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Also of interest to the following committees Intéresse également les comités suivants CISPR/A, TC69	Supersedes document Remplace le document CISPR/D/419/CD, CISPR/D/424/CC

Proposed horizontal standard
Norme horizontale suggérée

☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the TC/SC secretary
Les autres CE/SC sont requis d'indiquer leur intérêt, si nécessaire, dans ce CDV à l'intention du secrétaire du CE/SC

Functions concerned
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☐ Safety Sécurité	☒ EMC CEM	☐ Environment Environnement	☐ Quality assurance Assurance qualité

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Titre : CISPR 25: Véhicules, bateaux et moteurs á combustion interne - Caractéristique des pertubations radioélectriques - Limites et méthodes de mesure pour la protection des récepteurs embarqués

Title : CISPR 25: Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers

Introductory note

This draft contains test methods for vehicles in charging mode as well as specific methods needed to test components for a shielded high voltage board net as used in electric and hybrid electric vehicles.

It also contains the results of the CISPR/D-CISPR/A-project on chamber validation for ALSEs used for component testing.

*__IEC CO Note:__ Please be informed that an "A" version of the CDV is circulated due to a problem which occurred in the document during the pdf conversion with some figures and the formatting of the document. The closing date for voting remains unchanged.

ATTENTION **VOTE PARALLÈLE** **IEC – CENELEC** L'attention des Comités nationaux de l'IEC, membres du CENELEC, est attirée sur le fait que ce projet de comité pour vote (CDV) de Norme internationale est soumis au vote parallèle. Les membres du CENELEC sont invités à voter via le système de vote en ligne du CENELEC.	**ATTENTION** **IEC – CENELEC** **PARALLEL VOTING** The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) for an International Standard is submitted for parallel voting. The CENELEC members are invited to vote through the CENELEC online voting system.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

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VEHICLES, BOATS AND INTERNAL COMBUSTION ENGINES – RADIO DISTURBANCE CHARACTERISTICS – LIMITS AND METHODS OF MEASUREMENT FOR THE PROTECTION OF ON-BOARD RECEIVERS

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International Standard CISPR 25 has been prepared by CISPR subcommittee D: Electromagnetic disturbances related to electric/electronic equipment on vehicles and internal combustion engine powered devices.

This fourth edition cancels and replaces the third edition published in 2008. This edition constitutes a technical revision.

The following significant changes were made with respect to the previous edition:

- inclusion of charging mode for EV and PHEV,
- overall improvement
- the methods for chamber validation have been included
- test methods for shielded power supply systems for high voltages for electric and hybrid electric vehicles have been included

The text of this standard is based on the following documents:

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The National Committees are requested to note that for this publication the stability date is 2020.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

INTRODUCTION

This International Standard is designed to protect on-board receivers from disturbances produced by conducted and radiated emissions arising in a vehicle.

Test procedures and limits given are intended to provide provisional control of vehicle radiated emissions, as well as component/module conducted/radiated emissions of long and short duration.

To accomplish this end, this standard:

- establishes a test method for measuring the electromagnetic emissions from the electrical system of a vehicle;
- sets limits for the electromagnetic emissions from the electrical system of a vehicle;
- establishes test methods for testing on-board components and modules independent from the vehicle;
- sets limits for electromagnetic emissions from components to prevent objectionable disturbance to on-board receivers;
- classifies automotive components by disturbance duration to establish a range of limits.

NOTE Component tests are not intended to replace vehicle tests. Exact correlation between component and vehicle test performance is dependent on component mounting location, harness length, routing and grounding, as well as antenna location. Component testing, however, permits components to be evaluated prior to actual vehicle availability.

VEHICLES, BOATS AND INTERNAL COMBUSTION ENGINES – RADIO DISTURBANCE CHARACTERISTICS – LIMITS AND METHODS OF MEASUREMENT FOR THE PROTECTION OF ON-BOARD RECEIVERS

1 Scope

This International Standard contains limits and procedures for the measurement of radio disturbances in the frequency range of 150 kHz to 2 500 MHz. The standard applies to any electronic/electrical component intended for use in vehicles, trailers and devices. Refer to International Telecommunications Union (ITU) publications for details of frequency allocations. The limits are intended to provide protection for receivers installed in a vehicle from disturbances produced by components/modules in the same vehicle. The method and limits for a complete vehicle (whether connected to the power mains for charging purposes or not) are in Clause 5 and the methods and limits for components/modules are in Clause 6. Only a complete vehicle test can be used to determine the component compatibility with respect to a vehicle’s limit.

The receiver types to be protected are, for example, broadcast receivers (sound and television), land mobile radio, radio telephone, amateur, citizens' radio, Satellite Navigation (GPS etc.) and Bluetooth. For the purpose of this standard, a vehicle is a machine, which is self-propelled by an internal combustion engine, electric means, or both. Vehicles include (but are not limited to) passenger cars, trucks, agricultural tractors and snowmobiles. Annex A provides guidance in determining whether this standard is applicable to particular equipment.

The limits in this standard are recommended and subject to modification as agreed between the vehicle manufacturer and the component supplier. This standard is also intended to be applied by manufacturers and suppliers of components and equipment which are to be added and connected to the vehicle harness or to an on-board power connector after delivery of the vehicle.

This International Standard does not include protection of electronic control systems from radio frequency (RF) emissions, or from transient or pulse-type voltage fluctuations. These subjects are included in ISO publications.

Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, Clause 6 of this standard defines multiple limit levels. The level class to be used (as a function of frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

CISPR 25 defines test methods for use by Vehicle Manufacturers and Suppliers, to assist in the design of vehicles and components and ensure controlled levels of on-board radio frequency emissions.

Vehicle test limits are provided for guidance and are based on a typical radio receiver using the antenna provided as part of the vehicle, or a test antenna if a unique antenna is not specified. The frequency bands that are defined are not applicable to all regions or countries of the world. For economic reasons, the vehicle manufacturer must be free to identify what frequency bands are applicable in the countries in which a vehicle will be marketed and which radio services are likely to be used in that vehicle.

As an example, many vehicle models will probably not have a television receiver installed; yet the television bands occupy a significant portion of the radio spectrum. Testing and mitigating noise sources in such vehicles is not economically justified.

The vehicle manufacturer should define the countries in which the vehicle is to be marketed, then choose the applicable frequency bands and limits. Component test parameters can then be selected from CISPR 25 to support the chosen marketing plan.

The World Administrative Radio communications Conference (WARC) lower frequency limit in region 1 was reduced to 148,5 kHz in 1979. For vehicular purposes, tests at 150 kHz are considered adequate. For the purposes of this standard, test frequency ranges have been generalized to cover radio services in various parts of the world. Protection of radio reception at adjacent frequencies can be expected in most cases.

Annex E defines artificial networks used for the measurement of conducted disturbances and for tests on vehicles in charging mode.

Annex H defines a qualitative method of judging the degradation of radio communication in the presence of impulsive noise.

Annex I defines test methods for shielded power supply systems for high voltage networks in electric and hybrid vehicles.

Annex J defines methods for the validation of the ALSE and the reference ground plane used for component testing.

Annex K lists work being considered for future revisions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*
Amendment 1 (1997)
Amendment 2 (1998)
Amendment 3 (2014)
Amendment 4 (2014)

CISPR 12:2009, *Vehicles, motorboats, and internal combustion engine-driven devices – Radio disturbance characteristics - Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices*

CISPR 16-1-1:2010, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*
Amendment 1 (2010)
Amendment 2 (2014)

CISPR 16-1-2:2014, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Conducted disturbances*

CISPR 16-1-4:2010, Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Radiated disturbances
Amendment 1 (2012)

CISPR 16-2-1:2014, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-1: Methods of measurement of disturbances and immunity - Conducted disturbance measurements*

CISPR 16-2-3:2010, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements*
Amendment 1 (2010)
Amendment 2 (2014)

ISO 11452-4:2011, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Bulk current injection (BCI)*

SAE ARP 958.1 Rev D: 2003-02 - Electromagnetic Interference Measurement Antennas; Standard Calibration Method

3 Definitions

For the purpose of this International Standard, the following definitions apply.

3.1
absorber lined shielded enclosure (ALSE)
shielded enclosure/screened room with radio frequency-absorbing material on its internal ceiling and walls

3.2
antenna factor
the factor which is applied to the voltage measured at the input connector of the measuring instrument to give the field strength at the antenna

3.3
antenna matching unit
a unit for matching the impedance of an antenna to that of the 50 Ω measuring instrument over the antenna measuring frequency range

3.4
class
a performance level agreed upon by the purchaser and the supplier and documented in the test plan

3.5
component continuous conducted emissions
the noise voltages/currents of a steady-state nature existing on the supply or other leads of a component/module which may cause disturbance to reception in an on-board receiver

3.6
compression point
the input signal level at which the gain of the measuring system becomes non-linear such that the indicated output deviates from an ideal linear receiving system's output by the specified increment in dB

3.7
device
a machine driven by an internal combustion engine which is not primarily intended to carry persons or goods

Note **devices** include, but are not limited to, chainsaws, irrigation pumps, snow blowers, air compressors, and landscaping equipment.

3.8
receiver terminal voltage (antenna voltage)
the voltage generated by a source of radio disturbance and measured in dB(μV) by a radio disturbance measuring instrument conforming to the requirements of CISPR 16

3.9
RF boundary
an element of an EMC test setup that determines what part of the harness and/or peripherals are included in the RF environment and what is excluded. It may consist of, for example, ANs, filter feed-through pins, RF absorber coated wire, and/or RF shielding.

3.10
artificial network (AN)
a network inserted in the supply lead or signal/load lead of apparatus to be tested which provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages and which may isolate the apparatus from the supply or signal sources/loads in that frequency range

Note network inserted in the d.c power lines of the vehicle in charging mode which provides, in a given frequency range, a specified load impedance and which isolates the vehicle from the d.c power supply in that frequency range"

3.11
average detector
a detector, the output voltage of which is the average value of the envelope of an applied signal

Note The average value must be taken over a specified time interval.

[IEV 161-04-26]

3.12
bandwidth

bandwidth (of an equipment)
the width of a frequency band over which a given characteristic of an equipment or transmission channel does not differ from its reference value by more than a specified amount or ratio

Note The given characteristic may be, for example, the amplitude/frequency characteristic, the phase/frequency characteristic or the delay/frequency characteristic.

[IEV 161-06-09, modified]

bandwidth (of an emission or signal)
the width of the frequency band outside which the level of any spectral component does not exceed a specified percentage of a reference level

[IEV 161-06-10]

3.13
broadband emission
an *emission* which has a *bandwidth* greater than that of a particular measuring apparatus or receiver

Note An emission which has a pulse repetition rate (in Hz) less than the bandwidth of a particular measuring instrument can also be considered as a broadband emission.

[IEV 161-06-11, modified]

3.14
disturbance suppression
action which reduces or eliminates *electromagnetic disturbance*

[IEV 161-03-22]

3.15
disturbance voltage; interference voltage (deprecated in this sense)
voltage produced between two points on two separate conductors by an *electromagnetic disturbance*, measured under specified conditions

[IEV 161-04-01]

3.16
electromagnetic environment
the totality of electromagnetic phenomena existing at a given location

[IEV 161-01-01]

3.17
reference ground plane
a flat conductive surface whose potential is used as a common reference.

Note For the purpose of this standard, the reference ground plane is defined as the top metallic surface of the test bench/table.

[IEV 161-04-36]

3.18
narrowband emission
an *emission* which has a *bandwidth* less than that of a particular measuring apparatus or receiver

Note An emission which has a pulse repetition rate (in Hz) greater than the bandwidth of a particular measuring instrument can also be considered as a narrowband emission.

[IEV 161-06-13]

3.19
peak detector
a detector, the output voltage of which is the peak value of an applied signal

[IEV 161-04-24]

3.20
quasi-peak detector
a detector having specified *electrical time constants* which, when regularly repeated identical *pulses* are applied to it, delivers an output voltage which is a fraction of the peak value of the pulses, the fraction increasing towards unity as the pulse repetition rate is increased

[IEV 161-04-21]

3.21
shielded enclosure; screened room
a mesh or sheet metallic housing designed expressly for the purpose of electromagnetically separating the internal and the external environment

[IEV 161-04-37]

3.22
validation reference ground plane
an elevated reference ground plane with the dimensions of 2,5 m x 1 m which is used as the standard for the reference measurements/modelling per Annex J. The validation reference ground plane size and grounding used during the reference measurements and/or modelling may be different than what a laboratory would use during EUT measurements.

3.23
artificial mains network (AMN)
provides a defined impedance to the EUT at radio frequencies, couples the disturbance voltage to the measuring receiver and decouples the test circuit from the supply mains. There are two basic types of AMN, the V-network (V-AMN) which couples the unsymmetrical voltages, and the delta-network which couples the symmetric and the asymmetric voltages separately. The terms line impedance stabilization network (LISN) and V-AMN are used

Note network inserted in the power mains of the vehicle in charging mode or of a component (e.g. charger) which provides, in a given frequency range, a specified load impedance and which isolates the vehicle /component from the power mains in that frequency range”

3.24
Asymmetric artificial network (AAN)
network used to measure (or inject) asymmetric (common mode) voltages on unshielded symmetric signal (e.g. telecommunication) lines while rejecting the symmetric (differential mode) signal

Note This network is inserted in the communication/signal lines of the vehicle in charging mode or of a component (e.g. charger) to provide a specific load impedance and/or a decoupling (e.g. between telecommunication signal and power main)

3.25
measurement time
the effective, coherent time for a measurement result at a single frequency

- for the peak detector, the effective time to detect the maximum of the signal envelope,
- for the quasi-peak detector, the effective time to measure the maximum of the weighted envelope
- for the average detector, the effective time to average the signal envelope

3.26
bonded (ground connection and d.c. resistance)
when the term “bonded” is used to describe a grounding connection within this standard, the purpose of the bonding is to provide the lowest possible impedance (resistance and inductance) connection between two metallic parts (see 5.3 of CISPR 16-2-1). The d.c. resistance of this connection shall not exceed 2,5 mΩ.

Note A low current (≤100 mA) 4-wire milliohm meter is recommended for this measurements

3.27
low voltage (LV)
operating d.c. voltage below 60 V, e.g. nominal voltages of 12 V, 24 V or 48 V

Note The term low voltage may be defined with a different voltage range in other standards.

3.28
high voltage (HV)
operating voltage between 60 V to 1 000 V.

Note The term low voltage may be defined with a different voltage range in other standards.

4 Requirements common to vehicle and component/module emissions measurement

4.1 General test requirements and test plan

4.1.1 Categories of disturbance sources (as applied in the test plan)

Electromagnetic disturbance sources can be divided into two main types:

- Narrowband sources (examples of narrowband disturbance sources are vehicle electronic components which include clocks, oscillators, digital logic from microprocessors and displays)
- Broadband sources (examples of broadband disturbance sources are electrical motors and ignition system)

Note 1 While most vehicle or electrical/electronic components are a source of both narrowband and broadband disturbances, some may be a source of only one type of disturbance.

Note 2 Broadband sources can be classified in short-duration broadband (examples are washer pump, door mirror, electrical windows) and long-duration broadband (examples are front wiper motor, heater blower, engine cooling)

For the purposes of this standard, categorization of the disturbance type is used only in simplifying the testing demands by potentially reducing the number of detectors that must be used (i.e. eliminating the average detector if the device is known to be broadband-type of source, such as a d.c. brush commutated motor). Otherwise, this standard requires that sources comply with limits based upon both types of measurement detectors and not the type of disturbance.

4.1.2 Test plan

A test plan shall be established for each item to be tested. The test plan shall specify the

- frequency range to be tested,
- the emissions limits,
- antenna types and locations,
- test report requirements,
- supply voltage and other relevant parameters.

The test plan shall define for each frequency band whether the conformance can be obtained with average and peak limits or with average and quasi-peak limits.

4.1.3 Determination of conformance of equipment under test (EUT) with limits

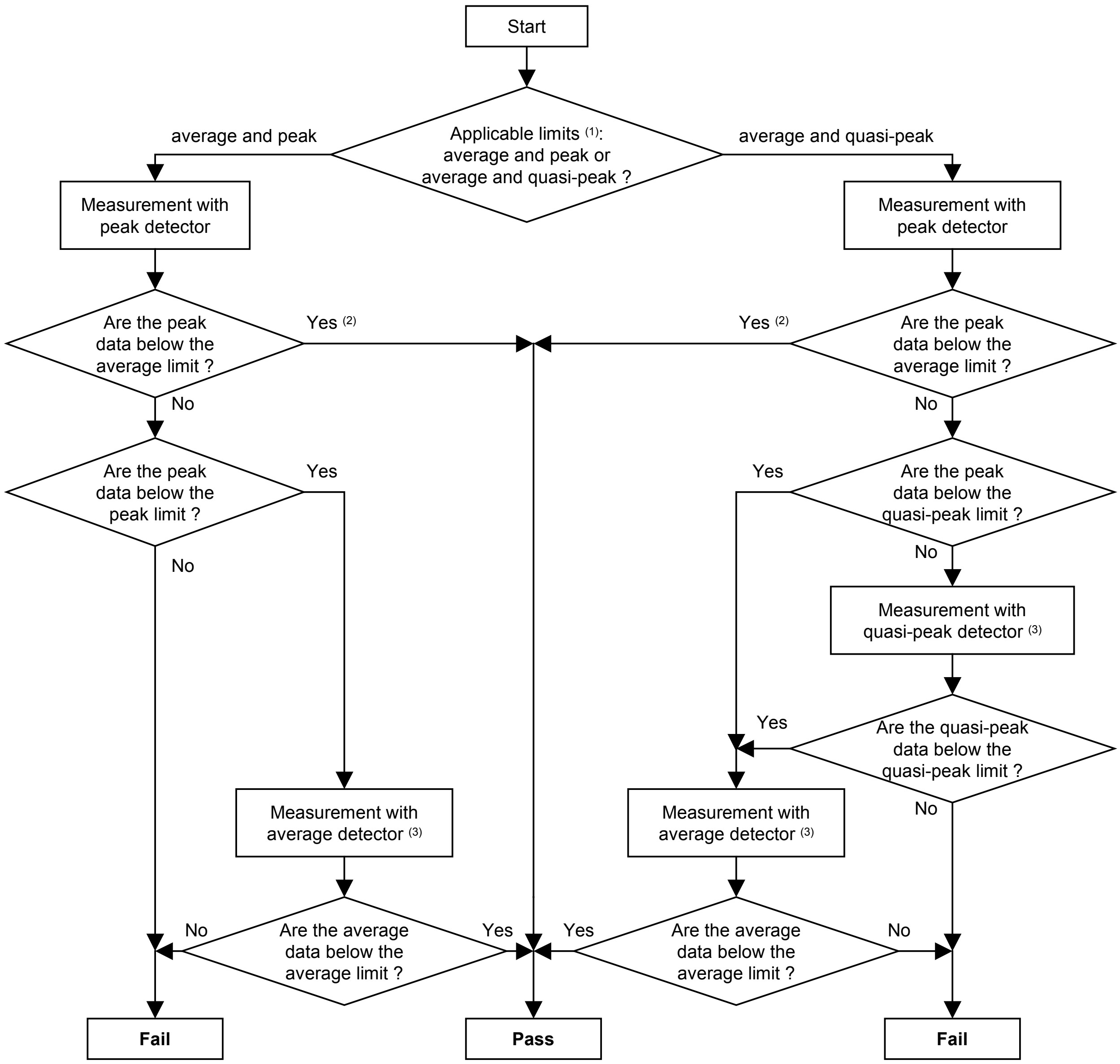
In all cases the EUT shall conform with the average limit.

The EUT shall also conform with either peak or quasi-peaks limits as follows.

- For frequencies where both peak and quasi-peak limits are defined, the EUT shall conform with either the peak or the quasi-peak limits (as defined in the test plan).
- For frequencies where only peak limits are defined, the EUT shall conform with the peak limit.

The general procedure applicable for all frequency bands is described in Figure 1.

The limits given in this standard take into account uncertainties.



Note 1 The conformance should normally be obtained by compliance to both average and peak limits or both average and quasi-peak limits, unless the test plan defines that conformance can be obtained by compliance to the single appropriate limit. *(depending on the case, peak, or average, or quasi-peak).*

Note 2 Because measurements with a peak detector are always higher than or equal to measurements with an average detector and the applicable peak limit is always higher than or equal to the applicable average limit, this single detector measurement can lead to a simplified and quicker conformance process.

Note 3 This flow-chart is applicable for each individual frequency, e.g. only frequencies that are above the applicable limit need to be remeasured with average or quasi-peak detector.

Figure 1 – Method of determination of conformance for all frequency bands

4.1.4 Operating conditions

Different operating conditions of the EUT can influence emission measurement results. When performing component/module tests, the EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. The operating conditions shall be specified in the test plan.

To ensure correct operation of components/modules during test, a peripheral interface unit shall be used which simulates the vehicle installation. Depending on the intended operating modes, all significant sensor and actuator leads of the EUT shall be connected to a peripheral interface unit. The peripheral interface unit shall be capable of controlling the EUT in accordance with the test plan.

The peripheral interface unit may be located internal or external to the shielded enclosure. If located in the shielded enclosure, the disturbance levels generated by the peripheral interface unit shall be at least 6 dB below the test limits specified in the test plan.

4.1.5 Test report

The report shall contain the information agreed upon by the customer and the supplier, e.g.

- sample identification,
- date and time of test,
- bandwidth,
- step size,
- required test limit,
- ambient data and test data.

4.2 Shielded enclosure

The ambient electromagnetic noise levels shall be at least 6 dB below the limits specified in the test plan for each test to be performed. The shielding effectiveness of the shielded enclosure shall be sufficient to assure that the required ambient electromagnetic noise level requirement is met.

NOTE Although there will be reflected energy from the interior surfaces of the shielded enclosure, this is of minimal concern for the measurement of conducted disturbances because of the direct coupling of the measuring instrument to the leads of the EUT. The shielded enclosure may be as simple as a suitably grounded bench-top screened cage.

4.3 Absorber-lined shielded enclosure (ALSE)

For radiated emission measurements, however the reflected energy can cause errors of as much as 20 dB. Therefore, it is necessary to apply RF absorber material to the walls and ceiling of a shielded enclosure that is to be used for radiated emission measurements. No absorber shall be placed on the floor for vehicle tests. For component testing, no absorber shall be placed on the floor, however, flat ferrite tiles with a maximum thickness of 25 mm may be utilised on the floor for component level testing if the chamber performance in this configuration meets the requirements of Annex J.

The following ALSE requirements shall also be met for performing radiated RF emissions measurements.

4.3.1 Size

For radiated emissions tests, the shielded enclosure shall be of sufficient size to ensure that neither the vehicle/EUT nor the test antenna shall be closer than 1 m from the walls or ceiling, or to the nearest surface of the absorber material used thereon.

4.3.2 Objects in ALSE

For radiated emissions measurements in particular, the ALSE shall be cleared of all items not pertinent to the tests. This is required in order to reduce any effect they may have on the measurement. Included are unnecessary equipment, cable racks, storage cabinets, desks, chairs, etc. Personnel not actively involved in the test shall be excluded from the ALSE.

4.3.3 ALSE performance validation

4.3.3.1 Vehicle ALSE

Performance of the absorption material shall be greater than or equal to 6 dB in the 70 MHz to 2 500 MHz frequency range.

Note 1 A test method is described in IEEE STD 1128-1998: IEEE recommended practice for radio frequency (RF) absorber – Evaluation in the range of 30 MHz to 5 GHz."

4.3.3.2 Component ALSE

Performance of the absorption material shall be greater than or equal to 6 dB in the 70 MHz to 2 500 MHz frequency range.

Note 1 A test method is described in IEEE STD 1128-1998: IEEE recommended practice for radio frequency (RF) absorber – Evaluation in the range of 30 MHz to 5 GHz."

Note 2 Additionally, it is recommended that the ALSE Performance Validation procedure described in Annex J be used to evaluate the performance of the shielded enclosure as configured for Clause 6.5 component radiated emissions testing. This performance verification procedure will evaluate the influences of the chamber, absorber, ground plane, ground plane grounding, and any other possible cause for measurement variation

4.4 Measuring instrument

The measuring instrument shall comply with the requirements of CISPR 16-1-1. Either manual or automatic frequency scanning may be used.

For the limits given in CISPR 25 the appropriate average detector is the linear detector with meter time constants defined in CISPR 16-1-1.

Note 1 Spectrum analysers and scanning receivers are particularly useful for disturbance measurements. The peak detection mode of spectrum analysers and scanning receivers provides a display indication which is never less than the quasi-peak indication for the same bandwidth. It may be convenient to measure emissions using peak detection because of the faster scan possible than with quasi-peak detection.

Note 2 A preamplifier may be used between the antenna and measuring instrument in order to achieve the 6 dB ambient noise requirements (see 4.2). If a preamplifier is used to achieve the 6 dB ambient noise requirement, the laboratory should establish a procedure to avoid overload of the preamplifier, such as using a step attenuator.

4.4.1 Spectrum analyser parameters

The scan rate of the spectrum analyser shall be adjusted for the CISPR frequency band and detection mode used.

Spectrum analysers may be used for performing compliance measurements to this standard providing the precautions cited in CISPR 16-1-1 on the use of spectrum analysers are adhered to and that the broadband emissions from the product being tested have a repetition frequency greater than 20 Hz.

The minimum scan time in Table 1 is applicable only for the measurement of emissions where the pulse repetition interval of the signal is shorter than the minimum observation time at each frequency based on a step size equal to half of the resolution bandwidth B_{res}. For the measurement of signals with a pulse repetition interval longer than the minimum observation time and for the measurement of intermittent signals the minimum scan time has to be increased.

If the pulse repetition interval of the signal is known the scan shall be performed with a scan time that allows an observation time at each frequency that is longer than the reciprocal of the pulse repetition frequency of the signal.

As alternative multiple faster scans with the use of a maximum hold function may be used if the total scanning time is equal to or greater than the time that would have been spent using the minimum scan time defined in Table 1. The following equation can be used to calculate the minimum scan time for multiple scans.

$$T_{s,\mathrm{min}} = 2 \times \frac{\Delta f}{B_{res}} \qquad (1)$$

where

$T_{s,min}$ is the minimum scan time for multiple scans,

Δf is the frequency span,

B_{res} is the resolution bandwidth.

For further guidance on the measurement of the duration of disturbance and the determination of the minimum scan time see CISPR 16-2-1 and CISPR 16-2-3.

4.4.2 Scanning receiver parameters

The dwell time of the scanning receiver shall be adjusted for the CISPR frequency band and detection mode used. The minimum measurement time, maximum step size and recommended bandwidth (BW) are listed in Table 2.

The minimum measurement time in Table 2 is applicable only for the measurement of emissions where the pulse repetition interval of the signal is shorter than the minimum measurement time in Table 2. For the measurement of signals with a pulse repetition interval longer than the minimum measurement time in Table 2 and for the measurement if intermittent signals the minimum measurement time has to be increased.

If the pulse repetition interval of the signal is known the scan shall be performed with a measurement time that is longer than the reciprocal of the pulse repetition frequency of the signal.

For further guidance on the measurement of the duration of disturbance and the determination of the minimum measurement time see CISPR 16-2-1 and CISPR 16-2-3.

Table 1 – Spectrum analyser parameters

Service / Band	Frequency MHz	Peak detection		Quasi-peak detection		Average detection	
		RBW at -3 dB	Min. scan time	RBW at -6 dB	Min. scan time	RBW at -3 dB	Min. scan time
BROADCAST							
LW	0,15 - 0,30	9 or 10 kHz	10 s / MHz	9 kHz	200 s / MHz	9 or 10 kHz	10 s / MHz
MW	0,53 - 1,8						
SW	5,9 - 6,2						
FM	76 - 108	100 or 120 kHz	100 ms / MHz	120 kHz	20 s / MHz	100 or 120 kHz	100 ms / MHz
TV Band I	41 - 88						
TV Band III	174 - 230						
DAB III	171 - 245						
TV Band IV/V	468 - 944						
DTTV	470 - 770	100 or 120 kHz	100 ms / MHz	Does not apply	Does not apply	100 or 120 kHz	100 ms / MHz
DAB L band	1 447 – 1 494						
SDARS	2 320 – 2 345						
MOBILE SERVICES							
CB	26 - 28	9 or 10 kHz	10 s / MHz	9 kHz	200 s / MHz	9 or 10 kHz	10 s / MHz
VHF	30 - 54	100 or 120 kHz	100 ms / MHz	120 kHz	20 s / MHz	100 or 120 kHz	100 ms / MHz
VHF	68 - 87						
VHF	142 -175						
Analogue UHF	380 - 512						
RKE	300 - 330						
RKE	420 - 450						
Analogue UHF	820 - 960						
GSM 800	860 - 895						
EGSM/GSM 900	925 - 960						
GPS L1 civil	1 567 – 1 583	Does not apply	Does not apply	Does not apply	Does not apply	9 or 10 kHz	1 s / MHz
GLONASS L1	1 591 – 1 613						
GSM 1800 (PCN)	1 803 – 1 882	100 or 120 kHz	100 ms / MHz	Does not apply	Does not apply	100 or 120 kHz	100 ms / MHz
GSM 1900	1 850 – 1 990						
3G / IMT 2000	1 900 – 1 992						
3G / IMT 2000	2 010 – 2 025						
3G / IMT 2000	2 108 – 2 172						
Bluetooth/802.11	2 400 – 2 500						

When a spectrum analyser is used for measurements, the video bandwidth shall be at least three times the resolution bandwidth (RBW).

<table>
<tr><th rowspan="2">Service / Band</th><th rowspan="2">Frequency
MHz</th><th colspan="3">Peak detection</th><th colspan="3">Quasi-peak detection</th><th colspan="3">Average detection</th></tr>
<tr><th>BW at -6 dB</th><th>Step size</th><th>Min. measurement time</th><th>BW at -6 dB</th><th>Step size</th><th>Min. measurement time</th><th>BW at -6 dB</th><th>Step size</th><th>Min. measurement time</th></tr>
<tr><td>BROADCAST</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>LW</td><td>0,15 - 0,30</td><td rowspan="3">9 kHz</td><td rowspan="3">5 kHz</td><td rowspan="3">50 ms</td><td rowspan="3">9 kHz</td><td rowspan="3">5 kHz</td><td rowspan="3">1 s</td><td rowspan="3">9 kHz</td><td rowspan="3">5 kHz</td><td rowspan="3">50 ms</td></tr>
<tr><td>MW</td><td>0,53 - 1,8</td></tr>
<tr><td>SW</td><td>5,9 - 6,2</td></tr>
<tr><td>FM</td><td>76 - 108</td><td rowspan="5">120 kHz</td><td rowspan="5">50 kHz</td><td rowspan="5">5 ms</td><td rowspan="5">120 kHz</td><td rowspan="5">50 kHz</td><td rowspan="5">1 s</td><td rowspan="5">120 kHz</td><td rowspan="5">50 kHz</td><td rowspan="5">5 ms</td></tr>
<tr><td>TV Band I</td><td>41 - 88</td></tr>
<tr><td>TV Band III</td><td>174 - 230</td></tr>
<tr><td>DAB III</td><td>171 - 245</td></tr>
<tr><td>TV Band IV/V</td><td>468 - 944</td></tr>
<tr><td>DTTV</td><td>470 - 770</td><td rowspan="3">120 kHz</td><td rowspan="3">50 kHz</td><td rowspan="3">5 ms</td><td rowspan="3">Does not apply</td><td rowspan="3">Does not apply</td><td rowspan="3">Does not apply</td><td rowspan="3">120 kHz</td><td rowspan="3">50 kHz</td><td rowspan="3">5 ms</td></tr>
<tr><td>DAB L band</td><td>1 447 – 1 494</td></tr>
<tr><td>SDARS</td><td>2 320 – 2 345</td></tr>
<tr><td>MOBILE SERVICES</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CB</td><td>26 - 28</td><td>9 kHz</td><td>5 kHz</td><td>50 ms</td><td>9 kHz</td><td>5 kHz</td><td>1 s</td><td>9 kHz</td><td>5 kHz</td><td>50 ms</td></tr>
<tr><td>VHF</td><td>30 - 54</td><td rowspan="10">120 kHz</td><td rowspan="10">50 kHz</td><td rowspan="10">5 ms</td><td rowspan="10">120 kHz</td><td rowspan="10">50 kHz</td><td rowspan="10">1 s</td><td rowspan="10">120 kHz</td><td rowspan="10">50 kHz</td><td rowspan="10">5 ms</td></tr>
<tr><td>VHF</td><td>68 - 87</td></tr>
<tr><td>VHF</td><td>142 -175</td></tr>
<tr><td>Analogue UHF</td><td>380 - 512</td></tr>
<tr><td>RKE</td><td>300 - 330</td></tr>
<tr><td>RKE</td><td>420 - 450</td></tr>
<tr><td>Analogue UHF</td><td>820 - 960</td></tr>
<tr><td>GSM 800</td><td>860 - 895</td></tr>
<tr><td>EGSM/GSM 900</td><td>925 - 960</td></tr>
<tr><td>GPS L1 civil</td><td>1 567 – 1 583</td><td rowspan="2">Does not apply</td><td rowspan="2">Does not apply</td><td rowspan="2">Does not apply</td><td rowspan="2">Does not apply</td><td rowspan="2">Does not apply</td><td rowspan="2">Does not apply</td><td rowspan="2">9 kHz</td><td rowspan="2">5 kHz</td><td rowspan="2">5 ms</td></tr>
<tr><td>GLONASS L1</td><td>1 591 – 1 613</td></tr>
<tr><td>GSM 1800 (PCN)</td><td>1 803 – 1 882</td><td rowspan="6">120 kHz</td><td rowspan="6">50 kHz</td><td rowspan="6">5 ms</td><td rowspan="6">Does not apply</td><td rowspan="6">Does not apply</td><td rowspan="6">Does not apply</td><td rowspan="6">120 kHz</td><td rowspan="6">50 kHz</td><td rowspan="6">5 ms</td></tr>
<tr><td>GSM 1900</td><td>1 850 – 1 990</td></tr>
<tr><td>3G / IMT 2000</td><td>1 900 – 1 992</td></tr>
<tr><td>3G / IMT 2000</td><td>2 010 – 2 025</td></tr>
<tr><td>3G / IMT 2000</td><td>2 108 – 2 172</td></tr>
<tr><td>Bluetooth/802.11</td><td>2 400 – 2 500</td></tr>
</table>

Note For emissions generated by brush commutator motors without an electronic control unit, the maximum step size may be increased up to 5 times the bandwidth

Table 2 – Scanning receiver parameters

4.5 Power supply

The power supply shall have adequate regulation to maintain the supply voltage U_s within the ranges specified:

Vehicle tests: Ignition on, engine off

The vehicle battery voltage shall be recorded before and after the measurement with ignition off and battery disconnected from the vehicle electrical network. The values shall be within the following values:

$$U_s = \left(12^{+2}_{-1}\right) \text{V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(24^{+4}_{-2}\right) \text{V for systems with 24 V nominal supply voltage}$$

Vehicle tests: Engine running

The vehicle battery voltage shall be recorded before and after the measurement with engine running in idle mode and battery connected to the vehicle electrical network. The values shall be within the following values:

$$U_s = \left(13^{+3}_{-0}\right) \text{V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(26^{+6}_{-0}\right) \text{V for systems with 24 V nominal supply voltage}$$

NOTE Most of the vehicle tests will be performed without the engine running, but with the ignition switched on, therefore care must be taken to ensure that the battery is sufficiently well charged. A permanent recording of the battery voltage may be installed during the measurements as a complementary information.

Vehicle tests: Charging mode

The d.c. power supply voltage during the test shall be nominal ±10 %.

