Altair Technology Conference 2018

알테어의 e-Mobility 솔루션

Altair`s e-Mobility Solutions

한국 알테어 황의준

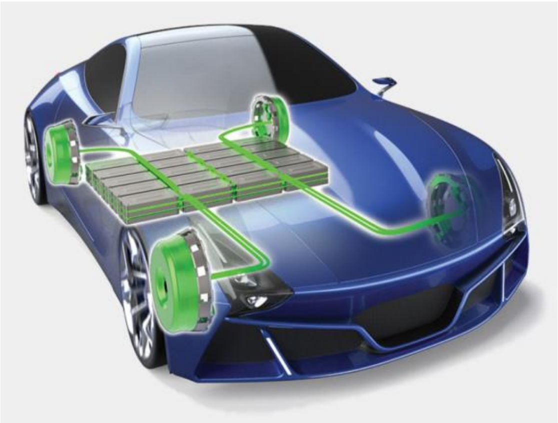
ATC 2018

Agenda

- E-mobility: Electrifying transportation
- Efficient Design Workflow for an Electric Motor for EV/HEV Application
- Refined Electromagnetic design and Optimization of the motor
- Connected Vehicles
- Wireless Power Transfer
- Summary & Conclusions

E-mobility:
Electrifying transportation

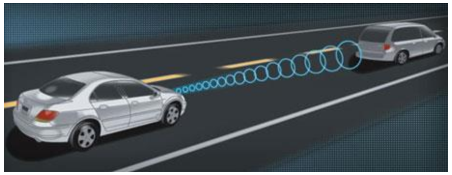
e-Mobility?



Electric car/Hybrid car

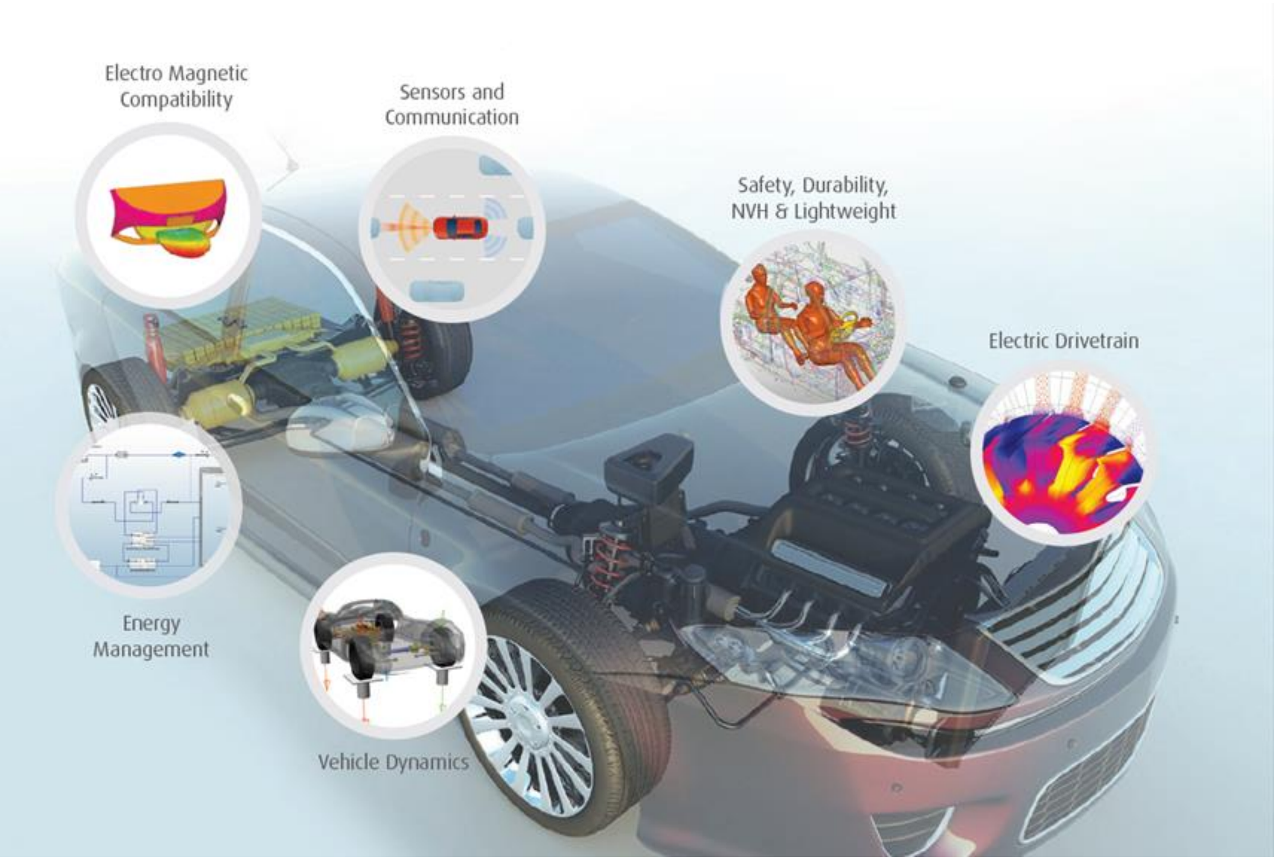
Connected car

Environmental car



Autonomous car

Altair`s Simulation Solution for e-Mobility



Electromagnetics

- FEKO, Flux

Thermal

- AcuSolve

Structural

- OptiStruct & RADIOSS

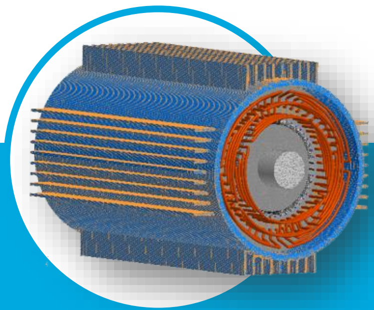
Multibody Systems

- MotionSolve

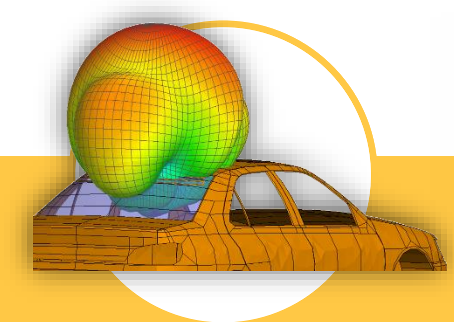
Systems & Math

- Compose, Activate, Embed

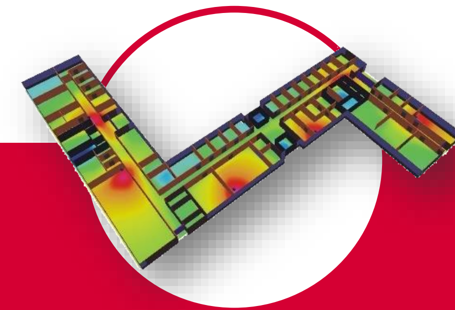
Altair Electro-Magnetic Solvers



Flux for EM simulation of static and low frequency applications related to electric machines, actuators and sensors, high power equipment and heat treatment



FEKO for EM simulation of applications related to antenna design, antenna placement, EMC, radiation hazard, bio-electromagnetics, radomes, etc.



WinProp for wave propagation modelling and radio network planning complementing FEKO

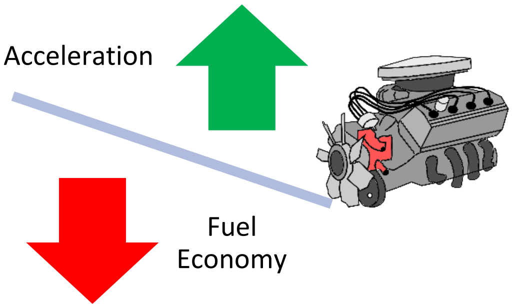
Low Frequency

High Frequency

Efficient Design Workflow
for an Electric Motor for EV/HEV Application

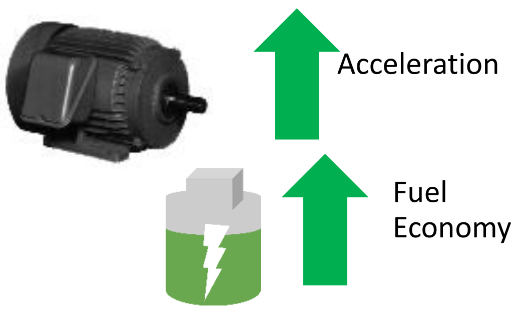
e-Mobility Powertrain Metrics

- Objective and quantitative
  - Fuel economy
  - Powertrain Performance
  - Drivability
  - Emissions
  - Safety
  - Traction/Handling Performance
  - …



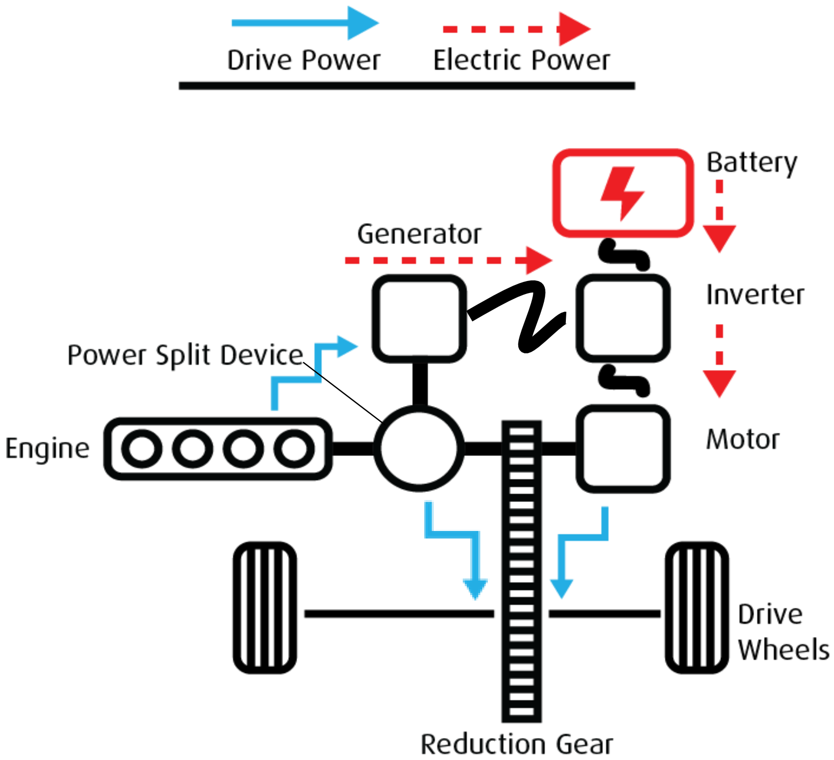
Typical powertrain

- e-Mobility technologies/topologies are allowing **system performance to be improved** over traditional designs



