ANSYS
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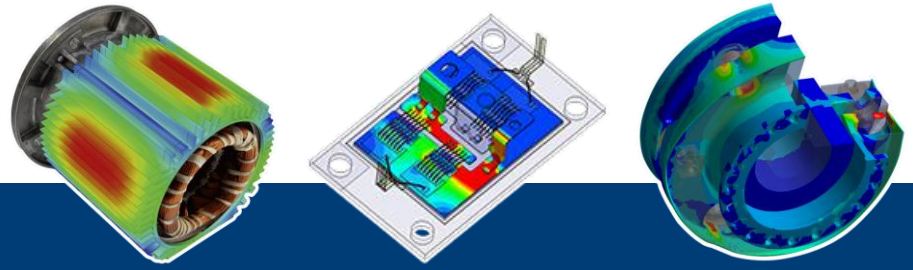
Simulation ist mehr als Software®



EMV in der Leistungselektronik am Beispiel eines SEPIC Wandlers

Christian Römelsberger CADFEM GmbH,
Felix Müller Continental Automotive GmbH

Continental
The Future in Motion

Agenda

- Sources of EMI
- Conducted emissions
- Emissions of a 12V SEPIC converter
- EMI Filters

DC-DC Converters and EMI in the Board Net

Larger Electrical Power Consumption

Difficult with 12V Board Net

Introduce 48V Board Net

Source: emo-berlin.de

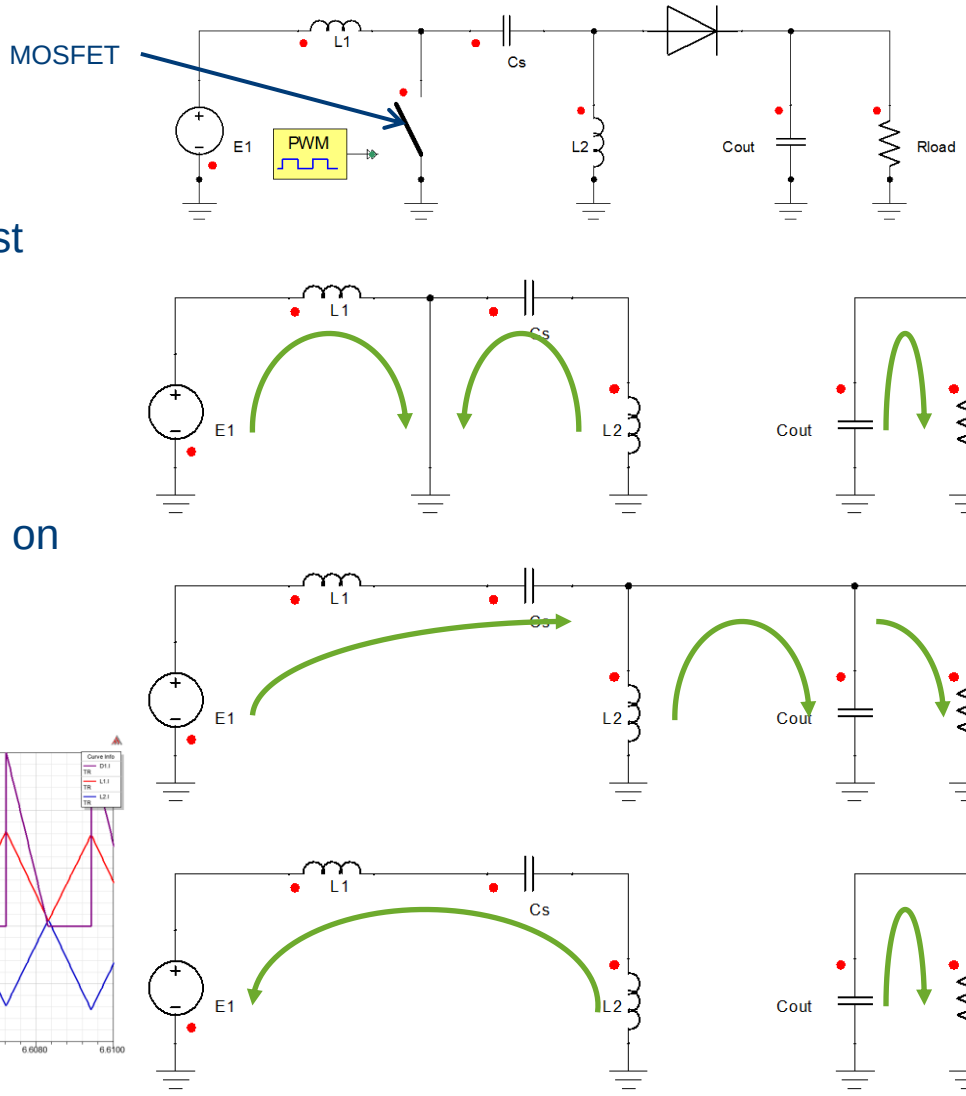
Need/Callenge to ensure EMC!

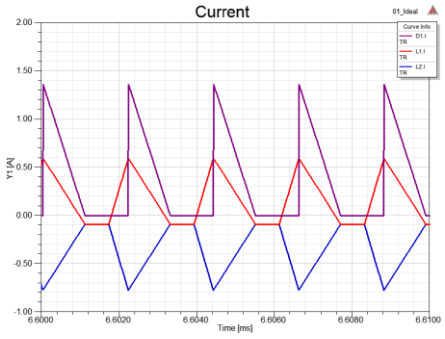
Source of EMI with large Power Throughput

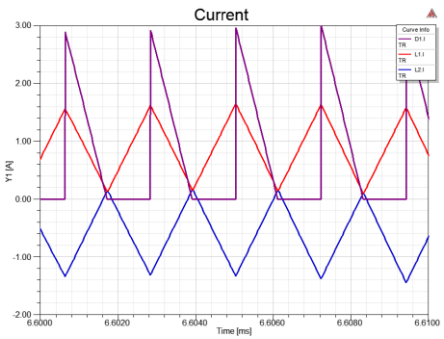
Need DC-DC Converter between Nets

Sources of EMI – DC-DC Converters

- Example: SEPIC converter
  - Switching frequency 0.5MHz → Fast switching device!
  - Up- and Down-Conversion
  - Two modes of operation depending on load and duty cycle
    - Two-phase or Three-phase

