Investigation of the Effectiveness of RF Absorbers for Mitigation of Automotive Radiated Emission by Measurement and Simulation

Dr. Tamara Monti, DASSAULT SYSTEMES, Nottingham, United Kingdom
Waldemar Schulz, DASSAULT SYSTEMES, Darmstadt, Germany
Dr. Abhishek Ramanujan, Analog Devices International, Limerick, Ireland
Patrick DeRoy, Analog Devices, Inc. Wilmington, MA, USA
Cyrous Rostamzadeh, Robert Bosch, LLC, Plymouth, MI, USA
Micajah Worden, Robert Bosch, LLC, Plymouth, MI, USA
Motivation

- Progressive connectivity leads to increase of data rates in and between components while EMC requirements at automotive sector remain strict or even increase like GPS/GLONASS band RE (4 dBµV/m @ 1.575 GHz)
Motivation in more Detail

- Harsh GPS + GLONASS emission requirements on component level lead to a need to look out for additional components to suppress radiation

- RF Absorber materials can improve EMC behavior and be purposeful on the last steps to EMC compliant development of ICs and ECU

- This collaboration investigates near field and far field behavior of a commercial RF absorbers on real automotive component development by simulation and field measurements.
What exactly is an RF absorber?

- Electrically non-conductive silicone rubber sheet
- Elastomer based, “magnetically loaded” material
- Frequency dependent complex permeability (and permittivity)
- Intended to absorb energy in the *near-field*
Field Theory – Electric and Magnetic Fields

• How will the material act on these fields?
Absorption loss depends on material thickness, permeability, electrical conductivity, and the frequency of the incident wave. It is the same for all electromagnetic waves.

Reflection loss depends on the distance of the EMI source to the material (different for electric, magnetic, and plane waves), material electrical conductivity, and the frequency of the incident wave.

Absorption loss and reflection loss
Field Theory – Multi Layer Printed Circuit Board

- Effects, which can be suppressed by absorber pads
Field Theory – Multi Layer Printed Circuit Board

- Effects, which can be suppressed by absorber pads
Field Theory – Multi Layer Printed Circuit Board

- Effects, which can be suppressed by absorber pads
Approaches

- Wide range of industry procedures to verify absorber effectiveness at GPS-Band
  - 3D EM Simulation
  - Radiation source
    - Dipole and Loop Antenna
  - Antenna Distance
    - 5, 15, 25, 1e3 mm
    - 1 mm to absorber
  - Near field IC measurement
    - Radiation source
      - Stripline
    - Antenna distance
      - 6.7 mm
  - Far field RE measurement
    - Radiation source
      - Horn-, Loop-, Rod-Antenna
    - Antenna distance
      - 1 m
IC Stripline Emission Measurement

- IC-EMC PCB as per IEC 61967-1
- Stripline measurement as per IEC 61967-8

- TEM or GTEM cells could also be used
  → Stripline is more sensitive
IC Stripline Emission Measurement

• IC-EMC PCB as per IEC 61967-1
• Stripline measurement as per IEC 61967-8

• TEM or GTEM cells could also be used → Stripline is more sensitive
Emission Result – 0 Degree Orientation
Approach – Far Field Measurement

- Reproduce Emission Setup
  - Vary transmitter to radiate
    - electric (rod antenna)
    - magnetic (loop antenna)
    - OEM compliant (ETS 3115 horn antenna)

Measure with and without absorber gap pad

Derive attenuation by subtraction
Approach – Far Field Measurement

- Reproduce Radiated Emission Setup + Real ECU measurement
  - Unshielded Loop Antenna
- Wrap transmitter with absorber

**ATTENUATION AT GPS BAND (1.575 GHZ)**

<table>
<thead>
<tr>
<th>Antenna Type</th>
<th>Attenuation [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop Antenna</td>
<td>6</td>
</tr>
<tr>
<td>Rod Antenna</td>
<td>10</td>
</tr>
<tr>
<td>Horn Antenna</td>
<td>8, 6</td>
</tr>
</tbody>
</table>

Vertical: 8, 6
Horizontal: 6
Simulation analysis of absorber, effect of source type

- Dipole (electric) and loop (magnetic) sources, close to absorber material (1mm separation distance)
- Absorber modelled as thin panel, with 0.2 mm thickness defined, with complex frequency dependent $\epsilon$, $\mu$
- Study field behaviour, E- and H- Field probes located 5, 15, 25 mm beyond absorber pad, and in Farfield (1m)