e-Mobility

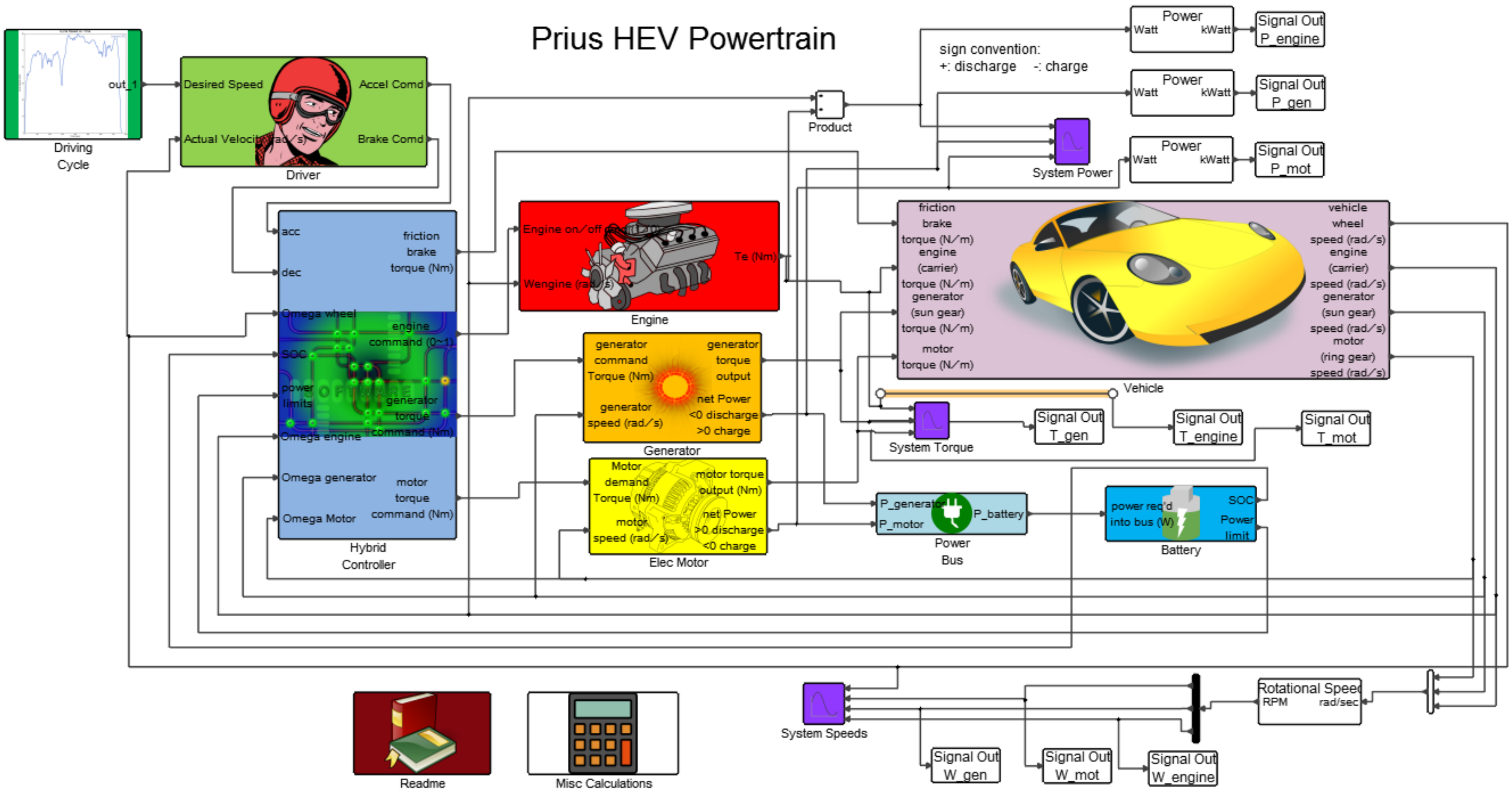
Hybrid System



Series/Parallel Hybrid System

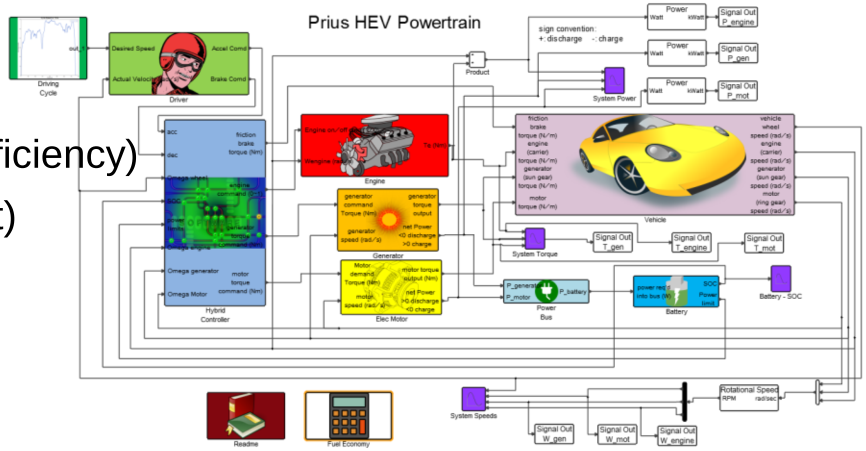
- Power-split device! (planetary gear)
- Planetary gear set acts like CVT – connects engine, motor, and generator to differential
- 2 Electric Machines (EM’s)
- Pro: Engine operates at optimal load and gets good performance, drivability, efficiency
- Con: Complexity, cost

Hybrid System



Hybrid System

- Component abstraction:
  - Look-up tables (engine & motor torque, efficiency)
  - Physics based (vehicle, planetary gear set)



- Used to explore:
  - Supervisory controller design
    - Minimize fuel consumption, battery usage
  - Performance (straight-line acceleration, braking, etc.)
  - Component selection: engine, battery, motor, etc.
    - Power needs
    - Efficiencies of system → effects on fuel consumption

Hybrid System

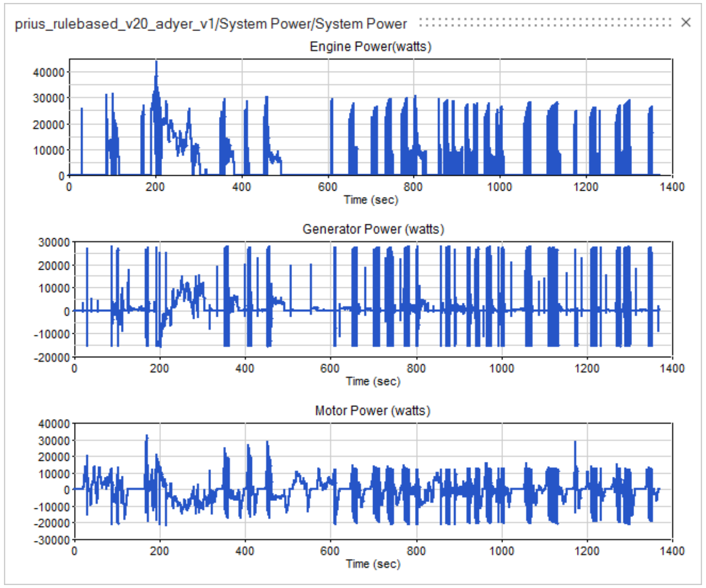
Inputs:

1) Drive Cycles
- EPA Urban Drive cycle
- > 1200 seconds runs in < 10 simulation seconds

2) Initial Battery State-of-Charge (SOC)

Input

Output



Outputs:

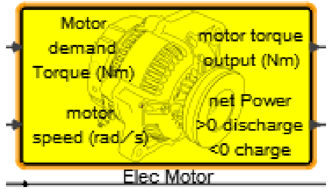
1) Fuel Economy, Battery SOC

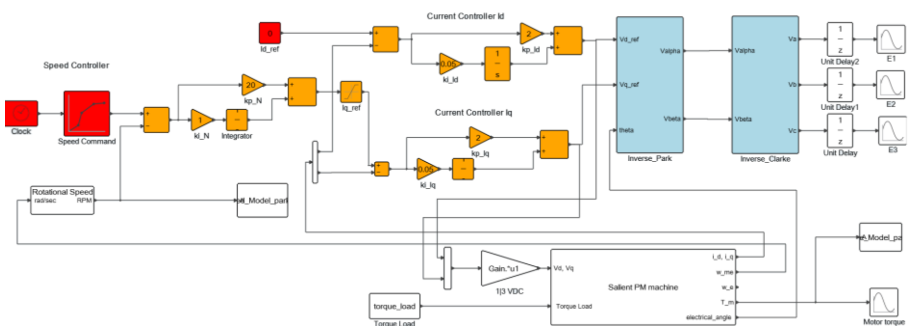
2) Power Demands – Engine, Electric Machines

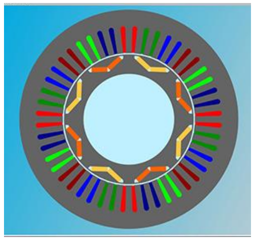
Model-Based Development Workflows

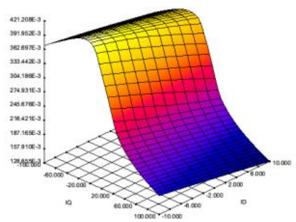
Activate + Flux support of Model-Based Development

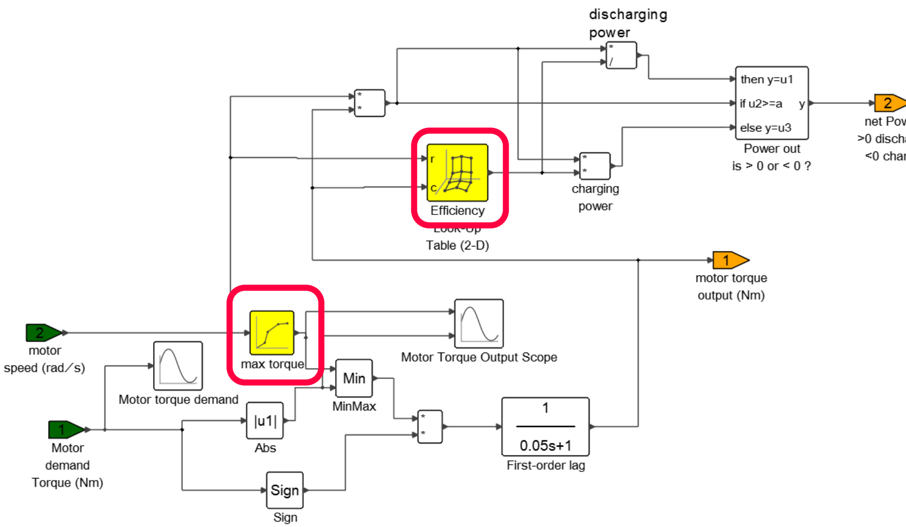
- Work with different levels of fidelity depending on your analysis needs
  - Motor Design/Control
  - Supervisory HEV Control