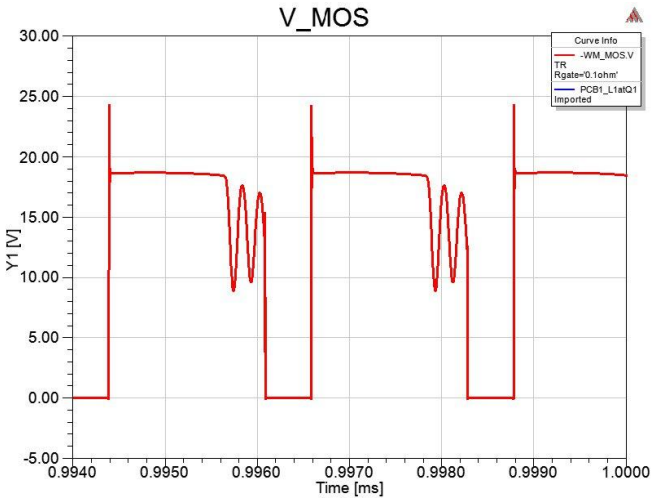


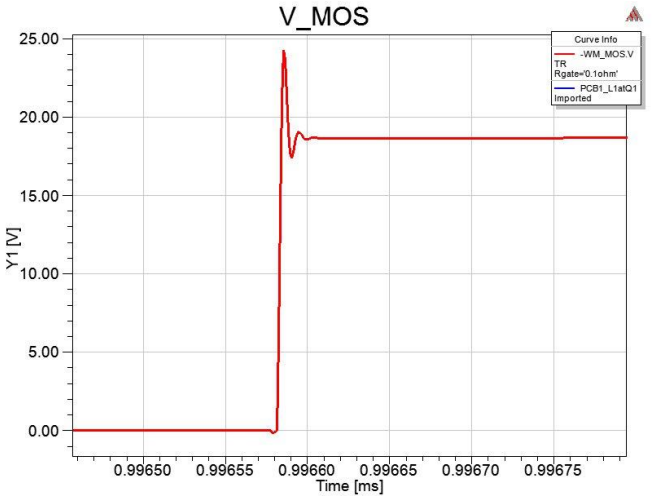




Sources of EMI – DC-DC Converters

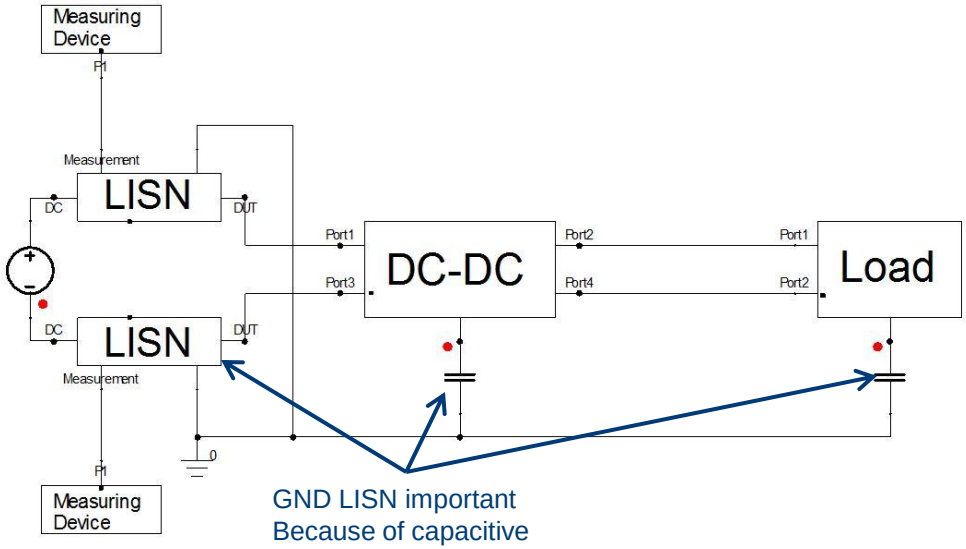
- Periodic Signal
  - Contributions in the spectral domain at multiples of 0.5MHz
  - Largest Contribution at 0.5MHz (typically)
- Switching and Resonant Circuits
  - Resonant circuits due to parasitic inductances and capacities
    - Board
    - Components
  - Frequency much higher than switching period
  - Steep switching edges excite those circuits
  - Contribution largely independent of switching period





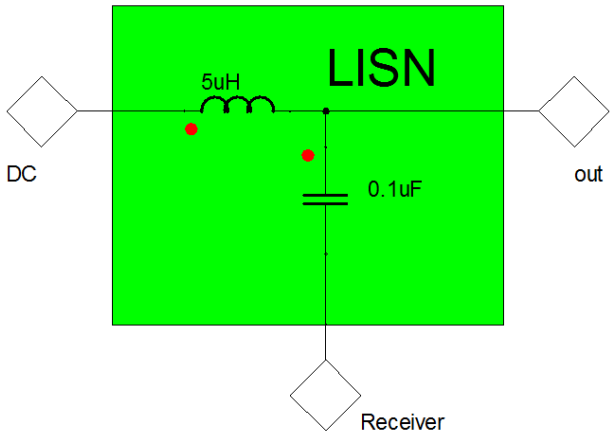
Quantifying EMI

- Disturbances in form of
  - Conducted emissions (CE)
  - Radiated emissions (RE)



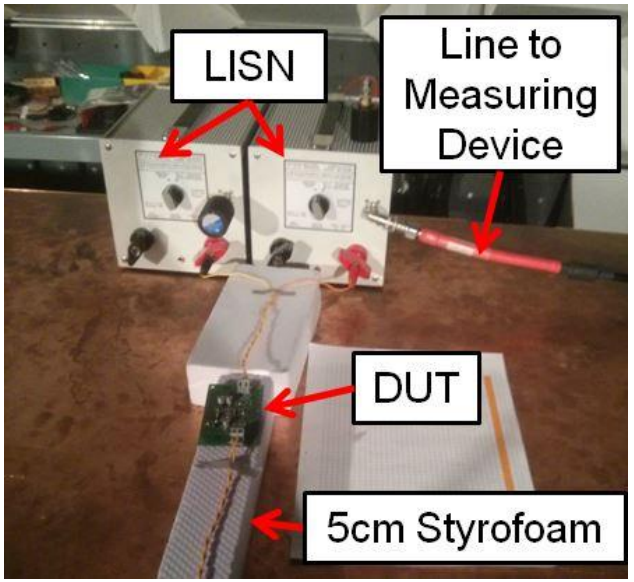
GND LISN important
Because of capacitive
Coupling to true GND
→ Common Mode!

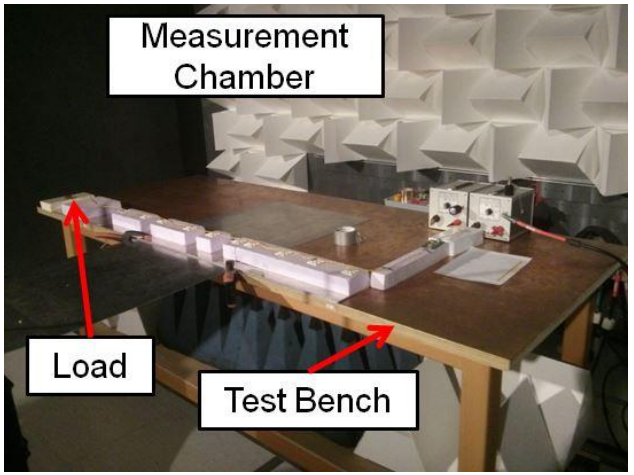
- CISPR standard:
  - Artificial network (LISN)
  - Conducted emissions measured over a 50Ω termination
  - Two LISNS for power and GND



Quantifying EMI

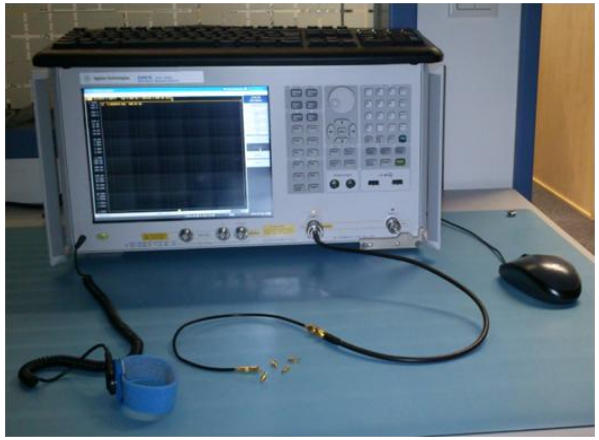
- Important
  - Shielding from external signals
  - Proper ground
  - Wiring harnesses
  - Distance from proper ground

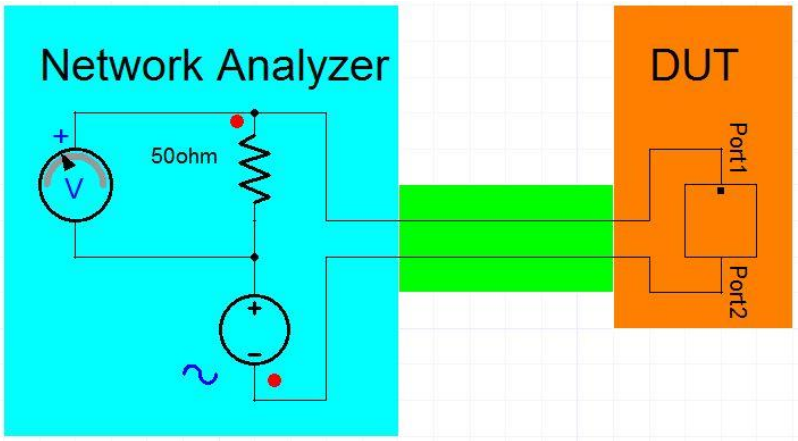


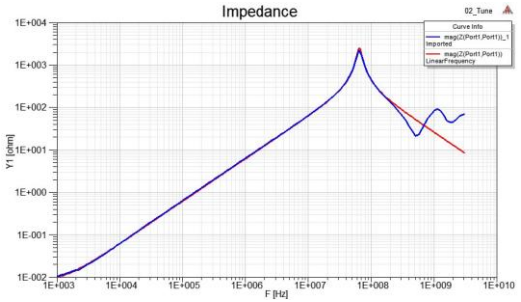


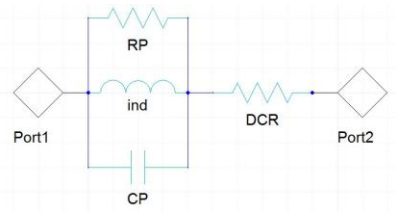
Modeling EMI

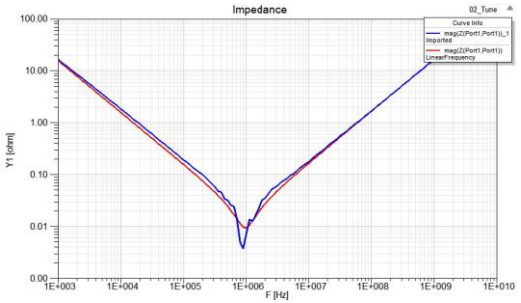
- Parasitic behavior of capacitors and inductors
  - Measured
  - Equivalent circuit fitted
- Behavioral models of active components from manufacturer
  - SPICE models





