

Use of Simulation Software in Pre-Qualification Tests

1. Short EMC Introduction

2. Benefits of EMC Simulation

3. Key points for a Successful EMC Simulation

4. Illustration Examples

- Avionic 



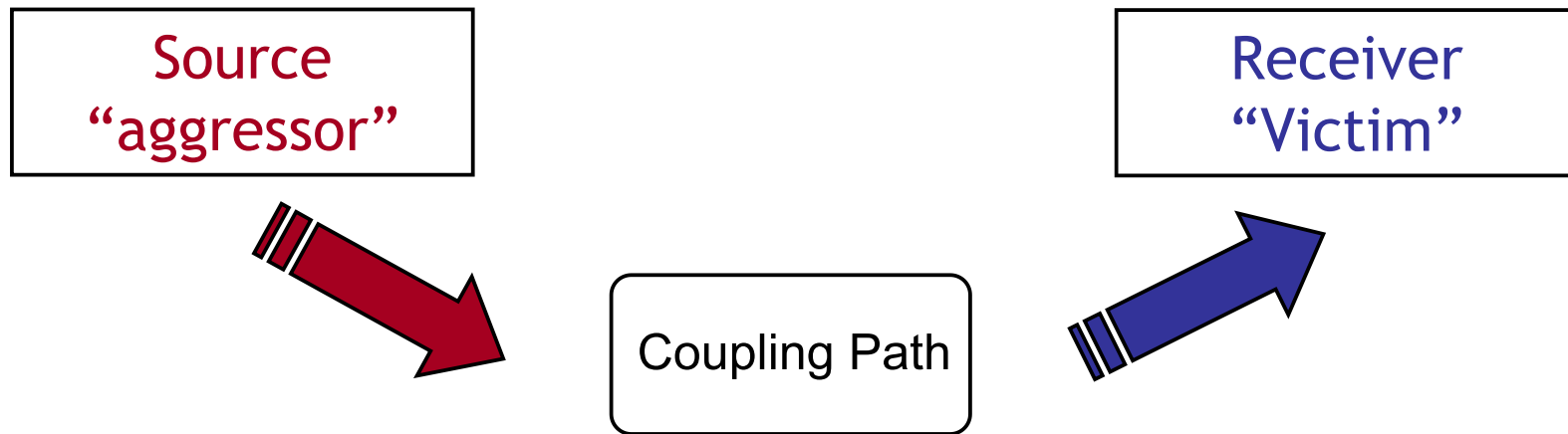
- Automotive 



5. Conclusion

EMC/EMI

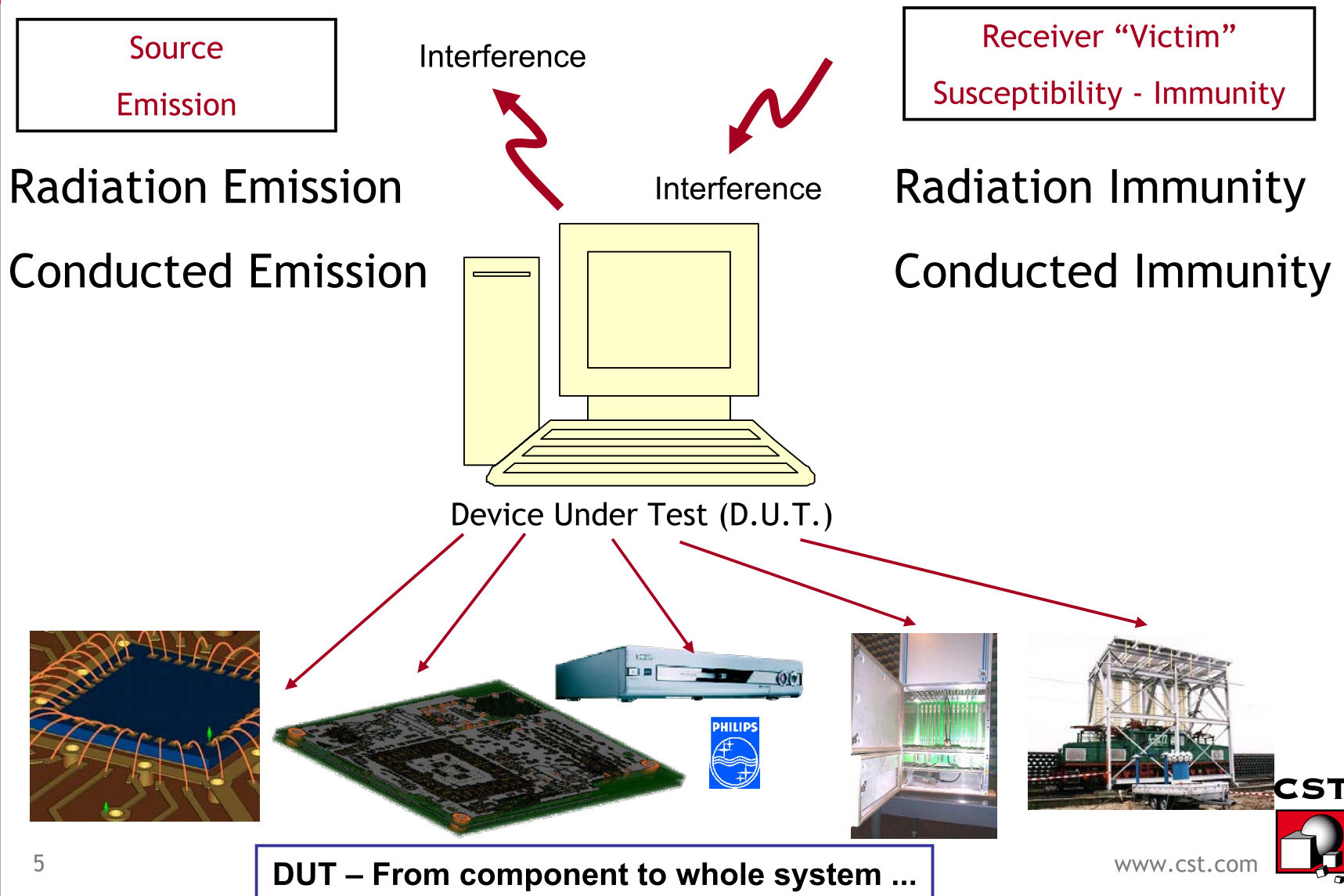
The three essential elements



Methods of coupling path:

- radiation
- conducted
- every combinations of both.

A first EMC/EMI classification



EMC / EMI

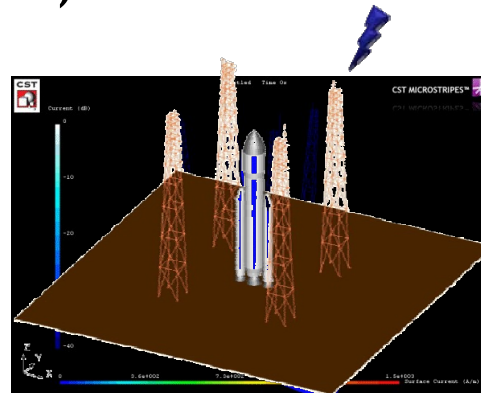
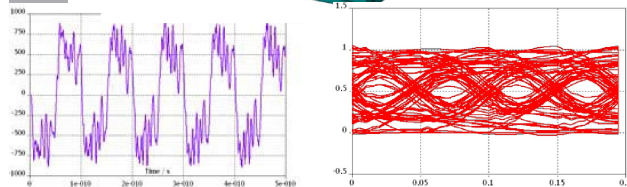
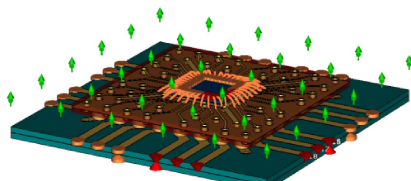
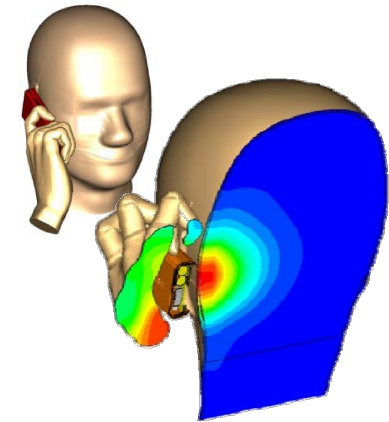
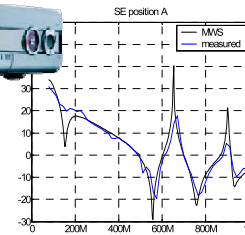
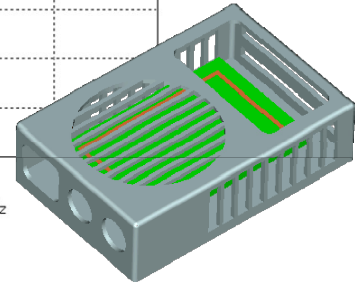
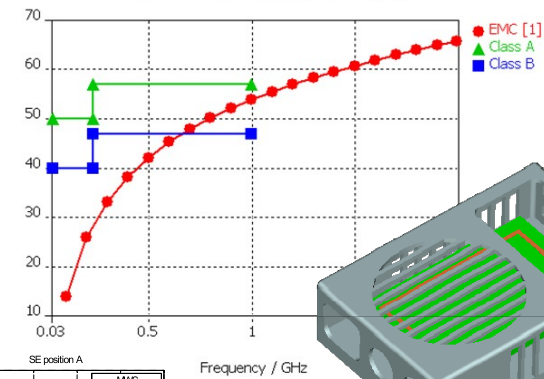
Typical Simulation Requirements