[Diagrams showing Dipole, Parallel Loop, Perpendicular Loop]
Simulation analysis of absorber, effect of source type

- Frequency dependent, complex permeability and permittivity data loaded into thin sheet material
- Material properties are approximate (only known to certain extent)

Modeling approach adopted from following reference material:

*IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY, VOL. 59, NO. 2, APRIL 2017*

**Near-Field Shielding Performances of EMI Noise Suppression Absorbers**

Stefano Piersanti, Student Member, IEEE, Francesco de Paulis, Member, IEEE, Antonio Orlando, Fellow, IEEE,
Sam Ceron, Senior Member, IEEE, Qian Liu, Member, IEEE, Bruce Archambault, Fellow, IEEE,
Phil Trione, Member, IEEE, Mohammad Khosravi, Member, IEEE, and James L. Demers, Fellow, IEEE.

Permeability curves

Permittivity curves
Simulation analysis of absorber, effect of source type

- Field plots provide insight into the nature of the noise source and its role in the absorber effectiveness.
Simulation analysis of absorber, effect of source type

• Electric Field (dB V/m) at 1.575 GHz – dipole source, no absorber and with absorber

*Values below -130 dB
hidden from view
Simulation analysis of absorber, effect of source type

- Electric Field (dB V/m) at 1.575 GHz – dipole source, no absorber and with absorber

*Values below -130 dB hidden from view
Simulation analysis of absorber, effect of source type

- Magnetic Field (dB A/m) at 1.575 GHz – dipole source, no absorber and with absorber

*Values below -100 dB hidden from view
Simulation analysis of absorber, effect of source type

- Magnetic Field (dB A/m) at 1.575 GHz – dipole source, no absorber and with absorber

*Values below -100 dB hidden from view
Simulation analysis of absorber, effect of source type

- SE derived from field probe measurements, with and without absorber material present
- All values assessed at 1.575 GHz

<table>
<thead>
<tr>
<th>Dipole Source</th>
<th>E (dB V/m) 5mm</th>
<th>E (dB V/m) 15mm</th>
<th>E (dB V/m) 25mm</th>
<th>E (dB V/m) 1 meter Farfield</th>
<th>H (dB A/m) 5mm</th>
<th>H (dB A/m) 15mm</th>
<th>H (dB A/m) 25mm</th>
<th>H (dB A/m) 1 meter Farfield</th>
</tr>
</thead>
<tbody>
<tr>
<td>No absorber</td>
<td>25.1</td>
<td>5.08</td>
<td>-7.4</td>
<td>-42.89</td>
<td>-38.05</td>
<td>-51.78</td>
<td>-59.5</td>
<td>-94.4</td>
</tr>
<tr>
<td>With absorber</td>
<td>-2.7</td>
<td>-12.8</td>
<td>-18.7</td>
<td>-46.99</td>
<td>-45.63</td>
<td>-58.5</td>
<td>-66.79</td>
<td>-98.5</td>
</tr>
<tr>
<td>SE (dB)</td>
<td>27.8</td>
<td>17.88</td>
<td>11.3</td>
<td>4.1</td>
<td>7.58</td>
<td>6.72</td>
<td>7.29</td>
<td>4.1</td>
</tr>
</tbody>
</table>
Simulation analysis of absorber, effect of source type

- Electric Field (dB V/m) at 1.575 GHz – loop source (parallel), no absorber and with absorber

*Values below -120 dB hidden from view
Simulation analysis of absorber, effect of source type

- Electric Field (dB V/m) at 1.575 GHz – loop source (parallel), no absorber and with absorber

*Values below -120 dB hidden from view
Simulation analysis of absorber, effect of source type

- Magnetic Field (dB A/m) at 1.575 GHz – loop source (parallel), no absorber and with absorber
Simulation analysis of absorber, effect of source type

- Magnetic Field (dB A/m) at 1.575 GHz – loop source (parallel), no absorber and with absorber
Simulation analysis of absorber, effect of source type

- Electric Field (dB V/m) at 1.575 GHz – loop source (perpendicular), no absorber and with absorber

*Values below -110 dB hidden from view
Simulation analysis of absorber, effect of source type

- Electric Field (dB V/m) at 1.575 GHz – loop source (perpendicular), no absorber and with absorber

*Values below -110 dB hidden from view
Simulation analysis of absorber, effect of source type

- Magnetic Field (dB A/m) at 1.575 GHz – loop source (perpendicular), no absorber and with absorber
Simulation analysis of absorber, effect of source type

