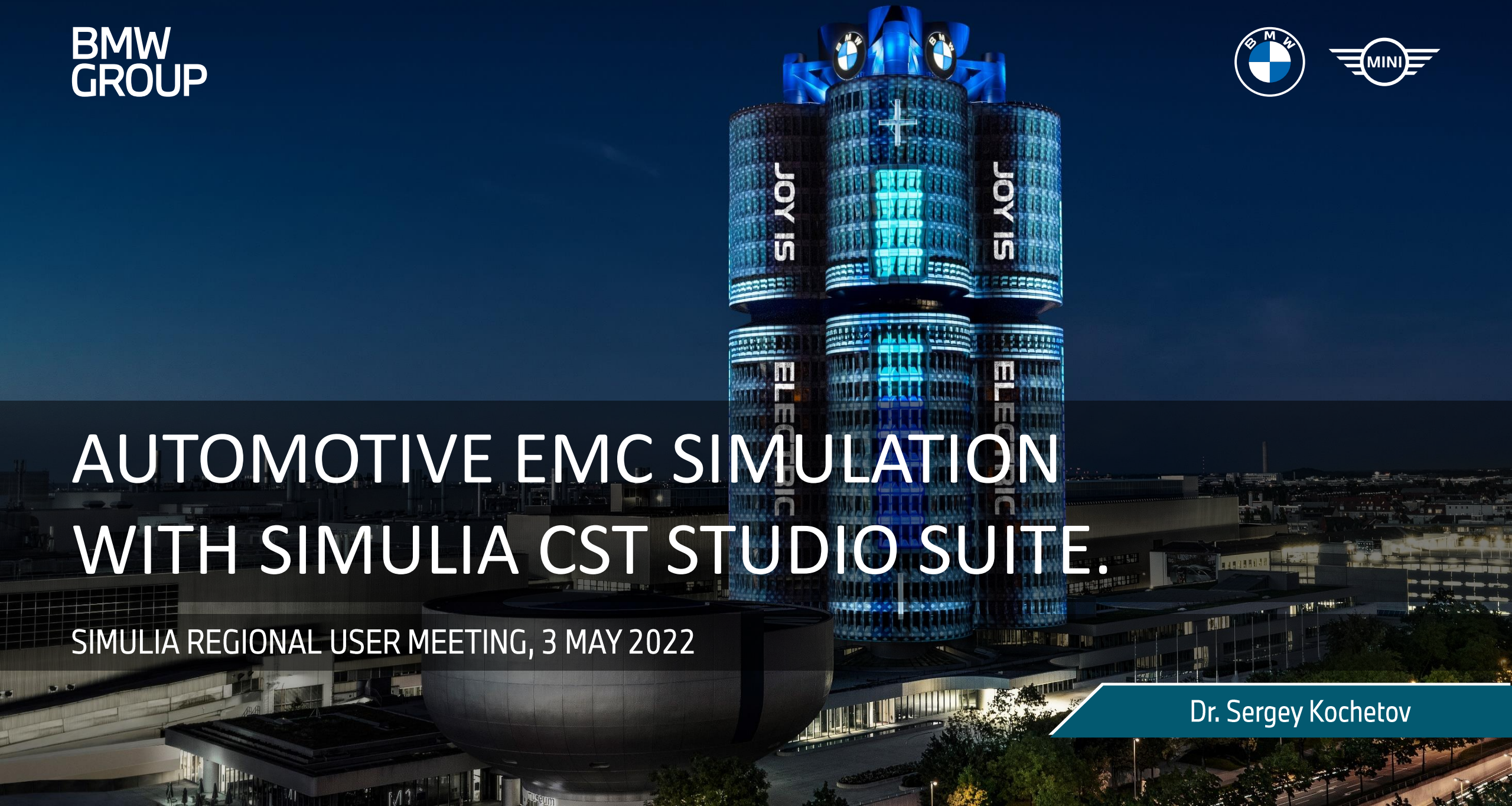
BMW GROUP

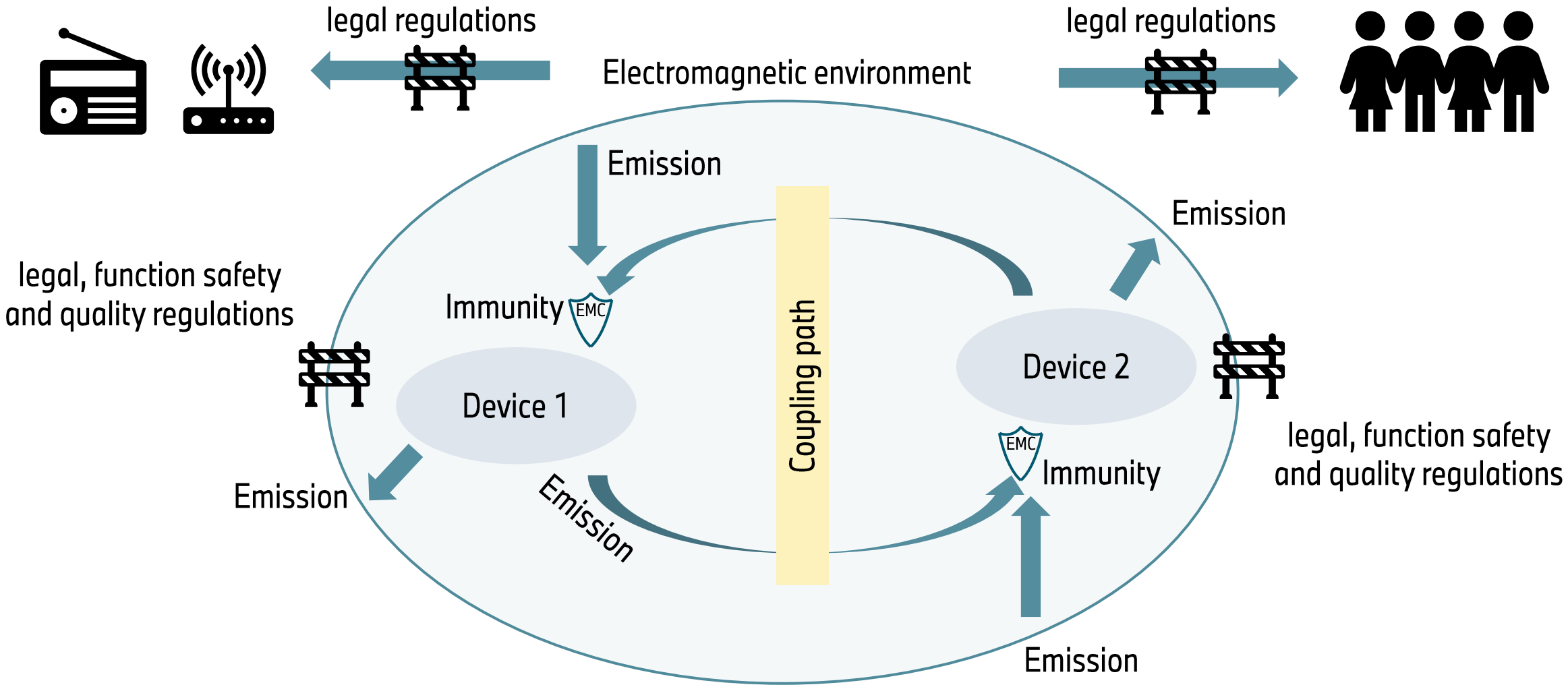


AUTOMOTIVE EMC SIMULATION WITH SIMULIA CST STUDIO SUITE.