- EMC norm compliance
- SAR compliance
- Shielding effectiveness

$$SE_E = \frac{E_{\text{without shield}}}{E_{\text{with shield}}}$$



- ESD
- Lightning strikes
- Radiated emission
- Signal & Power Integrity (SI, PI)

EMC: Efield at 3 meter distance [dB(microV/m)]



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 - Avionic  Royal Military College of Canada
 - Automotive 
5. Conclusion

Benefits of EMC Simulation

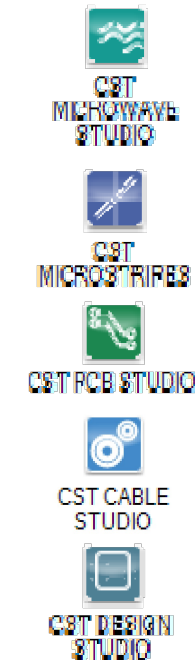
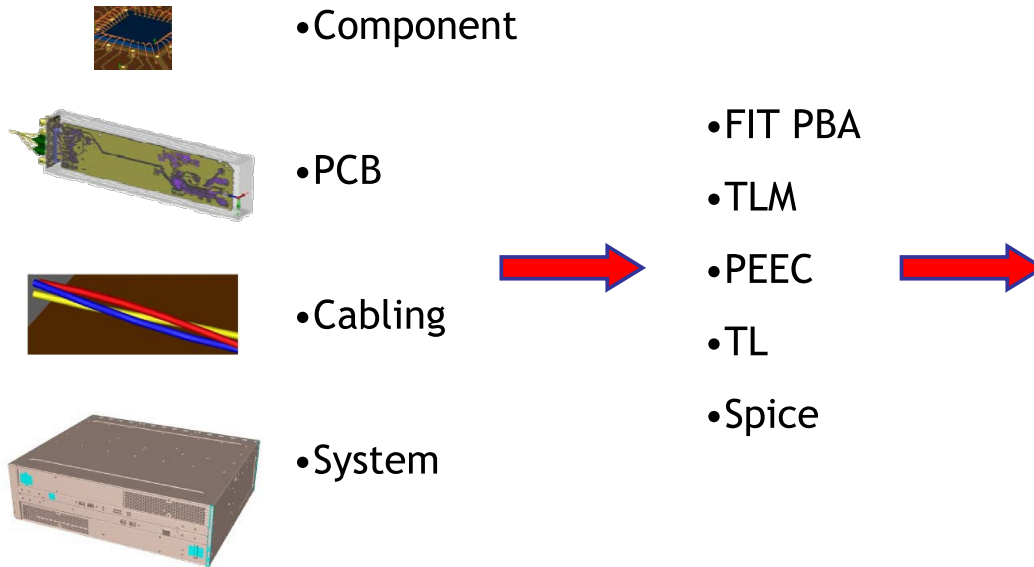
- **Problems anticipation**
 - Before first prototype
 - No testing capabilities
 - Test impossible
- **Targeted Studies**
 - Seams, gasket, air vent, cabling...
- **Better problems understanding**
 - Visualization capabilities
 - Post processing tools
 - Improve Communication
- **Better time to market**
 - Testing optimization
 - Cost reduction

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Key points for a successful EMC simulation

- **EMC knowledge**
- **Model simplification**
 - Geometry
 - Material
- **Adapted simulation tool**



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Electromagnetic Interference Threat Posed by a Wireless Network Inside a Passenger Aircraft

- EMI from PEDs on commercial aircraft has been suspected of causing anomalous events during flights for years.
- Documented EMI incidents include autopilot disconnects, erratic flight deck indications, course deviations and uncommented turns.
- Reports of EMI incidents on an aircraft are normally qualitative accounts, which can often be impossible to repeat due to the complex nature of the aircraft EME. The aircraft EM model presented herein offers a platform for examining a variety of EMC coupling scenarios in a controlled, repeatable environment.
- The EMI threat will be determined by comparing the numerical results obtained

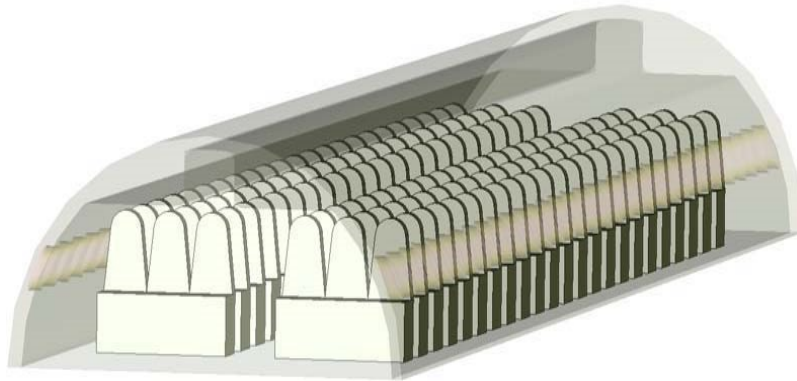


Courtesy Capt Nicole L. Armstrong and Prof. Yahia M.M. Antar
Department of Electrical and Computer Engineering
Royal Military College of Canada

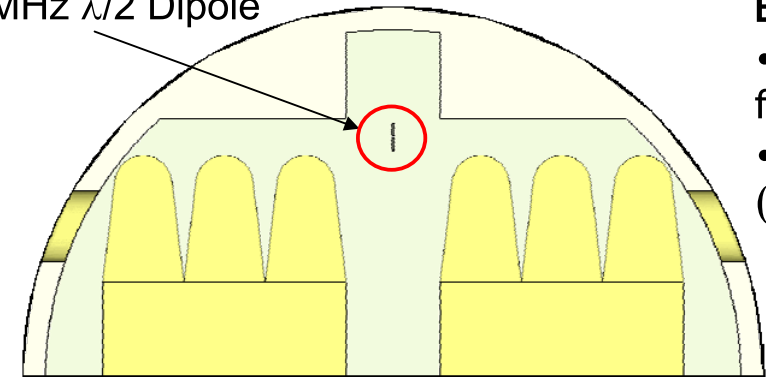
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Electromagnetic Interference Threat Posed by a Wireless Network Inside a Passenger Aircraft



800 MHz $\lambda/2$ Dipole



Airbus A319 EM Model

EM Model

- PEC background
- Lossy windows
- Walls, overhead bins and seats modeled with representative homogeneous, lossy dielectric shapes to include effect of details (cables and isolation in walls, baggage, blankets in overhead bins, etc.)

Excitation

- 800 MHz $\lambda/2$ dipole (GSM 800 frequency band for cellular communication)
- Dipole located in the centre aisle of row 21C (near the back of the passenger cabin).

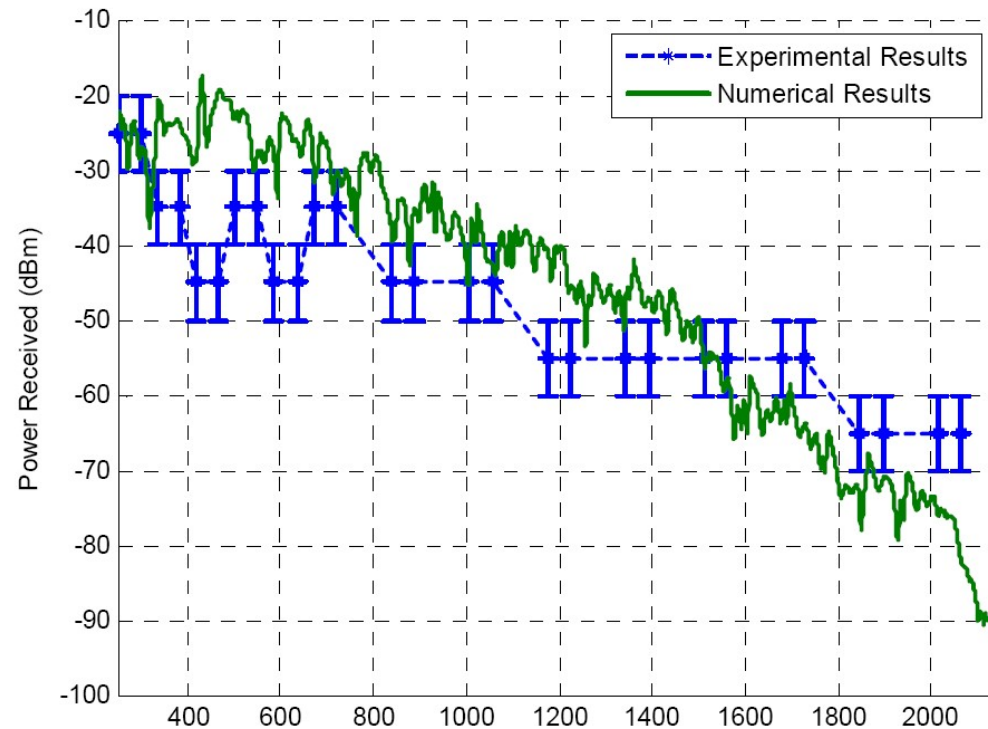


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Validation of aircraft EM Model



Power received at 800 MHz along window seats of A319 cabin.

