

PCB Radiated Emissions Linked with Enclosure

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PCB Radiated Emissions Linked with Enclosure

**A three step design flow to
improve EMI/EMC performance**



Outline

- Defining the Problem
 - The terms Electromagnetic Compatibility (EMC) and Electromagnetic Interference (EMI) have grown in meaning over the years. The scope of the problem to be solved will first be defined.
- Applying Numerical Analysis to EMI/EMC
 - Describing the multi-scale problem for EMI/EMC
 - Three-step design approach for EMI/EMC
 - PCB in an Enclosure
 - Ground to Shield Coupling



What does EMI/EMC mean?

- Undesired signals interfere with system performance.
- Examples:
 - Car radio interference due to automobile electronics.
 - Mobile phone interference with television, radio, etc.
 - Cross-talk between digital and analog signals on a PCB resulting in reduced degraded system performance.
 - Noise on power and ground planes due to switching.
- The mechanisms responsible for these problems are due to electromagnetic effects.



EMI and EMC Standards

- A formal definition of EMI/EMC....

IEEE Project 1597.1 „IEEE Standard for Validation of Computational Electromagnetics (CEM) Computer Modeling and Simulation“

IEEE Project 1597.2 „IEEE Recommended Practice for Computational Electromagnetics (CEM) Computer Modeling and Simulation Applications“

European Union Directive 1999/5/EC

European Union Directive 2004/108/EC



Electromagnetic disturbance means any electromagnetic phenomenon which may degrade the performance of equipment. An electromagnetic disturbance may be electromagnetic noise, an unwanted signal, or a change in the propagation medium itself.

Immunity means the ability of equipment to perform as intended without degradation in the presence of an electromagnetic disturbance.

See also: <http://aces.ee.olemiss.edu/>

[Public domain benchmarks for EMI/EMC Simulation](#)

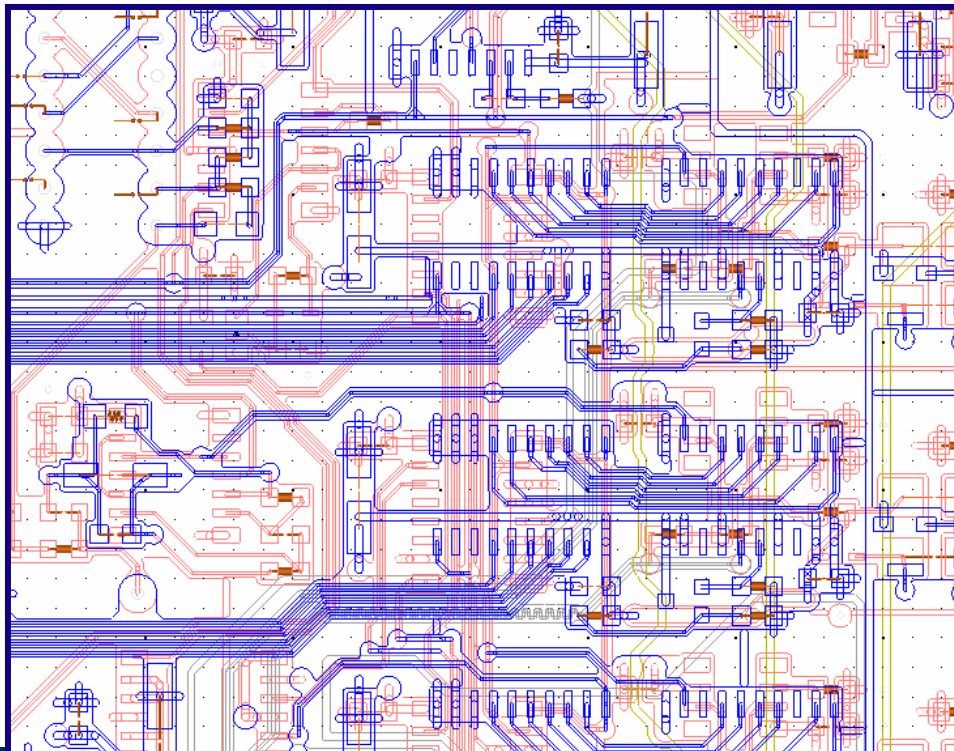
<http://www.ewh.ieee.org/soc/emcs/>

[IEEE EMC Society](#)



Approaches to using Electromagnetic Simulation in an EMI/EMC Design Flow

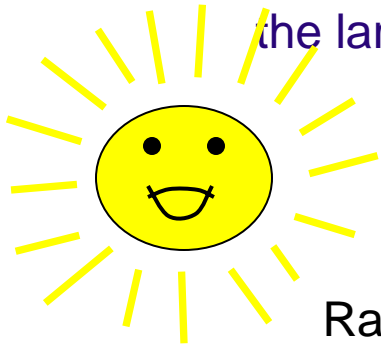
- A major EMI/EMC Problem for complex printed circuit boards is emission of signals on the PCB.
- The complexity of such problems is enormous (this is known as the *multi-scale problem*):



One section of a multi-layer PCB that may radiate.

Overcoming the Multi-Scale Problem in EMI/EMC Analysis

- The multi-scale problem means that a single electromagnetic analysis will most likely not address the system solution.
 - The printed circuit board is comprised of a large number of nets, as well as many active and passive components, all of which play a role in electromagnetic emission.
 - The smallest feature sizes are on the order of several microns, while the largest features may be 10's of centimeters.



Solution!?

SIWAVE™ + HFSS™

almost

Radiation leakage from the PCB will almost always be minimized using shielding.

... thus, the coupling between the PCB and 3D analysis is needed.

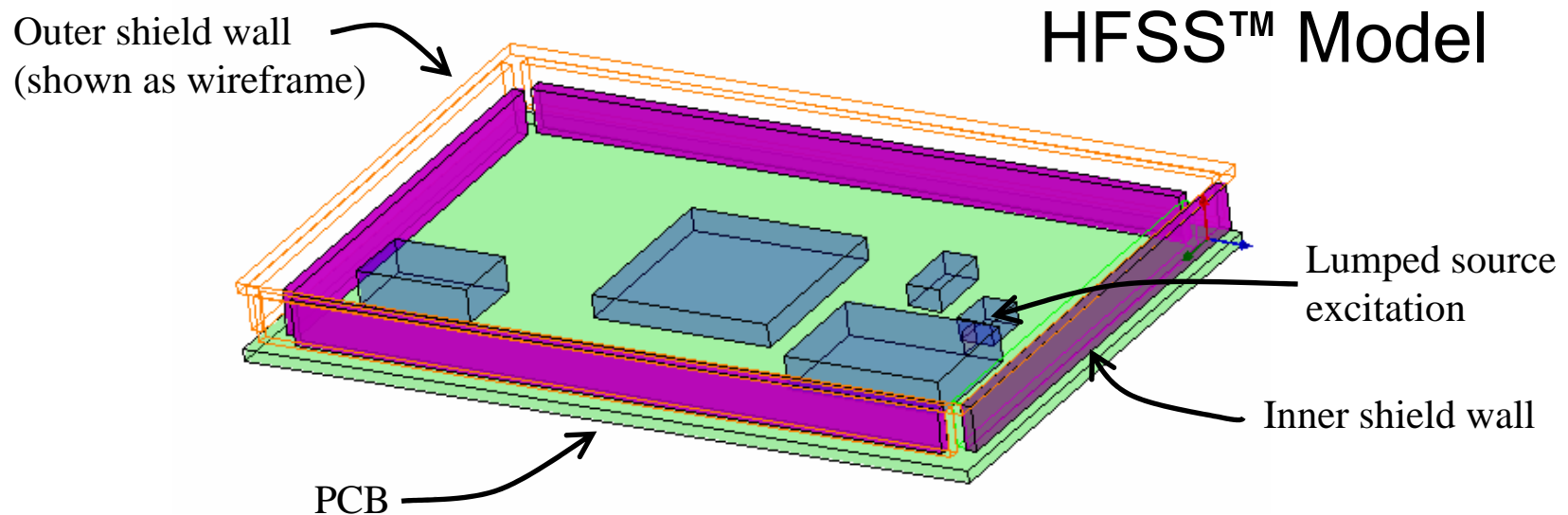
3-Step Design Approach for EMC

1. Identify critical components in the system and analyze them individually using HFSS or Q3D.
 - Traces supporting high speed data,
 - Eigenmode analysis to identify resonances.
 - Other packages, components, antennas.
2. Signal and Power Integrity Analysis in Nexxim and SIwave
 - Analysis in SIwave combined with circuit analysis can be used to verify circuit performance and identify signal integrity issues.
3. Combine PCB extraction, circuit analysis and 3D electromagnetic analysis to verify EMC system performance.



3-Step Design Approach (Step 1)

- Examine the properties of the isolated EMC shield:

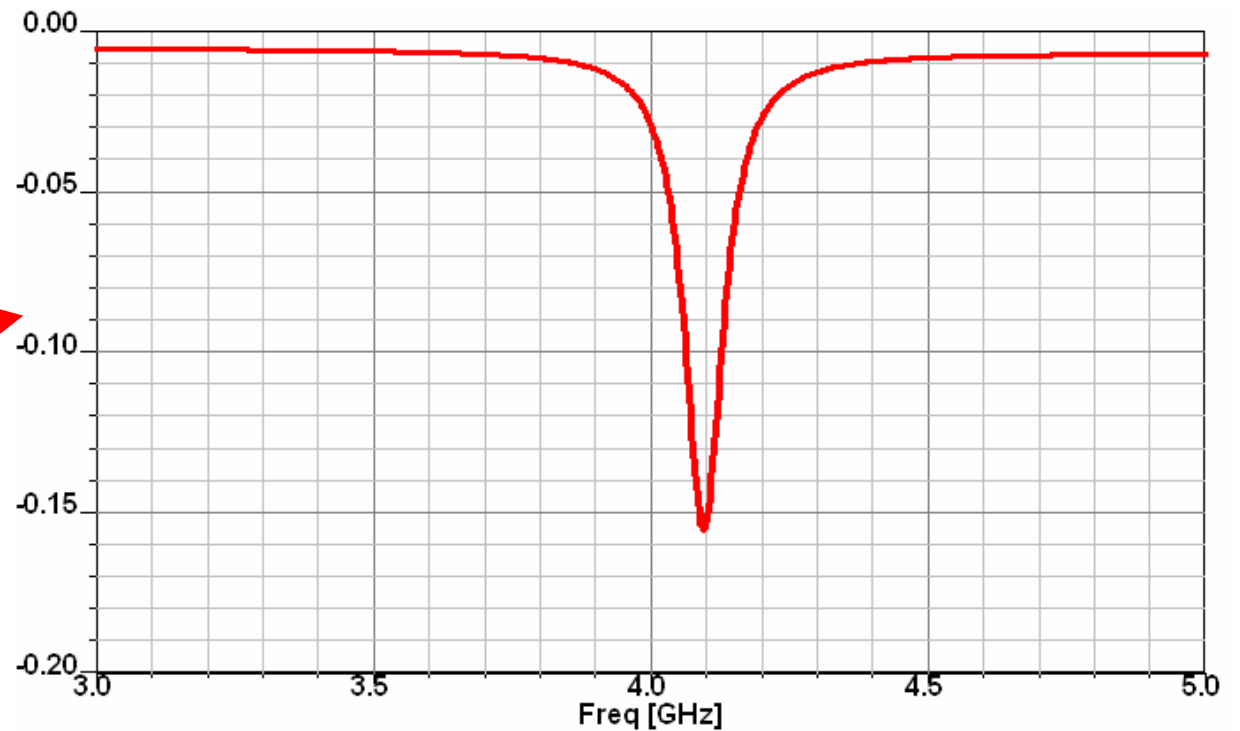
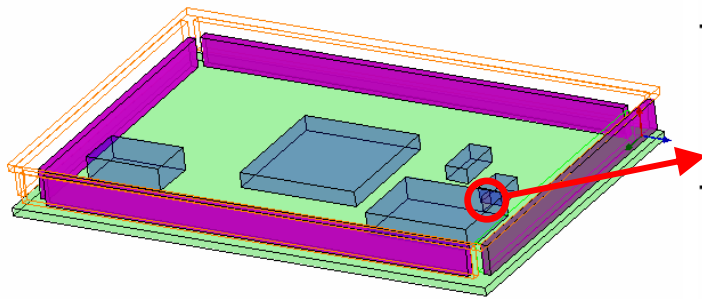


- Low frequency resonances may occur in shielding due to long current paths arising from gaps in the shielding.



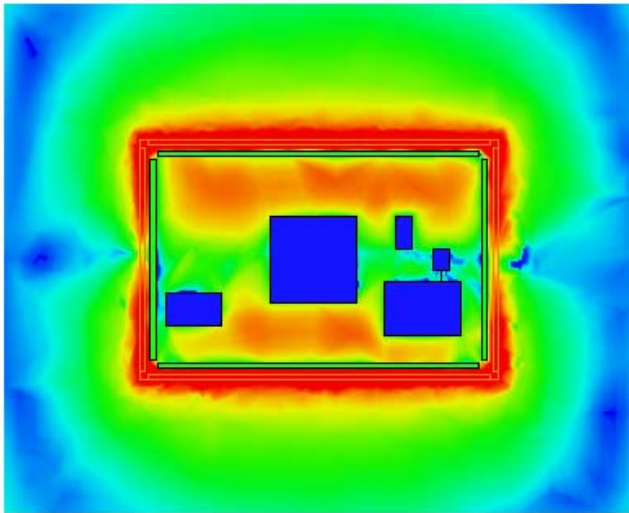
Investigating the EMC Shield in HFSS

- Coupling to a resonance can be seen by the drop-out in S11 at 4.09 GHz, indicating a possible EMI problem.

