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Testing of Automotive Systems (Part I)

Module 7 – EMC

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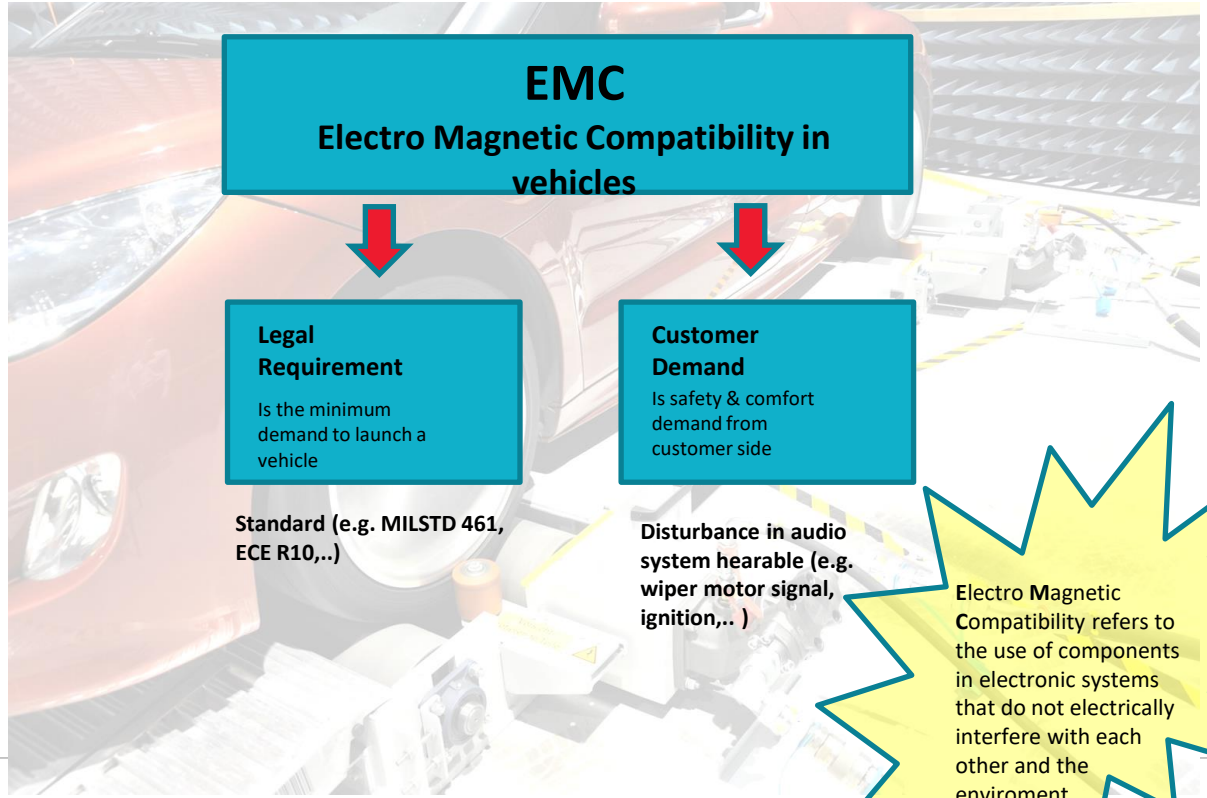
EMC Overview