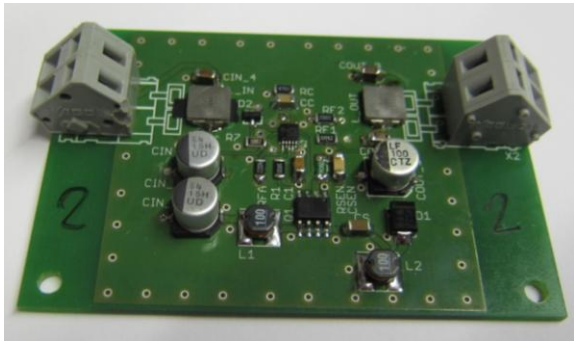


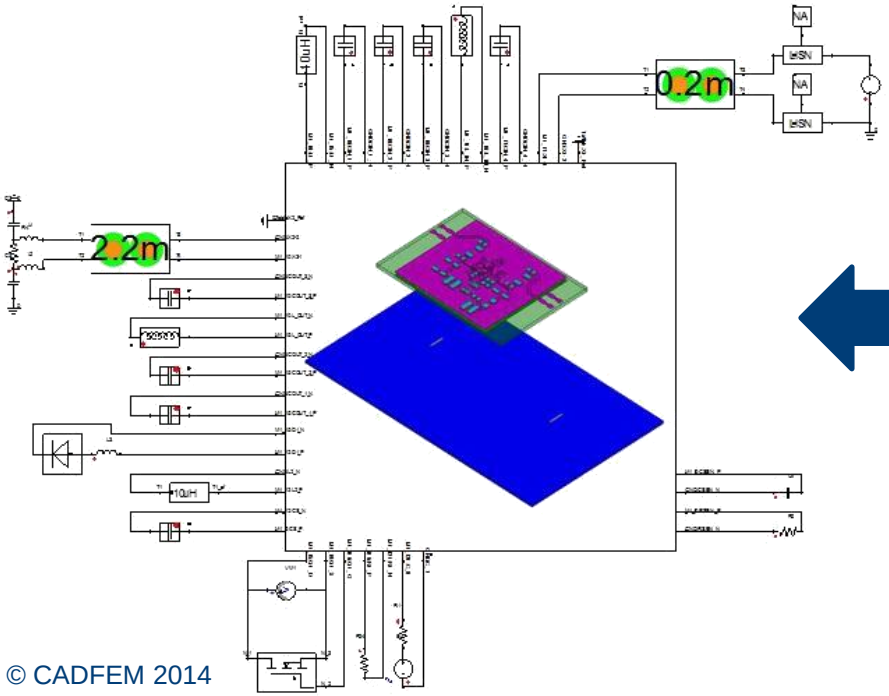


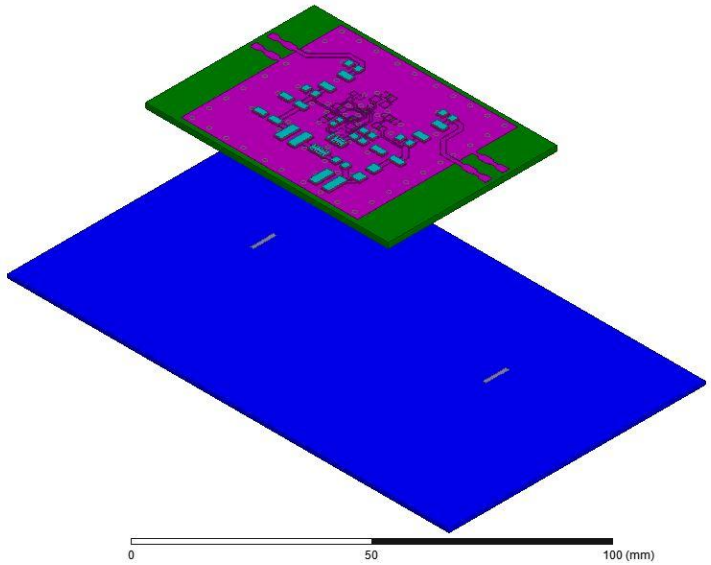


Modeling EMI

- Parasitics of the board and cables from field simulation
  - State space models
  - Important to take care of ground!

