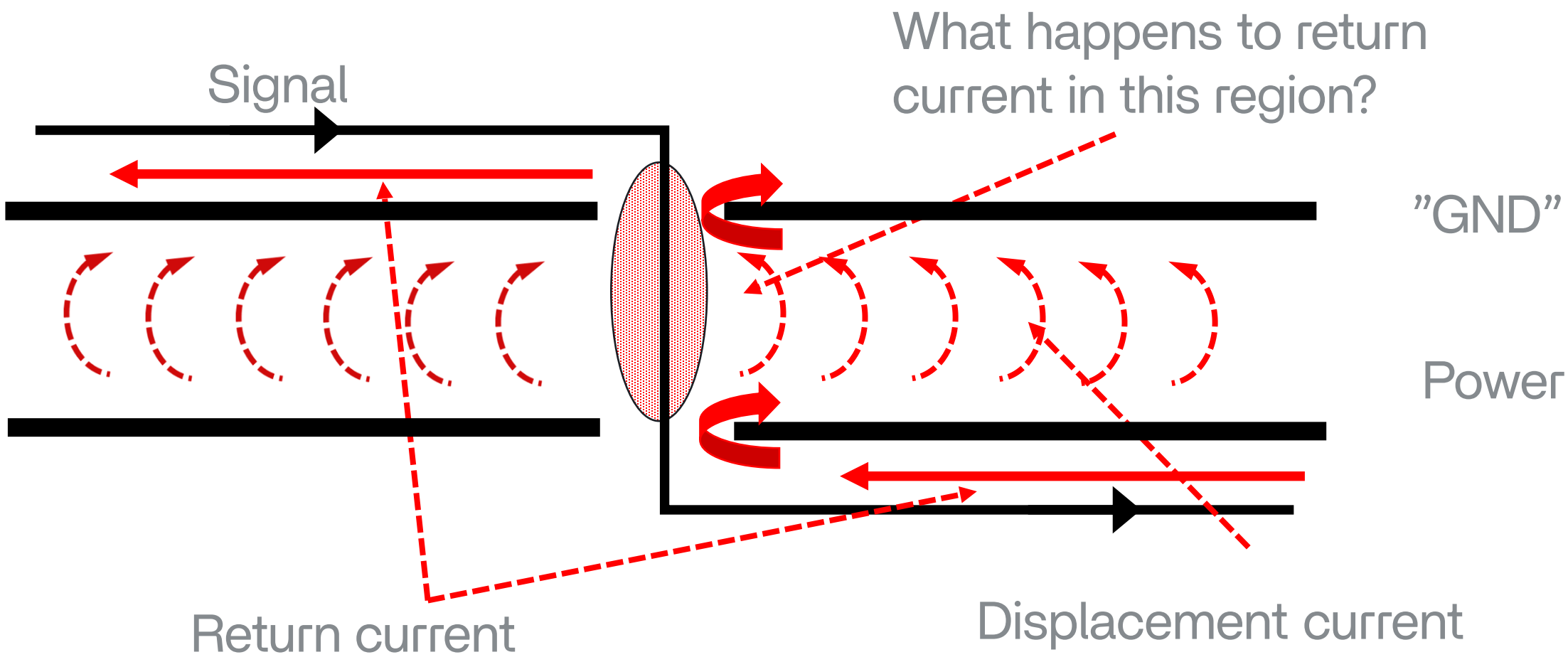

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