SIMULIA REGIONAL USER MEETING, 3 MAY 2022

Dr. Sergey Kochetov

WHAT IS ELECTROMAGNETIC COMPATIBILITY?



EMC: SOURCE – PATH –RECEIVER MODEL.

- Communication services
- Narrow band senders
- Intentional sources

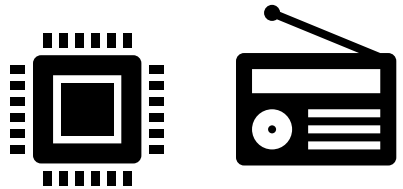
The coupling path:

- Conducted
- Inductive
- Capacitive
- Radiated

Emission source

Susceptible receiver

Usually low-power circuits, logic and broadcast



Not intentional sources:

- Power electronics
- HF circuits
- IC circuits

strictly coupled to the not intended parasitic behavior of devices

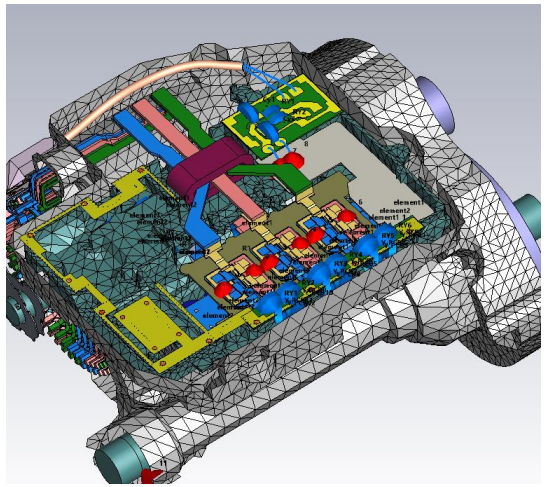
Frequency range of interest:

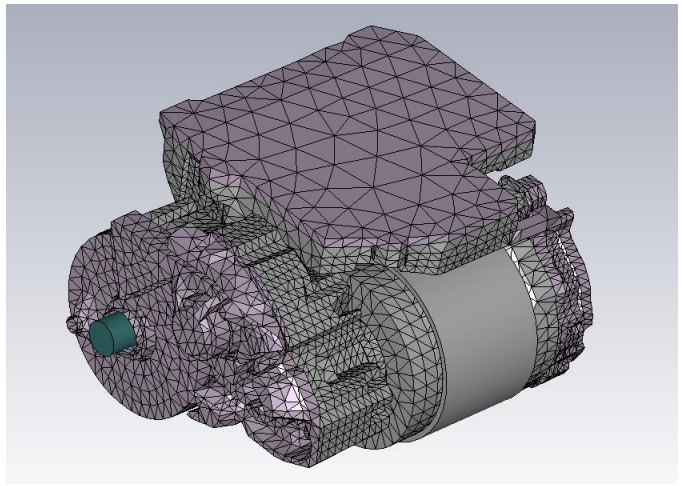
- from 1 Hz (LF EMF exposure protection, ICNIRP)
- Up to 6 GHz (modern communication bands)

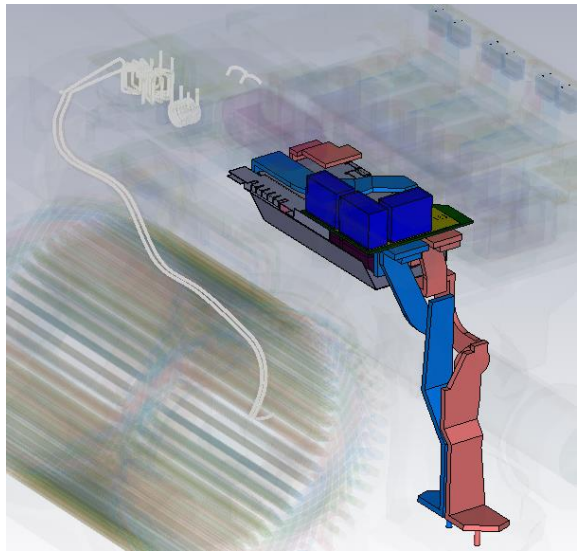
EMC SIMULATION: SOURCE – PATH –RECEIVER MODEL (1/3).

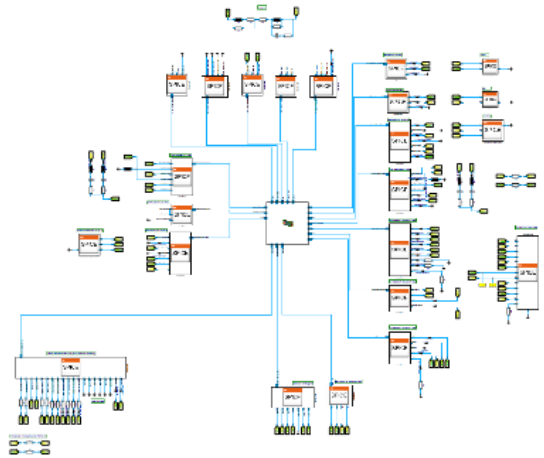
1. Simulation of electromagnetic emission sources (example: electric powertrain)

- The devices operate at relatively low frequencies.
- The devices generate the emission up to several hundreds MHz including (UKW and DAB bands).
- EMC model for power electronics:
  - 3D model of interconnections;
  - 3D or 2D model of PCBs;
  - Circuit-level model or MOR models for the ICs and function schematics;
  - 3D models for EMC filters.
- Domain
  - Time domain: long scale simulation
  - Frequency domain: no functional simulation









EMC SIMULATION: SOURCE – PATH –RECEIVER MODEL (2/3).

2. Simulation of the coupling path in a vehicle.

- Path though the harness:
  - Total length may be several km;
  - The cross-sections are electrically small;
  - Large number of wires in a bundle;
  - Shielded cables (i.e. HV System);