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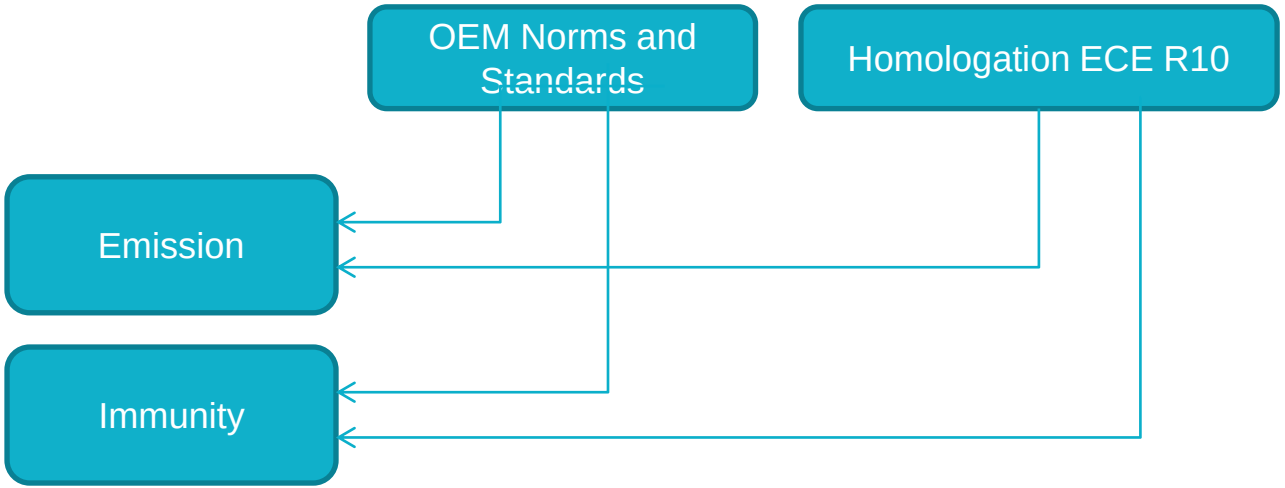
EMC Norms and homologation



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EMC Overview

1. EMC between the vehicle and its surroundings

All vehicle systems must remain impervious to electromagnetic radiation emitted from such external sources as extremely powerful radio transmitters (Immunity). Stationary receivers should remain unaffected by passing traffic. Both considerations are governed by national and international codes → Homologation

2. EMC between different systems in the vehicle

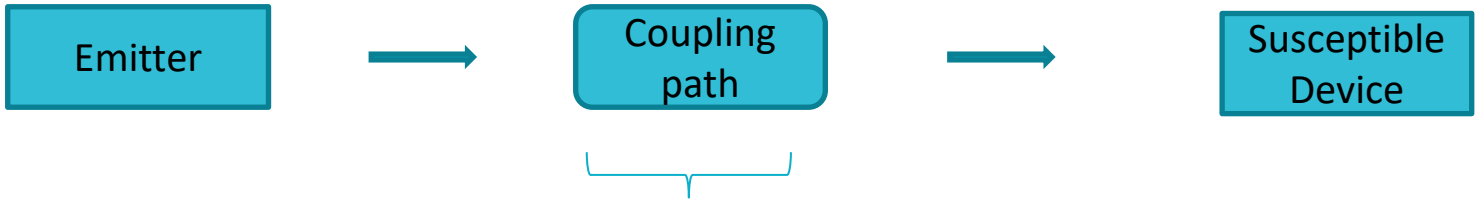
E/E vehicle components must rely on a single vehicle electrical system for their power supply. It is thus vital to avoid mutual interference and feedback phenomena generated by one or several systems so that these do not cause malfunction

3. On-board electronic systems (reception)

Mobile communications equipment – such as the radio – also exists within an interlinked environment including all of the vehicle's electronic systems. Strict limits are imposed on the levels of interference emitted by on-board electronic systems. It is important to maintain interference-free reception in the vehicle

EMC Emission+Immunity

Interference Model



- Interference control

- Galvanic
- capacitive
- inductive
- electromagnetic

- Susceptibility control

Interference can be either conducted (CE/CI) or radiated (RE/RI)

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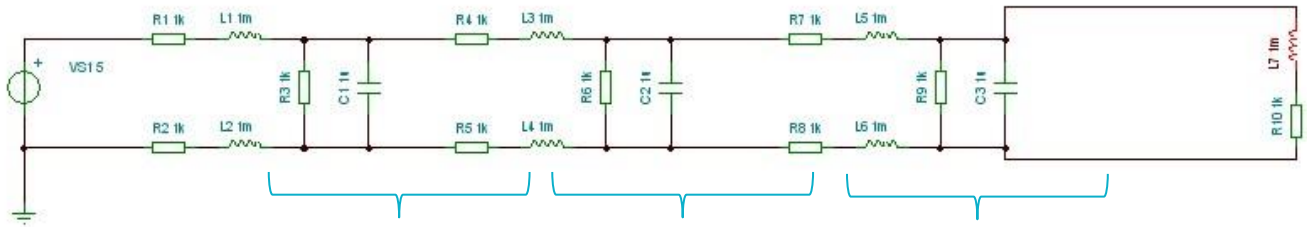
Conductor Model