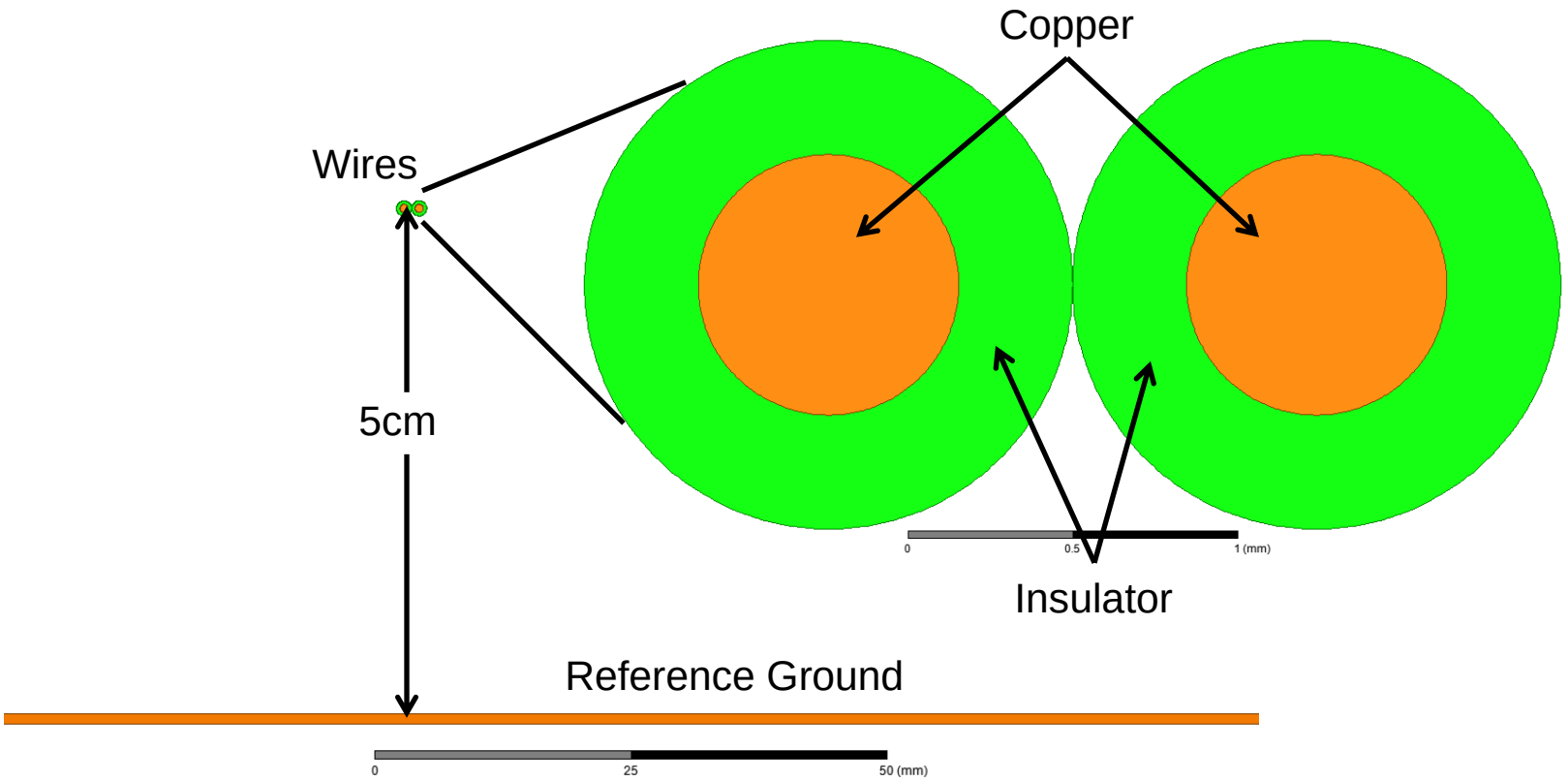






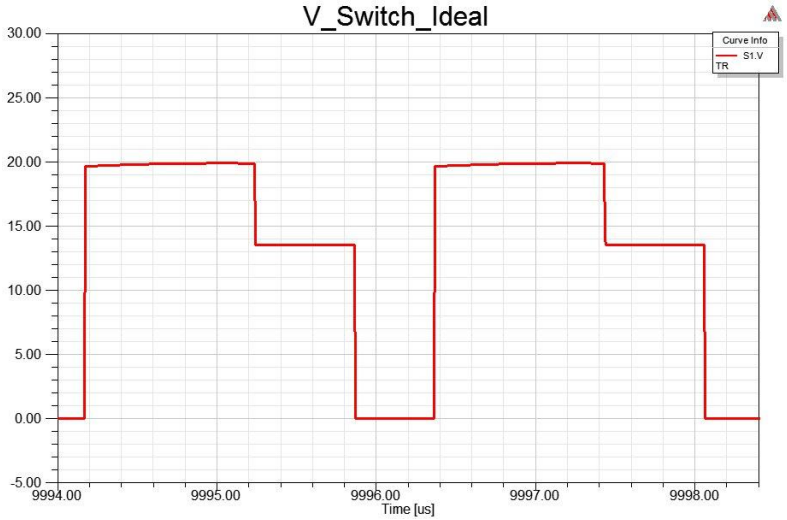
Modeling EMI

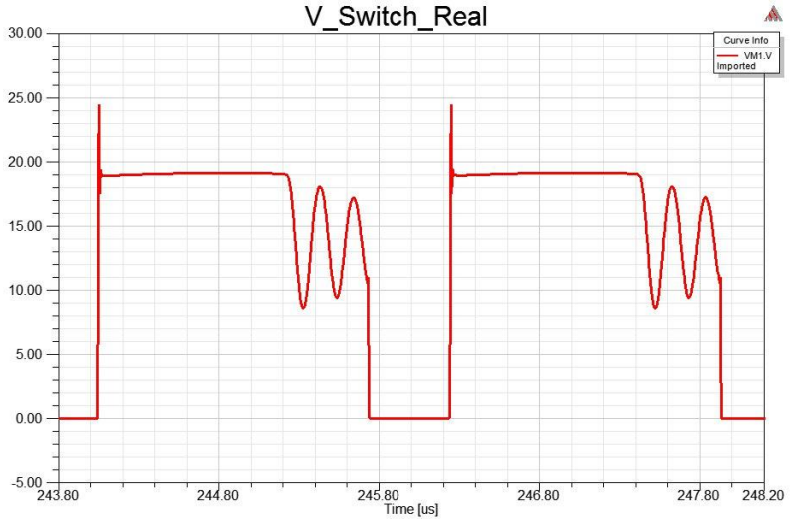
- Wiring Harness as a 2D model



Modeling EMI

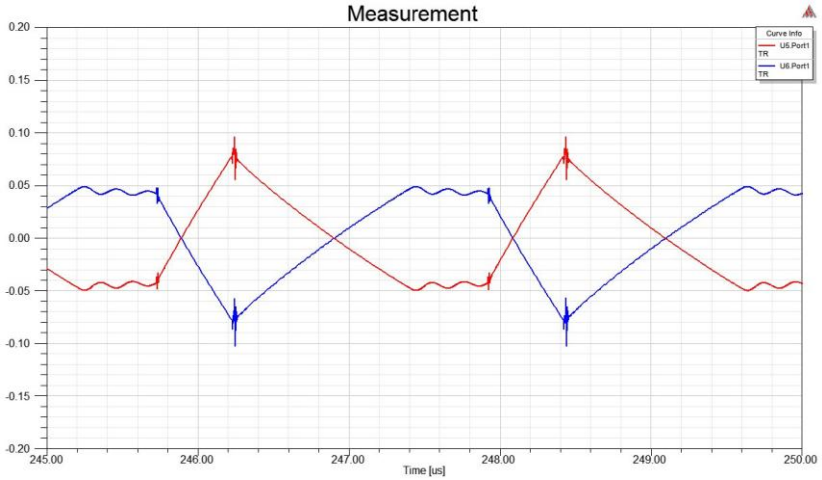
- With ideal components and no parasitics from the layout
  - No resonant circuits
  - No spikes due to switching
- The lower part of the emissions spectrum is modeled by an ideal circuit.
- For the higher part of the spectrum parasitics are important!

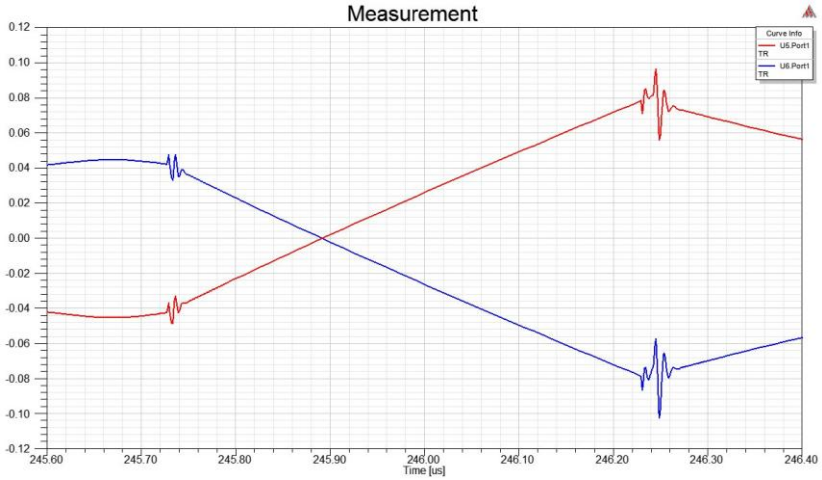




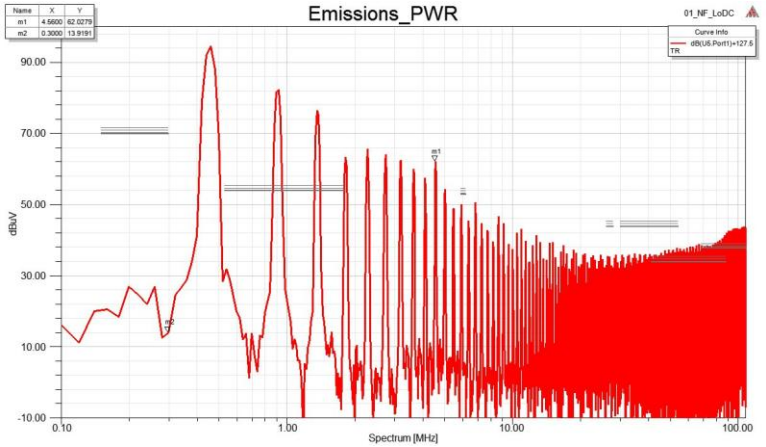
Conducted Emissions of the SEPIC Converter

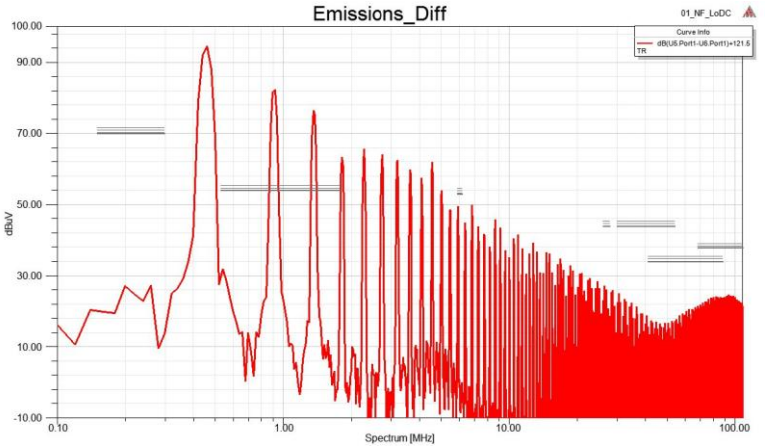
- Transient signal measured at the LISNs
  - Periodic
  - Three phases of SEPIC
- Lower part of spectrum: Differential mode
- Higher part of spectrum Common mode