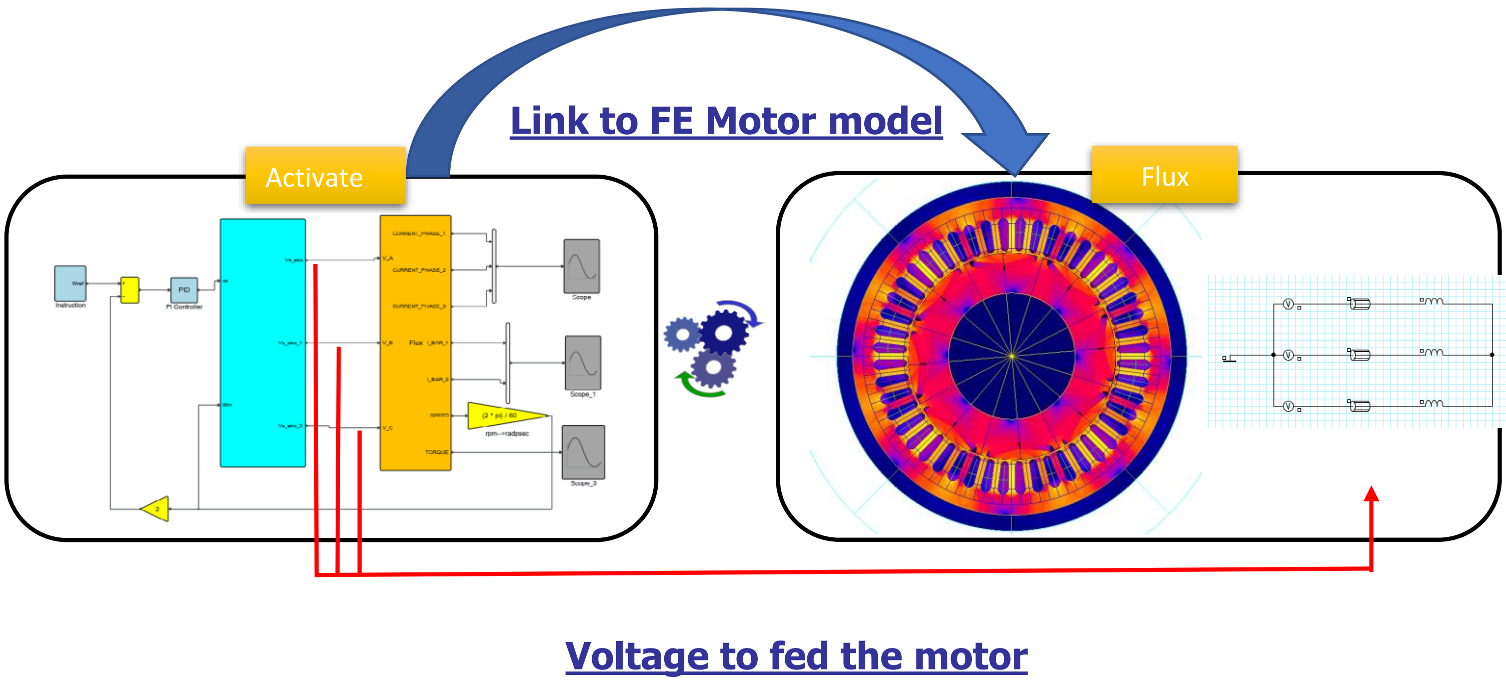




Model-Based Development Workflows

PMSM Modeling Methods

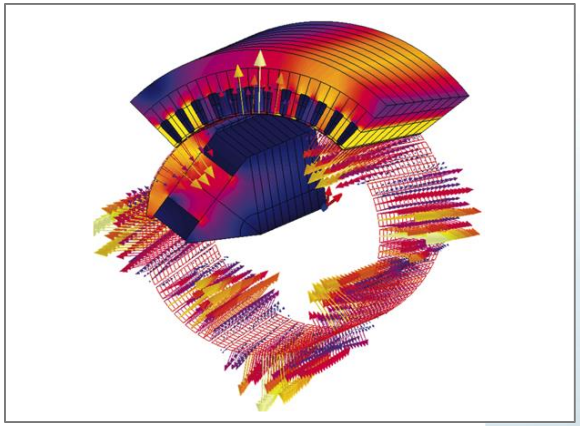
- Full co-simulation Flux + Activate for Best Accuracy

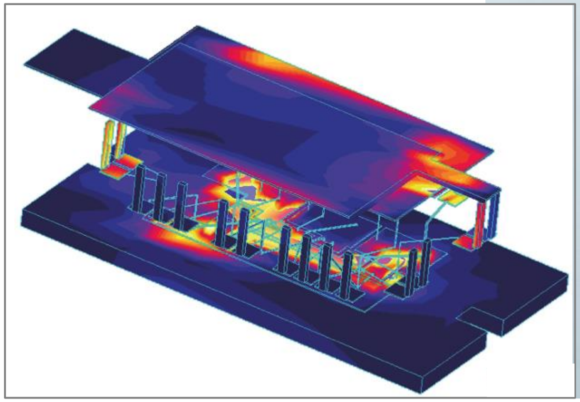


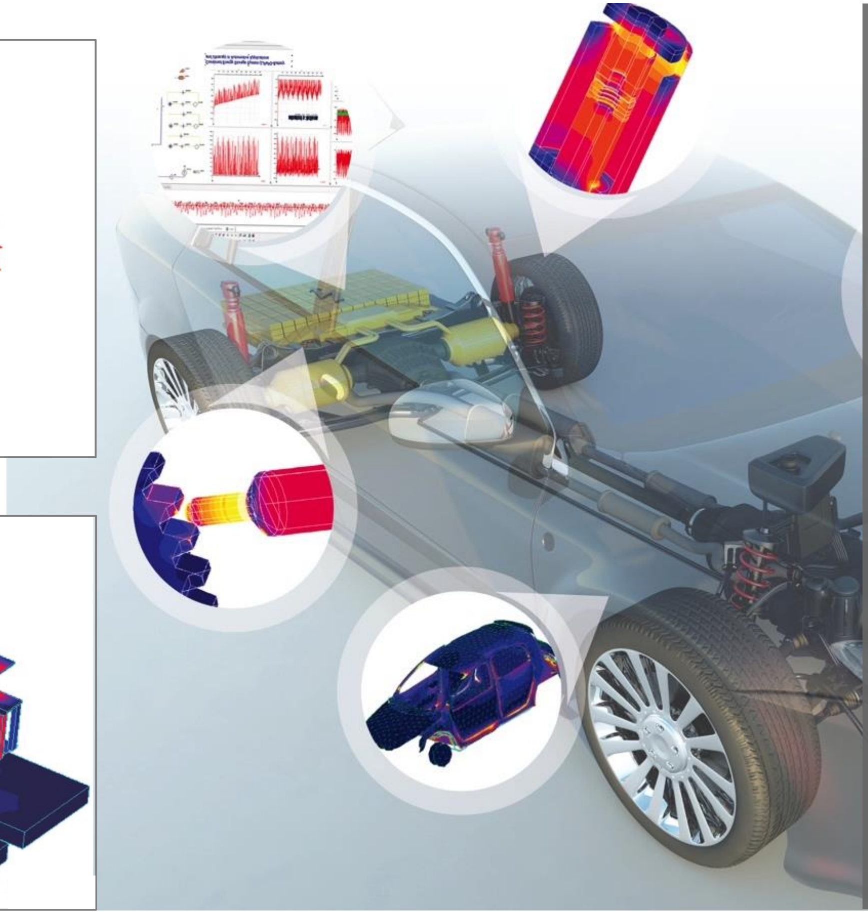
Output:
- Current
- Speed
- Torque…

Refined Electromagnetic design and Optimization of the motor

Flux: Low Frequency Analysis for Electrical Engineering







For more than 35 years, Flux simulation software has been used worldwide in leading industries and university labs for electromagnetic and thermal analyses. It has become a reference for the high accuracy it delivers.

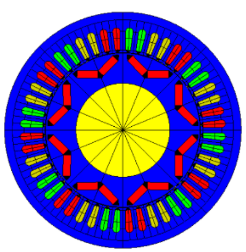
Whatever the electric device or equipment you are designing, it captures the complexity of electromagnetic and thermal phenomena to predict the behaviour of your products with precision.

Design & Optimization

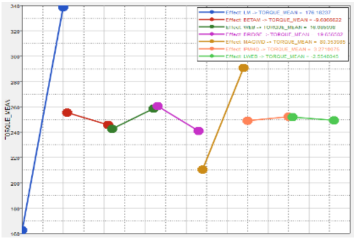
- The HyperStudy-Flux coupling allows applying the HyperStudy approaches (DOE, Fit, Optimization and Stochastic) for Flux models design exploration and optimization
- The general workflow is:

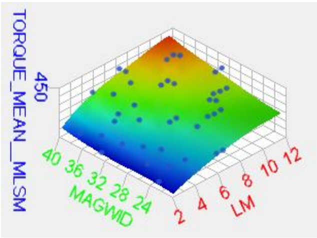
Optional

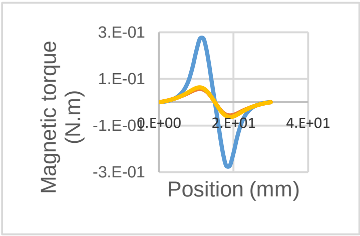
Build parametric model in Flux → Setup new study in HyperStudy → Setup and perform a DoE study → Fit approximation using DoE data → Perform optimization