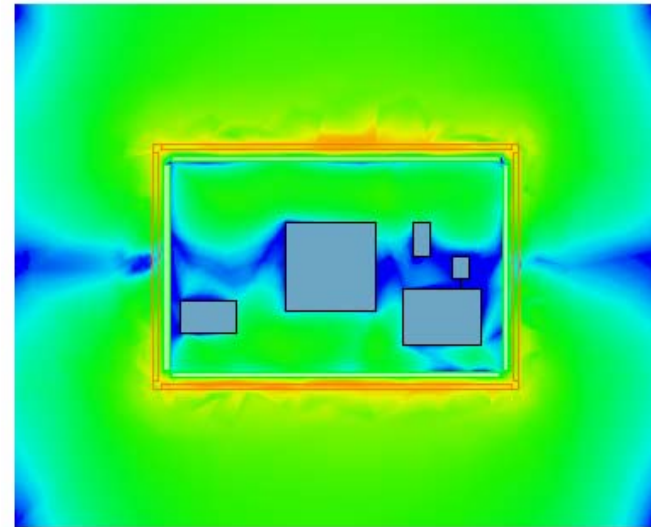


Investigating the EMC shield in HFSS

- The Eigenmode solver in HFSS can be used to find the resonance as well.



E-field magnitude of the driven problem at 4.09 GHz



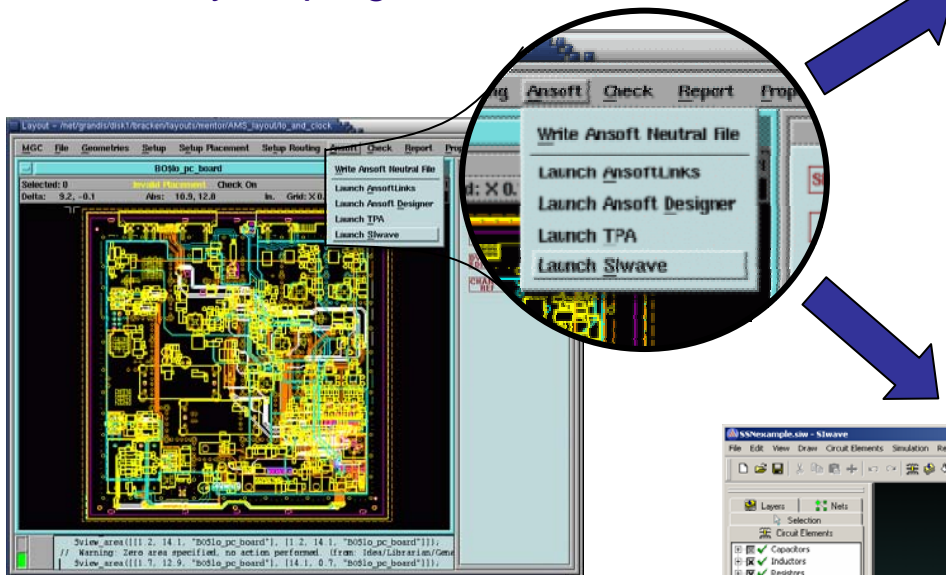
E-field magnitude of the Eigenmode resonance at 3.97 GHz

- Eigenmode analysis adapts the mesh to the field distribution at resonance.
- Radiation boundary cannot be used in the eigenmode solver, so the resonance will be slightly different than that determined by the driven solution.

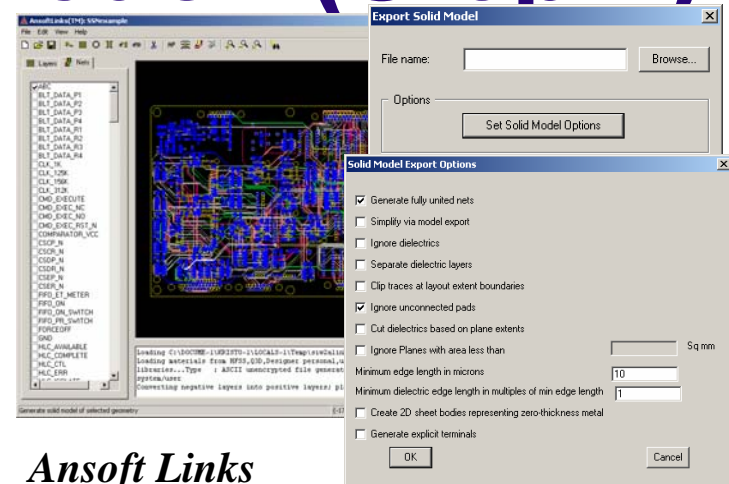


3-Step Design Approach (Step 2)

- Prepare PCB for simulation
 - Use Ansoft Links to import the layout and components from the 3rd party layout program

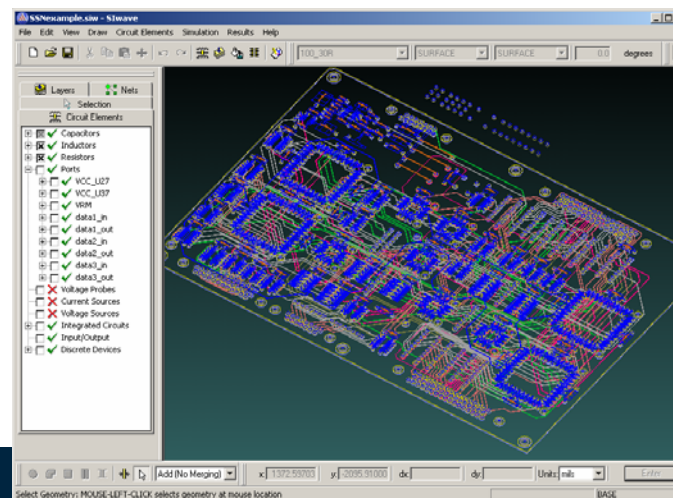


Design export from Cadence, Mentor, Synopsys, Zuken tools



Ansoft Links

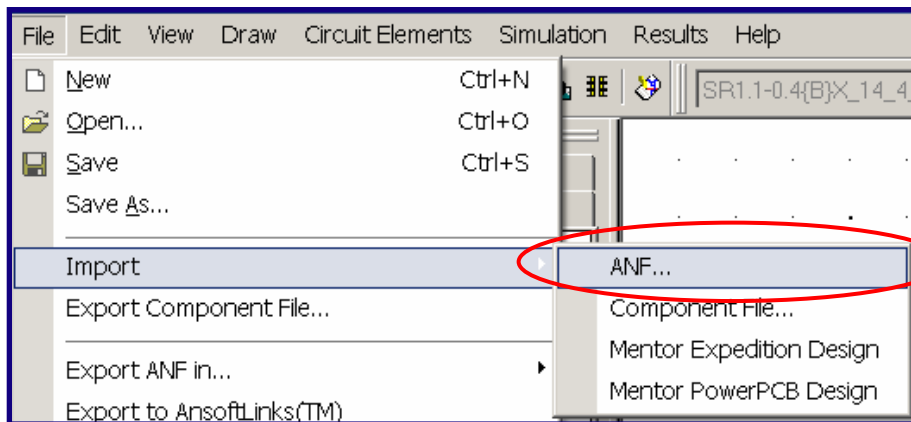
Clean-up, choose critical nets, de-feature and export 3D model (HFSS / Q3D analysis)



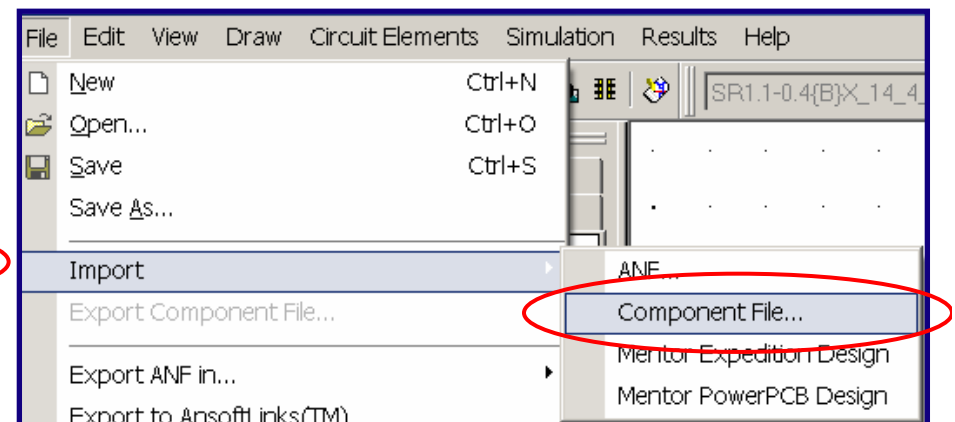
SIwave Analysis of complete PCB

3-Step Design Approach (Step 2)

- The three-step approach for EMI/EMC is directly linked to the signal and power integrity design-flow.



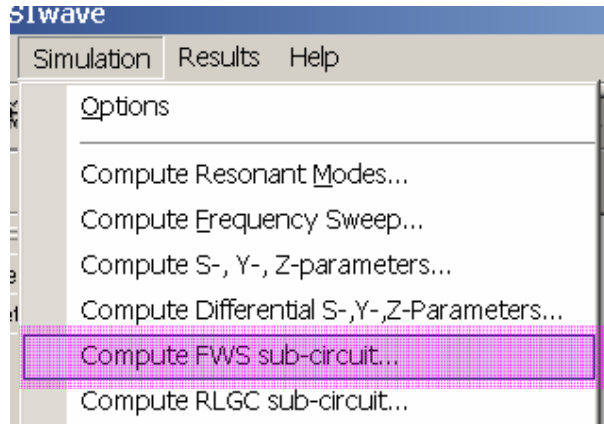
Import ANF imports layout, stackup and padstack information for full-wave analysis.



Import CMP imports component information including component type, location and value.



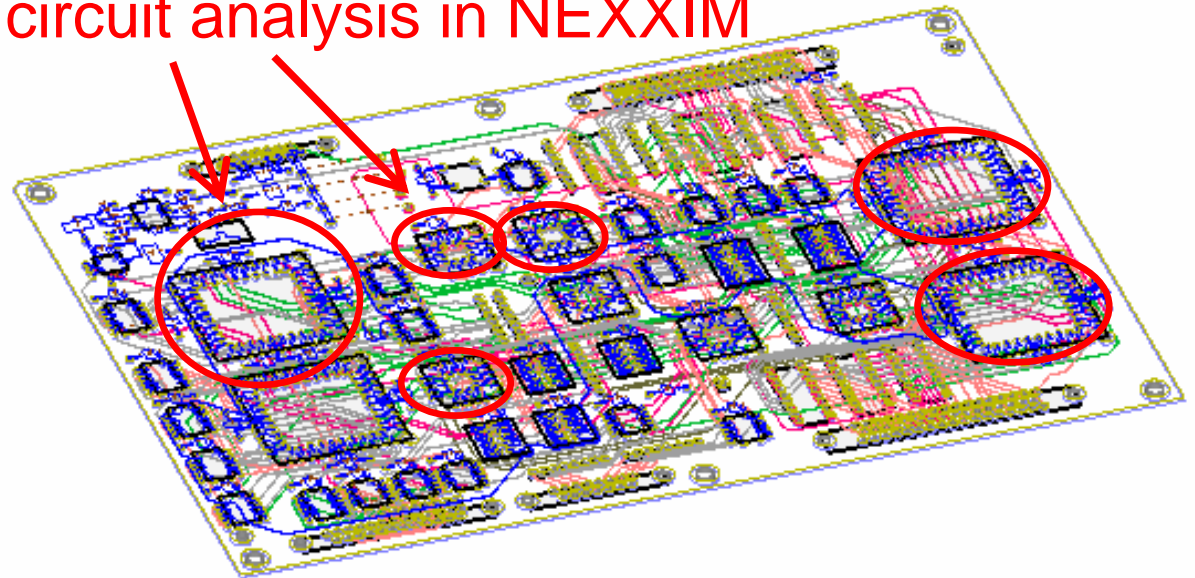
Analysis in SIwave



After full-wave analysis, a Full-Wave SPICE model of the PCB can be generated.

PCB Model in SIwave

IC's as place-holders for circuit analysis in NEXXIM



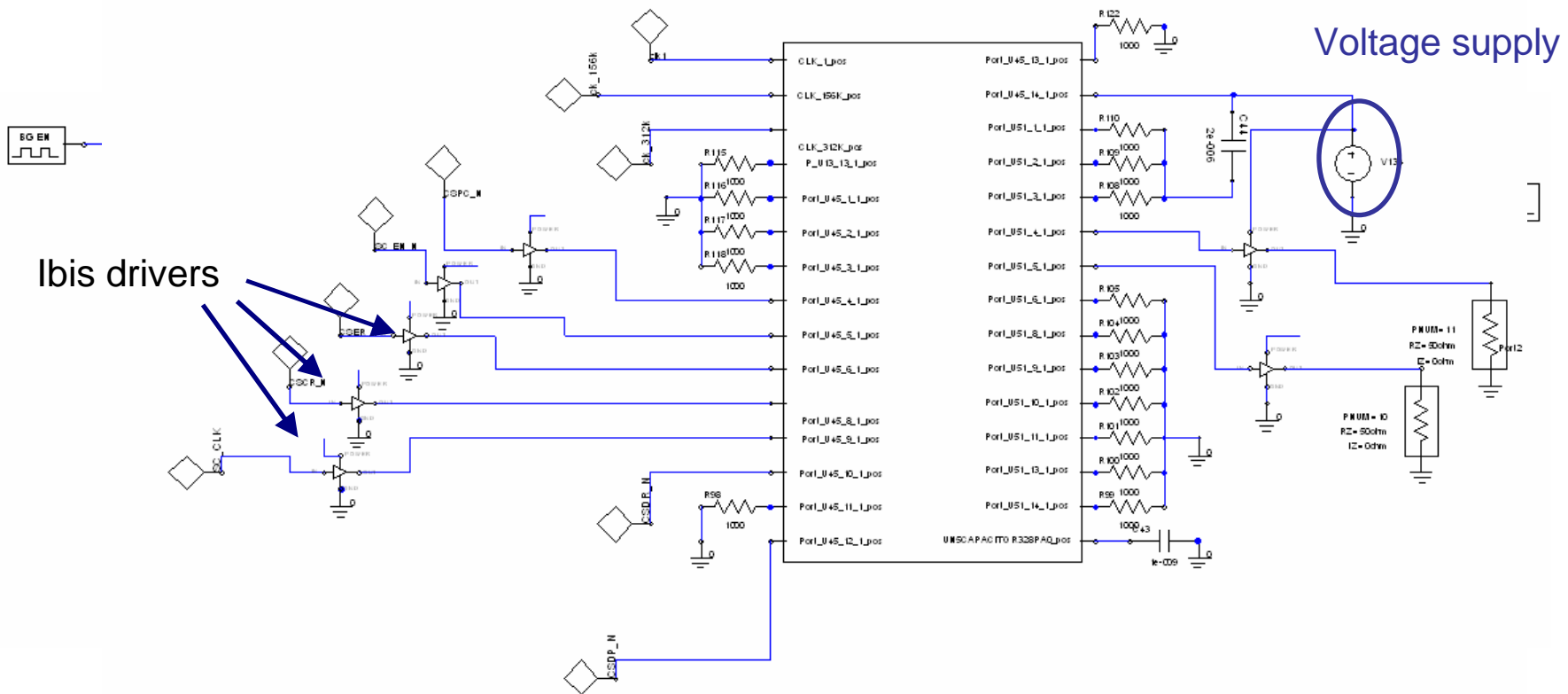
Resistors, Capacitors and Inductors are included in the SIwave model.