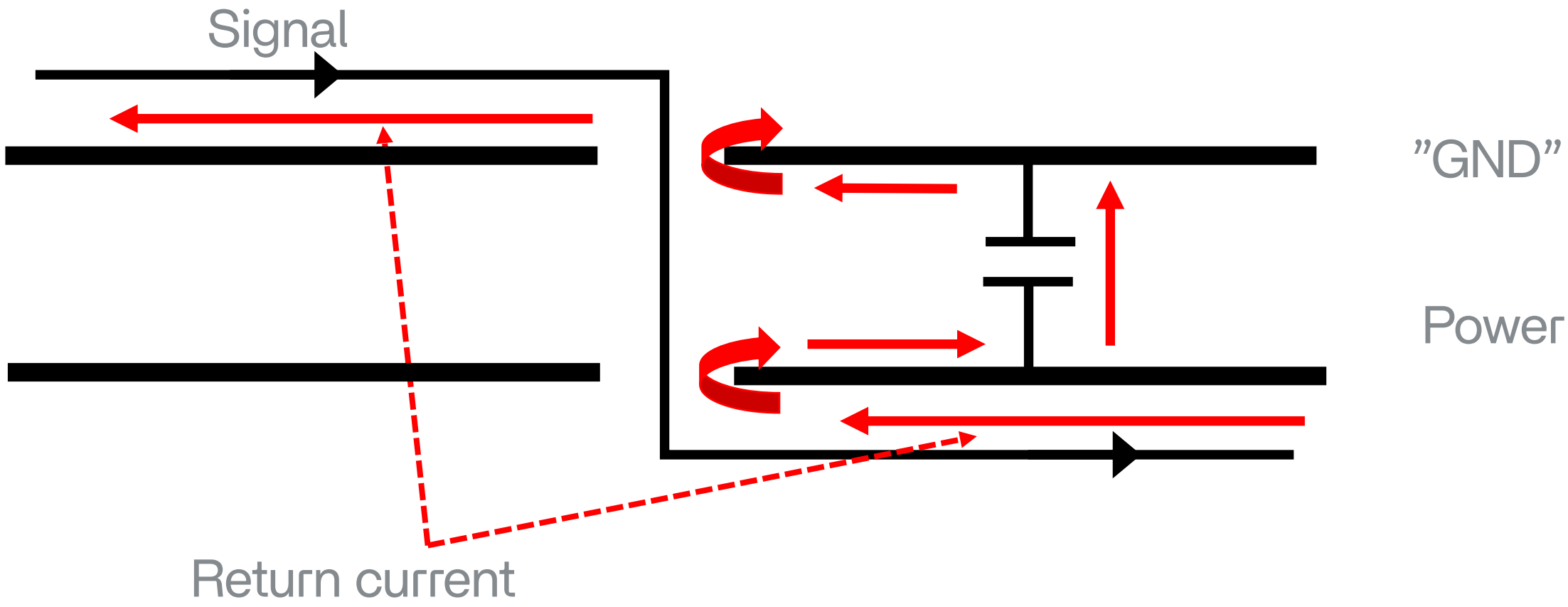
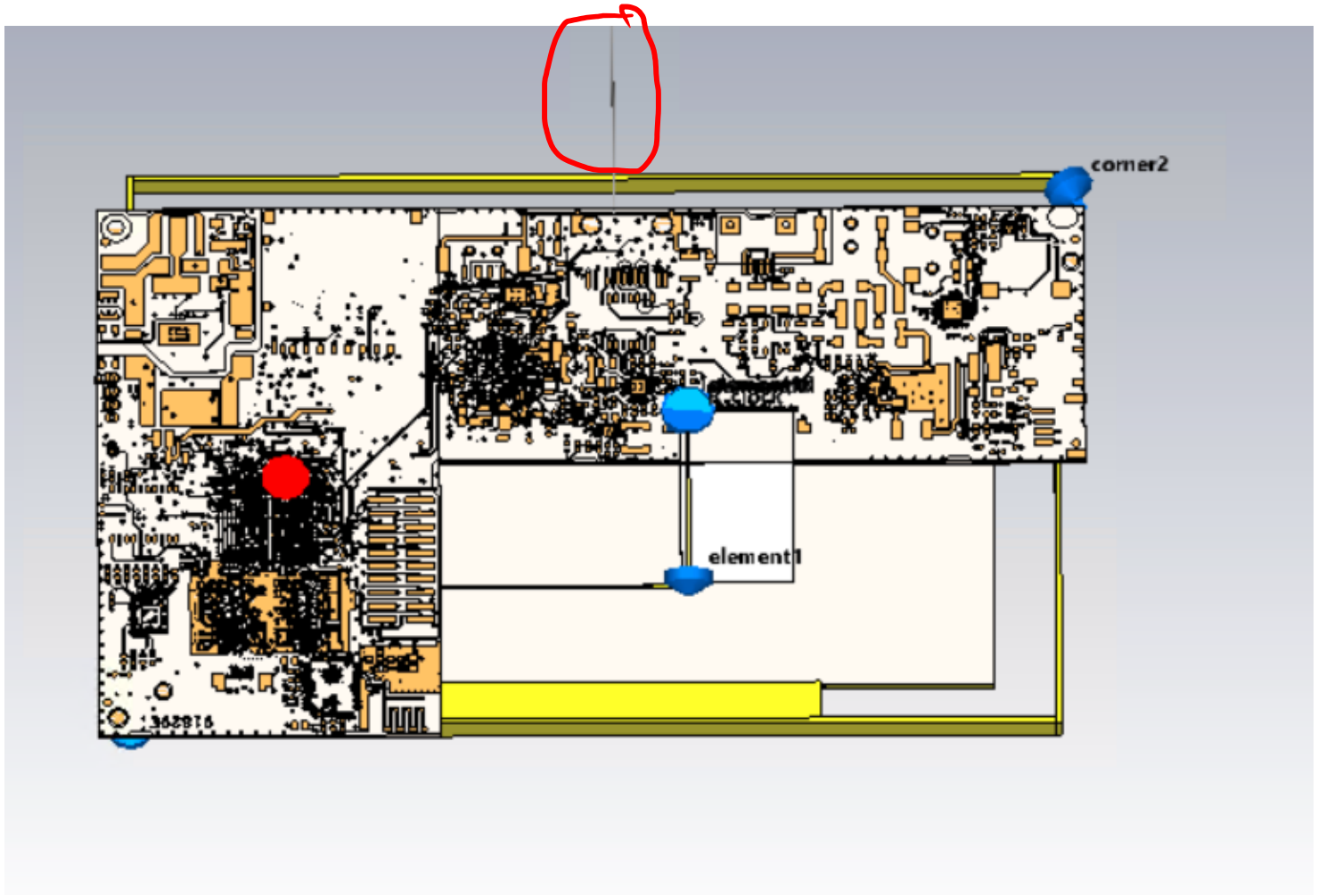