2.5D TL models

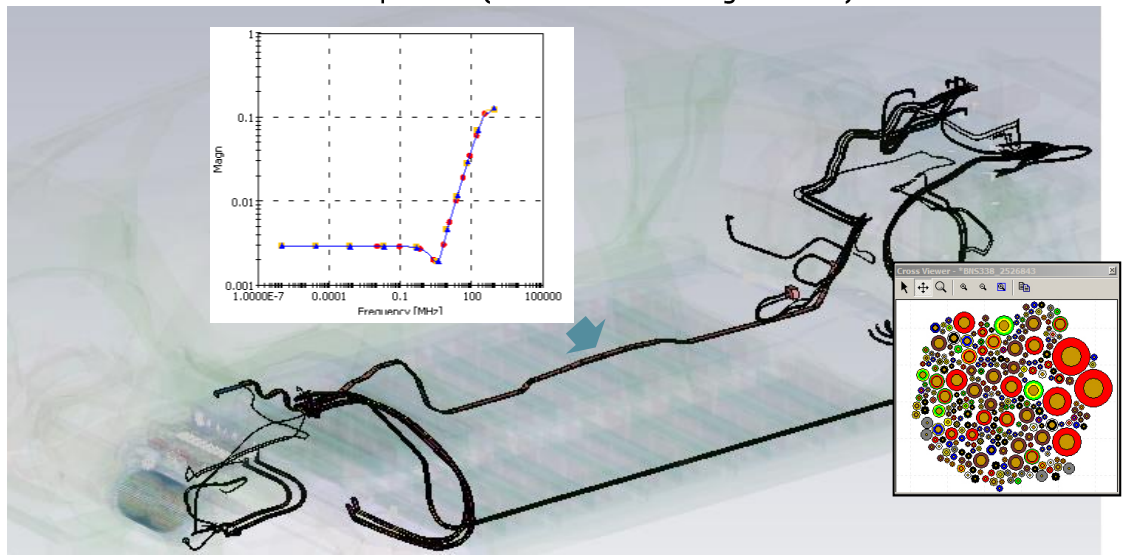
3D models

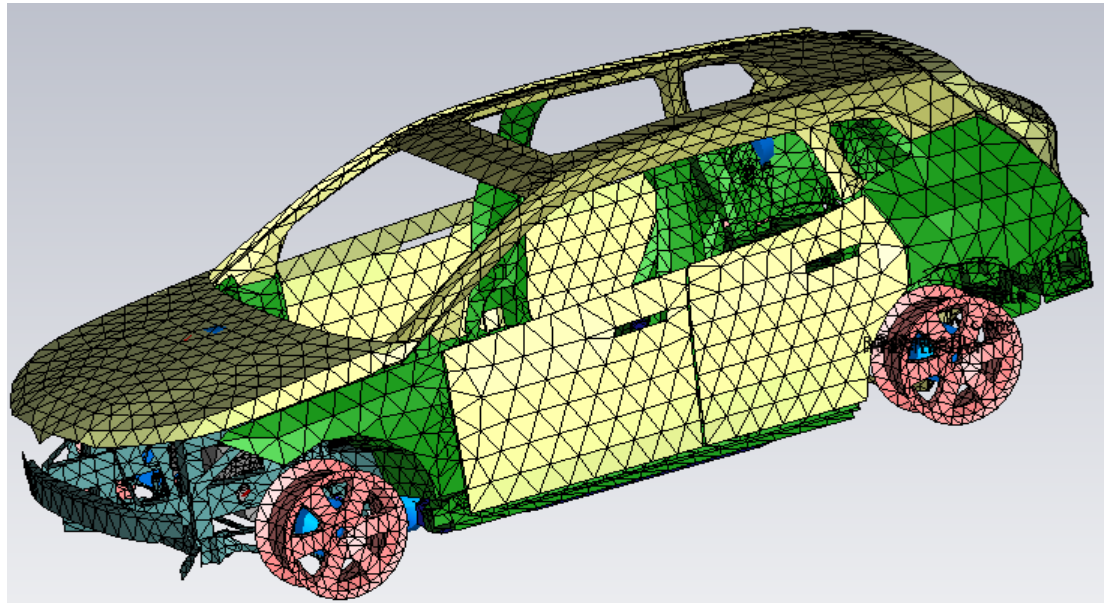
- Path though the chassis and package:
  - The chassis has own eigenmodes and may radiate;
  - The chassis is usually exited though the harness;

- Grounding connections.

3D models

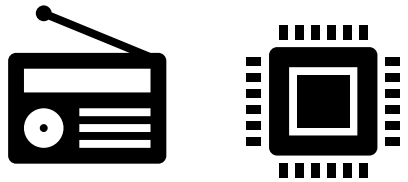
Transfer impedance (Measure for shielding of cables)!





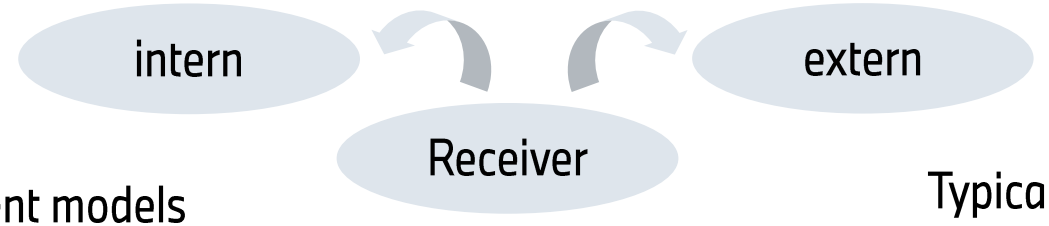
EMC SIMULATION: SOURCE – PATH –RECEIVER MODEL (3/3).

3. Simulation of the emission receivers.



Receiver = Device

Receiver = Environment



Receiver is an immunity component models

- 3D model of vehicle antennas
- 3D model of interconnections;
- 3D or 2D model of PCBs;
- Circuit-level model or MOR models for
- the ICs and function schematics;
- 3D models for EMC filters.

Typical EMC measurement equipment according to legal requirements:

- Antennas for RE
- LISN for CE
- Magnetic field probes for ICNIRP
- Human body models for ICNIRP
- Simulation volume ~ 10-30 λ (λ = c/f)
- Mesh step: λ /10

THE CHALLENGES AND TRADE-OFF OF EMC SIMULATION.

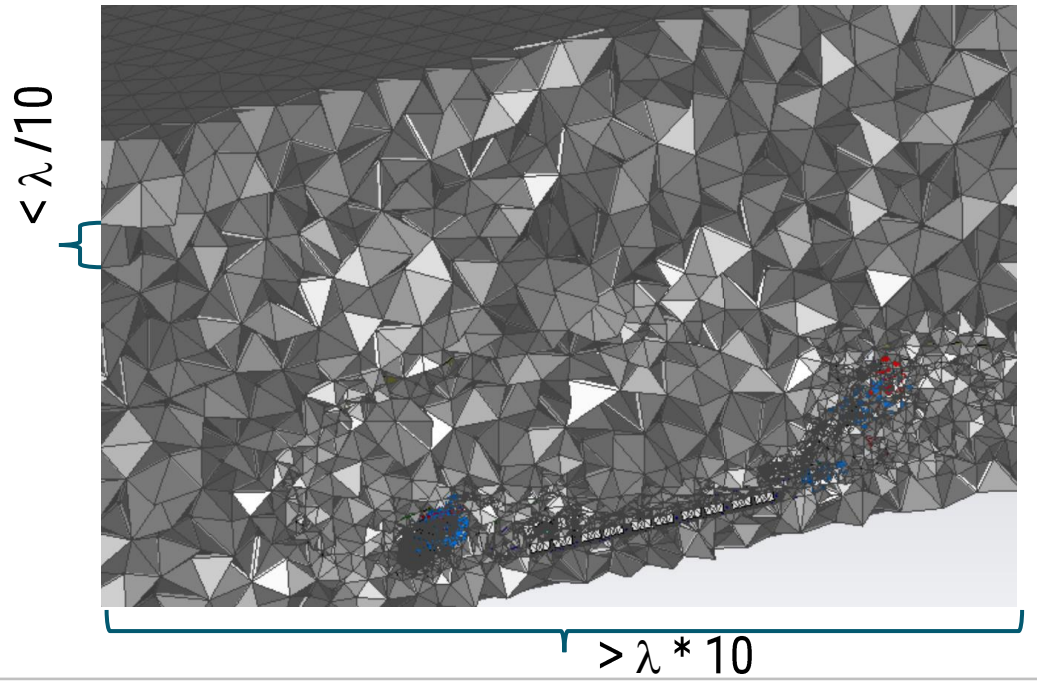
- Wide-scale problems:
  - Functional process may be about 1 Hz, while the EMC interest is up to 1GHz
  - Trade-off: a functional EMC model up to 30 MHz vs. a pure EMC full-wave model