The a.c. power supply voltage during the test shall be nominal –15 % / +10 %. The rated value of the frequency shall be nominal ±1 %.

$$U_s = \left(14^{+1}_{-1}\right) \text{V for systems with 12 V nominal supply voltage}$$

$$U_\mathrm{s} = \left(24\,^{+4}_{-2}\right) \text{ V for systems with 24 V nominal supply voltage}$$

Component/module tests:

The d.c. power supply voltage during the test shall be nominal ±10 %.

The a.c. power supply voltage during the test shall be nominal –15 % / +10 %. The rated value of the frequency shall be nominal ±1 %.

Unless otherwise stated in the test plan the values below shall be used.

$$U_\mathrm{s} = \left(13\,^{+1}_{-1}\right) \text{ V for systems with 12 V nominal supply voltage}$$

$$U_\mathrm{s} = \left(26\,^{+2}_{-2}\right) \text{ V for systems with 24 V nominal supply voltage}$$

$$U_\mathrm{s} = \left(48\,^{+4}_{-4}\right) \text{ V for systems with 48 V nominal supply voltage}$$

The power supply shall also be adequately filtered such that the RF noise produced by the power supply is at least 6 dB lower than the limits specified in the test plan.

When specified in the test plan, a vehicle battery shall be connected in parallel with the power supply.

5 Measurement of emissions received by an antenna on the same vehicle

5.1 Antenna measuring system

5.1.1 Type of antenna

An antenna of the type to be supplied with the vehicle shall be used as the measurement antenna for the bands for which it is designed to be used for radio reception.

If no antenna is to be furnished with the vehicle (as is often the case with a mobile radio system), the antenna types in Table 3 shall be used for the test. The antenna type and location shall be included in the test plan.

If an active antenna is used, the noise floor of the measured signal at the radio antenna connector may increase (see also the note in 5.4).

Table 3 – Antenna types

Frequency MHz	**Antenna type**
0,15 to 6,2	1 m monopole

26 to 54	Loaded quarter-wave monopole
68 to 1 000	Quarter-wave monopole
1 000 to 2 500	As recommended by the vehicle manufacturer

5.1.2 Measuring system requirements

5.1.2.1 Broadcast bands

For each band, the measurement shall be made with instrumentation which has the following specified characteristics.

5.1.2.1.1 AM broadcast:

Long wave (0,15 MHz to 0,3 MHz)

Medium wave (0,53 MHz to 1,8 MHz)

Short wave (5,9 MHz to 6,2 MHz)

The measuring system consisting of antenna element, antenna matching unit, coaxial cable(s) and preamplifier, if used, shall have the following characteristics:

– noise floor of the measurement system shall be at least 6 dB lower than the applicable limits.

Antenna matching unit

– input impedance shall have a resistance of at least 100 kΩ in parallel with a maximum capacitance of 10 pF;

– output impedance: 50 Ω resistive;

– gain: The gain (or attenuation) shall be known with an accuracy of ± 0,5 dB. The gain shall remain within a 6 dB envelope for each frequency band as shown in Figure 2. Verification shall be performed in accordance with Annex B;

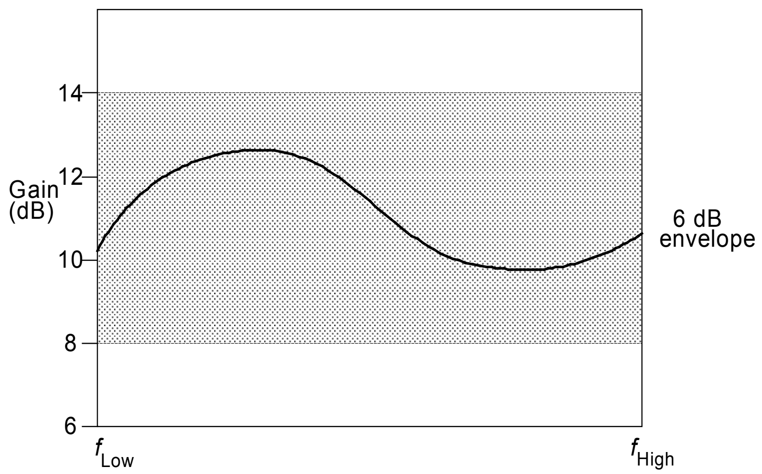


Figure 2 – Example of gain curve

– **compression point**: The 1 dB **compression point** shall occur at a sine wave voltage level (generator output level) greater than 60 dB(μV). Verification shall be performed in accordance with annex B;

5.1.2.1.2 FM broadcast (76 MHz to 108 MHz) and Digital audio and TV broadcast

Measurements shall be taken with a measuring instrument which has an input impedance of 50 Ω. If the voltage standing wave ratio (VSWR) of the antenna is greater than 2:1 an input matching network shall be used. Appropriate correction shall be made for any attenuation/gain of the matching unit.

5.1.2.2 Mobile services (26 MHz to 2 500 MHz)

Measurements shall be taken with a measuring instrument which has an input impedance of 50 Ω. If the voltage standing wave ratio (VSWR) of the antenna is greater than 2:1 an input matching network shall be used. Appropriate correction shall be made for any attenuation/gain of the matching unit.

5.2 Method of measurement

The disturbance voltage shall be measured at the receiver end of the antenna coaxial cable using the ground contact of the connector as reference. The antenna connector shall be grounded to the housing of the on-board radio. The radio housing shall be grounded to the vehicle body using the production harness. A coaxial bulkhead connector shall be used for connection to the measuring instrument outside the shielded room. In the case of an active vehicle antenna, which is fed by the radio via the antenna cable (phantom network), a decoupling network similar to that used in the radio shall be installed at the antenna connector to feed the active antenna from the vehicle supply voltage.

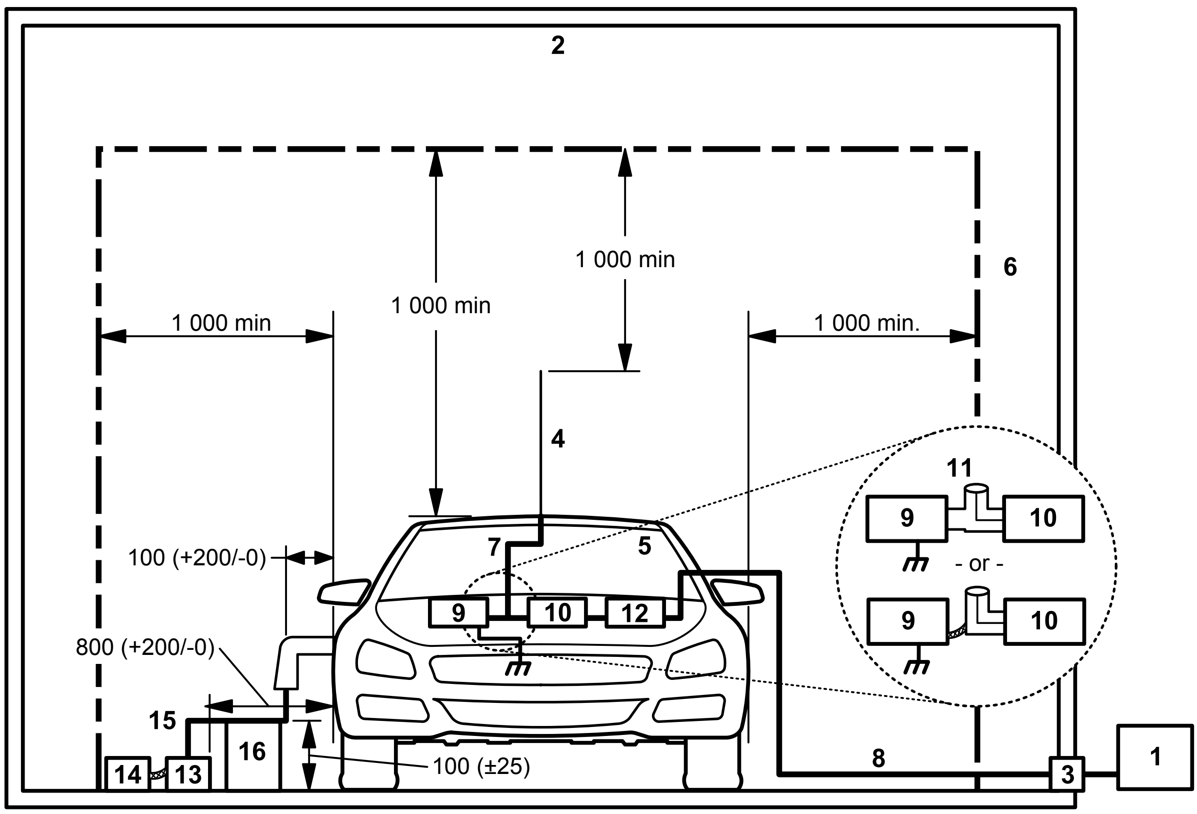
When making measurements in the AM broadcast bands (LW, MW, SW), the vehicle/matching unit ground and ground of the ALSE shall be electrically isolated from each other by means such as an isolation transformer, sheath-current suppressor, battery-powered measurement instrumentation, fiber optics, etc. Appropriate correction shall be made for the insertion loss of any isolation network. (See Annex C for an example of a sheath-current suppressor).

Note The use of a high-quality coaxial cable e.g. double-shielded cable for connection to the measuring instrument is recommended as well as the use of ferrite rings on the cable for suppression of surface currents.

Some vehicles may allow a receiver to be mounted in several locations (e.g. under the instrument panel, under the seat, etc.). In these cases a test shall be carried out as specified in the test plan for each receiver location.

The test setup is described in Figure 3.

Dimensions in mm



Key

1 Measuring instrument
2 ALSE
3 Bulkhead connector
4 Antenna (see 5.1)
5 Vehicle
6 Typical absorber material
7 Antenna coaxial cable
8 High-quality coaxial cable e.g. double-shielded (50 Ω)
9 Housing of on-board radio
10 Impedance matching unit (when required)
11 Modified coaxial "T" connector
12 AM broadcast band ground isolation network (when required)
13 Artificial Mains Network (only for Charging mode configuration)
14 Power mains (only for Charging mode configuration)
15 Charging cable (only for Charging mode configuration)
16 Insulating support (only for Charging mode configuration)

Figure 3 –Vehicle-radiated emissions – Example for test layout (end view with monopole antenna)

5.3 Test setup for vehicle in charging mode

The various configurations (a.c. or d.c., with or without communication) are considered in this clause.

5.3.1 a.c. power charging without communication

5.3.1.1 Power mains

The power mains socket can be placed anywhere in the test location with the following conditions:

- It shall be placed on the reference ground plane.
- The length of the harness between the power mains socket and the AMN(s) shall be kept as short as possible.
- The harness shall be placed on the reference ground plane.

5.3.1.2 Artificial mains network

Power mains shall be applied to the vehicle through 50 µH/50 Ω AMN(s) (see Annex E).

The AMN(s) shall be mounted directly on the reference ground plane. The case of the AMN(s) shall be bonded to the reference ground plane. The d.c. resistance between the ground of the AMN measurement port and the ground plane shall not exceed 2,5 mΩ

The measuring port of each AMN shall be terminated with a 50 Ω load.

The power charging cable shall be placed in a straight line between the AMN(s) and the vehicle charging plug and shall be routed perpendicularly to the vehicle longitudinal axis as shown in Figure 4 and 5.

For vehicles with plug located front/rear of the vehicle, the AMN shall be placed on one side of the vehicle and perpendicularly to the vehicle power charging plug and shall be aligned with the vehicle charging cable.

5.3.1.3 Power charging cable

The power charging cable shall be placed in a straight line between the AMN(s) and the vehicle charging plug. The projected cable length shall be 800 (+200 / -0) mm.

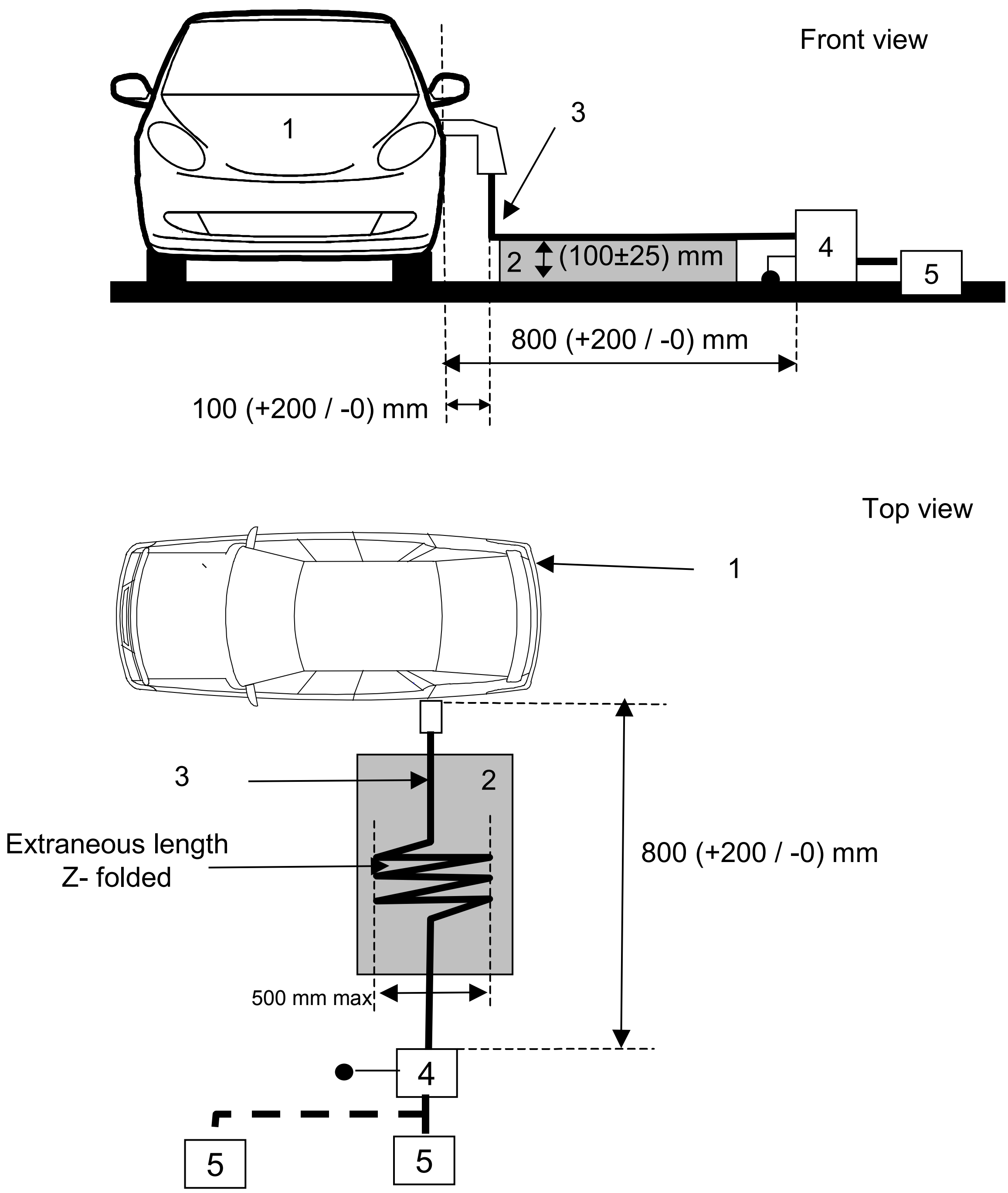
If the length of the cable is longer than 1 m, the extraneous length shall be “Z-folded” in less than 0,5 m width. If it is impractical to do so because of cable bulk or stiffness, or because the testing is being done at a user installation, the disposition of the excess cable shall be precisely noted in the test report.The charging cable at vehicle side shall hang vertically at a distance of 100 (+200 / -0) mm from the vehicle body.

The whole cable shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leq 1,4$), at (100 ± 25) mm above the reference ground plane.

5.3.1.4 Measuring system

The measuring system (receiver, impedance matching unit, cable…) shall be placed as defined in Figure 3.

Examples of test setups are shown in Figures 4 and 5.



Key

1 Vehicle under test

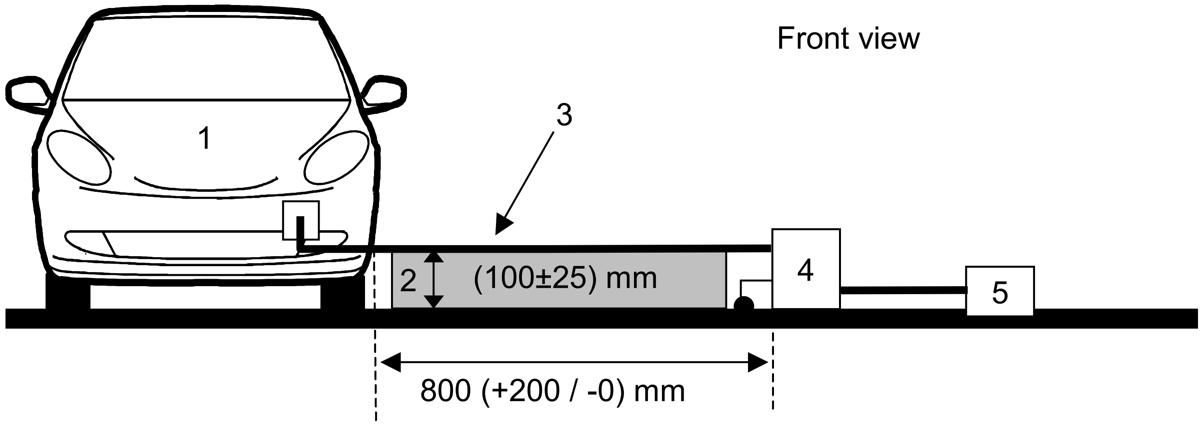
2 Insulating support

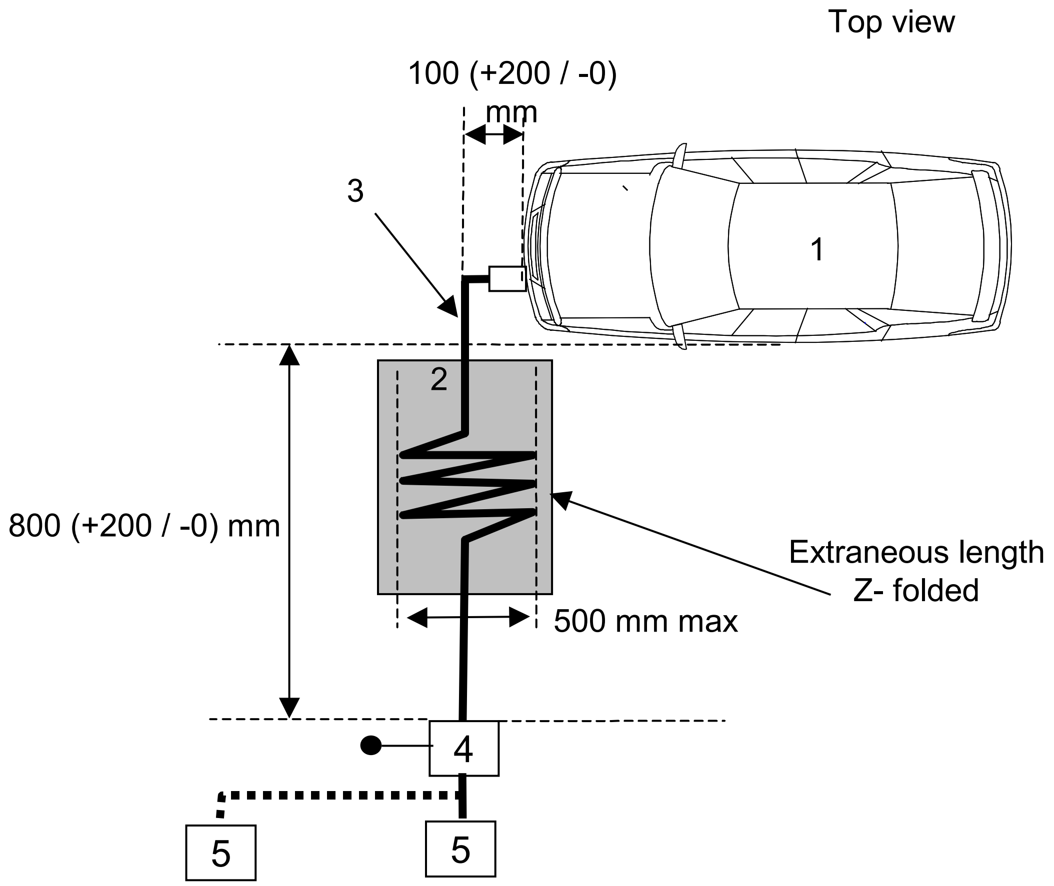
3 Charging cable

4 Artificial Mains Network(s) grounded

5 Power mains socket (see 5.3.1.1, alternative positions shown in the figure)

Figure 4 – Example of test setup for vehicle with plug located on vehicle side (a.c. powered without communication)





Key

1 Vehicle under test

2 Insulating support

3 Charging cable

4 Artificial Mains Network(s) grounded

5 Power mains socket (see 5.3.1.1, alternative positions shown in the figure)

Figure 5 – Example of test setup for vehicle with plug located front / rear of vehicle (a.c. powered without communication)

5.3.2 a.c. or d.c. power charging with communication line(s) or with signal line(s)

5.3.2.1 General

This configuration concerns charging mode for a.c. power and for d.c. power using communications or signal lines.

Note In some cases the lines used for communication between vehicle and charging station cannot be considered as “communication line” (as defined in CISPR 22) but rather as signal lines.

5.3.2.2 Charging station / Power mains

The charging station may be placed either in the test location or outside the test location.

Note If communications between the vehicle and the charging station can be simulated, the charging station may be replaced by the supply from power mains.

In both case duplicated power mains and communication or signal lines socket(s) shall be placed in the test location with the following conditions:

– It shall be placed on the reference ground plane.

– The length of the harness between the power mains / communication or signal lines socket and the AMN(s) / AN(s) / AAN(s) shall be kept as short as possible.

– The harness between the power mains / communication or signal lines socket and the AMN(s) / AN(s) / AAN(s) shall be placed on the reference ground plane.

Note The power mains and communication or signal lines socket(s) should be filtered.

If the charging station is placed inside the test location then harness between charging station and the power mains / communication or signal lines socket shall be placed with the following conditions :

– The harness at charging station side shall hang vertically down to the reference ground plane.

– The extraneous length shall be placed as close as possible of the reference ground plane and “Z-folded” if necessary.

5.3.2.3 Artificial mains networks / artificial networks

A.c. Power mains shall be applied to the vehicle through 50 µH/50 Ω AMN(s) (see Annex E).

D.c. power mains shall be applied to the vehicle through 5 µH/50 Ω High Voltage Artificial Networks (HV-AN(s))”. (see Annex E).

The AMN(s) / HV-AN(s) shall be mounted directly on the reference ground plane. The cases of the AMN(s) / HV-AN(s) shall be bonded to the reference ground plane. The d.c. resistance between the ground of the AMN / HV-AN measurement port and the ground plane shall not exceed 2,5 mΩ

The measuring port of each AMN / HV-AN shall be terminated with a 50 Ω load.

The AMN / HV-AN shall be placed in front, aligned and on the same side of the vehicle power charging plug.

5.3.2.4 Asymmetric artificial network

Communication lines shall be applied to the vehicle through AAN(s) (see Annex E).

Note Signal lines may be applied to the vehicle through AAN(s) (see Annex E).

The AAN(s) shall be mounted directly on the reference ground plane. The case of the AAN(s) shall be bonded to the reference ground plane.

The measuring port of each AAN shall be terminated with a 50 Ω load.

The power charging cable shall be placed in a straight line between the AMN/AAN or HV-AN/AAN and the vehicle charging plug and shall be routed perpendicularly to the vehicle longitudinal axis as shown in Figure 6 and 7.

5.3.2.5 Power charging / communication or signal cable

The power charging / communication or signal cable shall be placed in a straight line between the AMN(s) / HV-AN(s) / AAN(s) and the vehicle charging plug. The projected cable length shall be 0,8 (+0,2 / -0) m.

If the length of the cable is longer than 1 m, the extraneous length shall be “Z-folded” in less than 0,5 m width.

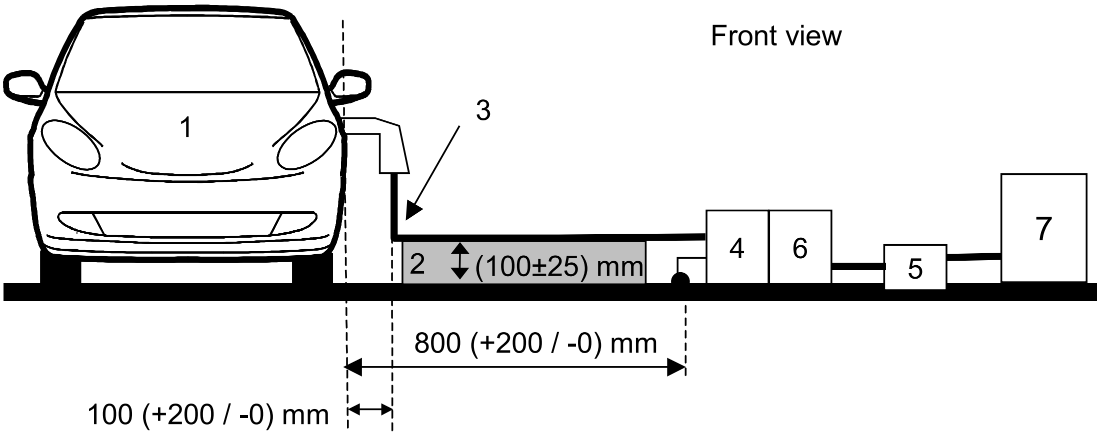
The charging / communication or signal cable at vehicle side shall hang vertically at a distance of 100 (+200 / -0) mm from the vehicle body.

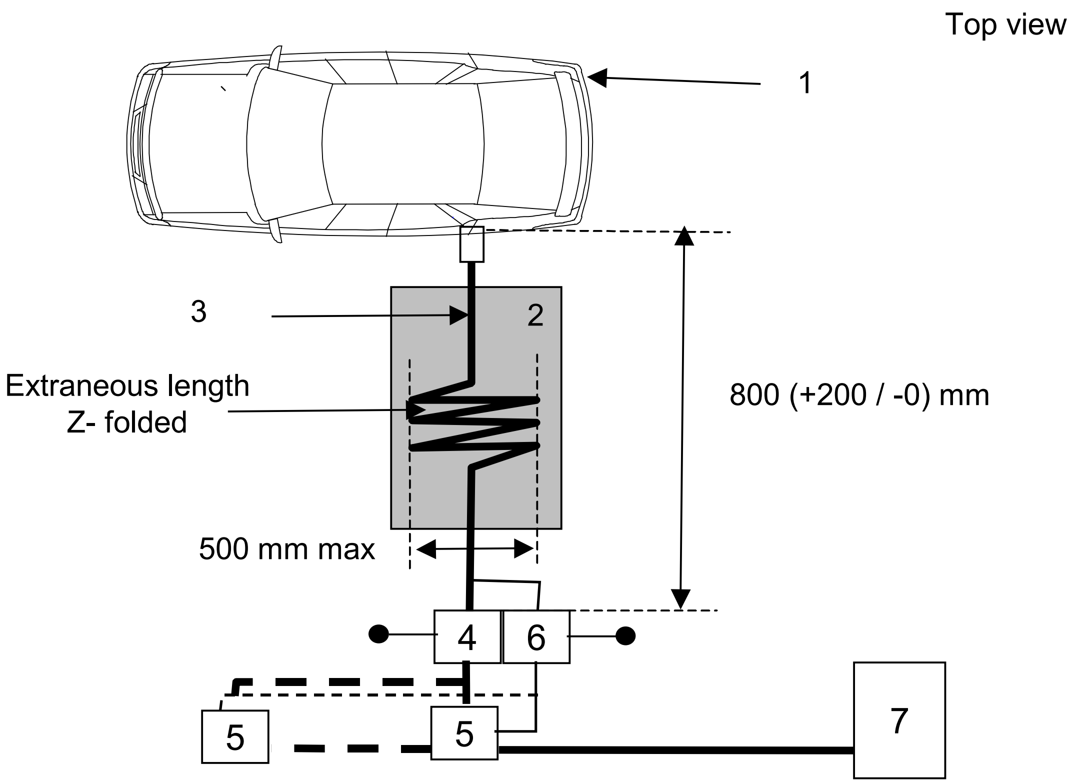
The whole cable shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leq 1,4$), at (100 ± 25) mm above the reference ground plane.

5.3.2.6 Measuring system

The measuring system (receiver, impedance matching unit, cable…) shall be placed as defined in Figure 3

Examples of test setups are shown in Figures 6 and 7.





Key

1 Vehicle under test

2 Insulating support

3 Charging / communication or signal cable

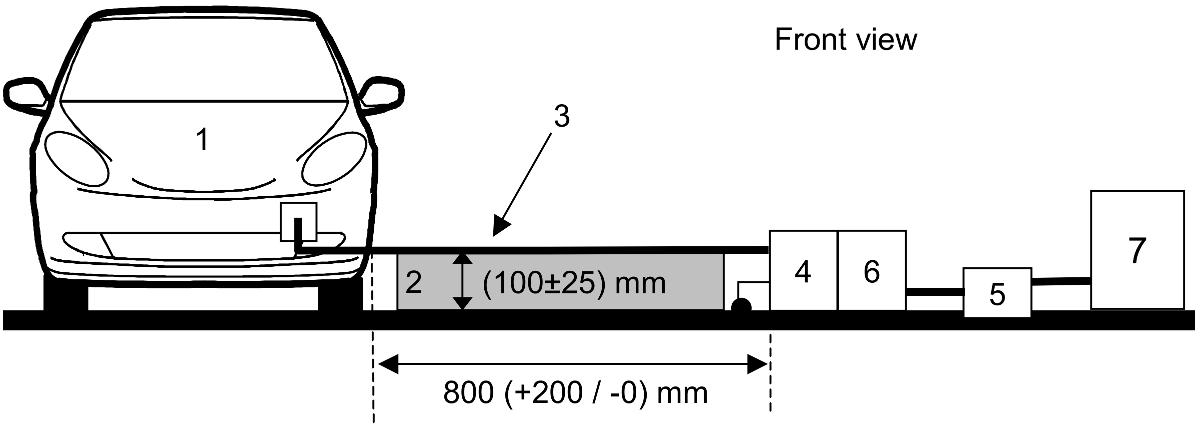
4 a.c.-AMN(s) or d.c. HV-AN(s) grounded

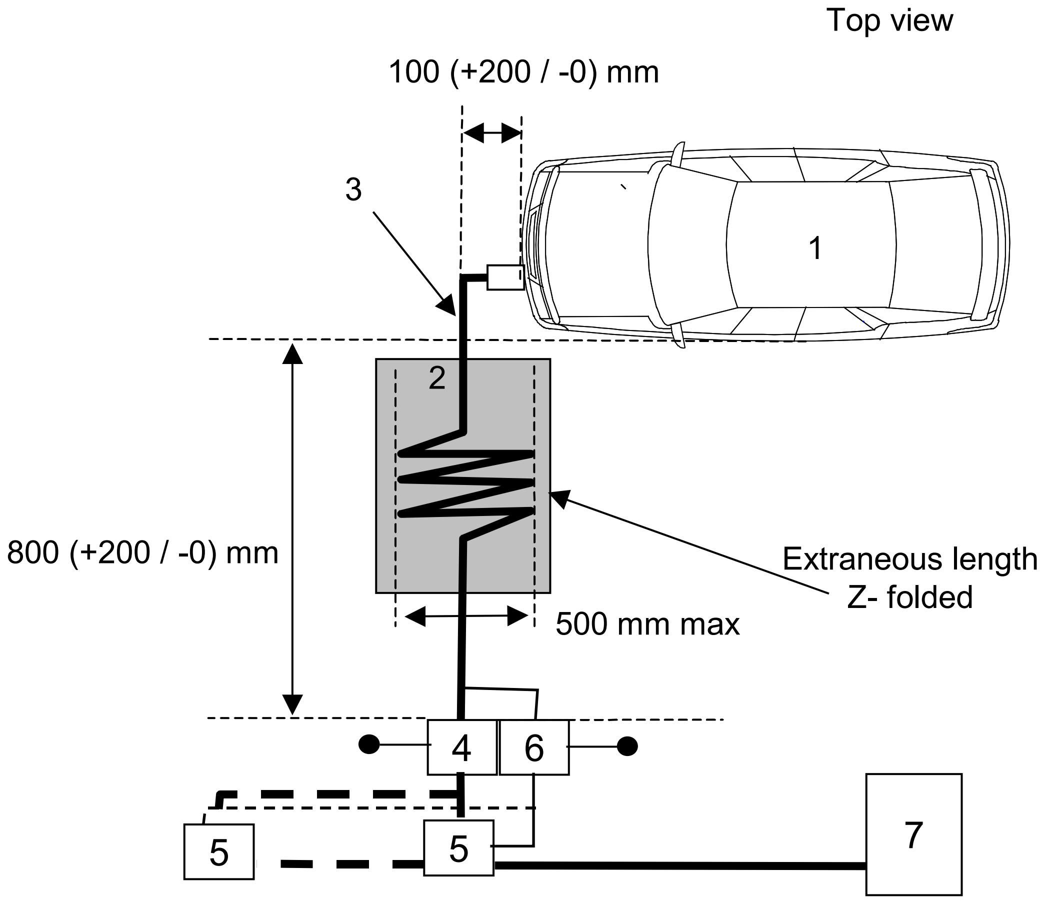
5 Power mains socket (alternative positions shown in the figure)

6 Asymmetric artificial network(s) grounded

7 Charging Station

Figure 6 – Example of test setup for vehicle with plug located on vehicle side (a.c. or d.c. powered with communication)





Key

1 Vehicle under test

2 Insulating support

3 Charging / communication or signal cable

4 a.c. AMN(s) or d.c. HV-AN(s) grounded

5 Power mains socket (alternative positions shown in the figure)

6 Asymmetric artificial network(s) grounded

7 Charging Station

Figure 7 – Example of test setup for vehicle with plug located front /rear of vehicle (a.c. or d.c. powered with communication)

5.4 Examples of limits for vehicle radiated disturbances

It is recommended for acceptable radio reception in a vehicle using typical radio receivers, that the disturbance voltage at the end of the antenna cable should not exceed the values shown in Table 4. Where different receivers are used or different coupling models for the propagation of disturbances are valid, the limits may be changed and detailed in the vehicle manufacturer's own specification.

