Virtual Prototyping of Interior Automotive Systems
Ralf Kakerow, Continental Automotive

CST European Automotive Workshop, Munich, 23 Nov 2015
# Agenda

1. **Interior Division at Continental**
2. **Virtual Prototyping Motivation**
3. **The Multidisciplinary Challenge**
4. **EMC Simulation**
   - 4.1 Simulation on PCB level
   - 4.2 Mechanics and EMC
   - 4.3 GSM Interference Analysis
5. **Electrostatic Discharge**
6. **Conclusion**
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Continental Corporation
Five Strong Divisions

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PLT – Passenger and Light Truck Tires
Megatrend: Information  
Our Contribution to Intelligent Driving

- Navigation systems
- Tachographs
- Instruments
- Instrument clusters
- Secondary displays
- Head-up displays
- Cockpit modules
- Multimedia systems
- Telematics systems
- Infotainment solutions
- Passive start and entry systems
- Tire information systems

Thanks to our solutions, the driver can make the right decision fast in any situation.
Multimedia head unit

Head unit
› Radio reception
› Navigation
› Connectivity
› Telematic
› HMI
› System integration
› Applications
› Services

… and finally
› Computing power
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Automotive specific requirements

› Automotive products have to function under worst case environmental conditions
  › Wide range of temperature conditions (~ -40 °C to +85 °C)
  › Wide range of power supply voltage (~ 4.5 V to 16.0 V)
  › Superimposed alternating voltages
  › ESD polluted environment (ESD = Electrostatic Discharge up to +/-15 kV)
  › Full range of humidity (0% - 100%)
  › Mechanical strength and stability (static / dynamic): Vibration & mechanical shock
  › Chemical influences
  › Minimal or no power consumption allowed when system is switched off
  › Automotive products are additionally characterized by strong limitations regarding dimensions and weight and have to fulfill tough requirements regarding risk of injury (Head Impact) and product liability
Virtual prototyping

Reduction of Costs and Time
Additional Freedom
Increase Knowledge

Product evolution vs. Time

Potential Time Savings

100%
Analysis and optimization stages

**Product Functionality**
- Simulation Model
  - geometry, materials
  - excitation, loads
  - boundary conditions
  - analysis type

**Parameter Influence**
- Sensitivity Model
  - design variables
  - system response
  - DOE techniques

**Design Optimization**
- Optimization Model
  - objective function
  - constraints
  - design variables

**Simulation**
- Simulation Results
  - structural, thermal, EM
  - interpretation

**Design Study Results**
- local/global sensitivity
  - influence curves, Response Surface

**Optimization Results**
- optimal design variable values
  - objective improved
  - constraints satisfied
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Simulation of automotive interior systems
Multidisciplinary interaction

**Structural (FEM)**

**Thermal**

**Fluidodynamics (CFD)**

**Electro-statics**

**Electro-dynamics (EMC)**

**Light/Illuminance**
Structural mechanics

Torque computation in a rotary knob (axial design)
Structural mechanics

› Dynamic system analysis (shock, vibration)
Thermal / CFD simulation of a car radio – initial design
Thermal / CFD simulation of a car radio – optimized
Optical simulation

Ray tracing analysis of display backlight to detect stray light

Improvement of the homogeneity in button design
Simulation of automotive interior systems
Multidisciplinary interaction

- **Structural (FEM)**
- **Thermal**
- **Fluiddynamics (CFD)**

- **Electro-statics**
- **Electro-dynamics (EMC)**
- **Light/Illuminance**
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Signal integrity analysis

Processor IC200
Flash IC400
FPGA IC500
USB IC2204
3D PCB simulation
PCB critical signal trace
PCB – return currents and resonance effects
PCB with Bluetooth antenna

Component: ABS
3D Maximum [A/m]: 722.1
Frequency: 2440
Phase: 0
PCB with Bluetooth antenna
PCB with Bluetooth antenna

BT Antenna

SDRAM
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Interior simulation models
EMC relevance of mechanical designs

E-field with silverbox

Surface current on PCB with housing

E-field without silverbox

Surface current on PCB without housing
Head unit – Effect of assembly to EMC
Simple simulation model

Model setup

› Import of mechanical design data to CST MWS
› Simplify the model (and „convert“ it from mechanical to electrical world)
› Set materials of mechanical parts; electrical contacts need to be modeled properly (oxide layers, etc.)
› Simplify PCB to reduce meshing complexity (just an FR4 brick with one GND layer)
› Electronics on PCB is modeled by equivalent radiation source
  › Discrete port at a trace and unmatched termination
  › Current through connectors to investigate return currents
Head unit – Effect of assembly to EMC
Simulation vs. EMC test results

