A Review of Automotive EMC Environment & Tests

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Outline

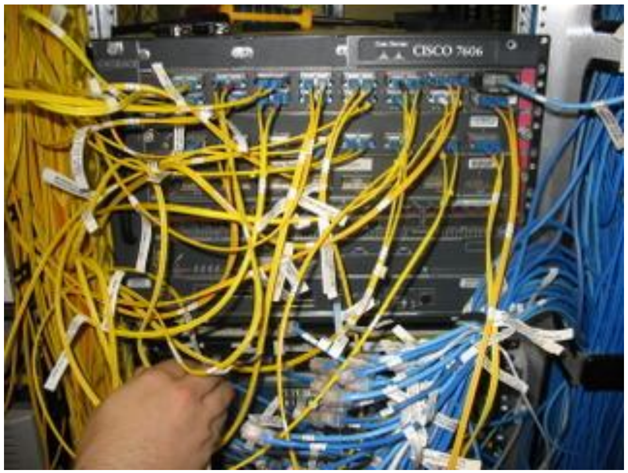
- Motivation
- Automotive Environment
- Overview of Automotive EMC Tests
- A Few Selected EMC Tests
- Summary

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.

Automotive Environment

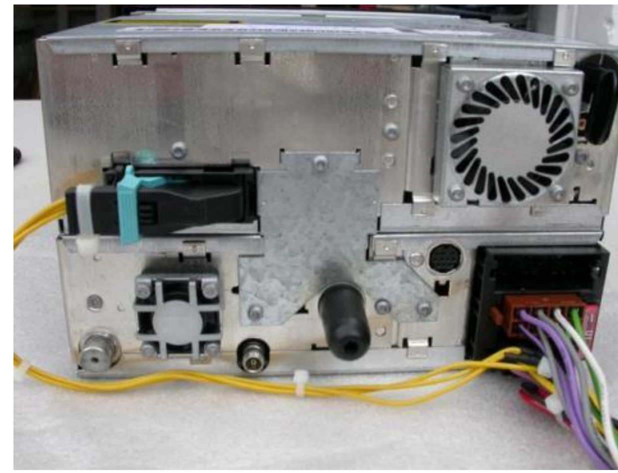


- **Industrial/CE:**

You have to cope with complex Switching Banks, etc. However you can use “RF-optimized” connectors

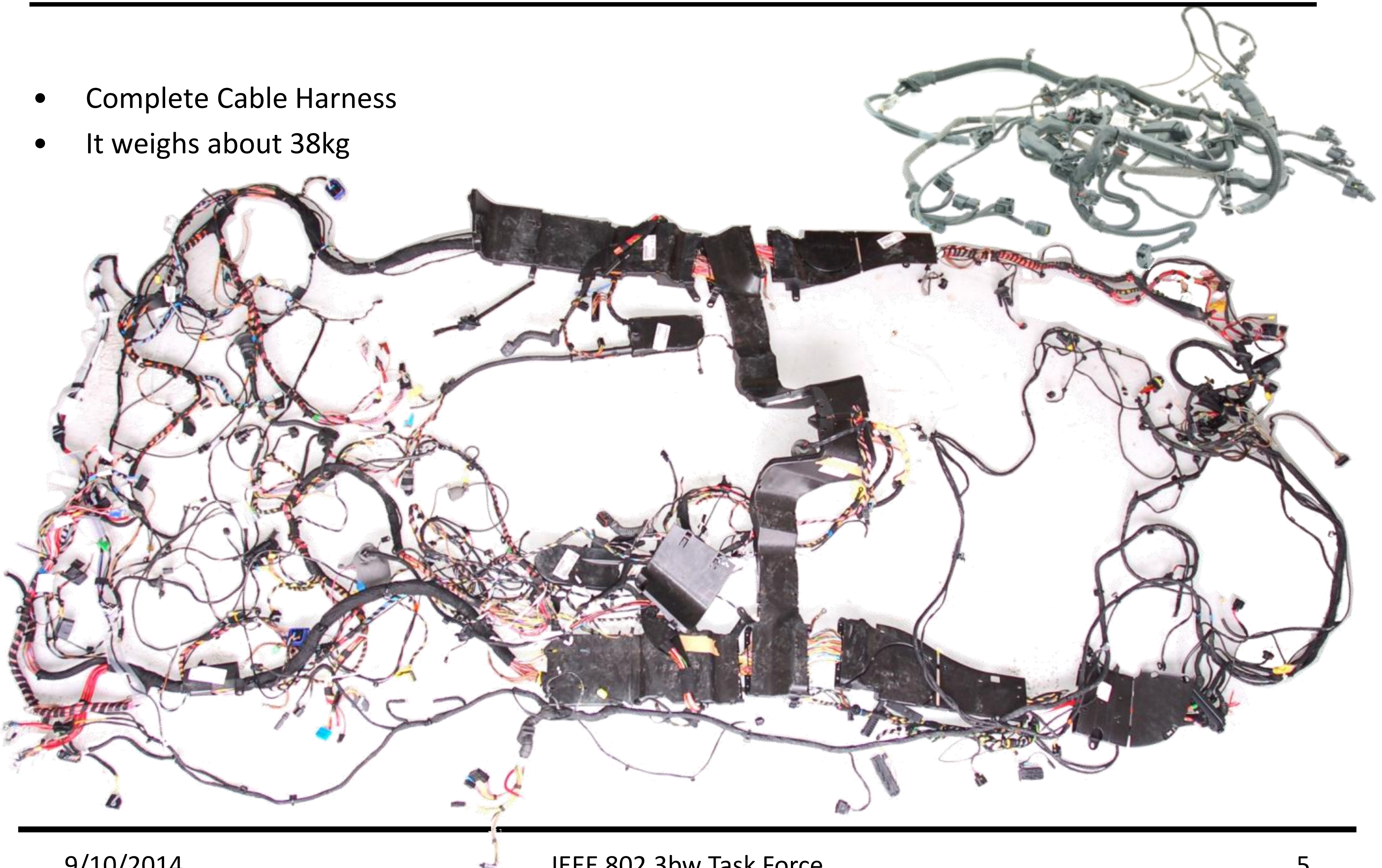
- **Automotive:**

The amount of connectors is much less, however space requirements and (of course) cost are much tighter.



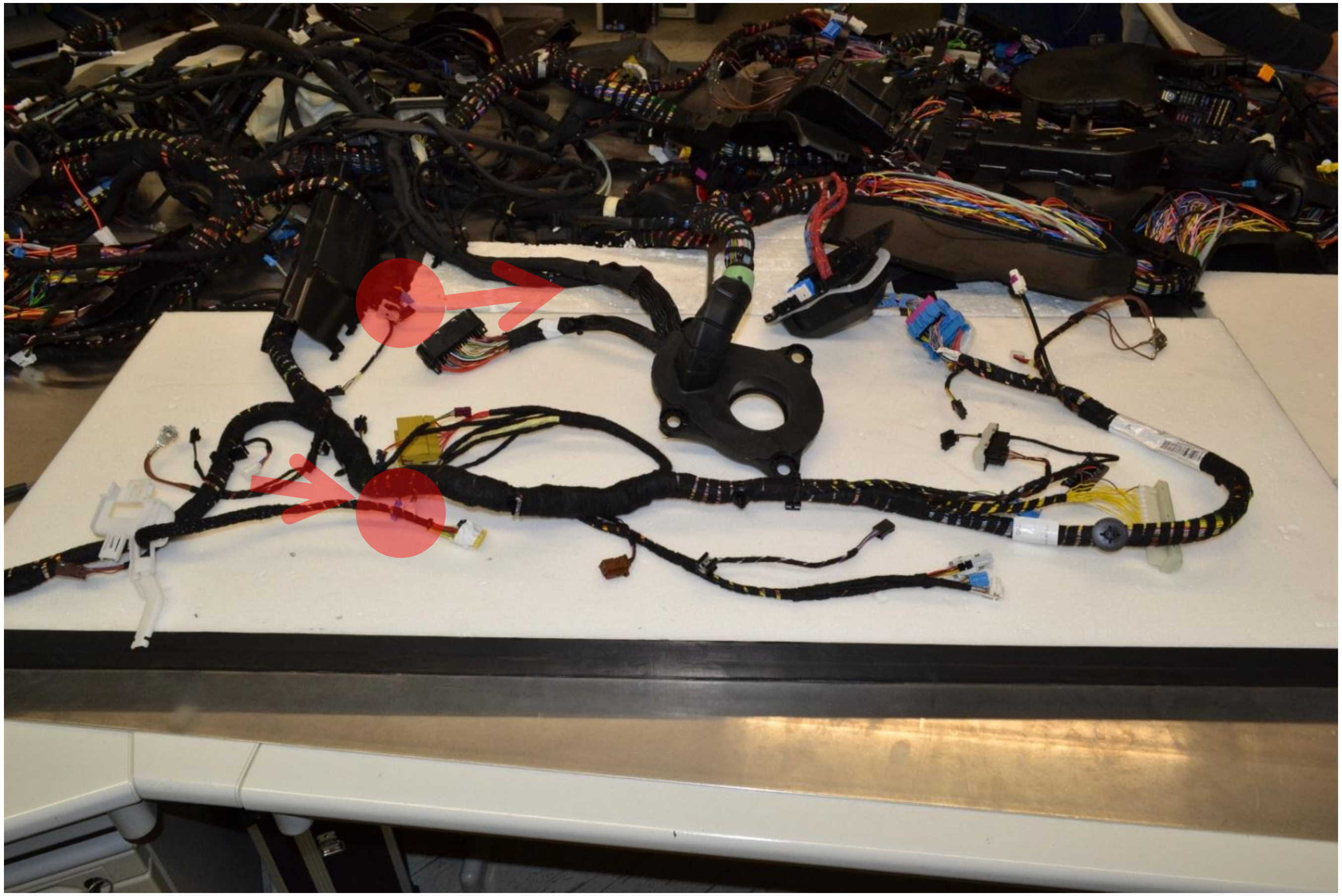
Cable Harness: Mercedes-Benz S-Class(2006)

- Complete Cable Harness
- It weighs about 38kg

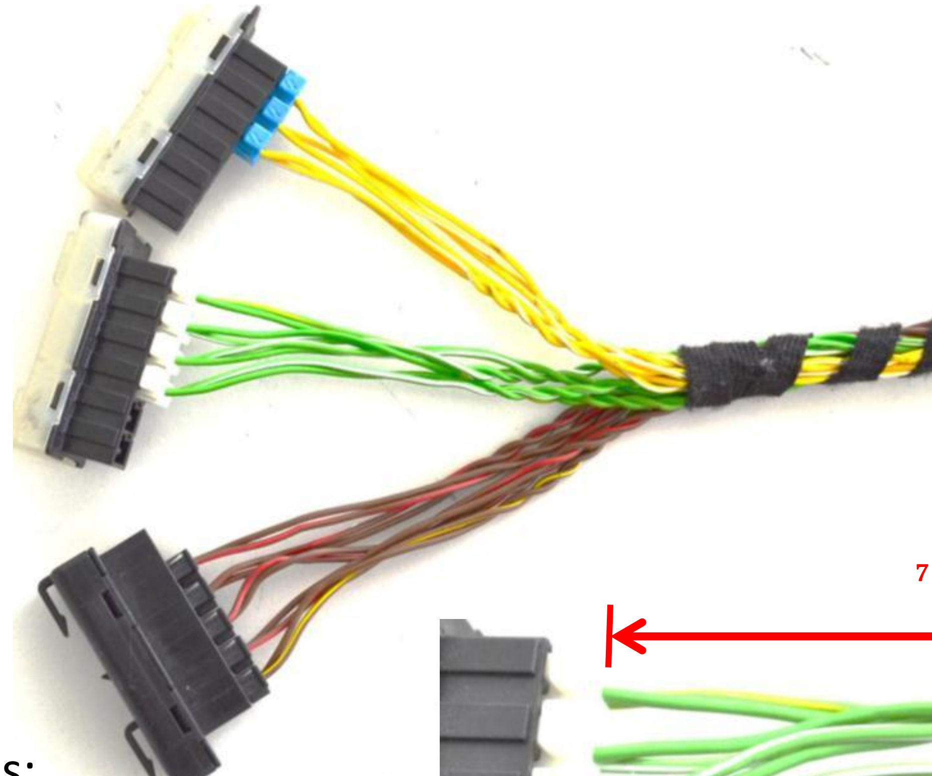


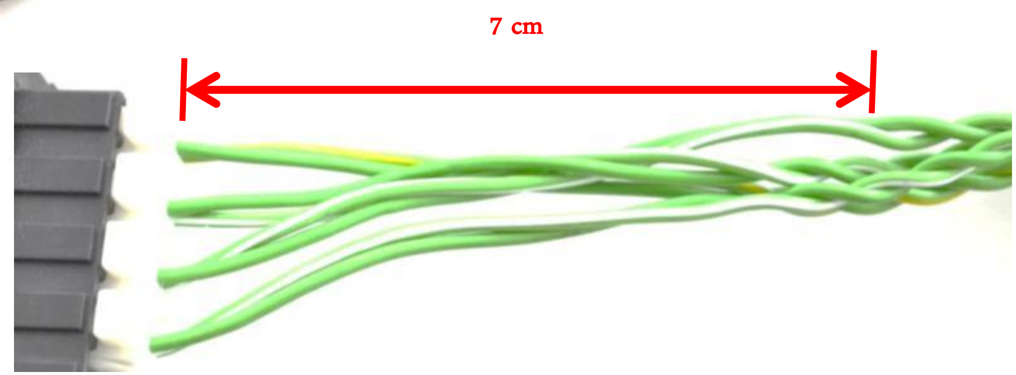
Cable Harness: DUT/measurement setup

- 2x0,35mm² 100 ohm jacketed cable in harness (ca. 3600mm) with inline connector.
  (FlexRay)