Table 4 – Example for limits of disturbance – Complete vehicle

Service / Band [a]	Frequency MHz	Terminal disturbance voltage at receiver antenna terminal in dB (µV)		
		Peak	**Quasi-peak**	**Average**
BROADCAST				
LW [b]	0,15 - 0,30	26	13	6
MW [b]	0,53 - 1,8	20	7	0
SW [b]	5,9 - 6,2	20	7	0
FM [b]	76 - 108	26	13	6
TV Band I [c]	41 - 88	16	-	6
TV Band III [c]	174 - 230	16	-	6
DAB III	171 - 245	10	-	0
TV Band IV/V [c]	468 - 944	16	-	6
DTTV	470 - 770	20 [d]	-	10 [d]
DAB L band	1 447 – 1 494	10	-	0
SDARS	2 320 – 2 345	16	-	6
MOBILE SERVICES				
CB [b]	26 - 28	20	7	0
VHF [b]	30 - 54	20	7	0
VHF [b]	68 - 87	20	7	0
VHF [b]	142 -175	20	7	0
Analogue UHF [b]	380 - 512	20	7	0
RKE [f]	300 - 330	20	-	6
RKE [f]	420 - 450	20	-	6
Analogue UHF [b]	820 - 960	20	7	0
GSM 800	860 - 895	26	-	6
EGSM/GSM 900	925 - 960	26	-	6
GPS L1 civil [e,g]	1 567 – 1 583	-	-	0
GLONASS L1 [e,h]	1 591 – 1 613	-	-	0
GSM 1800 (PCN)	1 803 – 1 882	26	-	6
GSM 1900	1 850 – 1 990	26	-	6
3G / IMT 2000	1 900 – 1 992	26	-	6
3G / IMT 2000	2 010 – 2 025	26	-	6
3G / IMT 2000	2 108 – 2 172	26	-	6
Bluetooth/802.11	2 400 – 2 500	26	-	6

[a] LW: Long wave, MW: Medium wave, SW: Short wave (amplitude modulation, AM)
VHF: Very high frequency, UHF: Ultra high frequency (frequency modulation, FM)
DAB: Digital audio broadcasting, TV: Television, DTTV: Digital Terrestrial Television
RKE: Remote keyless entry, GPS: Global positioning system, GSM: Global system mobile
3G: Third generation

[b] In this analogue service the peak and quasi-peak limits can be relaxed by 6 dB for short duration disturbances (e.g. short duration PK (or QPK) limit = PK (or QPK) limit + 6 dB)

[c] Analogue TV only

d This limit is less stringent than the analogue limit and should only be applied where analogue TV is no longer in use

e The bandwidth and frequency steps to be used for the GPS and GLONASS L1 civil band are respectively 9 kHz and 5 kHz rather than the bandwidth and frequency steps defined in Table 1 and Table 2 for services above 30 MHz.

f RKE limits are defined over a large frequency band. Any modification of the average limit around the operating frequency due to sensitivity of RKE systems should be defined in the test plan.

g The values given in the table apply for the 1 574,42 MHz to 1 576,42 MHz frequency range. The limits for the whole GPS L1 frequency range are given in Figure 8a.

h The values given in the table apply for the 1 598,065 MHz to 1 606,5 MHz frequency range. The limits for the whole GLONASS L1 frequency range are given in Figure 8b.

NOTE 1 Stereo signals may be more susceptible to disturbance than monaural signals in the FM broadcast band. This phenomenon has been factored into the FM (76 MHz to 108 MHz) limits.

NOTE 2 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of ambient noise requirements, then applicable limits should be defined in the test plan and the applied limits and bandwidths should be documented in the test report.

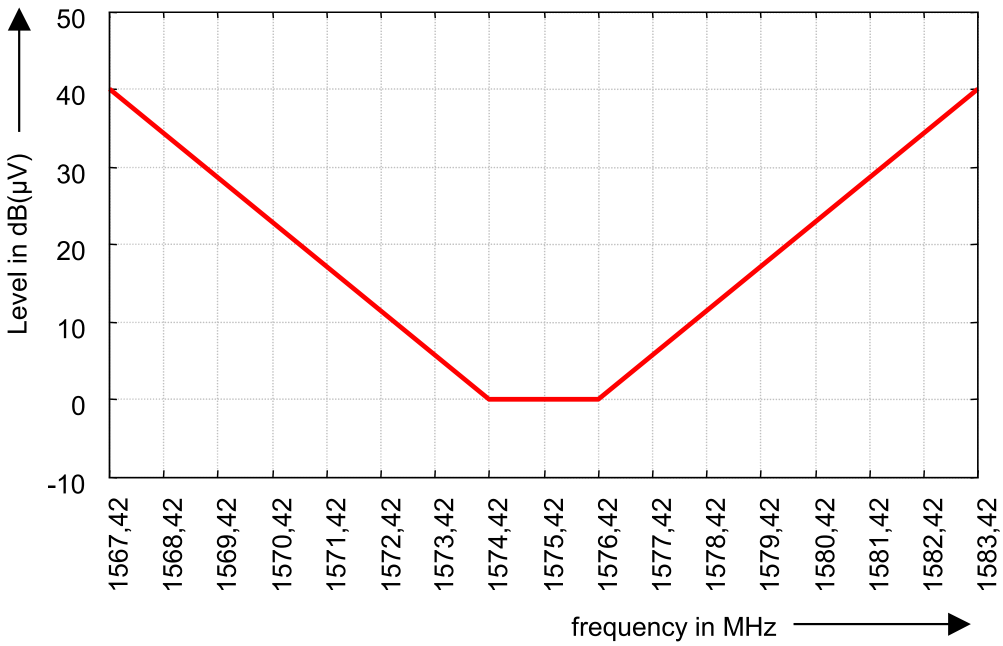


Figure 8a – Average limit for radiated disturbances from vehicles GPS band 1 567,42 to 1 583,42 MHz

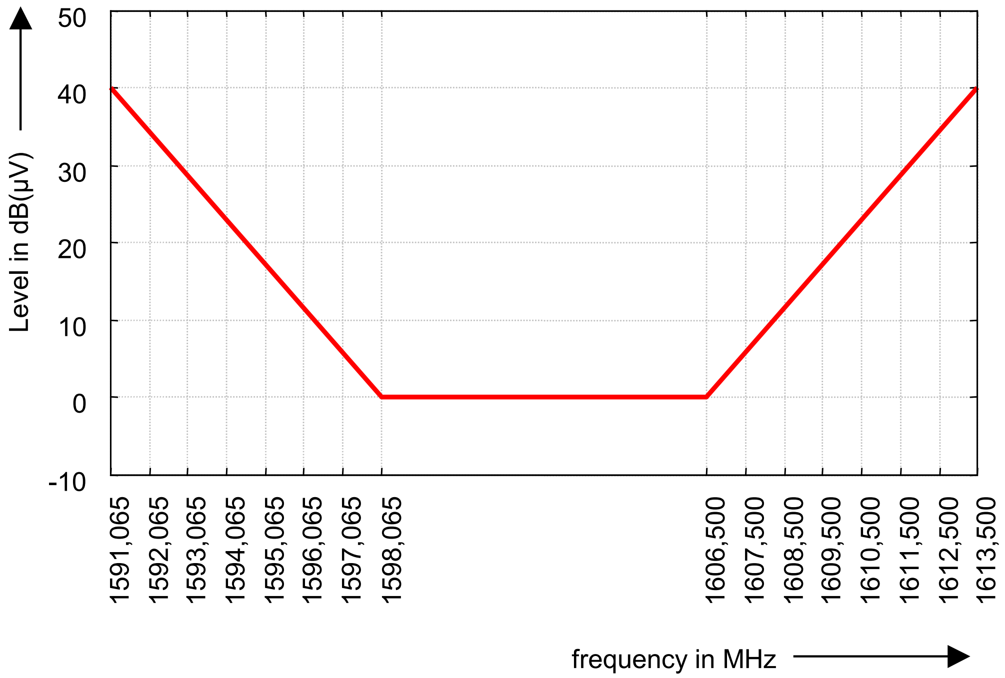


Figure 8b – Average limit for radiated disturbance from vehicles GLONASS band 1 591,065 to 1 613,5 MHz

NOTE - If an active antenna is used, the noise floor may increase. The additional noise floor depends on the type of antenna and must be subtracted from the measured value to determine the real value of the disturbance using the following formula (all terms in µV):

$$U_{real\ Disturbance} = \sqrt{U^2_{Measured} - U^2_{Antenna\ noise}} \qquad (2)$$

A relaxation of the limit because of the active antenna noise floor does not guarantee compliance. Subsequent changes to the active antenna design may result in non-compliance. This topic remains under study. Annex D describes a method to determine the noise floor of an active antenna.

6 Measurement of components and modules

6.1 General

For LV components test methods and requirements are defined in this clause.

For LV/HV components additional test methods and limits are defined in Annex I.

For LV/HV components:

- Conducted emission (voltage method) on LV lines shall be performed according to setup defined in clause I.3 and requirement in 6.2.3
- Conducted emission (voltage method) on HV lines shall be performed according to setup defined in clause I.3 and requirement in I.3.3

6.2 Test equipment

6.2.1 Reference ground plane

The reference ground plane shall be defined as the top metallic surface of the test bench/table.

The reference ground plane shall be made of 0,5 mm thick (minimum) copper, brass, bronze or galvanized steel.

The minimum size of the reference ground plane for conducted emissions (voltage method) shall be 1 000 mm x 400 mm.

The minimum size of the reference ground plane for conducted emissions (current probe method) shall be 2 500 mm x 400 mm.

The minimum width of the reference ground plane for radiated emissions shall be 1 000 mm. The minimum length of the reference ground plane for radiated emissions shall be 2 000 mm, or underneath the entire equipment plus 200 mm, whichever is larger.

The height of the reference ground plane (test bench) shall be (900 ± 100) mm above the floor.

The distance from the edge of the ground strap to the edge of the next strap shall not be greater than 300 mm. The maximum length to width ratio for the ground straps shall be 7:1.

Note 1 Because of resonances of the reference ground plane the location, width and length of the bond straps may influence the measurement results. A sufficient number of low inductive bond straps are necessary to ensure a low impedance connection to the shielded room.

6.2.2 Power supply and AN

For the tests defined in 6.3, 6.4, 6.5, 6.6 and 6.7, each positive EUT power supply lead shall be connected to the power supply through an artificial network. For the TEM cell emissions tests of 6.6, an AN with a coaxial connector will facilitate connection to the TEM cell EUT power connector. The AN shall have a nominal 5 μH inductance. The impedance characteristics and a suggested schematic are shown in Annex E.

Power supply is assumed to be negative ground. If the EUT utilizes a positive ground then the test setups shown in the figures need to be adapted accordingly. Depending on the intended EUT installation in the vehicle:

- – EUT remotely grounded (vehicle power return line longer than 200 mm): two artificial networks are required, one for the positive supply line and one for the power return line.
- – EUT locally grounded (vehicle power return line 200 mm or shorter): one artificial network is required, for the positive supply.

The AN(s) shall be mounted directly on the reference ground plane. The case(s) of the AN(s) shall be bonded to the reference ground plane. The d.c. resistance between the ground of the AN measurement port and the ground plane shall not exceed 2,5 mΩ

The power supply return shall be connected to the reference ground plane (between the power supply and the AN(s)).

The measuring port of the AN not connected to the measuring instrument shall be terminated with a 50 Ω load.

6.2.3 Load Simulator

The load simulator includes sensors and actuators, and terminates the test harness connected to the EUT.

To ensure sufficient reproducibility the same termination must be used for each measurement either by using special termination equipment (e.g. artificial networks, filters) – located at the RF boundary – or by using the same load simulator.

6.2.4 Signal/control line filters

In the TEM cell test method using the coaxial connectors for EUT leads each lead shall pass through a filter which has impedance characteristics similar to that of the AN defined above.

The attenuation of the filters shall be specified for the whole frequency range of the intended component/module test (see 6.3 to 6.7) according to the requirements shown in Figure 9. The minimum attenuation shall be more than 40 dB from 30 MHz up to the upper cut-off frequency (f_c), which depends on the intended test method. Figure 9 shows e.g. an upper cut-off frequency (f_c) of the chosen test method of 400 MHz.

NOTE Other low pass RF filter configurations may be used if the filter characteristics are not applicable to special wanted signals of the EUT's inputs or outputs (e.g. high speed network data interfaces). The filters shall be specified in the test plan.

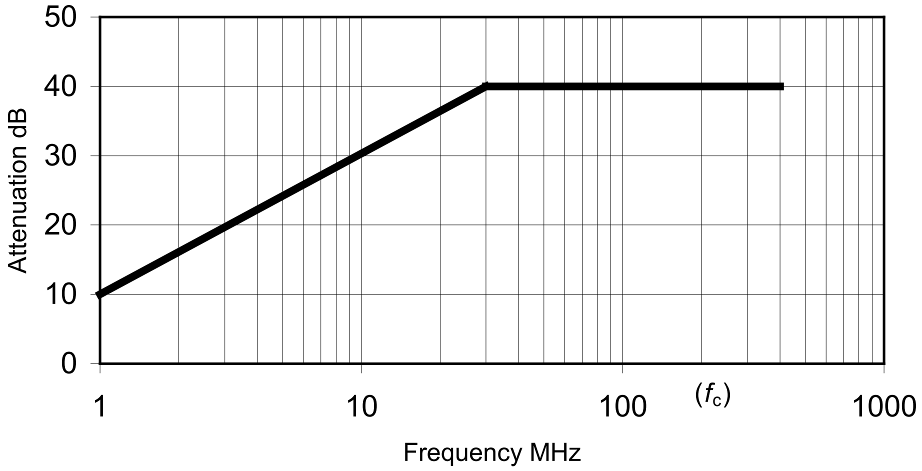


Figure 9 – Example for the required minimum attenuation of the Signal / Control line filters

The attenuation of such a filter can be determined by a two-port network analyser measurement ($-s_{21}$). The input and output impedance of the network analyzer shall be 50 Ω.

The test setup is shown in Figure 10.

Note Equivalent methods for measuring in a 50 Ω system such as a measuring receiver or equivalent equipment with built-in tracking generator can also be used for the measurement since only the magnitude of the attenuation is to be measured.

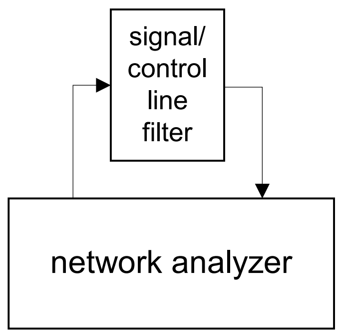


Figure 10 – Setup for measurement of the filter attenuation

6.3 Conducted emissions from components/modules – Voltage method

6.3.1 General

Voltage measurements are able to characterize the emissions on single leads only. The test method is not usable to characterize the radiated emission transmitted e.g. by different antenna structures on the printed board of electronic components or to characterize the efficiency of shielding. Therefore, voltage measurements are not able to characterize the complete EUT emission. At lower frequencies (e.g. in the AM-bands) voltage measurements usually ensure more dynamic range than radiated measurements.

6.3.2 Reference ground plane arrangement

6.3.2.1 Test setup

6.3.2.1.1 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the reference ground plane.

The case of the EUT shall not be grounded to the reference ground plane unless it is intended to simulate the actual vehicle configuration.

All sides of the EUT shall be at least 100 mm from the edge of the reference ground plane. In the case of a grounded EUT, the ground connection point shall also have a minimum distance of 100 mm from the edge of the reference ground plane.

6.3.2.1.2 Location of the test harness

The power supply line(s) between the connector of the AN(s) and the connector(s) of the EUT (l_p) shall have a standard length of $\left(200\ {}^{+200}_{\ \ 0}\right)$ mm.

The harness shall be placed in a straight line on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the reference ground plane.

To minimize the coupling between power and input/output leads, the space between those lead types shall be maximized (≥ 200 mm from or perpendicular to the power supply lines connecting the AN(s) and the EUT).

The total length of the test harness (excluding power lines) shall not exceed 2 m. The wiring type is defined by the actual system application and requirement.

All leads and cables shall be located at a minimum distance of 100 mm from the edge of the reference ground plane.

6.3.2.1.3 Location of the load simulator

Preferably, the load simulator shall be placed directly on the reference ground plane. If the load simulator has a metallic case, this case shall be bonded to the reference ground plane.

Note Alternatively, the load simulator may be located adjacent to the reference ground plane (with the case of the load simulator bonded to the reference ground plane) or outside of the test chamber, provided the test harness from the EUT passes through an **RF boundary** bonded to the reference ground plane.

When the load simulator is located on the reference ground plane, the d.c. power supply lines of the load simulator shall be connected directly to the power supply and not through the AN(s).

6.3.2.2 Test procedure

The general arrangement of the disturbance source (EUT), connecting harnesses, etc. represents a standardised test condition. Any deviations from the standard test harness length etc. shall be agreed upon prior to testing and recorded in the test report.

The EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. These operating conditions must be clearly defined in the test plan to ensure supplier and customer are performing identical tests.

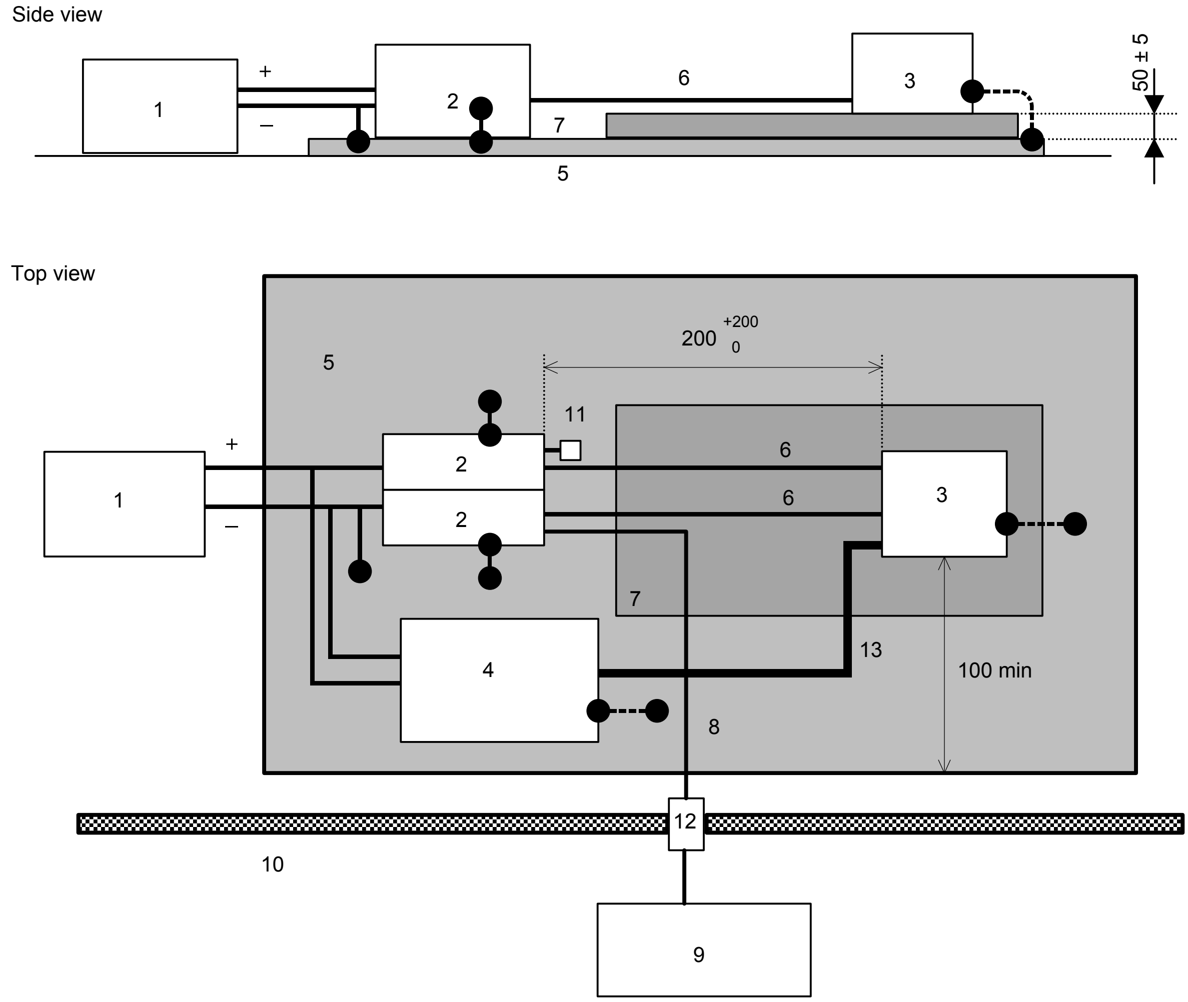
The conducted emissions on power lines are measured successively on positive power supply and power return by connecting the measuring instrument on the measuring port of the related AN, the measuring port of the AN in the other supply lines being terminated with a 50 Ω load.

For voltage measurements the following apply:

– For EUT remotely grounded (vehicle power return line longer than 200 mm), the voltage measurements shall be made on each lead (supply and return) relative to the reference ground plane (see Figure 11).
– For EUT locally grounded (vehicle power return line 200 mm or shorter), voltage measurements on power supply leads shall be made relative to the reference ground plane (see Figure 12).
– Generators/alternators shall be loaded with a battery and parallel resistor combination, and connected to the artificial network in the manner shown in Figure 13. The load current, operating speed, harness length and other conditions shall be defined in the test plan.
– For the tests of ignition systems refer to Figure 14.

Note For EUT's with multiple positive power supply connections and/or multiple power return connections, the measurements (on power supply and on power return) may be performed with all power supply connections tied together at the AN and all power return connections tied together at the other AN. The details of the AN connection should be defined in the test plan.

Dimensions in millimetres – not to scale



Key

1 Power supply (may be placed on the reference ground plane)

2 Artificial network

3 EUT (housing grounded if required in test plan)

4 Load simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

6 Power supply lines

7 Low relative permittivity support ($\varepsilon_r \leq$ 1,4)

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

11 50 Ω load

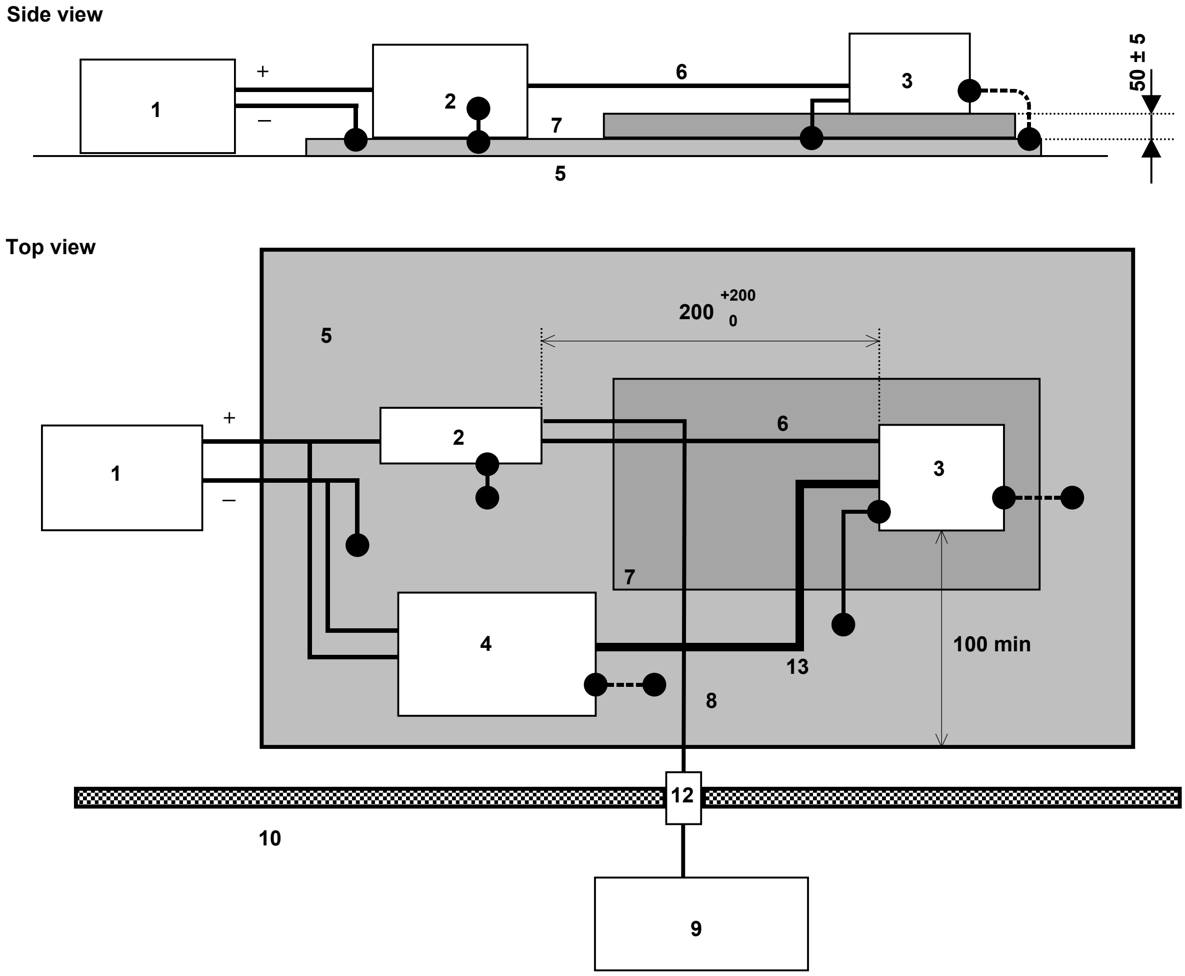
12 Bulkhead connector

13 Test harness (excluding power lines)

Note The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 11 – Conducted emissions – Example of test setup for EUT with power return line remotely grounded.

Dimensions in millimetres – not to scale



Key

1 Power supply (may be placed on the reference ground plane)

2 Artificial network

3 EUT (housing grounded if required in test plan)

4 Load simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

6 Power supply line

7 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

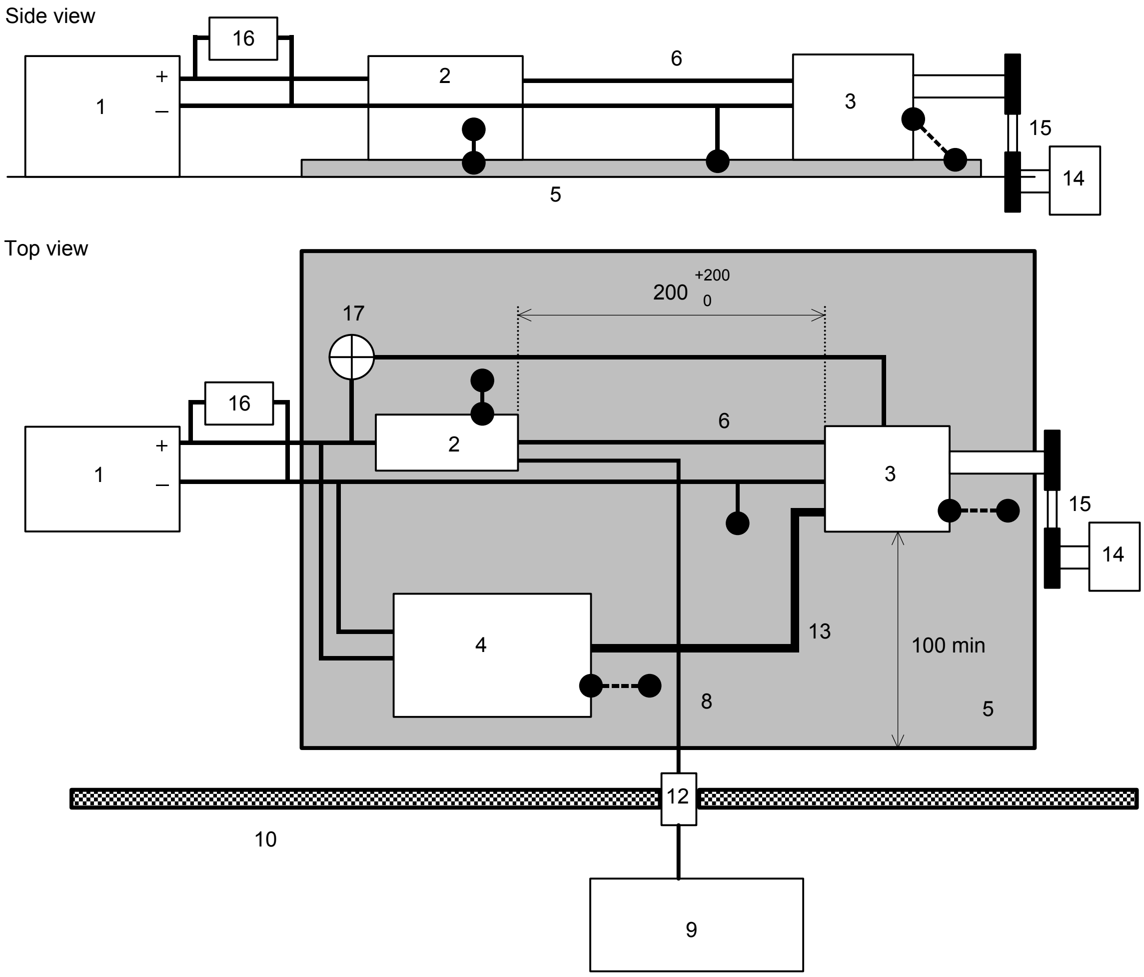
12 Bulkhead connector

13 Test harness (excluding power lines)

Note The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 12 – Conducted emissions – Example of test setup for EUT with power return line locally grounded

Dimensions in millimetres – not to scale



Key

1 Battery (may be placed on the reference ground plane)

2 Artificial network

3 EUT

4 Load simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

6 Power supply lines

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

11 50 Ω load

12 Bulkhead connector

13 Test harness (excluding power lines)

14 Motor (Air/Low Emissions)

15 Non-conductive belt/coupler

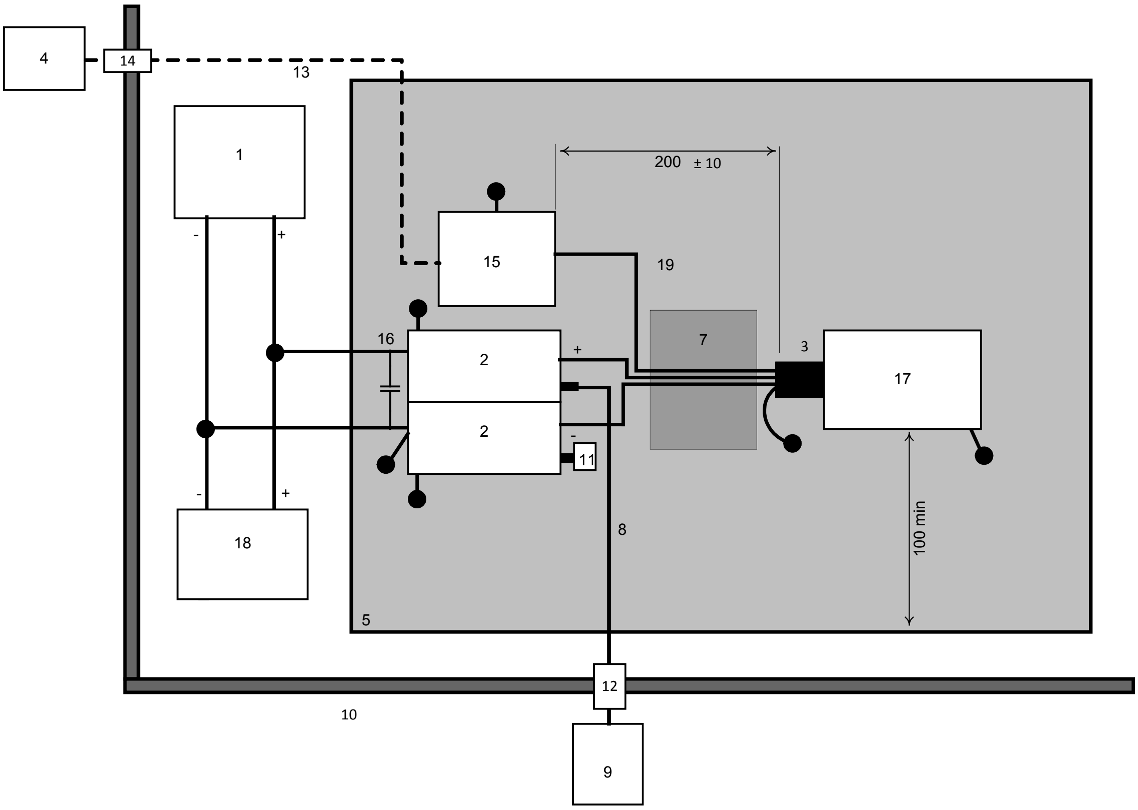
16 Load resistor

17 Indicator lamp/control resistor (if applicable)

Note The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 13 – Conducted emissions – Example of test setup for alternators and generators

Dimensions in millimetres – not to scale



Key

1 Power supply (may be placed on the reference ground plane)

2 Artificial network

3 Pencil coil

4 ECU simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

7 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

11 50 Ω load

12 Bulkhead connector

13 Optical fibres

14 Fiber optic feed through

15 Optical fibre converter

16 1 000 µF capacitor

17 Engine simulator

18 Battery

19 Signal line

Note The pencil coil housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 14 – Conducted emissions – Example of test setup for ignition system components

6.3.3 Limits for conducted disturbances from components/modules – Voltage method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

Note 1 The method to be used for characterisation of the Voltage Division Factor of the AN, sometimes referred to as insertion loss, is given in Annex A.8 of CISPR 16-1-2.

Note 2 It is recommended for acceptable radio reception in a vehicle that the conducted noise should not exceed the values shown in Table 5, peak and average or quasi-peak and average, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table 5 – Examples of limits for conducted disturbances – Voltage Method

Service / Band	Frequency MHz	Levels in dB(µV) Class 5			Class 4			Class 3			Class 2			Class 1		
		Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average
BROADCAST																
LW	0,15 – 0,30	70	57	50	80	67	60	90	77	70	100	87	80	110	97	90
MW	0,53 – 1,8	54	41	34	62	49	42	70	57	50	78	65	58	86	73	66
SW	5,9 – 6,2	53	40	33	59	46	39	65	52	45	71	58	51	77	64	57
FM	76 – 108	38	25	18	44	31	24	50	37	30	56	43	36	62	49	42
TV Band I	41 – 88	34	-	24	40	-	30	46	-	36	52	-	42	58	-	48
TV Band III	174 – 230	Conducted emission – Voltage method Not Applicable														
DAB III	171 – 245															
TV Band IV	468 – 944															
DTTV	470 – 770															
DAB L Band	1447 – 1494															
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	44	31	24	50	37	30	56	43	36	62	49	42	68	55	48
VHF	30 – 54	44	31	24	50	37	30	56	43	36	62	49	42	68	55	48
VHF	68 – 87	38	25	18	44	31	24	50	37	30	56	43	36	62	49	42
VHF	142 – 175	Conducted emission – Voltage method Not Applicable														
Analogue UHF	380 – 512															
RKE	300 – 330															
RKE	420 – 450															
Analogue UHF	820 – 960															
GSM 800	860 – 895															
EGSM/GSM 900	925 – 960															
GPS L1 civil	1567 – 1583															
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

6.4 Conducted emissions from components/modules – current probe method

6.4.1 Test setup

6.4.1.1 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the reference ground plane.

The case of the EUT shall not be grounded to the reference ground plane unless it is intended to simulate the actual vehicle configuration.

The EUT shall be at least 100 mm from the edge of the reference ground plane and at least 500 mm from the chamber wall. The test plan shall simulate the actual vehicle configuration and shall specify: remote versus local grounding, the use of an insulating spacer, and the electrical connection of the EUT case to the reference ground plane.

The measuring equipment shall be as shown in Figure 15.

6.4.1.2 Location of the test harness

The test harness shall be $\left(1700\ {}^{+300}_{\ \ 0}\right)$ mm long (or as agreed upon in the test plan), and shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$), positioned (50 ± 5) mm above the reference ground plane. The test harness wires shall be nominally parallel and adjacent unless otherwise defined in the test plan.