Models connection



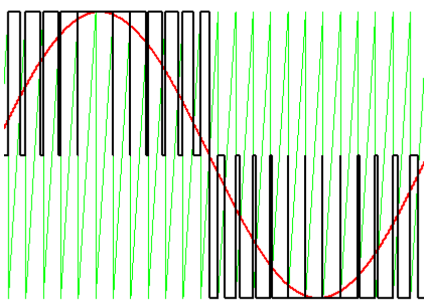


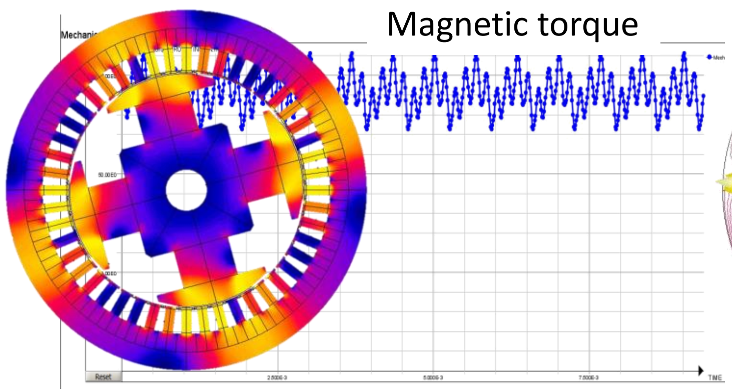


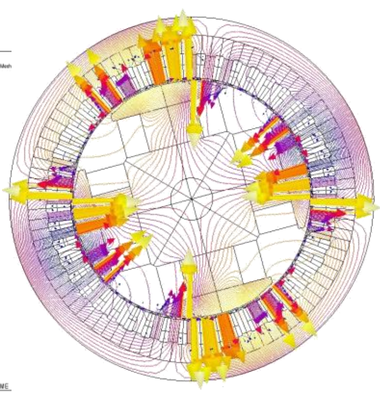
Coupled Simulations for Motor's Noise Analysis

- From electric excitation … to noise
  - electric energy creates the electromagnetic field that generates the torque
  - It also generates parasitic forces at the iron/air interface

- Parasitic forces generating noise depend on:
  - the type and topology of the machine
  - the electric excitation frequencies



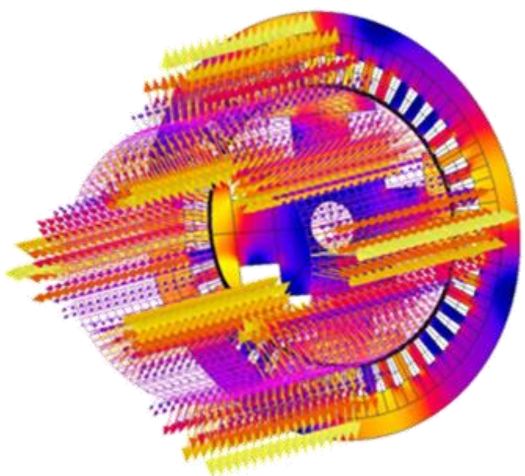




Coupled Simulations for Motor's Noise Analysis

Chaining **3 types of analysis**

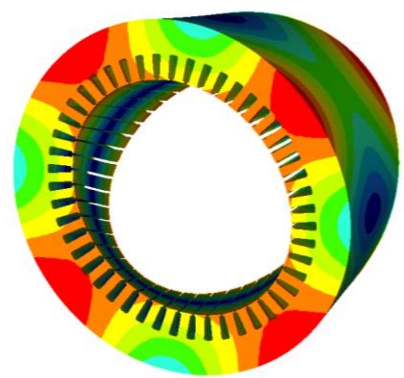
Magnetic forces



Magnetic

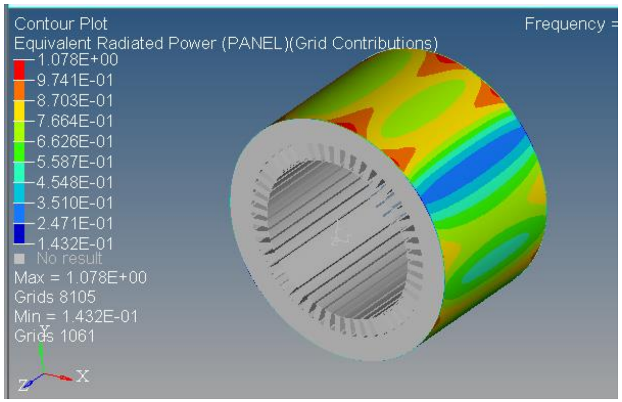
Flux

Displacements



Vibration

Noise

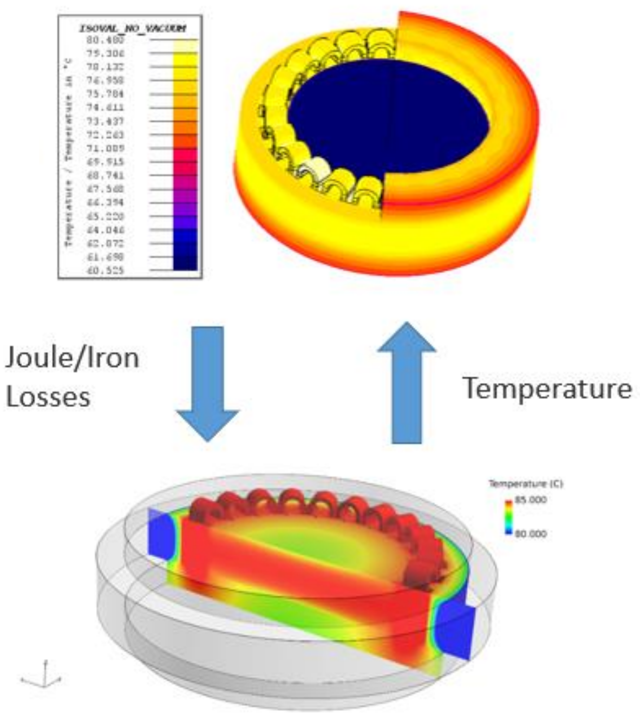


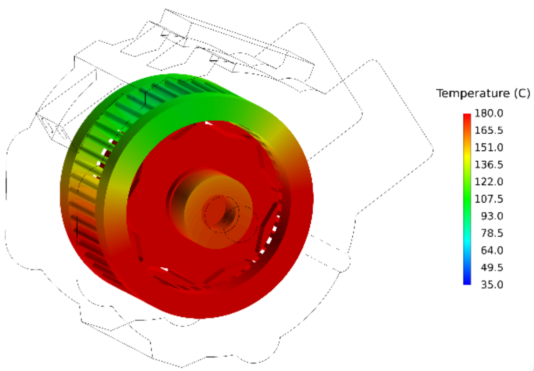
Acoustic

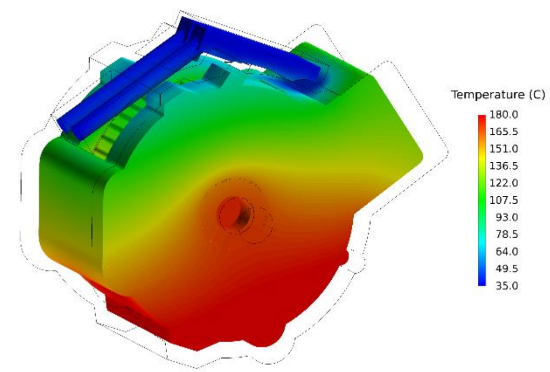
OptiStruct

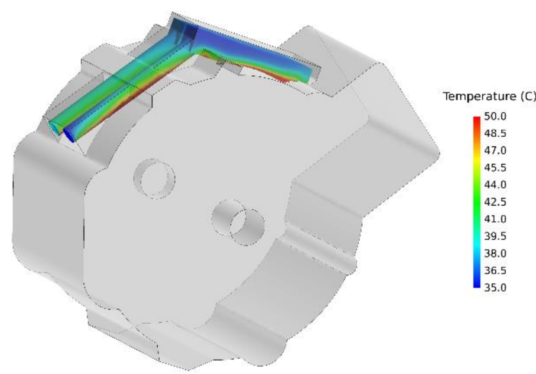
Coupled Thermal + Electromagnetic analysis

- Coupling with AcuSolve for CFD simulation





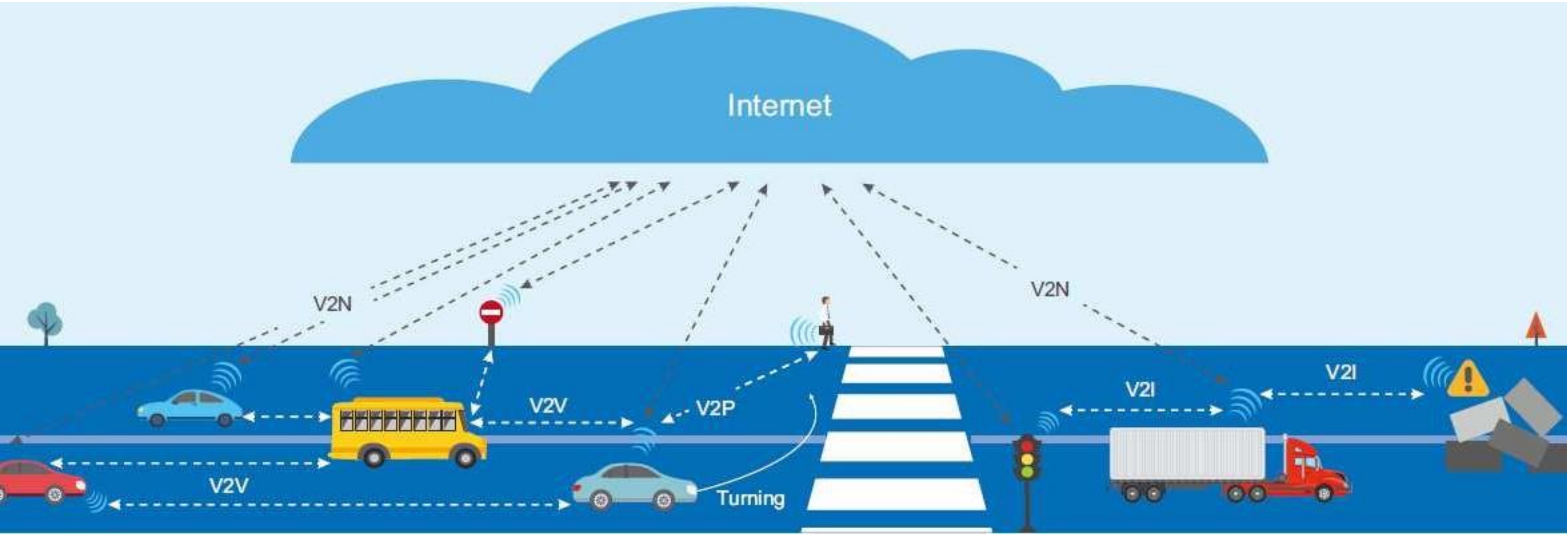




Connected Vehicles

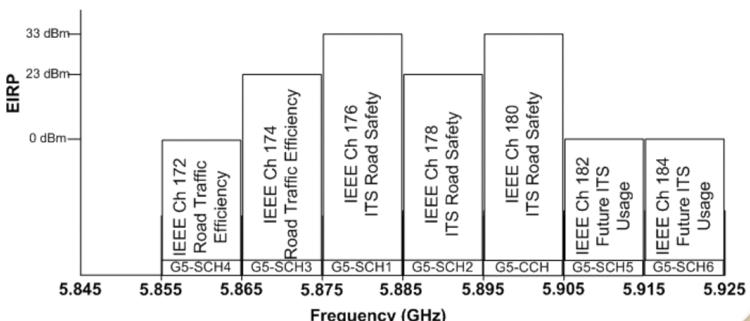
V2X Communications

- Two main technologies and solutions:
  1. **short-range communications** (DSRC based **on IEEE 802.11p** standard)
  2. **wide-area infrastructure-based communications** (including LTE-V2X and 5G)

