A Review of Automotive EMC Environment & Tests

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Outline

• Motivation
• Automotive Environment
• Overview of Automotive EMC Tests
• A Few Selected EMC Tests
• Summary
Motivation

In order to enable understanding of the automotive environment, this slideset is a review of former IEEE slidesets for Automotive requirements with focus on EMC requirements and relevant tests:

- Demonstrate exemplary cases of cable harnesses as they had been before Ethernet (Eg: CAN, FlexRay)
- Demonstrate how EMC is ensured in automotive environment.
- Demonstrate how EMC measurements are done on component/chip level and what the typical requirements for those measurements are.
Industrial/CE:
You have to cope with complex Switching Banks, etc. However you can use “RF-optimized” connectors

Automotive:
The amount of connectors is much less, however space requirements and (of course) cost are much tighter.
Cable Harness: Mercedes-Benz S-Class (2006)

- Complete Cable Harness
- It weighs about 38kg
Cable Harness: DUT/measurement setup

• 2x0,35mm² 100 ohm jacketed cable in harness (ca. 3600mm) with inline connector. (FlexRay)
Connector Examples (CAN star coupler)

- CAN Cables: 70mm of untwisted cable

7 cm
Connector Examples (cont.)
S-Parameter with In-line-connector

Port 1

In-Line-Stecker

Port 2

ca. 5.60m

ca. 2.10m
Cable Harness: DUT/measurement setup

Test adapter
(as these were older measurements the test adapter is maybe not perfect...)
- Direct connection to GND plane.
- SMA heads soldered to Pins which are plugged into harness header.
- Complete harness on GND plane.
- No special treating of harness and assemblies to achieve high symmetry
TDR results $Z_{cm}$ and $Z_{diff}$

- As harness is placed 50mm above GND plane $Z_{CM}$ is nearly constant
S-Parameter with In-line-connector

![Graphs showing S-parameters with in-line connectors.](image-url)
Overview of Automotive EMC Tests

• There are three stages of EMC testing and requirements
  o IC level testing (bench test without connectors & cables)
  o Component level testing (bench testing with connectors & cables)
  o In-vehicle testing

• The following standards cover the most common EMC test setups and limits:
  o IEC62123-4 (Direct Power Injection)
  o IEC61967-4 (150 Ohm Emissions)
  o ISO 11452-4 (Bulk Current Injection)
  o ISO 11452-2 (Radiated Immunity)
  o CISPR 25 (Radiated emissions)
  o ISO 7637-3 (Coupling of transients by capacitive clamp)
  o ISO 10605 (ESD testing and it mainly involves connectors)

• Exact test-setup and test limit values are adapted by each OEM for each DUT/System
Ensuring EMC for Automotive Bus Systems

Derivation of test procedures and correct disturbance levels as well as corresponding requirements and limits

Special test methods at component (IC) level
- Independent of special car type / ECU
- High dynamic and reproducibility
- Separation of different impacts possible

→ Common evaluation

Investigation and Optimization of each part of the physical layer (cable, connector, Choke, filters, ...) possible
Ensuring EMC for Automotive Bus Systems

**e.g. CISPR12/CISPR25/ISO 11451**
- radiated immunity
- radiated emission
- ESD

**e.g. CISPR25/ISO 11452**
- radiated immunity
- radiated emission
- conducted immunity
- conducted emission
- Transients/ESD

- immunity against direct injected power (DPI)
- Direct conducted emission (150 ohms method)
- ESD

**Special test methods at component (IC) level**
Independent of special car type / ECU
High dynamic and reproducibility
Separation of different impacts possible

→ **Common evaluation**

**Investigation and Optimization of each part of the physical layer (cable, connector, Choke, filters, ...) possible**
Ensuring EMC for Automotive Bus Systems

• to ensure EMC on component-/chip-level all parts of the communication system have to fulfill dedicated requirements:
  – Physical layer chip (PHY)
  – Bus interface network (BIN, this includes filters, chokes, etc)
  – Connector (CON)
  – Cable (including inline connectors)
  – Power supply (coupling to PHY path)
  – Higher layer interfaces (coupling to PHY path)

**Special test methods at component (IC) level**
- Independent of special car type / ECU
- High dynamic and reproducibility
- Separation of different impacts possible