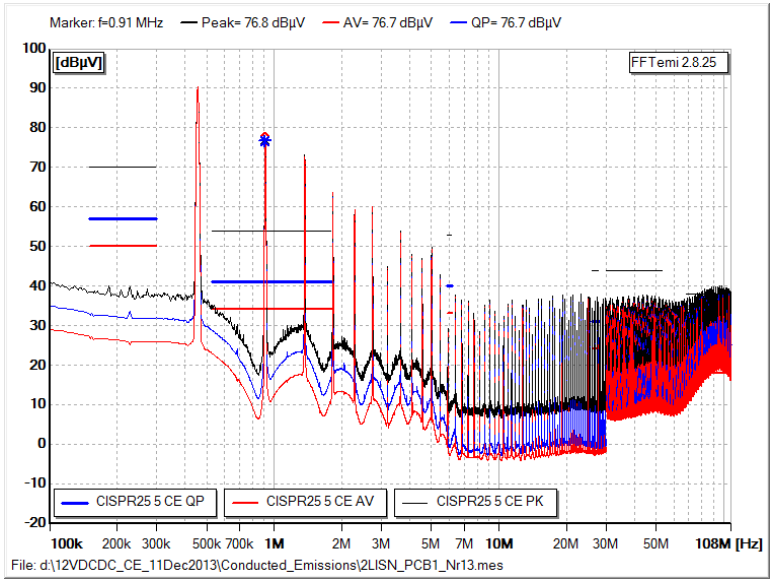


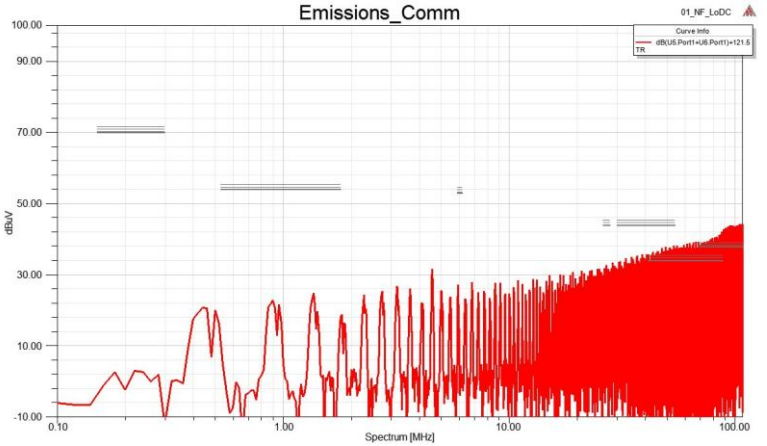


Conducted Emissions of the SEPIC Converter



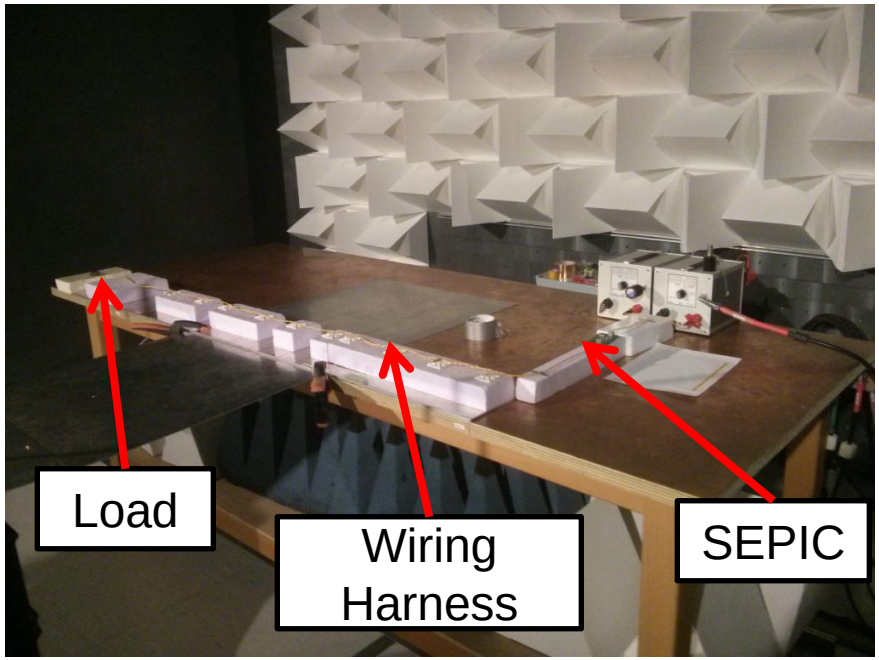






Influence of a Wiring Harness

- Conducted (guided) waves on the wiring harness can form standing waves.
- Those resonances influence the emissions of the converter.

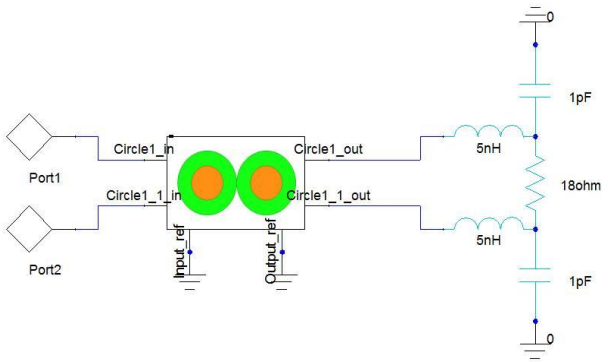


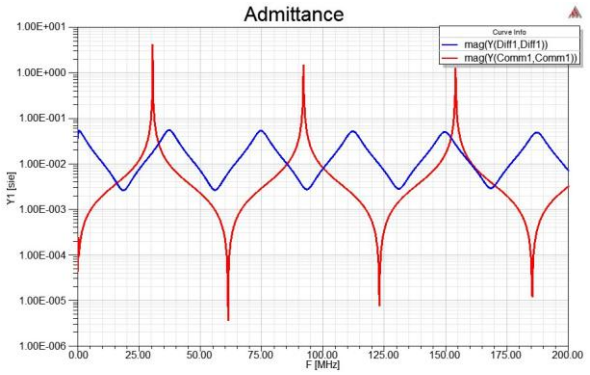
Influence of a Wiring Harness

- Standing waves in the wiring harness lead to resonances!

Mode	$l[\mu\mathrm{H/m}]$	$c[\mathrm{pF/m}]$	$v_0[10^8\mathrm{m/s}]$	$Z_0[\Omega]$
Differential	0.50	72	1.7	83
Common	0.99	12	2.9	287

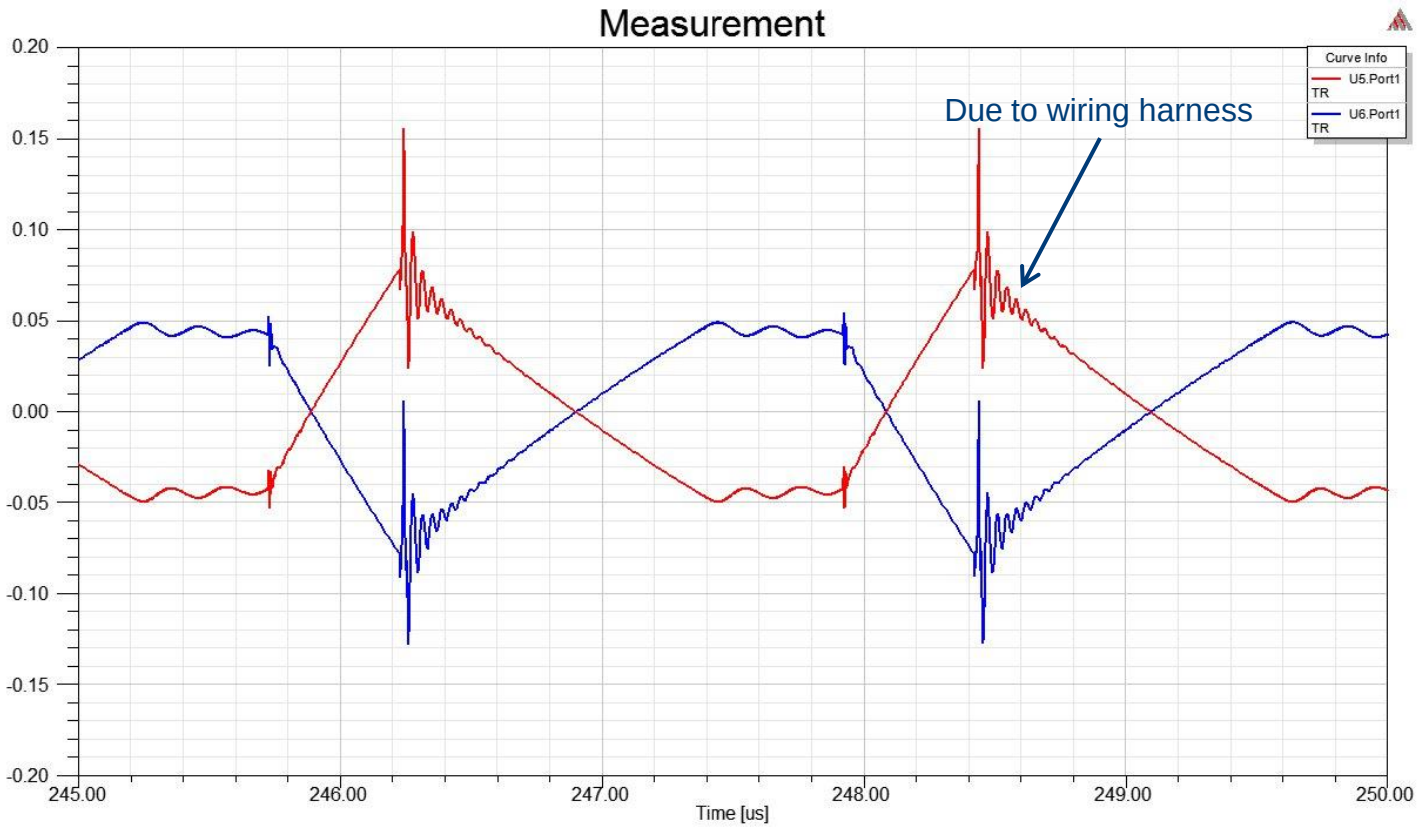
$$\Delta f_{\mathrm{diff}} = \frac{v_0}{2L} \approx 39\mathrm{MHz} \quad \text{or} \quad \Delta f_{\mathrm{comm}} = \frac{v_0}{2L} \approx 66\mathrm{MHz}.$$