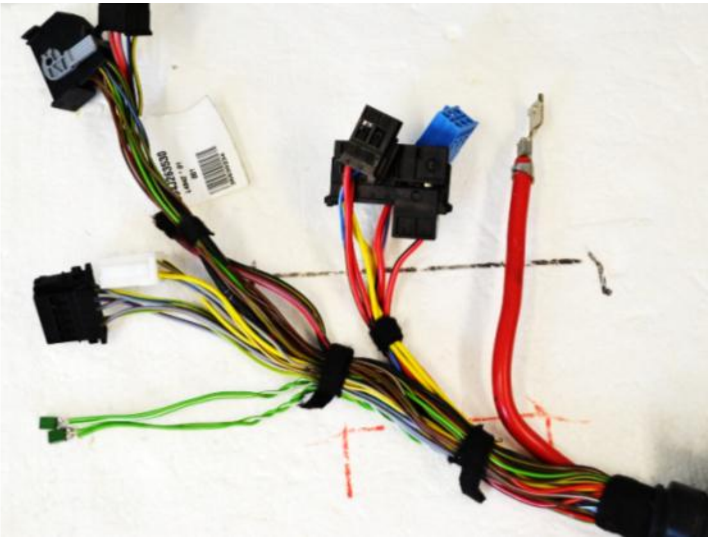
Connector Examples (CAN star coupler)

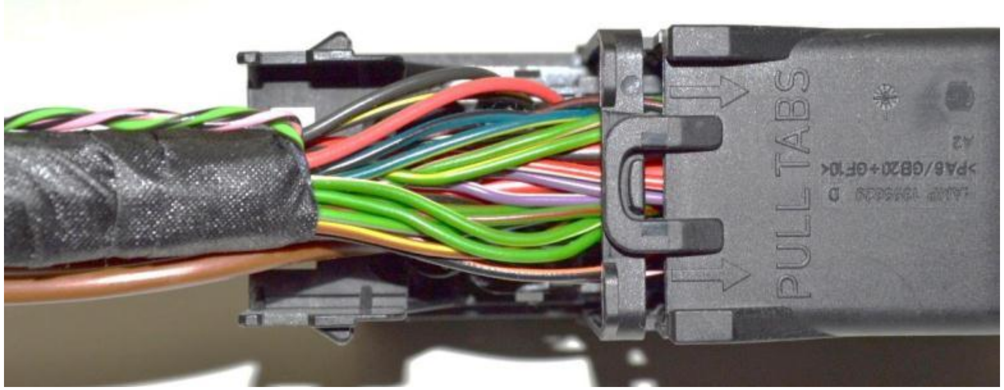


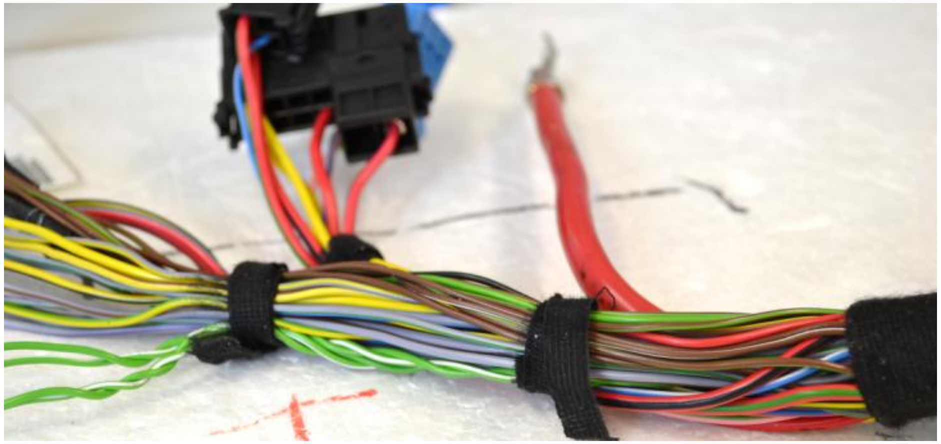


- CAN Cables:
  70mm of untwisted cable

Connector Examples (cont.)







S-Parameter with In-line-connector

Port 1

ca. 5.60m

In-Line-Stecker

ca. 2.10m

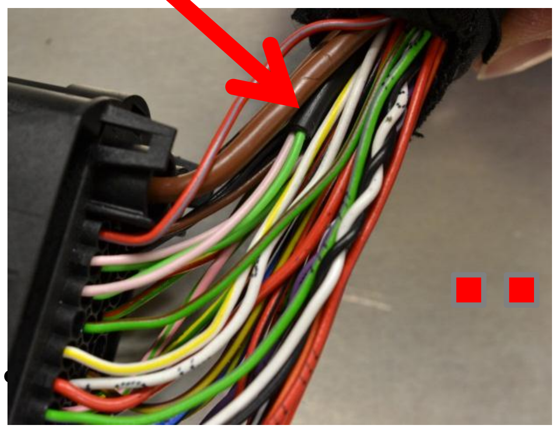
Port 2

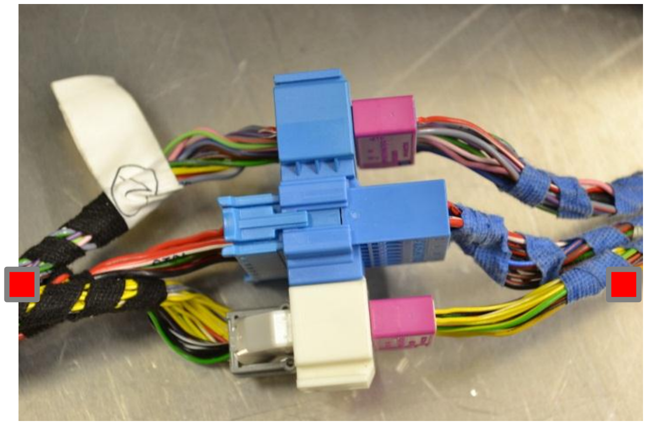
Cable Harness: DUT/measurement setup

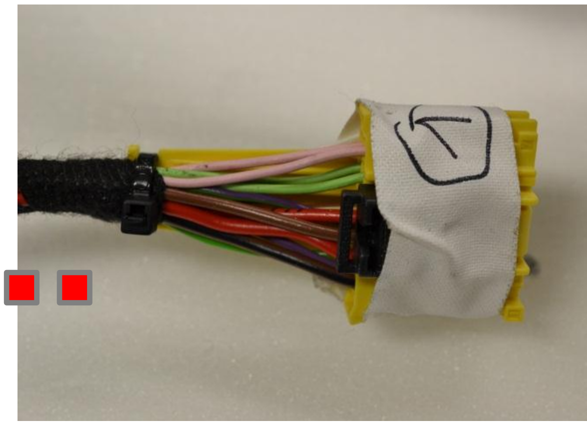
Connector1/Jacketed Cable

inline

Connector2





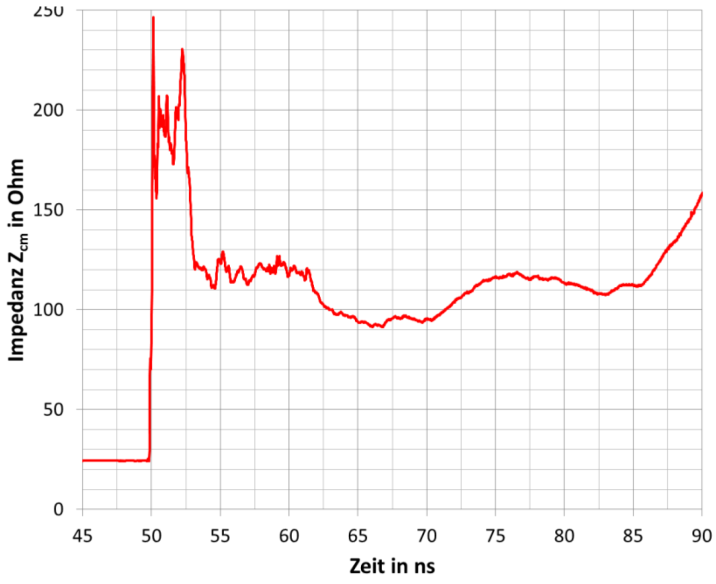


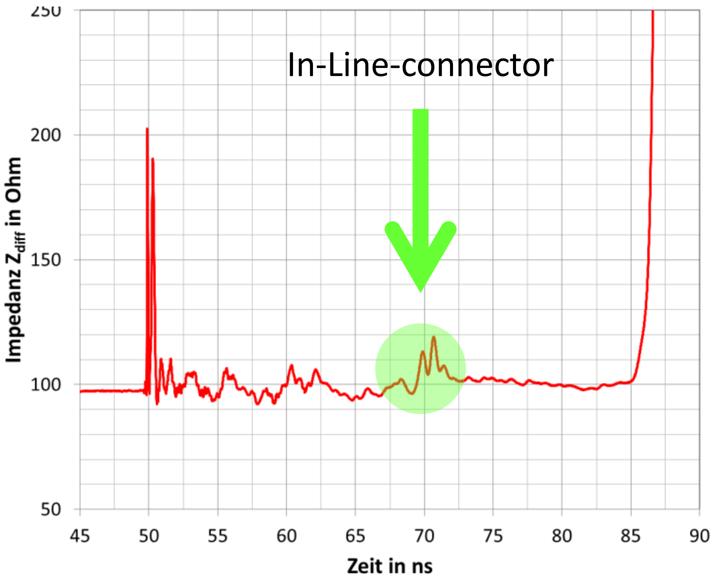
Test adapter
(as these were older measurements the test adapter is maybe not perfect…)