Despite highly variable measurement results, there is general agreement
-> validity of developed A319 model

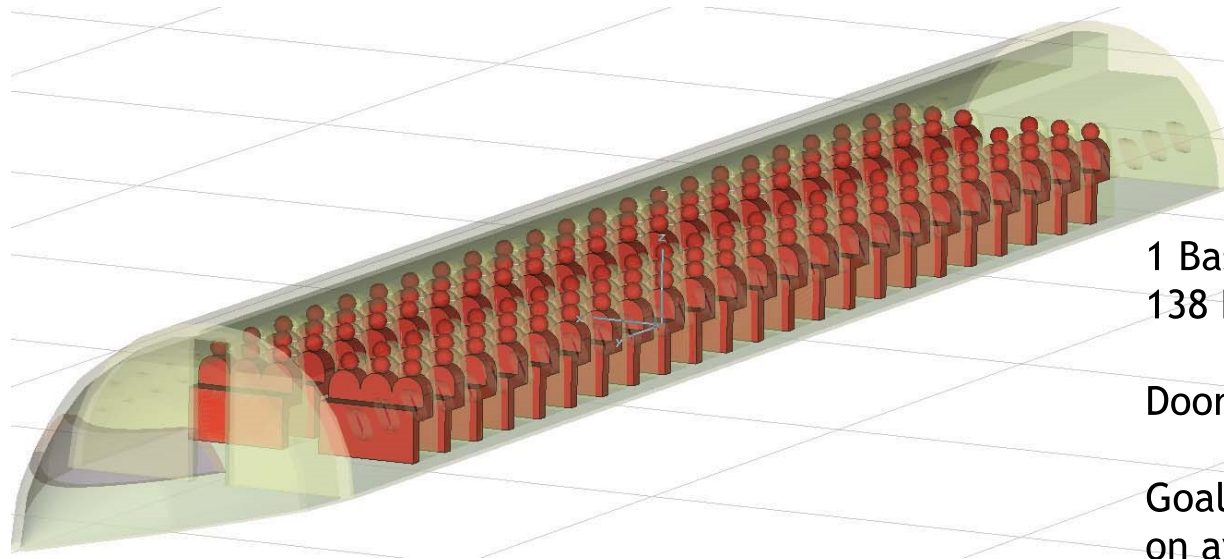


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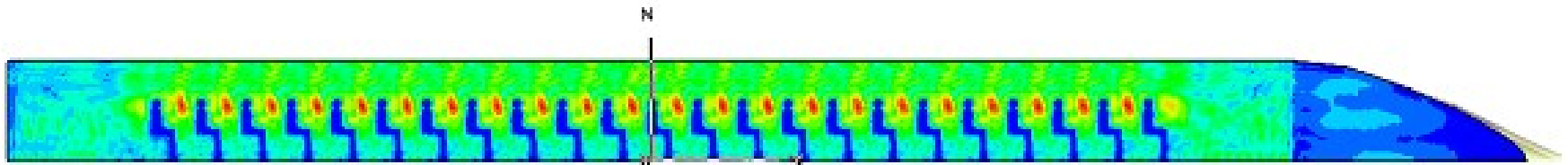
EMI Threat Scenario 1



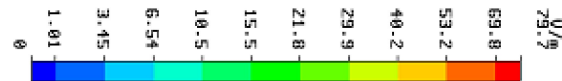
1 Base Station
138 Portable Electronic Devices

Door cockpit - cabin open

Goal: evaluate field levels
on avionic systems in cockpit



Type = E-Field (peak)
Monitor = e-field (f=800) [Case 1]
Component = Abs
Plane at x = 44.29
Frequency = 800
Amplitude Plot
Maximum-Zd = 79.6631 V/m at 44.29 / -35.6061 / 106.237





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 - **Automotive** Johnson Controls 
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Combining PCB, Enclosure and Cable Modeling for EMC Assessment of an Automotive Module

Courtesy Scott Mee: Johnson Controls / David Johns: CST of America

Case Study - Product Overview

■ Instrument cluster

■ Main board

→ CAN, stepper motors, switching power supply, microcontroller, telltales

■ Graphics board

→ High speed memory bus and graphics controller

■ TFT display board

→ High-speed timing controller and internal switching power supplies

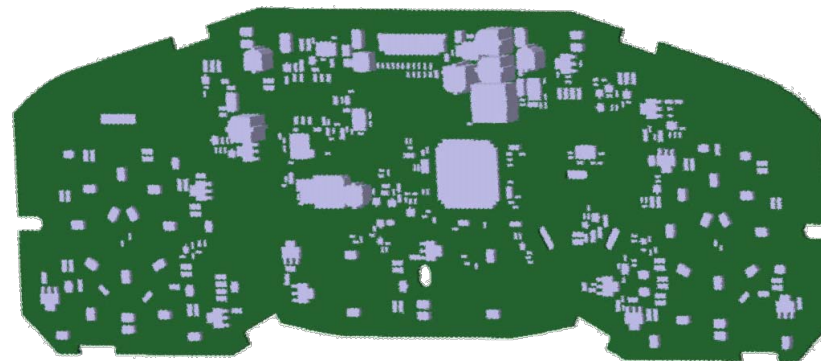
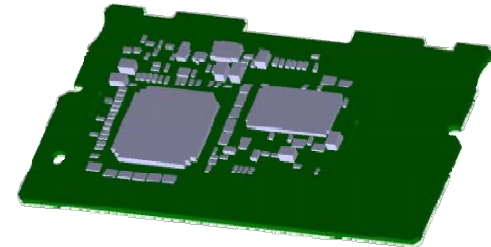
→ Metal housing

■ Interconnects

■ 2 flexible cables used to connect between 3 boards (main, graphic, display)

Case Study - Sources Of Emissions

- SDRAM memory clock (65MHz and harmonics)
 - Main focus in this case study
- TFT pixel clock and data lines (not focus of this study)
- SSN (simultaneous switching noise) of high-speed IC's (not focus of this study)
- Switched mode power supplies (not focus of this study)



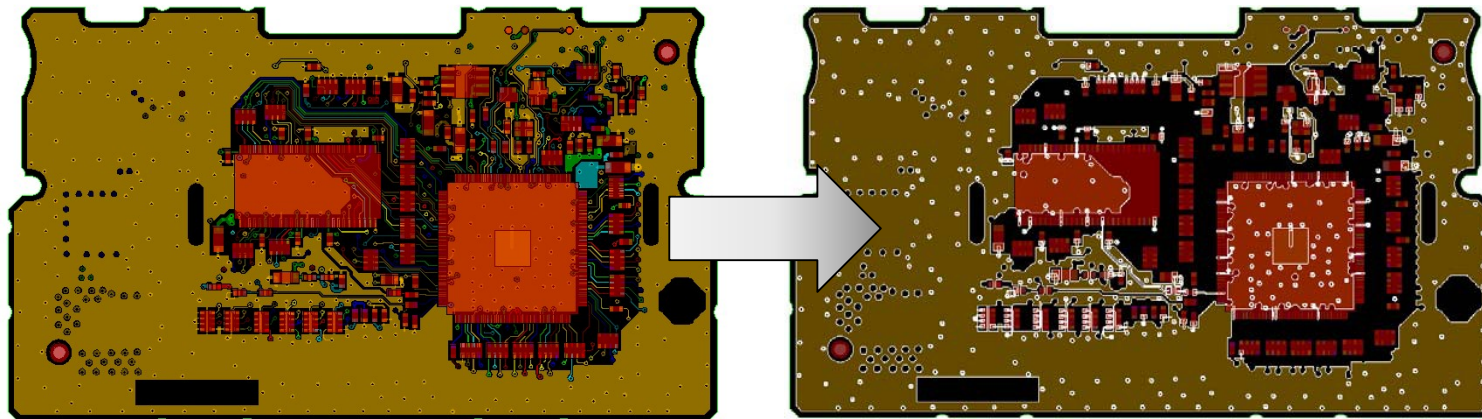
Case Study – Model “Build-Up” Process and Simplifications

- Begin with detailed high-speed graphics PCB analysis (PEEC)
- Remove unwanted nets and generate equivalent source (equivalent currents)
- Model equivalent source in free space (TLM) and compare back to original results from detailed PCB (validation)
- Add TFT display with metallic enclosure and shielded flexible cable interconnect
- Model three board scenario (main, graphic → source, TFT) in free space
- Add CISPR 25 RF setup (ground plane, chamber floor, antenna, artificial networks)
- Add single wire vehicle harness with termination into the artificial networks