→ Common evaluation

**EMC requirements**

component level / chip level

Optimization

Verification

Investigation and Optimization of each part of the physical layer (cable, connector, Choke, filters, ...) possible
Example – Conducted Measurements

- Transient
  - Direct Capacitive Coupling
  - Damage Malfunction

- RF
  - Direct Power Injection
  - Damage Malfunction

- ESD
  - HMB acc. to DIN EN 61000-4-2
  - Damage

- Modes
  - Normal
  - Low power

- Frequency domain
  - bus lines
  - supply
  - other pins

- Emission
- Immunity
- Transceiver
- Embedded Systems (ASIC)
- Stand alone
- Pins
  - Bus
  - Supply
  - Other

Measurements
Evaluation by limits

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Example – Conducted Measurements

- **μC**: Automotive microcontroller with MII interface
- **TC**: Ethernet transceiver (device under test – DUT)
- **BIN**: Bus interface network (including choke/transformer, termination, additional filter elements, ESD protection)
- **CN**: EMC coupling network

\[ V_{DDx} \]

Proper function / error indication

Supplies / others

MII interface

Proper function / error indication

Supplies / others

Proper function / error indication

Node 1

Node 2

Other global pins

Bus

9/10/2014

IEEE 802.3bw Task Force
Example – Conducted Measurements

Host µC board  MII interface  RF test board

Node 1

Coupling networks ETN

Coupling networks voltage supply

Node 2
Example – Conducted Measurements

Measuring network ETN

RF Analyzer

Test board

EMI

RF Analyzer

Test board

120 pin Vx

Rx

Ri

50

Rm1

51

6.8 nF

C

Cx

4.7 µH

L

pin Vx

Measuring network
Voltage supply

9/10/2014

IEEE 802.3bw Task Force
Example – Conducted Measurements

Asymmetry variation of resistors $R_{1x}/R_{2x}$ is ±2.5% (limits to be fulfilled).

Typically/often additional measurements with ±5% are done for information purposes.

<table>
<thead>
<tr>
<th>Symmetry</th>
<th>$R_{1x} , [\Omega]$ (Bus +)</th>
<th>$R_{2x} , [\Omega]$ (Bus -)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 2.5 % unbalance</td>
<td>121</td>
<td>118</td>
</tr>
<tr>
<td>- 2.5 % unbalance</td>
<td>118</td>
<td>121</td>
</tr>
<tr>
<td>+ 5 % unbalance</td>
<td>121</td>
<td>115</td>
</tr>
<tr>
<td>- 5 % unbalance</td>
<td>115</td>
<td>121</td>
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**Table: Settings of the measurement device**

- **Detector**
- **Spectrum analyzer**
  - Frequency range: 0.15 to 2750 MHz
  - Resolution bandwidth (RBW):
    - 150 kHz to 30 MHz: 10 kHz
    - 30 MHz to 2750 MHz: 100 kHz
  - Video bandwidth (VBW): equal to RBW
  - Numbers of passes: 10 (max hold)
  - Measurement time per step: ≥ 1 ms
  - Frequency sweep time: ≥ 20 s
  - Frequency step width:
    - 150 kHz to 30 MHz: -
    - 30 MHz to 2750 MHz: 9 kHz

- **Measuring receiver**
  - Peak: 9 kHz
  - 120 kHz

Example – Conducted Measurements

Example for test results - 150 Ohm emission method

- Increased emission caused by unbalance
  - simulates possible asymmetry of connectors and cables

Impact of asymmetry clearly visible

From: “Methodologies for EMC optimization of Automotive Ethernet Systems” by Dr. Bernd Körber, 1st Ethernet & IP @ Automotive Techday
Example – Conducted Measurements

Line Immunity coupling network

- Input power is 39dBm for setup with BIN (1MHz-1GHz) CW and AM 80% 1kHz with peak conservation ($P_{\text{max,AM}} = P_{\text{max,CW}}$)
- Asymmetry variation of resistors $R_{1x}/R_{2x}$ is ±2.5% (limits to be fulfilled). Typically additional measurements with ±5% are done for information purposes.

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Exemplary positive DPI Immunity test result

Example – Conducted Measurements

Example for test results – DPI (direct power injection/RF immunity)

→ Impact of unbalanced measurements clearly visible.

→ Correlation of unbalanced measurements and unsymmetrical components (inline connectors).