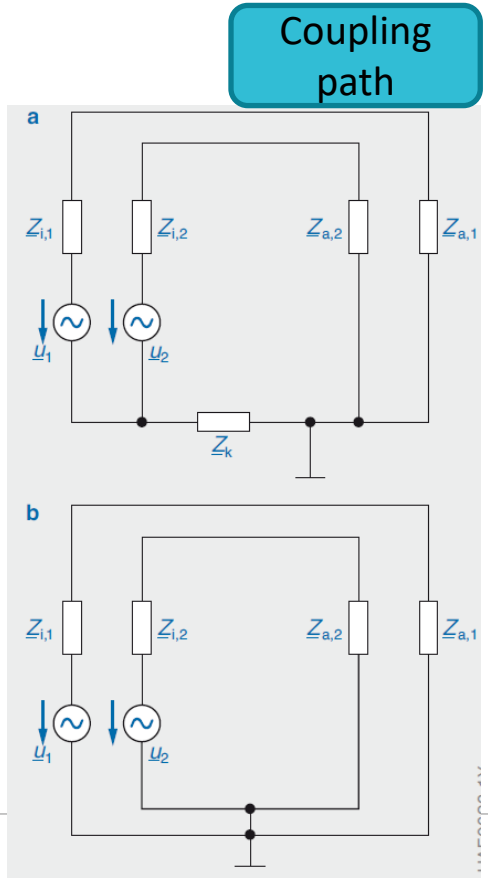
Coupling path



- Conductor cross section (ρ*l/A)
- Isolation Resistance
- Conductor capacities
- Inductive conductor resistance

Galvanic Coupling

- Currents for two different electric circuits flowing through a single conductive path will both generate a voltage owing to the consistent impedance in the shared conductor (picture a)
- Voltage produced by radio-interference source u1 has the effect of a supplementary signal voltage in signal circuit 2
- Inductive conductor resistance increases with frequency
- Remedy
  - use separate return lines for each electric circuit (picture b) → wiring efforts increase
  - Increase conductor cross section
  - Prevent high frequencies (ripple), DC filtering



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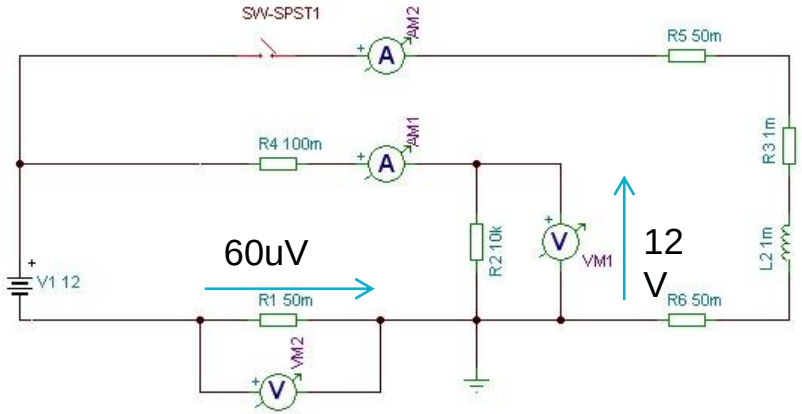
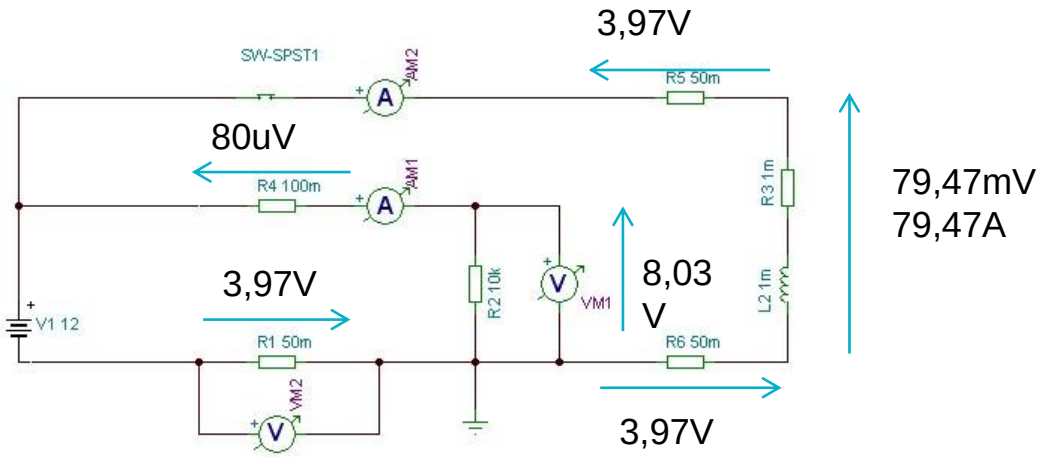
Example: Galvanic Coupling