- 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

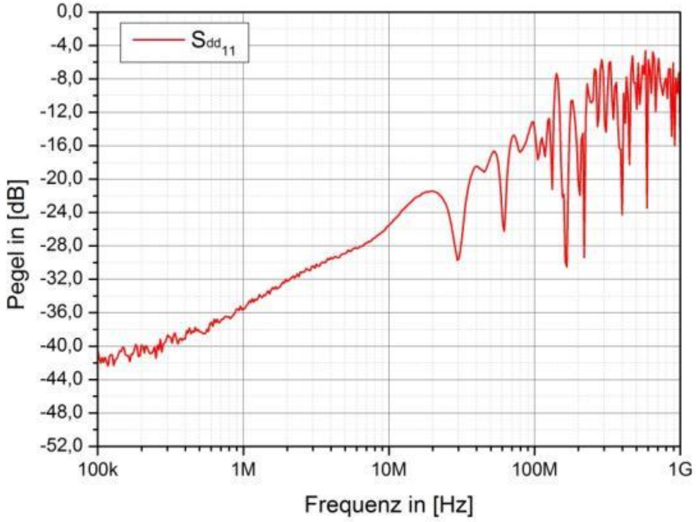
TDR results Z_{cm} and Z_{diff}

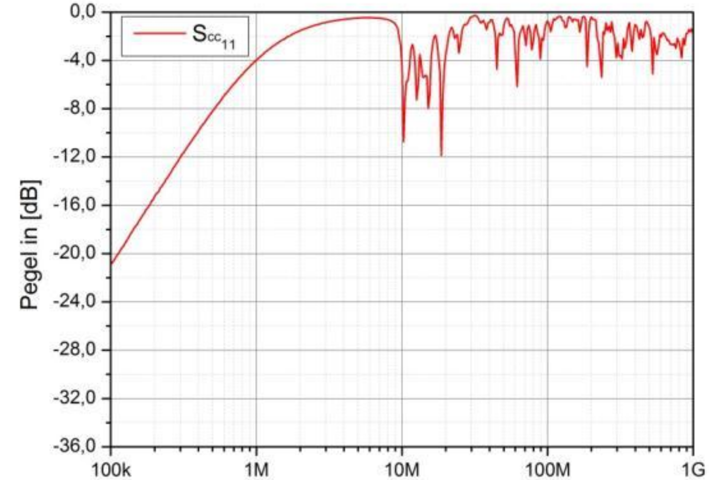
- As harness is placed 50mm above GND plane Z_{CM} is nearly constant

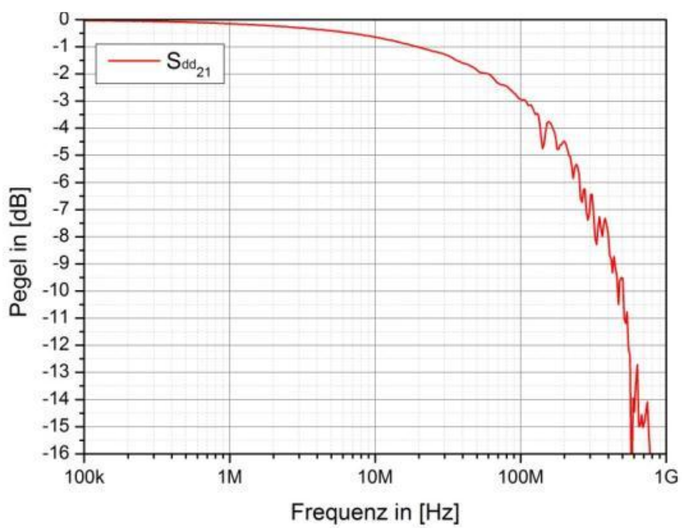


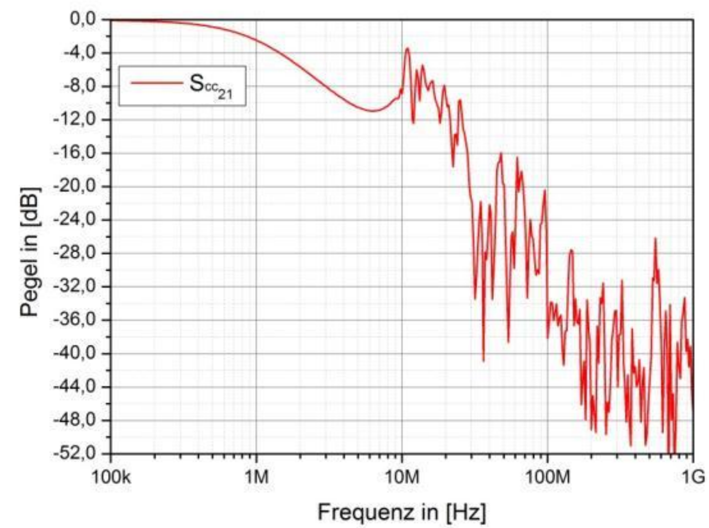


S-Parameter with In-line-connector





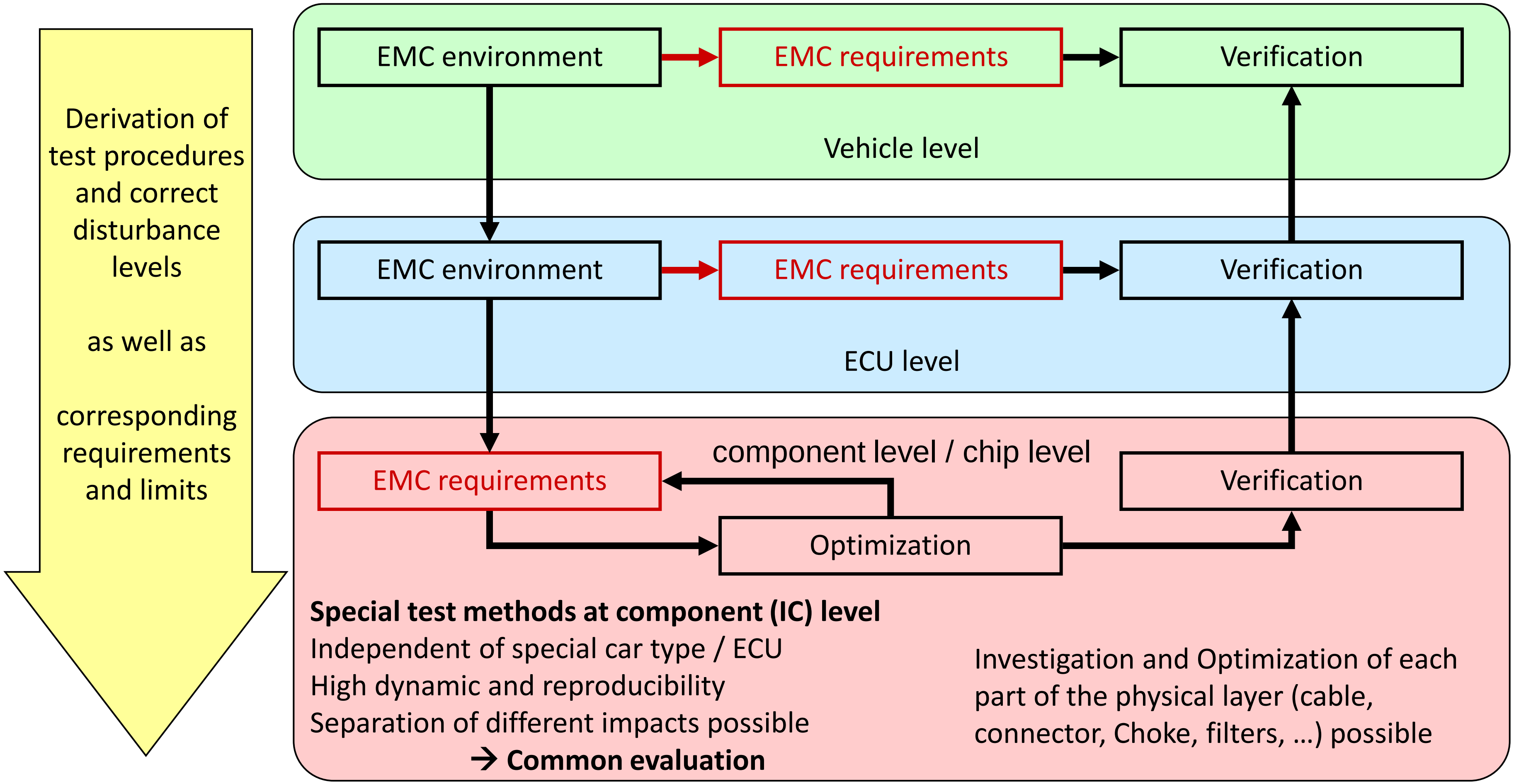




Overview of Automotive EMC Tests

- There are three stages of EMC testing and requirements
  - IC level testing (bench test without connectors & cables)
  - Component level testing (bench testing with connectors & cables)
  - In-vehicle testing
- The following standards cover the most common EMC test setups and limits:
  - IEC62123-4 (Direct Power Injection)
  - IEC61967-4 (150 Ohm Emissions)
  - ISO 11452-4 (Bulk Current Injection)
  - ISO 11452-2 (Radiated Immunity)
  - CISPR 25 (Radiated emissions)
  - ISO 7637-3 (Coupling of transients by capacitive clamp)
  - 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



Ensuring EMC for Automotive Bus Systems

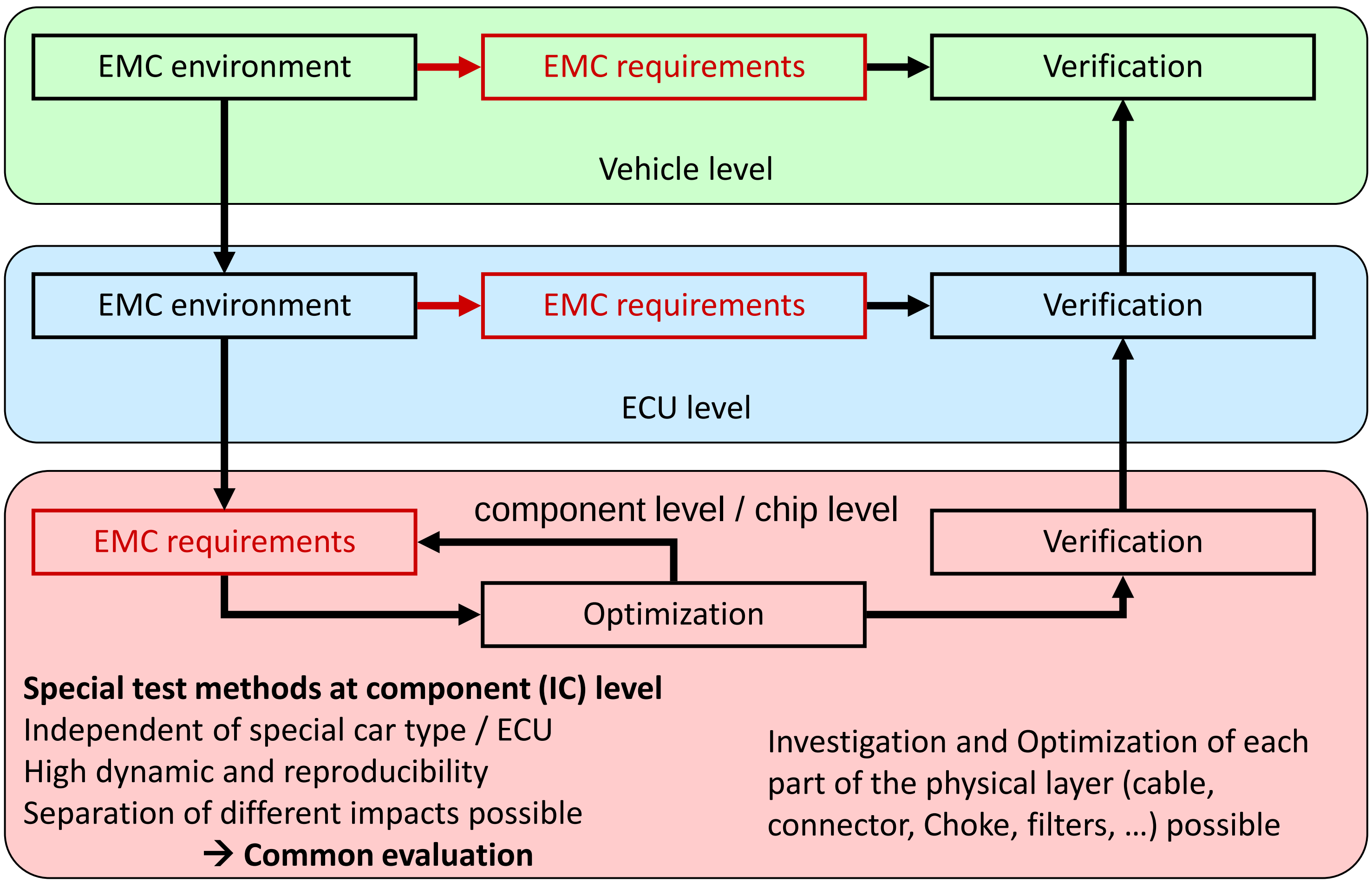
e.g. CISPR12/CISPR25/ ISO 11451

- radiated immunity
- radiated emission
- ESD

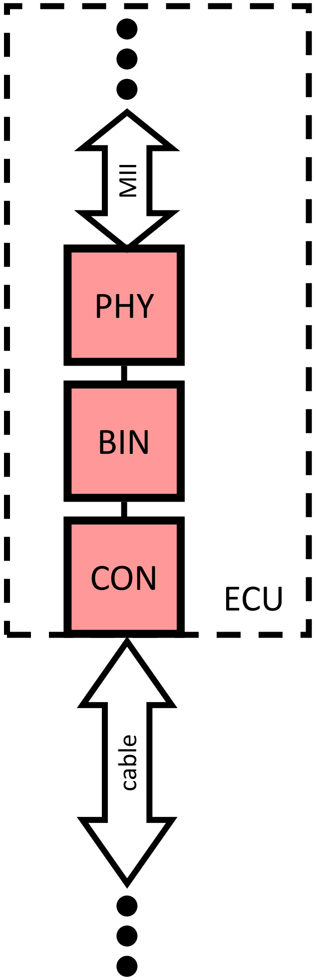
e.g. CISPR25/ISO11452

- radiated immunity
- radiated emission
- conducted immunity
- conducted emission
- Transients/ESD