- Magnetic Field (dB A/m) at 1.575 GHz – loop source (perpendicular), no absorber and with absorber
Simulation analysis of absorber, effect of source type

- SE derived from field probe measurements, with and without absorber material present
- All values assessed at 1.575 GHz

<table>
<thead>
<tr>
<th>Loop Source</th>
<th>E (dB V/m) 5mm</th>
<th>E (dB V/m) 15mm</th>
<th>E (dB V/m) 25mm</th>
<th>H (dB A/m) 5mm</th>
<th>H (dB A/m) 15mm</th>
<th>H (dB A/m) 25mm</th>
<th>H (dB A/m) 1m Farfield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No absorber</td>
<td>27.09</td>
<td>0.99</td>
<td>-10.24</td>
<td>-44.57</td>
<td>0.19</td>
<td>-24.9</td>
<td>-36.5</td>
</tr>
<tr>
<td>With absorber</td>
<td>0.22</td>
<td>-13.13</td>
<td>-19.73</td>
<td>-47.59</td>
<td>-4.34</td>
<td>-26.26</td>
<td>-38.36</td>
</tr>
<tr>
<td>SE (dB)</td>
<td>26.87</td>
<td>14.12</td>
<td>9.49</td>
<td>3.02</td>
<td>4.53</td>
<td>1.36</td>
<td>1.86</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loop Source</th>
<th>E (dB V/m) 5mm</th>
<th>E (dB V/m) 15mm</th>
<th>E (dB V/m) 25mm</th>
<th>H (dB A/m) 5mm</th>
<th>H (dB A/m) 15mm</th>
<th>H (dB A/m) 25mm</th>
<th>H (dB A/m) 1m Farfield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpendicular</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No absorber</td>
<td>32.36</td>
<td>15.77</td>
<td>7.58</td>
<td>-27.05</td>
<td>-10.63</td>
<td>-35.65</td>
<td>-47.15</td>
</tr>
<tr>
<td>With absorber</td>
<td>20.78</td>
<td>6.33</td>
<td>-1.81</td>
<td>-29.22</td>
<td>-14.04</td>
<td>-35.09</td>
<td>-47.23</td>
</tr>
<tr>
<td>SE (dB)</td>
<td>11.58</td>
<td>9.44</td>
<td>9.39</td>
<td>2.17</td>
<td>3.41</td>
<td>-0.56 (?)</td>
<td>0.08</td>
</tr>
</tbody>
</table>
Simulation analysis observations and conclusions

- Wave impedance vs. Absorber’s characteristic impedance – main factor for reflection loss
- Using modelled permittivity and permeability values, the absorber impedance can be calculated:

\[ Z_0 = \sqrt{\frac{\mu}{\varepsilon}}. \]
Simulation analysis observations and conclusions

• Absorber is non-conductive, meaning high frequency or high permeability values are needed for it to have high absorption loss

• Reflection loss will be very low if the source wave impedance closely matches the absorber’s characteristic impedance

• E-field is highly attenuated in the nearfield in all cases, H-field slightly attenuated

• H-field is largely unaffected in the case of the loop sources, E-field slightly attenuated

• Never much SE in farfield (values range between 0.22 to 4.1 dB depending on field and source type)

• Dipole source E- and H- values equate to high wave impedance (> 377 Ω) in nearfield and converge to ~377 Ω in farfield

• Loop sources E- and H- values equate to low wave impedance (< 377 Ω) in nearfield and converge to ~377 Ω in farfield
Conclusion and Outlook

• Near field measurement (Stripline)
  • No significant improvement in measurement at 90 degree orientation of the IC w.r.t to the Stripline
  • Some improvement (in the order of 3 to 6 dB) is obtained at 0 degree orientation of the IC
  • To be correlated to simulations comparing nature of source (electric dipole or a magnetic loop) to see effectiveness of the material

• Far field (RE)
  • Similar attenuation at vertical and horizontal orientation (approximately 7 dB)
  • Sources are never truly one or the other (electric or magnetic) in practice, this is also the case within the simulations
    • Would need idealized infinitesimally small sources
  • Simulation results do make sense for what was modelled, with some peculiarities – accurate material model is critical for further investigation
Conclusion and Outlook

• Correlation to real ECU measurement to be performed in the future
• Understand impact of source wave impedance and achievable attenuation
• Investigate the location (separation distance) of the source with respect to the absorber (affects wave impedance at the interface of the absorber, thus influences reflection loss) – this was not studied in detail
References