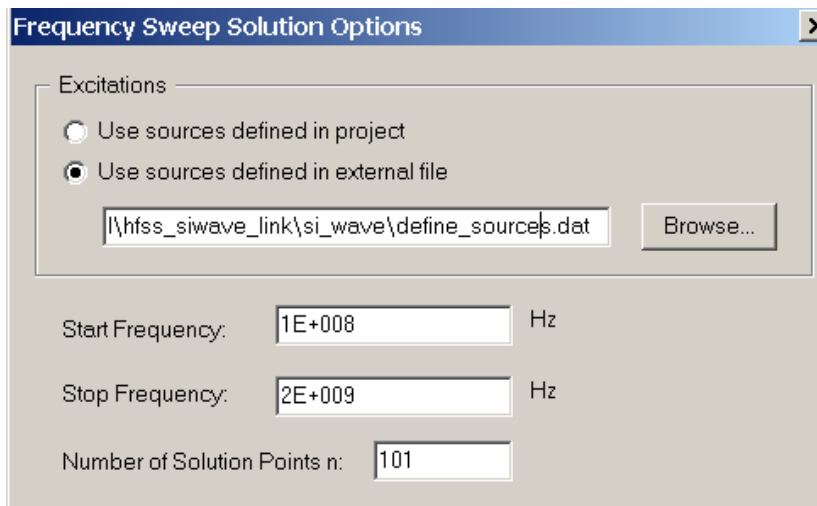
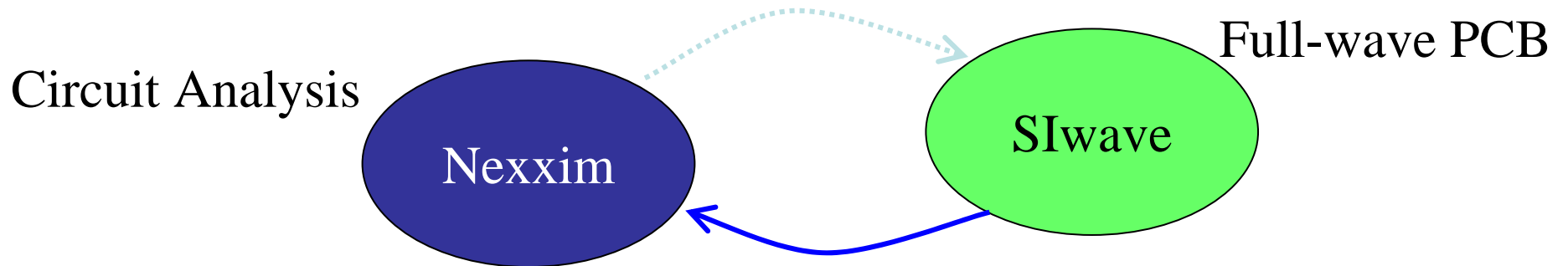
3-Step Design Approach (Step 2)

- Signal integrity analysis can be carried out by combining circuit and system level analyses.

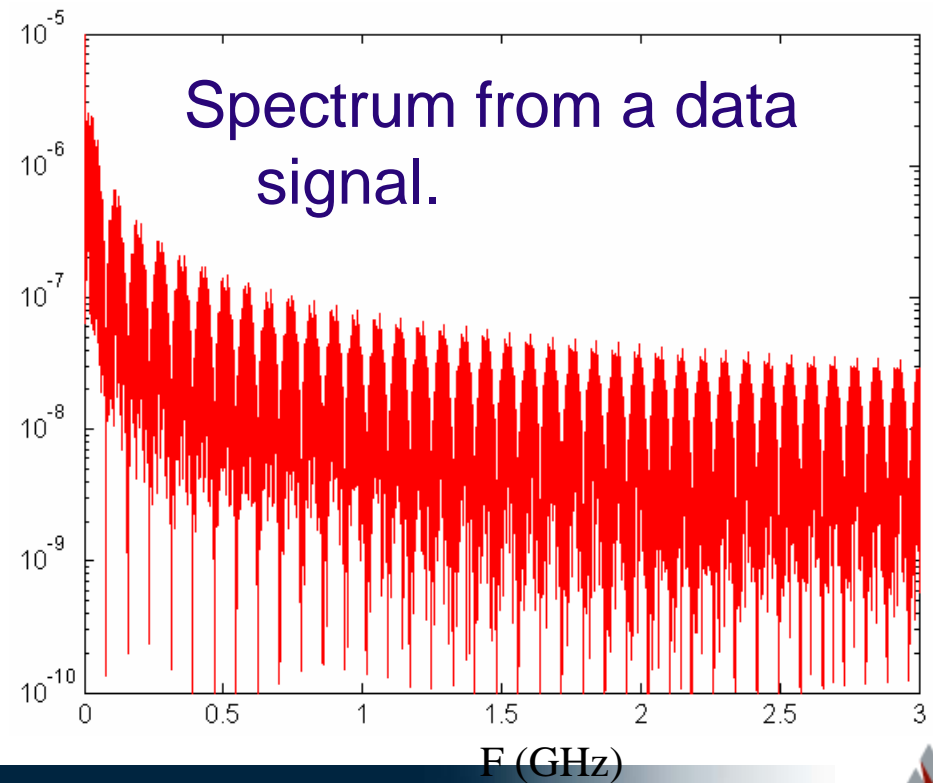
Passive components



EMC Analysis from PCB

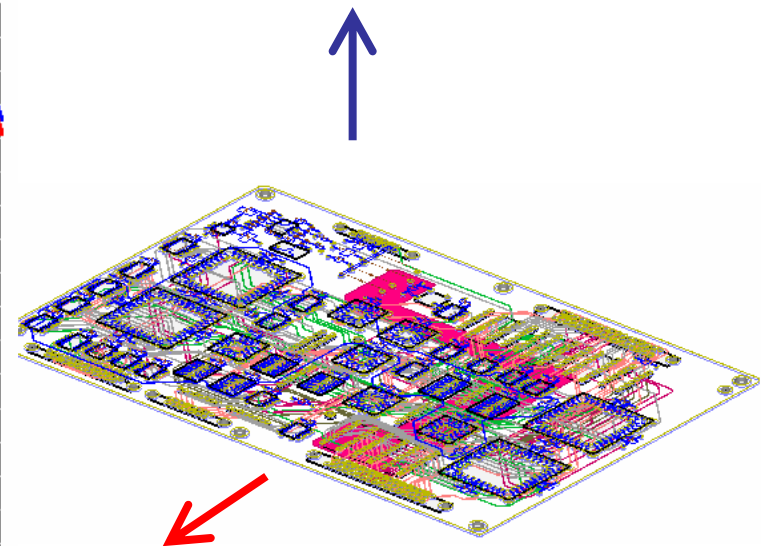
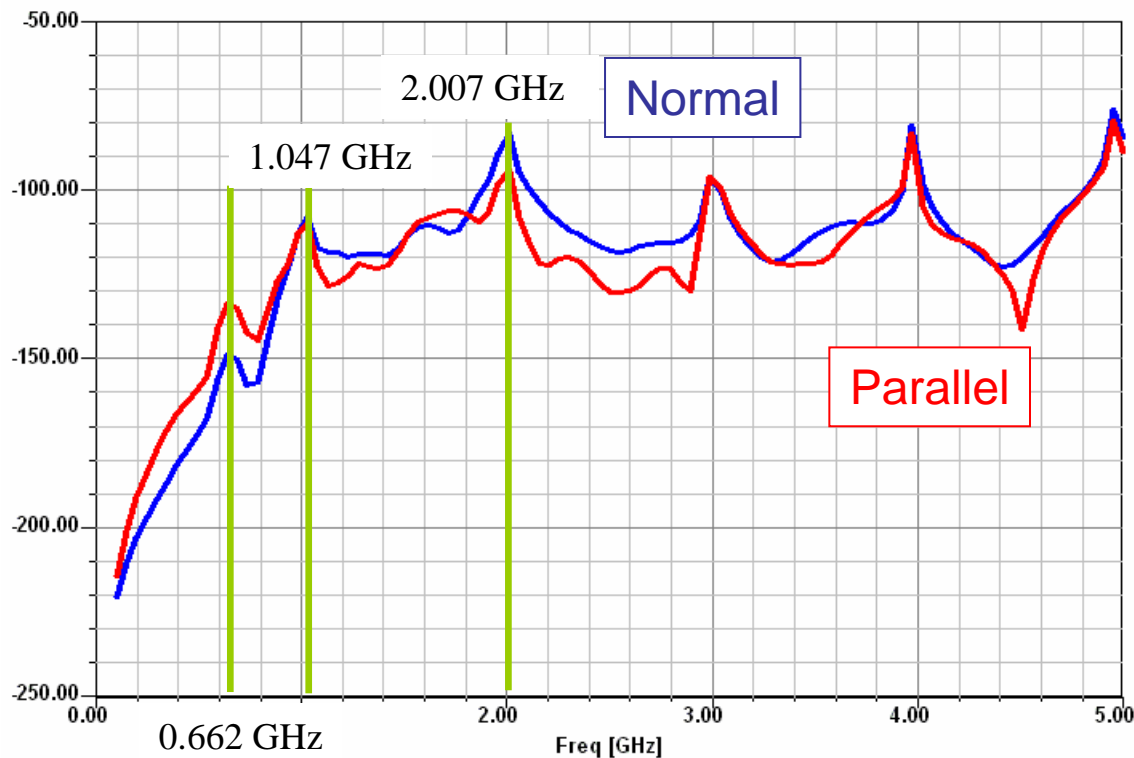


Complex spectral data from SPICE analysis can be loaded into SIwave.

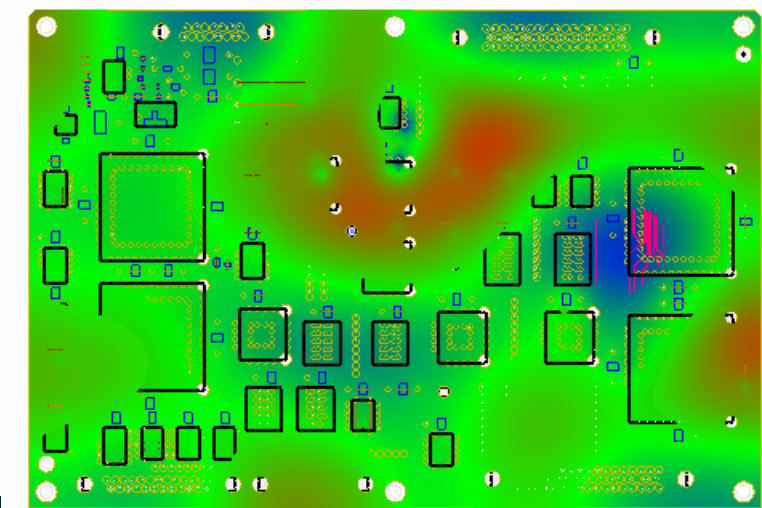
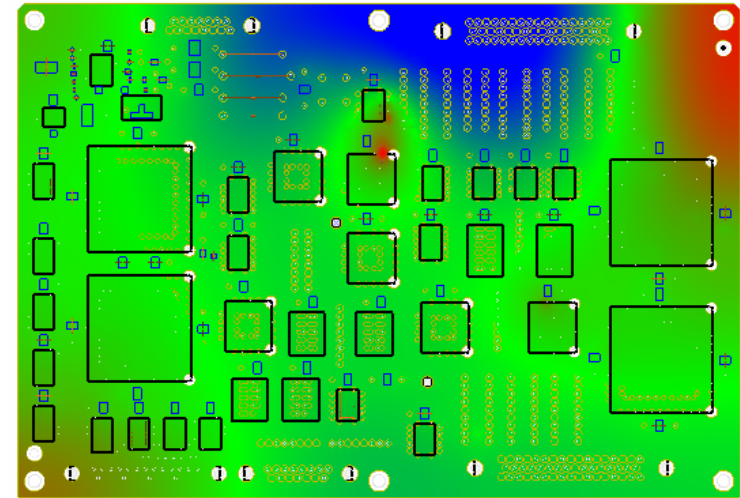
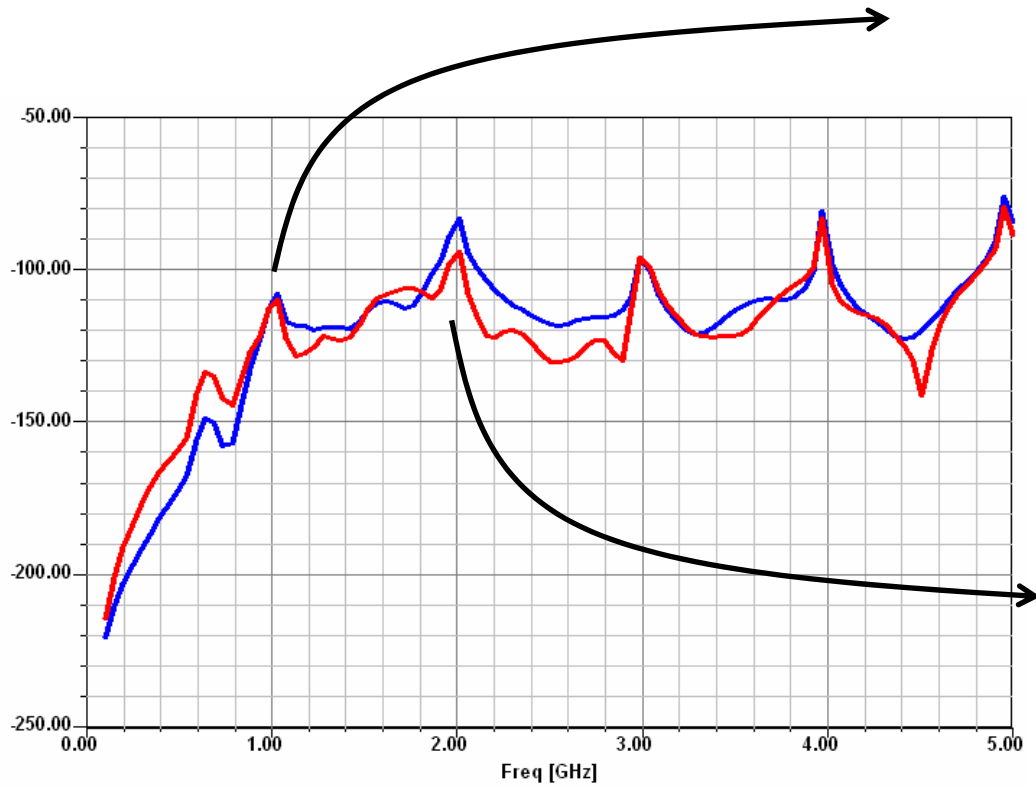