Result → Trend model available for evaluating design alternatives

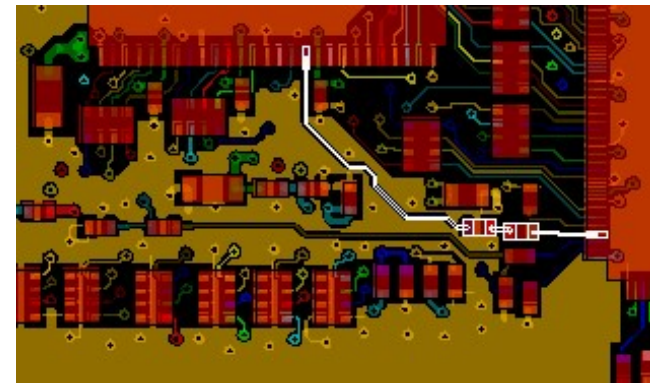
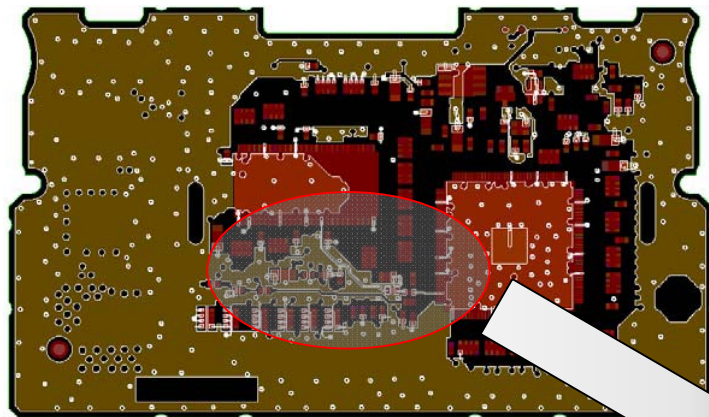
Note: Trend model does not predict EMC test results directly; it shows the trends

Start “Build-Up” Process With Complex Graphics Board



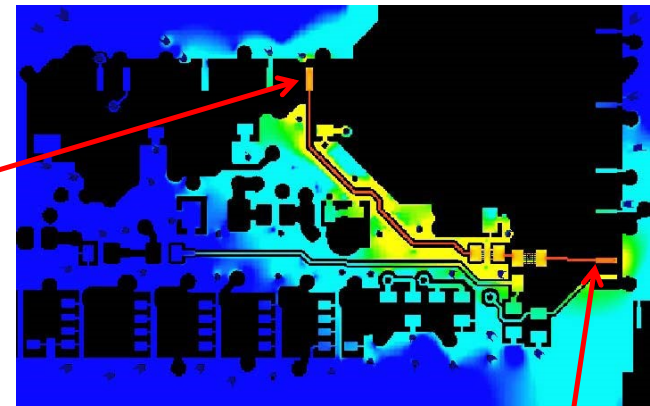
- Graphics controller (Driver → 65MHz)
 - SDRAM memory (Receiver/Load)
 - 6 layer PCB
- Keep ground nets on all 6 layers
 - Keep memory clock nets and related component pins
 - Remove all others

Simulate Detailed Memory Clock Line Using (PEEC) Method



- DRAM CLK net excited using constant amplitude 1V swept frequency signal
- Peak current density shown over localized region at 715 MHz

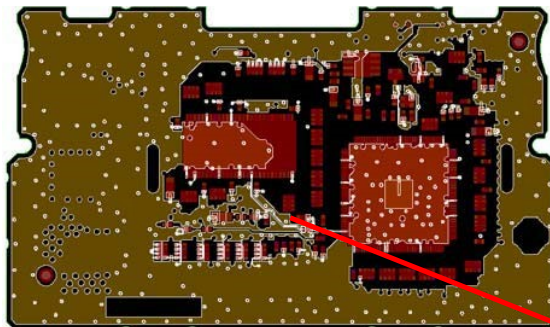
Receiver



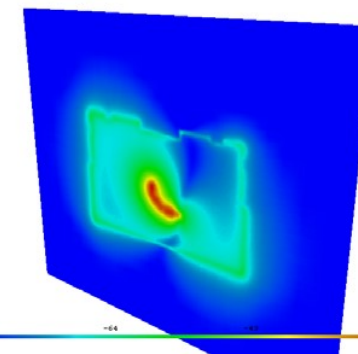
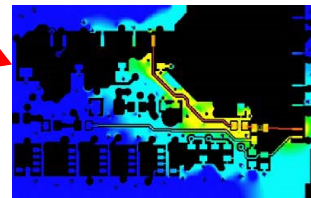
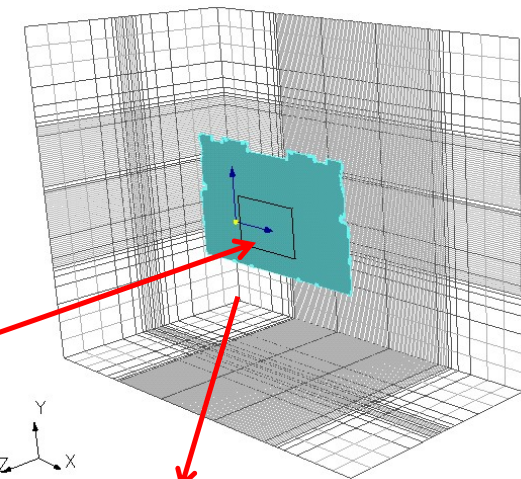
Driver

Generate Equivalent Source Model

Simplified Graphics Board (PEEC)



Equivalent Model (TLM)

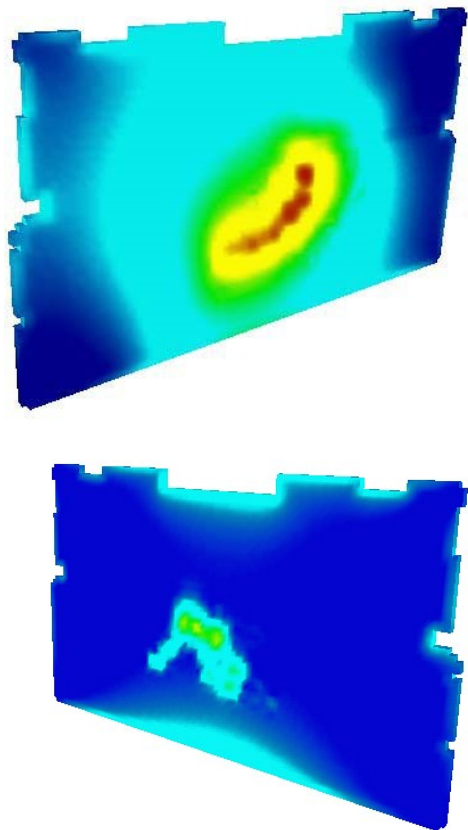


Near E Field
(715 MHz)

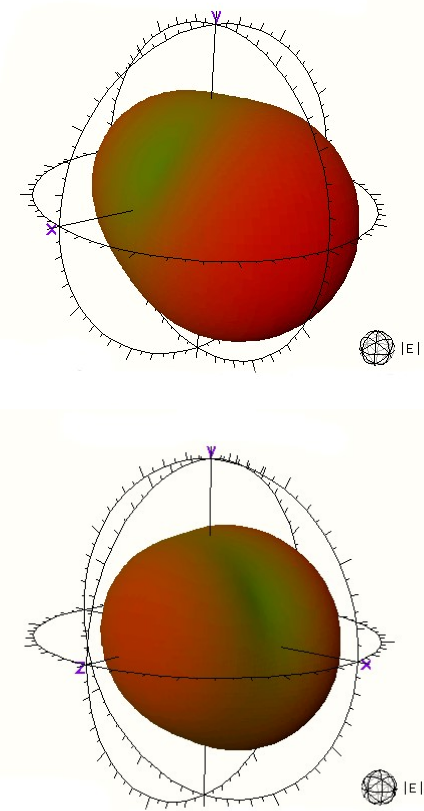
- Equivalence Principle applied to create a fields-based source representation of the PCB
- Source attached to a simplified reference plane in 3D TLM
- Enables more accurate representation of source without retaining all the PCB detail

Equivalent Source Model

Near Electric Field (715 MHz)



Far Field Patterns (715 MHz)



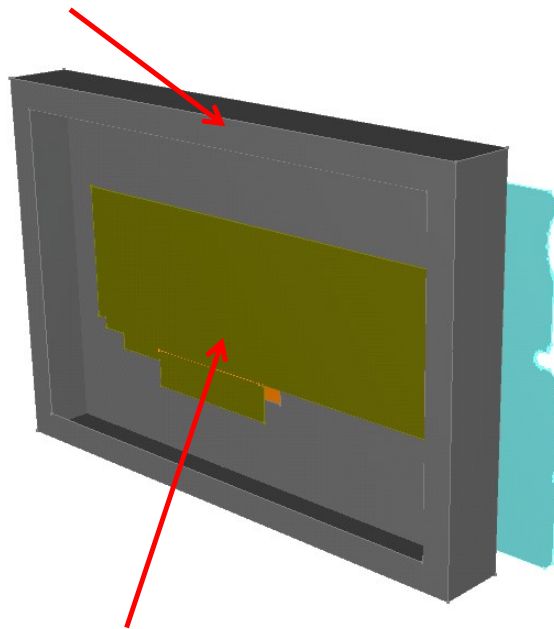
Driven side of PCB
(field generated by
DRAM CLK net
clearly seen)

**Near to Far Field
Transform**

Opposite side of
PCB (field coupled
through vias and
wrapped around
edges of planes)