- Multiple method model:
  - Hybridization of solvers (i.e. Design Studio, IDEM, Microwave Studio, Cable Studio, PCB Studio)

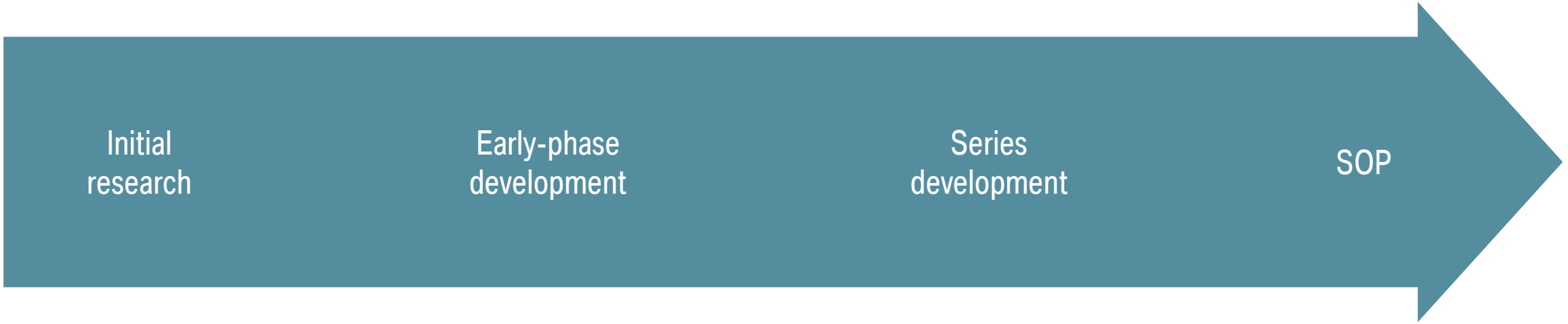
- Mesh for EMC models:
  - Trade-off 1: EFIE/MPIE methods vs. FEM/FIT/FDTD/TLM
    EFIE/MPIE: full-filled matrix for only conductors
    FEM/FIT/FDTD/TLM: sparse-matrix for total volume
  - Trade-off 2: 3D model (CST MWS) vs.
    TL-theory based hybrid model (CST CS + CST MWS)

Resume: EMC model may be built very different!

Cross-section of the FEM mesh for a vehicle in the EMC chamber



APPLICATION OF THE EMC SIMULATION IN THE DEVELOPMENT.



Quick check of ideas

Derivation of requirements

Virtual EMC test

Analysis of EMC problem

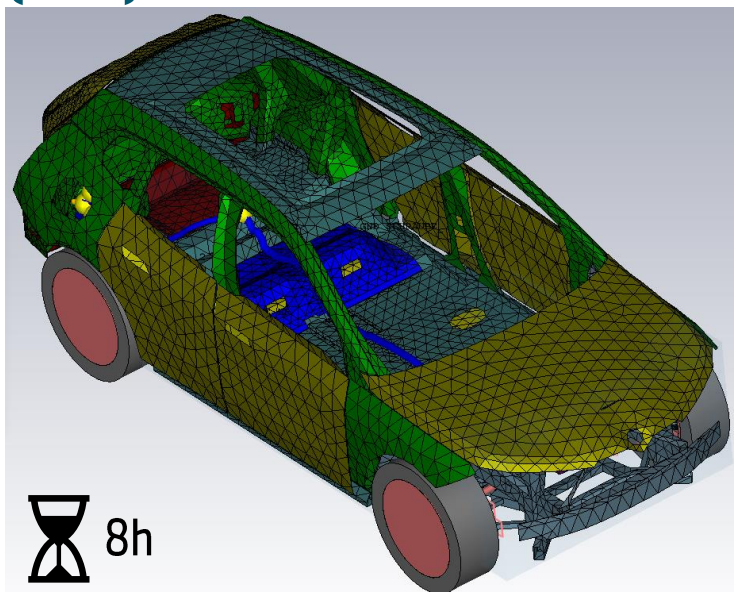
Reduction of the test-vehicle number

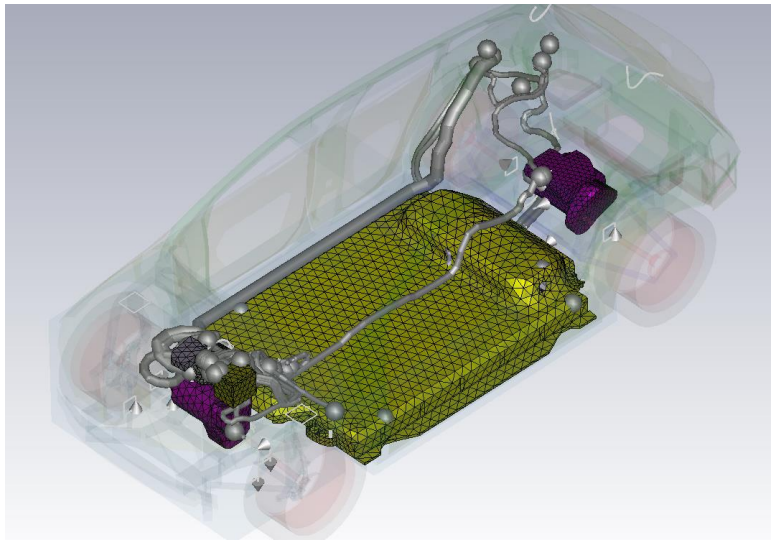
Simulation of early prototypes or of the prototypes from the old generation

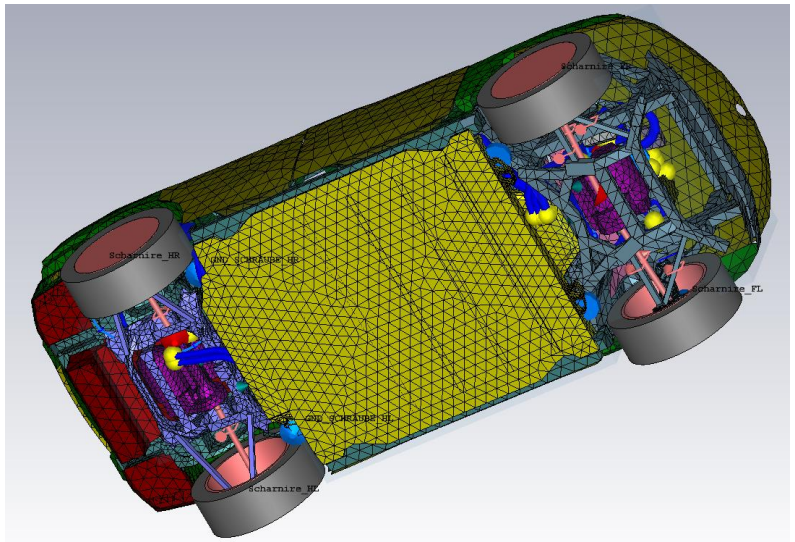
Simulation of serial prototypes

EXAMPLE 1: SIMULATION OF iX IN THE ECE-R10 SET-UP (1/2).