Switch on leads to high current and galvanic coupling

Coupling path

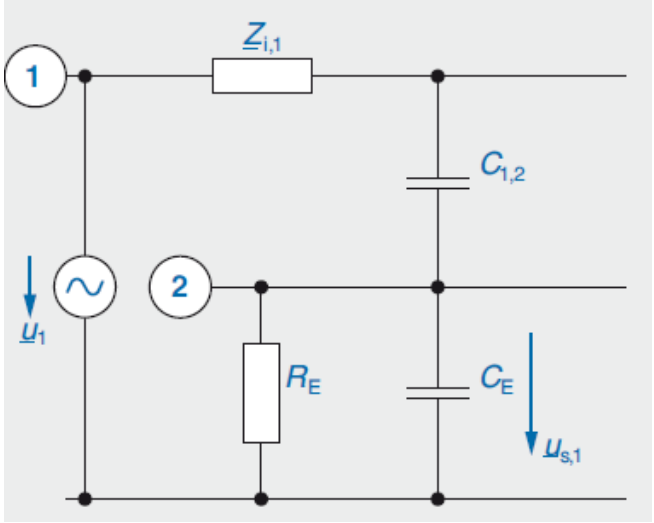




Capacitive Coupling

- Variable-periodicity signals such as pulse voltages and sinusoidal alternating voltages produce interference and crosstalk in adjacent electric circuits, even without the existence of a direct physical link
- Interference voltage is proportional to closeness of the neighboring conductor paths and the frequency of the alternating voltage
- Remedies
  - Separate conductive paths, reduce coupling
  - Limit frequency of alternating voltages
  - Low-impedance increases signal-to-noise ratio SNR
  - Isolation

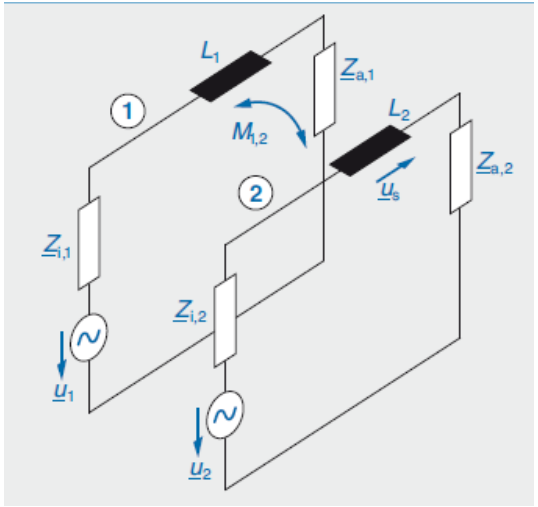
Coupling path



Inductive Coupling

Coupling path

- Currents recurring with variable periodicity (e.g. electrical machines with ripple) in one conductor induce voltage pulses in adjoining circuits (voltage Us in figure)
- These voltage pulses generate current in the secondary circuit (inductive principle)
- Inductive interference especially pronounced in circuits with low-frequency signals (e.g. loudspeaker wiring)
- Remedies
  - Reduce coupling inductivity, increase distance or orthogonal
  - Minimize wiring dimensions
  - Isolation difficult, especially at low frequencies