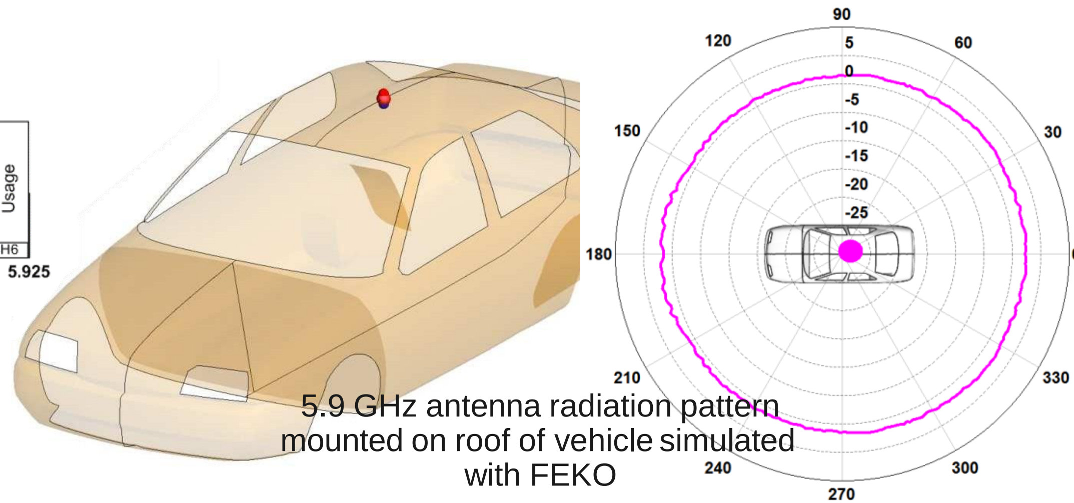


V2V Case – Technology and Antenna Requirements

- Case of study focused on **V2V communication based on IEEE 802.11p standard**
- Car manufacturer requirement for the antenna: **omnidirectional coverage**



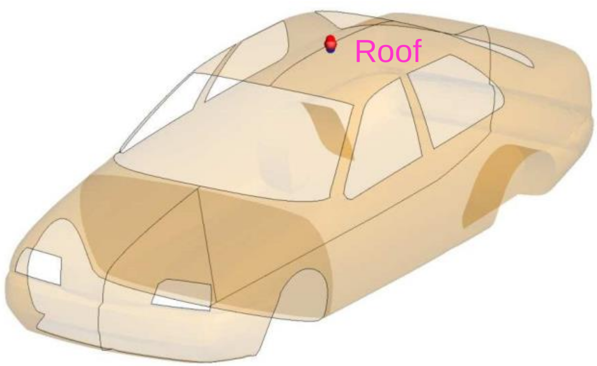
Parameters	20 MHz Bandwidth	10 MHz Bandwidth	5 MHz Bandwidth
Bit rate (Mbit/s)	6, 9, 12, 18, 24, 36, 48, 54	3, 4.5, 6, 9, 12, 18, 24, 27	1.5, 2.25, 3, 4.5, 6, 9, 12, 13.5
Modulation mode	BPSK, QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM
Code rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
Symbol duration	4 μs	8 μs	16 μs
Guard time	0.8 μs	1.6 μs	3.2 μs
FFT period	3.2 μs	6.4 μs	12.8 μs
Preamble duration	16 μs	32 μs	64 μs
Subcarrier spacing	312.5 kHz	156.25 kHz	78.125 kHz



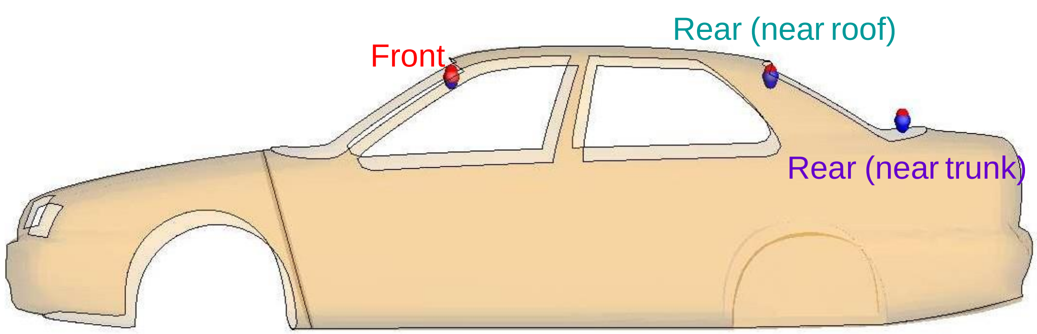
5.9 GHz antenna radiation pattern mounted on roof of vehicle simulated with FEKO

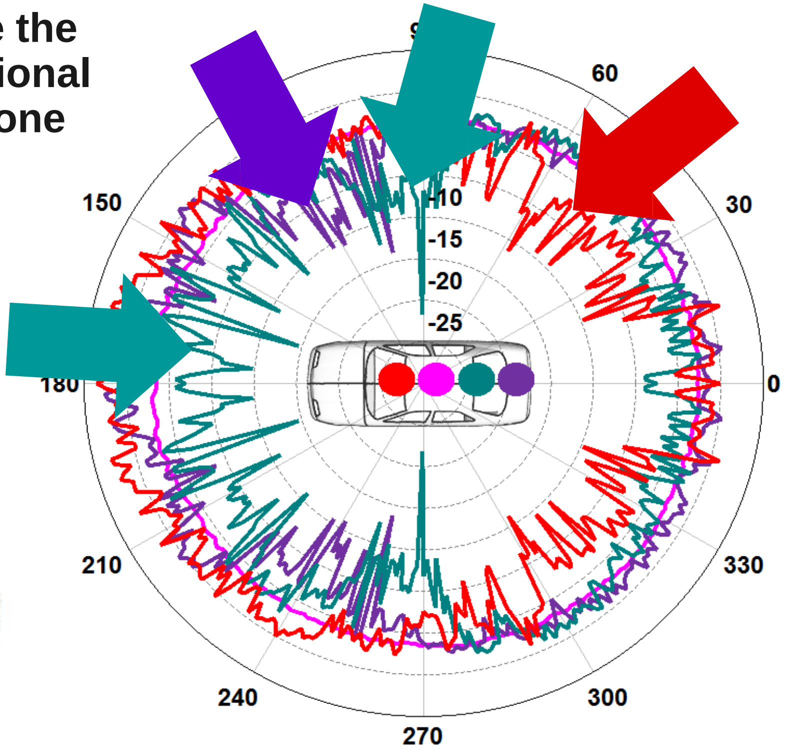
But car manufacturer wants the **antenna to be less visible**

V2V Case – Antenna Placement Analysis with FEKO



Difficult to achieve the desired omnidirectional pattern with only one antenna

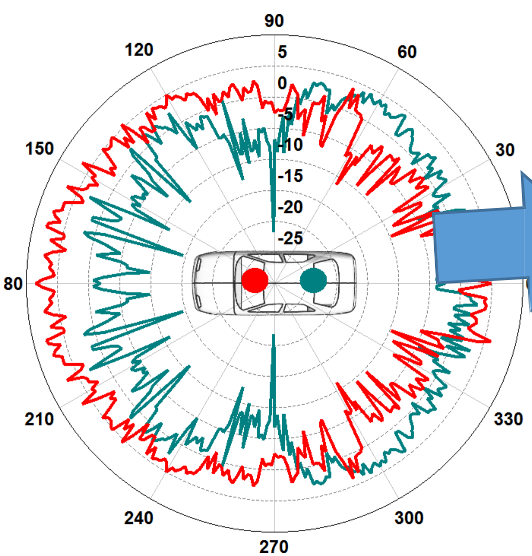




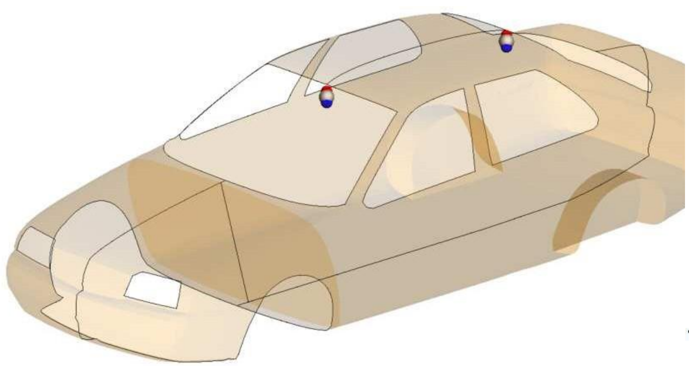
Simulations of 5.9 GHz antenna in different locations of vehicle done with FEKO

V2V Case – Defined Configuration for Antennas

Solution – Use a system of 2 antennas and combine their patterns

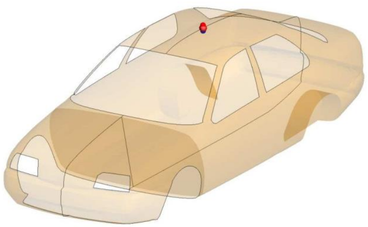


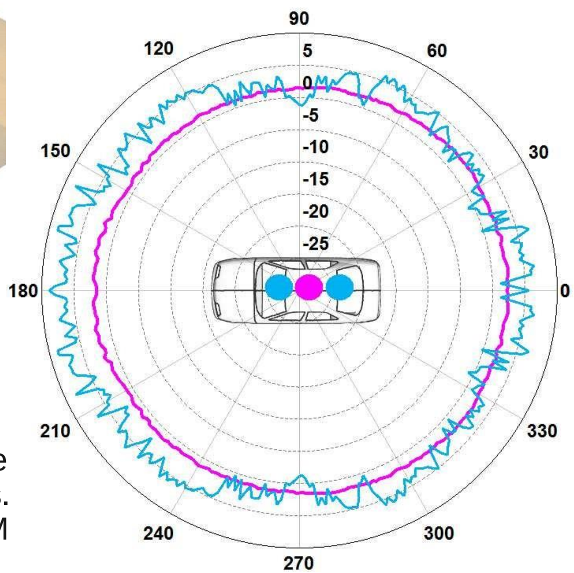
System using 2 antennas to achieve an omnidirectional pattern