- Toolchain:
  CST Cable Studio – CST Microwave Studio – CST Design Studio.
  Mesh: hexahedral
  Domain: time domain
- Goal of the Simulation: Understanding of a resonance at about 53 MHz.
- Components:
  - Black-box models extracted from validated 3D models;
  - HV battery: 3D model.
- Source of emission:
  HV/12V DCDC converter.
- Observations:
  - E-Field corresponding to ECE-R10 set-up.
  - 3D Current distribution.

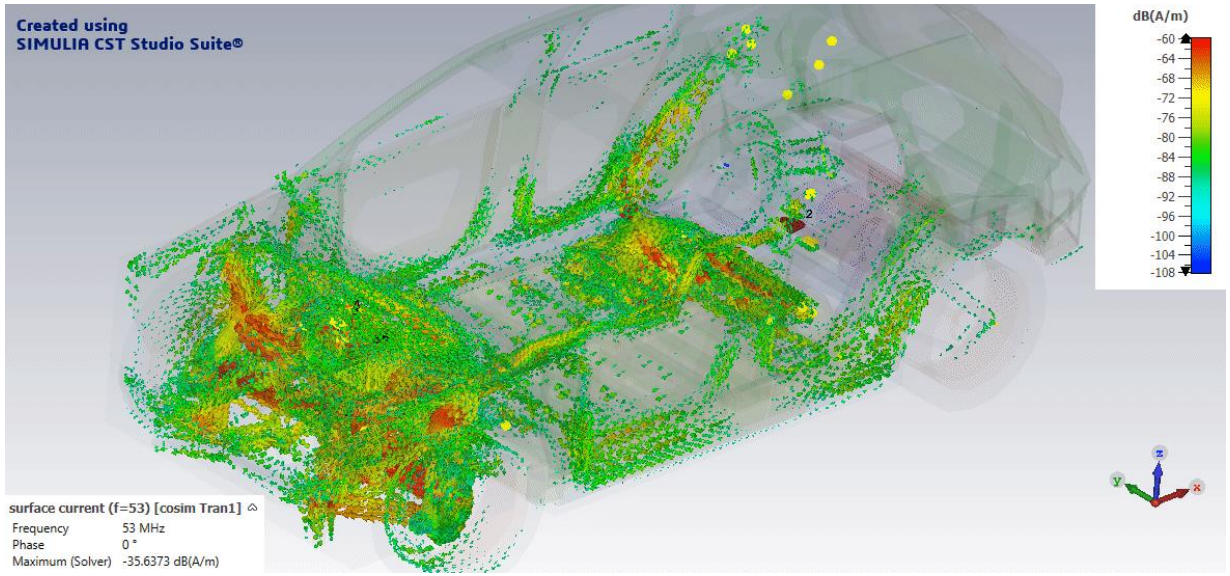




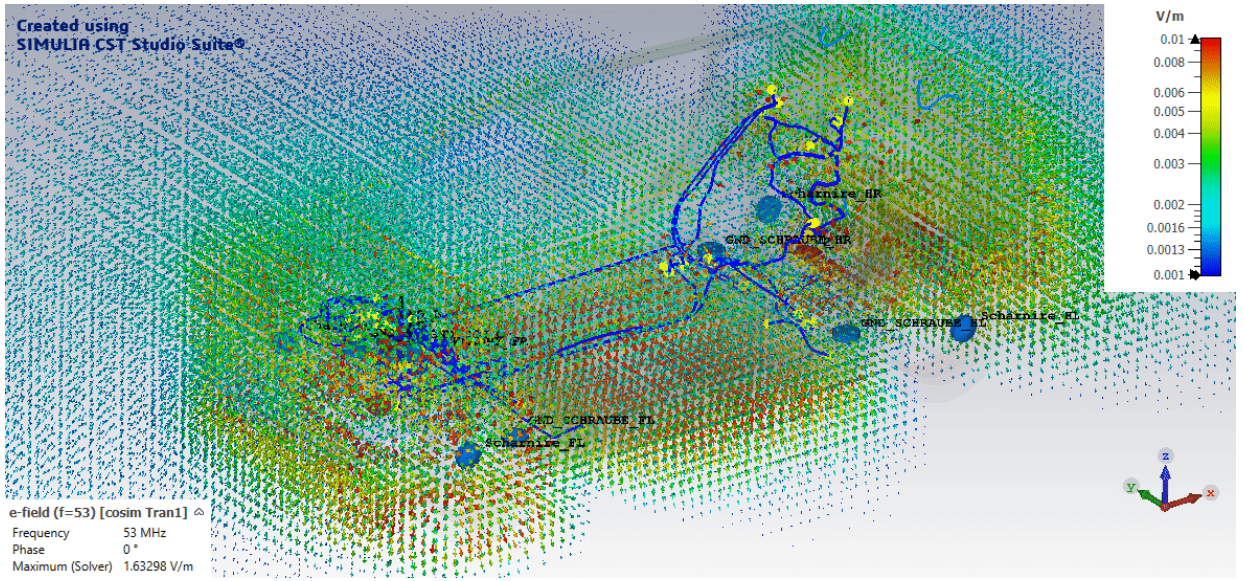


EXAMPLE 1: SIMULATION OF iX IN THE ECE-R10 SET-UP (1/2).

3D Current distribution at 53 MHz



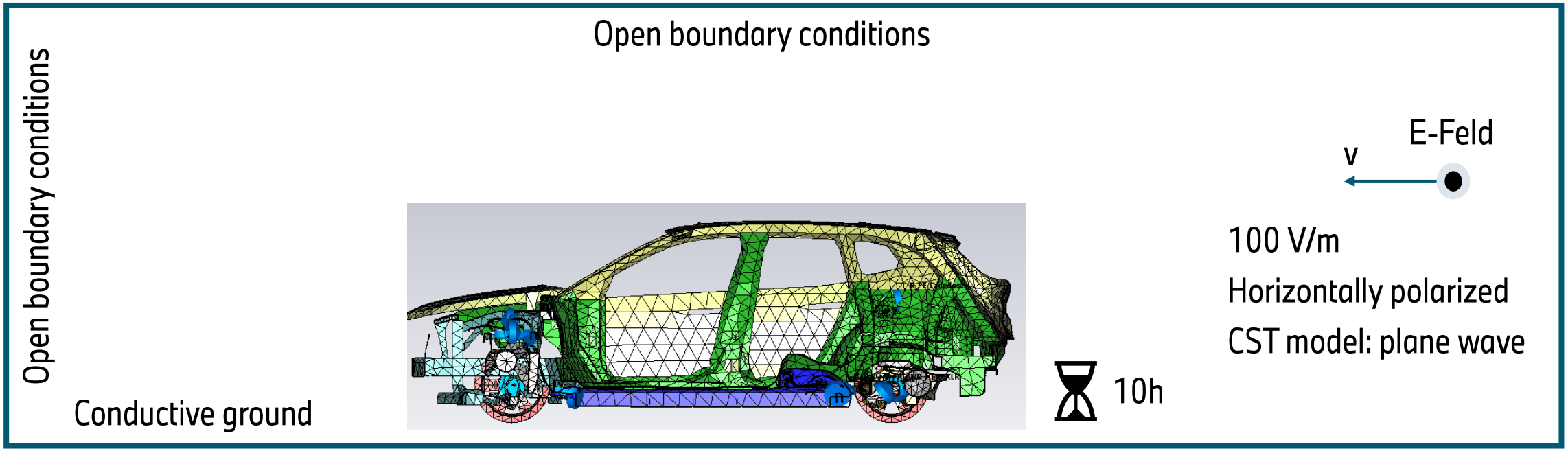
E-field distribution at 53 MHz



Analysis:

- CM resonance in the component overlap with a resonance in the grounding system of the engine compartment.
- These resonances result in the radiation of E-field.