Electromagnetic Emission from the PCB

- The emission spectrum from the PCB exhibits distinct peaks that correlate with the resonances on the 5V supply.



Examining the plane voltages



Step 3

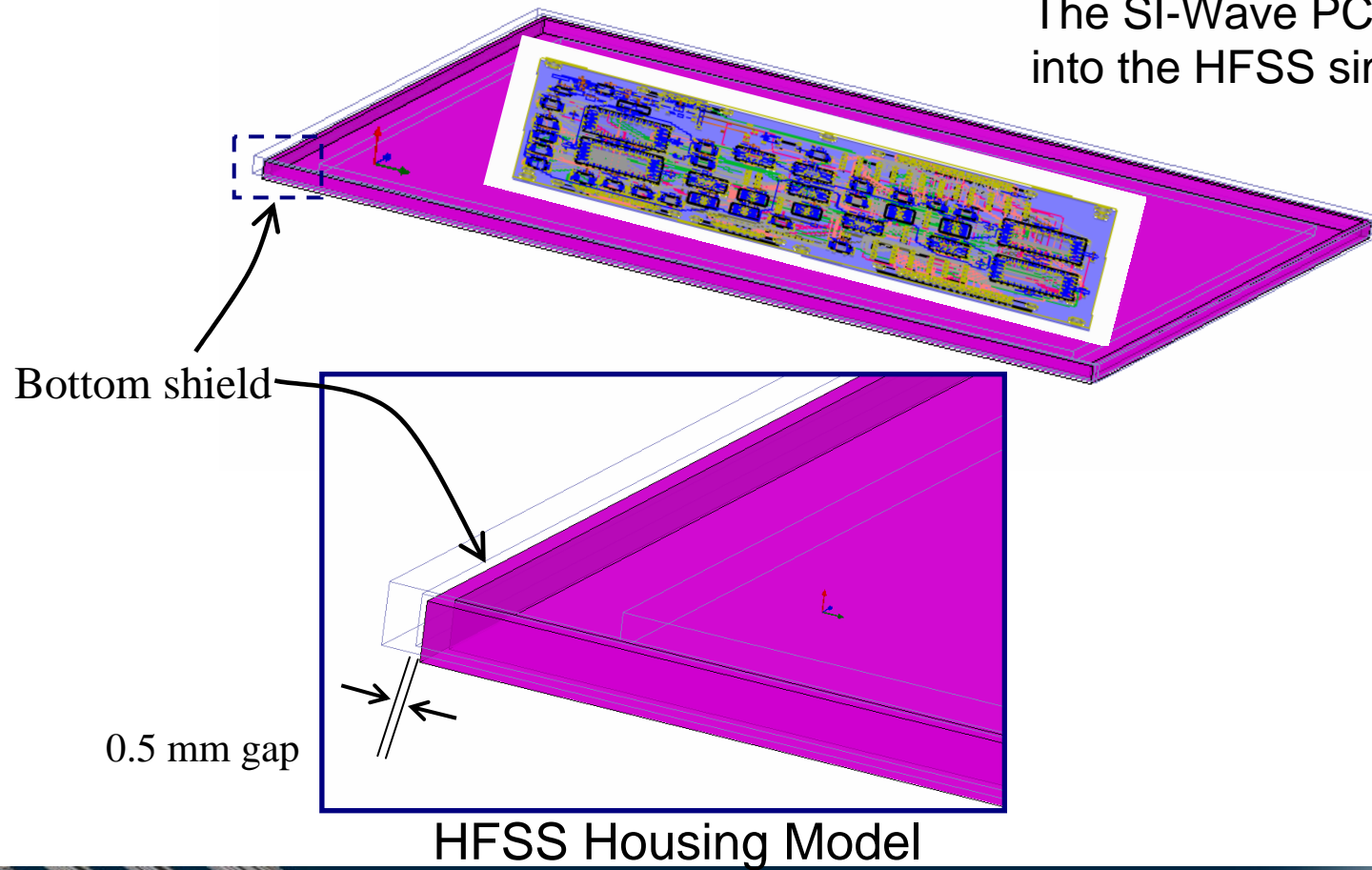
- The third step in the EMC/EMI design flow aims to verify the system performance.
- System verification requires the combination of circuit analysis, PCB full-wave extraction, and 3D electromagnetic analysis of the shielding and environment.



3-Step Design Approach (Step 3)

- Use the field distribution in SI-wave as an excitation for an HFSS project.

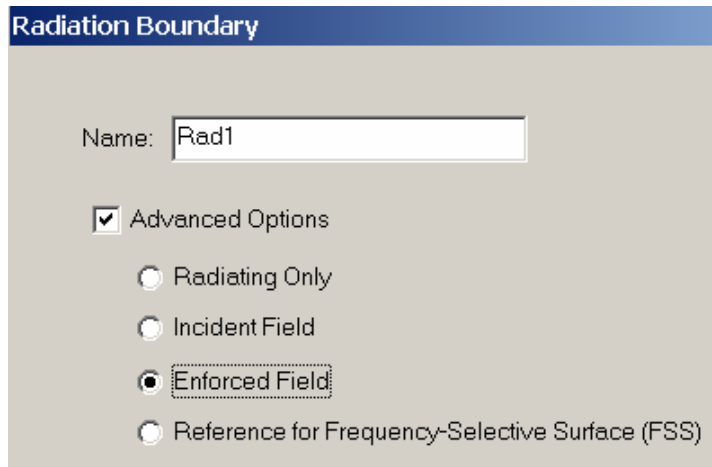
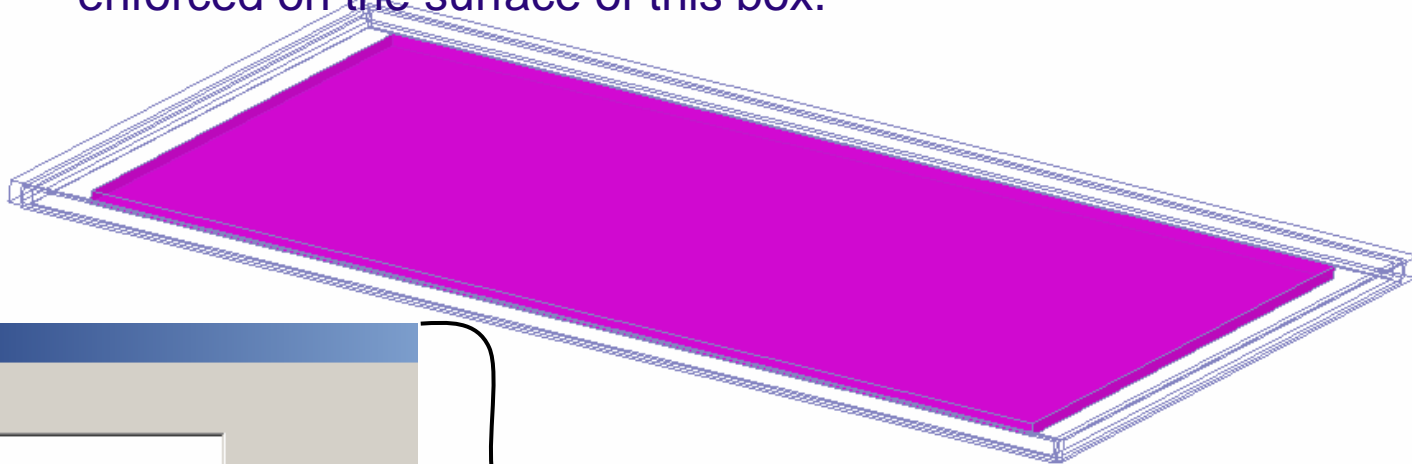
The SI-Wave PCB Model is built into the HFSS simulation.



3-Step Design Approach (Step 3)

- The incident field from SI-wave is calculated using the free-space near-field Green's function to project the fields in SI-wave onto a surface in HFSS.

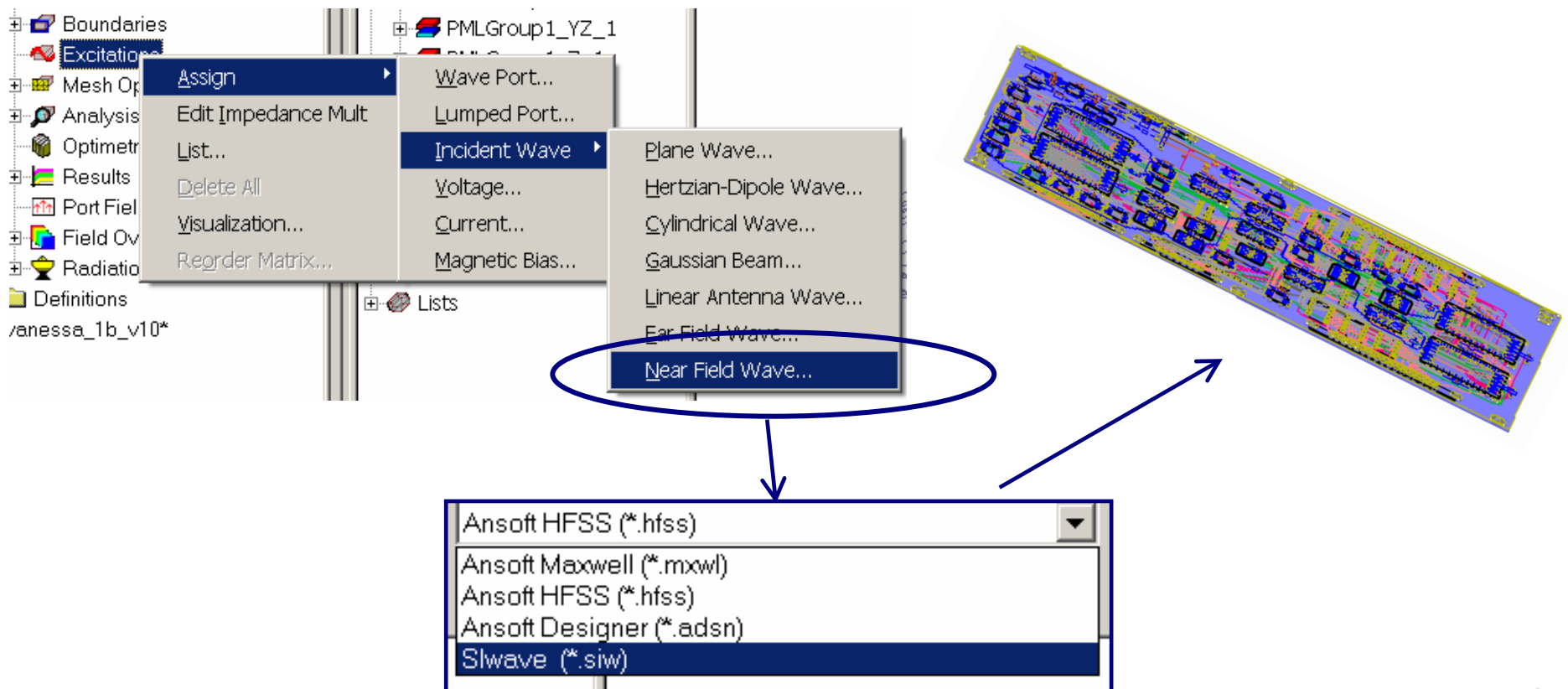
1. A box is placed inside the shield. The fields from SI-wave are enforced on the surface of this box.



A new „advanced option“ in the radiation boundary for HFSS Version 10 tells HFSS that this is the surface on which the fields from SI-wave will be enforced.