6.4.2 Test procedure

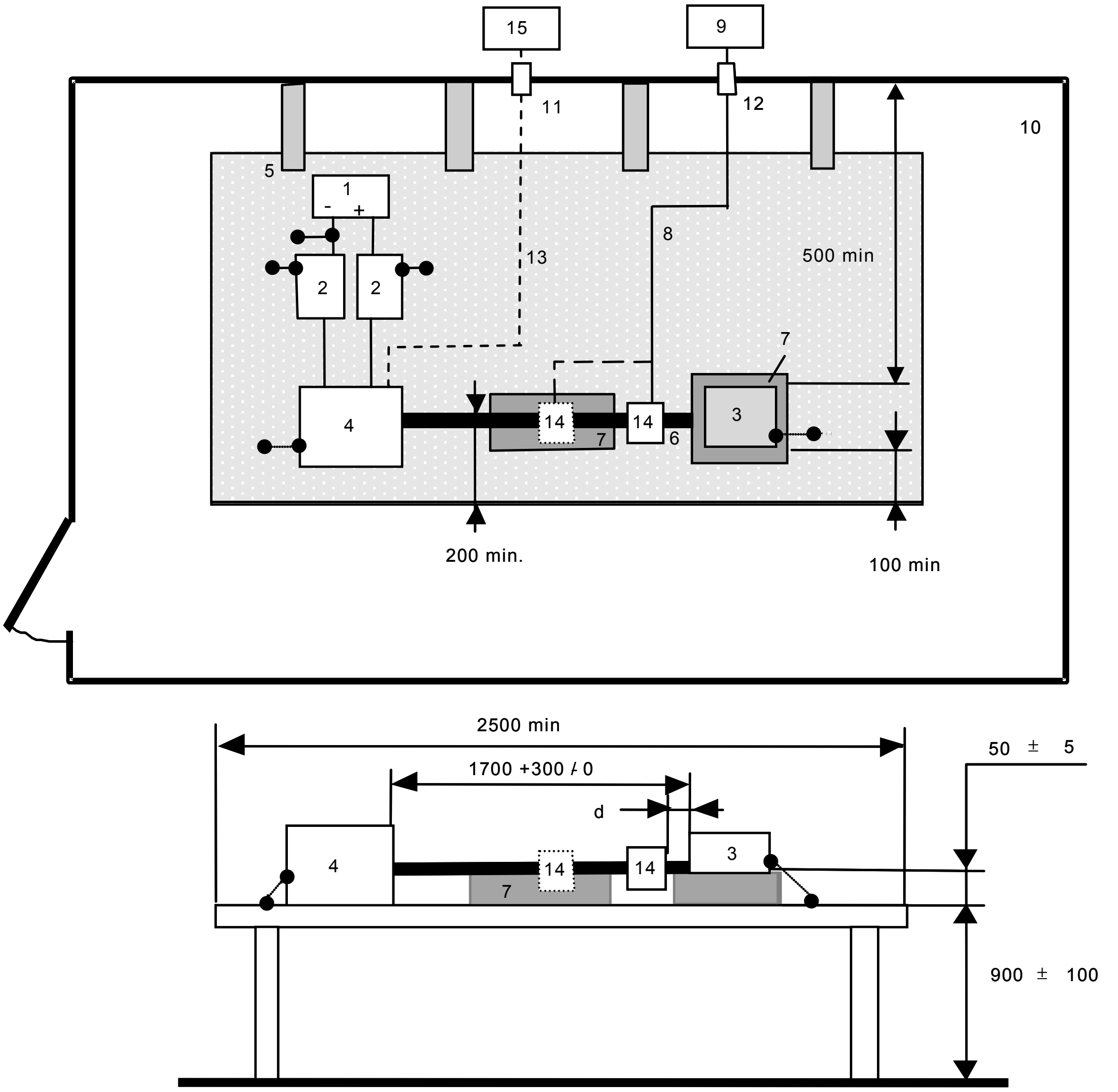
The probe (see CISPR 16-1-2) shall be mounted around the complete harness (including all wires). If the EUT has multiple connectors on the unit resulting in multiple wire bundles, the test plan shall define which wires shall be included in the probe for measurement. In the absence of any definition, measurements shall be made for each bundle (connector) independently and for all wires together.

If the EUT wiring has too many wires to be accommodated in the measurement probe, the test plan may define the wires to be measured and this shall be included in the test report.

Measure the emissions with the probe positioned 50 mm and 750 mm from the EUT.

In most cases, the position of maximum emission will be as close to the EUT connector as possible. Where the EUT is equipped with a metal shell connector, the probe shall be clamped to the cable immediately adjacent to the connector shell, but not around the connector shell itself. The EUT shall be at least 100 mm from the edge of the reference ground plane and at least 500 mm from the chamber wall. The test plan shall simulate the actual vehicle configuration and shall specify remote versus local grounding, the use of an insulating spacer and the electrical connection of the EUT case to the reference ground plane.

Note Some additional measurements may be defined in the test plan with only the positive supply wire in the probe and/or only the negative supply wire in the probe. For these test configurations limits are to be defined in the test plan.



Dimensions in millimetres – not to scale

Key

1 Power supply

2 Artificial network

3 EUT (connected to ground if specified in the test plan)

4 Load simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

6 Wiring harness

7 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

11 Fiber optic feed through

12 Bulkhead connector

13 Optical fibers

14 Current probe (represented at 2 positions)

15 Stimulation and monitoring system

d The distance from the EUT to the closest probe position

Figure 15– Conducted emissions – Example of test setup for current probe measurements

6.4.3 Limits for conducted disturbances from components/modules – Current probe method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

Note It is recommended for acceptable radio reception in a vehicle that the conducted noise should not exceed the values shown in Table 6, peak and average or quasi-peak and average limits, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table 6 – Examples of limits for conducted disturbances - control/signal lines – Current probe method

Service / Band	Frequency MHz	Levels in dB(µA)														
		Class 5			Class 4			Class 3			Class 2			Class 1		
		Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average
BROADCAST																
LW	0,15 – 0,30	50	37	30	60	47	40	70	57	50	80	67	60	90	77	70
MW	0,53 – 1,8	26	13	6	34	21	14	42	29	22	50	37	30	58	45	38
SW	5,9 – 6,2	19	6	-1	25	12	5	31	18	11	37	24	17	43	30	23
FM	76 – 108	4	-9	-16	10	-3	-10	16	3	-4	22	9	2	28	15	8
TV Band I	41 – 88	0	-	-10	6	-	-4	12	-	2	18	-	8	24	-	14
DAB III	171 – 245	-2	-	-12	4	-	-6	10	-	0	16	-	6	22	-	12
TV Band III	174 – 230	Conducted emission – control/signal lines Not Applicable														
TV Band IV	468 – 944															
DTTV	470 – 770															
DAB L Band	1447 – 1494															
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	10	-3	-10	16	3	-4	22	9	2	28	15	8	34	21	14
VHF	30 – 54	10	-3	-10	16	3	-4	22	9	2	28	15	8	34	21	14
VHF	68 – 87	4	-9	-16	10	1	-10	16	7	-4	22	13	2	28	15	8
VHF	142-175	4	-9	-16	10	1	-10	16	7	-4	22	13	2	28	15	8
Analogue UHF	380 – 512	Conducted emission – control/signal lines Not Applicable														
RKE	300 – 330															
RKE	420 – 450															
Analogue UHF	820 – 960															
GSM 800	860 – 895															
EGSM/GSM 900	925 – 960															
GPS L1 civil	1567 – 1583															
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

6.5 Radiated emissions from components/modules - ALSE method

6.5.1 General

Measurements of radiated field strength shall be made in an ALSE to eliminate the high levels of extraneous disturbance from electrical equipment and broadcasting stations.

Note 1 Conducted emissions will contribute to the radiated emissions measurements because of radiation from the wiring in the test setup. Therefore, it is advisable to establish conformance with the conducted emissions requirements before performing the radiated emissions test.

Note 2 Disturbance to the vehicle on-board receiver can be caused by direct radiation from one or more leads in the vehicle wiring harness. This coupling mode to the vehicle receiver affects both the type of testing and the means of reducing the disturbance at the source.

Note 3 Vehicle components which are not effectively grounded to the vehicle by short ground leads, or which have several harness leads carrying the disturbance voltage, will have radiated emissions that do not correlate well with its conducted emissions. This has been shown to give better correlation with the complete vehicle test for components installed in this way.

Examples of component installations for which this test is applicable include, but are not limited to:

– electronic control systems containing microprocessors;
– two speed wiper motors with negative supply switching;
– suspension control systems with strut-mounted actuator motors;
– engine cooling and heater blower motors mounted in plastic or other insulated housings.

6.5.2 Test setup

For radiated emissions measurements, the arrangement of the EUT, test harness, load simulator and measuring equipment shall be equivalent to the examples shown in Figures 17 to 20.

6.5.2.1 Antenna systems

Measurements shall be made using linearly polarised electric field antennas that have a nominal 50 Ω output impedance.

Note 1 To improve consistency of results between laboratories, the following antennas are recommended:

a) 0,15 MHz to 30 MHz 1 m vertical monopole (where this is not 50 Ω, a suitable antenna matching unit shall be used);

b) 30 MHz to 300 MHz a biconical antenna;

c) 200 MHz to 1 000 MHz a log-periodic antenna;

d) 1 000 MHz to 2 500 MHz a horn or log periodic antenna.

The method to be used for characterization of the vertical monopole (rod) antenna is given in CISPR 16-1-4.

Note 2 Use the 1 m method in SAE ARP 958.1 Rev D February 2003 for determining biconical, log periodic and horn antenna factors.

Note 3 Biconical antennas usually have a SWR of up to 10:1 in the frequency range of 30 MHz to 80 MHz. Therefore an additional measurement error may occur when the receiver input impedance differs from 50 Ω. The use of an attenuator (3 dB minimum) at the receiver's input or the input of an additional preamplifier (if possible) will keep this additional error low.

6.5.2.2 Antenna matching unit for monopole antenna

Correct impedance matching between the antenna and the measuring instrument of 50 Ω shall be maintained in the frequency ranges selected for the test. There shall be a maximum SWR of 2:1 at the output port of the matching unit. Appropriate correction shall be made for any attenuation/gain of the antenna system from the antenna to the receiver.

Note Care should be taken to ensure that input voltages do not exceed the pulse input rating of the unit or overloading may occur. This is particularly important when active matching units are used.

6.5.2.3 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the reference ground plane.

The case of the EUT shall not be grounded to the reference ground plane unless it is intended to simulate the actual vehicle configuration.

The side of the EUT, which is nearest to the front edge of the reference ground plane, shall be located at a distance of (200 ± 10) mm from the front edge of the reference ground plane.

6.5.2.4 Test harness and location

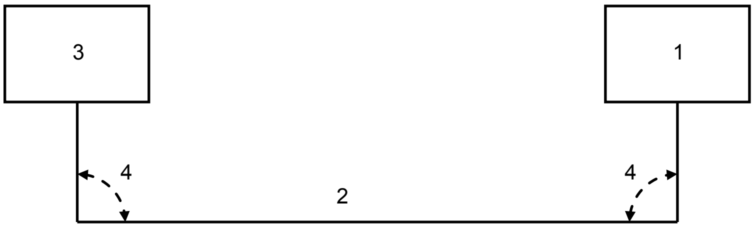
The total length of the test harness between the EUT and the load simulator (or the RF boundary) shall not exceed 2 000 mm (or as defined in the test plan). The wiring type is defined by the actual system application and requirement.

Care shall be taken with the power lines that these are also not exceeding 2 000 mm. Where the power is taken separately from the load box, the AN shall be located such that the power lines can be maintained at less than 2 000 mm. If the power is derived from the load box, the line between the load box and the AN shall be kept as short as is practically possible to avoid excessive length being added to the power lines.

The test harness shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the reference ground plane.

The length of test harness parallel to the front of the reference ground plane shall be (1 500 ± 75) mm.

The long segment of test harness shall be located parallel to the edge of the ground plane facing the antenna at a distance of (100 ± 10) mm from the edge. Location of the EUT and load simulator requires that the harness bend angle shall be $\left(90\ ^{+45}_{\ \ 0}\right)$ degrees as shown in Figure 16.



Key

1 EUT

2 Test harness

3 Load simulator

4 Angle $\left(90\,^{+45}_{\ 0}\right)$ degrees

Figure 16 – Test harness bending requirements

6.5.2.5 Location of the load simulator

Preferably, the load simulator shall be placed directly on the reference ground plane. If the load simulator has a metallic case, this case shall be bonded to the reference ground plane.

Alternatively, the load simulator may be located adjacent to the reference ground plane (with the case of the load simulator bonded to the reference ground plane) or outside of the test chamber, provided that the test harness from the EUT passes through an RF boundary bonded to the reference ground plane. The layout of the test harness that is connected to the load simulator shall be defined in the test plan and recorded in the test report.

When the load simulator is located on the reference ground plane, the d.c. power supply lines of the load simulator shall be connected through the AN(s).

6.5.2.6 Location of the measuring antenna

The phase centre of the measuring antenna shall be (100 ± 10) mm above the reference ground plane for the biconical, log-periodic and horn antenna.

The height of the counterpoise of the rod antenna shall be (+10 / -20) mm relative to the reference ground plane and shall be bonded to the reference ground plane.

For radiated emissions tests, the shielded enclosure shall be of sufficient size to ensure that neither the EUT nor the test antenna shall be closer than 1 m from the walls or ceiling, or to the nearest surface of the absorber material used thereon. No part of any antenna radiating element shall be closer than 250 mm to the floor.

The distance between the longitudinal part (1 500 mm length) of the wiring harness and the reference point of the antenna shall be (1 000 ± 10) mm. For a biconical or other antenna (e.g. biconilog) no part of the antenna shall be closer to the wiring harness or EUT than 700 mm.

The reference point of the antenna is defined as:

– the vertical monopole element for rod antennas,
– the phase centre (mid-point) for biconical antennas,
– the tip for antennas with log-periodic elements (including biconilog antennas),
– the front aperture for horn antennas.

Each antenna (excluding the rod antenna) shall be calibrated for this reference point for a 1 000 mm measuring distance (see 6.5.2.1).

Note 1 The rod antenna is excluded because calibration is achieved by using the method defined in CISPR 16-1-4.

The phase centre of the antenna shall be in line with the centre of the longitudinal part of the wiring harness for frequencies up to 1 000 MHz.

The phase center of the antenna for frequencies above 1 000 MHz shall be in line with the EUT.

Note 2 The users of this standard should be aware that antenna manufacturers may give:

- independent antenna factors for horizontal and vertical polarisations: in this case the appropriate antenna factor should be used for measurement in each polarisation.

- A single antenna factor: in this case this antenna factor should be used for measurements in both polarisations.

6.5.3 Test procedure

The general arrangement of the disturbance source and connecting harnesses, etc. represents a standardised test condition. Any deviations from the standard test harness length, etc. shall be agreed upon prior to testing and recorded in the test report.

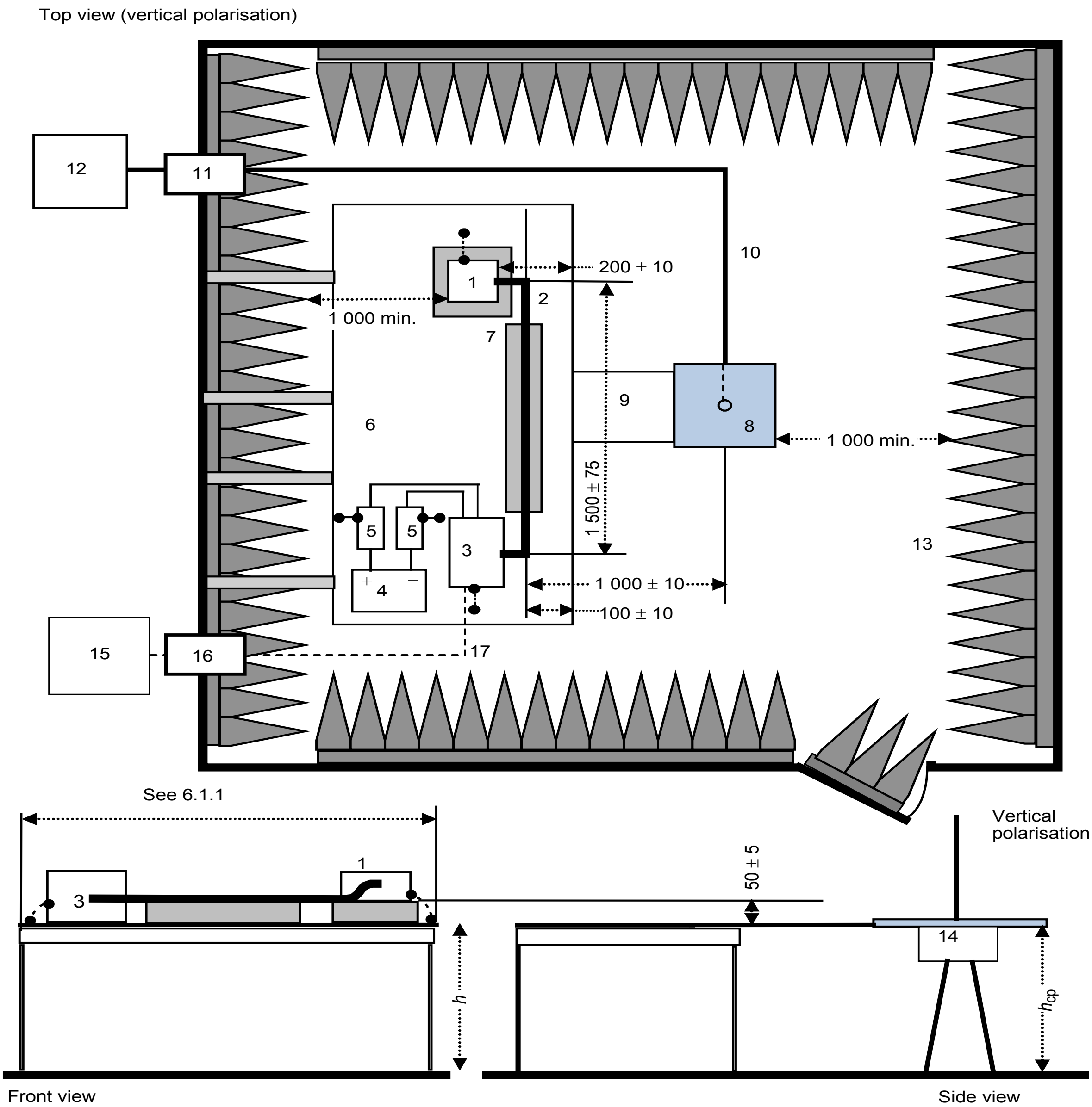
The EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. These operating conditions must be clearly defined in the test plan to ensure supplier and customer can perform identical tests. The orientation(s) of the EUT for radiated emission measurements shall be defined in the test plan.

From 150 kHz to 30 MHz measurements shall be performed in vertical polarisation only.

From 30 MHz to 2 500 MHz measurements shall be performed in vertical and horizontal polarisations.

For radiated emission measurements, the arrangement of the EUT and measuring equipment shall be functionally equivalent to the examples shown in Figures 17 to 20.

1187 Dimensions in millimetres – not to scale



1188

Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.5.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Reference ground plane (bonded to shielded enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 Rod Antenna with counterpoise

(dimensions: 600 mm by 600 mm typical)

9 Grounding connection (full width bond between counterpoise and reference ground plane)

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

14 Antenna matching unit (the preferred location is below the counterpoise; if above the counterpoise then the base of the antenna rod shall be at the height of the reference ground plane)

15 Stimulation and monitoring system

h = (900 ± 100) mm

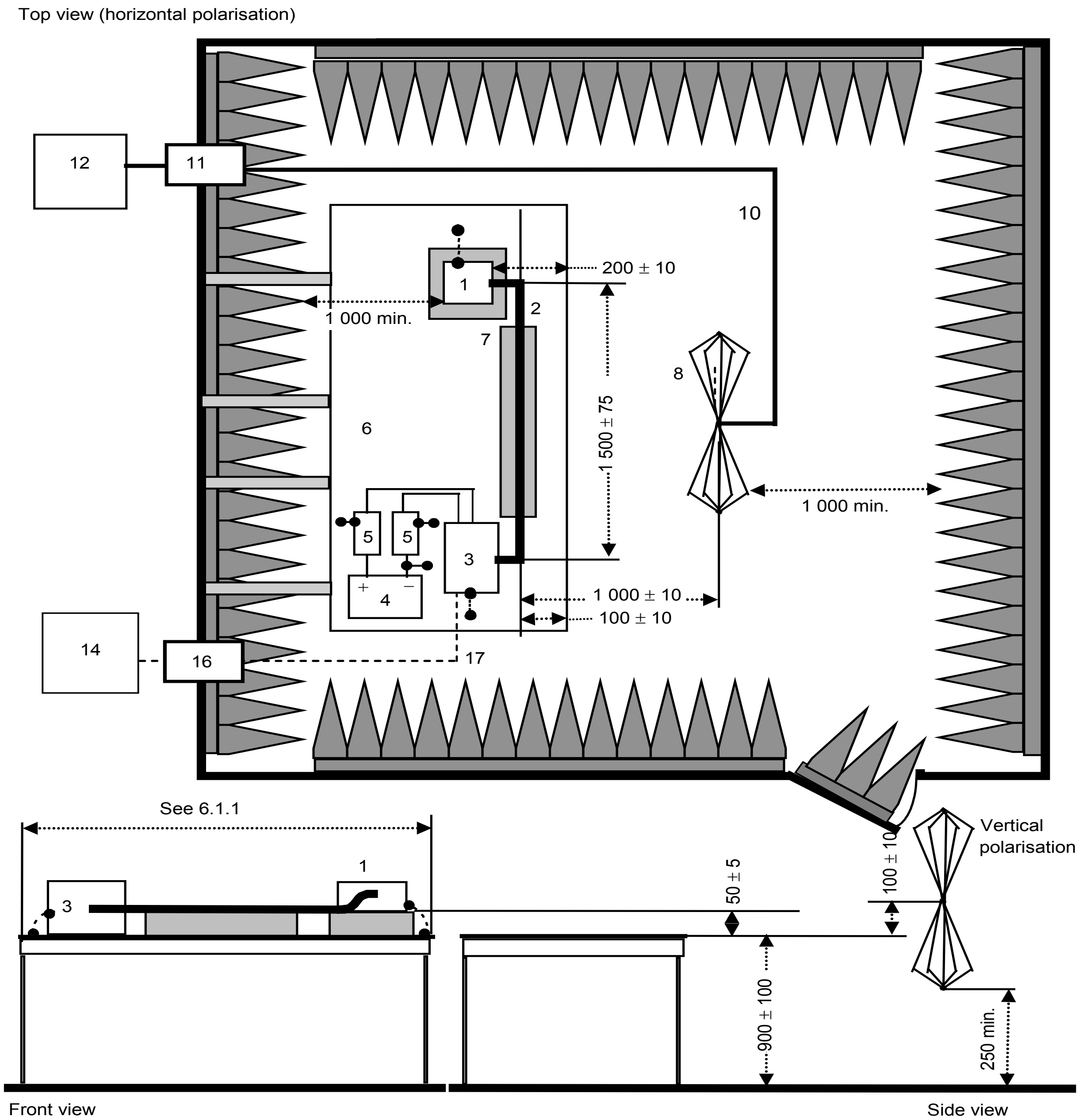
h_{cp} = h + (+10 / -20) mm

16 Fiber optic feed through

17 Optical fibers

Figure 17 – Example of test setup – rod antenna

Dimensions in millimetres – not to scale



1191 **Key**

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.5.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Reference ground plane (bonded to shielded enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)

8 Biconical antenna (no part of the antenna closer than 700 mm to the wiring harness or EUT)

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

14 Stimulation and monitoring system

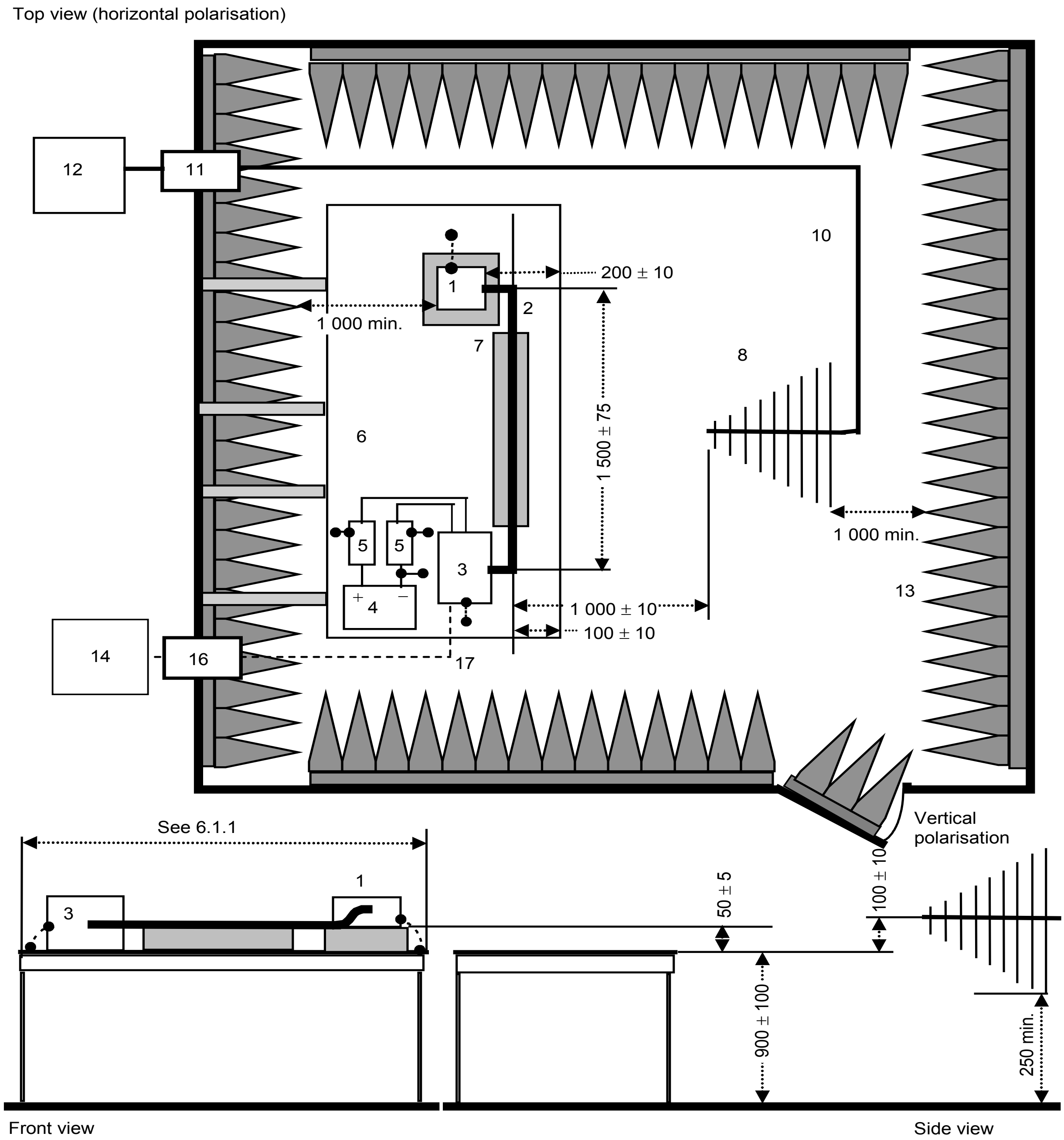
16 Fiber optic feed through

17 Optical fibers

1192 **Figure 18 – Example of test setup – biconical antenna**

1193

Dimensions in millimetres – not to scale



Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.5.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Reference ground plane (bonded to shielded

8 Log-periodic antenna

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

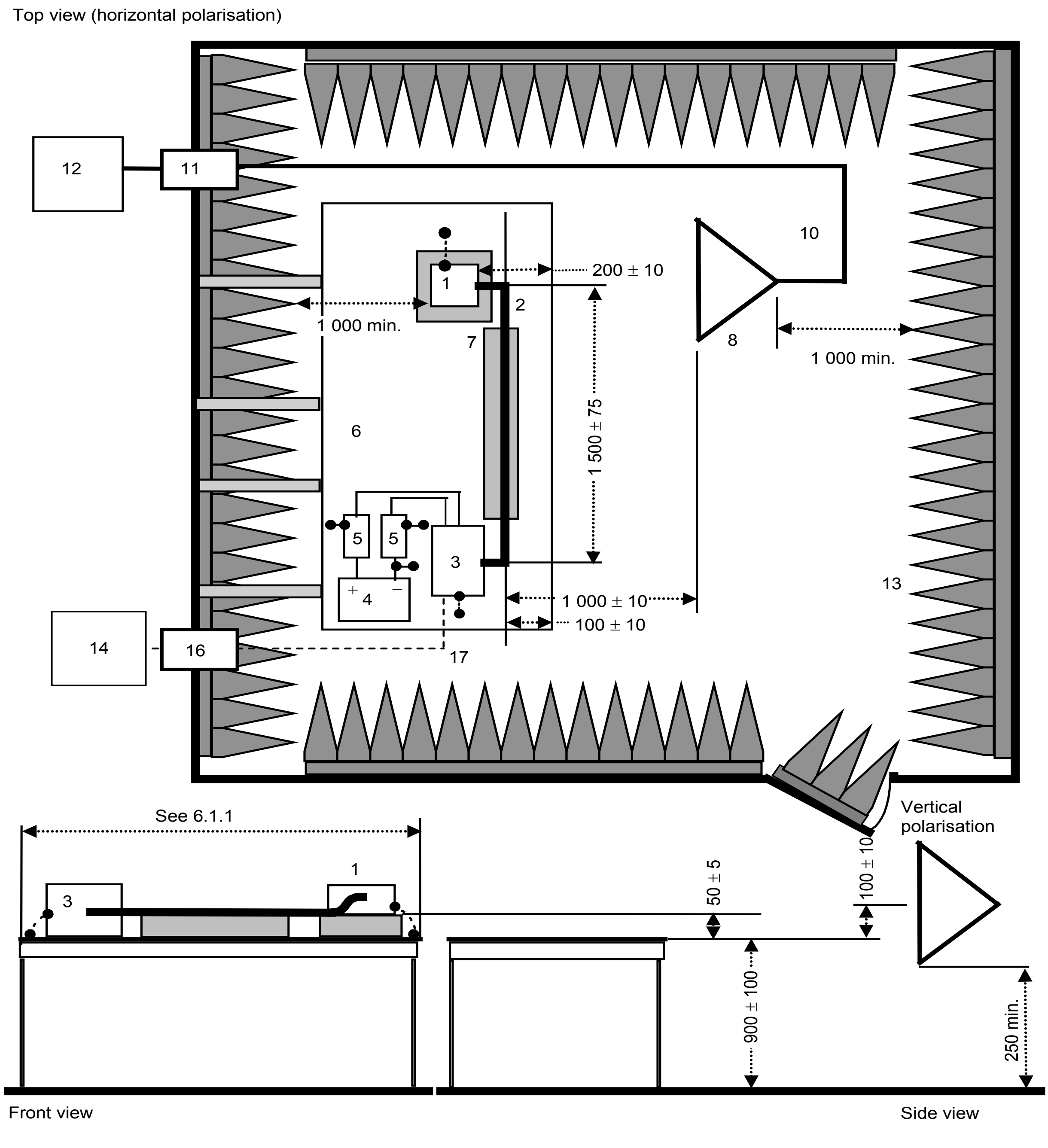
14 Stimulation and monitoring system

16 Fiber optic feed through

17 Optical fibers

1196 **Figure 19 – Example of test setup – log-periodic antenna**

1197 Dimensions in millimetres – not to scale



1198

Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.5.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Reference ground plane (bonded to shielded enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 Horn antenna

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

14 Stimulation and monitoring system

16 Fiber optic feed through

17 Optical fibers

Figure 20 – Example of test setup – above 1 GHz

6.5.4 Limits for radiated disturbances from components/modules – ALSE method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

Note It is recommended for acceptable radio reception in a vehicle that the radiated noise should not exceed the values shown in Table 7, peak and average or quasi-peak and average limits, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined. For the GPS band a specific limit characteristic is recommended. This is shown in Figure 21.

Table 7 – Examples of Limits for radiated disturbances – ALSE method

Service / Band	Frequency MHz	Levels in dB(μV/m)														
		Class 5			Class 4			Class 3			Class 2			Class 1		
		Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average
BROADCAST																
LW	0,15 – 0,30	46	33	26	56	43	36	66	53	46	76	63	56	86	73	66
MW	0,53 – 1,8	40	27	20	48	35	28	56	43	36	64	51	44	72	59	52
SW	5,9 – 6,2	40	27	20	46	33	26	52	39	32	58	45	38	64	51	44
FM	76 – 108	38	25	18	44	31	24	50	37	30	56	43	36	62	49	42
TV Band I	41 – 88	28	-	18	34	-	24	40	-	30	46	-	36	52	-	42
TV Band III	174 – 230	32	-	22	38	-	28	44	-	34	50	-	40	56	-	46
DAB III	171 – 245	26	-	16	32	-	22	38	-	28	44	-	34	50	-	40
TV Band IV	468 – 944	41	-	31	47	-	37	53	-	43	59	-	49	65	-	55
DTTV	470 – 770	45	-	35	51	-	41	57	-	47	63	-	53	69	-	59
DAB L Band	1447 – 1494	28	-	18	34	-	24	40	-	30	46	-	36	52	-	42
SDARS	2320 – 2345	34	-	24	40	-	30	46	-	36	52	-	42	58	-	48
MOBILE SERVICES																
CB	26 – 28	40	27	20	46	33	26	52	39	32	58	45	38	64	51	44
VHF	30 – 54	40	27	20	46	33	26	52	39	32	58	45	38	64	51	44
VHF	68 – 87	35	22	15	41	28	21	47	34	27	53	40	33	59	46	39
VHF	142 – 175	35	22	15	41	28	21	47	34	27	53	40	33	59	46	39
Analogue UHF	380 – 512	38	25	18	44	31	24	50	37	30	56	43	36	62	49	42
RKE	300 – 330	32	-	18	38	-	24	44	-	30	50	-	36	56	-	42
RKE	420 – 450	32	-	18	38	-	24	44	-	30	50	-	36	56	-	42
Analogue UHF	820 – 960	44	31	24	50	37	30	56	43	36	62	49	42	68	55	48
GSM 800	860 – 895	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
EGSM/GSM 900	925 – 960	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
GPS L1 civil	1567 – 1583	-	-	10	-	-	16	-	-	22	-	-	28	-	-	34
GLONASS L1	1 591 – 1 613	-	-	10	-	-	16	-	-	22	-	-	28	-	-	34
GSM 1800 (PCN)	1803 – 1882	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
GSM 1900	1850 – 1990	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
3G / IMT 2000	1900 – 1992	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
3G / IMT 2000	2010 – 2025	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
3G / IMT 2000	2180 – 2172	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
Bluetooth/802.11	2400 – 2500	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 The values given in the table apply for the 1 574,42 MHz to 1 576,42 MHz frequency range. The limits for the whole GPS L1 frequency range are given in Figure 21a.

Note 4 The values given in the table apply for the 1 598,065 MHz to 1 606,5 MHz frequency range. The limits for the whole GLONASS L1 frequency range are given in Figure 21b.