Classification EMC Interferences

Coupling	Immunity	Emission
Inductive (H) Capacitive (E) Electro Magnetic (E/H)	Incident radiaton [V/m] Magnetic field immunity [A/m]	Near-field interference [dBµV] Far-field interference [dBµV] Magnetic field emission [µT]
Galvanic	Impulse Immunity [V] Electrostatic discharge [kV]	Impulse Emission [V] Coupling[dB]

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EMC inside the vehicle

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Ripple/impulse interference

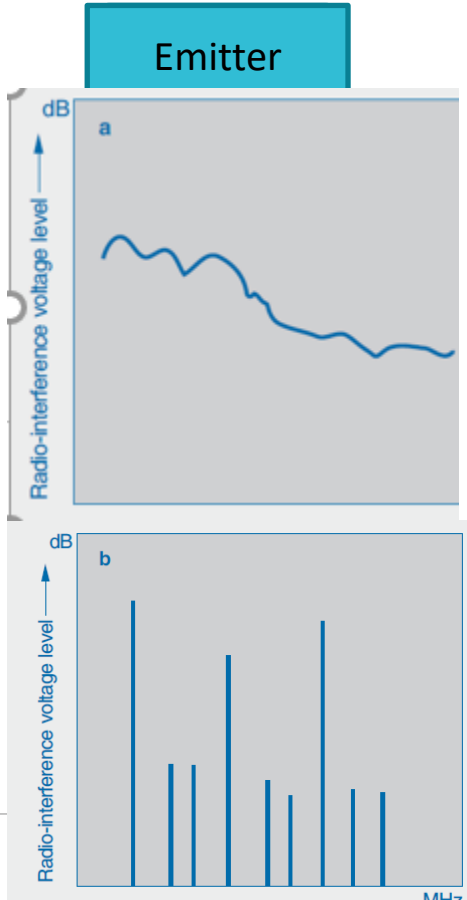
Emitter

- Ripple
  - Vehicle generator couples rectified three-phase current
  - Frequency proportional to generator rpm (kHz)
  - This leads to rippled 12V power supply
- Impulses
  - Switching operations cause impules on power supply lines via all coupling methods
  - Impulses can be described in 5 groups, pulse amplitude in 4 classes (test standard ISO7637)
  - Find cost/complexity balance of requirements of reducing sensitivity at receptors (higher amplitude class) and suppressing interference at the scource (lower amplitude class)

Test pulses as defined in DIN 40 839, Section 1					Max. pulse amplitude classes			
Pulse pattern		This is caused by	Internal resistance	Pulse duration	I	II	III	IY
1		Shutdown of inductive consumers	10 Ω	2 ms	−25 V	−50 V	−75 V	−100 V
2		Shutdown of motorized consumers	10 Ω	50 µs	+25 V	+50 V	+75 V	+100 V
3a		Steep over-voltages	50 Ω	0.1 µs	−40 V	−75 V	−110 V	−150 V
3 b					+25 V	+50 V	+75 V	+100 V
4		Voltage curve dur-ing starting operation	10 mΩ	to 20 s	12 V −3 V	12 V −5 V	12 V −6 V	12 V −7 V
5		Alternator load dump [1])	1 Ω	to 400 ms	+35 V	+50 V	+80 V	+120 V

High-frequency interference

- Interference from periodic switiching, ignition systems, CPU clock signals
- Interference impairs mobile or radio reception (bandwidth e.g. FM120kHz)
- Interference categories according to their frequency spectrum
  - wide-band interference with contiuous signal pattern(a)
    - Frequency recurs lower than the test bandwidth, e.g. 100Hz
    - Interference scource e.g.fans, wipers, e-motors
  - narrow-band interference with spike-pattern(b)
    - Frequency recurs higher than the test bandwidth, e.g. 2Mhz
    - Interference scource e.g. ECU µ-processor clock
- HF interference by radiated emission (EM- wave picked up by antennas)
  - Vehicle body and/or position of antenna influence
  - Wiring harness can become antenna (λ/4-coupling)
- HF interference by conducted emission