Simulations of antennas in vehicle at 5.9 GHz done with FEKO using MLFMM solver with 10 processes. Number of unknowns: 1.7 Million run time: 0.46h M emory: 46.4 GByte

1 antenna mounted at the center of the roof

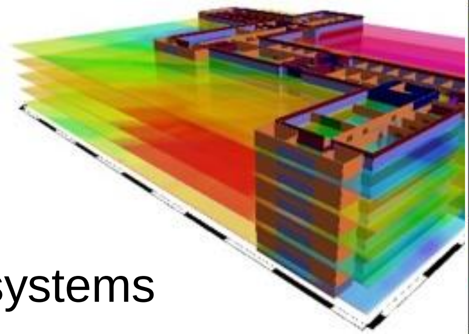


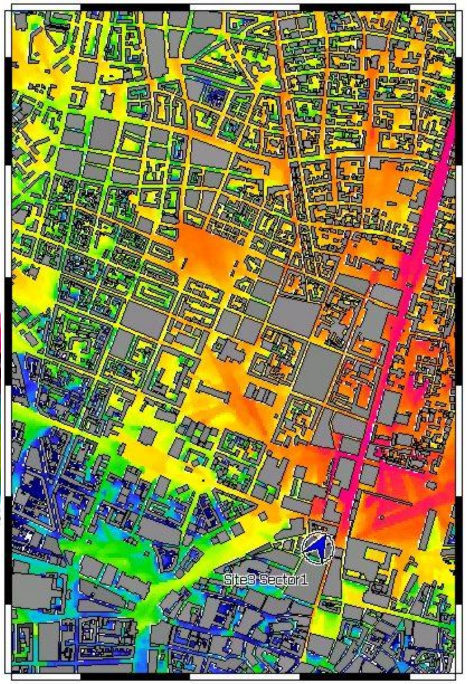


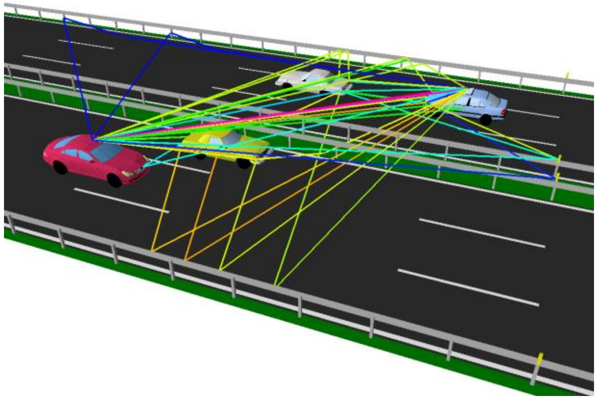
WinProp Software Suite

Radio network planning tool

- Wave propagation models for various scenarios
  - Indoor/Tunnel
  - Urban
  - Rural/Suburban
  - Satellite
- Radio network planning of various systems
  - Cellular incl. LTE and beyond
  - WLAN, WiMAX
  - TETRA, Broadcasting
- Applications
  - Radio channel analysis
  - Radio network planning

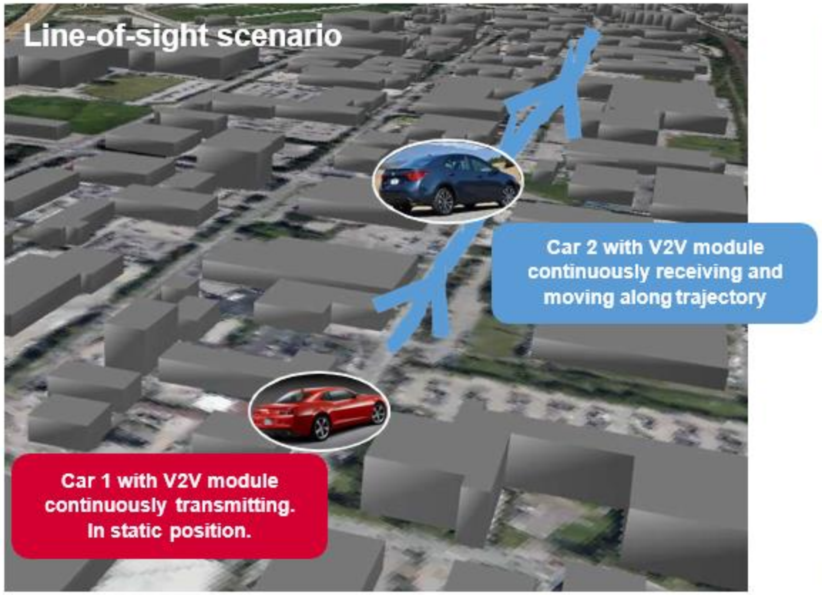


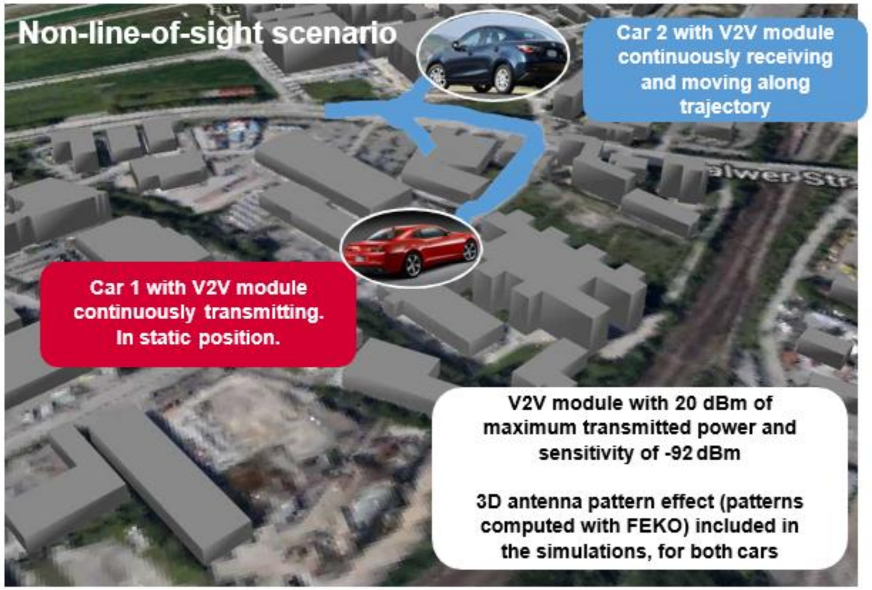




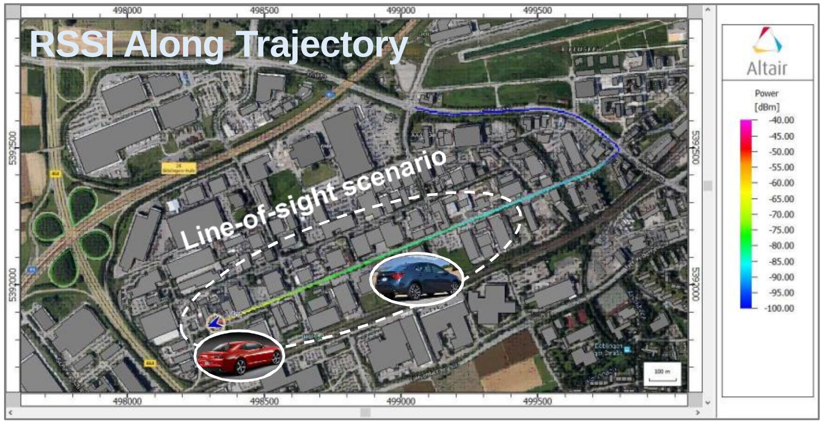
V2V Case – Range Analysis and Simulation with WinProp

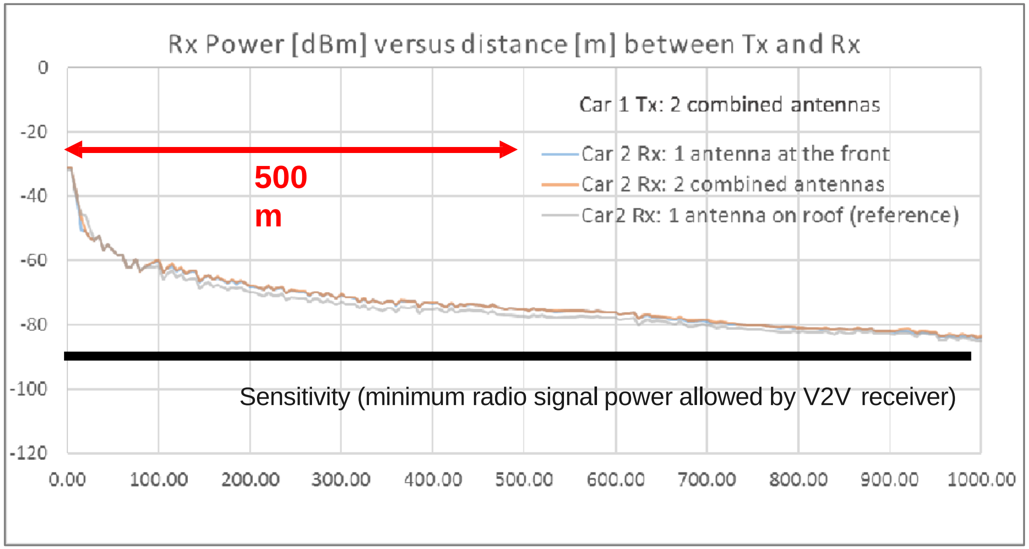
1. **Range** of communication **between 2 vehicles** should be **500m in line-of-sight (LoS) conditions**
2. **Analyze** the **impact** on the communication range in **non-line-of-sight (non-LoS) conditions**