Note 5 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

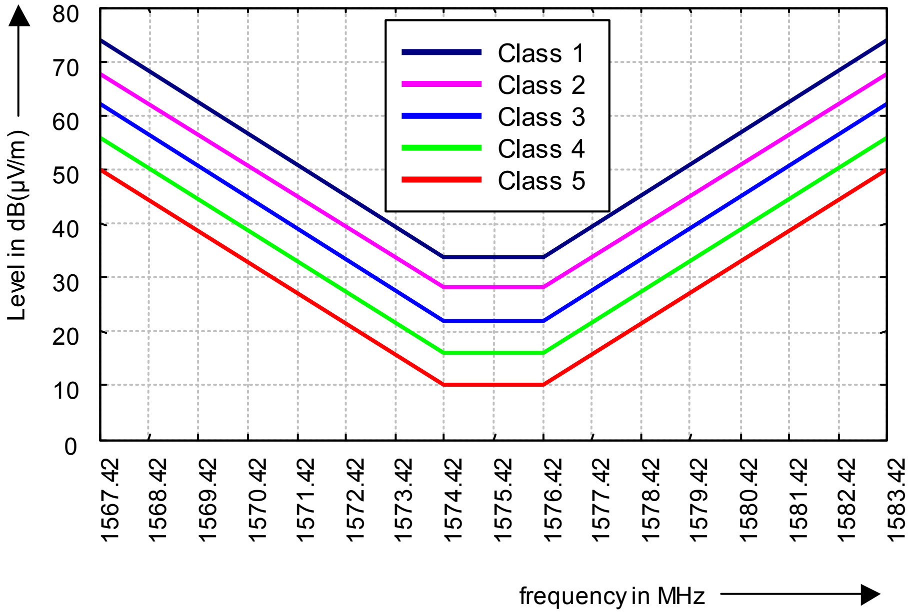


Figure 21a – Example of average limit for radiated disturbances from components GPS band 1 567,42 to 1 583,42 MHz

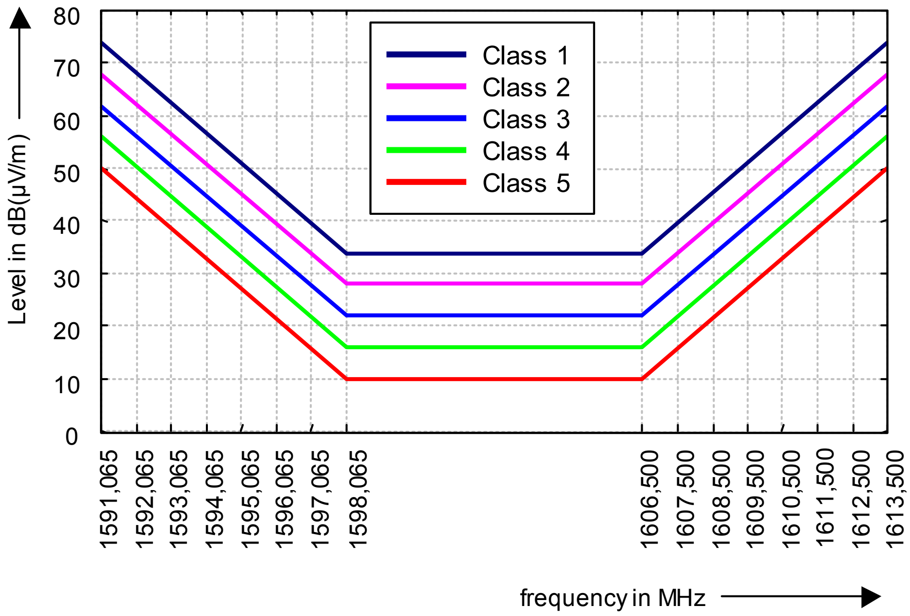


Figure 21b – Example of average limit for radiated disturbances from components GLONASS band 1 591,065 MHz to 1 613,5 MHz

6.6 Radiated emissions from components/modules – TEM cell method

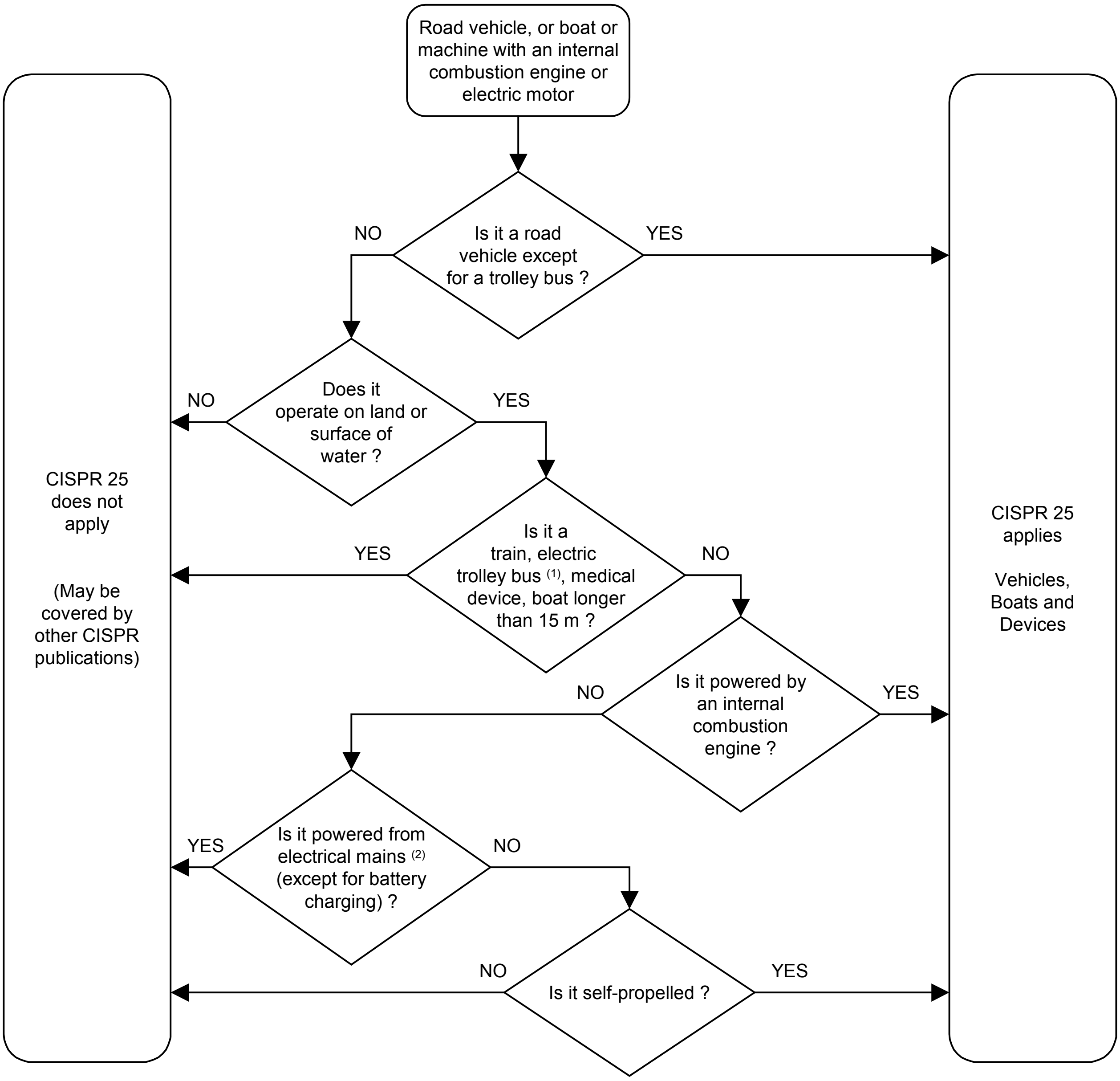
Refer to Annex F

6.7 Radiated emissions from components/modules – Stripline method

Refer to Annex G

Annex A
(informative)

Flow chart for checking the applicability of CISPR 25



(1) In the case of a dual-mode trolley bus (e.g. propelled by power from either a.c./d.c. mains or an internal combustion engine), the a.c./d.c. mains portion of the vehicle propulsion system shall be excluded from this standard.

(2) Connection to the electrical mains is the work of another CISPR subcommittee

This chart is intended to assist with determining whether a particular product is covered by this publication. In case of conflict between this chart and Clause 1, Scope, Clause 1 shall take precedence.

Annex B
(normative)

Antenna matching unit – Vehicle test

B.1 Antenna matching unit parameters (150 kHz to 6,2 MHz)

The requirements for the measurement equipment are defined in 5.1.2.1.

B.2 Antenna matching unit – verification

The 10 pF and 60 pF values for the artificial antenna network of Figure B.1 are used to represent a conventional antenna, e.g., 1 m rod, 2 m coax. The 60 pF capacitor represents the capacitance of the coaxial cable between the vehicle antenna and the input of the vehicle radio.

Note Actual values with on-glass antennas and diversity systems may vary greatly.

B.2.1 Gain measurement

The antenna matching unit and artificial antenna adapter (AAA) shall be measured to determine whether its gain meets the requirements of 5.1.2.1 using the test arrangement shown in Figure B.1.

B.2.2 Test procedure

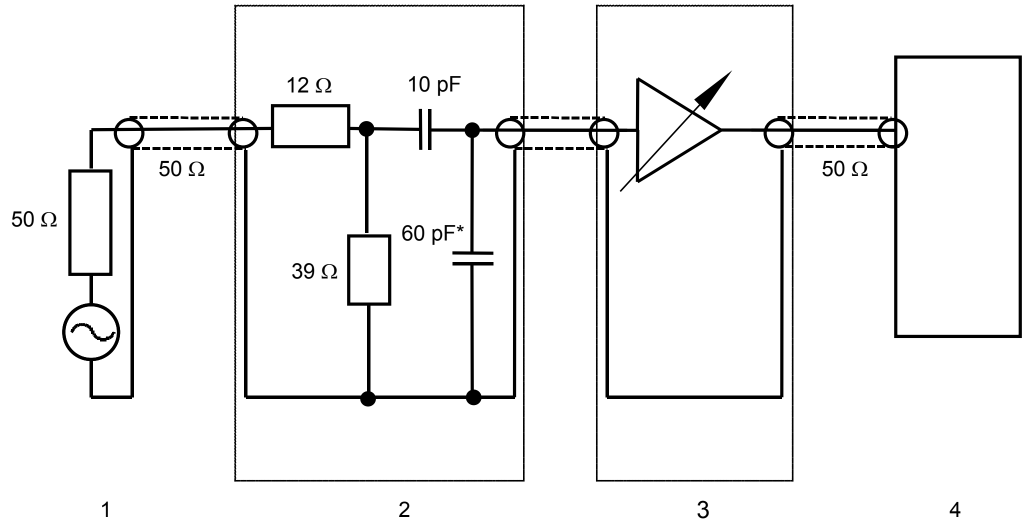
1) Set the signal generator 40 dB(μV) output level.
2) Plot the gain curve for each frequency segment.

Note For more precise calibration, the actual values of the components used in the AAA and the input parameters of the matching network may be measured. The actual attenuation for the specific measuring equipment can be calculated and used to obtain the matching network gain with greater precision.

The gain of the antenna matching unit shall be evaluated. This can be obtained either by calculation (with the actual values of the components used in the AAA the input parameters of the antenna matching unit) or by complimentary measurement (using two identical AAA head to tail).

B.3 Impedance measurement

Measurement of the output impedance of the antenna matching unit with the antenna attached shall be made with a vector impedance meter (or equivalent test equipment). The output impedance shall lie within a circle on a Smith chart crossing (100 + j0) Ω, having its centre at (50 + j0) Ω (e.g. SWR less than 2:1).



Key

1 Signal generator
2 Artificial antenna adapter
3 Antenna matching unit
4 Measuring instrument

* Includes connector capacitance and, if used, cable capacitance

Figure B.1 –Verification setup

Annex C
(informative)

Sheath-current suppressor

C.1 General Information

This Annex provides information on the proposed performance and verification of a sheath-current suppressor recommended for use when measuring vehicle antenna terminal voltage in the AM broadcast bands (LW, MW, SW). This suppressor electrically-isolates the ALSE from the vehicle ground.

C.2 Suppressor Construction

The performance curve below (Figure C.1) shows the attenuation of the sheath currents using 20 turns of a coaxial cable around a ferrite toroidal core:

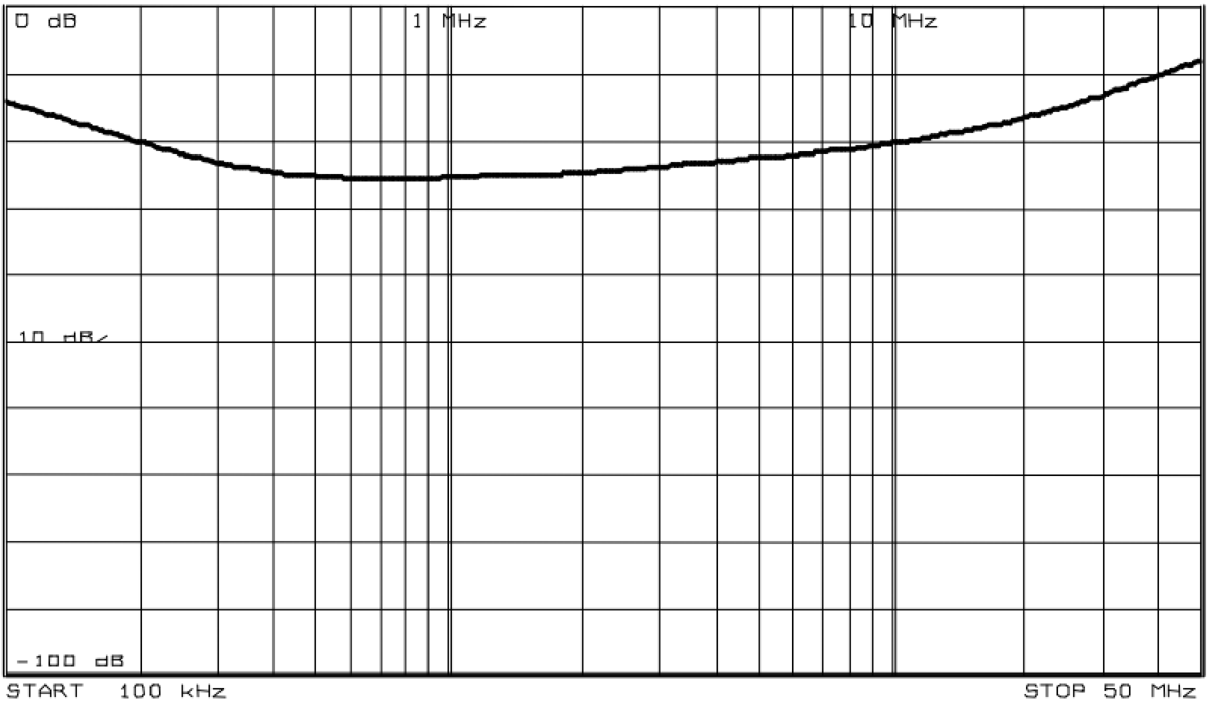
Material: N30; Al = 5 400 nH

Size: Toroidal core 58,3 x 40,8 x 17,6 mm

Manufacturer: TDK EPCOS Order No.: B64290L0040X830

Number of turns: 20 (coaxial cable)

Note To increase the attenuation, two sheath-current suppressors may be placed in series or more turns may be added to the single core.



1301

1302 **Figure C.1 – Characteristic S_{21} of the ferrite core**

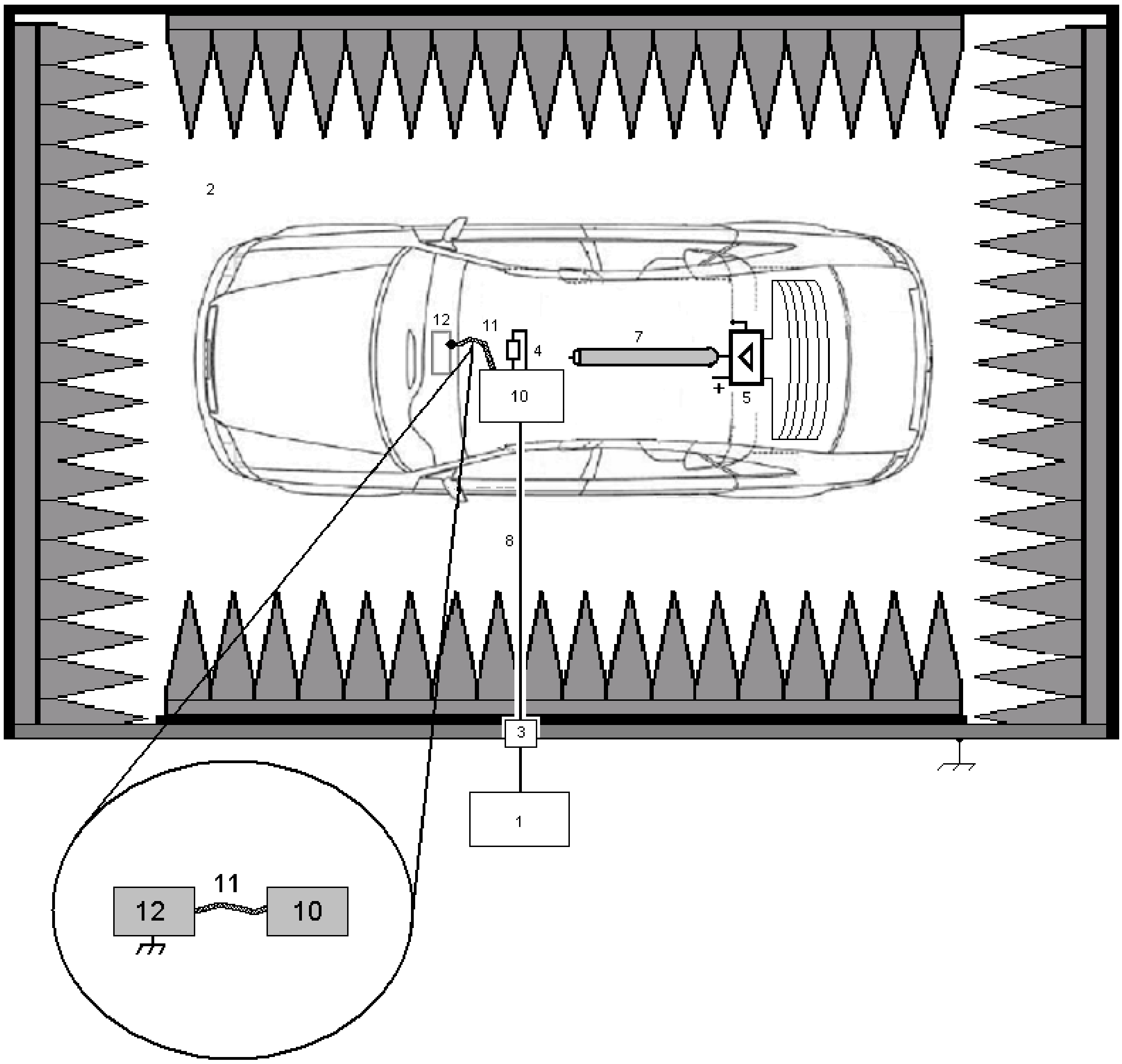
Annex D
(informative)

Guidance for the determination of the noise floor of active vehicle antennas in the AM and FM Range

Three steps are necessary to determine the noise floor of an active antenna installed in the vehicle:

1) Measurement of the noise floor of the test equipment (measuring receiver plus impedance converter) with coaxial cable impedance termination at the Impedance converter RF-Input in the AM- and FM-Range. ($U_{\text{Equipment noise}}$) (Test setup see Figure D.1).
2) Measurement of the noise floor of the active vehicle antenna including the noise floor of the test equipment. ($U_{\text{Equipment noise plus antenna noise}}$)(Test setup see Figure D.2).
3) Calculation of the active antenna noise floor with formula (D.1) (all terms in µV):

$$U_{Antenna\,noise} = \sqrt{U^2_{Equipment\,noise\,plus\,antenna\,noise} - U^2_{Equipment\,noise}} \qquad \text{(D.1)}$$

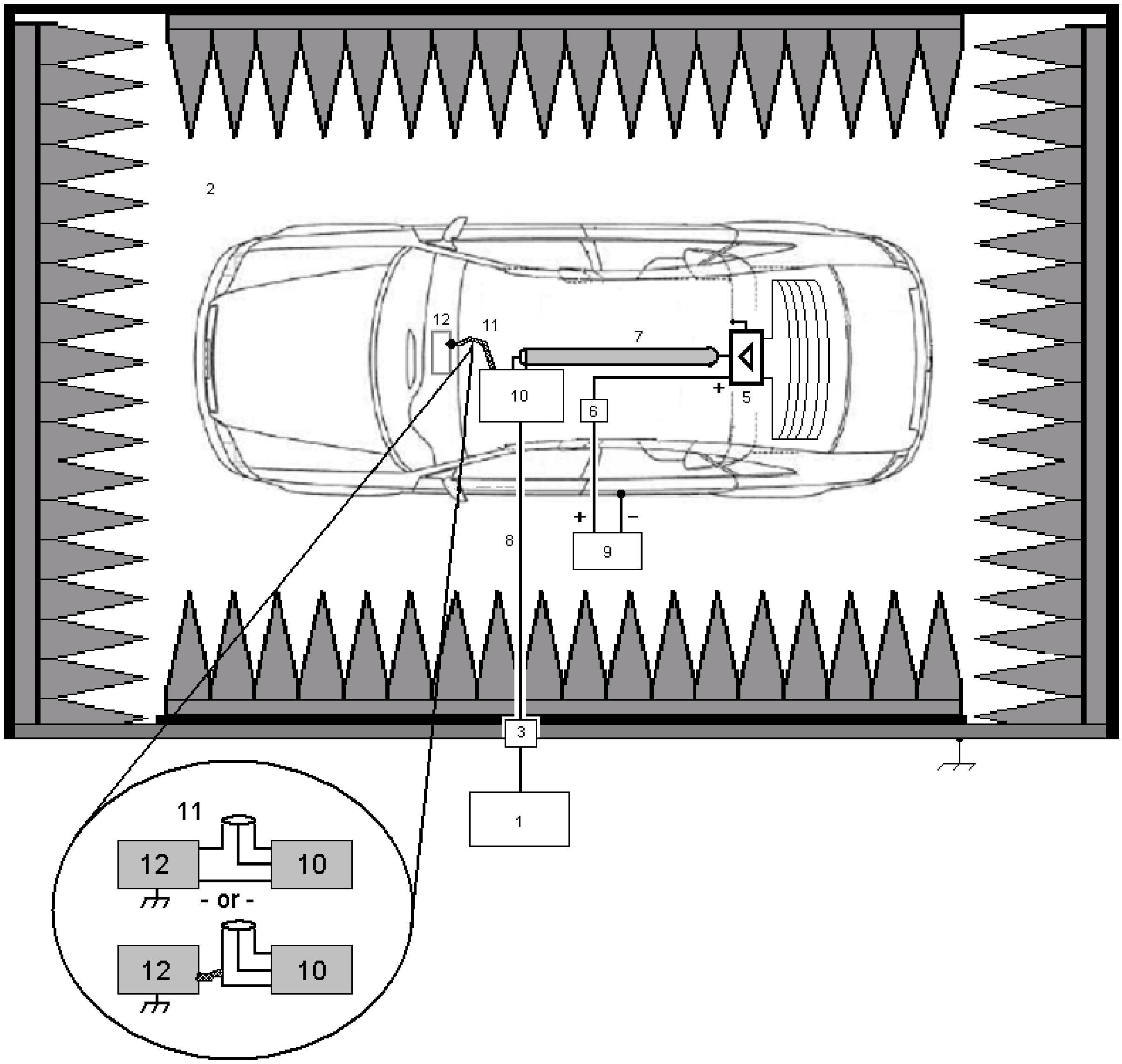


Key

1 Measuring instrument
2 ALSE
3 Bulkhead connector
4 Resistor according to coaxial cable impedance
5 Vehicle antenna amplifier
-
7 Antenna coaxial cable
8 High-quality double-shielded coaxial cable (50 Ω)
-
10 Impedance matching unit
11 Short connection to the housing of the on-board radio

12 Housing of on-board radio

Figure D.1 – Vehicle test setup for equipment noise measurement in the AM/FM range



Key

1 Measuring instrument
2 ALSE
3 Bulkhead connector
-
5 Vehicle antenna amplifier
6 Antenna amplifier power plug
7 Antenna coaxial cable
8 High-quality coaxial cable e.g. double-shielded (50 Ω)
9 External 12V battery
10 Impedance matching unit
11 Modified coaxial "T" connector or short connection to the housing of the on-board radio

12 Housing of on-board radio

Figure D.2 - Vehicle test setup for antenna noise measurement in the AM/FM range

Annex E
(normative)

Artificial Networks (AN), Artificial Mains Networks (AMN) and Asymmetric Artificial Networks (AAN)

E.1 General

Currently different types of power supplies and power supply cabling are used for a component powered by low voltage (LV) and/or high voltage (HV) and/or connected to the power grid (a.c. power mains, d.c. power supply). Therefore, it is necessary to use networks which provide specific load impedance and isolate the component from the power supply:

– Artificial networks (AN) : used for d.c. power supplies;

– Artificial Mains Networks (AMN) : used only for a.c. power mains;

– Asymmetric artificial network (AAN): used only for communication/signal lines.

E.2 Artificial networks (AN)

E.2.1 Component powered by LV

For a component powered by LV, a 5µH/50Ω-AN as defined in Figure E.1 shall be used.

The AN(s) shall be mounted directly on the ground plane. The grounding connection of the AN(s) shall be bonded to the ground plane.

Measurement ports of AN(s) shall be terminated with a 50 Ω load.

The AN impedance Z_{PB} (tolerance ± 20 %) in the measurement frequency range of 0,1 MHz to 100 MHz is specified in Table E.1 and shown in Figure E.2. It is measured between the terminals P and B (of Figure E.1) with a 50 Ω load on the measurement port with terminals A and B (of Figure E.1) short circuited.

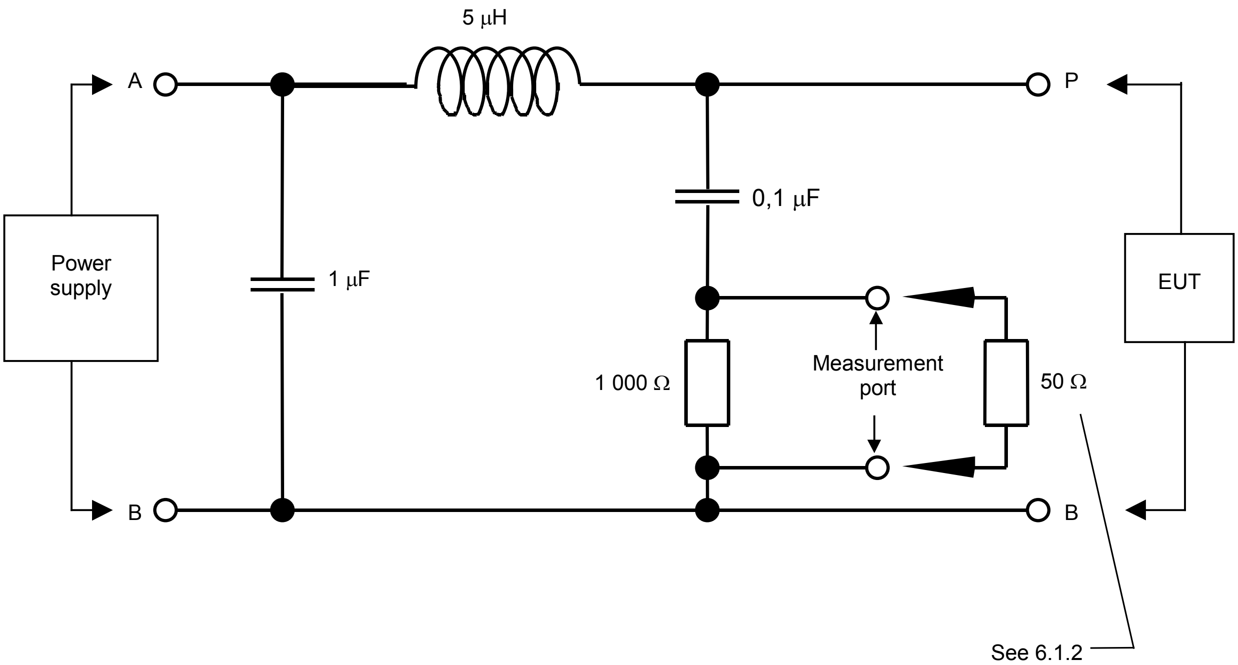


Figure E.1 – Example of 5 µH AN schematic

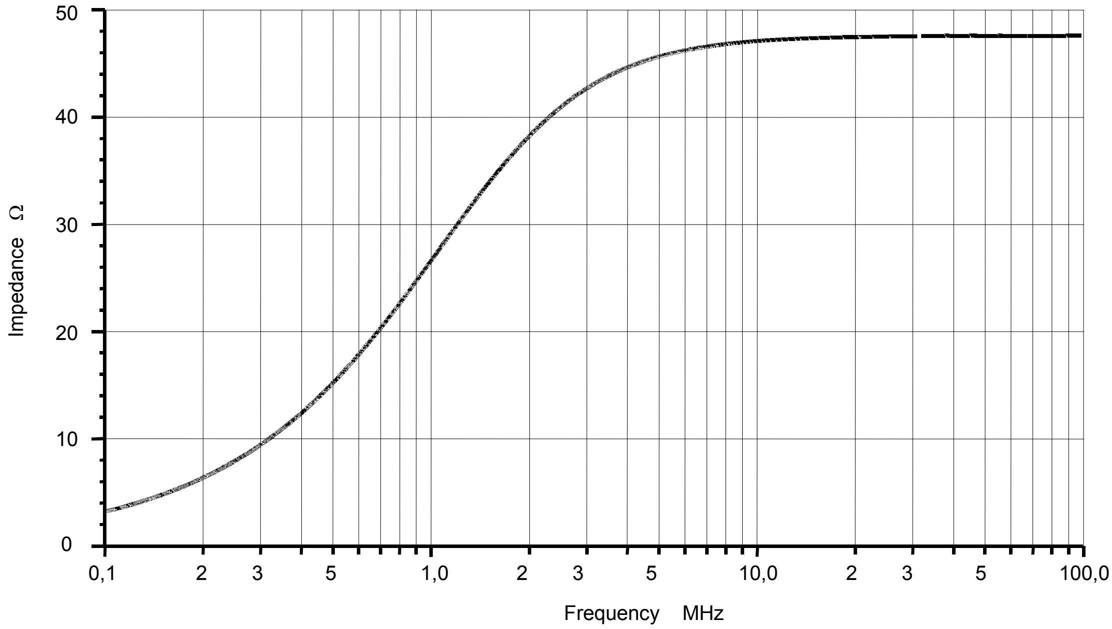


Figure E.2 – Characteristics of the AN impedance Z_{PB}

Table E.1 Magnitude of the AN impedance Z_{PB}

frequency MHz	magnitude of the impedance		
	nominal value Ω	lower tolerance Ω	upper tolerance Ω
0,10	3.20	2,56	3,84
0,15	4.79	3,83	5,75
0,20	6.37	5,09	7,64
0,30	9.45	7,56	11,34
0,40	12.41	9,93	14,89
0,50	15.23	12,18	18,27
0,70	20.34	16,27	24,41
1,00	26.64	21,31	31,97
1,50	33.88	27,10	40,65
2,00	38.26	30,61	45,92
2,50	40.97	32,77	49,16
3,00	42.70	34,16	51,24
4,00	44.65	35,72	53,59
5,00	45.66	36,53	54,79
7,00	46.59	37,27	55,90
10,00	47.10	37,68	56,53
15,00	47.39	37,91	56,87
20,00	47.49	37,99	56,99
30,00	47.56	38,05	57,07
50,00	47.60	38,08	57,12
100,00	47.61	38,09	57,14

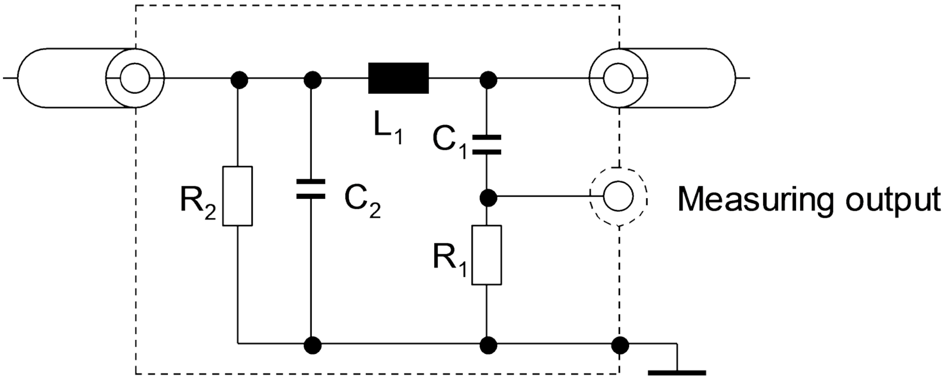
E.2.2 Component powered by HV

For a component powered by HV (e.g. 60 V – 1 000 V), a 5 µH / 50 Ω HV-AN as defined in Figure E.3 shall be used.

The HV-AN(s) shall be mounted directly on the ground plane. The grounding connection of the HV-AN(s) shall be bonded to the ground plane.

Measurement ports of HV-AN(s) shall be terminated with a 50 Ω load.

The HV-AN impedance Z_{PB} (tolerance ± 20 %) in the measurement frequency range of 0,1 MHz to 100 MHz is shown in Figure E.4. It is measured between the terminals P and B (of Figure E.3) with a 50 Ω load on the measurement port with terminals A and B (of Figure E.3) short circuited.



L_1: 5 µH
C_1: 0,1 µF
C_2: 0,1 µF (default value)
R_1: 1 kΩ
R_2: 1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

Figure E.3 – Example of 5 µH HV AN schematic

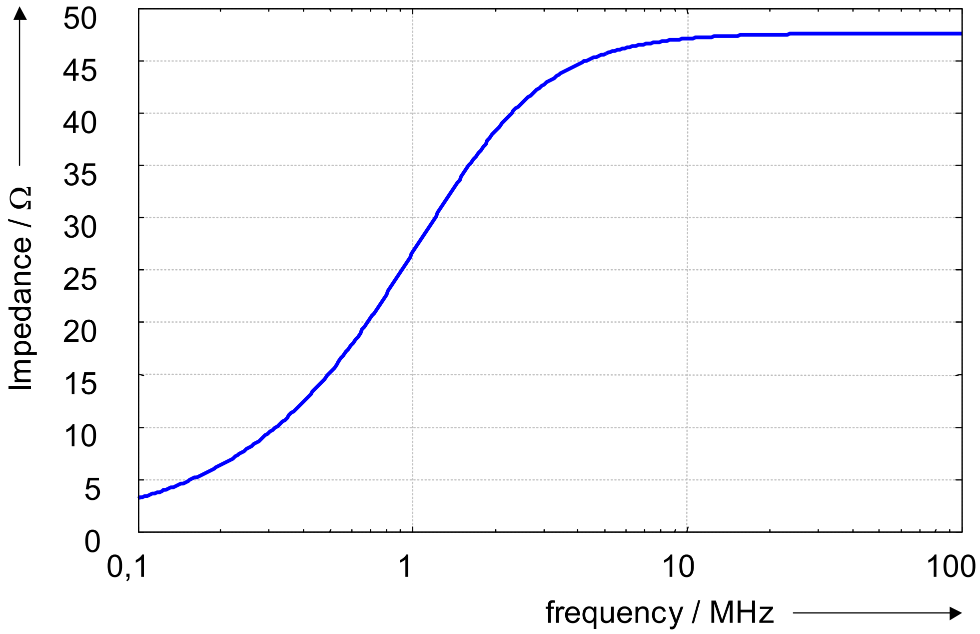
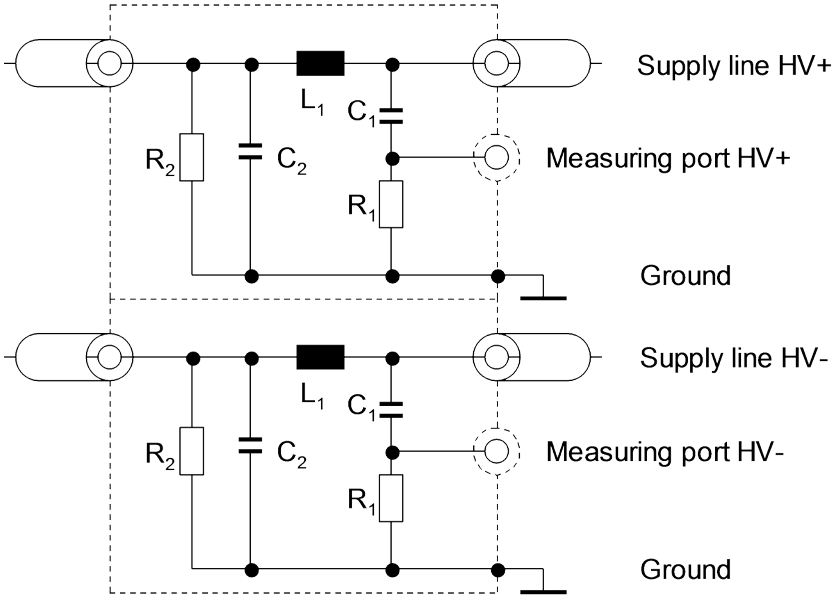


Figure E.4 – Characteristics of the HV AN impedance

See Table E1 for the nominal impedance and upper/lower tolerances in tabular form.