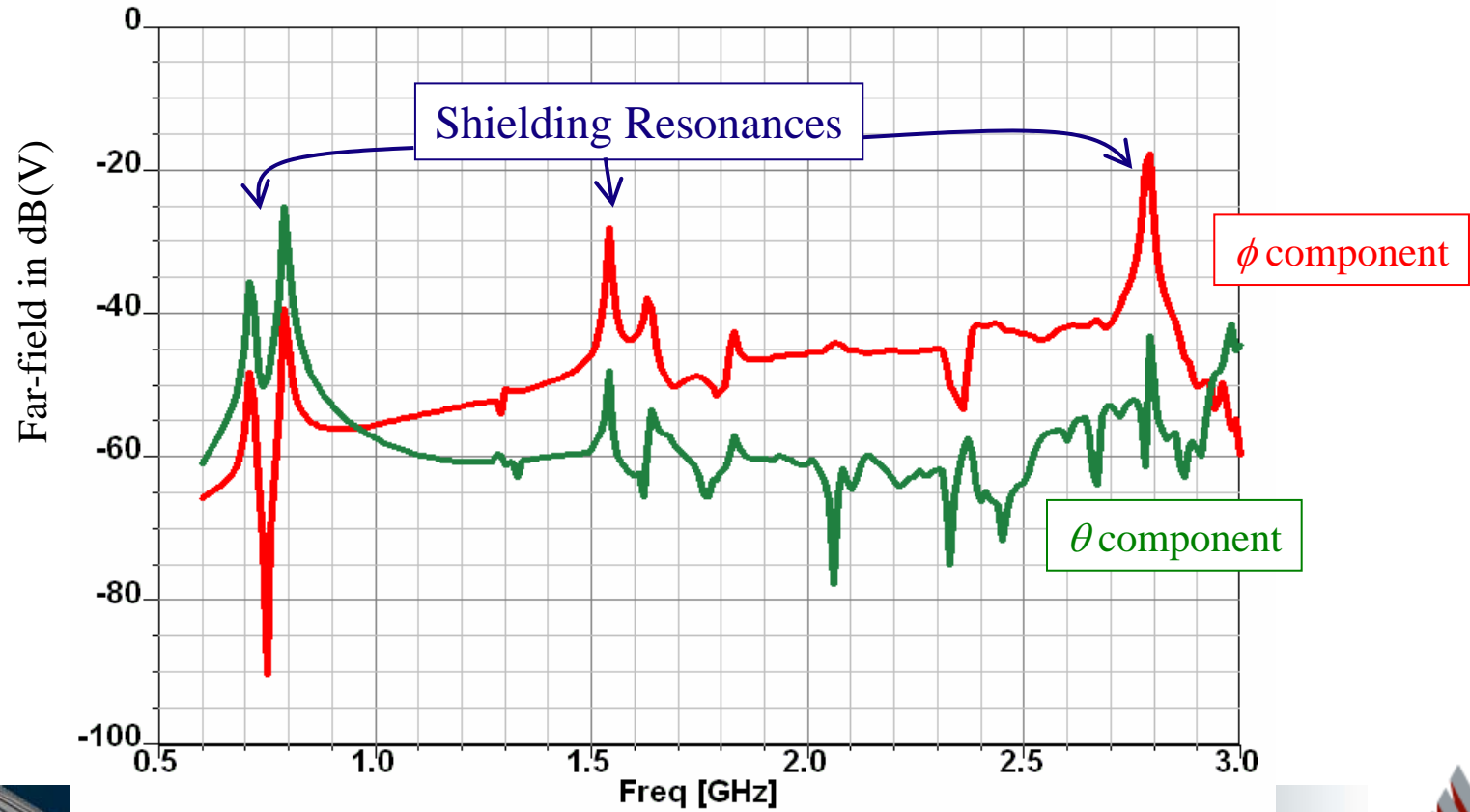
3-Step Design Approach (Step 3)

2. Define the Source Excitation in HFSS (this is what is enforced on the radiation boundary surface).

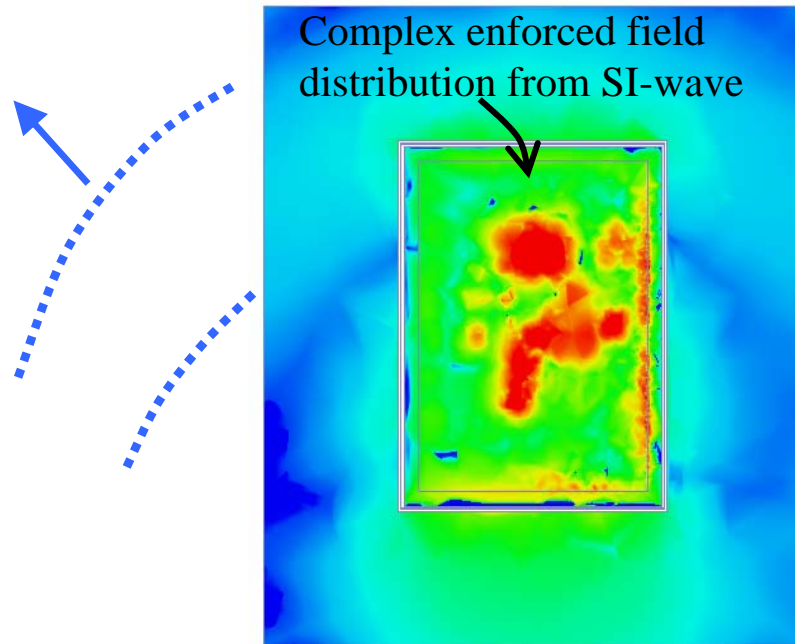


3-Step Design Approach (Step 3)

3. Link to the SI-wave project. Data is obtained from the frequency sweep solution.

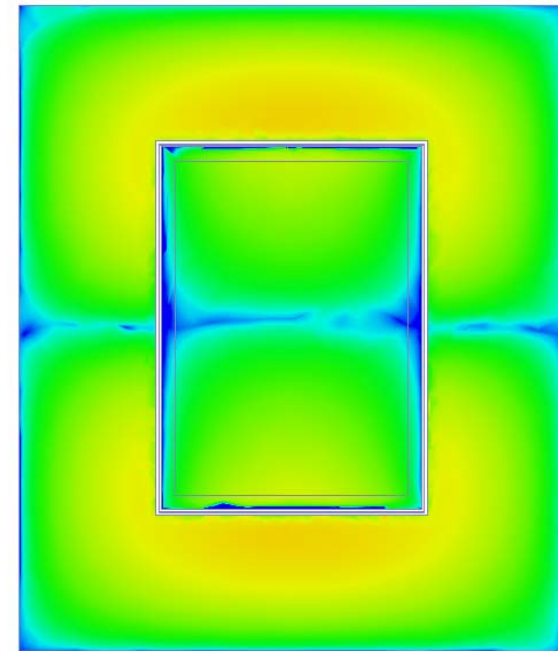


3-Step Design Approach (Step 3)



Electric field magnitude with the SIwave near-field used as the excitation.

- Eigenmode analysis of this shield alone predicts a resonance at 762 MHz.

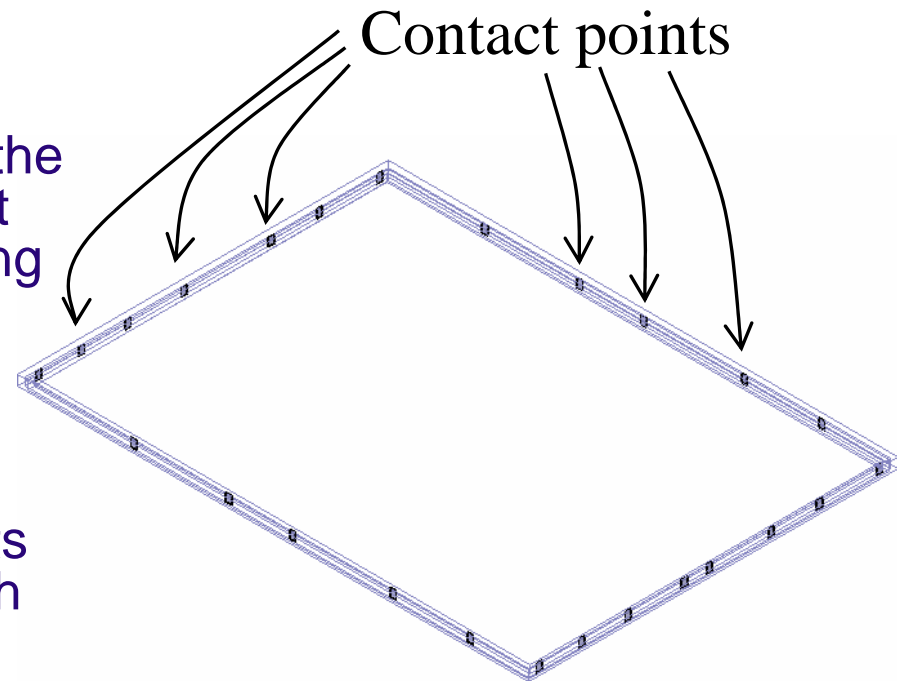


Eigenmode solution (no enforced field)

Coupling from the PCB to the shield resonance results in radiation!

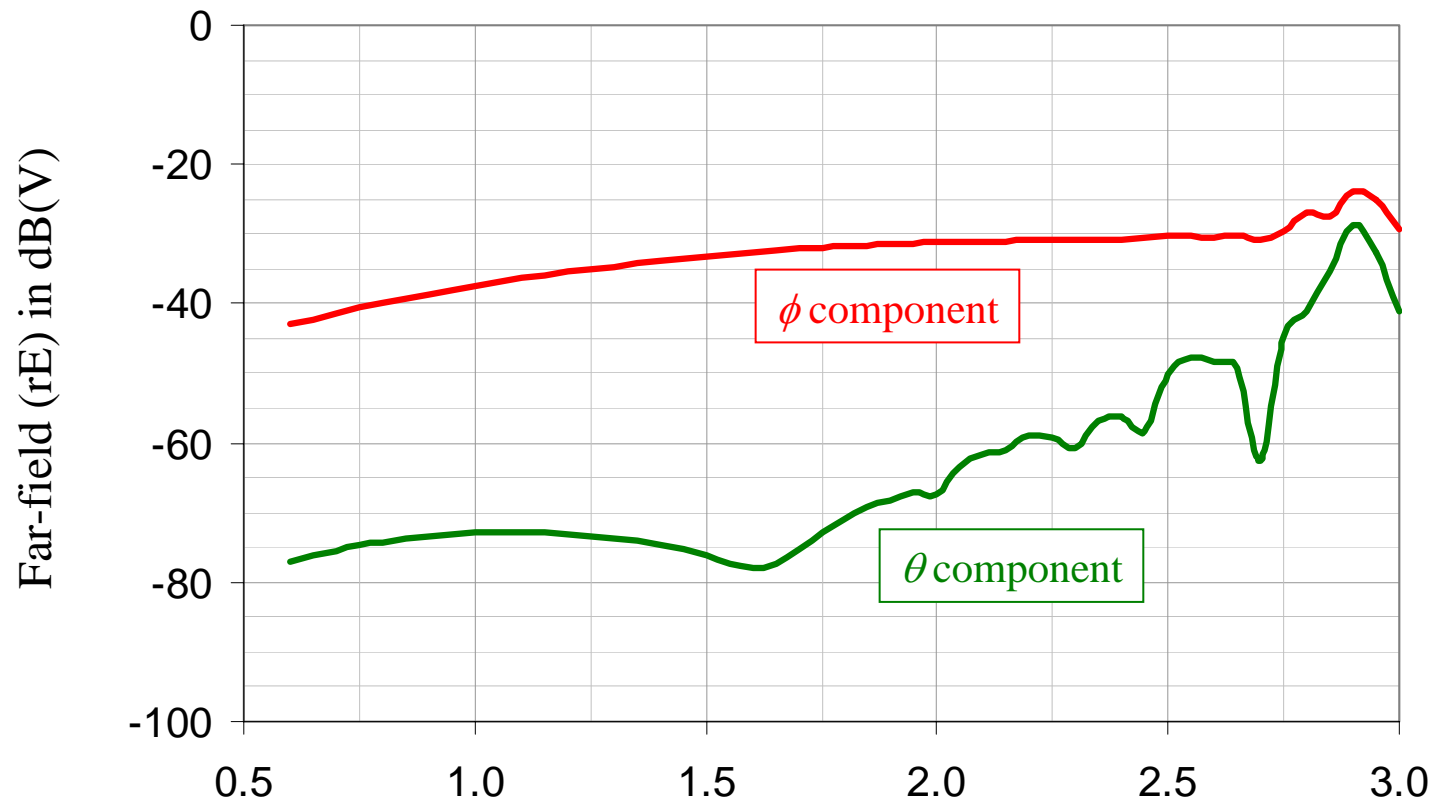
Modified enclosure

- Shielding that relies on contact between extended surfaces is prone to EMI problems because gaps may form.
- Intentionally designing gaps into the shielding ensures that the contact points between two metal shielding parts are known.
- The spacing between the gaps should be irregular. Regular spacing of shielding contact points leads to a periodic structure which will be resonant.