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Emission test technique (CISPR 25)

Emitter

- Monitoring conducted and radiated emission transmitted through wiring and antennas
- Test set-up in shielded chambers, monitoring with laboratory receiver
- Power supply / voltage scources precisely defined with laboratory specimens
- Interference-supression categories help to facilitate selection and design
  - Narrow-band interfence have higher requirements to supression as they are always present (e.g. CPU clock)
  - Wide-band interference sporadically active (e.g. window lifter) , lower supression category

2 Interference-suppression levels: permissible radio-interference voltage limits for individual frequency ranges in dBµV for wide-band (B) and narrow-band (S) interference as defined in CISPR 25 (DIN/VDE 0879-2)

Interference-suppression levels	Interference-suppression levels									
	0.15 to 0.3 MHz (LW)		0.53 to 2.0 MHz (MW)		5.9 to 6.2 MHz (SW)		30 to 54 MHz		70 to 108 MHz (VHF)	
	B	S	B	S	B	S	B	S	B	S
1	100	90	82	66	64	57	64	52	48	42
2	90	80	74	58	58	51	58	46	42	36
3	80	70	66	50	52	45	52	40	36	30
4	70	60	58	42	46	39	46	34	30	24
5	60	50	50	34	40	33	40	28	24	18

3 Permissible radio interference-field strength in dBµV/m for interference-suppression levels in individual frequency ranges according to DIN/VDE 0879, Section 2, or CISPR 25 for wide-band interferers, measured with quasi-peak detector (B), and narrow-band interference, measured with peak detector (S).

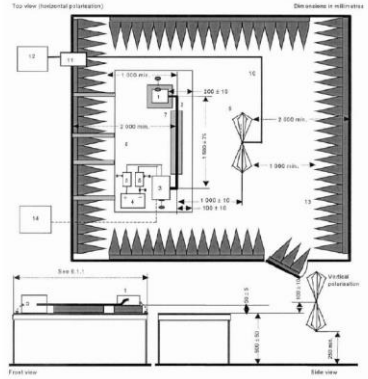
Interference-suppression level	Interference-field strength level																	
	0.15 to 0.3 MHz (LW)		0.53 to 2.0 MHz (MW)		5.9 to 6.2 MHz (SW)		30 to 54 MHz		68 to 87 MHz		76 to 108 MHz (VHF)		142 to 175 MHz		380 to 512 MHz		820 to 960 MHz	
	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S
1	83	61	70	50	47	46	47	46	36	36	36	42	36	36	43	43	49	49
2	73	51	62	42	41	40	41	40	30	30	30	36	30	30	37	37	43	43
3	63	41	54	34	35	34	35	34	24	24	24	30	24	24	31	31	37	37
4	53	31	46	26	29	28	29	28	18	18	18	24	18	18	25	25	31	31
5	43	21	38	18	23	22	23	22	12	12	12	18	12	12	19	19	25	25

Electro Magnetic Chamber:

The EMC chamber simulates a free E-field to measure all kind of EMC emission for complete vehicle, component and HV system measurements.

CISPR 25 ALSE

(Absorber Lined Shielded Environment)



i: pyramid absorbers
This absorbers are designed to prevent reflections of electromagnetic waves

i: bilogantenna is a high performance ultra wideband antenna for emission EMC testing with a frequency range from 30MHz to 1GHz

i: air supply is used to cool down the combustion engine during the operation.

i: hornantenna is used as antenna at Ultra High Frequency's and microwave frequencies up to 4GHz

i: dynamometer with hydraulic propulsion for simulation of drive conditions for electrical and hydride vehicles

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CISPR 25 on complete vehicle level

Emitter

- Vehicle configuration has a substantial effect on the broadcast reception (e.g. engine variant)
- Test describes measuring antenna voltage at the end of the antenna cable to which the radio receiver will subsequently be connected
- CISPR25 also prescribes limits for radio interference voltage for different bands (see below)
- Contiuous and sporadic wide-band and narrow-band interferences are handled differently