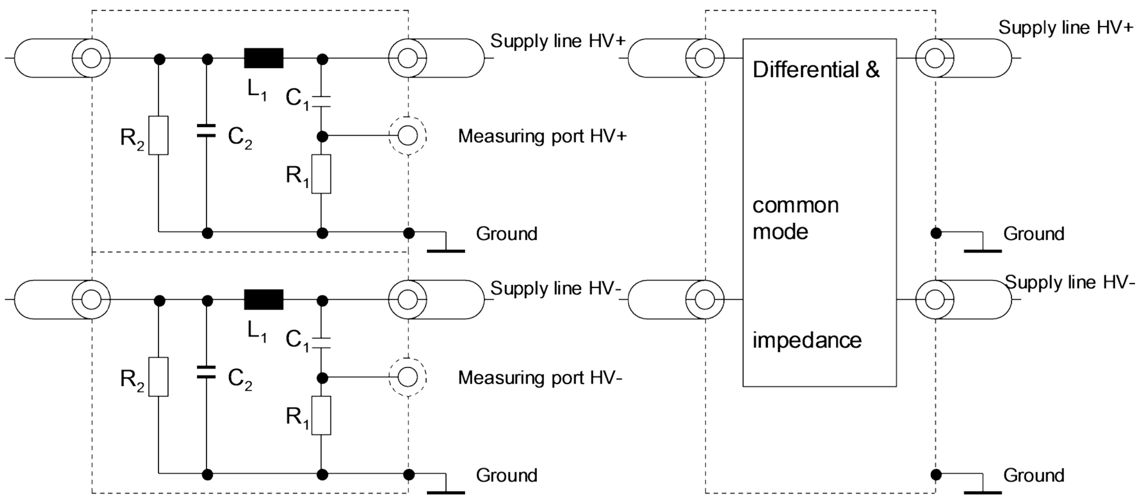
If unshielded HV AN´s are used in a single shielded box, then there shall be an inner shield between the HV AN´s as described in Figure E.5.



L_1: 5 µH
C_1: 0,1 µF
C_2: 0,1 µF (default value)
R_1: 1 kΩ
R_2: 1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

Figure E.5 – Example of 5 µH HV AN combination in a single shielded box

An optional impedance matching network may be used to simulate common mode / differential mode impedance seen by the EUT plugged on HV power supply (see Figure E.6).



L_1: 5 µH
C_1: 0,1 µF
C_2: 0,1 µF (default value)
R_1: 1 kΩ
R_2: 1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

Figure E.6 – Impedance matching network attached between HV ANs and EUT

E.2.3 Component involved in charging mode connected to d.c. power mains

For a component involved in charging mode (e.g. charger) connected to a d.c. power mains, a 5 µH / 50 Ω-d.c.-AN as defined in clause E.2.1 shall be used.

E.2.4 Vehicle in charging mode connected to d.c. power mains

For a vehicle in charging mode connected to a d.c. power mains, a 5 µH / 50 Ω-d.c.-AN as defined in clause E.2.1 shall be used.

E.3 Artificial Mains networks (AMN)

E.3.1 Component AMN

For a component involved in charging mode (e.g. charger) connected to a a.c. power mains, a 50 µH / 50 Ω-AMN as defined in CISPR 16-1-2 clause 4.3 shall be used.

The AMN(s) shall be mounted directly on the ground plane. The grounding connection of the AMN(s) shall be bonded to the ground plane.

Measurement ports of AMN(s) shall be terminated with a 50 Ω load.

E.3.2 Vehicle in charging mode connected to a.c. power mains

For a vehicle in charging mode connected to a a.c. power mains, a 50µH/50Ω-AMN as defined in clause E.3.1 shall be used.

E.4 Asymmetric artificial network (AAN):

Currently different types of communication system and communication cabling are used for the communication between charging station and component (e.g. charger) or vehicle. Therefore a distinction between some specific cabling/operation types is necessary.

The AAN(s) shall be mounted directly on the ground plane. The grounding connection of the AAN(s)) shall be bonded to the ground plane.

Measurement ports of AAN(s) shall be terminated with a 50 Ω load.

E.4.1 Symmetric communication lines

An asymmetric artificial network (AAN) to be connected between component (e.g. charger) or vehicle and charging station or any associated equipment (AE) used to simulate communication is defined in CISPR 16-1-2 Annex E clause E.2 (T network circuit) (see example in Figure E.7).

The AAN has a common mode impedance of 150 Ω. The impedance Z_{cat} adjusts the symmetry of the cabling and attached periphery typically expressed as longitudinal conversion loss (LCL). The value of LCL should be predetermined by measurements or be defined by the manufacturer of the charging station/charging cable. The selected value for LCL and its origin shall be stated in the test report.

Note ´For some networks (e.g. CAN) this AAN cannot be used for conducted emission and/or radiated emission measurements on these lines. Alternative methods (current and voltage measurements) should be used.

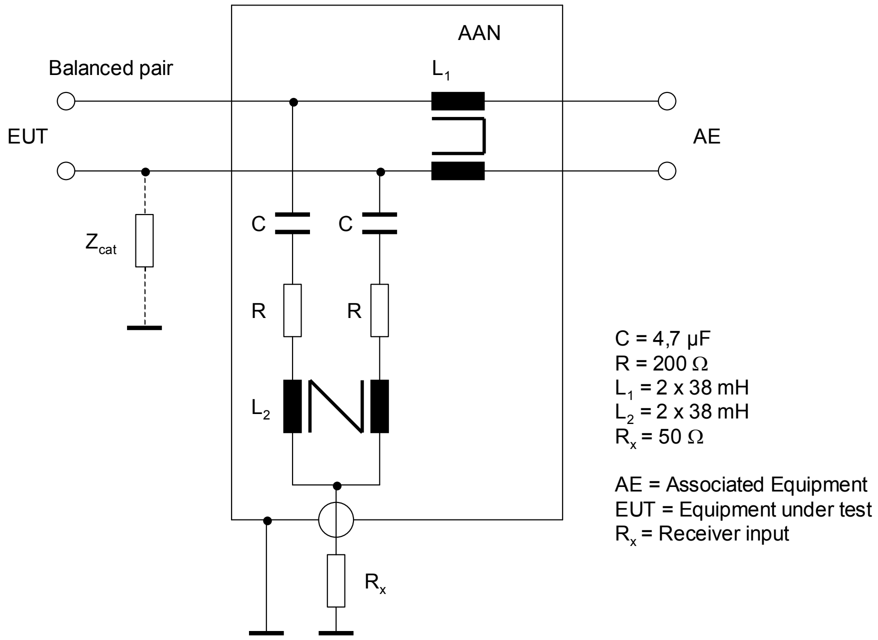


Figure E.7 Example of an AAN for symmetric communication lines

E.4.2 PLC on power lines

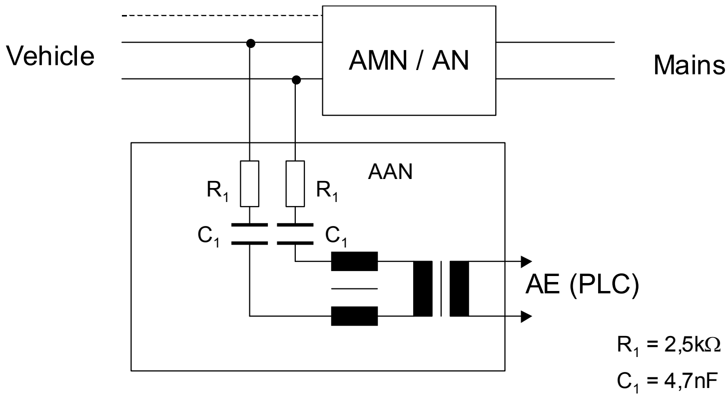
If an original charging station can be used for the test, it might be not necessary to add any AAN for PLC communication.

If PLC communication cannot be ensured with original charging station and AMN, or shall be simulated with use of an associated equipment (AE) (e. g. as a PLC modem) instead of an original charging station, it is necessary to add an AAN for PLC communication between PLC modem and the AMN (component or vehicle side) as defined in Figure E.8.

Note This AAN is not intended for any conducted emission measurement, but only to ensure adequate decoupling between PLC modem and power mains.

The circuits shown in Figures E.8 allow at least emission measurements for out-of-band emissions. For in-band emission measurements a disturbance current (common mode) measurement (as defined in CISPR 16-2-1) on the charging cable may be performed. In case of in-band emission measurements the disturbance current should fulfil the requirements for conducted disturbance currents on network and telecommunication access.

The circuit in Figure E.8 provides a common mode termination by the AN/AMN. For emission testing only the emissions from the PLC modem of the EUT should be measured. Therefore, an attenuator is located between powerline and the PLC modem at the AE side in the circuit for emission tests. This attenuator consists of two resistors in combination with the input/output impedance of the PLC modem. The value of the resistors depends on the design impedance of the PLC modems and the allowed attenuation for the PLC system.



The value of the resistors depends on the allowed attenuation and the design impedance of the PLC modem (here: 40dB attenuation, 100Ω PLC design impedance)

Figure E.8 Example of AAN circuit of PLC on a.c. or d.c. powerlines

E.4.3 PLC (technology) on control pilot

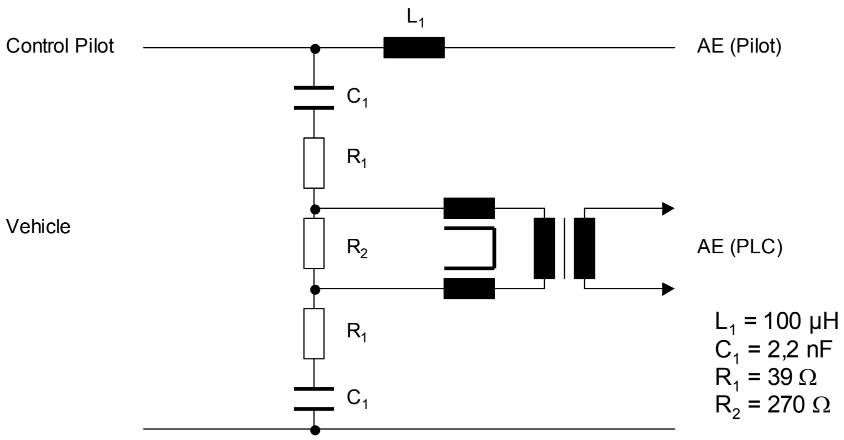
Some communication systems use the control pilot line (versus PE) with a superimposed (high frequency) communication. Typically the technology developed for powerline communication (PLC) is used for that purpose. On one hand the communication lines are operated unsymmetrically, on the other hand two different communication systems operate on the same line. Therefore a special AAN must be used as defined in Figure E.9.

It provides a common mode impedance of 150 Ω ± 20 Ω (150 kHz to 30 MHz) on the control pilot line (assuming a design impedance of the modem of 100 Ω). Both types of communications (control pilot, PLC) are separated by the network.

Therefore, typically a communication simulation is used in combination with this network. The attenuator built by the resistors and the design impedance of the PLC modem makes sure that the signal on the charging cable is dominated by the EUT’s communication signals rather than the AE PLC modem.

The values of inductance and capacitance in the networks added for PLC on control pilot shown in Figure E.9 shall not induce any malfunction of communication between component (e.g. charger) or vehicle and AE or charging station. It may therefore be necessary to adapt these values to ensure proper communication.

Note This AAN is not intended for any conducted emission measurement, but only to ensure a controlled impedance of the pilot line (and PLC) seen from the component or vehicle side.



The values of the three resistors depend on the design impedance of the PLC modem connected at AE side. The values given in the schematic are valid for a design impedance of 100 Ω.

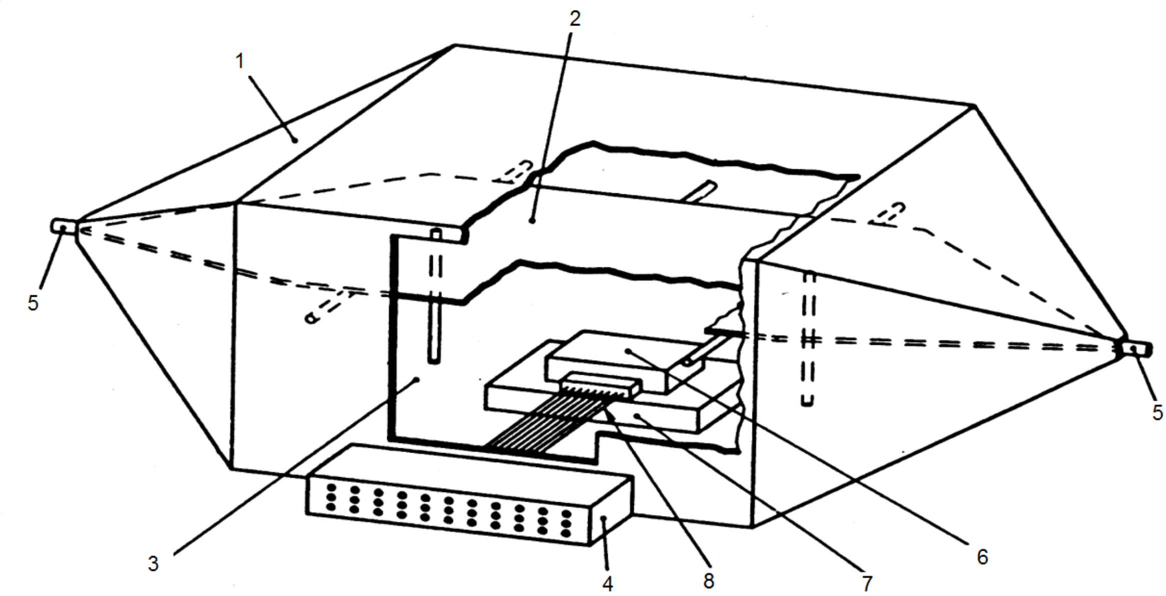
Figure E.9 Example of AAN circuit for PLC on pilot line

Annex F
(informative)

Radiated emissions from components/modules – TEM cell method

F.1 General

Measurements of radiated field strength shall be made in a shielded enclosure to eliminate the high levels of extraneous disturbance from electrical equipment and radiated fields from nearby broadcast and other radio transmitters. The TEM cell works as a shielded enclosure. An example of a TEM cell is shown in Figure F.1. Information relating to the size and construction of a TEM cell for component measurement is given in F.5.



Key

1 Outer shield

2 Septum (inner conductor)

3 Access door

4 Connector panel (optional)

5 Coaxial connectors

6 EUT

7 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)

8 Artificial harness

Note The connectors on the connector panel should be coaxial RF connectors if the RF boundary extends outside of the TEM cell

Figure F.1 - TEM cell (example)

The upper frequency limit of this test method is a direct function of the TEM cell dimensions, the dimensions of the components/module (arrangement included), and the RF filter characteristic. Measurements shall not be made near the TEM cell resonance frequencies.

A TEM cell is recommended for testing automotive electronic systems in the frequency range from 150 kHz to 200 MHz. The TEM cells boxed in Table F.2, are typical of those used in automotive work.

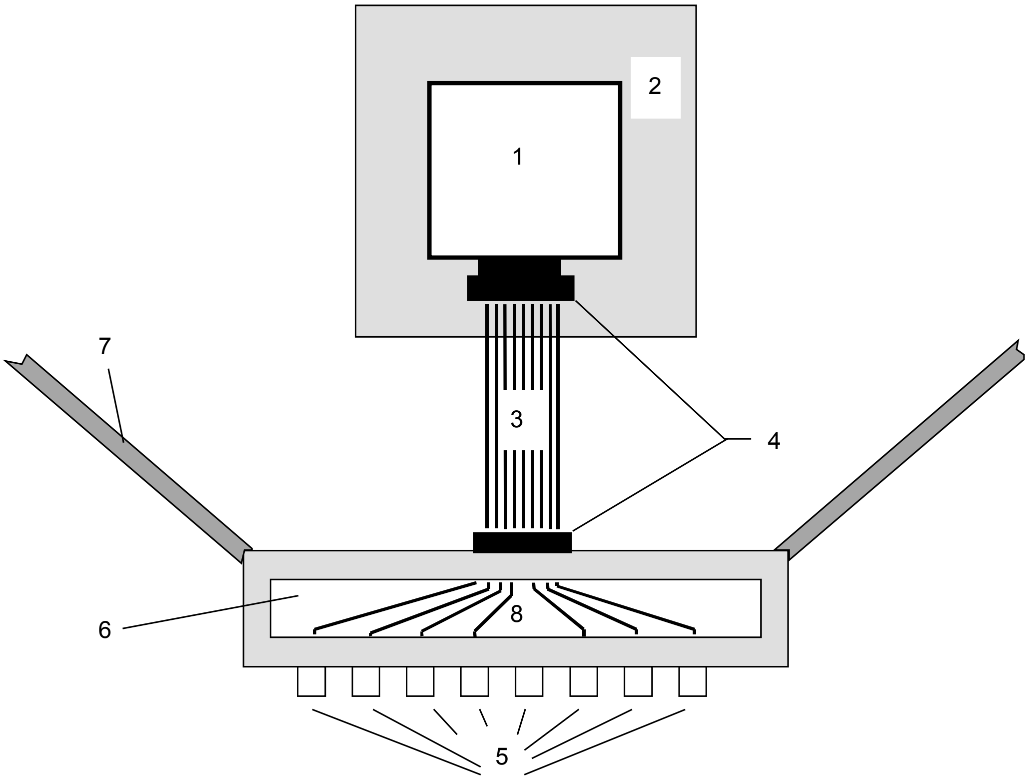
In order to achieve reproducible test results the EUT and the test harness shall be placed in the TEM cell in the same position for each repeated measurement.

For the purpose of this test, the septum of the TEM cell functions in a similar way to a receiving antenna.

F.2 Test setup

F.2.1 Setup with major field emission from the wiring harness

The TEM cell shall have a connector panel connected as close as possible to a plug connector (see Figures F.2 and F.3).



Key

1 EUT

2 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

3 Printed circuit board or wiring harness

4 Connector

5 Coaxial connectors

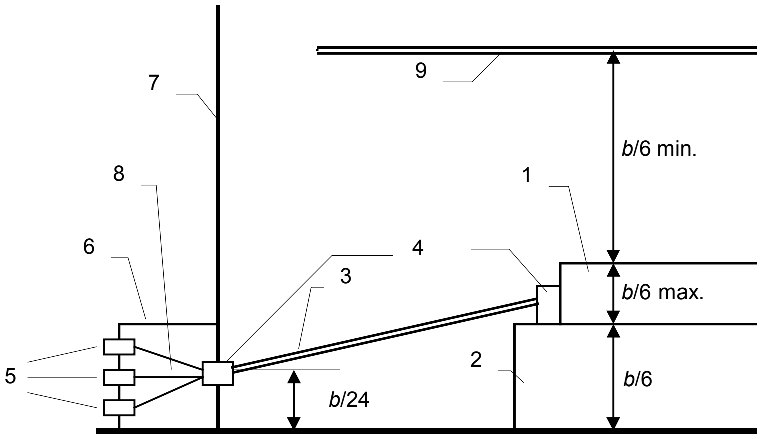
6 Connector panel (optional)

7 TEM cell wall

8 RF coaxial cables

Note All leads to the EUT shall pass through an RF boundary. The RF boundary is either at the wall of the TEM cell or extended through RF coaxial cable (8) and coaxial connectors (5). The boundary is terminated by RF-filters which can be connected inside the connector panel (6) or directly outside to the coaxial connectors (5). The cables in the connector panel should be coaxial if the RF-filters are connected to the coaxial connectors (5)

Figure F.2 – Example of arrangement of leads in the TEM cell and to the connector panel



Key

1 EUT

2 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

3 Printed circuit board (no ground plane) or wiring harness, not shielded

4 Connector

5 Coaxial connectors

6 Connector panel (optional)

7 TEM cell wall

8 Cables

9 Septum

b is the TEM cell height (see Annex F.5)

NOTE The connectors on the connector panel should be coaxial RF connectors if the RF boundary extends outside of the TEM cell.

Figure F.3 – Example of the arrangement of the connectors, the lead frame and the dielectric support

All supply and signal leads from the EUT are directly connected to the artificial harness (e.g. a lead frame). The plugs at the connector panel which are not required shall be sealed so that they are RF-tight.

The connection of the positive power lead shall be through the AN (6.2.2), direct at the connector panel.

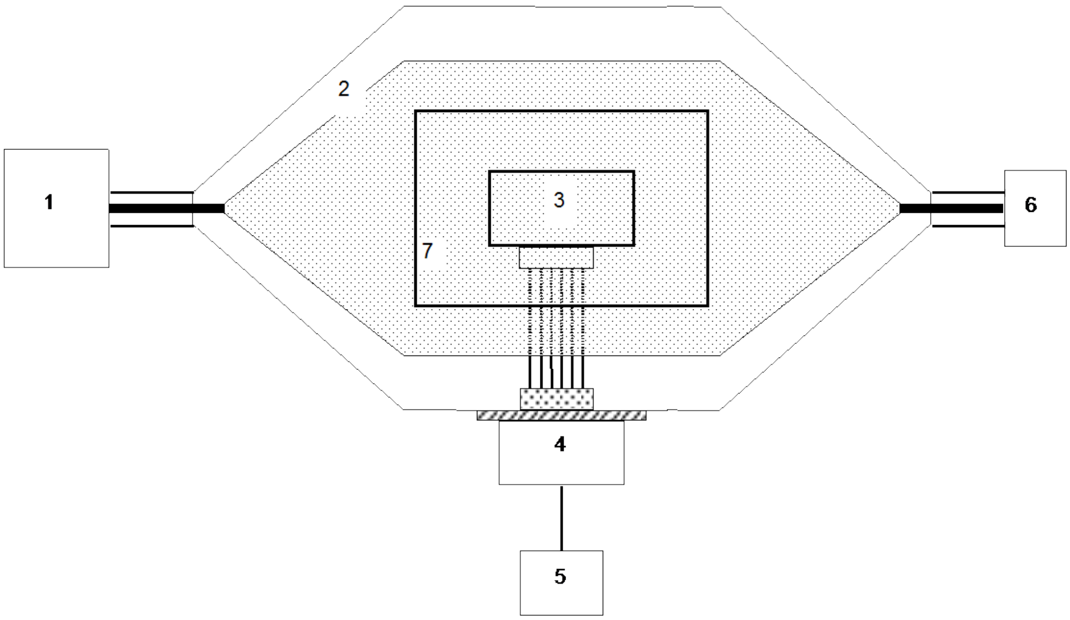
It is not permitted to ground the EUT directly to the TEM cell floor. The grounding shall be done at the connector panel.

F.2.2 Setup with major field emissions from the EUT

The test setup is similar to the method shown above, except that the leads to the EUT are positioned and shielded to minimise electromagnetic radiation from the leads. This is accomplished by positioning the leads flat across the bottom of the TEM cell and bringing them vertically to the EUT. The use of a sealed battery and shielded wiring in the TEM cell will further reduce the electromagnetic radiation from power and signal leads. To minimise the radiation from the wiring further, shielding foil tape can be applied over the leads.

F.3 Test procedure

An example of the TEM cell method test layout is given in Figure F.4. The general arrangement of the EUT, the harness, the filter system at the TEM cell's wall, etc. represent a standardised test condition. Any deviations from the standard test configuration shall be agreed upon prior to testing and recorded in the test report.



Key

1 Measuring instrument
2 TEM cell
3 EUT
4 AN (see 6.2.2)
5 Power supply
6 50 Ω termination resistor
7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

Figure F.4 – Example of the TEM cell method test setup

The EUT shall be supported *b*/6 (see Figure F.3) above the TEM cell floor by non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$) in the allowed working region. The length of the artificial harness (e.g. a lead frame) shall be 450 +/- 45 mm and positioned as shown in Figures F.2 and F.3.

The wiring arrangement of the artificial harness, the design and the overall height of the EUT's connector constitute electrical coupling loops and dipoles which have influence on the test results. All connections between the plug and contacts of the EUT's (multipole) connector and the artificial harness shall be as short as possible. Repeat measurements shall be performed using the same arrangement of the artificial harness, the same overall height of the EUT's connector and the same pin assignment on both connectors. Care shall be taken, if the size of the EUT and the allowed working region is nearly the same. In such a case, special care should be taken to define and document the test layout in the test plan.

The EUT shall be installed to operate under typical loading and other conditions in the vehicle in such a way that the maximum emission state occurs. These operating conditions must be defined in the test plan to ensure supplier and customer can perform identical tests.

Note Different orthogonal orientations of the EUT could lead to different levels of measured electromagnetic energy.

The positive supply line shall have an RF filter at the TEM cell input. The artificial network (AN) of 6.2.2 shall be used as this filter. The AN shall be connected directly to the TEM cell and shall be screened, so that the negative supply line is grounded at the connector panel. The RF sampling port of the AN shall be terminated with a 50 Ω load.

All sensor and actuator leads of the EUT shall be connected to a peripheral interface, which simulates the operation in the vehicle.

To minimise influences of the wiring outside the TEM cell, low pass filters shall be used, which shall be connected directly to the BNC panel. The performance of the filters depends on the frequency range of the EUT's wanted signals. If no other configuration is specified in the test plan the filters shall perform like the artificial network with a 50 Ω impedance as described in Annex E.

To eliminate influences of its length and arrangement the wiring inside the connector panel shall be as short as possible via 50 Ω coaxial cables if a BNC connector panel is used. The shielding (outer conductor) of the cables shall be grounded at both ends.

Repeat measurements shall be performed using the same RF port of the TEM cell, with the opposite port terminated by a 50 Ω impedance.

F.4 Limits for radiated disturbances from components/modules – TEM cell method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

Note Recommended limits for radiated disturbances from components (both the setup with major field coupling to the wiring harness (F.2.1) and the setup with major coupling to the EUT (F.2.2) are given in Table F.1. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table F.1 – Examples of limits for radiated disturbances – TEM cell method

Service / Band	Frequency MHz	Levels in dB(µV)														
		Class 5			Class 4			Class 3			Class 2			Class 1		
		Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average
BROADCAST																
LW	0,15 – 0,30	26	13	6	36	23	16	46	33	26	56	43	36	66	53	46
MW	0,53 – 1,8	20	7	0	28	15	8	36	23	16	44	31	24	52	39	32
SW	5,9 – 6,2	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
FM	76 – 108	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
TV Band I	41 – 88	16	-	6	22	-	12	28	-	18	34	-	24	40	-	30
TV Band III	174 – 230	16	-	6	22	-	12	28	-	18	34	-	24	40	-	30
DAB III	171 – 245	10	-	0	16	-	6	22	-	12	28	-	18	34	-	24
TV Band IV	468 – 944	Radiated emission – TEM cell Not Applicable														
DTTV	470 – 770															
DAB L Band	1447 – 1494															
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
VHF	30 – 54	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
VHF	68 – 87	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
VHF	142 – 175	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
Analogue UHF	380 – 512	Radiated emission – TEM cell Not Applicable														
RKE	300 – 330															
RKE	420 – 450															
Analogue UHF	820 – 960															
GSM 800	860 – 895															
EGSM/GSM 900	925 – 960															
GPS L1 civil	1567 – 1583															
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

F.5 TEM Cell design

The dimensions of a TEM cell are shown in the Figure F.5a and F.5b and given in Table F.2.

Dimensions in millimetres

Drawing not to scale

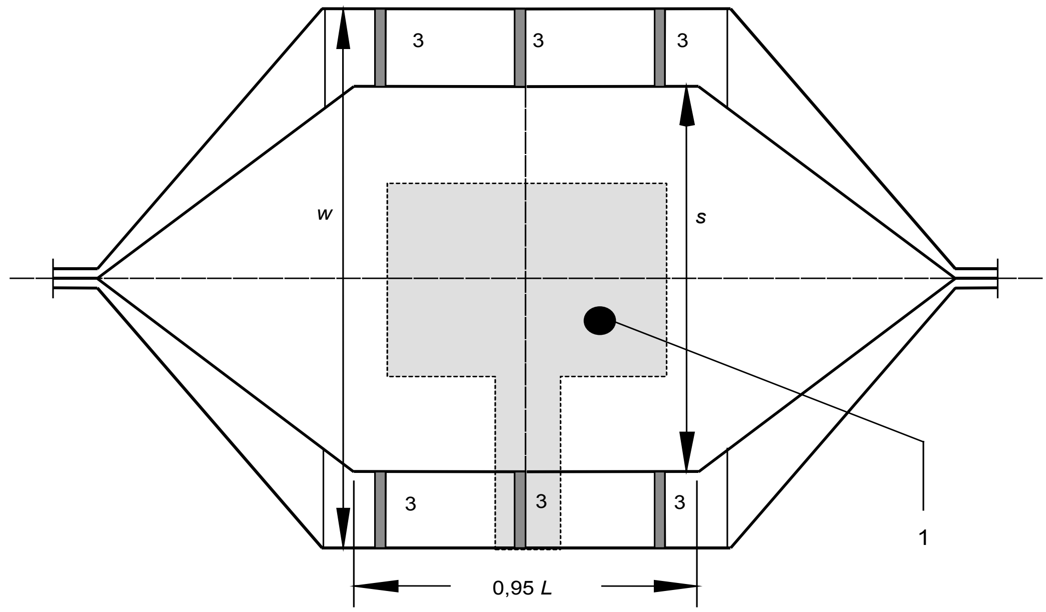


Figure F.5a – Horizontal section view at septum

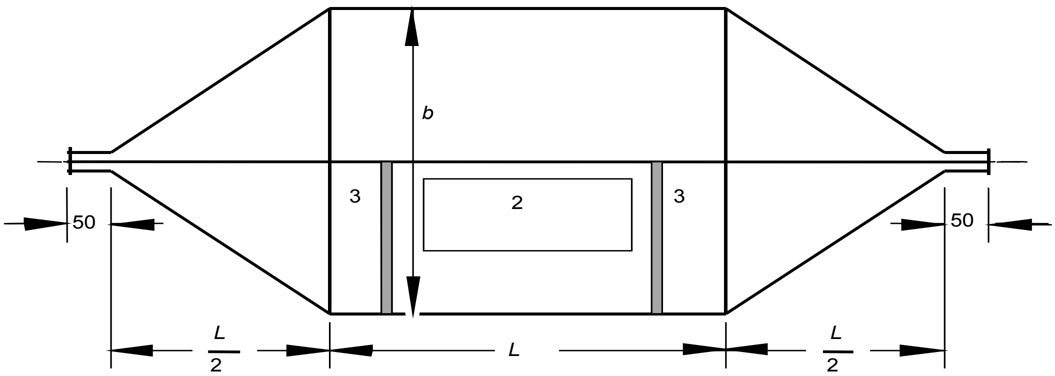


Figure F.5b – Vertical section view at septum

Key

1 Allowed working region: 0,33 *W*, 0,60 *L*

2 Access door

3 Dielectric supports

Figure F.5 – TEM cell

Table F.2 shows the dimensions for constructing TEM cells with specific upper frequency limits.

Table F.2 – Dimensions for TEM cells

Upper frequency MHz	Cell form factor *W*/*b*	Cell form factor *L*/*W*	TEM cell height *b* mm	Septum width *S* mm
100	1,00	1,00	1 200	1 000
200	1,69	0,66	560	700
200	1,00	1,00	600	500
300	1,67	1,00	300	360
500	1,50	1,00	200	230
NOTE The TEM cells in the box are typical for automotive component testing. For integrated circuit testing, even smaller TEM cells may be applicable for testing up to and above 1 GHz.				

Annex G
(informative)

Radiated emissions from components/modules – Stripline method

G.1 General

The stripline is an open waveguide, which consists of a reference ground plane and an active conductor (septum) and has characteristic impedance. Commonly used values for characteristic impedances are 50 Ω and 90 Ω. Information relating to the size and construction of a stripline is given in Figure G.2 and Figure G.3.

Users are encouraged to study and experiment with the test method to increase the body of knowledge with the aim of reaching consensus on including it in the main body of this standard at a future date.

The stripline may be used in the frequency range from 150 kHz to 400 MHz where the harness is the primary radiating/coupling element.

The limits of the frequency range can be extended up to 1 000 MHz, if:

- the dominance of TEM mode can be shown [1]);
- and the EUT is located under the septum;
- and the height of the EUT is limited to 1/3 of the septum height.

Measurements shall be made in a shielded enclosure to eliminate high levels of external disturbances. For further details see Figure G.1.

Note The influence of the shielded enclosure on the measured impedance (i.e. reflection coefficient as measured with a network analyser) of the stripline should be less than 6 dB compared with an open field test site. To realize this it might be necessary to equip the shielded enclosure partially with absorbers. An example is shown in Figure G.1.

G.2 Test setup

For radiated emissions measurements, the arrangement of the EUT, test harness, load simulator and measuring equipment shall be equivalent to the example shown in G.1.

Deviations of the location and length of the test harness (e.g. the original vehicle harness) and the location of the EUT have to be agreed between customer and supplier.

In order to achieve reproducible test results the EUT and the test arrangement shall be located at the same position in the stripline for each repeated measurement.

G.2.1 Stripline impedance matching

Correct impedance matching between the stripline and the measuring instrument of 50 Ω shall be maintained for all frequencies. This can be achieved by using lossless transmission line transformers (non-linear shape of the septum tapers or an additional external waveguide) or lumped passive network.

---

1) For the design shown in Figure G.2 it is presumed that the TEM mode is dominant up to 400 MHz. For the design shown in Figure G.3 it is presumed that the TEM mode is dominant up to 1 000 MHz.

If the matching unit is a lumped passive network, appropriate correction of measurement results shall be made for any insertion loss.

G.2.2 Location of the EUT

The EUT shall be placed (50 ± 5) mm above the reference ground plane on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$) and must be located on the same side as the 50 Ω load of the stripline as shown in Figure G.1. The case of the EUT shall not be grounded to the reference ground plane unless it is intended to simulate the real vehicle configuration. In the case that the EUT is not located under the septum, the EUT shall be located at a distance of $\left(200\ ^{+50}_{\ 0}\right)$ mm from the edge of the septum.

G.2.3 Location and length of the test harness

The length of test harness parallel to the septum shall be (1 000 ± 50) mm.

The total length of the test harness between the EUT and the load simulator (or the RF boundary) is typical 1 700 mm and shall not exceed 2 000 mm. The same test harness can be used as with the ALSE test method (see 6.5).

The long segment of the test harness shall be within the inner one-third of the width of the septum. Ideally, it is placed under the centreline of the septum.

The wiring type is defined by the intended system application and requirement. The test harness shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), (50 ± 5) mm above the reference ground plane. The locations of the EUT and load simulator require a harness bend angle of (90 ± 15) degrees.