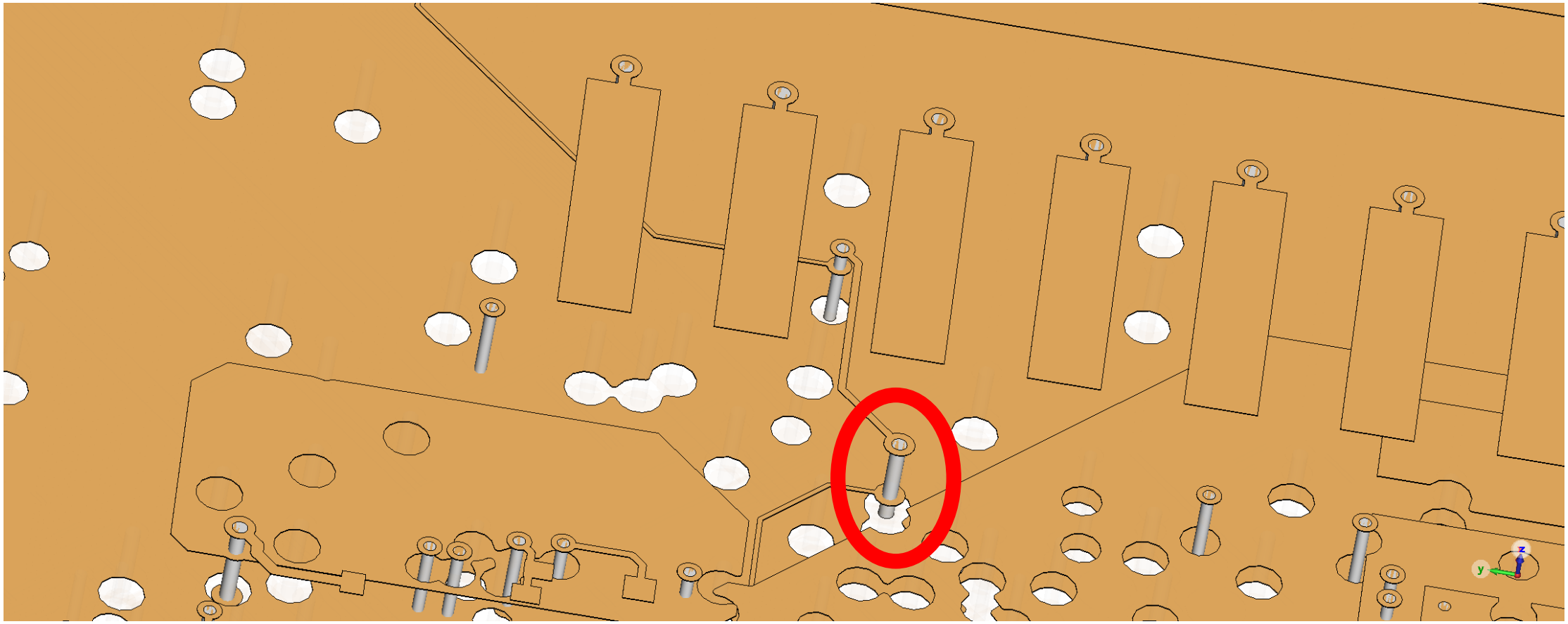


Simulation of an Industrial Control Tablet