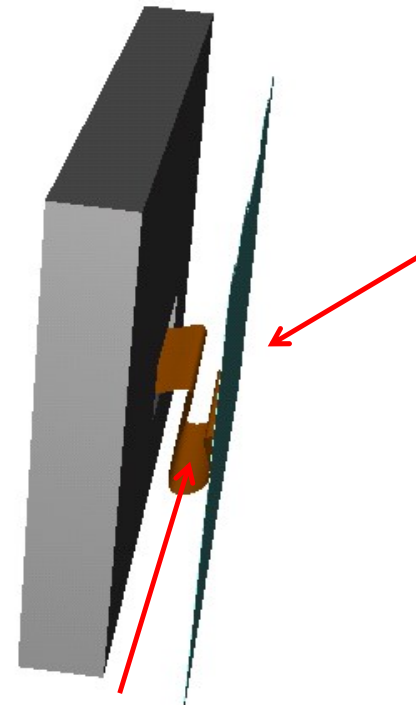
Add TFT Display PCB & Metallic Enclosure With Flexible Cable

TFT Display Enclosure



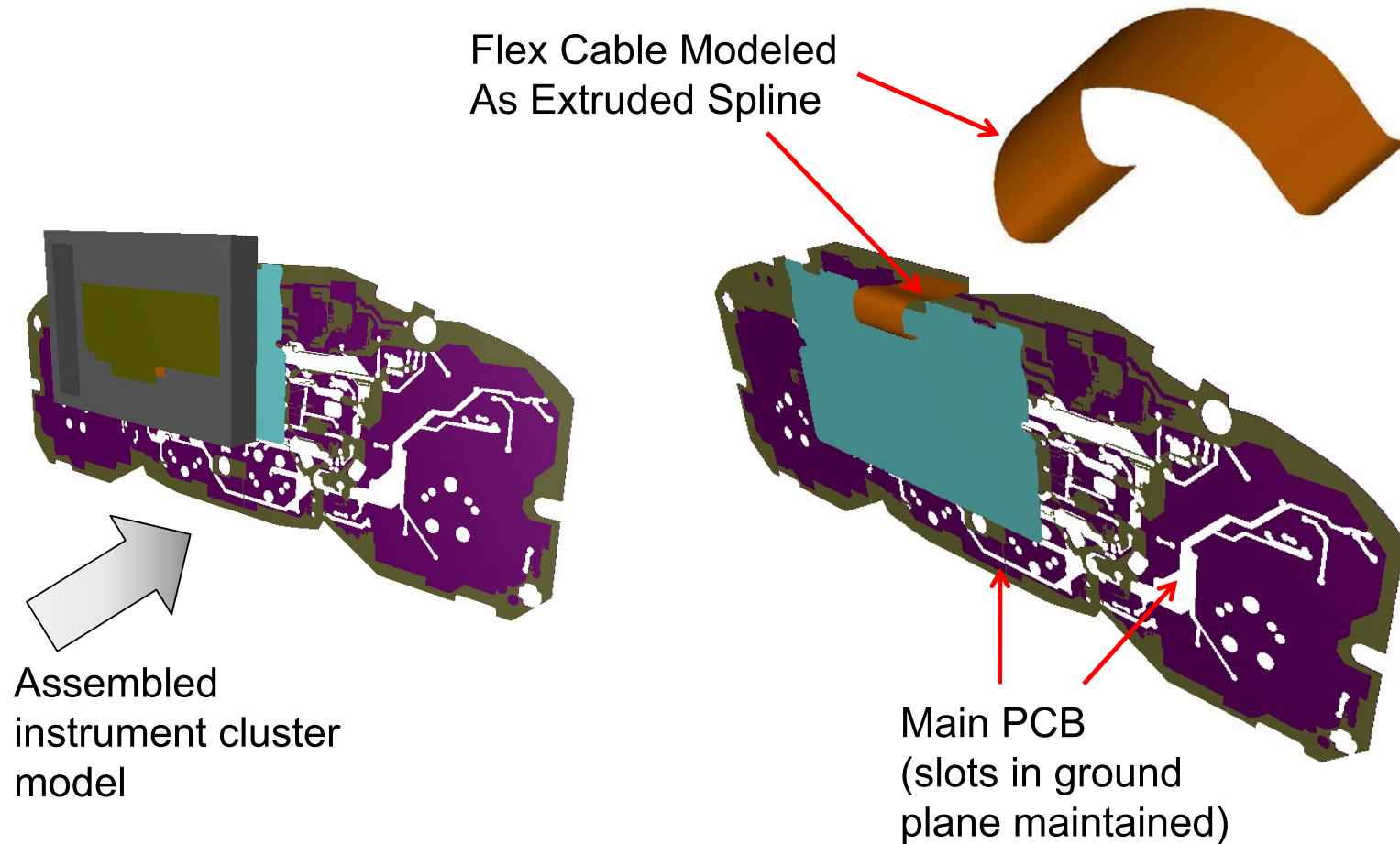
TFT Display PCB

Graphics PCB Equivalent Source Model



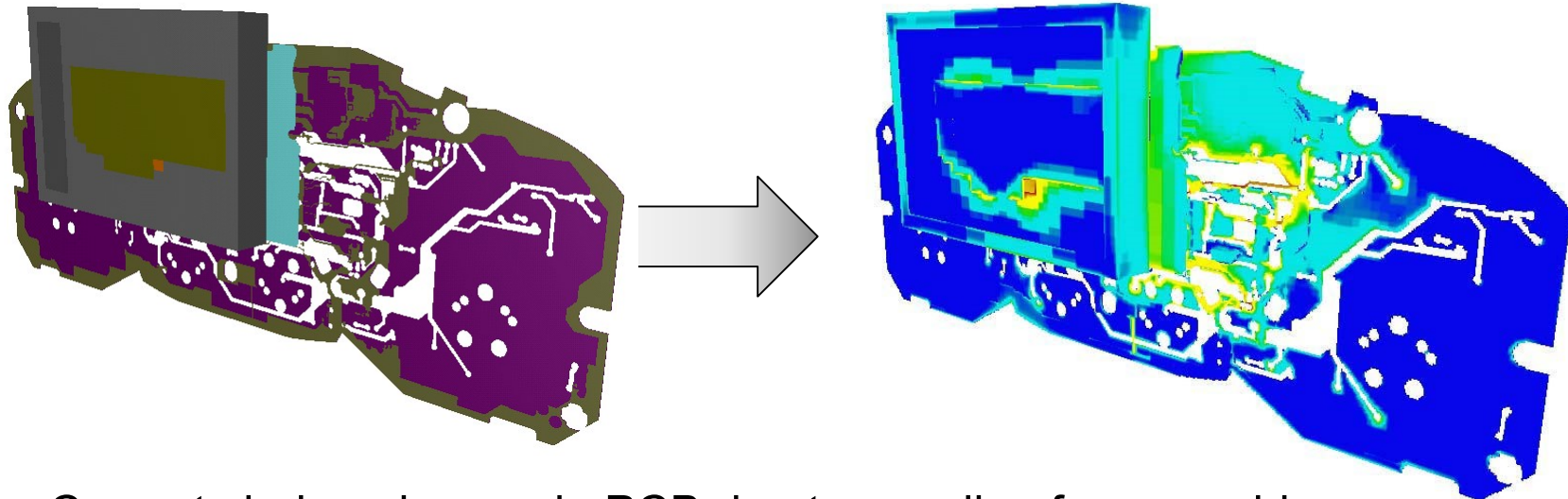
Flexible cable spline model

Add Main PCB With Flexible Cable



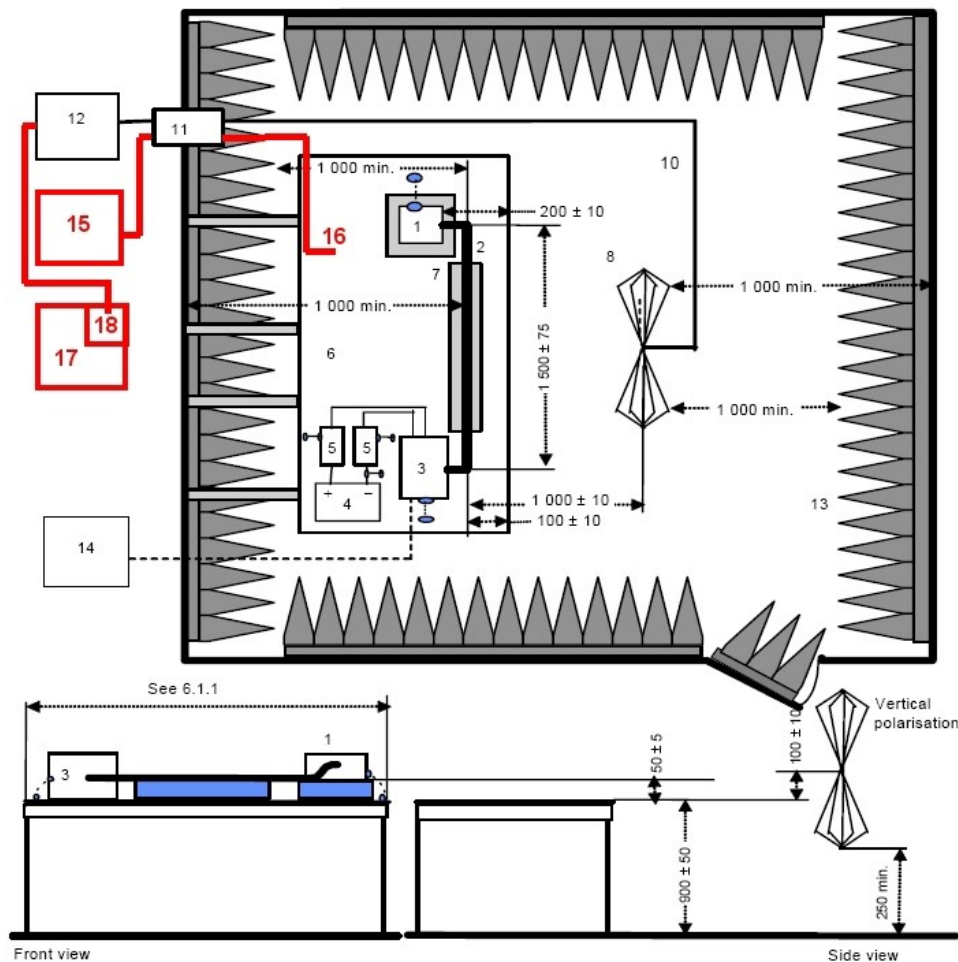
Instrument Cluster Surface Currents

Surface Currents – 715 MHz



- Currents induced on main PCB due to coupling from graphics PCB
- Slots in ground shapes on main PCB are electrically significant
- Slot resonances may enhance emissions near this frequency