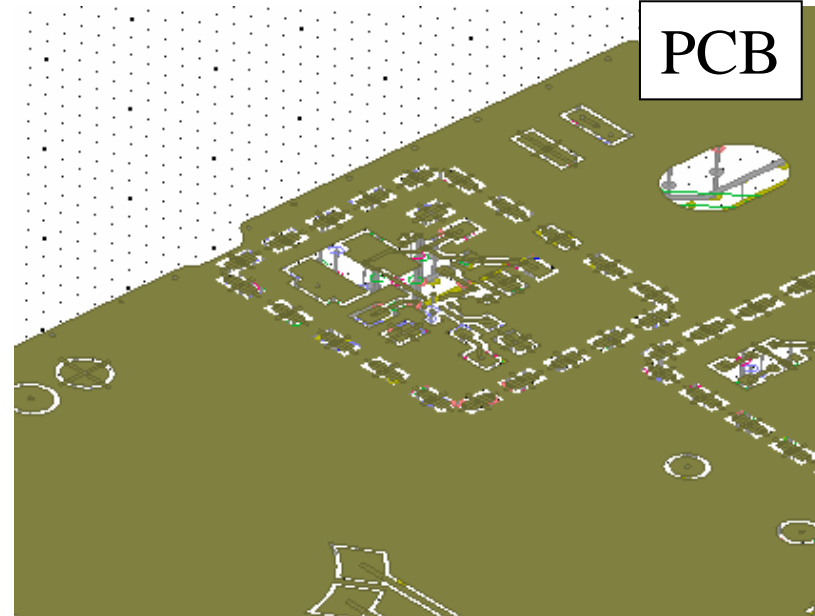
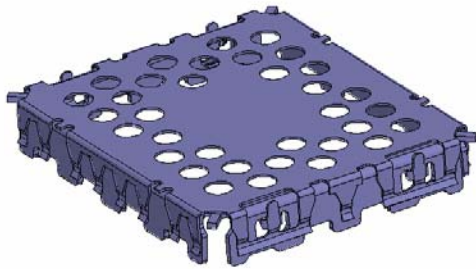
3-Step Design Approach (Step 3)

3. Housing resonances are suppressed by introducing small contact points between upper and lower parts of the housing.



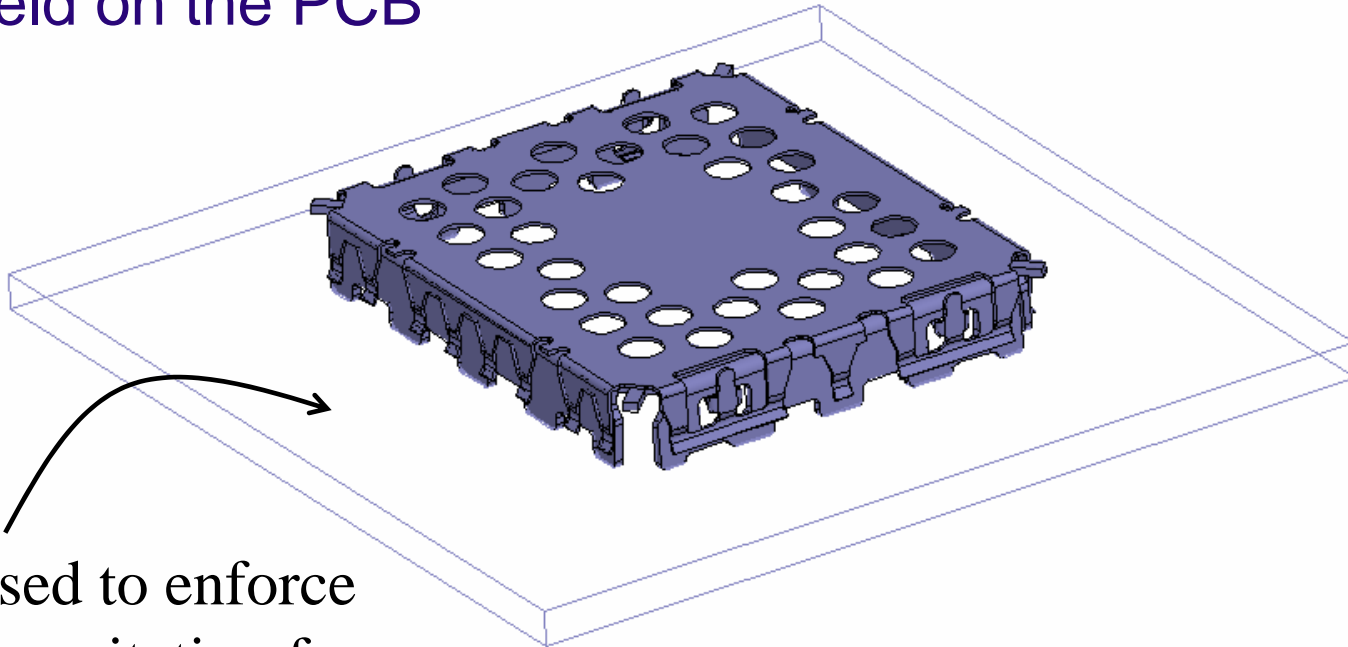
Shielding on a PCB

- The previous example demonstrated EMI for a housing. There was no direct contact between the shield and PCB.



Coupling Ground currents to the shield

- Shield on the PCB

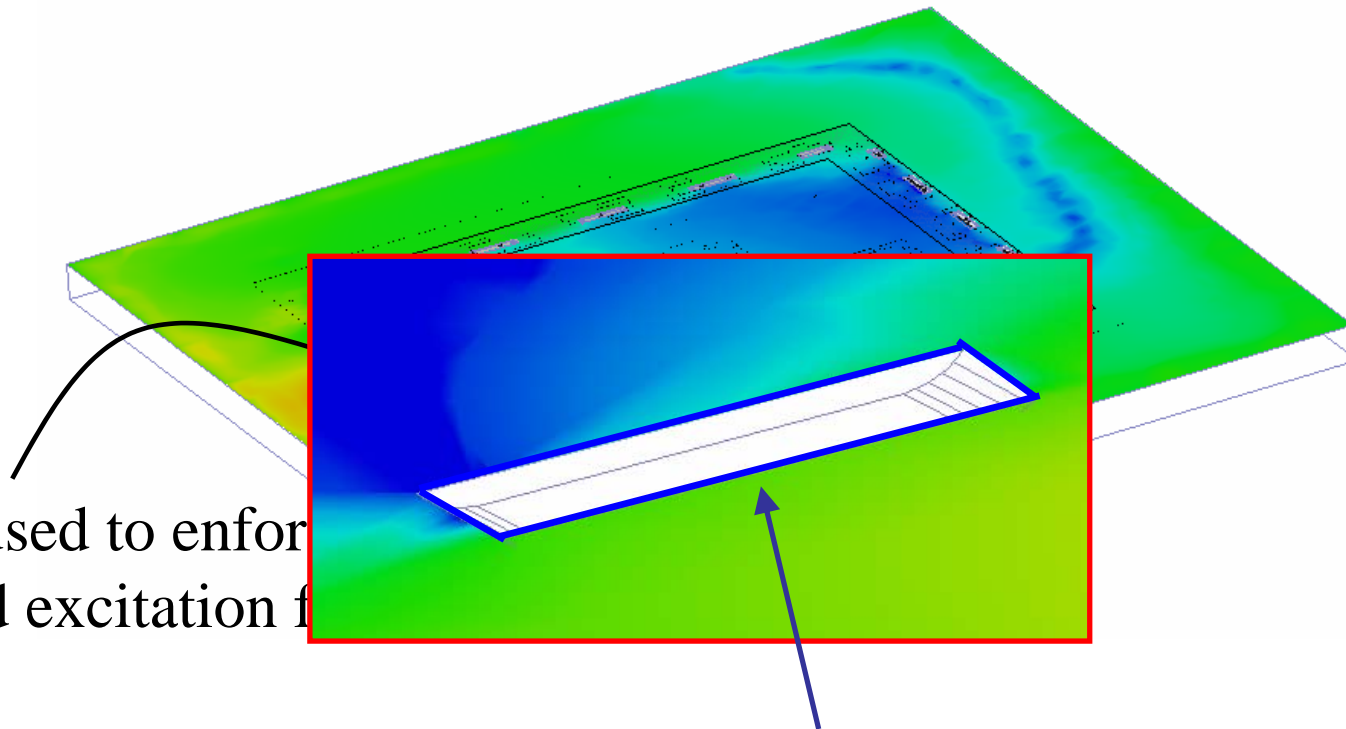


Surface used to enforce near-field excitation from the PCB.



Coupling Ground currents to the shield

- Shield on the PCB



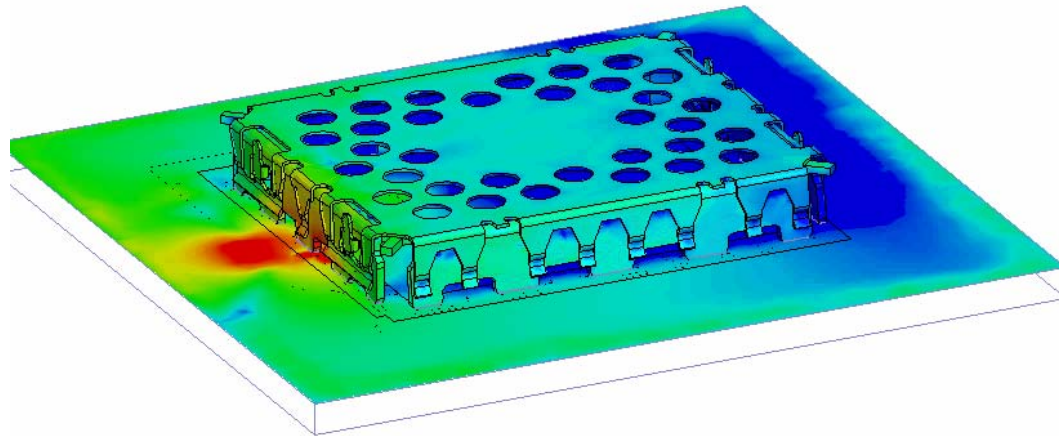
Surface used to enforce
near-field excitation for
the PCB.

Direct contact between the PCB and Shield is made on the edges
of the recess in the plane.



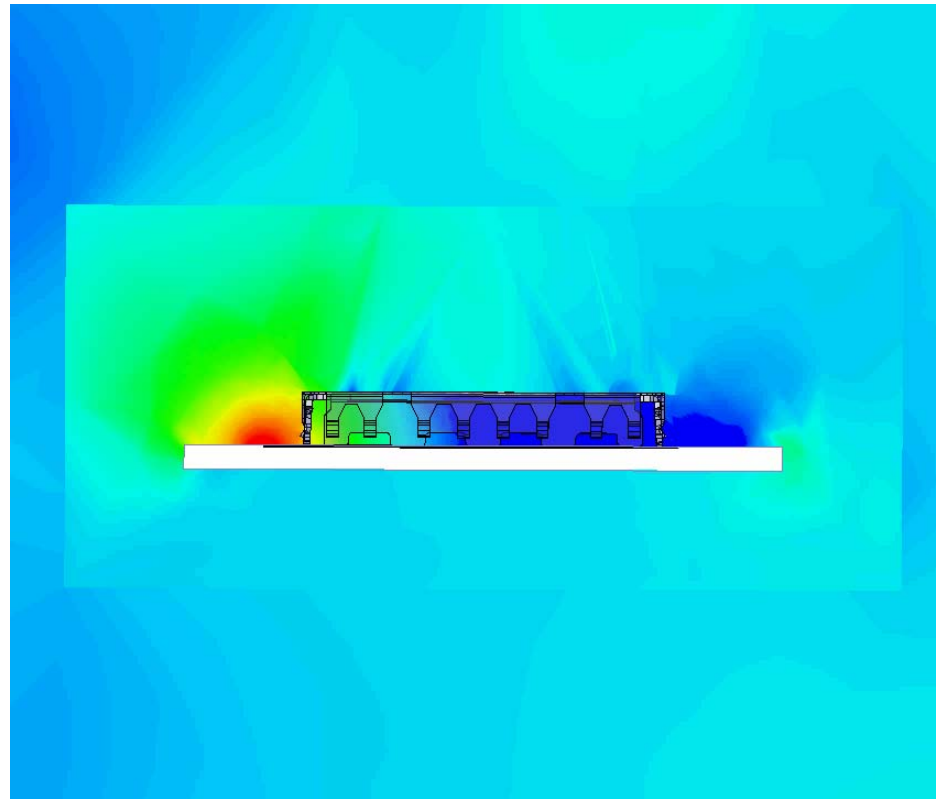
H-field magnitude (current) on the shield

- The current flows from the PCB into the shield. The currents flowing on the PCB ground can be determined using circuit analysis and this information can be used to realistically predict the shield performance.



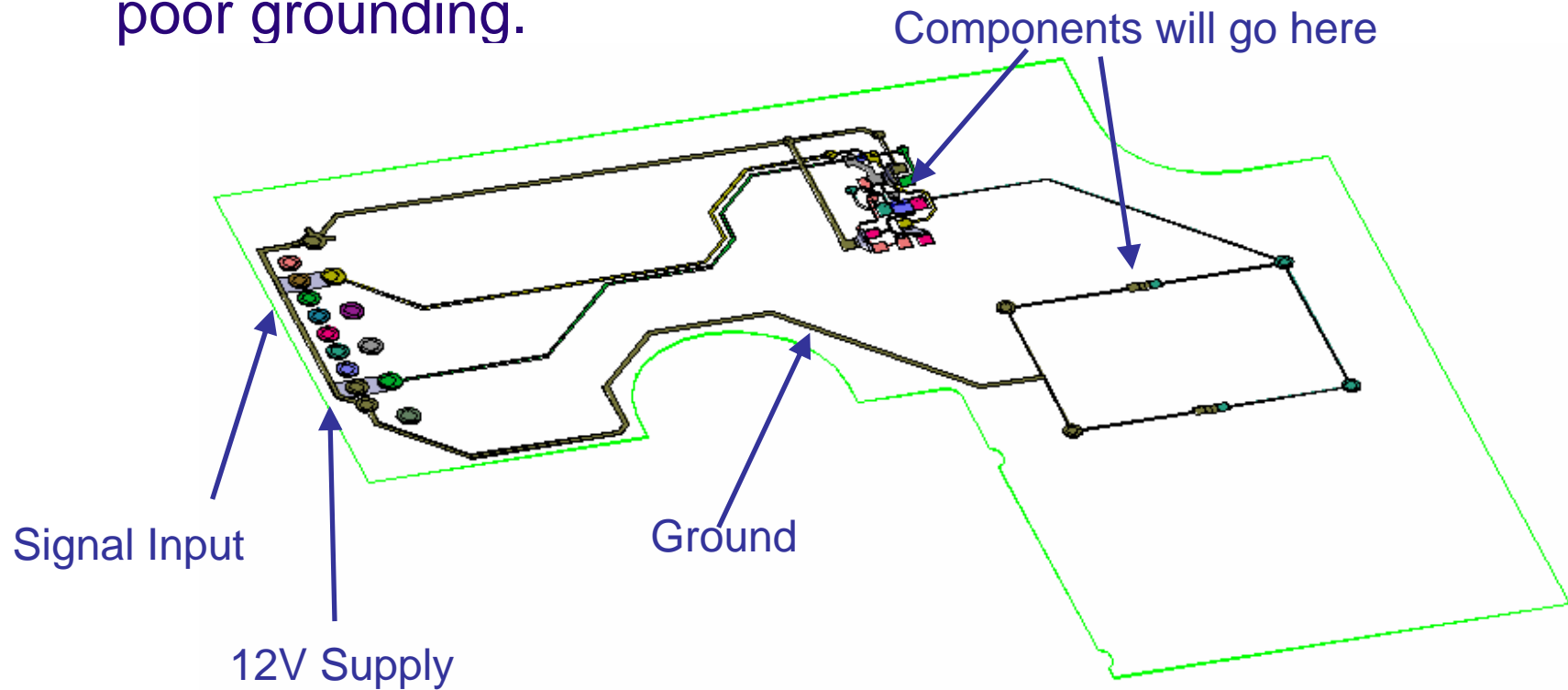
H-field magnitude

- Viewing the magnetic field we see that coupling to the shield poses a possible EMI risk.