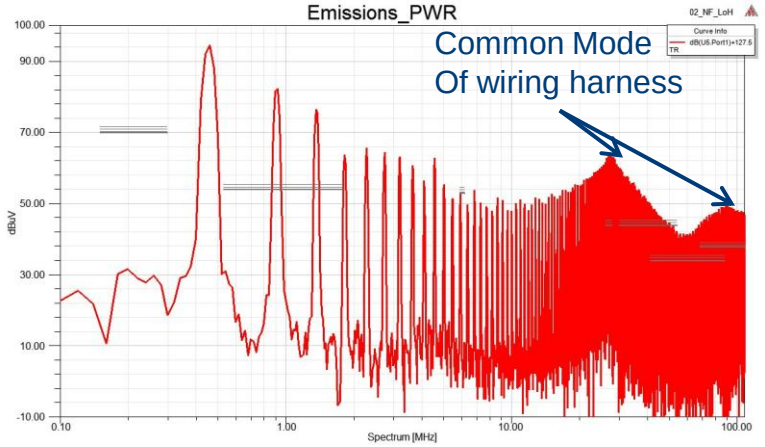


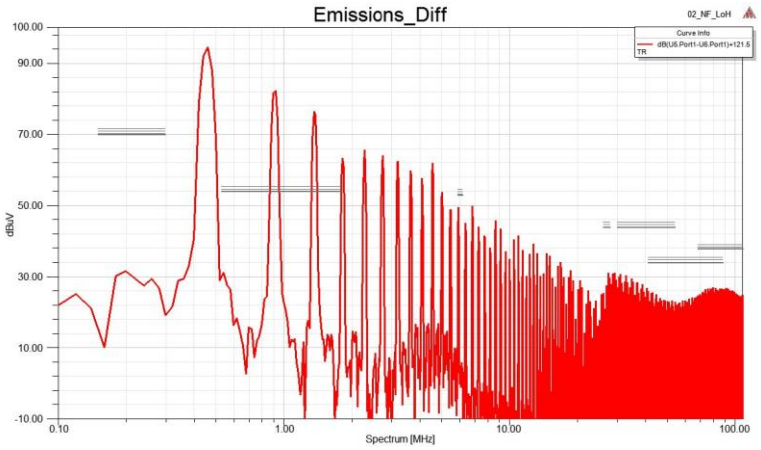
Influence of a Wiring Harness

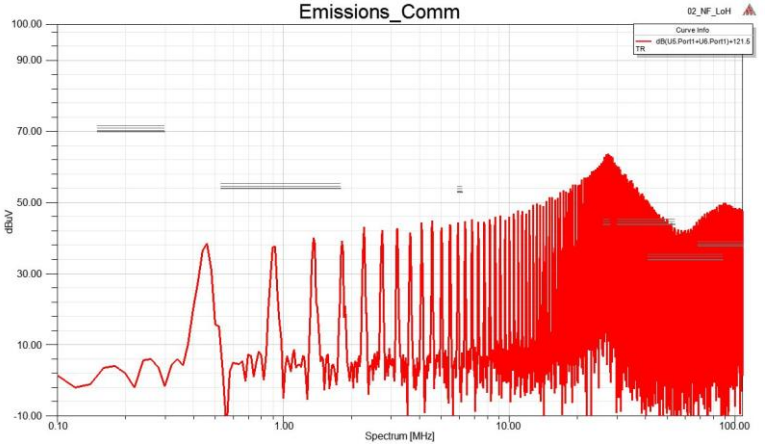
- The wiring harness forms a resonant circuit



Influence of a Wiring Harness

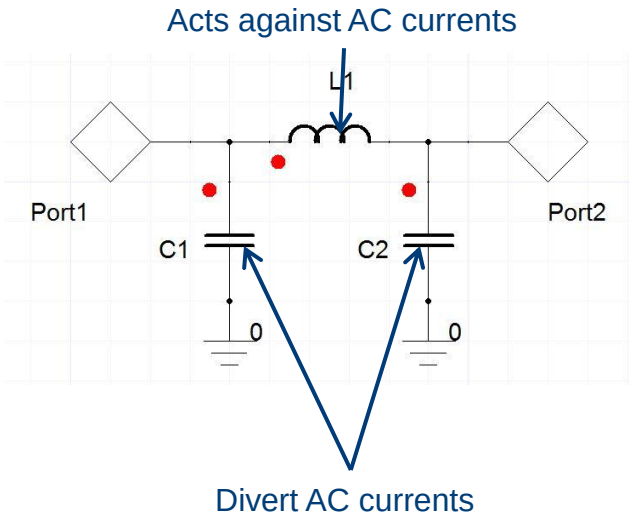




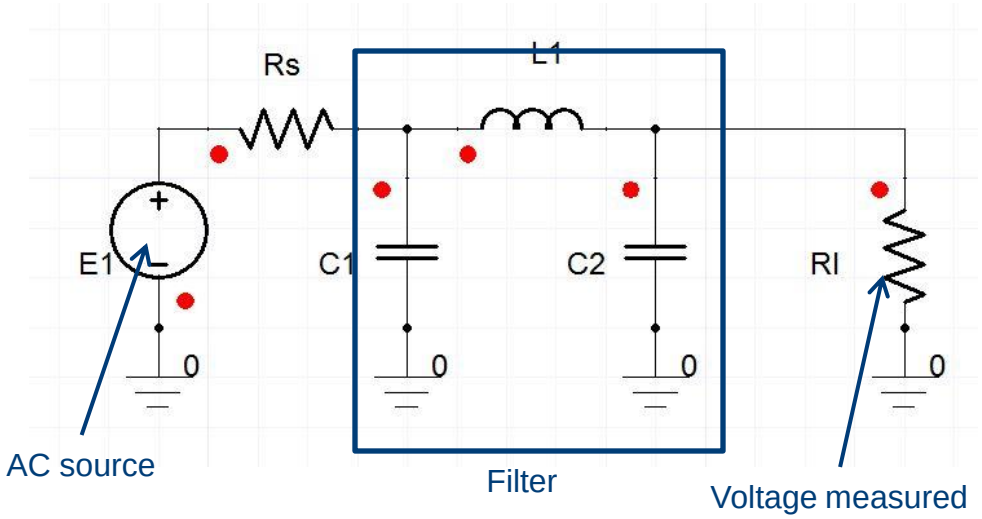


Filters

- Reduce emissions with the help of EMI filters



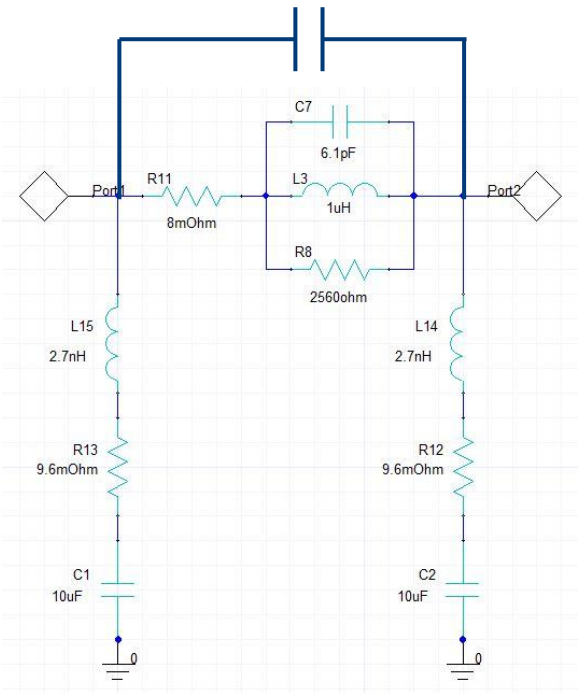
- Performance of a filter measured using S-Parameters