Good agreement of results in upper frequency bands even with this simplified model

It is important to find the right abstraction level of the model
Main connector variants

Variant A

Variant B
Main connector model for EMC simulation

New model has been drawn based on CAD data
Reduction to relevant information

Model example for main connector

Often suppliers only provide keep-out models
Simulation model (opened for visibility)
Probe signals in 3m distance (z direction)

Probe Value in V/m [Magnitude in dB]

576 MHz  950 ... 1,070 MHz  2,238 MHz
753 MHz

E-field (Farfield) (newCD nC) (X; -80 0 -35+3000) [1]
E-field (Farfield) (newCD olr) (X; -80 0 -35+3000) [1]
Surface currents @ 576 MHz, phase = 45 deg

Main connector with contact springs
- Slightly higher surface currents without contact springs at phase of 45 degrees

Main connector without contact springs
Surface currents @ 576 MHz, phase = 135 deg

Main connector with contact springs

- Significantly higher surface currents without contact springs at phase of 135 degrees
- Current phase shift of 90 degrees indicates coupling effect
Surface currents @ 576 MHz

Main connector with contact springs

Main connector without contact springs

› Without contact springs, coupling from Main Connector PCB to CD drive causes high surface currents and therefore high radiation

› CD drive mounting point distance (131 mm) is close to lambda/4 (130,1 mm)
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GSM interference
GSM interference

- The diagram shows the disturbance signal level on the left front loudspeaker output
- A significant disturbance signal is available in GSM D-net uplink frequency range (890 ... 940 MHz)
- The GSM pulse (217 Hz) from a GSM mobile phone is demodulated in the audio amplifier
- In the car the GSM pulse can be heard clearly what is not acceptable for the customer
Aluminium cooling bracket
Simulation of the aluminium cooling bracket
S11 – antenna effect

Port that feeds a wideband signal to the structure

Ports / lumped elements at contact points
S11 of the aluminium cooling bracket

![Graph showing S11 parameter with frequency in MHz and magnitude in dB. The curve indicates a geometry resonance at around 800 MHz.]
Audio amplifier region on PCB

Kind of resonant cavity
Simulation of audio amplifier region in 3D assembly

› Parts that are not relevant for this simulation have been removed from the model to increase simulation speed

› Simulation probes were placed close to the amplifier region
Simulation of audio amplifier region in 3D assembly E-field

- Resonance in all three geometrical E-field components x, y, and z at 917 MHz
The two electrolyte capacitors are removed in a second simulation to verify the availability of a resonance cavity.
Simulation of audio amplifier region in 3D assembly
E-field of modified model

No resonance at 917 MHz can be observed
Simulation of audio amplifier region in 3D assembly
Comparison of $E_z$

![Graph showing probe magnitude in dBV/m vs. frequency (GHz)]

- $E_{Cav_z\_MIT}$: 16.069212
- $E_{Cav_z\_OHNE}$: -27.061364

Frequency / GHz:
- 0
- 0.5
- 1.5
- 2
- 2.5
- 3

Probe Magnitude in dBV/m:
- 20
- 10
- 0
- -10
- -20
- -30
- -40
- -50
- -60
- -70
- -80

0.91713
The solution

- Removing the audio input filter capacitors (to reduce coupling)
- Soldering the amplifier holder to a pad with 5pF capacitance to PCB-GND (planar PCB copper pad; no additional component) tunes the resonating frequency to outside GSM band
- The diagram above shows the measured loudspeaker spectrum after performing the changes
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Electrostatic discharge (ESD)

- Simulation model for ESD simulation
- Normed ESD-voltage pulse used as excitation
Electrostatic discharge (ESD)
Current distribution of PCB / display frame

Current distribution after an ESD impulse at one of the rotary buttons
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Virtual prototyping is more than just pressing a button
Focus on the effects that you like to investigate
  Keep the model as simple as possible, but accurate enough
  Verification of model simplification is important
Model discretization belongs to the most important steps of simulation
Variant simulation allows easy „what – if“ analysis
Joint activity of developers, simulation engineers and laboratories
Understanding the functionality of a product is much more fun than debugging a prototype

Thank you to Dr. Uwe Lautenschlager and Michaela Rzehak for contributing part of the simulations shown in this presentation
… and to CST team for their good support and open discussions
Thank you for your attention