CISPR 25 Radiated Emissions Test Setup



- Mainly vehicle harness radiation below 400-500MHz
- Limits are as low as 12dBuV/m in some key ranges
- What aspects should be modeled?
 - Chamber floor
 - Absorber
 - Ground plane/table
 - Ground straps
 - Loads
 - LISNs

CISPR 25 Chamber Model

Instrument Cluster Model

Isotropic Antenna

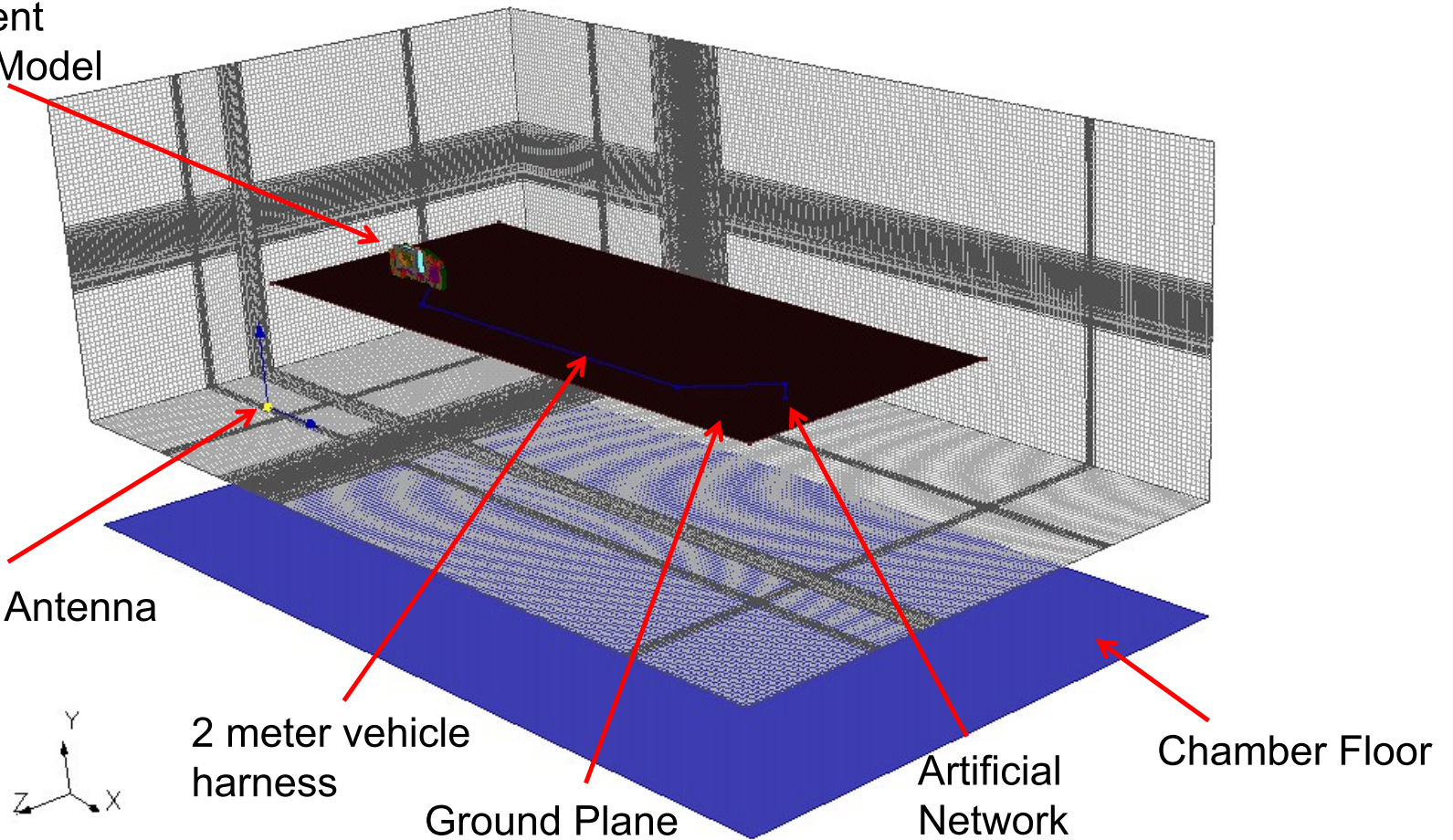


2 meter vehicle harness

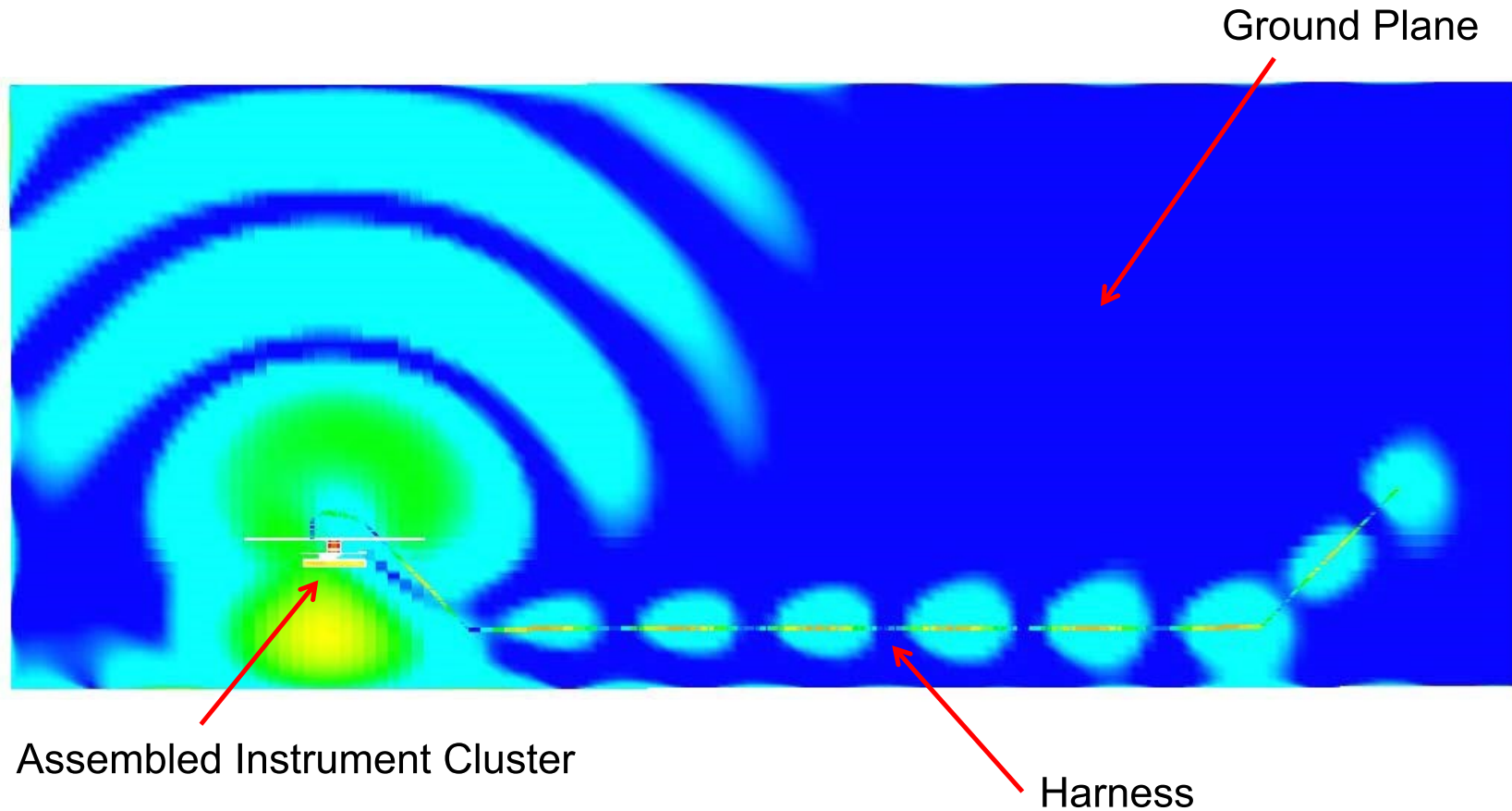
Ground Plane

Artificial Network

Chamber Floor



CISPR 25 Chamber Analysis – Surface Current



Case Study – Trend Model Completed



CISPR 25 simplifications

- Artificial network modeled as a simple circuit between the wire and ground plane
- Vehicle wire harness reduced to a single wire (assume common-mode)
- Antenna is assumed to be isotropic
- Assume absorbing boundary conditions for chamber walls and ceiling