G.2.4 Location of the load simulator

The load simulator should be located at a distance of $\left(200\ ^{+50}_{\ 0}\right)$ mm from the edge of the septum. If this cannot be met, the actual location of the load simulator shall be documented in the test report.

The load simulator shall be placed directly on the reference ground plane. If the load simulator has a metallic case, this case shall be bonded to the reference ground plane. Alternatively, the load simulator may be located adjacent to the reference ground plane (with the case of the load simulator bonded to the reference ground plane) or outside of the test chamber, provided the test harness from the EUT passes through an RF boundary bonded to the reference ground plane. When the load simulator is located on the reference ground plane, the d.c. power supply lines of the load simulator shall be connected through the AN(s) (see 6.2.2).

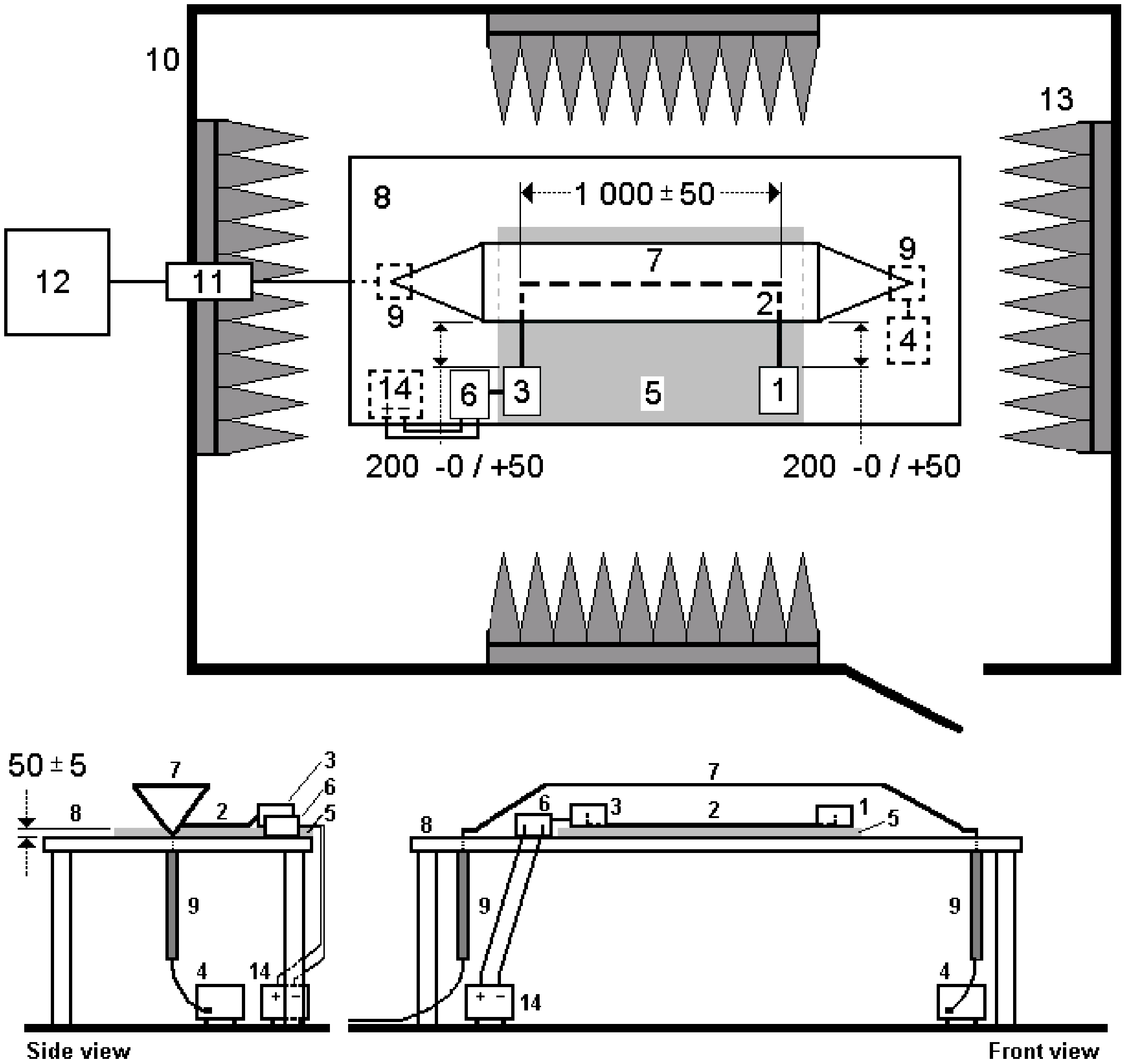
G.3 Test procedure

The general arrangement of the EUT, the harness and the peripherals, represents a standardized test condition. Any deviations from the standard test configuration shall be agreed between customer and supplier prior to testing and recorded in the test report.

The EUT shall be installed to operate under typical loading and operating conditions in the vehicle in such a way that the maximum emission state occurs. These operating conditions have to be defined in the test plan to ensure that customer and supplier are performing identical tests.

The arrangement of the EUT as well as the measuring equipment shall be functionally equivalent to the example shown in Figure G.1 and shall be defined in the test plan.

Top view Dimensions in millimetres



Key:

1 EUT

2 Test harness

3 Load simulator

4 50 Ω load (location optional)

5 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)

6 Artificial network (AN)

7 Septum

8 Reference ground plane

9 Matching unit (if necessary)

10 Wall of shielded room

11 Bulkhead connector

12 Measuring instrument

13 Absorbers (if necessary)

14 Power supply (location optional)

Figure G.1 – Example of a basic stripline test setup in a shielded enclosure

G.4 Limits for radiated emissions from components/modules – Stripline method

Some disturbance sources are continuous emitters and require a lower limit than a disturbance source which operates only periodically or for short intervals.

The limits of the radiated electromagnetic energy may be different for each disturbance source and arrangement (coupling between antenna and electronic equipment in the vehicle).

For evaluation of radiated emissions from components/modules the RF voltage at the stripline output is to be measured.

Table G.1 – Examples of limits for radiated disturbances – Stripline method

Service / Band	Frequency MHz	Levels in dB(µV)														
		Class 5			Class 4			Class 3			Class 2			Class 1		
		Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average
BROADCAST																
LW	0,15 – 0,30	47	34	27	57	44	37	67	54	47	77	64	57	87	74	67
MW	0,53 – 1,8	41	28	21	49	36	29	57	44	37	65	52	45	73	60	53
SW	5,9 – 6,2	41	28	21	47	34	27	53	40	33	59	46	39	65	52	45
FM	76 – 108	32	19	12	38	25	18	44	31	24	50	37	30	56	43	36
TV Band I	41 – 88	22	-	12	28	-	18	34	-	24	40	-	30	46	-	36
TV Band III	174 – 230	22	-	12	28	-	18	34	-	24	40	-	30	46	-	36
DAB III	171 – 245	16	-	6	22	-	12	28	-	18	34	-	24	40	-	30
TV Band IV	468 – 944	22	-	12	28	-	18	34	-	24	40	-	30	46	-	36
DTTV	470 – 770	26	-	16	32	-	22	38	-	28	44	-	34	50	-	40
DAB L Band	1447 – 1494	Radiated emission – Stripline Not Applicable														
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	40	28	21	46	34	27	52	40	33	58	46	39	64	52	45
VHF	30 – 54	32	19	12	38	25	18	44	31	24	50	37	30	56	43	36
VHF	68 – 87	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
VHF	142 – 175	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
Analogue UHF	380 – 512	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
RKE	300 – 330	20	-	6	26	-	12	32	-	18	38	-	24	44	-	30
RKE	420 – 450	20	-	6	26	-	12	32	-	18	38	-	24	44	-	30
Analogue UHF	820 – 960	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
GSM 800	860 – 895	32	-	12	38	-	18	44	-	24	50	-	30	56	-	36
EGSM/GSM 900	925 – 960	32	-	12	38	-	18	44	-	24	50	-	30	56	-	36
GPS L1 civil	1567 – 1583	Radiated emission – Stripline Not Applicable														
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

These limits have been established for a 90 Ω stripline design as shown in Figure G.3. In case of using other stripline impedance characteristics than 90 Ω, the limits have to be adapted in accordance with the following formula G.1:

$$K_{\frac{90\Omega}{Z_2}} = 20\lg\sqrt{\frac{90\Omega}{Z_2}}\ \ \text{dB} \tag{G.1}$$

Example for a stripline with 50 Ω characteristic impedance:

$$K_{\frac{90\Omega}{50\Omega}} = 20\lg\sqrt{\frac{90\Omega}{50\Omega}} = 2{,}54\ \text{dB} \tag{G.2}$$

Limits $Z_{50\Omega}$ = Limits $Z_{90\Omega}$ - $K_{90\Omega/50\Omega}$ = Limits $Z_{90\Omega}$ - 2,54 dB

where

K is the correction factor for limits in dB;

Z is the characteristic impedance of stripline in Ω.

G.5 Stripline design

An example of a 50 Ω stripline construction is shown in FigureG.2 and for a 90 Ω stripline in Figure G.3. The ratio of *b*/*h* determines the characteristic impedance. If dimension *b* is greater than *h*, the following equation G.3 applies:

$$Z = \frac{120\times\pi}{\frac{b}{h} + 2{,}42 - 0{,}44\times\frac{h}{b} + \left[1-\frac{h}{b}\right]^{6}} \tag{G.3}$$

where

Z is the characteristic impedance of the stripline in Ω;

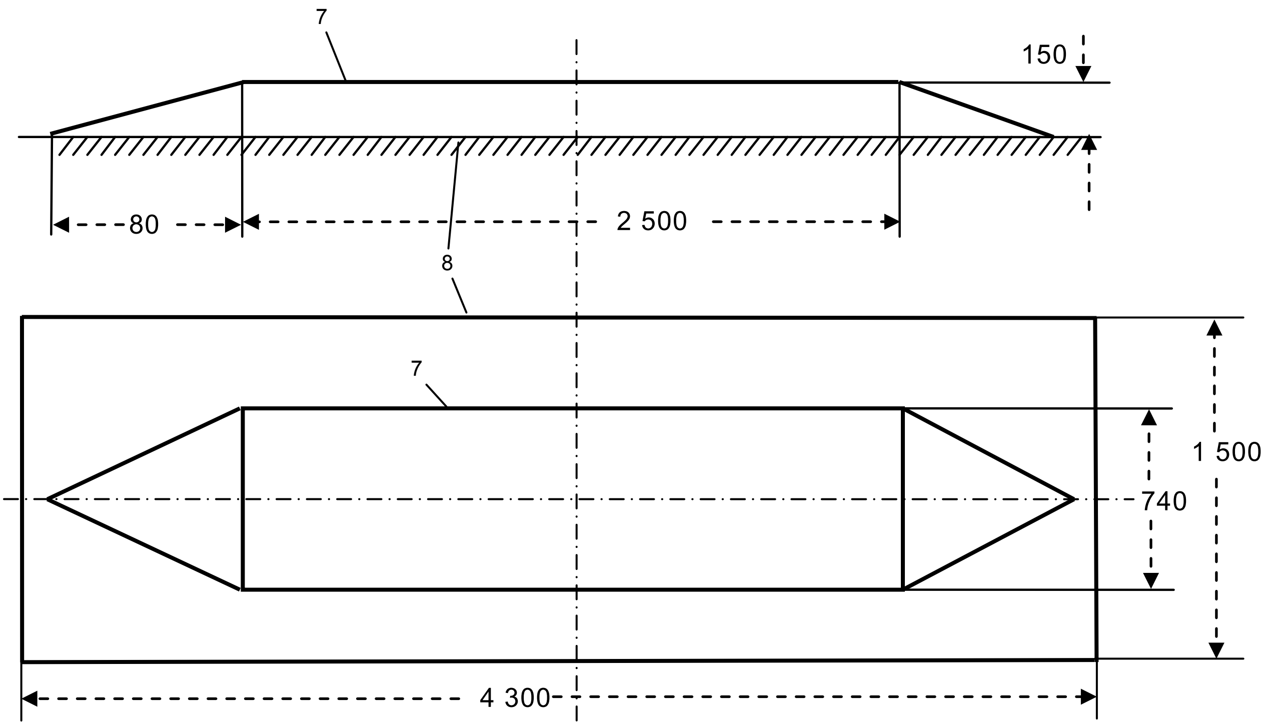
b is the stripline septum width in mm;

h is the stripline septum height above the reference ground plane in mm;

π = 3,14159

NOTE Typical striplines are constructed to have an impedance of either 50 Ω or 90 Ω with b/h equal to 5 and 1,83, respectively. The termination may be either a resistive load or a tapered matching section terminated in a 50 Ω coaxial resistive load. A resistive load may be constructed of carbon resistors, conductive strips, thick film on a ceramic substrate, etc. in such a way that it matches the characteristic impedance of the stripline and minimizes the standing waves ratio.

Dimensions in millimetres



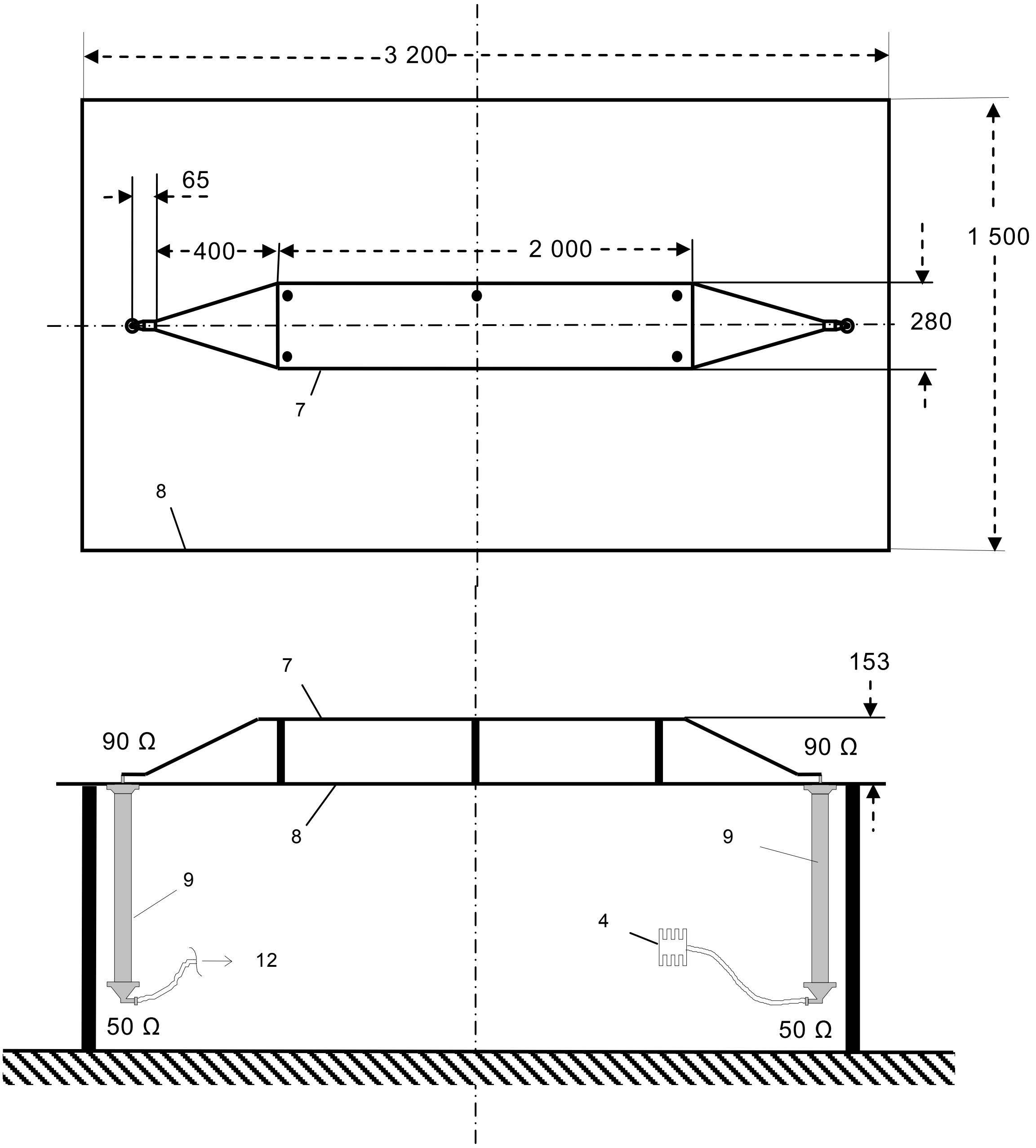
Key:

7 Septum

8 Reference ground plane

Figure G.2 – Example for a 50 Ω stripline

Dimensions in millimetres



Key:

4	50 Ω load
7	Septum
8	Reference ground plane
9	Matching unit
12	Measuring instrument

1846 **Figure G.3 – Example for a 90 Ω stripline**

Annex H
(informative)

Interference to mobile radio communication in the presence of impulsive noise – Methods of judging degradation

H.1 Introduction

This annex provides methods of judging the degradation of radio communication in the presence of impulsive noise.

H.2 Survey of methods of judging degradation to radio channel

Test programs have been conducted in the United States of America by the Federal Communications Commission (FCC) and the Motor Vehicle Manufacturers Association (MVMA, later the American Automobile Manufacturers Association, AAMA, now disbanded). These test programs were directed toward providing a better understanding of the effects of motor vehicles on mobile communications reception.

The tests measured the degradation to communications systems subjectively and objectively at numerous receiver frequencies using several classes of automotive ignition noise sources such as a traffic stream and a controlled matrix of vehicles. Correlation between various objective and subjective measures of degradation was studied using rating scales employed by the FCC and MVMA for grading communication quality.

H.2.1 Subjective tests

H.2.1.1 Subjective tests of annoyance

Subjective degradation tests were conducted by the FCC using a single vehicle and groups of vehicles simulating traffic patterns. The FCC proposed and used a subjective jury rating scale based upon annoyance which had been used traditionally to determine the effects of ambient noise on job performance, accident rate, and fatigue of personnel.

Grade	Interfering effect was
5	almost nil
4	noticeable
3	annoying
2	very annoying
1	so bad the presence of speech was barely discernible

This grade system is very nearly the same as that given in ITU-R Recommendation ITU-R BS.1284 which should be used for future work if annoyance testing is conducted.

Quality		Impairment	
5	excellent	5	imperceptible
4	good	4	perceptible, but not annoying
3	fair	3	slightly annoying
2	poor	2	annoying
1	bad	1	very annoying

Annoyance is a highly subjective psychological reaction. The degree of annoyance caused by audible noise has been found to be influenced by a large number of variable physical and psychological factors (including illness, fatigue, status of interpersonal relations, and family problems).

H.2.1.2 Subjective tests of intelligibility

H.2.1.2.1 General

Since land mobile communication systems are used primarily to transmit voice messages, the performance of such systems should be based primarily on the intelligibility of the received signal in the presence of ignition noise.

The most common procedure for determining the intelligibility of a voice channel is a subjective method involving trained speakers and listener jury panels that directly score the percentage of speech that is intelligible. These schemes have the merit of producing repeatable results. Unfortunately, subjective scoring methods are expensive and time-consuming. As a result, they are not widely used.

The subjective scale for intelligibility proposed by the MVMA is:

Grade	Description
5	could understand the message extremely well
4	could understand the message fairly well
3	think I understood, but had to guess at some words
2	could barely discern the message
1	could not detect speech at all

H.2.1.2.2 Intelligibility test method

Beginning at 20 dB quieting with the vehicle ignition noise source off, the radio frequency input level was reduced by 1 dB decrements and scored at each decrement by the jury until the jury reached

Grade 1 (worst). Then the radio frequency input level was increased by 1 dB increments until the 20 dB quieting level was again reached.

The radio frequency input level was then increased by 3 dB increments until the jury rated the quality Grade 5 (best). The radio frequency input level was then decreased by 3 dB decrements until the 20 dB quieting level was reached.

The entire process was repeated with the vehicle noise source in operation.

The results of the two tests (noise source off / noise source on) were then compared and the difference in radio frequency level for a particular quality grade (in decibels) was reported as the subjective degradation.

H.2.2 Objective tests

H.2.2.1 General

Uncertainty in subjective measurements arises from ambiguity of the rating scale definition, and variability of juror judgement. The latter source of error is largely caused by psychological factors. Objective measurements should have uncertainties less than those obtained from subjective tests.

A study carried out by the Institute for Telecommunication Sciences [1] develops a method of obtaining an objective intelligibility measure giving good results for speech sent through both analogue and digital noise-corrupted communication channels. The distortion measure is obtained using Linear Predictive Coding (LPC), a mathematical technique widely known for its application to the analysis and synthesis of speech.

H.2.2.2 Objective test method

To develop an objective intelligibility measure for corrupted speech, a comparison must be performed between the distorted speech and the original noise-free speech. A subjective intelligibility measure of the distorted speech must also be available in order to judge the quality of the objective measure being used. Both of these requirements are met by first making a noise-free master tape of preselected speech, then sending it through the voice communication channels to be tested and making a recording of the speech at the channel outputs. The latter recording can be subjectively scored for intelligibility, and also compared with the original speech by a mathematical technique to obtain an objective score.

The preselected speech to be sent over a voice channel for intelligibility scoring consists of phonetically balanced groups of isolated words, as opposed to complete sentences or nonsense syllables. These phonetically balanced words were used because subjective scores have been shown to be repeatable, which is a necessary criterion for this study. (During tests employing vehicles as a noise source, subjective scoring by listener panels was conducted and compared to the objective scores, resulting in good correlation.)

H.2.3 Conclusions relating to judgement of degradation

Numerous studies have been conducted over the years to develop a simple, inexpensive, objective method of measuring land mobile receiver degradation in the presence of ignition noise. Linear Predictive Coding (LPC) is neither simple nor inexpensive (when compared to the equipment used for CISPR 12 and CISPR 25 measurements), but it is technically a good objective method for measuring receiver degradation.

Subjective tests have proved to be effective in rating mobile receiver degradation. Of the two subjective rating methods in use, intelligibility was determined to be superior to annoyance in characterizing the effect of radio noise on a communication link. Most objective measurements taken during the subjective testing, however, showed poor correlation. The Linear Predictive Coding (LPC) method showed good correlation with the subjective intelligibility test method. Subjective tests are preferred, however, because of their reduced complexity and resulting lesser cost.

Considering only the subjective test methods, and as a result of the numerous tests conducted, it is recommended that intelligibility be used as the index of communications system performance rather than annoyance.

H.3 Bibliography

[1] GAMAUF K. J. and HARTMAN W. J., *Objective Measurement of Voice Channel Intelligibility*, October 1977; available from the National Technical Information Service, Springfield, Virginia 22151, USA, reference number FAA-RD-77-153.

Annex I
(normative)

Test methods for shielded power supply systems for high voltages in electric and hybrid vehicles

I.1 General

Components/modules used in electric vehicles are electronic components connected with LV network and/or HV power supply systems in the sense of CISPR 25. Therefore the requirements regarding emissions apply to them in their functions. The test methods, procedures and limit lines are defined in accordance with CISPR 25 requirements for vehicles.

This document gives additional test set-up methods and limits for emission measurement according to the main part when considering the HV power supply system parts, which are typically fully shielded.

Examples of HV power supply system parts are:

- inverter with electrical motor
- onboard charger
- DC-DC-converter
- electrical heater
- high voltage battery
- all devices which have in addition to the LV power supply a HV power connection

The limits in Table I.1 are derived taking into account the overall high voltage shielding and attenuation performance, see I.5.3.5.

For unshielded systems limits of the main body have to be applied.

The present electric vehicle technology provides two categories of electric systems. The first category consists of the common LV systems (typically unshielded) and the second of the HV systems (typically shielded).

The limits given when testing the HV systems are based on the limits already defined for the LV systems in the main part and on the coupling factor identified between the both networks.

This annex specifies the following tests:

- conducted RF voltage measurements on shielded power supply lines with shielded artificial networks
- conducted RF current measurements on shielded cables of power supply systems
- radiated RF emission measurements of components/modules
- interaction between HV and LV ports of the system due to coupling (decoupling factor)

I.2 Conducted emission from components/modules on HV power lines – Voltage method

I.2.1 Ground plane arrangement

The location of the EUT, test harness and load simulator on the ground plane is shown in Figures I.1, I.2 and I.3. The reference ground plane conditions defined in 6.2.1 (radiated emissions) apply.

I.2.2 Test set-up

The set-up is adapted from 6.3.2.1 and is shown in Figure I.1. The shielding configuration and any protective ground connection should be representative of the vehicle application and shall be defined in the test plan. The battery charger ground connection shall also be defined in the test plan. EUTs and loads shall be connected to ground using impedance as defined in the test plan. The vehicle HV battery should be used; otherwise the external HV power supply shall be connected via feed-through-filtering.

Unless otherwise specified in the test plan (e.g. use of original vehicle harnesses), the length of harnesses shall be as follows:

- $200\ ^{+200}_{0}$ mm for the LV lines
- $1700\ ^{+300}_{0}$ mm for the HV lines and the length of the HV test harness parallel to the front of the ground plane shall be (1500 ± 75) mm.
- less than 1000 mm for the three phase lines between EUT and electric motor(s)

All of the harnesses shall be placed on a non conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$) at (50 ± 5) mm above the ground plane.

HV lines shall be placed at a minimum distance of 100 mm from the edge of the reference ground plane.

Shielded supply lines for the positive HV d.c. terminal line (HV+), the negative HV d.c. terminal line (HV-) and three phase HV a.c. lines may be separate coaxial cables or in a common shield depending on the connector system used. The original HV harness from the vehicle may be used optionally.

Unless otherwise specified in the test plan the EUT case shall be connected to the ground plane either directly or via defined impedance.

Figure I.2 shows a more complex configuration adding an electric motor or load machine emulation to the setup, e.g. in case the EUT is an electric power unit. The electric motor shall be mounted on a non-conductive insulating support and its housing bonded to the ground plane, if applicable. The load machine emulation shall be placed outside the shielded room. In case of using a load machine emulation, the test plan shall define the connection conditions between the EUT and the load machine emulation and also the necessary grounding conditions. The load machine emulation will replace the “electric motor”, the “mechanical connection”, the “filtered mechanical bearing” and the “brake or propulsion motor”. The three phase motor supply lines will be fed through a power line filter.

The electric motor may be placed on a separate ground plane. In this case, the test plan shall define the connection configuration between this separate motor ground plane and the EUT ground plane (representing the vehicle grounding configuration).

The setup in Figure I.3 is an example for further HV- and LV load simulators and supplies attached to the EUT like e.g. for testing an on-board charger and its communication links. Various combinations of the shown setups are possible based on the true application of the HV component under study (EUT).

Note 1 Care shall be taken when using a power line filter (Key 16) on the HV supply line. This filter will increase the common mode capacitance between HV+ and ground reference or HV- and ground reference and may lead to the generation of extra resonances.

Note 2 Depending on the package situation in the vehicle and the material used for the chassis (e. g. metal or alternative material) the impedance of the connection of the shielding to the vehicle chassis may vary drastically.

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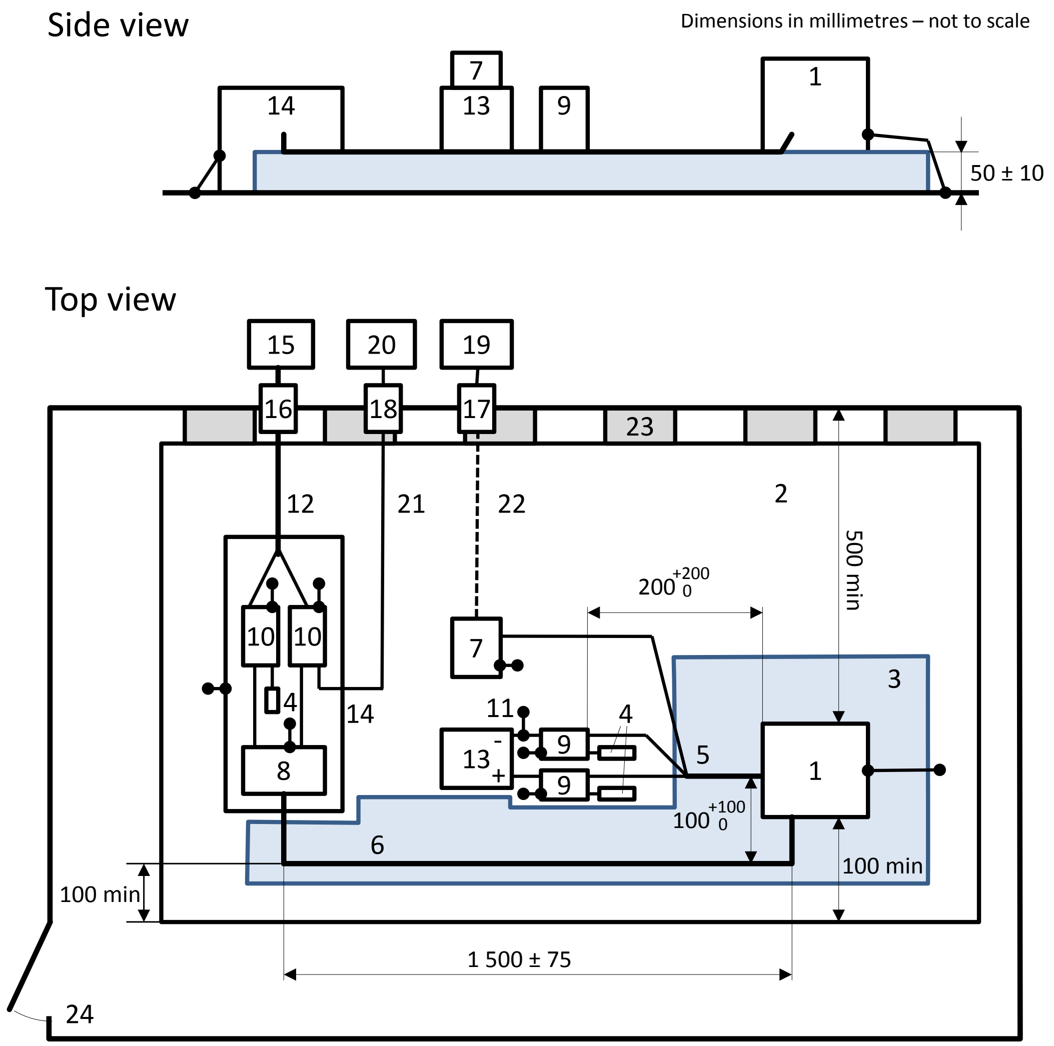

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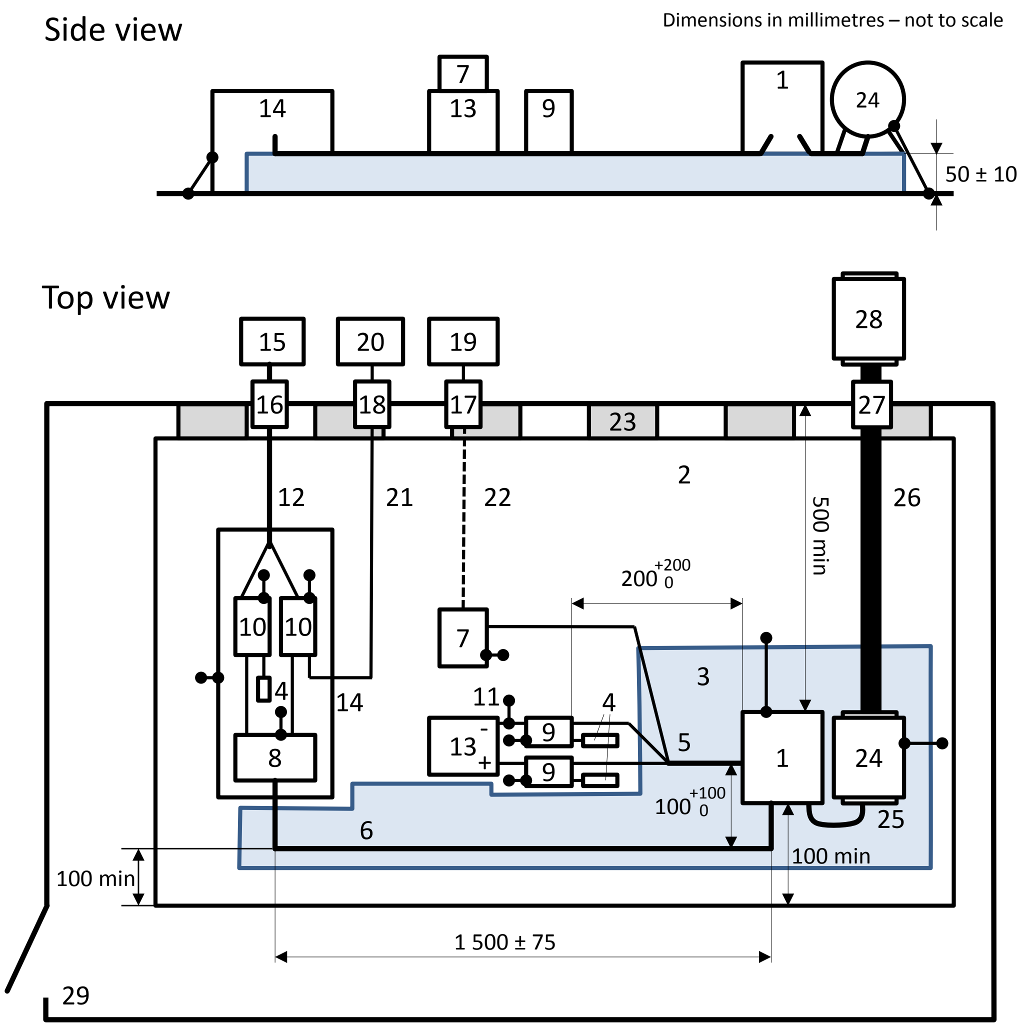
1	EUT	13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
2	Ground plane	14	Additional shielded box
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm	15	HV power supply (shielded if placed inside shielded enclosure)
4	50 Ω load	16	Power line filter
5	LV harness	17	Fiber optic feed through
6	HV lines (HV+, HV-)	18	Bulk head connector
7	LV load simulator	19	Stimulating and monitoring system
8	Impedance matching network (optional)	20	Measuring instrument
9	LV AN	21	High quality coaxial cable e. g. double shielded (50 Ω)
10	HV AN	22	Optical fibre
11	LV supply lines	23	Ground straps
12	HV supply lines	24	Shielded enclosure

Figure I.1 – Conducted emission – example for test setup for EUTs with shielded power supply systems

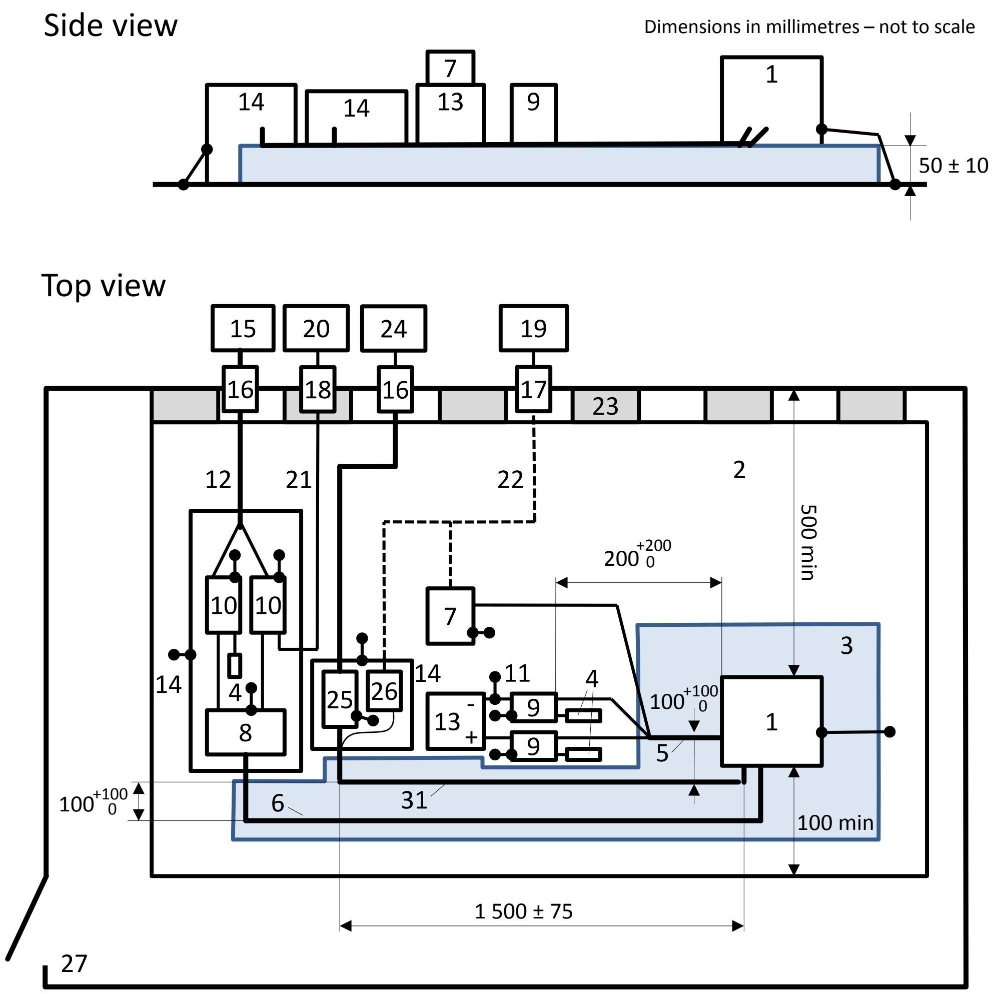


1	EUT	15	HV power supply (should be shielded if placed inside the shielded enclosure)
2	Ground plane	16	Power line filter
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm (a non-conductive support can be used for the electric motor)	17	Fiber optic feed through
4	50 Ω load	18	Bulk head connector
5	LV harness	19	Stimulating and monitoring system
6	HV lines (HV+, HV-)	20	Measuring instrument
7	LV load simulator	21	High quality coaxial cable e. g. double shielded (50 Ω)
8	Impedance matching network (optional)	22	Optical fibre
9	LV AN	23	Ground straps
10	HV AN	24	Electric motor
11	LV supply lines	25	Three phase motor supply lines
12	HV supply lines	26	Mechanical connection (e.g. non-conductive)
13	LV power supply 12 V / 24 V / 48 V	27	Filtered mechanical bearing

	(should be placed on the bench)	28	Brake or propulsion motor
14	Additional shielded box	29	Shielded enlosure

Note The electric motor, mechanical connection, filtered mechanical bearing and brake or propulsion motor may be replaced by a load machine emulation.