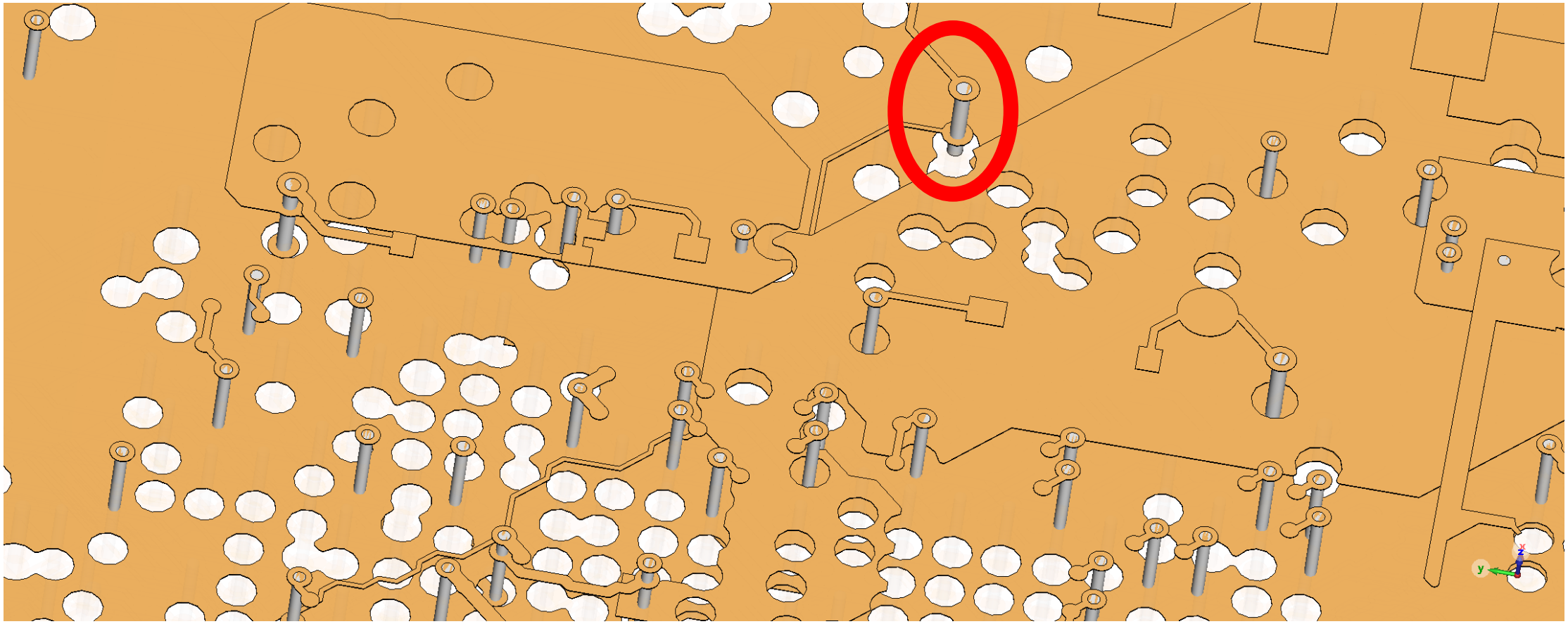
- Question: What is the root cause of the radiated emission problem?