Verification at ECU test level
BCI-Test
(bulk current injection)
106dBµA = 200mA

From: “Methodologies for EMC optimization of Automotive Ethernet Systems” by Dr. Bernd Körber, 1st Ethernet & IP @ Automotive Techday
Example – Conducted Measurements

- According to ISO7637-3
- Test pulses from ISO7637-2
- Direct capacitive coupling method (DCC) using 2 x 100pF (2 x 470pF) to the bus lines.
- Pulse generator typically with $R_i$ (which can slightly vary to match the pulse parameters).

<table>
<thead>
<tr>
<th>Test pulse</th>
<th>$V_{peak}$ (V)</th>
<th>Pulse repetition (Hz)</th>
<th>$R_i$ (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-100</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>2a</td>
<td>75</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3a</td>
<td>-150</td>
<td>10k</td>
<td>50</td>
</tr>
<tr>
<td>3b</td>
<td>100</td>
<td>10k</td>
<td>50</td>
</tr>
</tbody>
</table>

- The measurement of immunity against transient pulses shall be tested using the capacitive coupling clamp according to ISO 7637-3: 2007-07 (CCC method) and using the current probe (BCI) according to ISO 7637-3: 2007-07 (ICC method).

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<th>$V_{peak}$ (V)</th>
<th>Pulse repetition (Hz)</th>
<th>$R_i$ (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast a (CCC)</td>
<td>-75</td>
<td>10k</td>
<td>50</td>
</tr>
<tr>
<td>Fast b (CCC)</td>
<td>60</td>
<td>10k</td>
<td>50</td>
</tr>
<tr>
<td>Slow + (ICC)</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Slow – (ICC)</td>
<td>-6</td>
<td>2</td>
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BCI Immunity Test (derived from ISO 11452-4)
BCI Test Setup Photo
BCI Test Limit Lines (3 examples)

- Bulk injection by means of a current clamp onto a 1m/2m UTP length harness of the DUT
  - Test Frequency: 1 MHz – 400 MHz
  - Test Levels: Up to 200 mA
Stripline Emissions Test Setup

Both DUT and DUT may be in the stripline.

2m UTP Cable

LP

DUT
Radiated Emissions Test Setup (CISPR 25)
Radiated Emissions Test Setup (CISPR 25)

Monopole antenna, 150 kHz – 30 MHz

Biconical antenna, 30 MHz – 200 MHz

Log periodic antenna, 200 MHz – 1 GHz

Horn antenna, 1 GHz – 2.5 GHz
Radiated Emissions Limit Lines (CISPR 25)
Summary

• This presentation gives a brief overview of Automotive EMC environment and existing relevant tests
• The shown pictures are a few examples of many different automotive cable harness options
• The shown s-Parameter measurements are also a few examples (and by way not the “worst case“) of how an automotive channel could look like.
• Automotive channels have a wide variety and the channel model needs to include these parameter variations
• The test methods are standardized but the limit lines can vary among different OEMS with somewhat similar values
Appendix:

For informational purposes, please also review the following 1000BASE-T1 documents from the study group phase:

•  http://grouper.ieee.org/groups/802/3/RTPGE/public/may12/buntz_01_0512.pdf
•  http://grouper.ieee.org/groups/802/3/RTPGE/public/may12/hogenmuller_01_0512.pdf
•  http://grouper.ieee.org/groups/802/3/RTPGE/public/july12/hogenmuller_01a_0712.pdf
•  http://grouper.ieee.org/groups/802/3/RTPGE/public/july12/hogenmuller_02a_0712.pdf
•  http://grouper.ieee.org/groups/802/3/RTPGE/public/sept12/jones_01_0912.pdf
•  http://grouper.ieee.org/groups/802/3/RTPGE/public/nov12/buntz_01_1112_rtpge.pdf
•  http://grouper.ieee.org/groups/802/3/RTPGE/public/nov12/pischl_01_1112_rtpge.pdf

Also following further information could be helpful:

•  http://www.fordemc.com/
•  http://www.ieee802.org/3/bp/public/jan13/tazebay_3bp_01a_0113.pdf
•  http://www.ieee802.org/3/bp/public/may13/tazebay_3bp_01_0513.pdf
•  http://www.ieee802.org/3/bp/public/nov13/Chini_Tazebay_3bp_02a_1113.pdf
•  http://www.ieee802.org/3/bp/public/mar14/EMCnoise_ad_hoc_3bp_01_0314.pdf