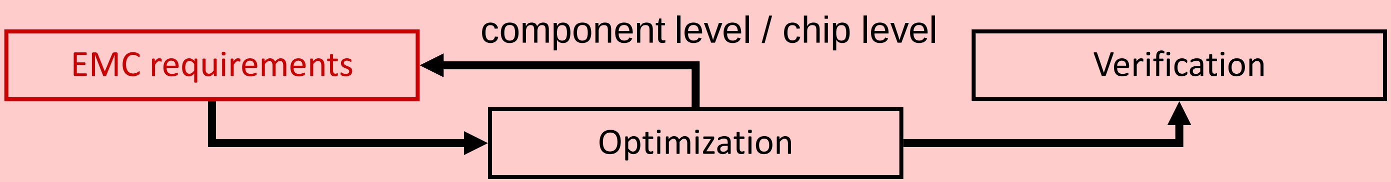
- immunity against direct injected power (DPI)
- Direct conducted emission (150 ohms method)
- ESD



Ensuring EMC for Automotive Bus Systems



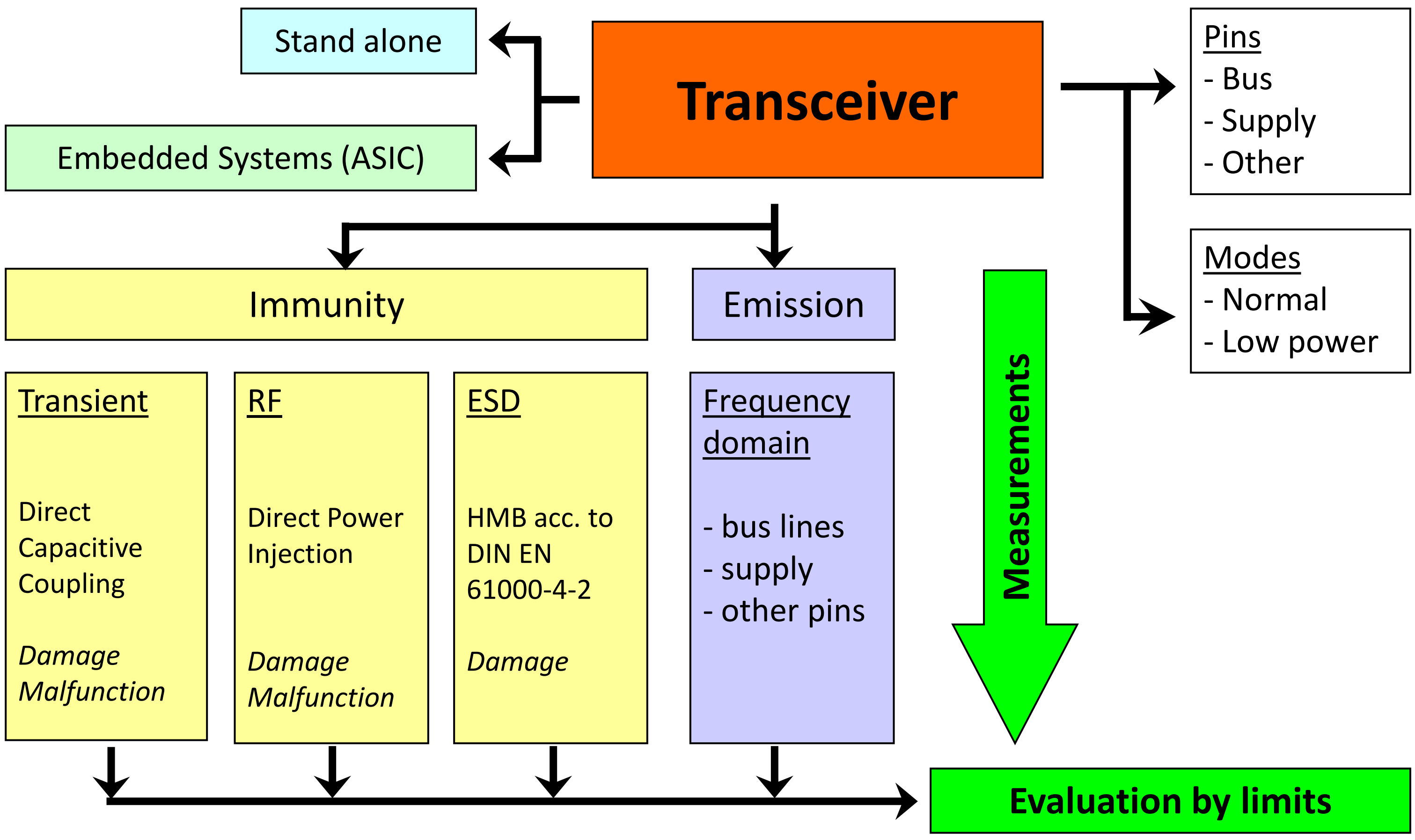
- to ensure EMC on component-/chip-level all parts of the communication system have to fulfill dedicated requirements:
  - Physical layer chip (PHY)
  - Bus interface network (BIN, this includes filters, chokes, etc)
  - Connector (CON)
  - Cable (including inline connectors)
  - Power supply (coupling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



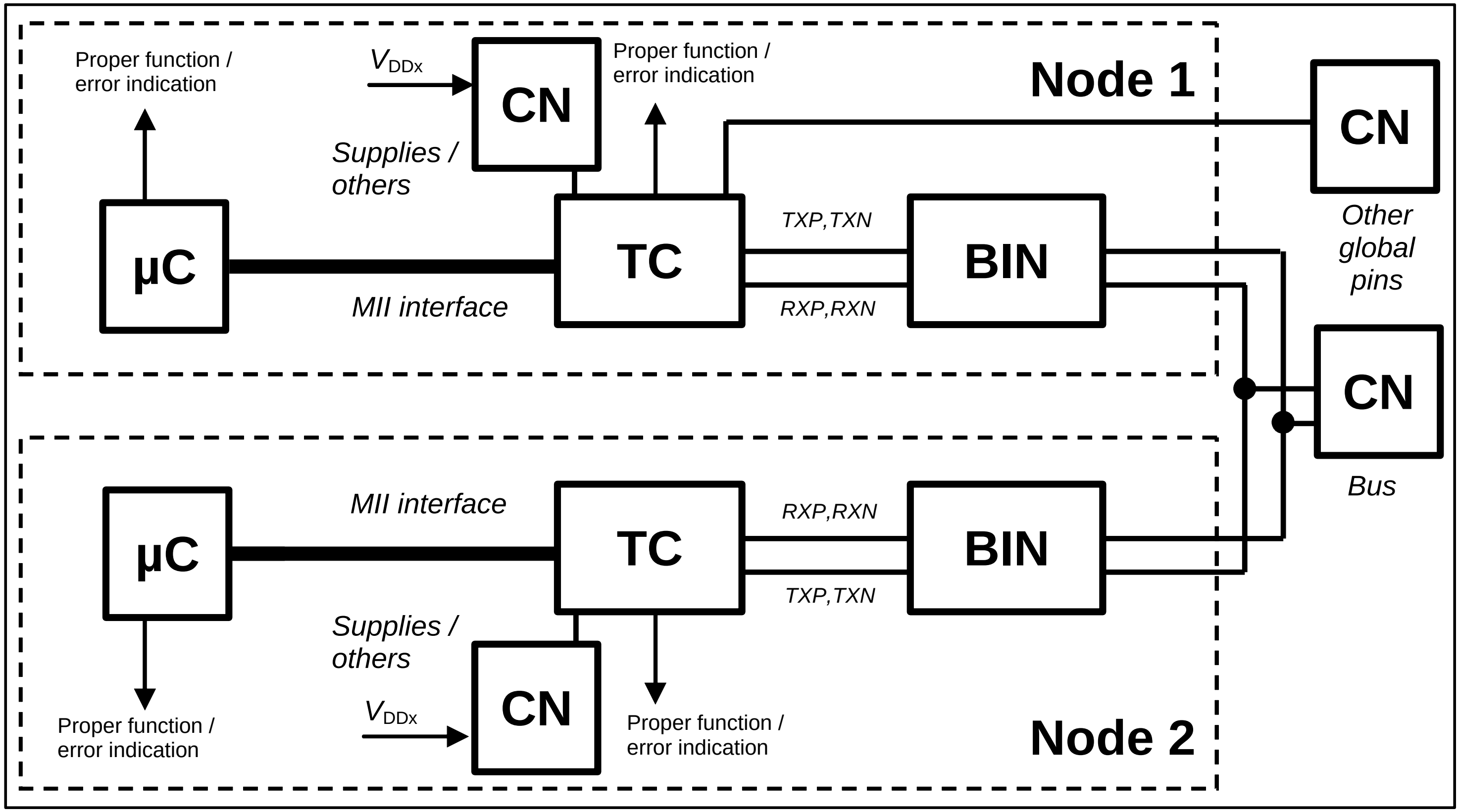
Special test methods at component (IC) level
Independent of special car type / ECU
High dynamic and reproducibility
Separation of different impacts possible
→ **Common evaluation**

Investigation and Optimization of each part of the physical layer (cable, connector, Choke, filters, …) possible

Example – Conducted Measurements



Example – Conducted Measurements

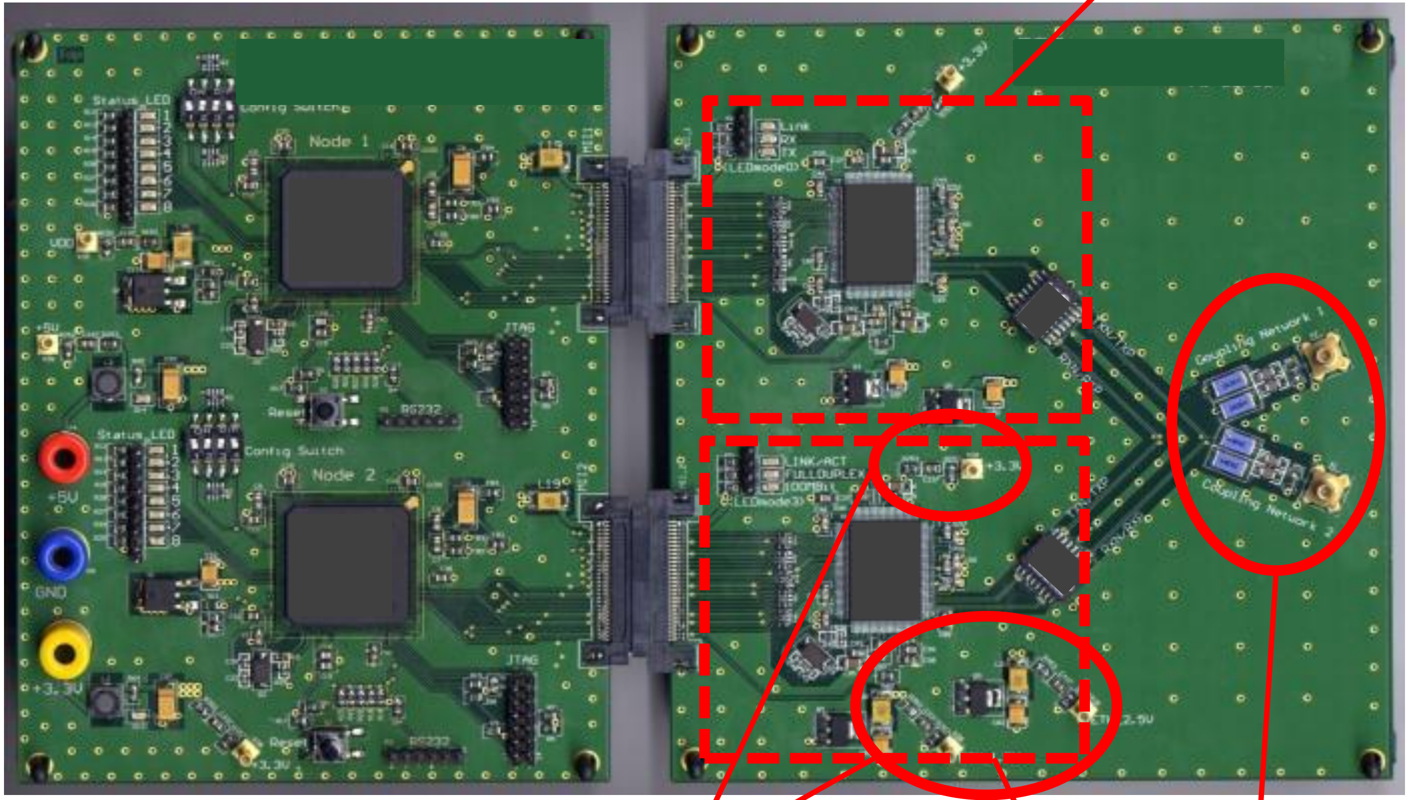


µC	Automotive microcontroller with MII interface	BIN	Bus interface network (including choke/transformer, termination, additional filter elements, ESD protection)
TC	Ethernet transceiver (device under test – DUT)	CN	EMC coupling network