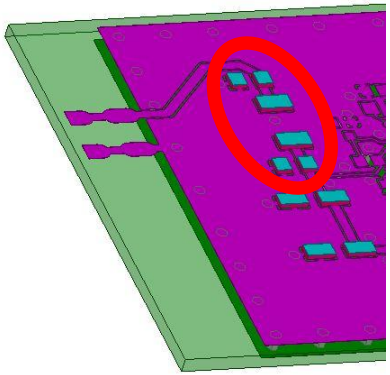


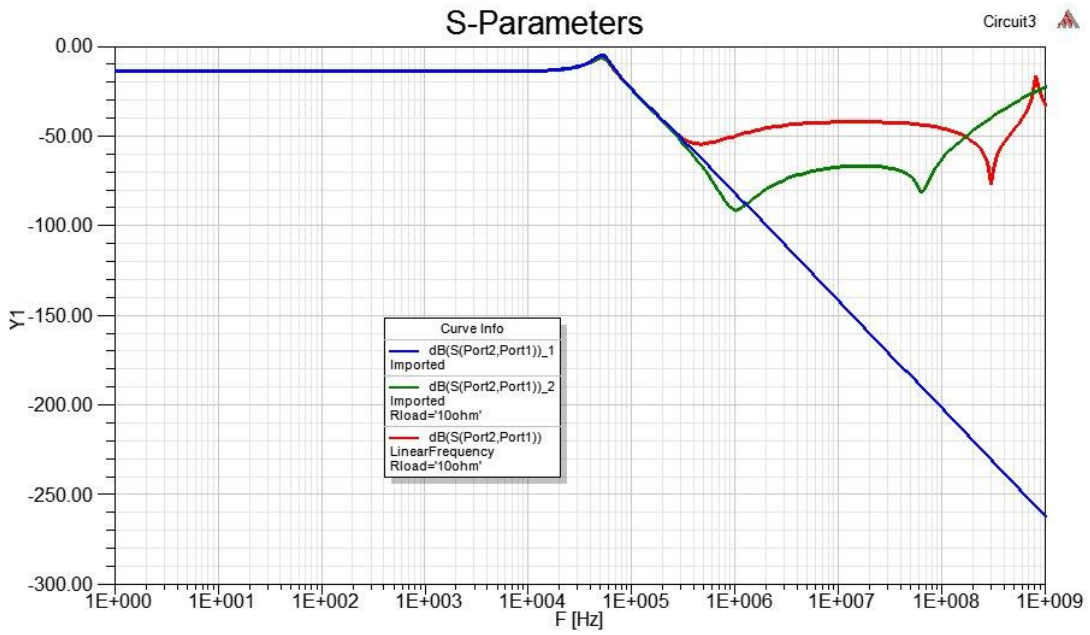
Filters

- Parasitic Effects reduce the performance of a filter

Board

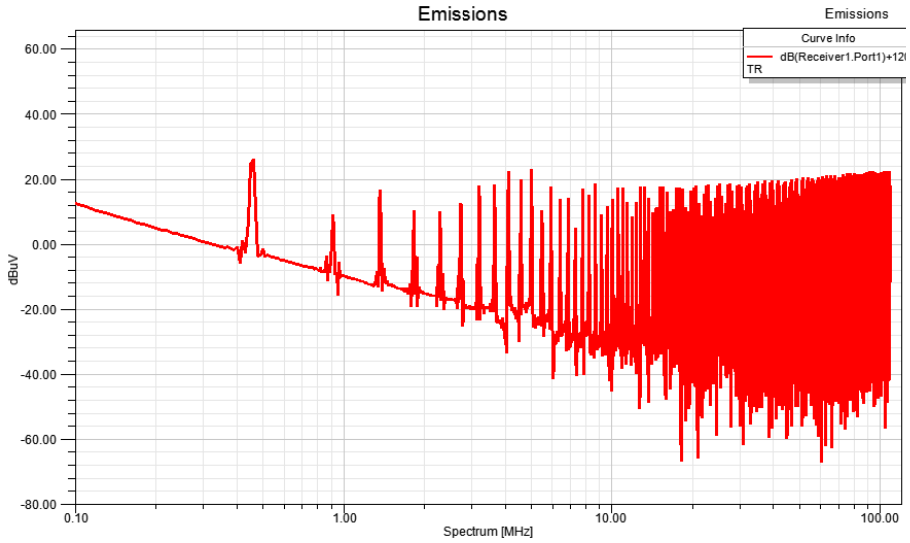




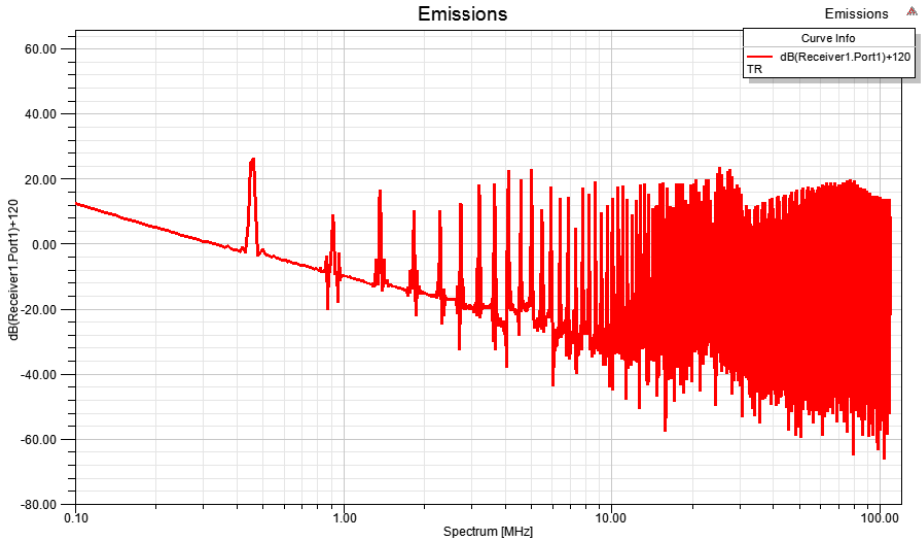


Effect of Filter

- No Harness

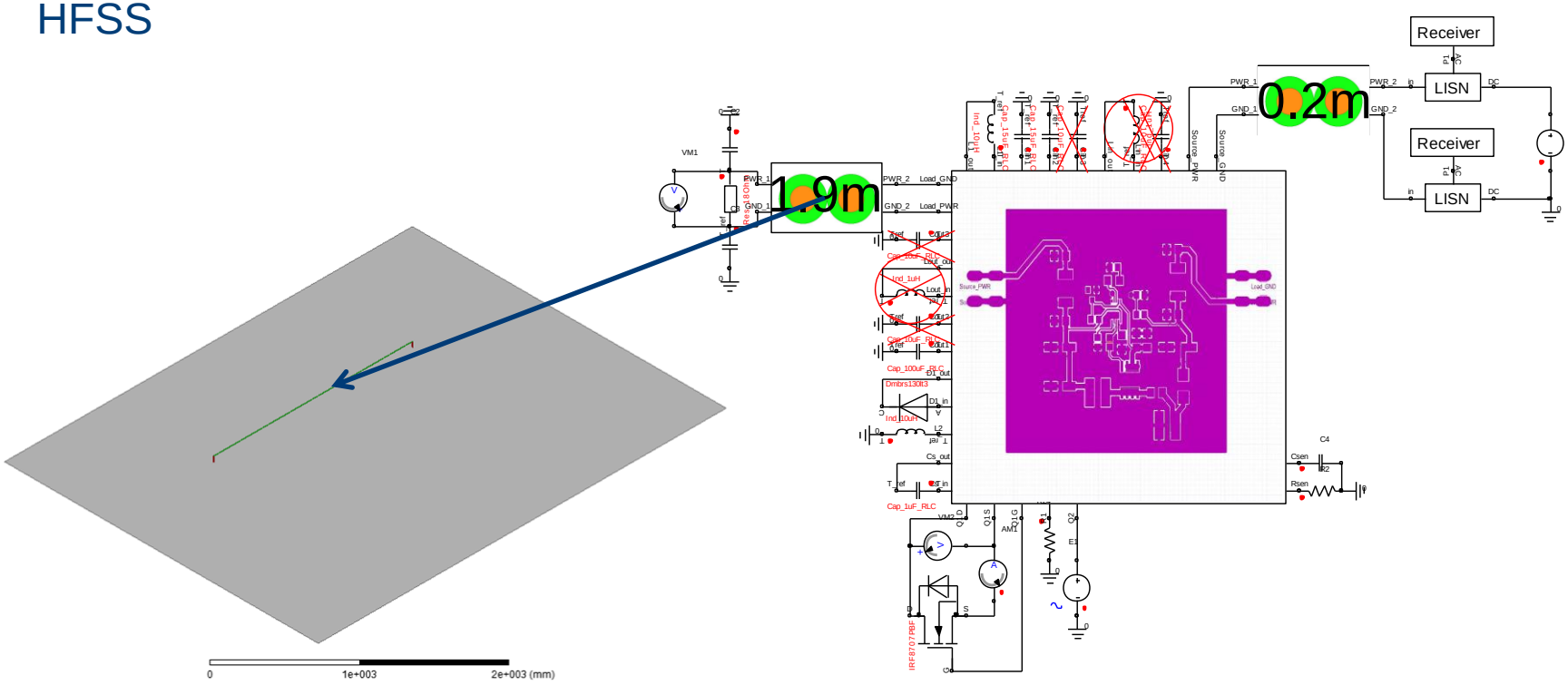


- With Harness

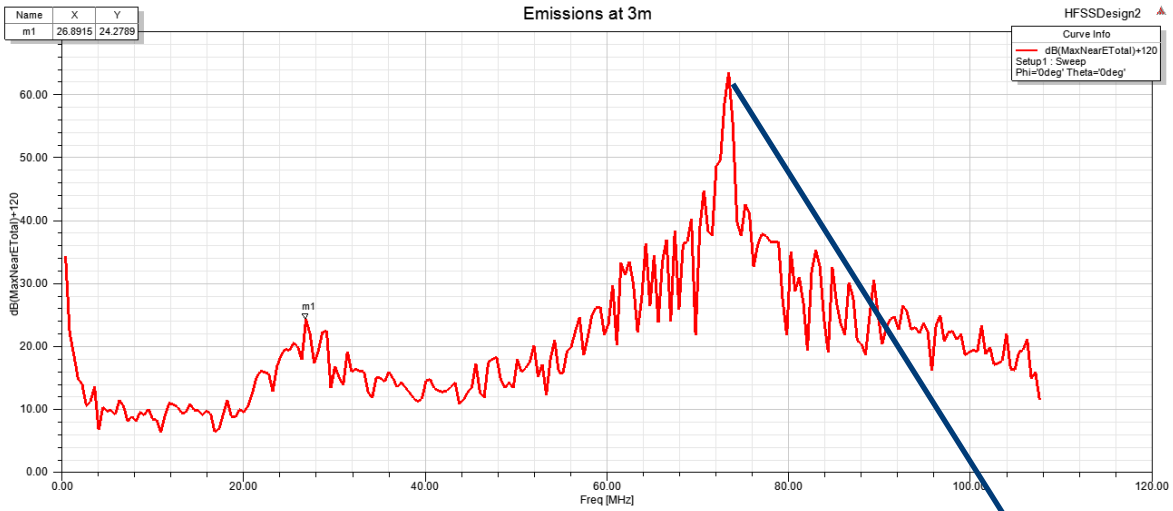


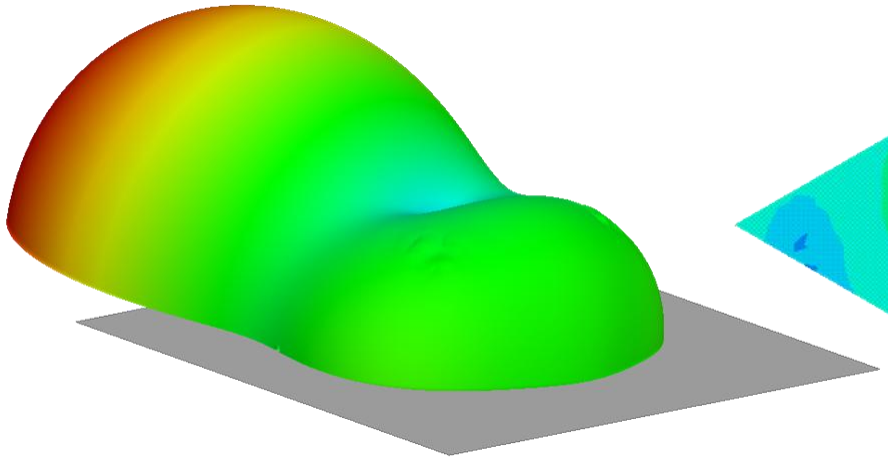
Radiated Emissions

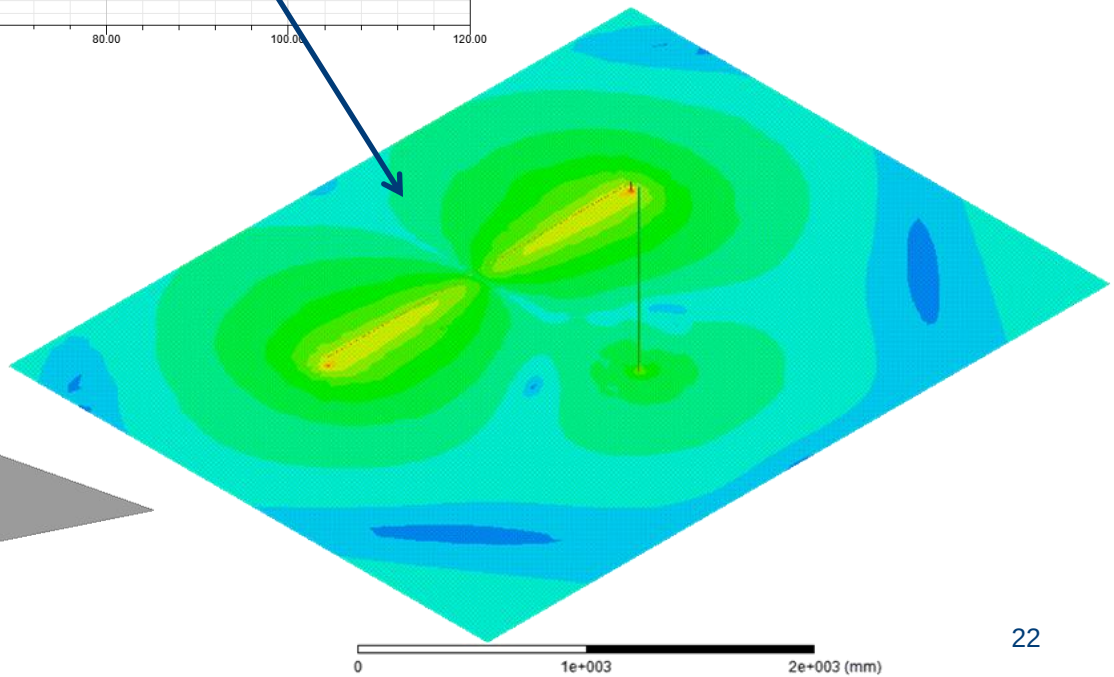
- Wiring Harness acts as Antenna
- Push Excitations from Simplorer to HFSS



Radiated Emissions







Summary:

With appropriate modeling many EMI effects can be captured and even quantified!

CADFEM – Simulation is more than Software

PRODUCTS

Software und IT Solutions

SERVICES

Advice, Support, Engineering

KNOW-HOW

Transfer of knowledge

CADFEM in D, A, CH

- 1985 founded
- 2,300 customers
- 12 locations
- 185 employees (worldwide > 250)

Thank you!