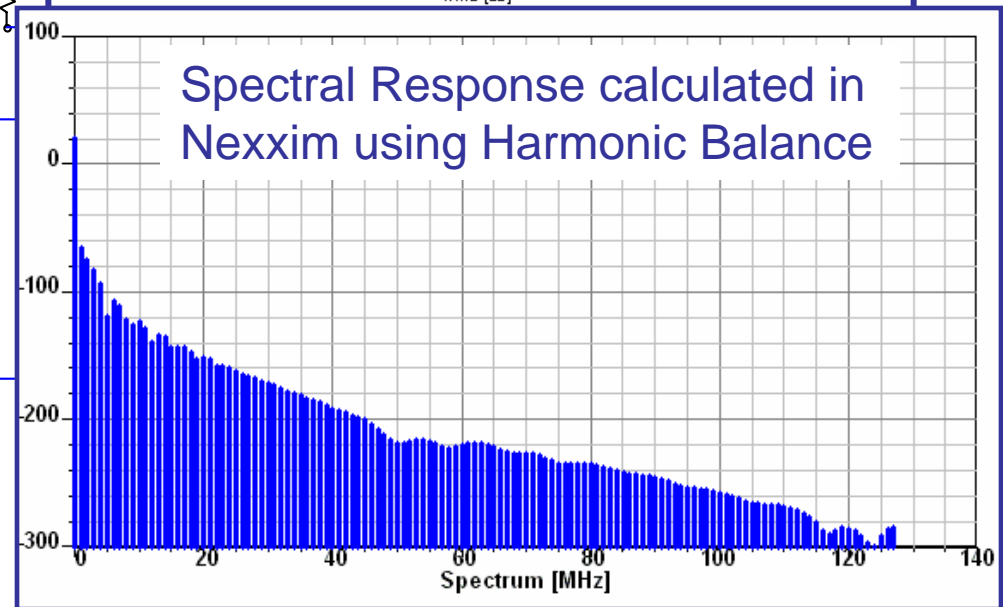
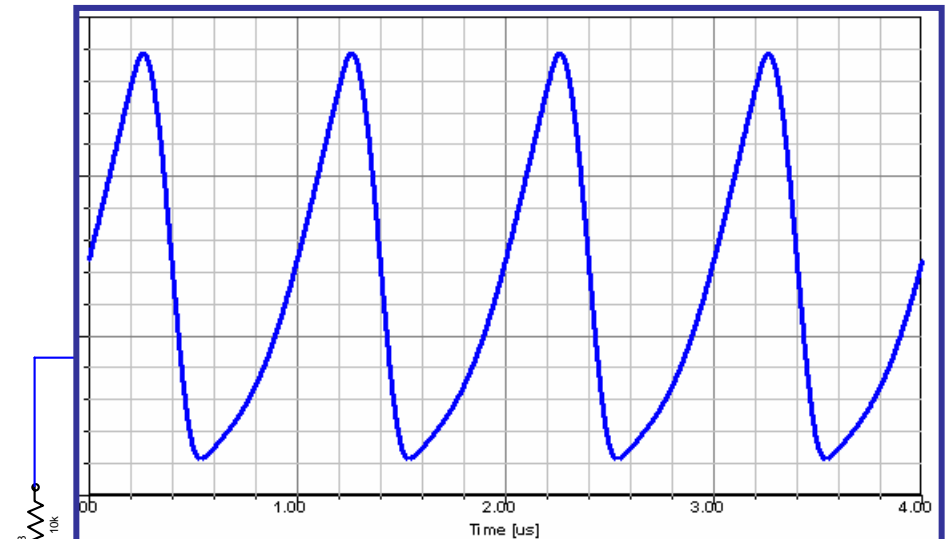
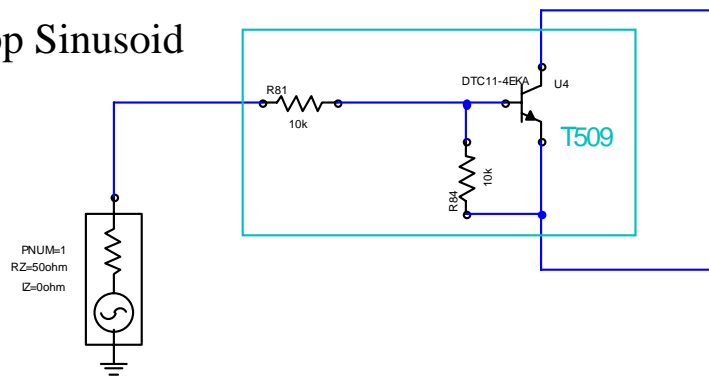
Linking Nexxim to HFSS

- This is a simple example that demonstrates the effect of poor grounding.

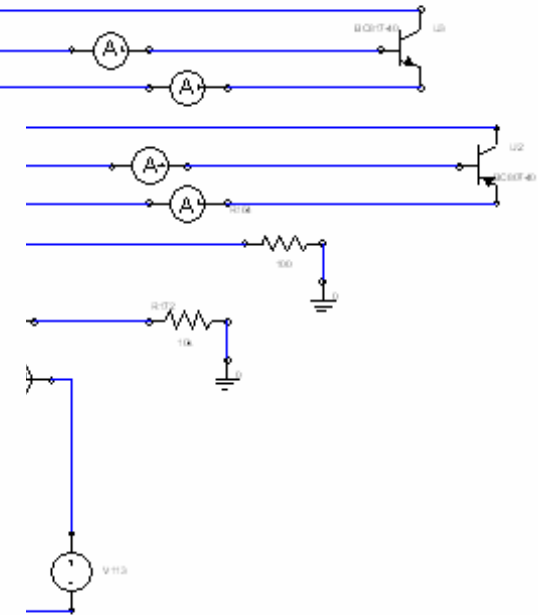
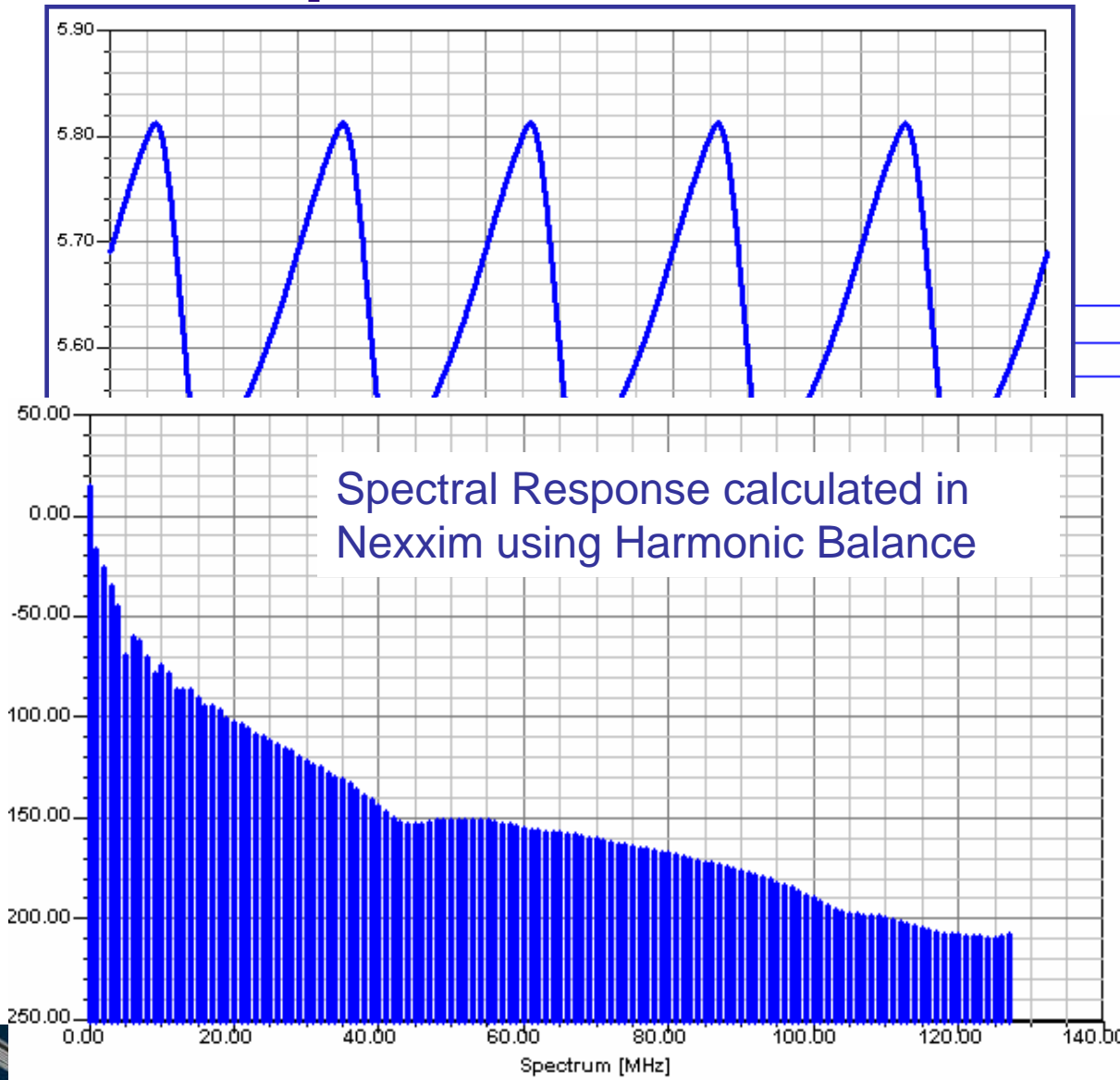


Circuit Analysis in Nexxim without parasitics

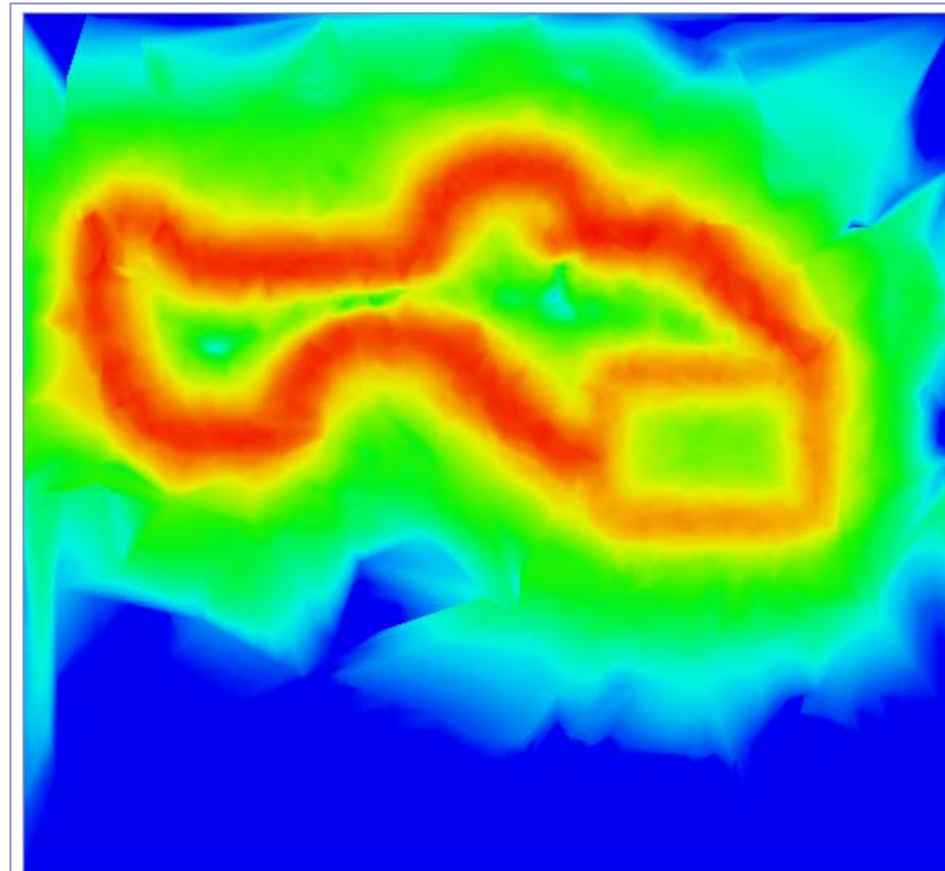
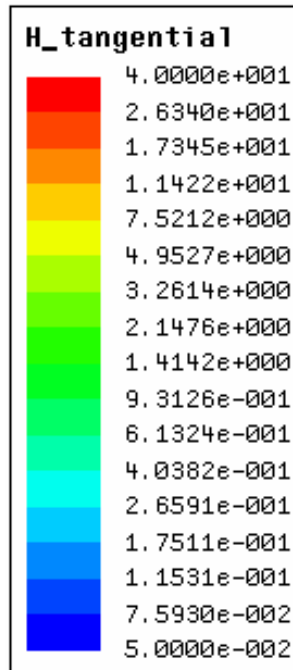
1Vpp Sinusoid