Example – Conducted Measurements

Node 1

Host µC board MII interface RF test board

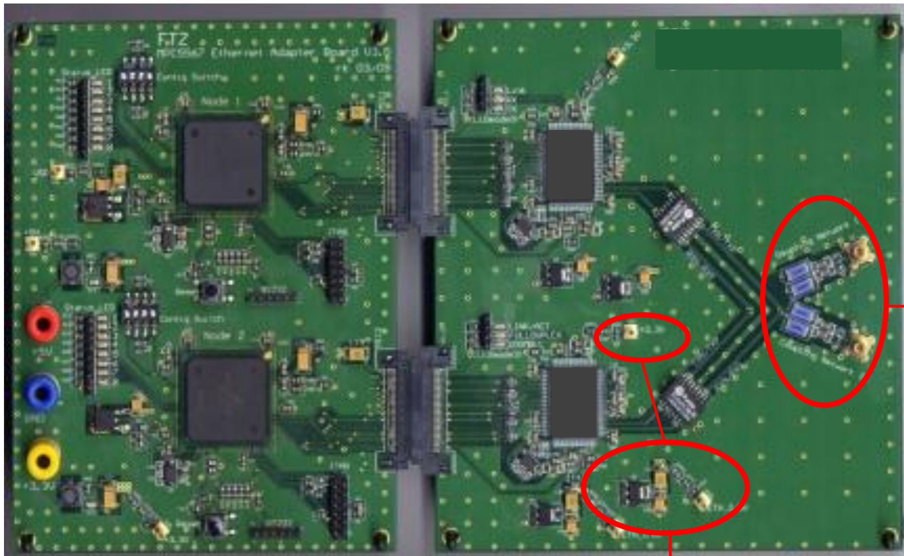


Coupling networks voltage supply

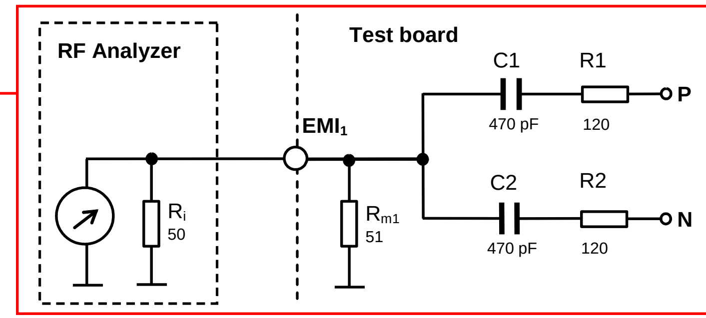
Node 2

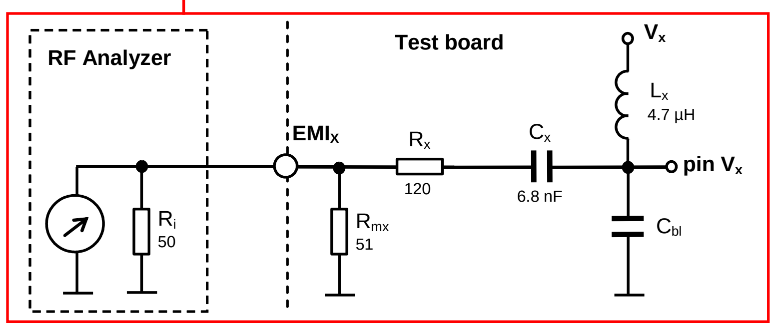
Coupling networks ETN

Example – Conducted Measurements



Measuring network ETN



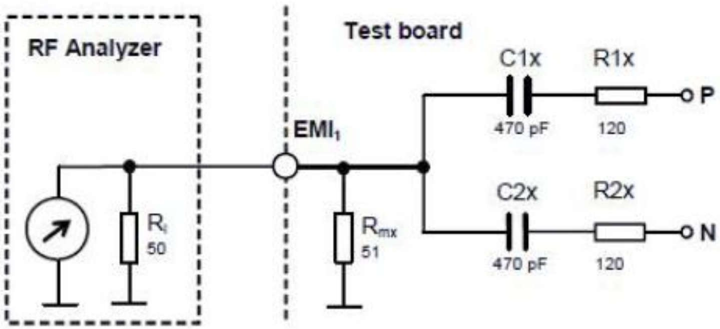


Measuring network Voltage supply

Example – Conducted Measurements

Line Emissions coupling network

Emission 150ohm method



	R_{1x} [Ω] (Bus +)	R_{2x} [Ω] (Bus -)
Symmetry	120	120
+ 2,5 % unbalance	121	118
- 2,5 % unbalance	118	121
+ 5 % unbalance	121	115
- 5 % unbalance	115	121

- Asymmetry variation of resistors R1x/R2x is ±2,5% (limits to be fulfilled).
- Typically/often additional measurements with ±5% are done for information purposes.

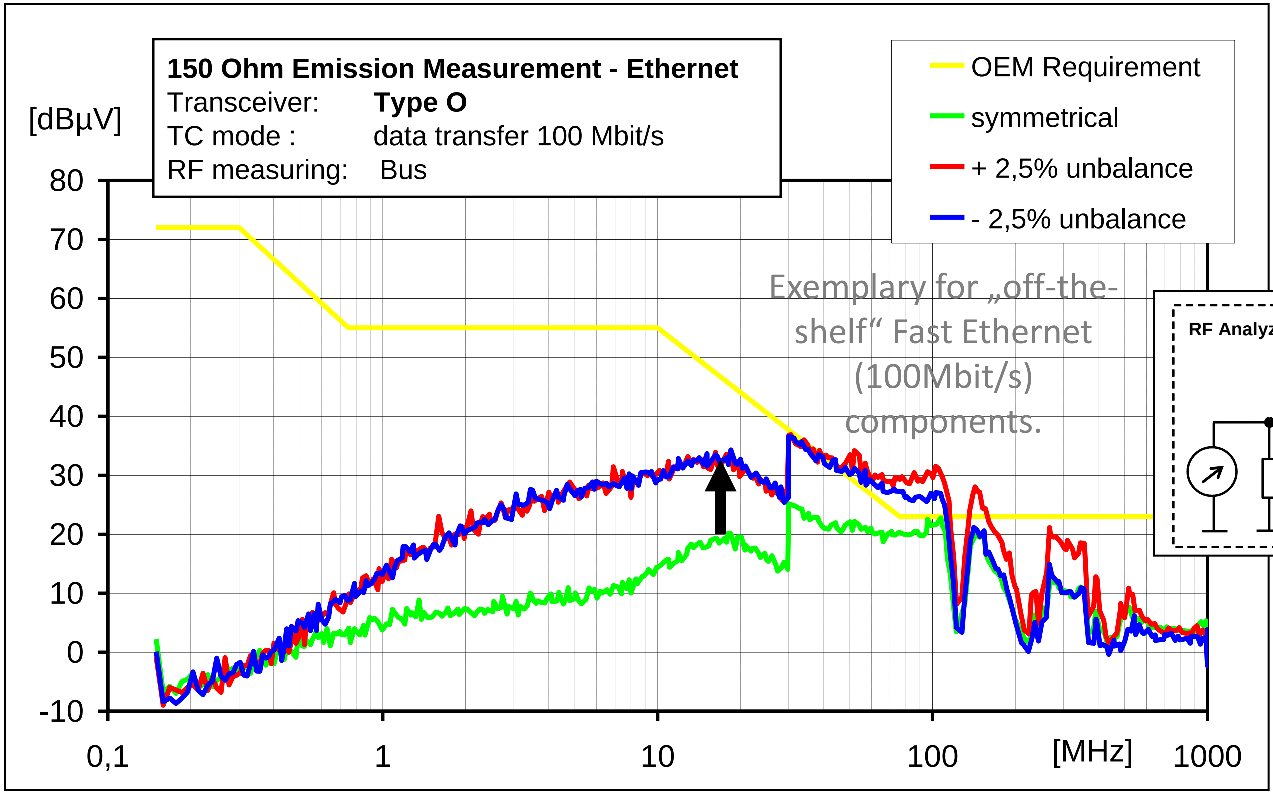
Measuring equipment	Spectrum analyzer	Measuring receiver
Detector	Peak	
Frequency range	0.15 to 2750 MHz	
Resolution bandwidth (RBW)		
150 kHz to 30 MHz:	10 kHz	9 kHz
30 MHz to 2750 MHz:	100 kHz	120 kHz
Video bandwidth (VBW)	equal to RBW	-
Numbers of passes	10 (max hold)	1
Measurement time per step	-	≥ 1 ms
Frequency sweep time	≥ 20 s	-
Frequency step width		
150 kHz to 30 MHz:	-	≤ 9 kHz
30 MHz to 2750 MHz:		≤ 120 kHz

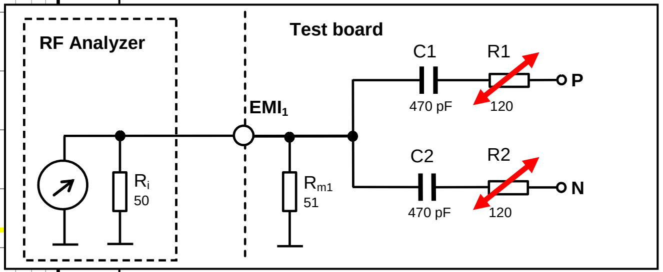
Table: Settings of the measurement device

All pictures from http://grouper.ieee.org/groups/802/3/RTPGE/public/sept12/jones_01_0912.pdf

Example – Conducted Measurements

→ **Example for test results - 150 Ohm emission method**





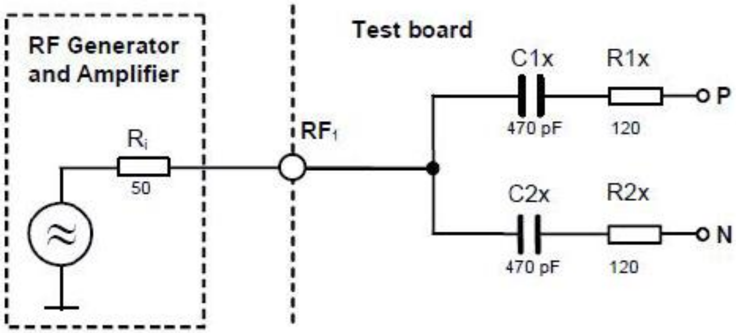
→ **Impact of asymmetry clearly visible**

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

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



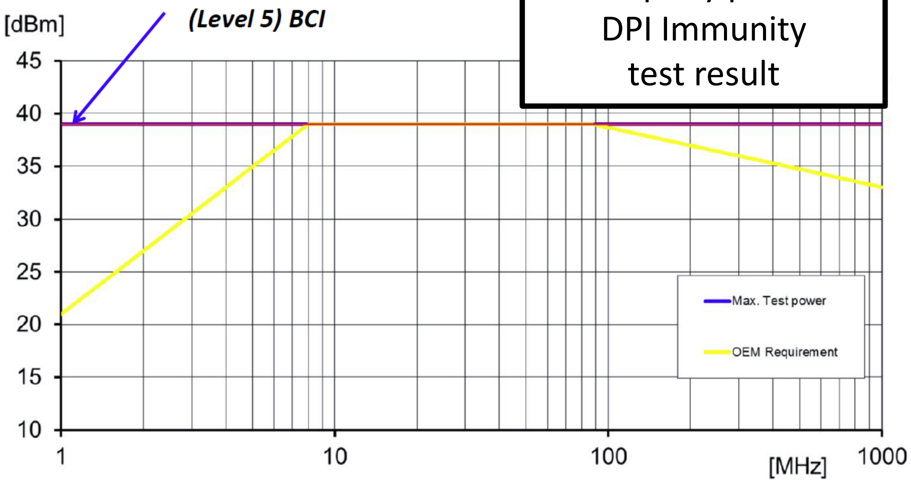
Immunity DPI method

	R_{1x} [Ω] (Bus +)	R_{2x} [Ω] (Bus -)
Symmetry	120	120
+ 2,5 % unbalance	121	118
- 2,5 % unbalance	118	121
+ 5 % unbalance	121	115
- 5 % unbalance	115	121

- Input power is 39dBm for setup with BIN (1MHz-1GHz) CW and AM 80% 1kHz with peak conservation ($P_{max,AM} = P_{max,CW}$)
- Asymmetry variation of resistors R1x/R2x is ±2,5% (limits to be fulfilled). Typically additional measurements with ±5% are done for information purposes.