EXAMPLE 2: SIMULATION OF iX IN THE SET-UP ECE-R10 RI (1/2).



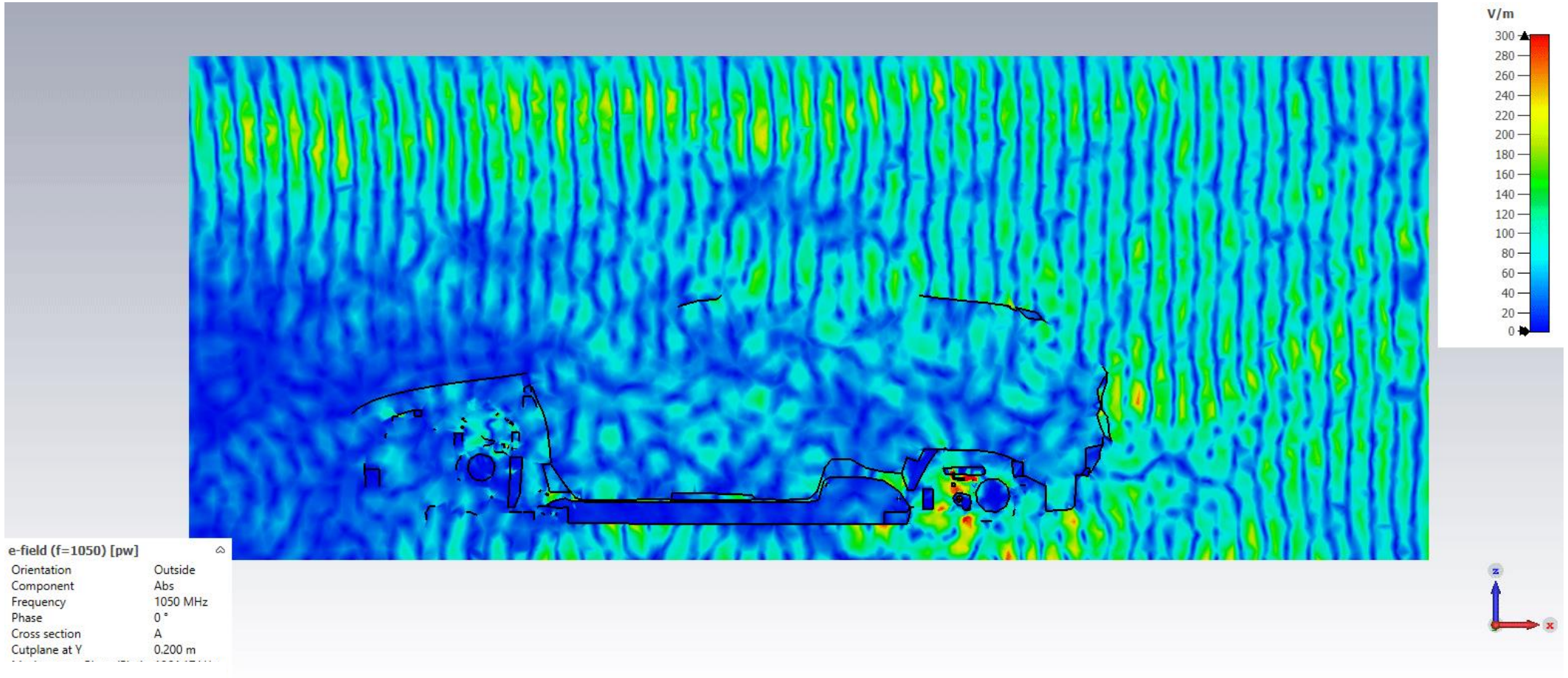
- Toolchain: only CST Microwave Studio.
- Mesh: tetrahedral.
- Domain: frequency domain.
- Goal of the Simulation: proof of the possibility that E-field may increase under the vehicle due to resonances.
- Components: Black-box models extracted from validated 3D models.
- Observations: E-Field according ECE-R10 RI set-up.

EXAMPLE 2: SIMULATION OF iX IN THE SET-UP ECE-R10 RI (2/2).

Result of the simulation:

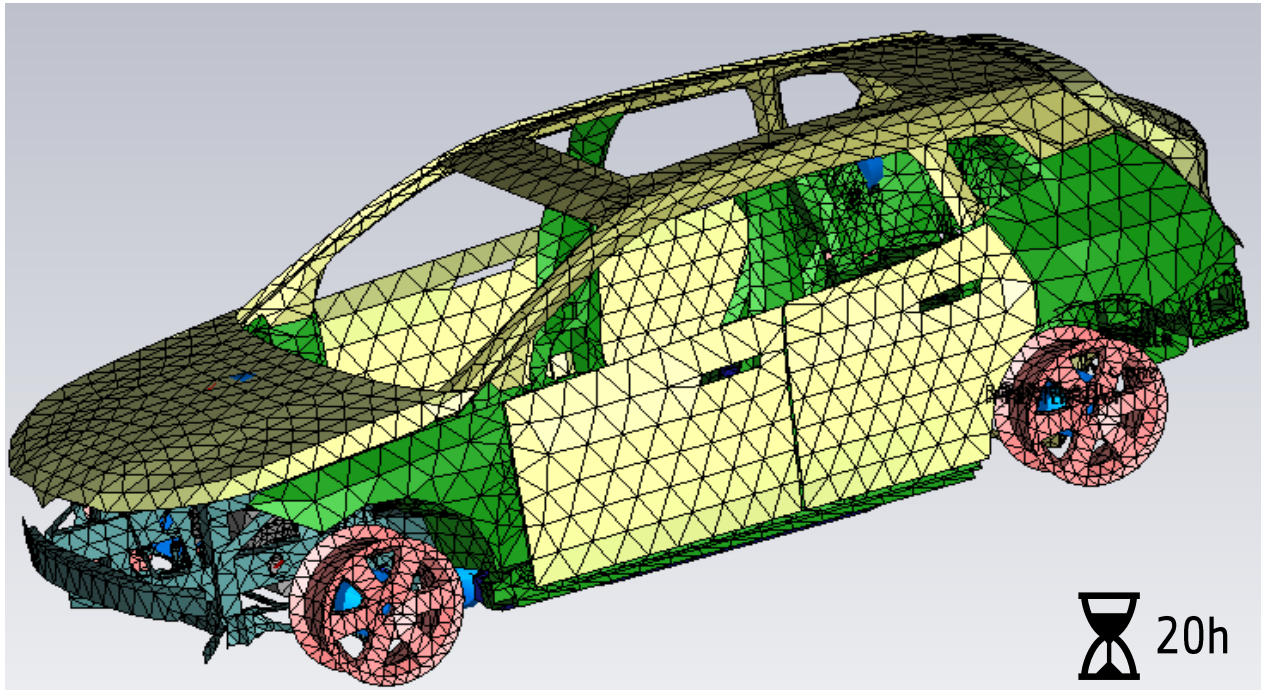
The E-field may increase up to three times.

This statement was validated with measurements.

