Shielding Behavior of an Y-Splice for an Automotive High Voltage Cabling System

Dipl.-Ing. (FH) Ahmad Hamadeh, LEONI Bordnetz-Systeme GmbH
Dr. Thomas Gneiting, AdMOS GmbH
• Object of simulation experiments
• Wire injection method as one standard for the evaluation of EMC behavior
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• Simulation example
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• Summary
Object of simulation experiments

- Plastic protection
- Full shielding
- Splitter into 2 DC power line pairs
- DC power lines (+,-)
Goal of simulation experiments

The goal of the described simulation experiments was:

• Enable the calculation of characteristic EMC values of the high voltage connecting element and compare them with given limits:
  ▪ Transfer impedance
  ▪ Shielding attenuation

• Visualize the sources of radiation and cooperate with the design team to remove them to ensure a good EMC behavior.

• AdMOS performed all required simulations and analyses for the EMC behavior while LEONI did all measurement in the companies EMC lab.
Wire injection measurement procedure according to DIN EN50289-1-6:2002:

- Injection line needs to be adjusted to $Z_{\text{meas}} = 50\Omega$
- Termination needs to be adjusted to average $Z$ of connector
Wire injection - calculations

Calculations according to DIN EN50289-1-6:2002:

**Shielding attenuation**

\[
a_{\text{meas}} = 10 \cdot \log_{10} \left( \frac{P_{\text{feed}}}{P_{\text{rad,max}}} \right)
\]

**Transfer impedance** \( \mathcal{Z}_T \)

\[
\mathcal{Z}_{\text{TE}n} = \frac{2 \cdot U_{1n}}{L_C \cdot U_{2n}} \cdot \mathcal{Z}_{\text{meas}}
\]
Verification of cable

Measurement of shielding attenuation and transfer impedance at LEONI EMC lab

- 50Ω termination of injection wire
- 20Ω termination of coupled cable wires
- 500mm length

Connection to injection wire

Connection to coupled cable wires

VNA
Verification of Y-Splice

Measurement of shielding attenuation and transfer impedance at LEONI EMC lab

- 50Ω termination of injection wire
- 20Ω termination of coupled cable wires.
- Connection to injection wire
- Connection to coupled cable wires
- 500mm
Design flow and iterations

Existing product:
- Measurement Report
- CST EM Simulation

New product design:
- Initial CAD design
- Design iterations based on CST EM simulations
- EMC test of prototype
- EMC test of series parts

Flowchart:
- Initial CAD design → CST EM simulation → Local modification in CST environment and EM analysis
- Ok ?
  - Yes → CAD design iteration → CST EM simulation
  - No
    - Yes
    - No

- Ok ?
  - Yes
  - No

- Yes
Application to Y-Splice

Line widths adjusted to $Z_{\text{meas}}=50\Omega$

Injection line transmitter with $Z_{\text{meas}}=50\Omega$

Adjusted termination of connector $Z_{\text{Conn}} \approx 20\Omega$

$Z(t)$ of measurement wire
First approach

Large difference between measured and simulated values!

Reason: Influence of cable was not taken into account!
Typically, a shielded cable has a braid and a thin aluminium foil for shielding. These are very irregular structures and difficult to represent in 3D. Furthermore, the full EM wave behavior needs to be kept. Therefore, we used an approach, where the non-ideal behavior of the cable shield is approximated and adjusted to measured values.

Size of quadratic openings was adjusted to match measured data.
Influence of shielded cable

Wave propagation outside the shield between shield and wire

E-Field distribution between shield and wire
Second approach: cable included

Perforated cable included (insulator removed for visibility)
Second approach: cable included

- Simulation was done changing a design parameter which accounts for manufacturing tolerances.
- Transfer impedance and shielding attenuation are drawn versus measurement.
Identify radiation sources

Possible slot due to manufacturing technology

Standard scaling (8320V/m) of E-field does not show any field inside the housing

Scaling needs to be adjusted to 10V/m to identify the field inside the housing
Summary

• The possibility to emulate measurement standards in a simulation environment was discussed to have a reliable prediction of a device behavior.
• It was possible to identify sources of radiation in a design which have a negative influence onto the EMC behavior.
• Single effects could be localized which is nearly impossible to do with measurements only as they always show a summary of all effects.
• The influence of the cable could not be neglected and an approximation was done in MW Studio. It was necessary to calibrate it to existing measurements of the cable only.
• The comparison between 3D simulations and measurements show a reasonable good agreement.