- 8-layer PCB imported.
- Chassis build manually.
- Critical signal excited with Gaussian pulse – could be improved.



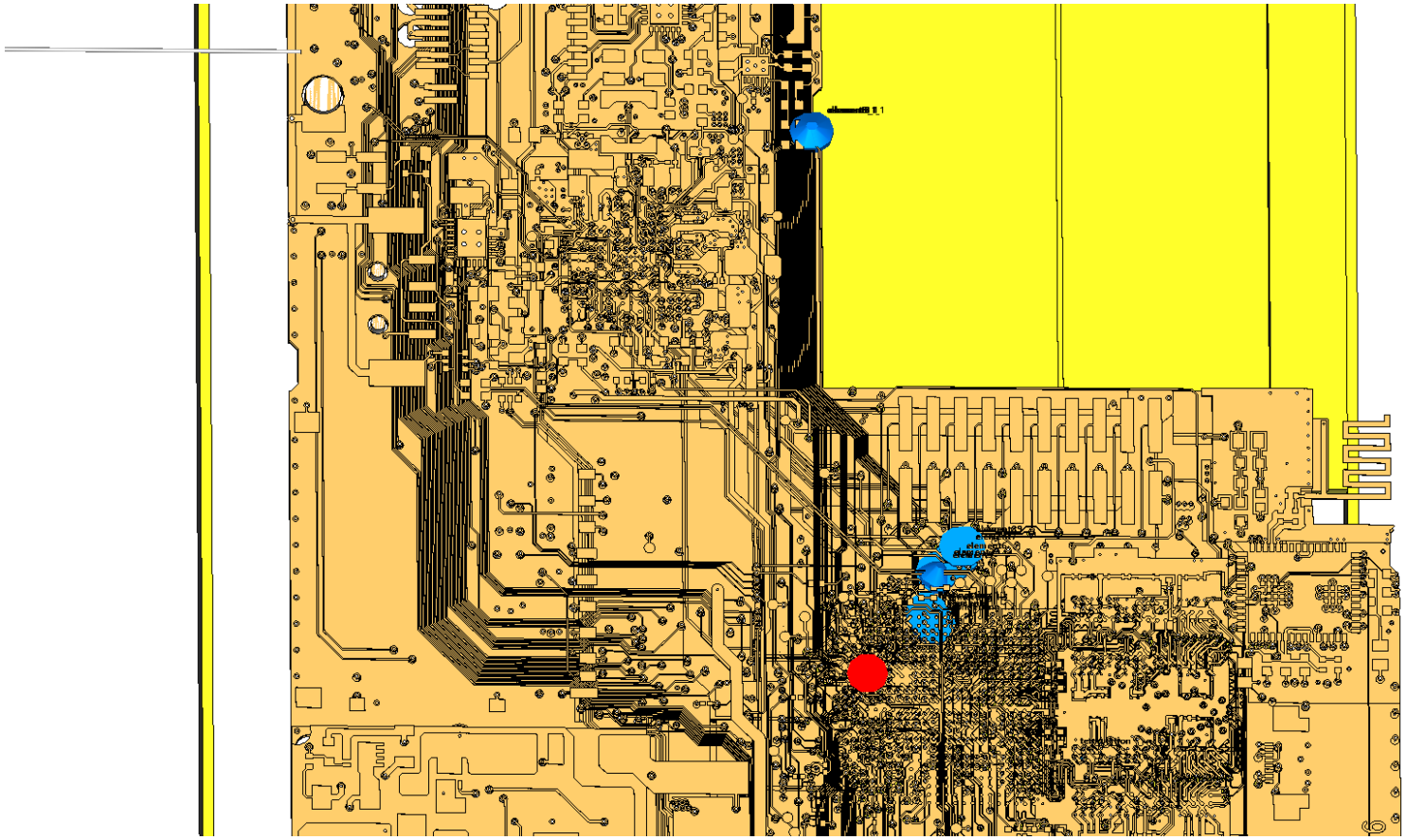
Clock: Change of Reference



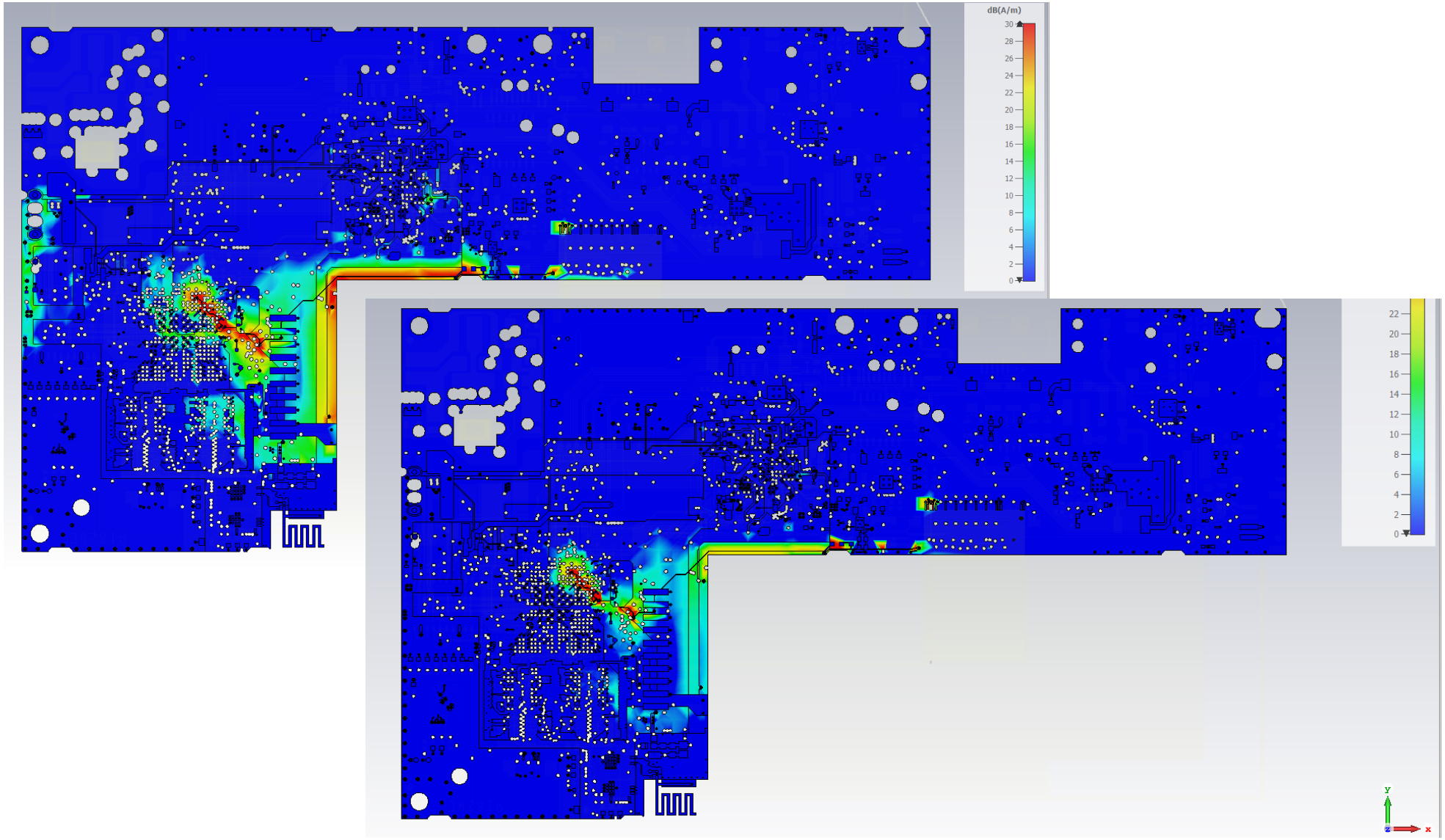
Clock: Change of Reference