4 Limits defined for permissible radio interference voltage at vehicle antenna in dBµV

Frequency range	Frequency	Continuous wide-band interference		Sporadic wide-band interference		Narrow-band interference
	MHz	QP-B	b	QP-B	b	S
LW	0.14 to 0.30	9	22	15	28	6
MW	0.53 to 2.0	6	19	15	28	0
SW	5.9 to 6.2	6	19	6	19	0
2-way transceivers	30 to 54	6 (15*)	28	15	28	0
2-way transceivers	70 to 87	6 (15*)	28	15	28	0
VHF	87 to 108	6 (15*)	28	15	28	6
2-way transceivers	144 to 172	6 (15*)	28	15	28	0
C-network car phone	420 to 512	6 (15*)	28	15	28	0
D-network car phone	800 to 1000	6 (15*)	28	15	28	0

Electrostatic Discharge (ESD)

- ESD is part of EMC, can damage or destroy electronic components
- Discharging events up to several volts can turn into very high pulsed currents
- Prevent destructive event or discharges themselves
- ISO TR 10605 defines test procedures
- Test is conducted with ESD test-pulse generator that produces hig-voltage pulses

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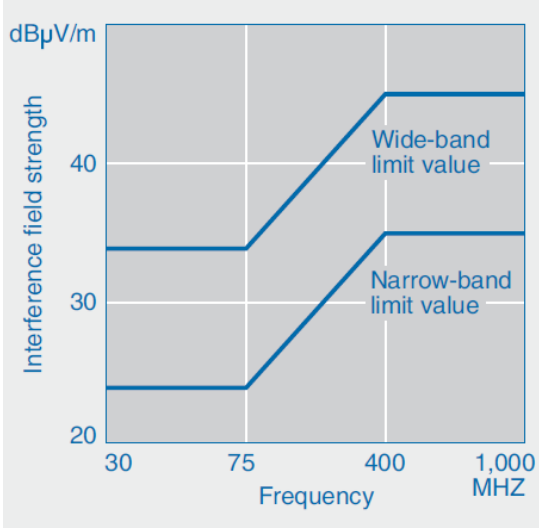
EMC between vehicle and its sourroundings

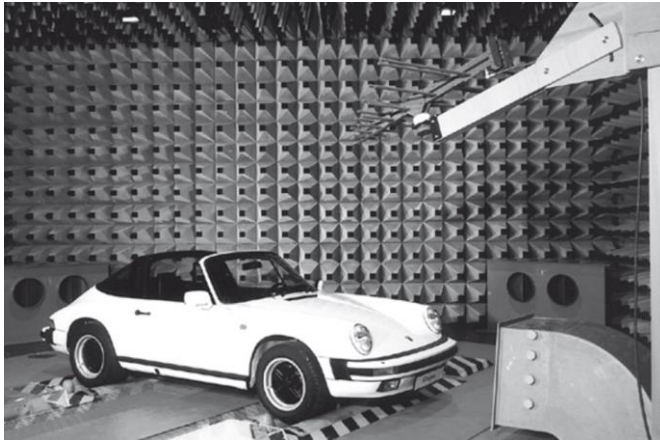
Emission regulation

- Emission test described in CISPR 12
  - limits for wide- and narrow-band values
  - Measured with antennas at 3m and 10m distance
- Resistance to incident radiation
  - Anechoic chamber with absorption materials shielded with metallic casing
  - Chambers are equipped with devices generating high-frequency fields (10kHz to 18Ghz) and field strength up to E=200V/m
- Compliance comfortably achied due to internal radio reception measures



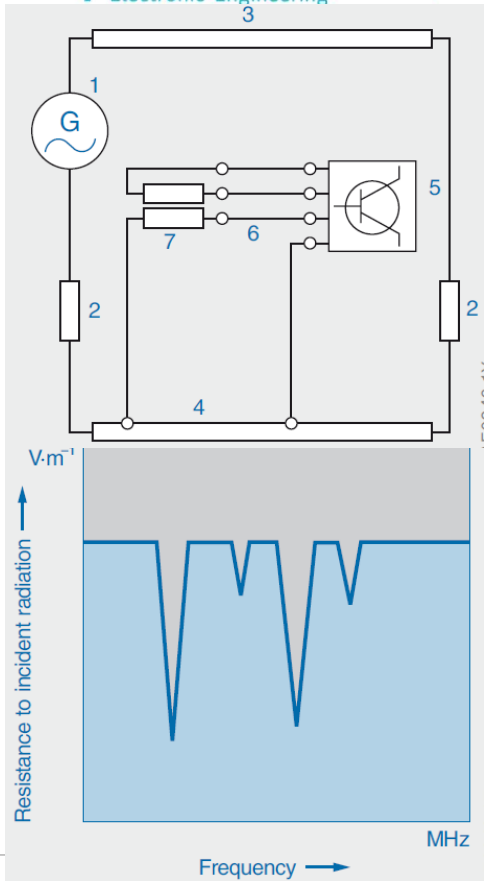
Incident Radiation (Immunity)