39dBm DPI equivalent to 106dBuA / 200mA (Level 5) BCI

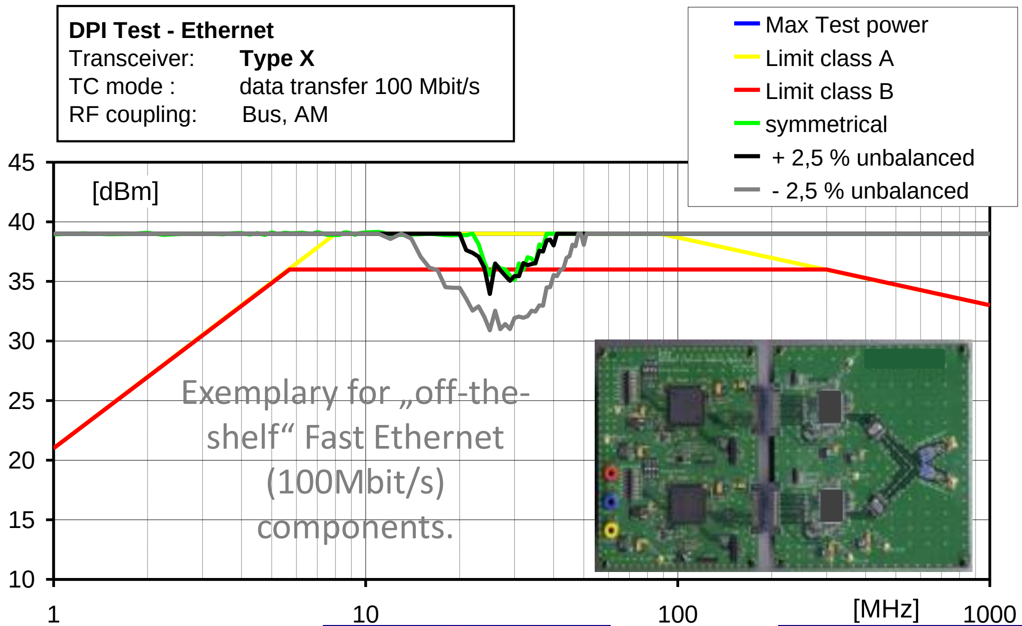
Exemplary positive DPI Immunity test result



All pictures from http://grouper.ieee.org/groups/802/3/RTPGE/public/sept12/jones_01_0912.pdf

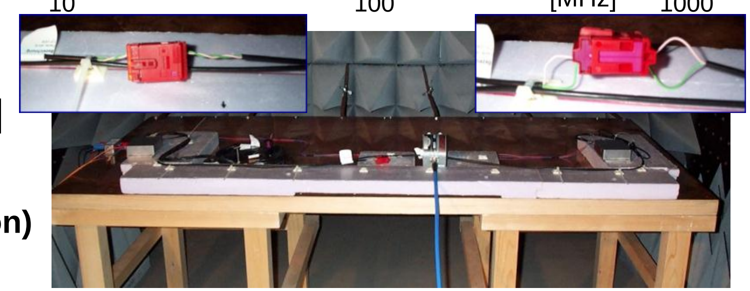
Example – Conducted Measurements

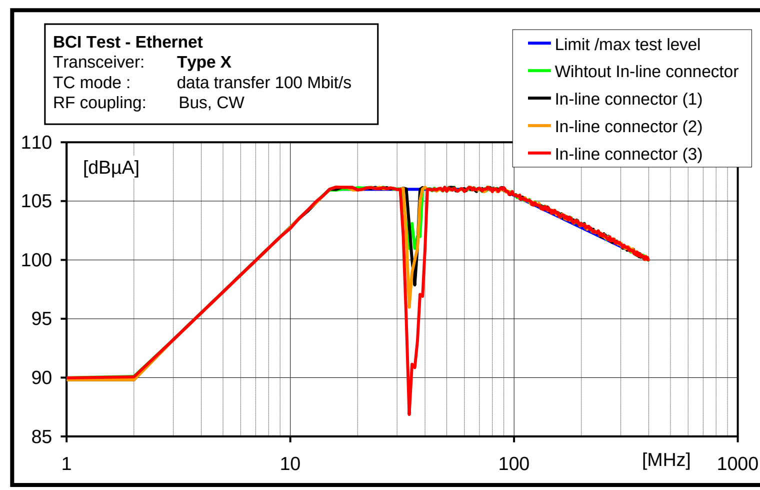
→ Example for test results – DPI (direct power injection/RF immunity)



- → **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





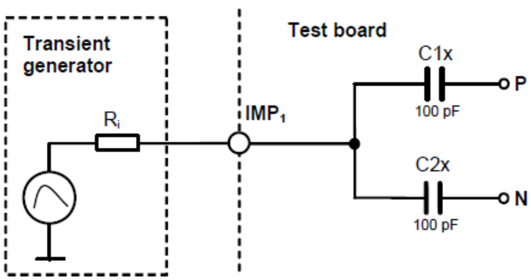
From: "Methodologies for EMC optimization of Automotive Ethernet Systems" by Dr. Bernd Körber, 1st Ethernet & IP @ Automotive Techday

Example – Conducted Measurements

Immunity to transients

- 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).

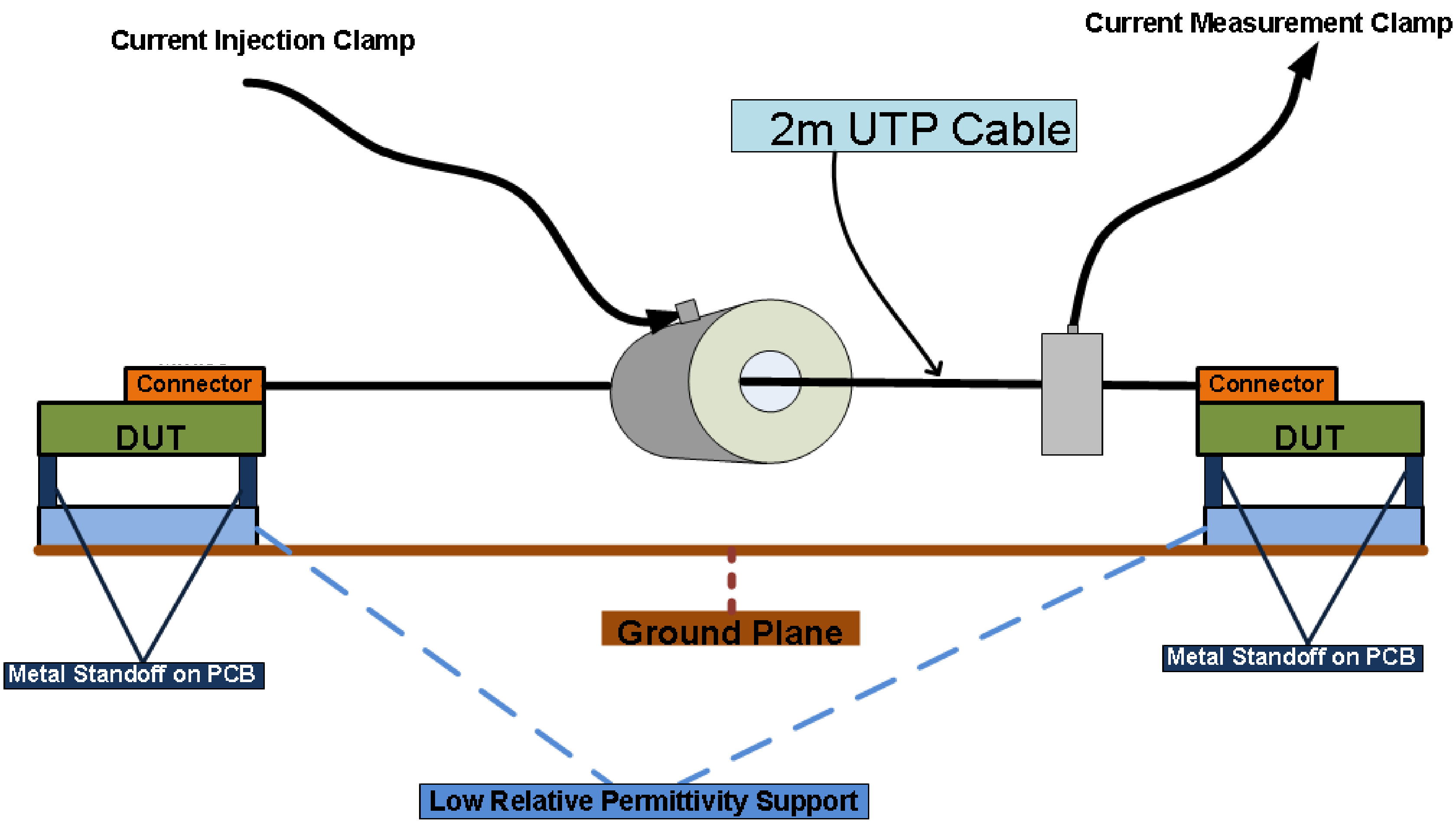
Test pulse	V_{peak} (V)	Pulse repetition (Hz)	R_i (Ω)
1	-100	2	10
2a	75	2	2
3a	-150	10k	50
3b	100	10k	50