Product model simplifications

- Source model simplified into an equivalent source modeling approach
- Main board ground shapes extracted rather than using completely routed PCB
- Flex cables modeled using an extruded spline
- Display PCB modeled as a single conductive PCB layer



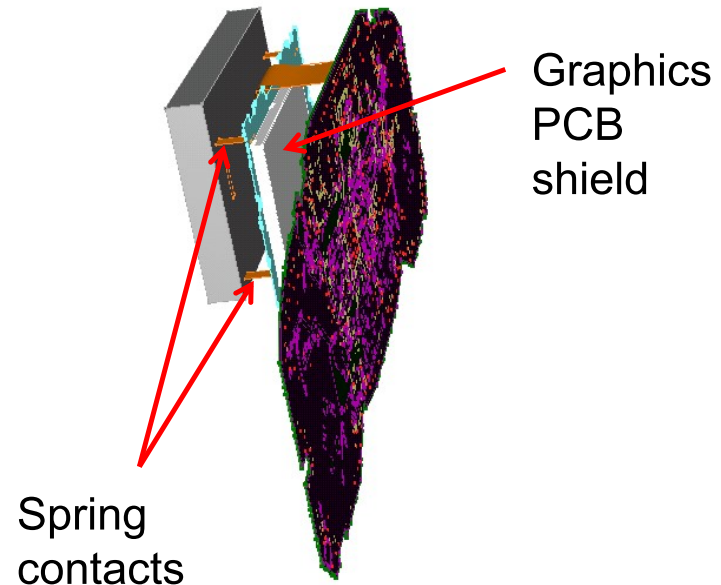
Case Study – Three Design Alternatives

- Increase series resistance in SDRAM clock line (0 ohms → 460 ohms)
- Install PCB shield cover over graphics board circuits
- Add four ground contact springs between graphics board and TFT display metallic enclosure



360 Ohm

100 Ohm

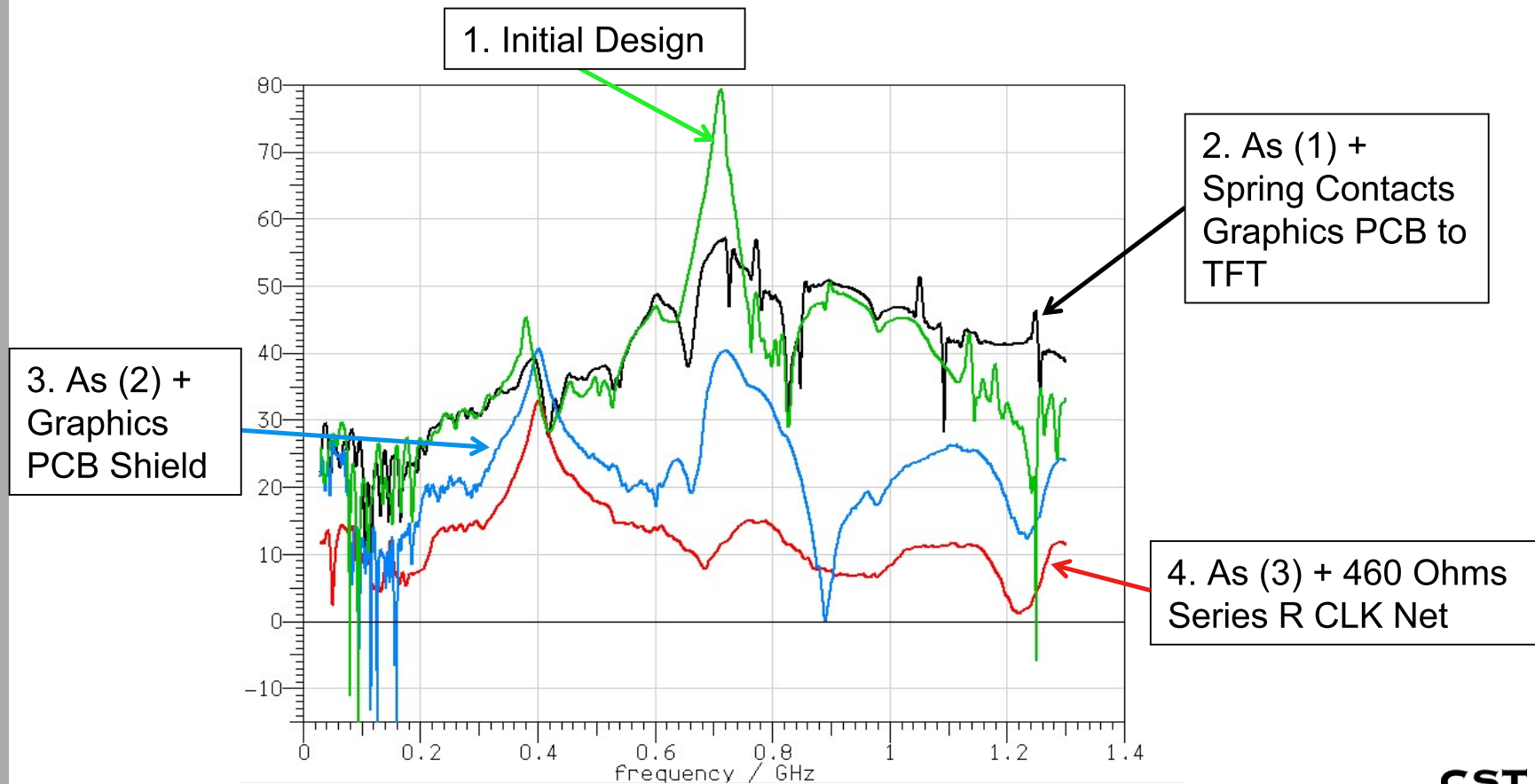


Graphics
PCB
shield

Spring
contacts

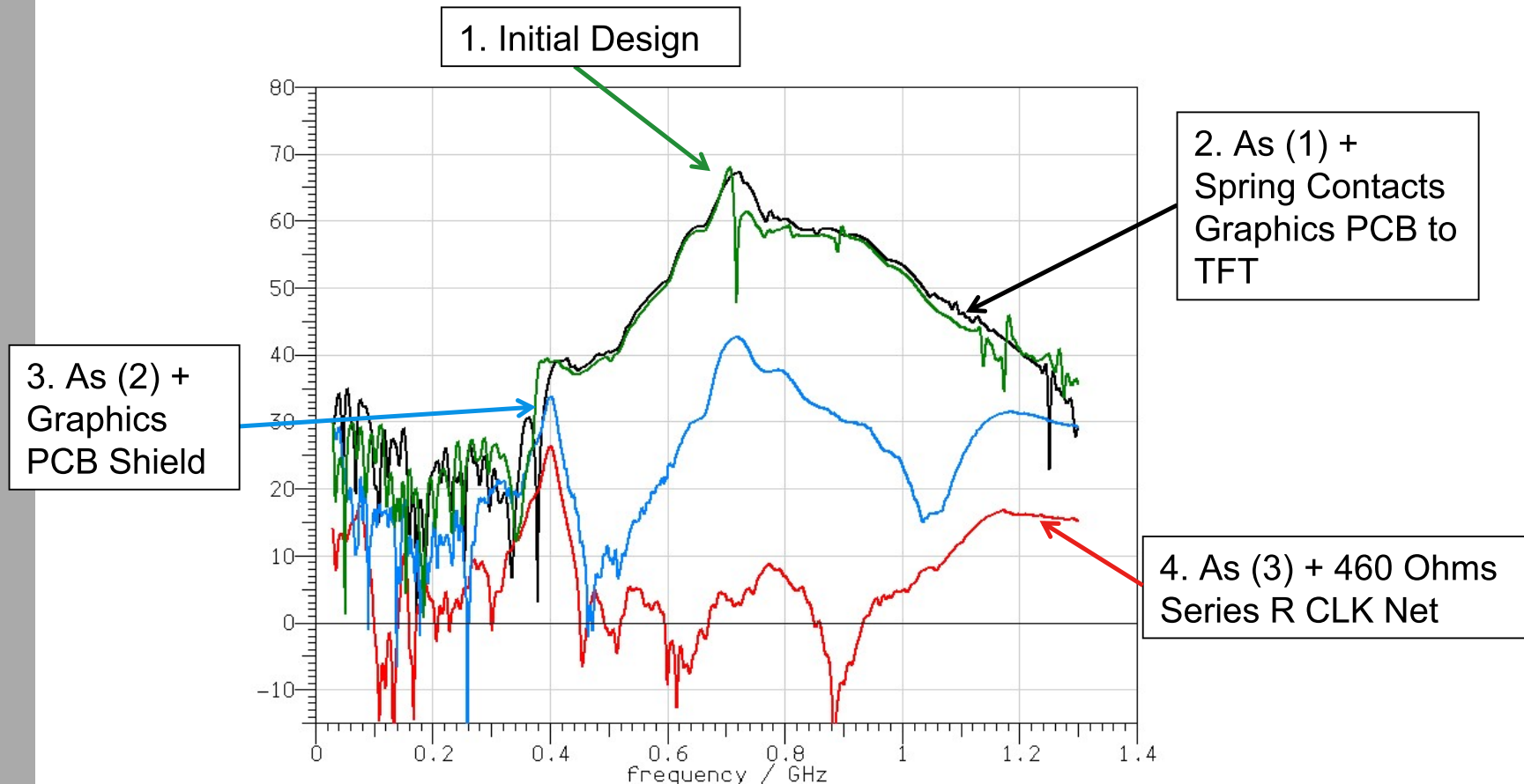
Trends Analysis by Simulation

Broadband Response (Vertical Polarization)