V2V Case – WinProp Simulation of LoS Scenario

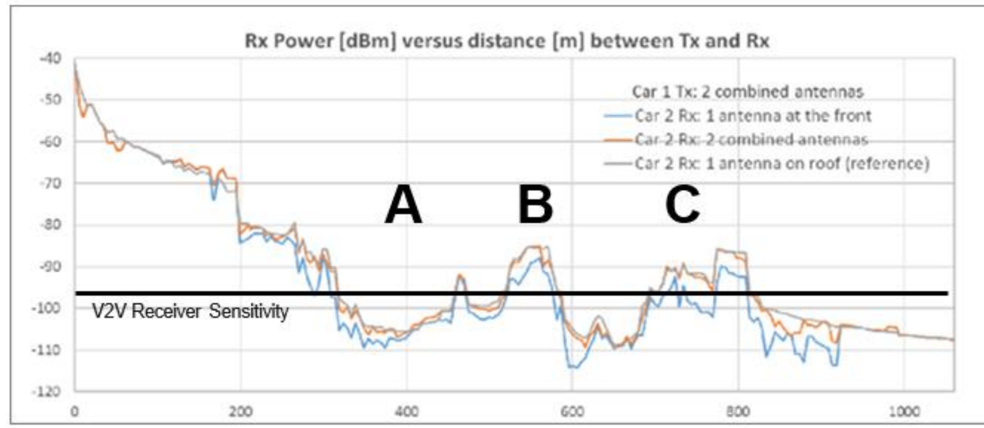




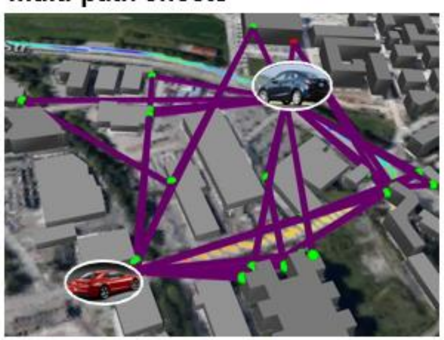
- **500m desired range is achieved in line-of-sight conditions with 1 or 2 antennas**

** Computational requirements for the simulation with WinProp – Run time: 1min 53s and memory: 1 GByte*

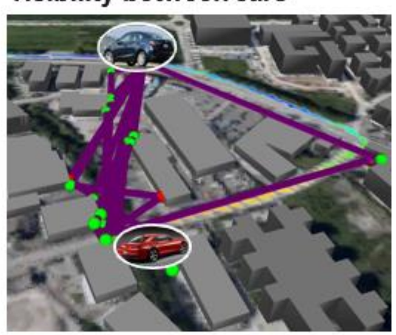
V2V Case – WinProp Simulation of Non-LoS Scenario



(A) Lost communication, even with multi-path effects



(B) Communication is possible because of visibility between cars

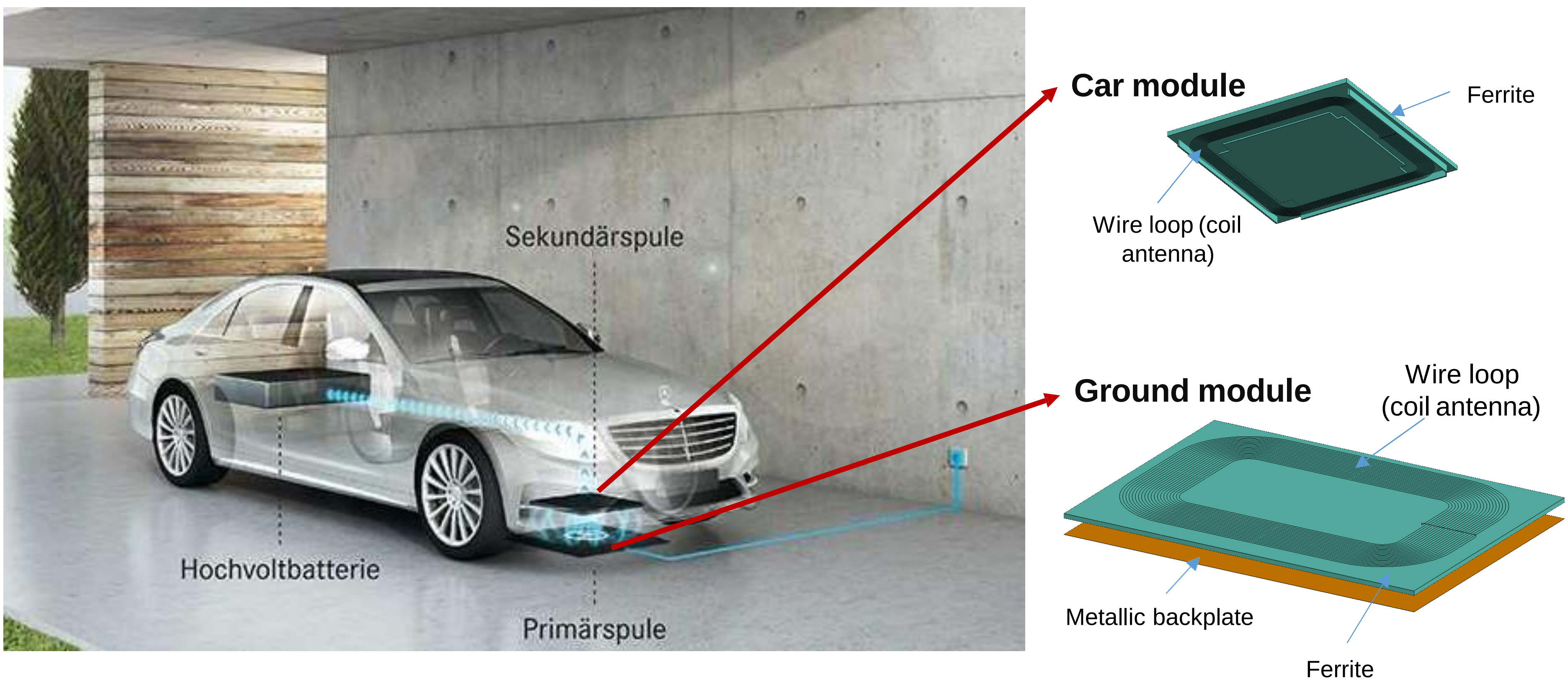


(C) Communication is possible because of:

- system using 2 antennas providing a more omnidirectional pattern
- some visibility between cars and multipath effect

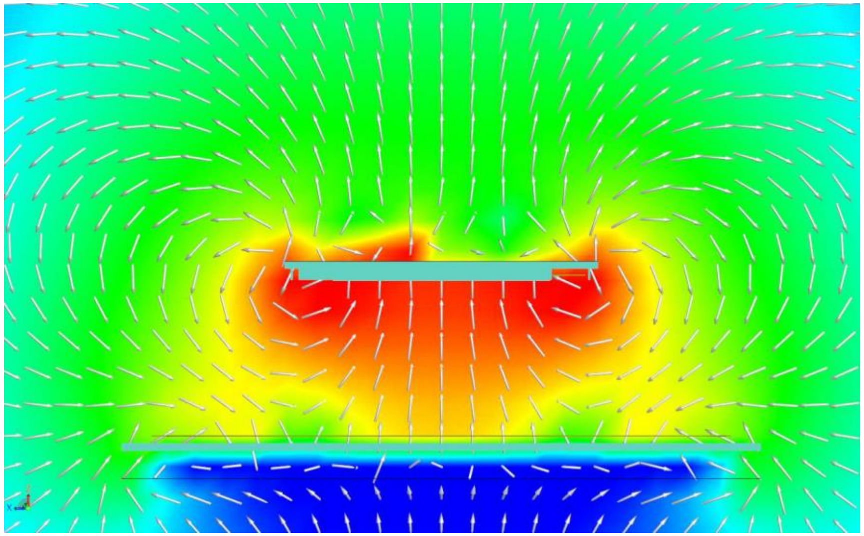
Wireless Power Transfer

Inductive Charging Systems for EV



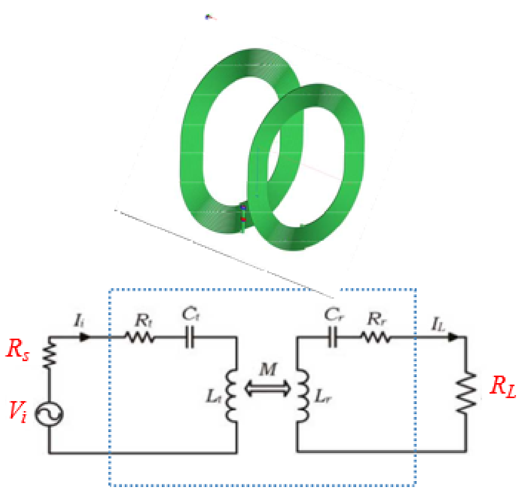
Some Key Topics on Inductive Charging with FEKO

- Efficiency of inductive charging systems
- Influence of offset between coils
- Radio interference to other systems (e.g. PEPS/KeylessGo)
- Thermal effects (with Flux)
- Radiation hazard analysis