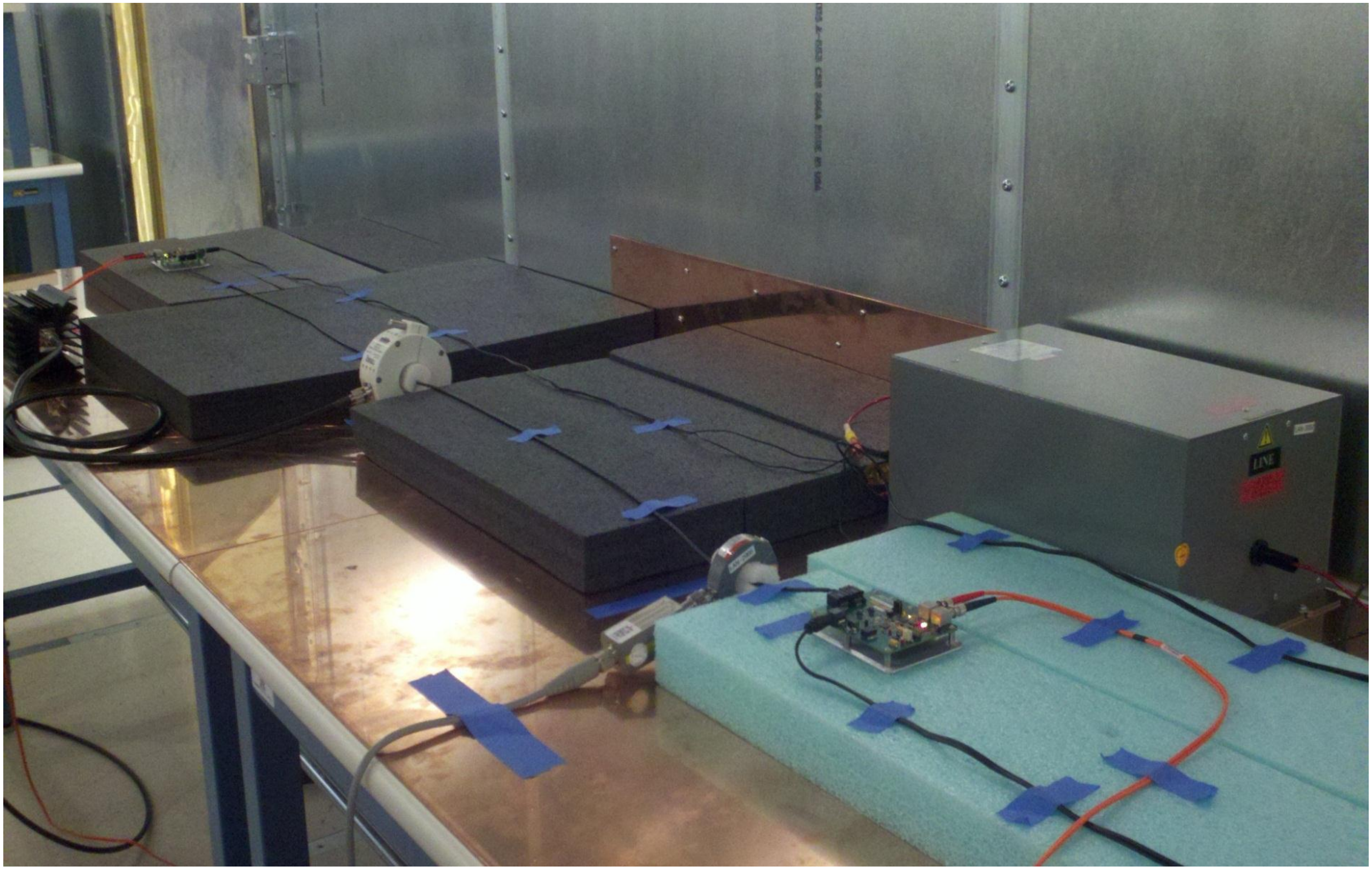
- The measurement of immunity against transient pulses shall be tested using the capacitive coupling clamp according to ISO 7637-3: 2007-07 (CCC method) and using the current probe (BCI) according to ISO 7637-3: 2007-07 (ICC method).

Test pulse	V_{peak} (V)	Pulse repetition (Hz)	R_i (Ω)
Fast a (CCC)	-75	10k	50
Fast b (CCC)	60	10k	50
Slow + (ICC)	6	2	2
Slow – (ICC)	-6	2	2

BCI Immunity Test (derived from ISO 11452-4)



BCI Test Setup Photo



BCI Test Limit Lines (3 examples)

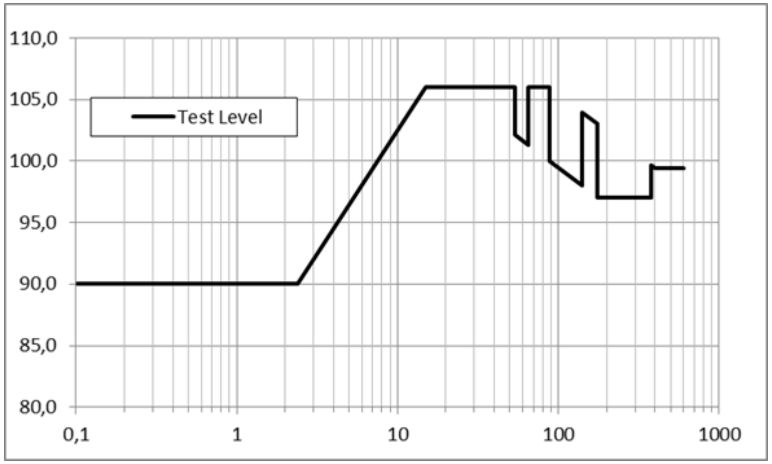
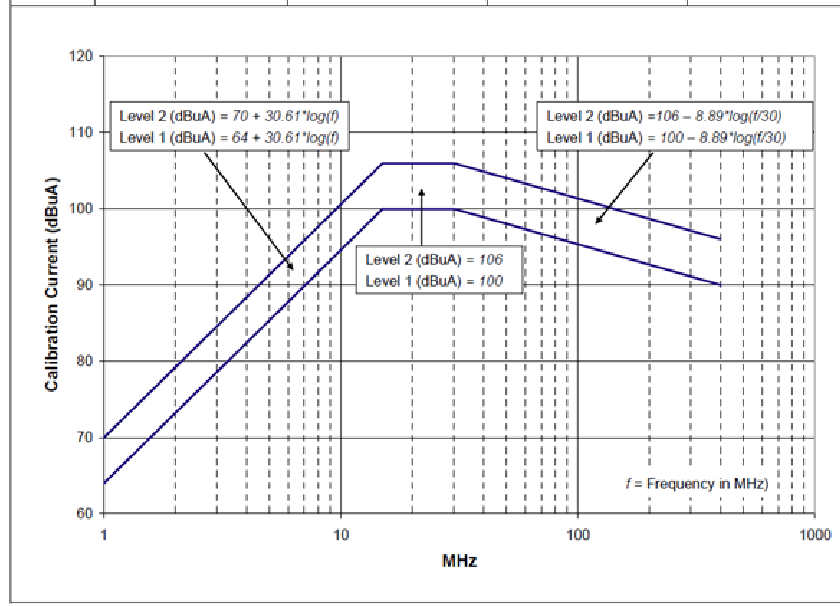
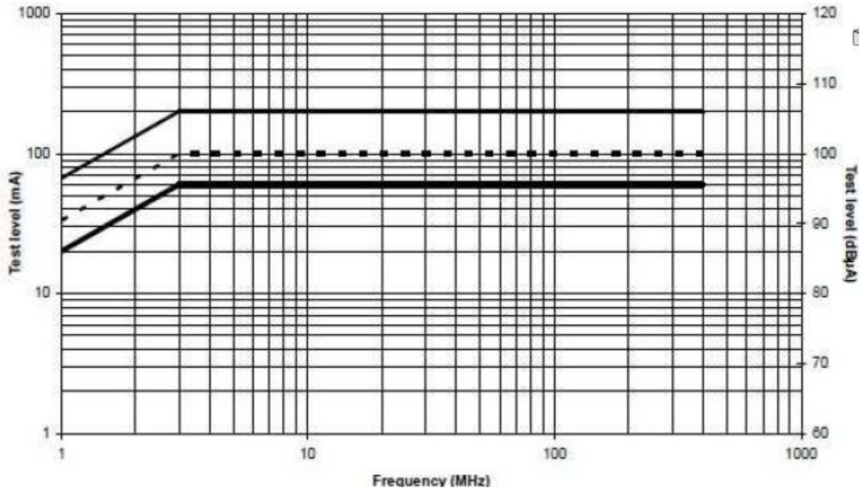


Figure 11-1: RI 112 Requirements using Bulk Current Injection (BCI)

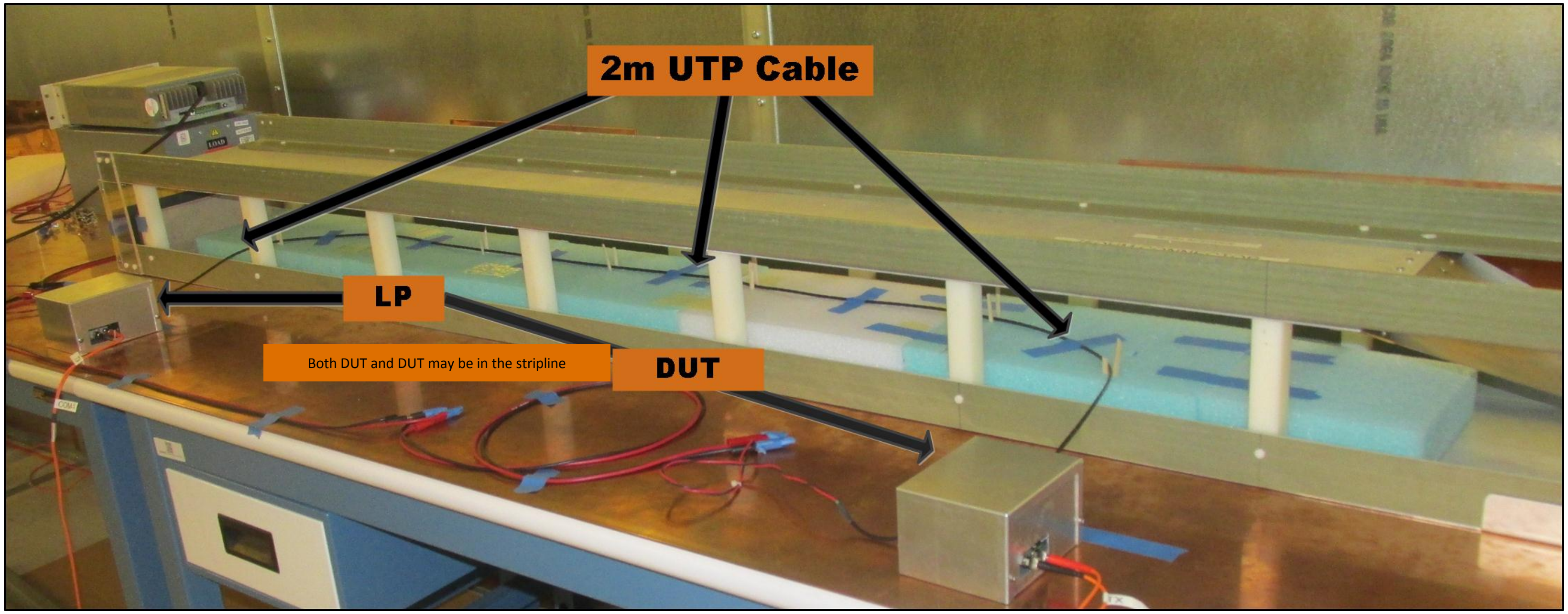
Band	Frequency Range (MHz)	Level 1 (dBµA)	Level 2 (dBµA)	Modulation
1	1 - 15	64 - 100	70 – 106	CW, AM 80%
2	15 - 30	100	106	CW, AM 80%
3	30 – 400	100 - 90	106 - 96	CW, AM 80%