Trends Analysis by Simulation

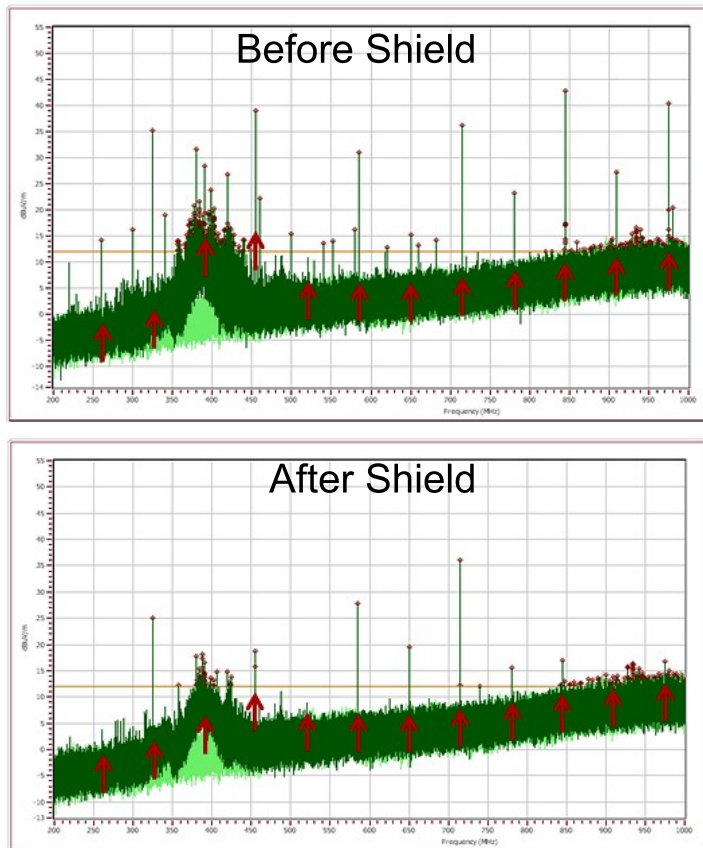
Broadband Response (Horizontal Polarization)



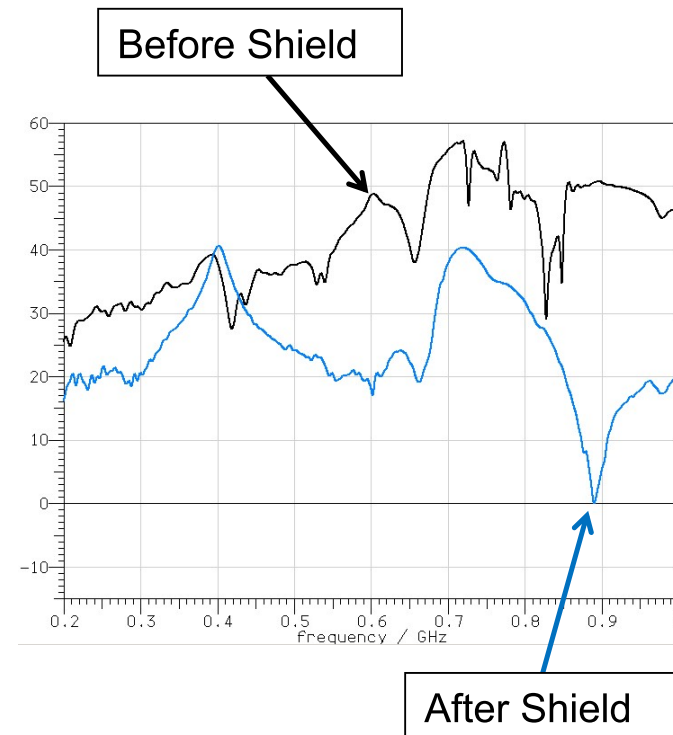
Validation

Comparison of Trends in Simulation and Testing

Test Results



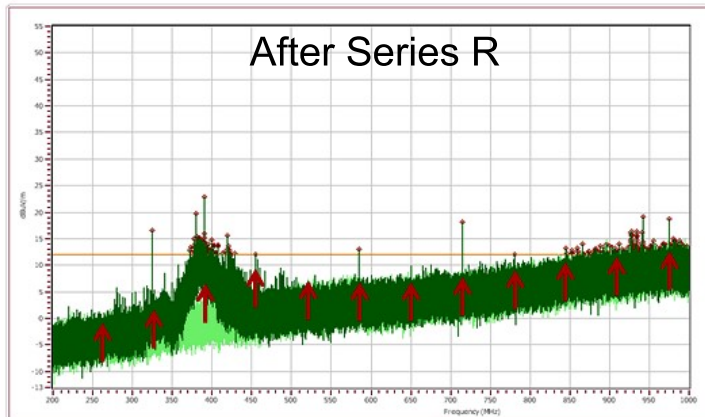
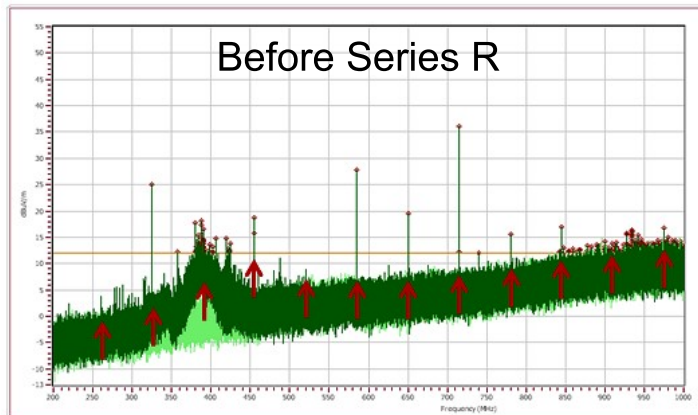
Simulation Results



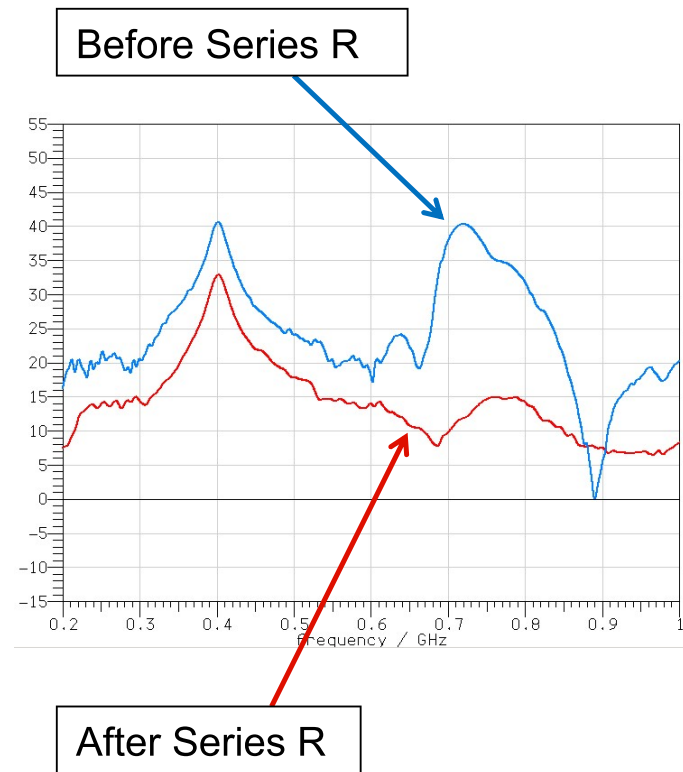
Validation

Comparison of Trends in Simulation and Testing

Test Results



Simulation Results



After Series R

Conclusions

- Simplified model follows the trends found during physical testing
- Design alternatives had more impact at higher frequencies
- Simulation times and model development resources were in-line with practical expectations of product development
- Results indicate the influence of the addition of the test setup, added cables and electronics
- Simulations were run on a dual processor quad-core Dell T7500 workstation with 32 GB RAM
- PCB (PEEC) simulation approximately 20 minutes
- Full system (TLM) simulation approximately 2 hours and 388 MB RAM

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Conclusion

- The goal of a simulation tool is not to replace the EMC Tests but to reduce the number of those.
- It must help the engineers to be more confident before the final compliance test by showing the potential threads in advance and validating his solutions.
- Keep in mind that prior to doing EMC simulations, you are doing EMC!
- No need to be a numerical method specialist to use our simulation solutions for emc but you need to be an EMC specialist.