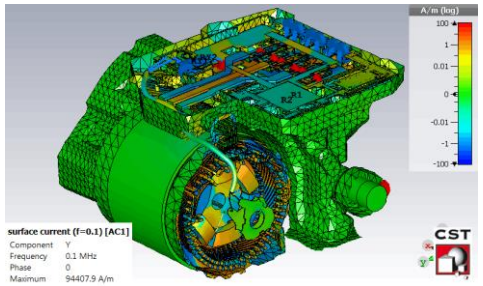


EXAMPLE 3: SIMULATION OF iX IN THE SET-UP ECE-R10 RE (1/5).

- Toolchain:
  CST Microwave Studio – CST Design Studio.
  Mesh: tetrahedral
  Domain: frequency domain
- Goal of the Simulation: Analysis of resonance behavior.
- Components:
  - Black-box models extracted from validated 3D models;
  - HV battery: full-wave 3D model;
  - Rear HEAT: full-wave 3D model (including E-Drive);
  - Cables: 3D models (see next page).
- Source of emission: Switching noise in the rear HEAT.



Emission Source



- Observations:
  - E-Field corresponding to ECE-R10 RE set-up.
  - 3D Current distribution.

EXAMPLE 3: SIMULATION OF iX IN THE SET-UP ECE-R10 RE (2/5).

Explanation: 3D cable modeling in SIMULIA CST Studio Suite ab 2022 as Preview.

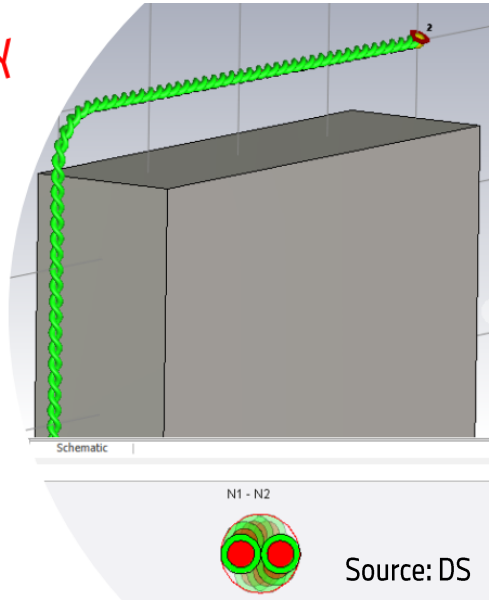
PREVIEW FUNCTIONALITY ONLY

3D MODEL FROM CABLE CROSS-SECTION

Important tester information – CST Studio Suite 2022

DASSAULT SYSTEMES | The 3DEXPERIENCE® Company

Version 1.3 November 2021

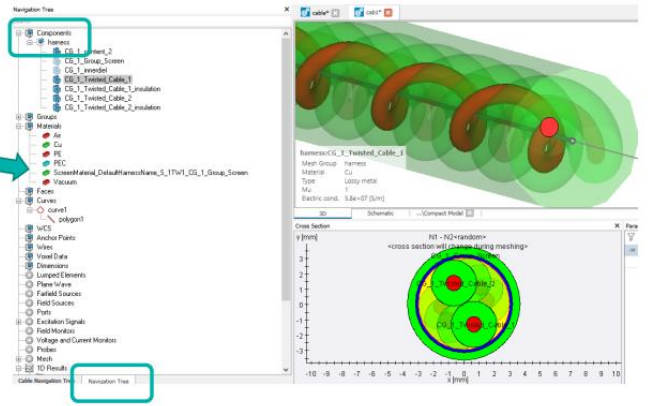


Source: DS

ACCESSING THE FEATURE (2)

CST Studio Suite 2022

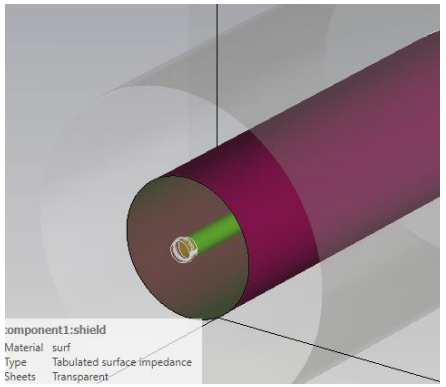
- The exported cable can be found in the regular Navigation tree
- Note that the materials were also assigned
- Shield information can be found in the appropriate material definition

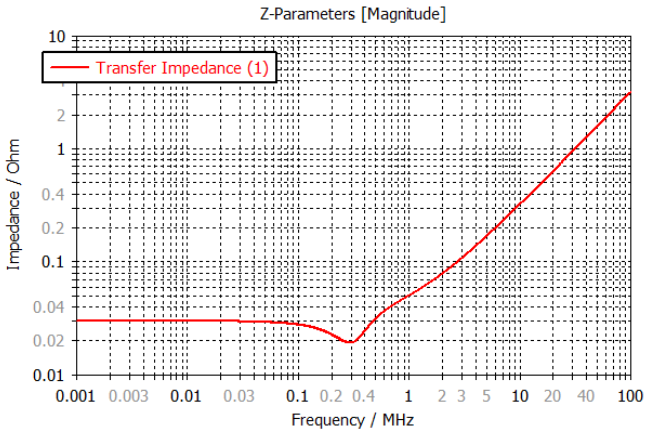


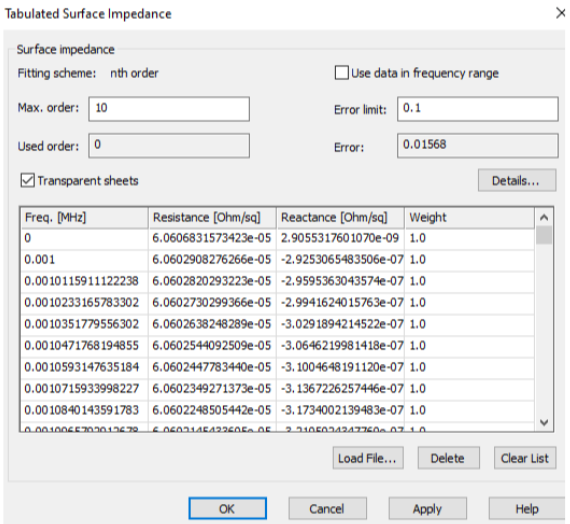
- This simulation was done in 2019-2020 as outrunner of this functionality.
- This simulation example use the same method as in CST 2022, but with manually created cable models including measured transfer impedance models for shielded cables.

EXAMPLE 3: SIMULATION OF iX IN THE SET-UP ECE-R10 RE (3/5).