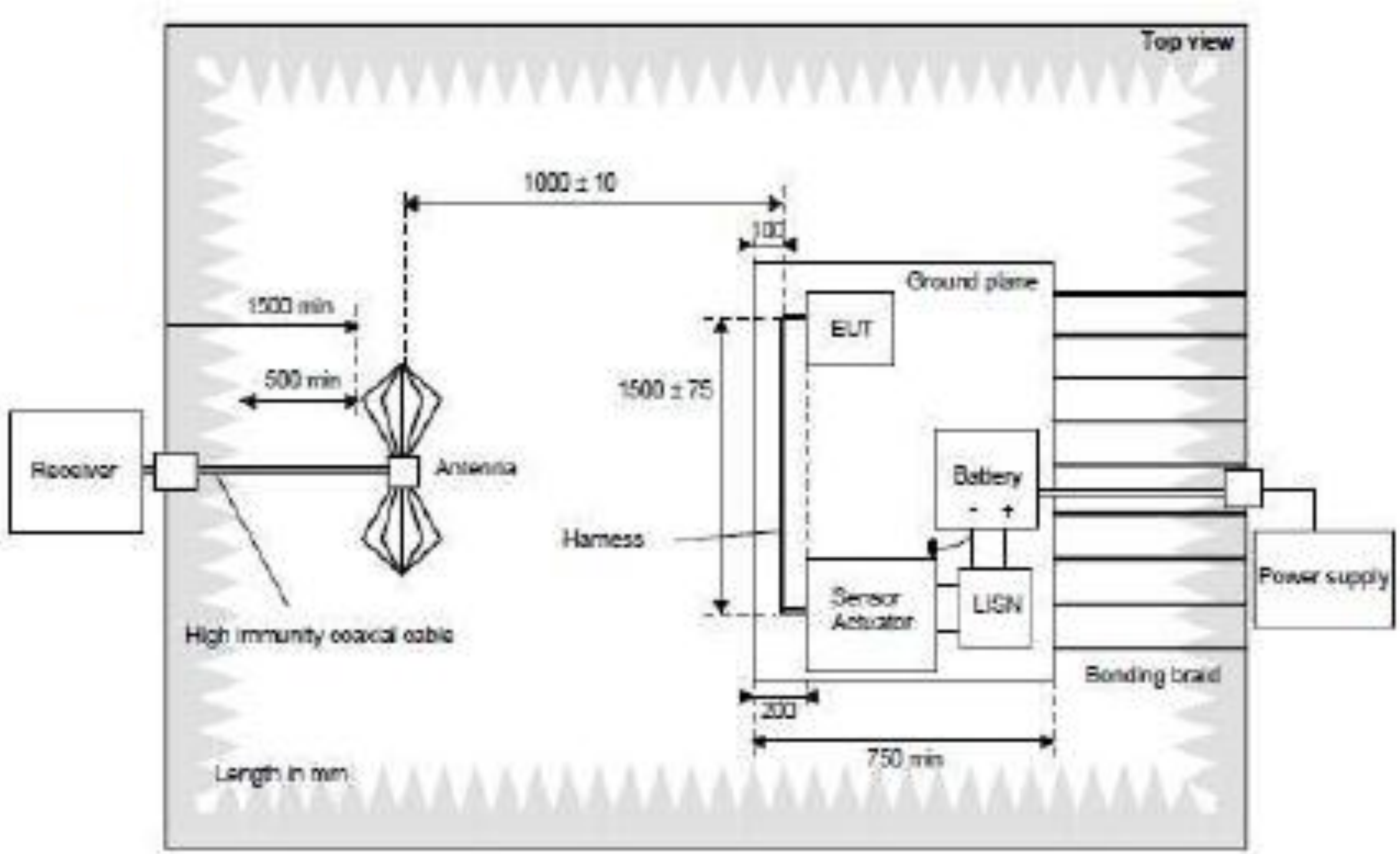


- Bulk injection by means of a current clamp onto a 1m/2m UTP length harness of the DUT
  - Test Frequency: 1 MHz – 400 MHz
  - Test Levels: Up to 200 mA

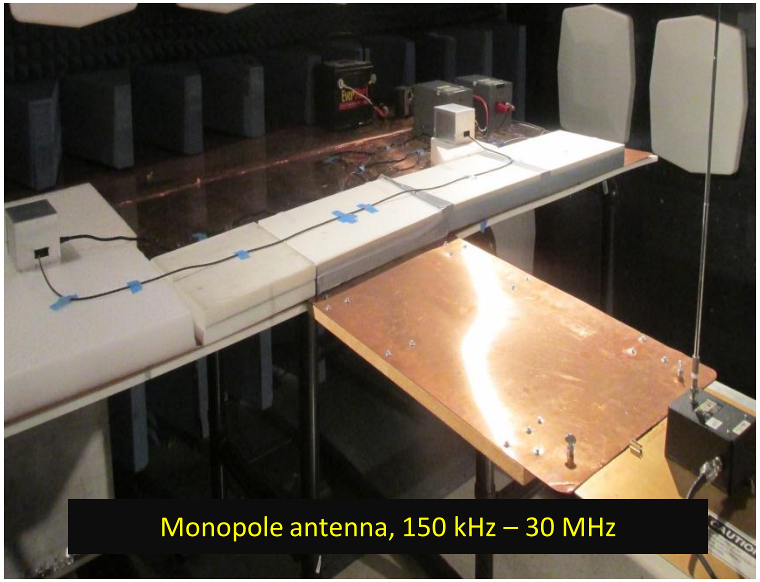
Stripline Emissions Test Setup



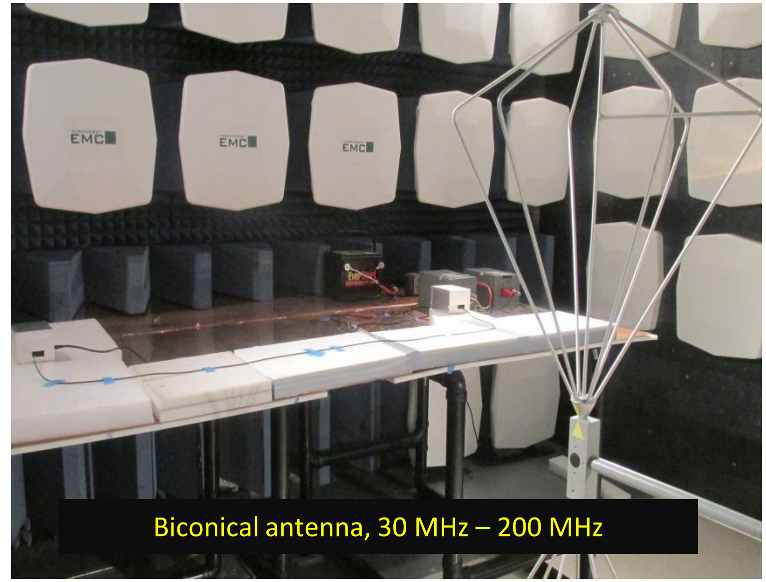
Radiated Emissions Test Setup (CISPR 25)



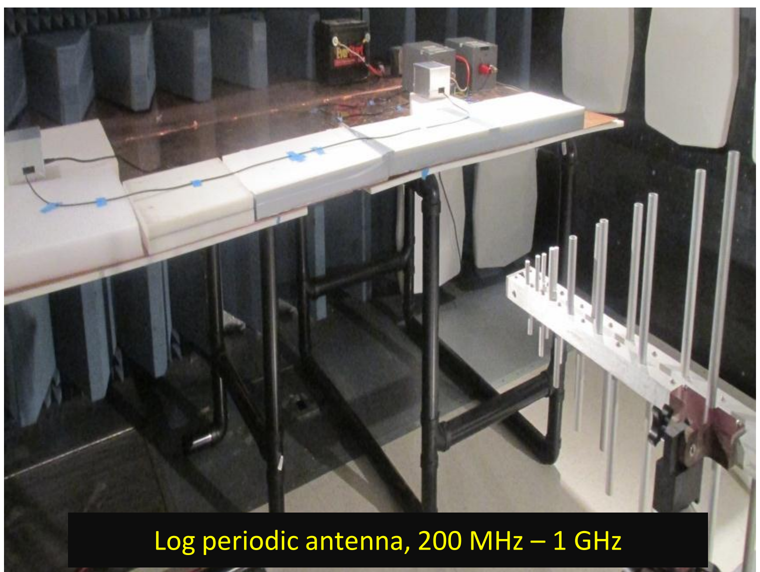
Radiated Emissions Test Setup (CISPR 25)



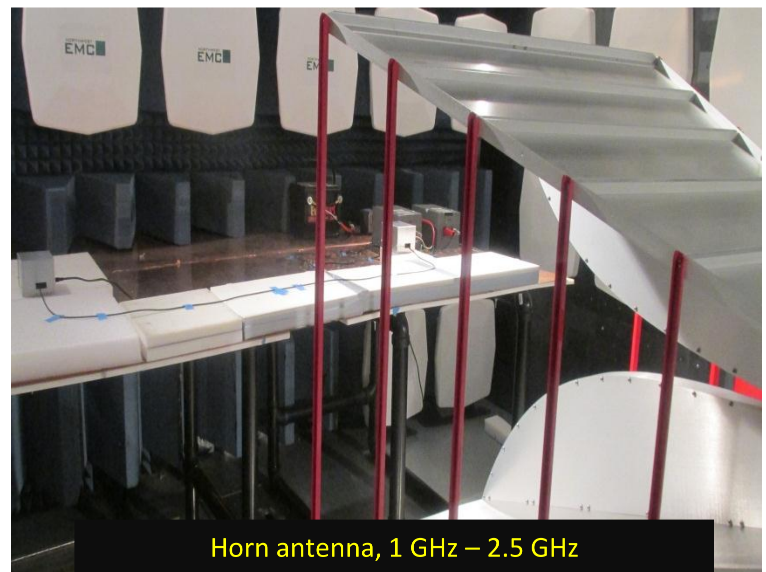
Monopole antenna, 150 kHz – 30 MHz



Biconical antenna, 30 MHz – 200 MHz

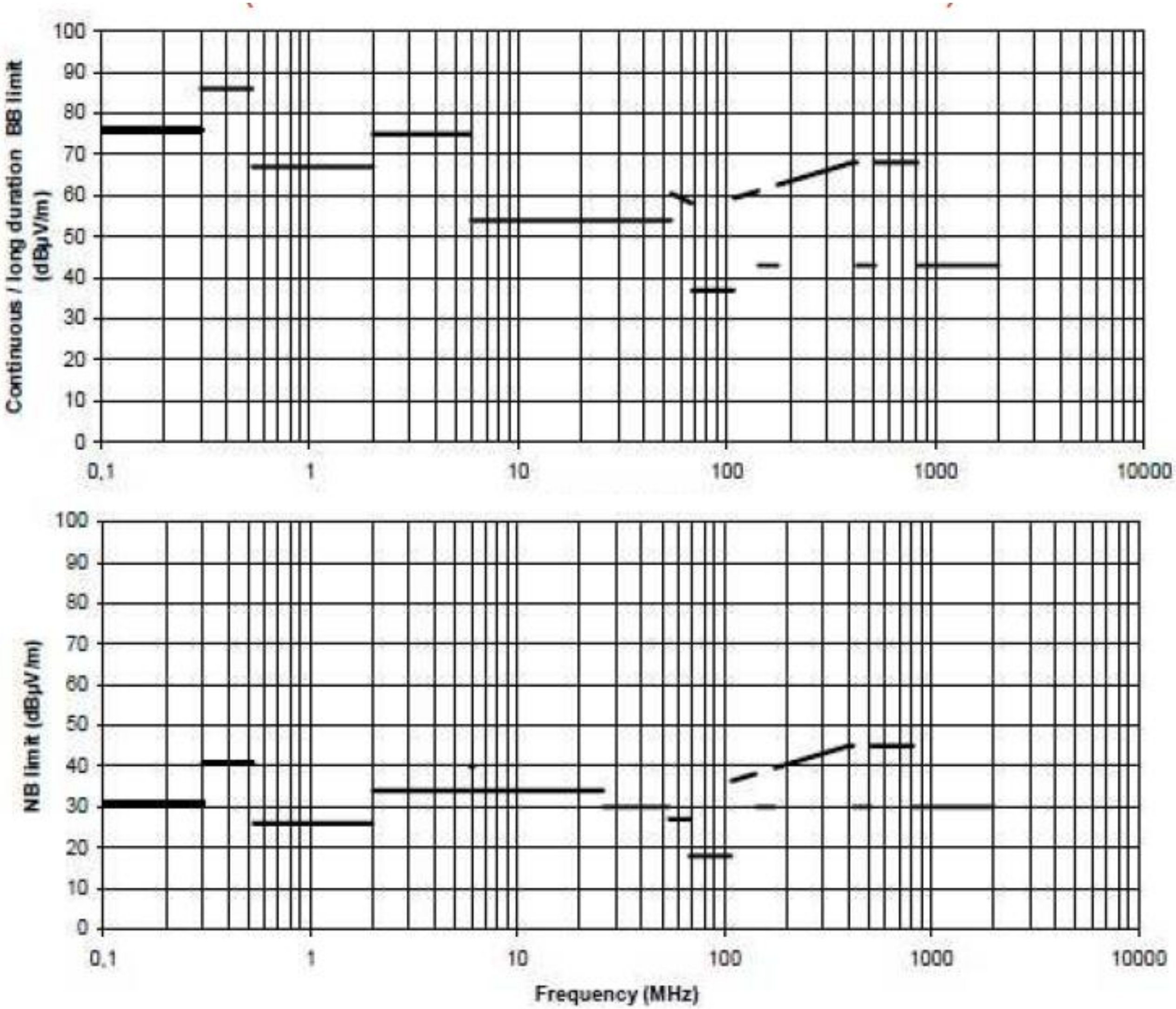


Log periodic antenna, 200 MHz – 1 GHz



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/buntz_03_0712.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/july12/zinner_02_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://www.ieee802.org/3/RTPGE/public/adhoc/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