- Anecoic chamber with pyramid absorption materials shielded with metallic casing
- Chambers are equipped with devices generating high-frequency fields (10kHz to 18Ghz) and field strength up to E=200V/m
- Operation via remote control (health hazard), video camera monitoring, test decribed in ISO 11452
- Vehicle testing on chassis dynamometer with speed up to 200km/h
- Besides chamber testing there is still on-the road immunity testing in the sourroundings of high-intensity interference (e.g. Tokio tower)
- Additional measurements to support early phase developments: stripline, BCI and TEM



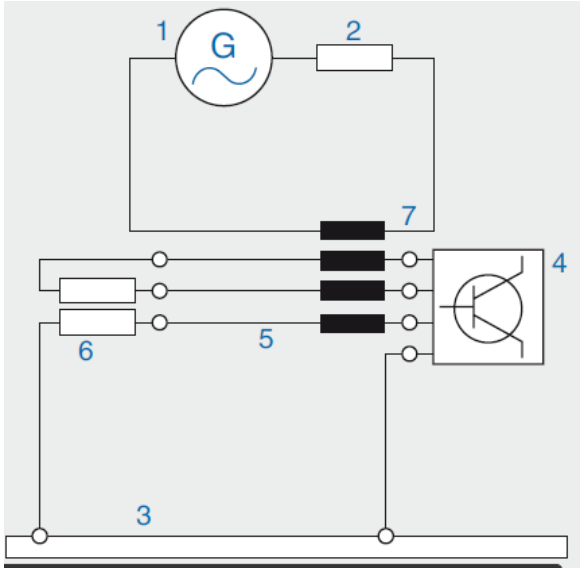
Stripline method

- Typical test setup: ECU , wiring harness (6) and peripherals (sensors and actuators) (7)
- High-frequency alternator (1) as scource of a transverse magnetic wave
- Interference waves through a conductor (3) are coupled into DUT‘s (5) wiring harness
- Conductor in form of a strip (4.1m long and 0.74m wide) 0.15m above the conductive sheet (4), test setup halfway between base and stripline
- Stripline dimensions minimize reflections at constant field-strength amplitudes vs. frequency
- Field strength at given frequencies is increased until malfunction of DUT or maximum level is reached → result is resistance as function of frequency



BCI and TEM cell

- Bulk current injection (BCI) method
  - As with stripline, system is arranged above conductive sheet
  - Current clamp (7) attached to wiring harness (5) injects transformer current into its wires
  - BCI relies on current increases instead of field strength (Stripline)
- Transverse electromagnetic field (TEM) cell
  - TEM is generated between strip conductor and enclosed counter-electrode
  - Therefore, TEM test benches do not need specially shielded chambers



Summary: Automotive EMC Standards

- Comité International Spécial des Perturbations Radioélectriques (CISPR)
  - English: International Special Committee on Radio Interference
  - Part of the International Electrotechnical Commission (IEC)

- Homologation
  - Regulation on radio interference suppression ECE-R 10
  - Compliance comfortably achied due to internal radio reception measures

Most important Test Standards:

- CISPR 25 – Component Level Emissions
- CISPR 12 – Vehicle Level Emissions
- ISO 11452 – Component Immunity (ALSE, TEM, stripline, BCI, direct injection)
- ISO 11451 – Vehicle Immunity
- ISO 10605 – Electrostatic discharge
- ISO 7637 - Transient immunity (impulses)

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