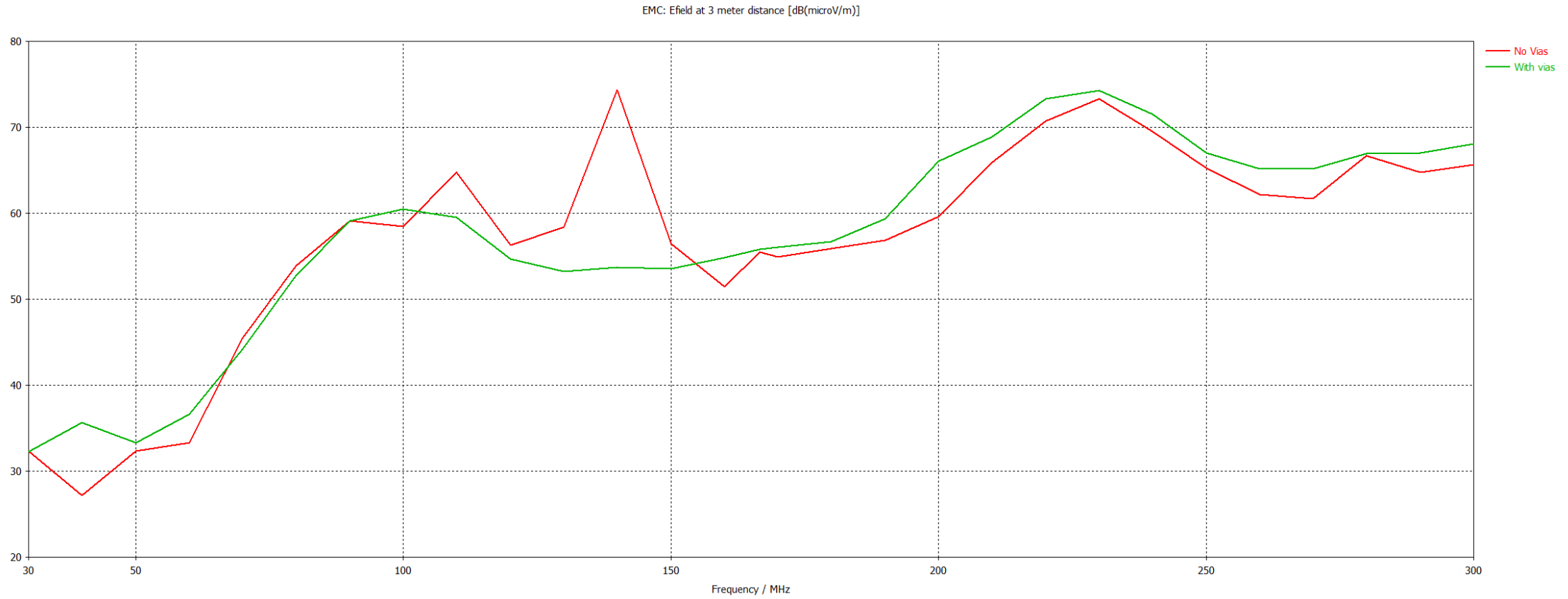
Solution: Extra Decoupling Capacitors



With and Without Extra Decoupling Capacitors



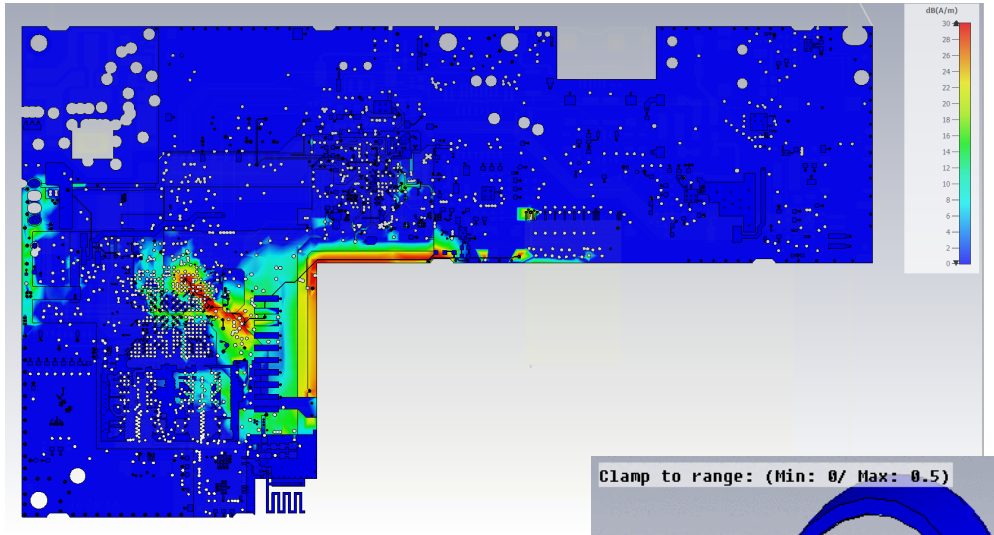
Radiated Emission With and Without Decap

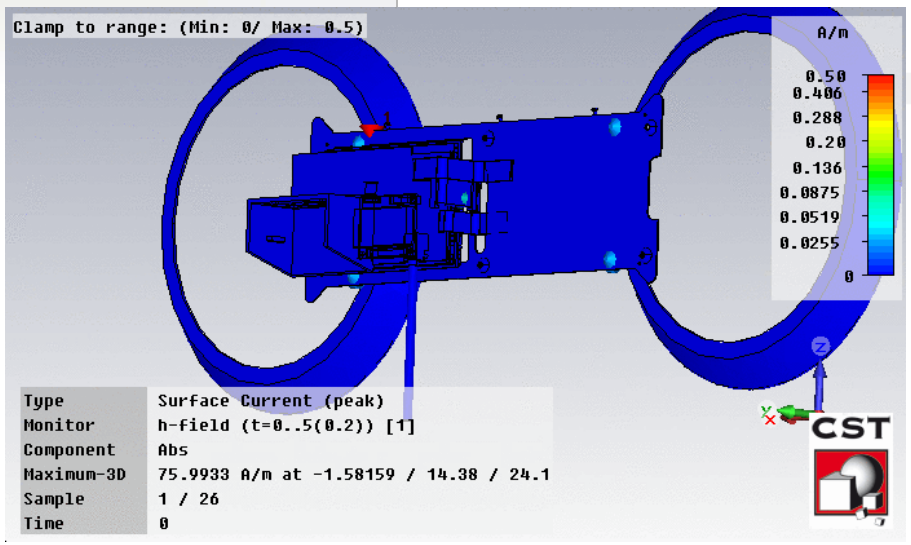


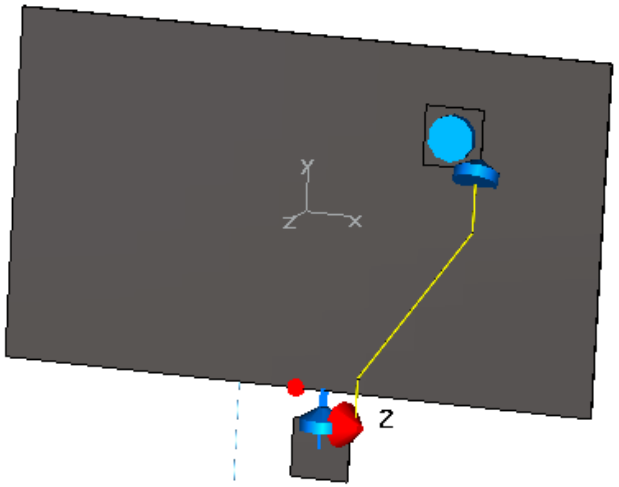
Simulation in Academia vs. Industry

Academia	Industry
Deep understanding of physics and mechanisms	Solve a practical problem
Highest possible accuracy	Good enough accuracy
Simulation is often the objective	Simulation is a tool
Time is less critical	ROI determines the effort

Questions




Clamp to range: (Min: 0/ Max: 0.5)
A/m
0.50
0.406
0.288
0.20
0.136
0.0875
0.0519
0.0255
0
Type Surface Current (peak)
Monitor h-field (t=0..5(0.2)) [1]
Component Abs
Maximum-3D 75.9933 A/m at -1.58159 / 14.38 / 24.1
Sample 1 / 26
Time 0
CST


2
0, -298, 1.5