Coupling Between Coil Antennas with FEKO

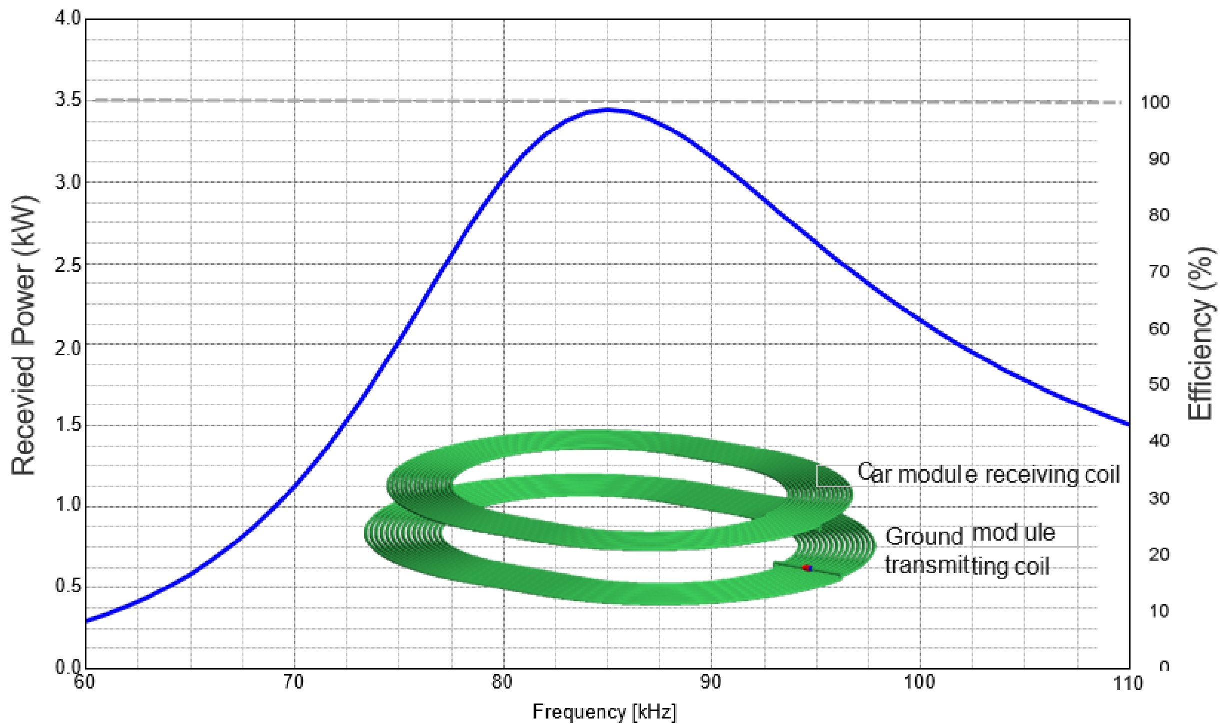
Equivalent circuit and power budget



P_{in} = 3.5 kW

P_{out} = 3.45 kW

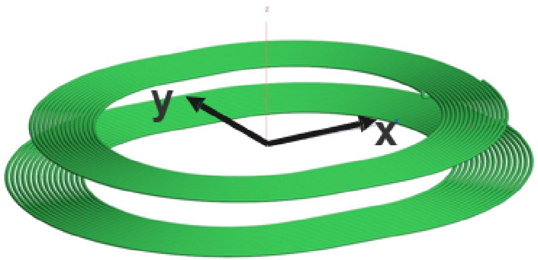
Efficiency(P_{out}/P_{in}) = 98.5 %

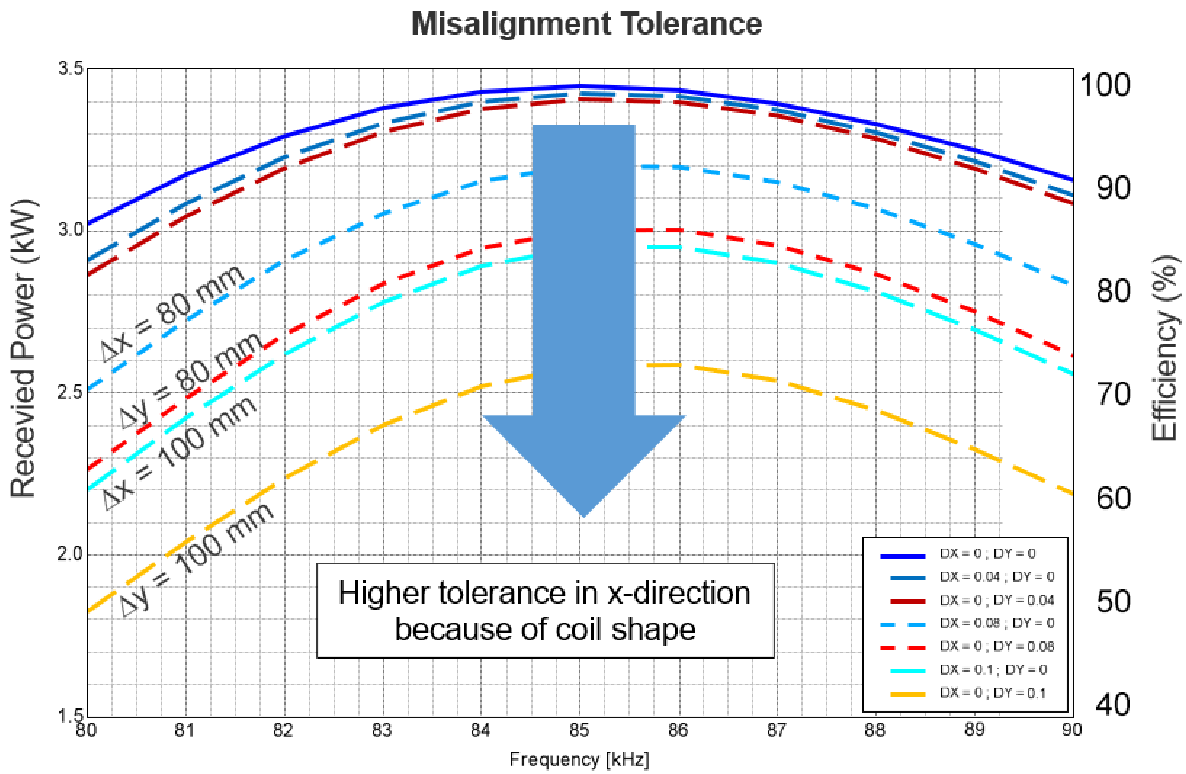


Misalignment Tolerance Between Coil Antennas with FEKO

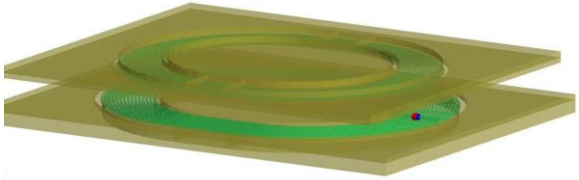
For WPT application both coils' positions may not perfectly match

- Offset in x-, y-, or z-direction
- Influence on efficiency





Importance of Ferrites in Design of WPT Systems



Function of ferrite plates on WPT systems:

- Reduce coil antenna size and increase efficiency
- Minimizing eddy currents on metallic scattering surfaces
- Minimize magnetic field emissions
  - to secure compliance with EM field safety standards for human exposure
  - to avoid EMC interference with other electric devices

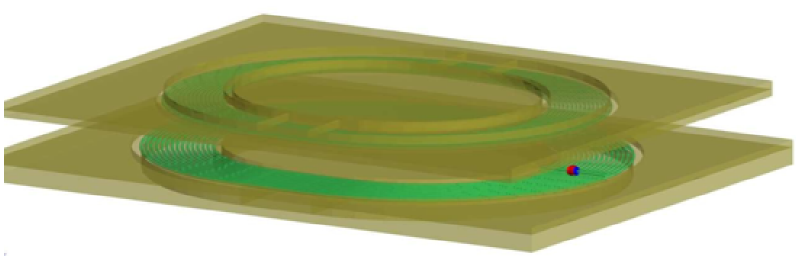
Modelling technique in FEKO for ferrite material

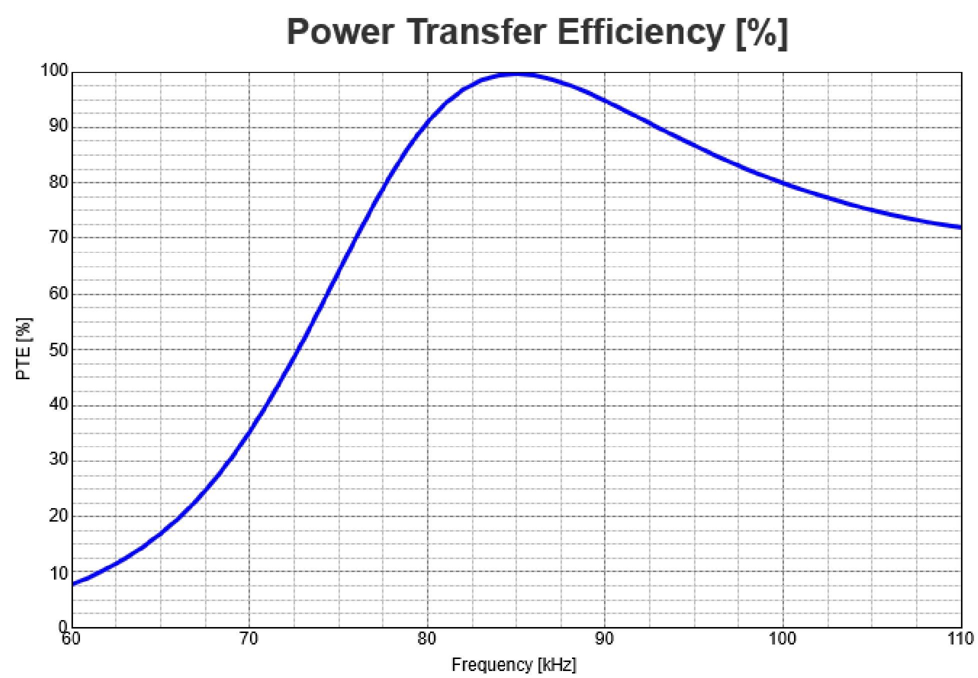
- For low frequency simulation (e.g. 85 kHz) Volume Equivalence Principle (VEP) is the appropriate method (mesh with tetrahedra)
- Double precision is recommended and for lower frequencies LF stabilization could be necessary

FEKO Simulation of Coils with Ferrites

- **Coil parameters:**
  - K = 0.81
  - C_1 = 5.38 nF
  - C_2 = 5.49 nF
  - R_L = 125 Ω

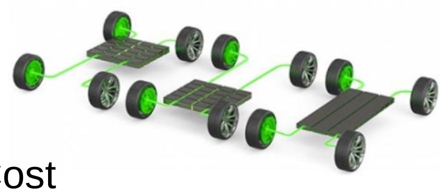
Ferrite with μ_r = 2400

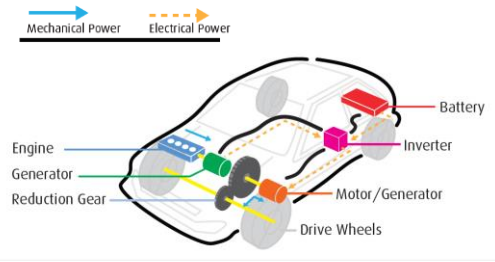




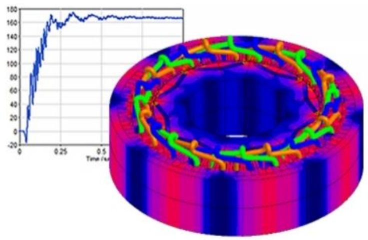
Summary & Conclusions

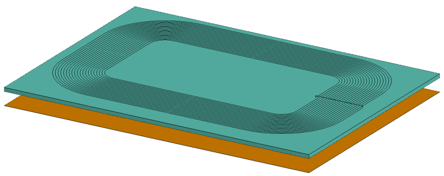
- System Modeling & Smart Control
  - Validate Architectural Choices
  - Improve Design Efficiency
  - Reduce Prototyping & Maintenance Cost



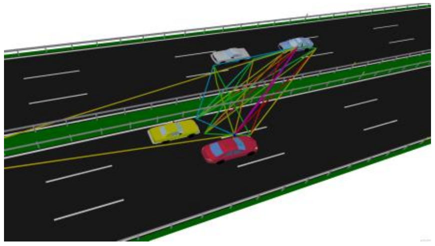


- Powertrain Electricfication & Hybridization
  - Design Efficient Electric Motors
  - Optimize Charging Systems





- Meeting EMC & Connectivity requirements



Thank you !!