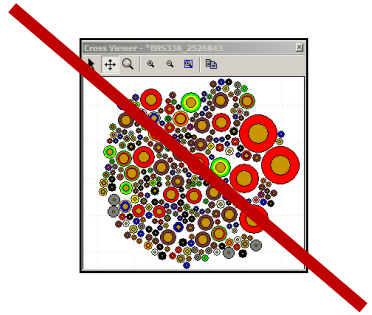
In the example: transfer impedance model as a "tabulated surface impedance":







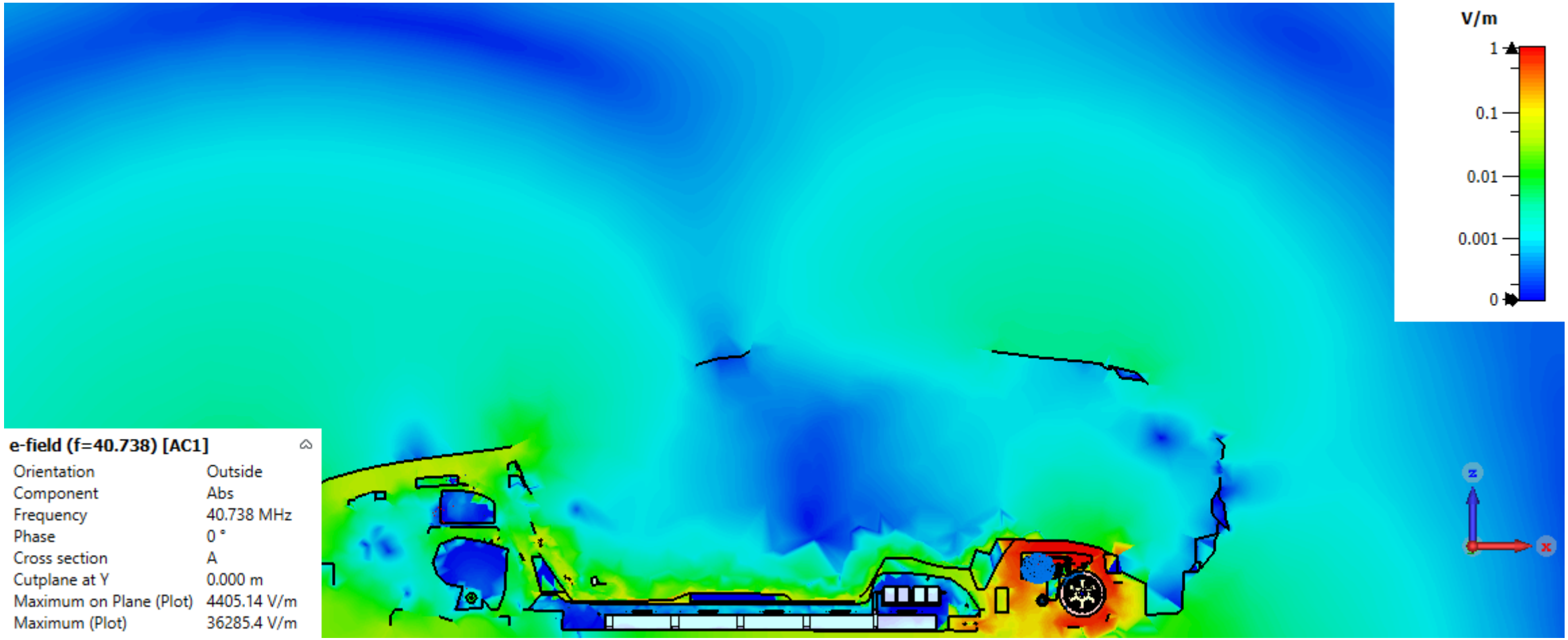
Too much effort



- CST2022: transfer impedance model as a "thin panel".
- The "thin panel" material for 3D model is automatically generated from a CST Cable Studio model.

EXAMPLE 3: SIMULATION OF iX IN THE SET-UP ECE-R10 RE (4/5).

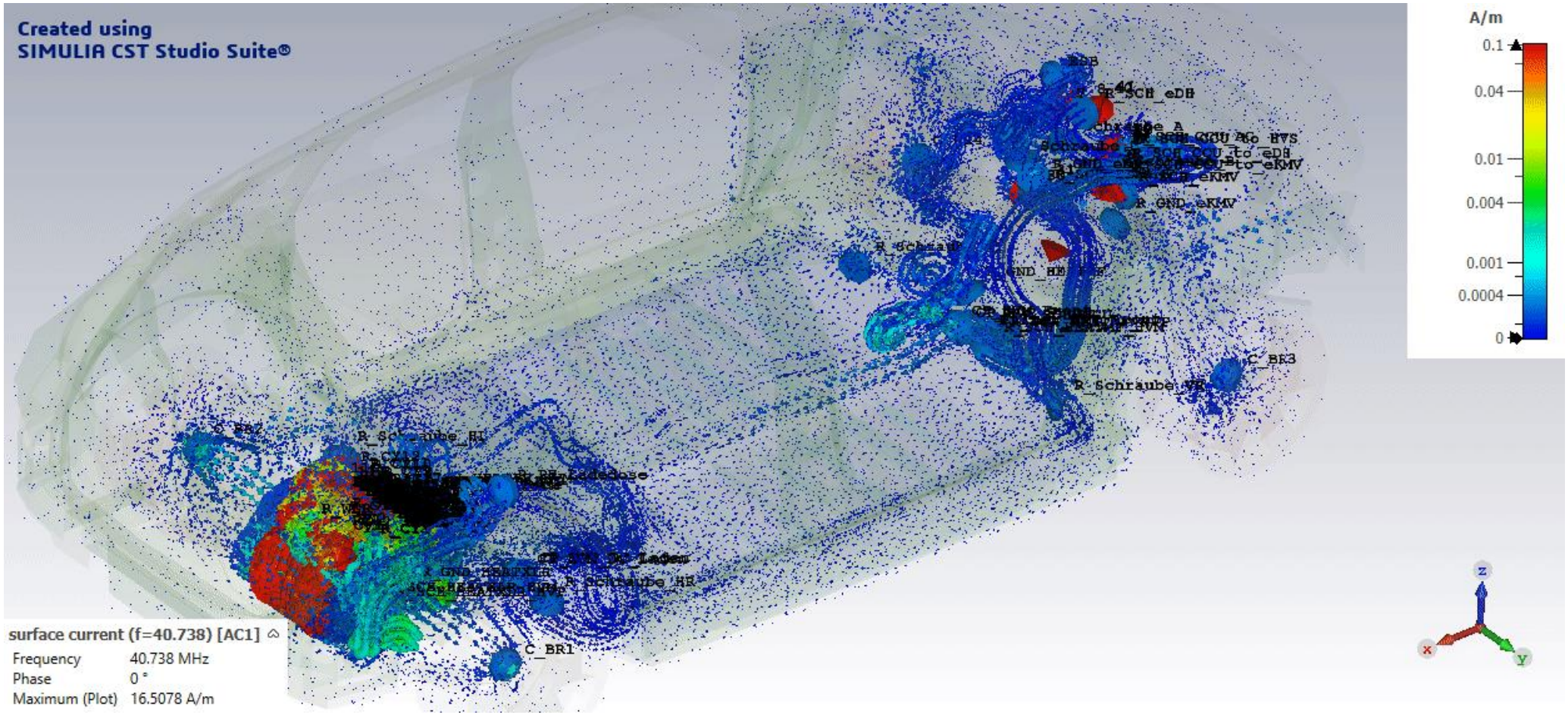
Result of the simulation: E-field radiation from power semiconductors to antenna.



EXAMPLE 3: SIMULATION OF iX IN THE SET-UP ECE-R10 RE (5/5).

Result of the simulation: full distribution of the HF current:

- Current in the power module, E-drive windings, drive shaft, battery cells, cables;
- Validated CE and RE results.



CONCLUSION.

- Today, the EMC simulation becomes more important for the automotive development.
- It brings the benefits for the early phase analysis and for the analysis in the series development.
- The EMV simulation of the vehicle sub-systems is possible with reasonable computation times.

THANK YOU FOR YOUR ATTENTION!