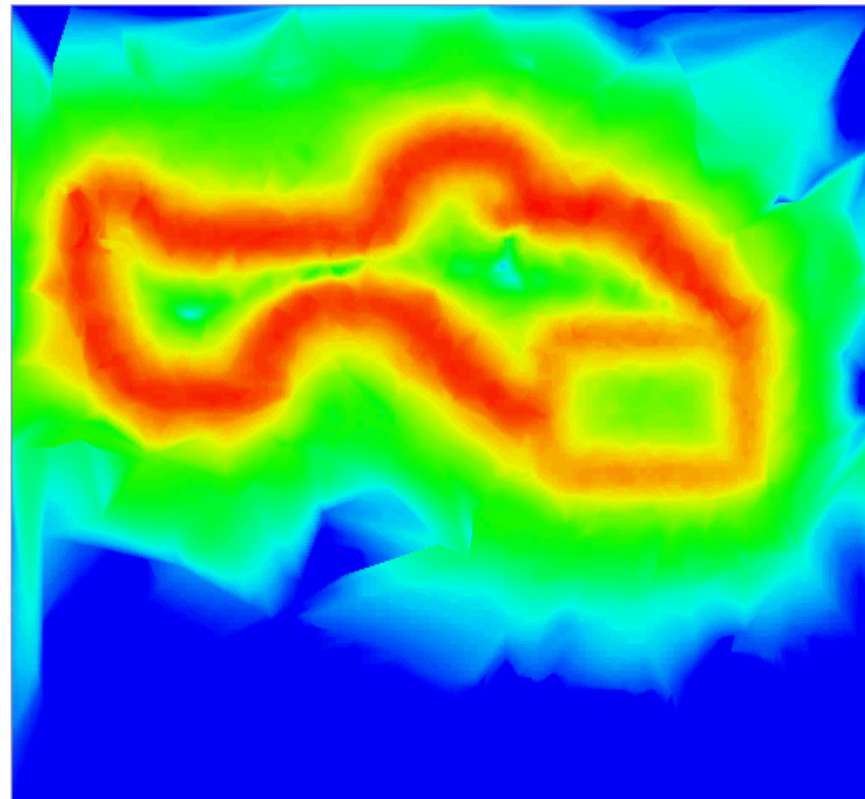
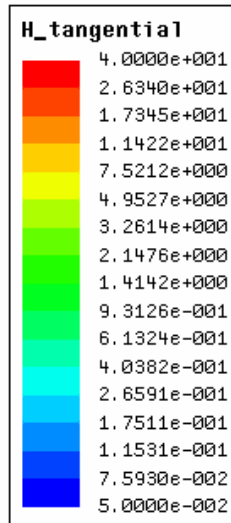
Circuit Analysis including parasitic model from HFSS



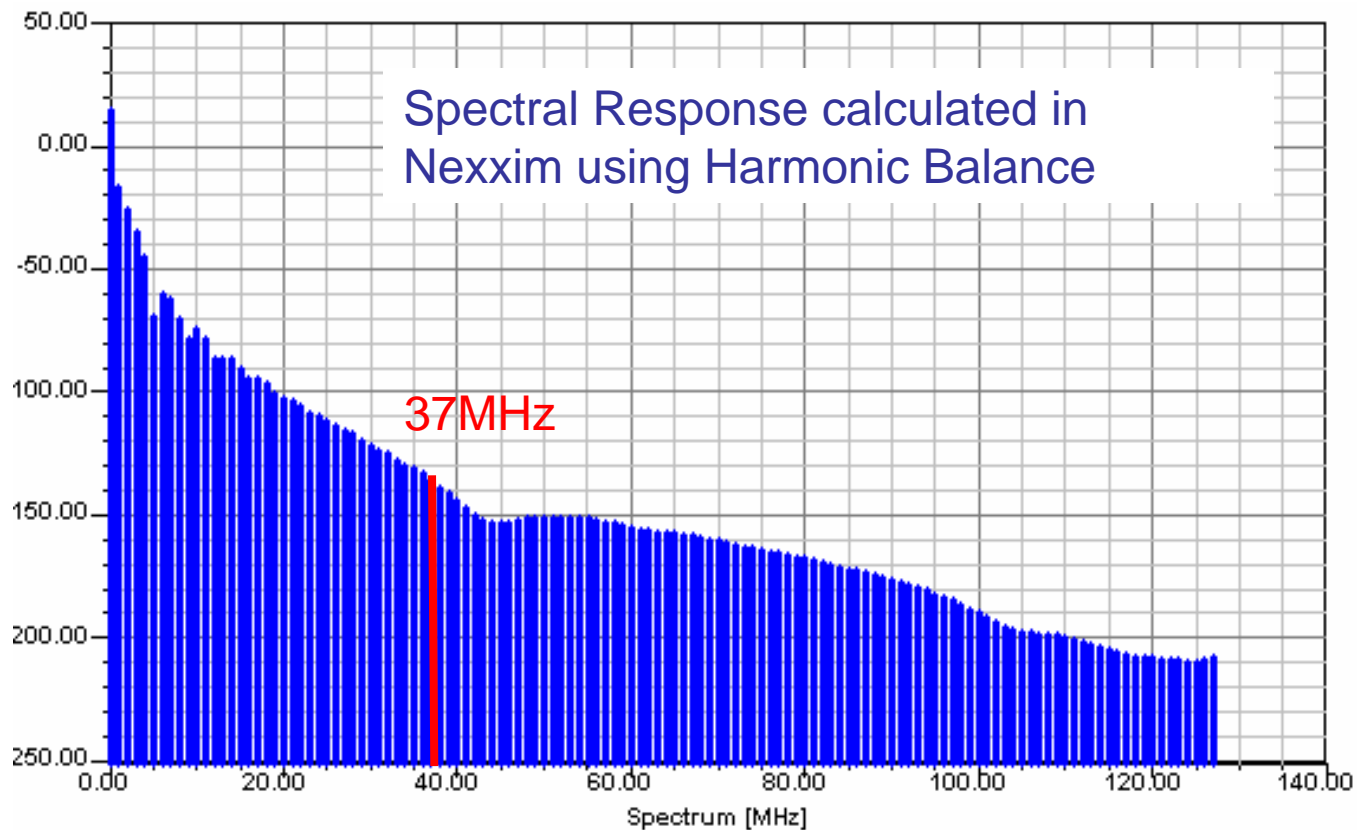
Tangential H-field 3mm above the PCB at 1 MHz



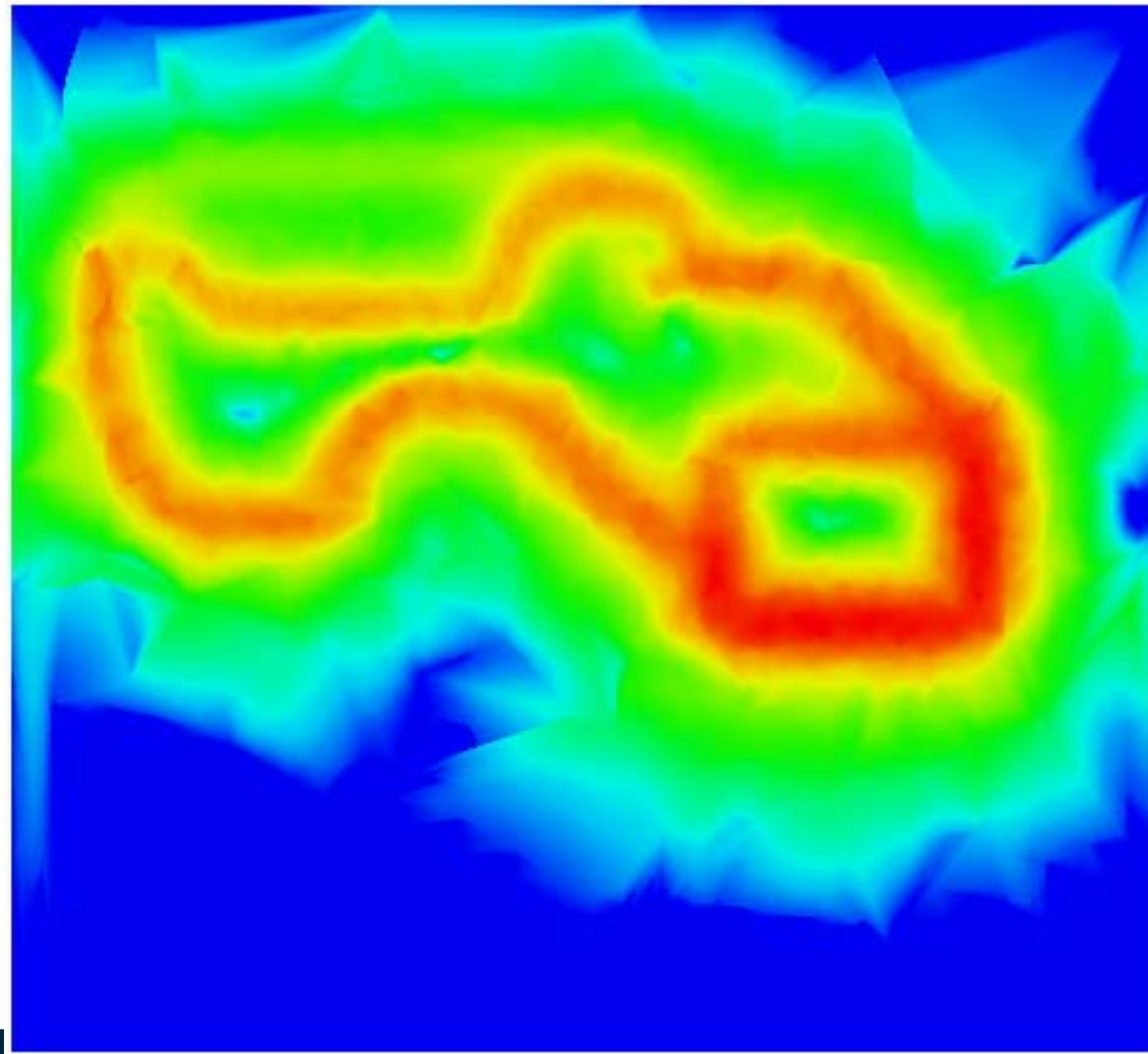
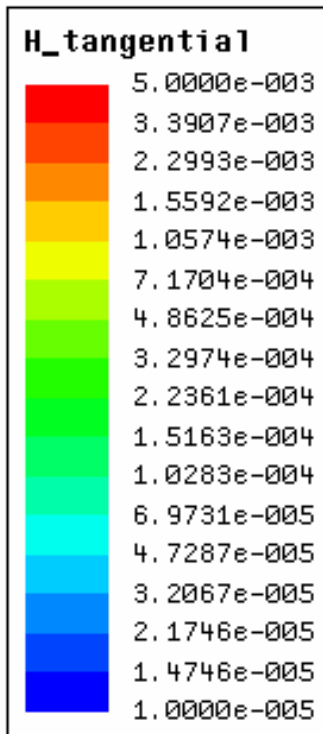
Tangential H-field 3mm above PCB at 1 MHz



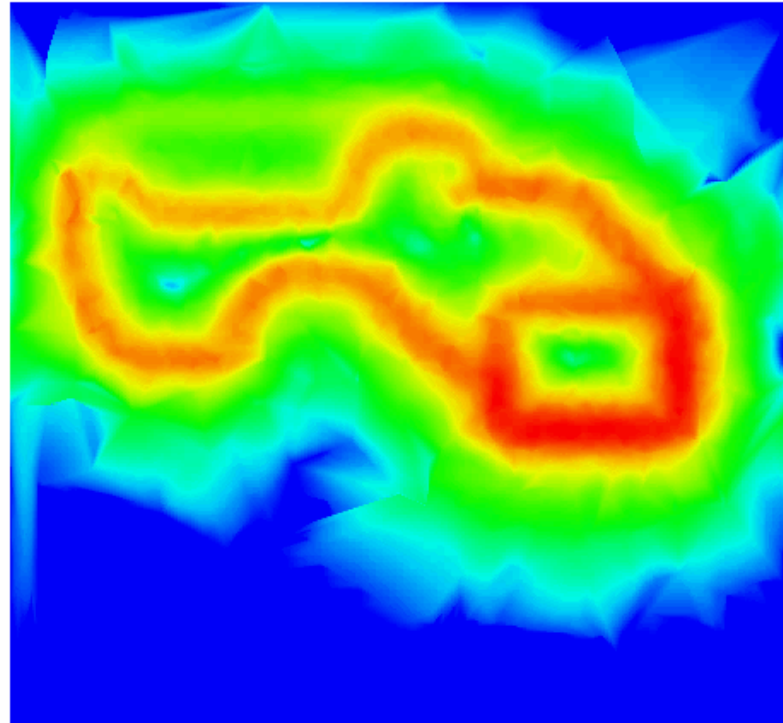
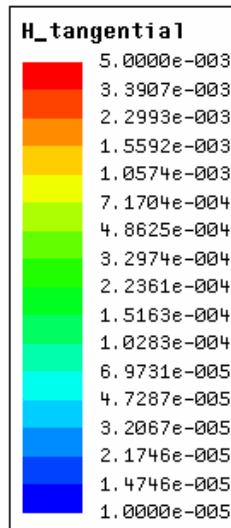
Emission due to nonlinear harmonics



Tangential H-field at 37 MHz



H-field at 37 MHz (due to 1MHz source)



Conclusions

- The multi-scale problem posed by the complex nature of EMI/EMC design challenges can be addressed using a 3 step approach.
- Compatibility between various electromagnetic simulation techniques such as circuit analysis (Nexxim), 3-D field analysis (HFSS) and 2-D finite element analysis (SI-wave) represent a major step toward full system EMI/EMC electromagnetic analysis.
- Both isolated housing and shielding that is directly connected to the PCB have been investigated.