Figure I.2 – Conducted emission – example of test setup for EUTs with shielded power supply systems with electric motor attached to the bench



1	EUT	14	Additional shielded box
2	Ground plane	15	HV power supply (should be shielded if placed inside shielded enclosure)
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm	16	Power line filter
4	50 Ω load	17	Fiber optic feed through
5	LV harness	18	Bulk head connector
6	HV lines (HV+, HV-)	19	Stimulating and monitoring system
7	LV load simulator	20	Measuring instrument
8	Impedance matching network (optional)	21	High quality coaxial cable e.g. double shielded (50 Ω)
9	LV AN	22	Optical fibre

10	HV AN	23	Ground straps
11	LV supply lines	24	a.c. power mains
12	HV supply lines	25	AMN for a.c. power mains
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)	26	a.c. charging load simulator
		27	Shielded enclosure
		31	a.c. lines

Figure I.3 – Conducted emission - example of test setup for EUTs with shielded power supply systems and inverter/charger device

I.2.3 Limits for conducted emission – Voltage method

The applicable limits are defined taking into account the shielding performance of the overall HV systems. It is determined by coupling between HV- and LV networks. This coupling can be internal to the component or external to the enclosure. Less HV shielding performance results in more severe HV limit classes. HV limit classes from Tables 1 and 2 are determined by the OEM based on his overall HV system knowledge. HV-LV decoupling can be tested according to I.5.

For unshielded systems CISPR25 main body voltage limits of clause 6.3 shall be used.

Basis for limits of Table I.1 are the limits (class 5) from 6.3.3, Table 5 modified by the addition of the required decoupling factors (attenuation) between HV and LV part, see I.5.3.

Table I.1 – Example for limits for conducted voltage measurements at shielded power supply devices

Service / Band	Frequency MHz	Levels in dB(µV)														
		Class 5			Class 4			Class 3			Class 2			Class 1		
		Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average
BROADCAST																
LW	0,15 – 0,30	107	94	87	117	104	97	127	114	107	136	123	116	146	133	126
MW	0,53 – 1,8	86	73	66	94	81	74	103	90	83	112	99	92	121	108	101
SW	5,9 – 6,2	81	68	61	89	76	69	97	84	77	106	93	86	114	101	94
FM	76 – 108	57	44	37	64	51	44	71	58	51	78	65	58	85	72	65
TV Band I	41 – 88	53	-	43	60	-	50	67	-	57	75	-	65	82	-	72
TV Band III	174 – 230	Conducted emission – Voltage method Not Applicable														
DAB III	171 – 245															
TV Band IV	468 – 944															
DTTV	470 – 770															
DAB L Band	1447 – 1494															
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	67	54	47	74	61	54	82	69	62	90	77	70	97	84	77
VHF	30 – 54	65	52	45	72	59	52	79	66	59	87	74	67	94	81	74
VHF	68 – 87	57	44	37	64	51	44	71	58	51	79	66	59	86	73	66
VHF	142 – 175	Conducted emission – Voltage method Not Applicable														
Analogue UHF	380 – 512															
RKE	300 – 330															
RKE	420 – 450															
Analogue UHF	820 – 960															
GSM 800	860 – 895															
EGSM/GSM 900	925 – 960															
GPS L1 civil	1567 – 1583															
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

NOTE 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

I.3 Conducted emission from components/modules on HV power lines – current probe method

I.3.1 Ground plane arrangement

The location of the EUT, the test harness and the load simulator on the ground plane (table with metal plane) are shown in Figures I.4, I.5 and I.6.

I.3.2 Test setup

The setup shall be as described in 6.4.1 with the extensions according to Figure I.4. The shielding configuration shall be according to the vehicle series configuration. Generally all shielded HV parts shall be properly connected with low impedance to ground (e.g. AN, cables, connectors etc.). EUTs and loads shall be connected to ground using impedance as defined in the test plan. The vehicle HV battery should be used; otherwise the external HV power supply shall be connected via feed-through-filtering.

Unless otherwise specified in the test plan (e.g. use of original vehicle harnesses), the length of harnesses shall be as follows:

- 1700 $^{+300}_{0}$ mm for the LV lines
- 1700 $^{+300}_{0}$ mm for the HV lines and the length of the HV test harness parallel to the front of the ground plane shall be (1500 ± 75) mm.
- less than 1000 mm for the three phase lines between EUT and electric motor(s)

All of the harnesses shall be placed on a non conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$) at (50 ± 5) mm above the ground plane. HV lines shall be placed at a minimum distance of 200 mm from the edge of the reference ground plane.

Shielded supply lines for HV+ and HV- lines and three phase lines may be coaxial cables or in a common shield depending on the plug system used. The original HV harness from the vehicle may be used optionally.

Unless otherwise specified in the test plan the case shall be connected to the ground plane either directly or via defined impedance.

– The electric motor may be placed on a separate ground plane. In this case, the test plan shall define the connection configuration between this separate motor ground plane and the EUT ground plane (representing the vehicle grounding configuration). The electric motor shall be mounted on a non-conductive insulating support and its housing bonded to the ground plane, if applicable. In case of using a load machine emulation, the test plan shall define the connection conditions between the EUT and the load machine emulation and also the necessary grounding conditions. The load machine emulation will replace the “electric motor”, the “mechanical connection”, the “filtered mechanical bearing” and the “brake or propulsion motor”. The three phase motor supply lines will be fed through a power line filter.

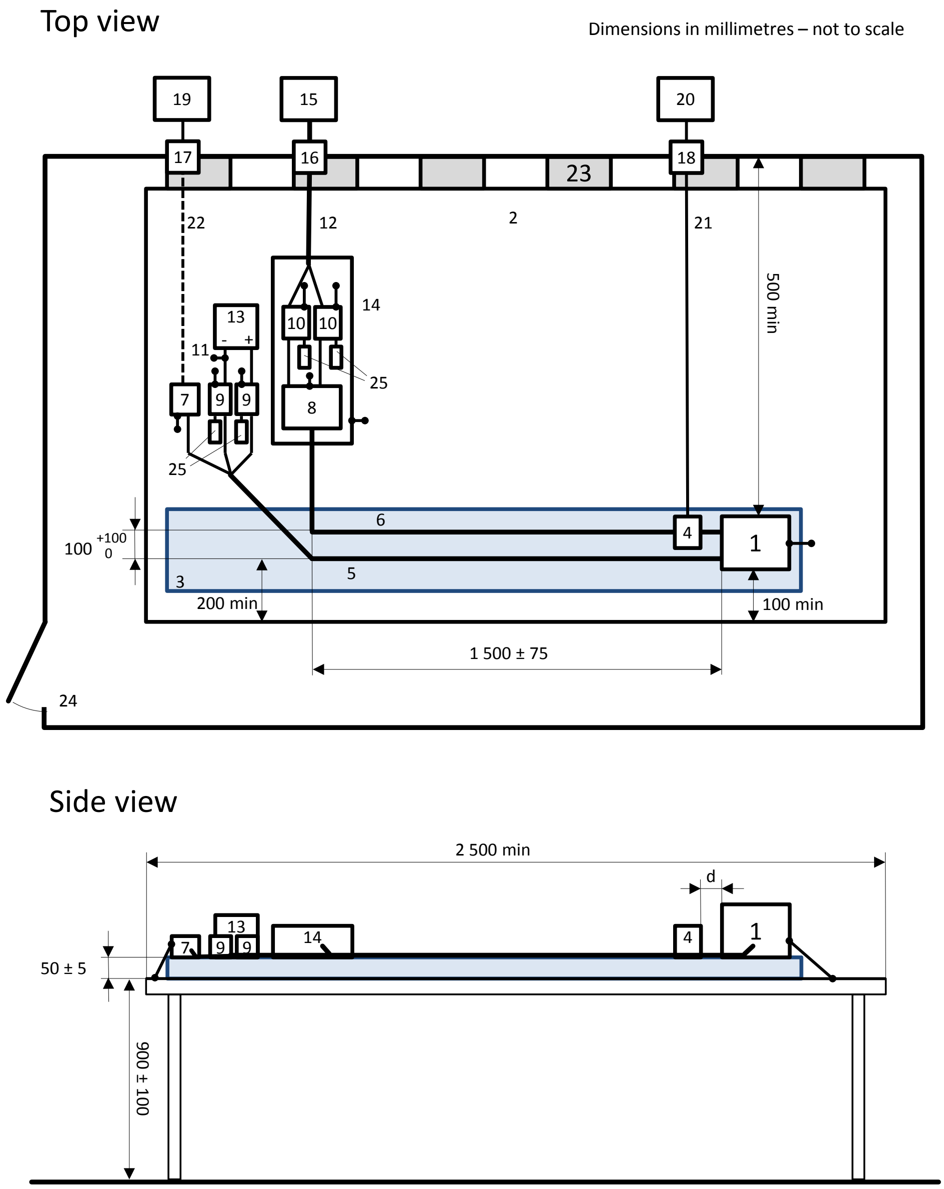
Note 1 Care shall be taken when using a power line filter (Key 16) on the HV supply line. This filter will increase the common mode capacitance between HV+ and ground reference or HV- and ground reference and may lead to the generation of extra resonances.

Note 2 Depending on the package situation in the vehicle and the material used for the chassis (e. g. metal or alternative material) the impedance of the connection of the shielding to the vehicle chassis may vary drastically.

Current probe measurements have to be performed on HV+ and HV- power supply lines, and the three phase lines of the electric motor, separately (if applicable) and commonly. Measure the emission with the probe positioned d = 50 mm and d = 750 mm (depending on harness length) from the EUT.

The deviations of the common test setup have to be defined in the test plan and/or in the test report. If electric motor and power unit is one unit measurement according to Figure I.5 is not applicable (not needed).

Note 3 Care shall be taken by using a protection earth line which can influence the test result.



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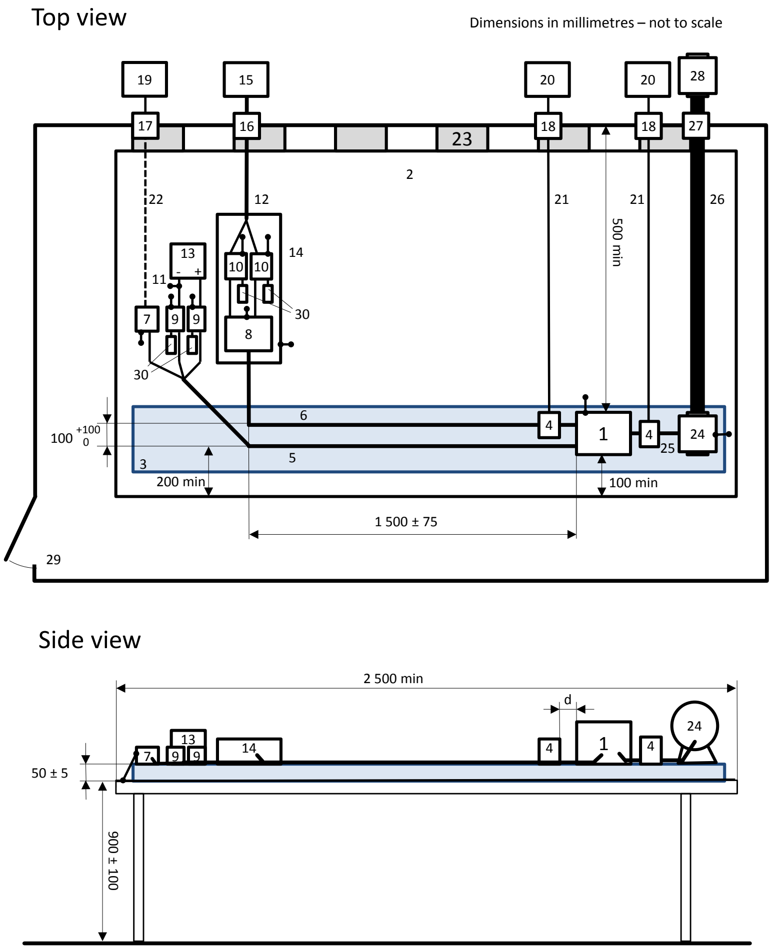
1	EUT	14	Additional shielded box
2	Ground plane	15	HV power supply (should be shielded if placed inside the shielded enclosure)
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm	16	Power line filter
4	Current probe (“d” see clause I.4.2)	17	Fiber optic feed through
5	LV harness	18	Bulk head connector
6	HV lines (HV+, HV-)	19	Stimulating and monitoring system
7	LV load simulator	20	Measuring instrument
8	Impedance matching network (optional)	21	High quality coaxial cable e.g. double shielded (50 Ω)
9	LV AN	22	Optical fibre
10	HV AN	23	Ground straps
11	LV supply lines	24	Shielded enclosure
12	HV supply lines		

13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)	25	50 Ω load

Figure I.4 – Conducted emission - example of test setup current probe measurement on HV lines for EUTs with shielded power supply systems



1	EUT	16	Power line filter
2	Ground plane	17	Fiber optic feed through
3	Low relative permittivity support ($\varepsilon_r \leq \leq 1,4$) thickness 50 mm (a non-conductive support can be used for the electric motor)	18	Bulk head connector
		19	Stimulating and monitoring system
4	Current probe (“d” see clause I.4.2)	20	Measuring instrument
5	LV harness	21	High quality coaxial cable e. g. double shielded (50 Ω)
6	HV lines (HV+, HV-)	22	Optical fibre
7	LV load simulator	23	Ground straps
8	Impedance matching network (optional)	24	Electric motor
9	LV AN	25	Three phase motor supply lines
10	HV AN	26	Mechanical connection (e.g. non-conductive)
11	LV supply lines	27	Filtered mechanical bearing
12	HV supply lines	28	Brake or propulsion motor
13	LV power supply 12 V / 24 V / 48 V		

(should be placed on the bench)

14 Additional shielded box

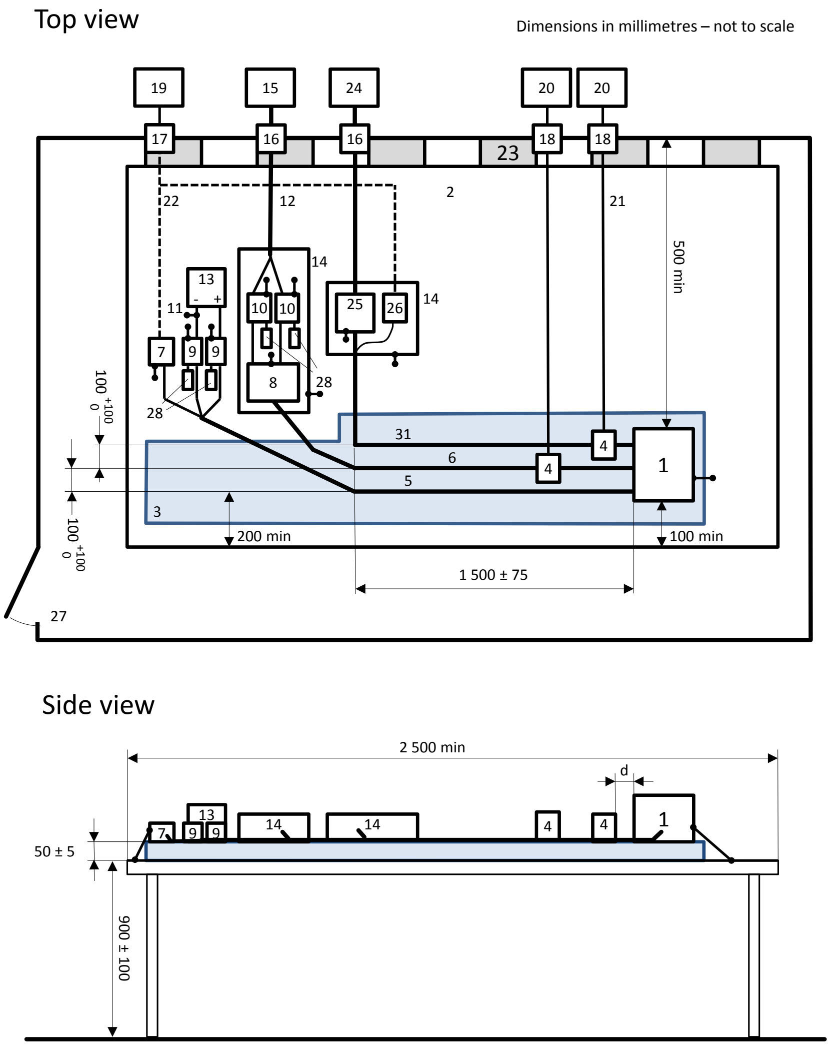
15 HV power supply (should be shielded if placed inside the shielded enclosure

29 Shielded enclosure

30 50 Ω load

Note The electric motor, mechanical connection, filtered mechanical bearing and brake or propulsion motor may be replaced by a load machine emulation.

Figure I.5 – Conducted emission - example of test setup current probe measurement on HV lines for EUTs with shielded power supply systems with electric motor attached to the bench



1 EUT

2 Ground plane

3 Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm

4 Current probe (“d” see clause I.4.2)

5 LV harness

6 HV lines (HV+, HV-)

7 LV load simulator

16 Power line filter

17 Fiber optic feed through

18 Bulk head connector

19 Stimulating and monitoring system

20 Measuring instrument

21 High quality coaxial cable e. g. double shielded (50 Ω)

22 Optical fibre

8	Impedance matching network (optional)	23	Ground straps
9	LV AN	24	a.c. power mains
10	HV AN	25	AMN for a.c. power mains
11	LV supply lines	26	a.c. charging load simulator
12	HV supply lines	27	Shielded enclosure
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)	28	50 Ω load
14	Additional shielded box	31	a.c. lines
15	HV power supply (should be shielded if placed inside the shielded enclosure		

Figure I.6 – Conducted emission - example of test setup current probe measurement on HV lines for EUTs with shielded power supply systems and inverter/charger device

I.3.3 Limits for conducted emission – current probe method

For limits see 6.4, Table 6.

I.4 Radiated emissions from components/modules – ALSE method

I.4.1 Ground plane arrangement

The location of the EUT, the test harness and the load simulator on the ground plane are shown in Figures I.7, I.8 and I.9.

I.4.2 Test setup

The setup shall be as described in 6.5.2, Figures 17, 18, 19 and 20 with the extensions according to Figures I.7, I.8 and I.9. The shielding configuration shall be according to the vehicle series configuration. Generally all shielded HV parts shall be properly connected with low impedance to ground (e. g. AN, cables, connectors etc.). EUTs and loads shall be connected to ground using impedance as defined in the test plan. The external HV power supply shall be connected via feed-through-filtering.

Unless otherwise specified in the test plan (e.g. use of original vehicle harnesses), the length of harnesses shall be as follows:

- 1700 $^{+300}_{0}$ mm for the LV lines
- 1700 $^{+300}_{0}$ mm for the HV lines and the length of the HV test harness parallel to the front of the ground plane shall be (1500 ± 75) mm.
- not larger than 1000 mm for the three phase lines between EUT and electric motor(s)

All of the harnesses shall be placed on a non conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the ground plane. The long segment of LV lines test harness shall be located parallel to the edge of the ground plane facing the antenna at a distance of (100 ± 10) mm from the edge. The long segment of the HV lines test harness shall be located at 100 $^{+100}_{0}$ mm from the LV lines test harness (as shown in Figures I.7, I.8 and I.9).

Unless otherwise specified in the test plan, the configuration with the long segment of HV lines test harness at a distance of (100 ± 10) mm from the edge and the LV lines test harness located at $100\ ^{+100}_{\ \ 0}$ mm from the HV lines shall also be tested.

Shielded supply lines for HV+ and HV- line and three phase lines may be coaxial cables or in a common shield depending on the used plug system. The original HV harness from the vehicle may be used optionally.

Unless otherwise specified in the test plan, the EUT case shall be connected to the ground plane either directly or via defined impedance.

The electric motor may be placed on a separate ground plane. In this case, the test plan shall define the connection configuration between this separate motor ground plane and the EUT ground plane (representing the vehicle grounding configuration). The electric motor shall be mounted on a non-conductive insulating support and its housing bonded to the ground plane, if applicable. In case of using a load machine emulation, the test plan shall define the connection conditions between the EUT and the load machine emulation and also the necessary grounding conditions. The load machine emulation will replace the “electric motor”, the “mechanical connection”, the “filtered mechanical bearing” and the “brake or propulsion motor”. The three phase motor supply lines will be fed through a power line filter.

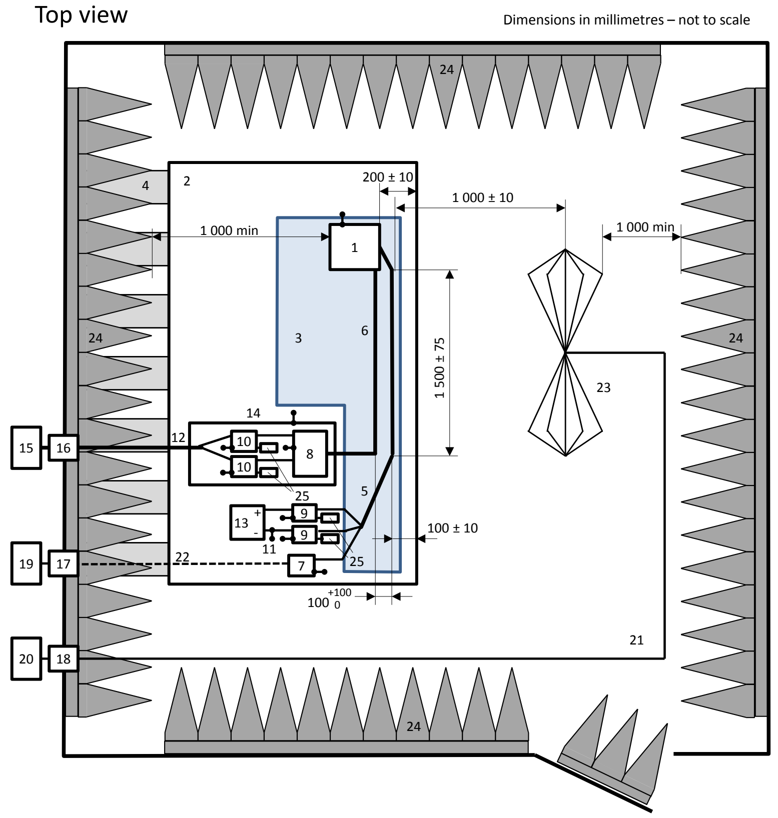
For onboard chargers (see Figure I.9) the a.c. power lines shall be placed the furthest from the antenna (behind LV and HV harness). The distance between the a.c. power lines and the closest harness (LV or HV) shall be $100\ ^{+100}_{\ \ 0}$ mm.

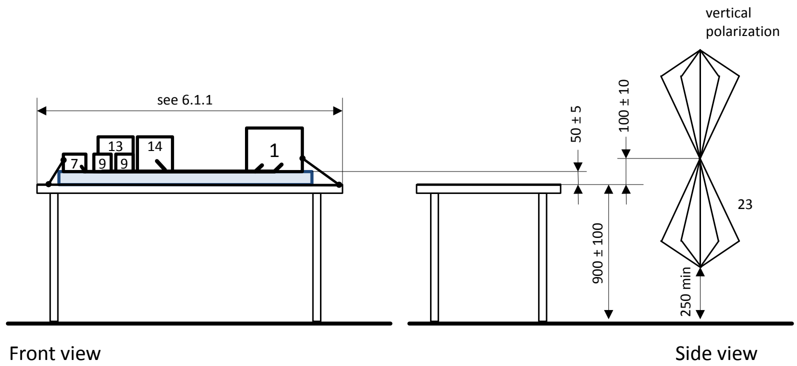
Note 1 Care shall be taken when using a power line filter (Key 16) on the HV supply line. This filter will increase the common mode capacitance between HV+ and ground reference or HV- and ground reference and may lead to the generation of extra resonances.

Note 2 Depending on the package situation in the vehicle and the material used for the chassis (e. g. metal or alternative material) the impedance of the connection of the shielding to the vehicle chassis may vary drastically.

NOTE 3 Care shall be taken by using a protection earth line which can influence the test result.

In this clause the test setup is shown with a biconical antenna. All other antenna types described in this document can be used for the corresponding frequency ranges and antenna configurations (e.g. rod, log-periodic, horn etc.).





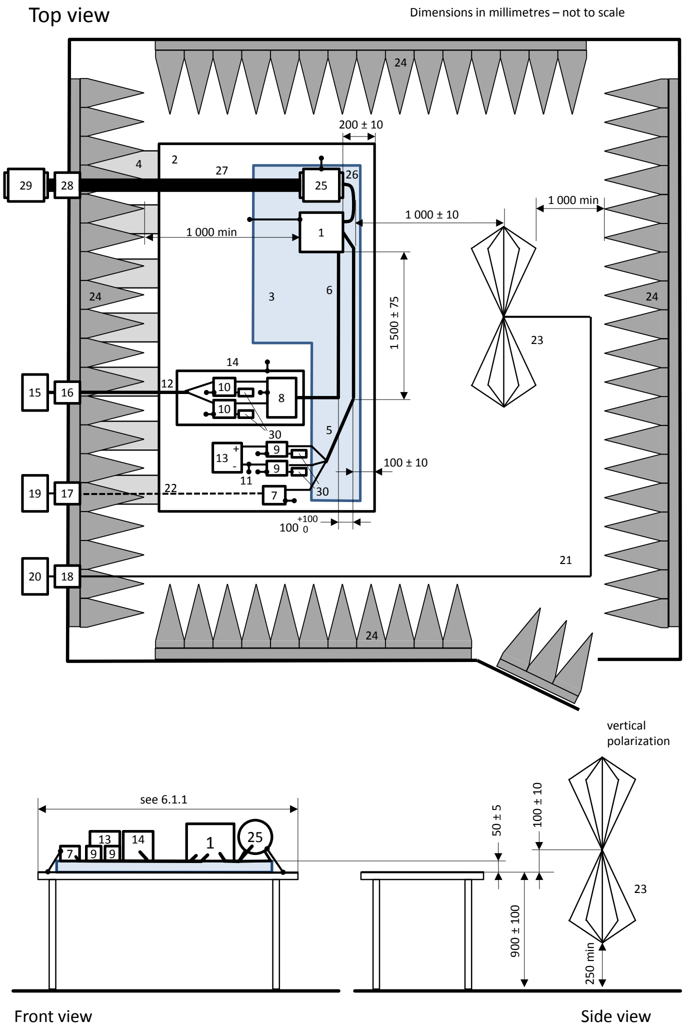
1	EUT	14	Additional shielded box
2	Ground plane	15	HV power supply (should be shielded if placed inside ALSE)
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm	16	Power line filter
4	Ground straps	17	Fiber optic feed through
5	LV harness	18	Bulk head connector
6	HV lines (HV+, HV-)	19	Stimulating and monitoring system
7	LV load simulator	20	Measuring instrument
8	Impedance matching network (optional)	21	High quality coaxial cable e.g. double shielded (50 Ω)
9	LV AN	22	Optical fibre
10	HV AN	23	Biconical antenna
11	LV supply lines	24	RF absorber material

12 HV supply lines

13 LV power supply 12 V / 24 V / 48 (should be placed on the bench)

25 50 Ω load

Figure I.7 – Radiated emission - example of test setup measurement with biconical antenna for EUTs with shielded power supply systems



Note The electric motor, mechanical connection, filtered mechanical bearing and brake or propulsion motor may be replaced by a load machine emulation.

1 EUT

2 Ground plane

3 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$) thickness 50 mm (a non-conductive support can be used for the electric motor)

4 Ground straps

5 LV harness

6 HV lines (HV+, HV-)

7 LV load simulator

8 Impedance matching network (optional)

9 LV AN

10 HV AN

16 Power line filter

17 Fiber optic feed through

18 Bulk head connector

19 Stimulating and monitoring system

20 Measuring instrument

21 High quality coaxial cable e.g. double shielded (50 Ω)

22 Optical fibre

23 Biconical antenna

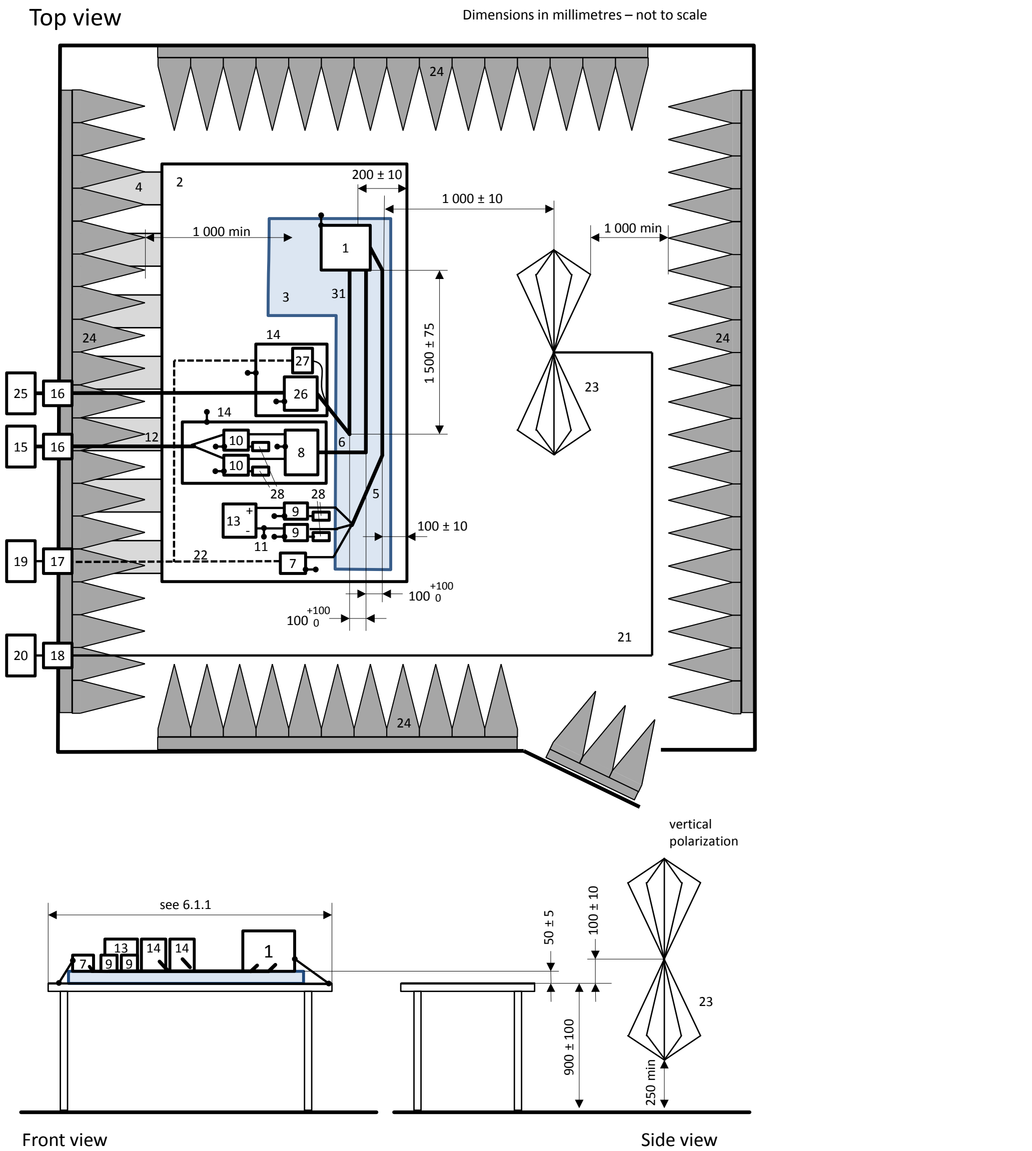
24 RF absorber material

25 Electric motor

26 Three phase motor supply lines

11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
14	Additional shielded box
15	HV power supply (should be shielded if placed inside the ALSE)
27	Mechanical connection (e.g. non-conductive)
28	Filtered mechanical bearing
29	Brake or propulsion motor
30	50 Ω load

Figure I.8 – Radiated emission - example of test setup measurement with biconical antenna for EUTs with shielded power supply systems with electric motor attached to the bench



1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm
4	Ground straps
5	LV harness
15	HV power supply (should be shielded if placed inside ALSE)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system

6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
14	Additional shielded box
20	Measuring instrument
21	High quality coaxial cable e. g. double shielded (50 Ω)
22	Optical fibre
23	Biconical antenna
24	RF absorber material
25	a.c. power mains
26	AMN for a.c. power mains
27	a.c. charging load simulator
28	50 Ω load
31	a.c. lines

Figure I.9 – Radiated emission - example of test setup measurement with biconical antenna for EUTs with shielded power supply systems and inverter/charger device

I.4.3 Limits for radiated emissions – ALSE method

For limits see 6.5, Table 7.

I.5 Coupling between HV and LV systems

I.5.1 General

In the previous sub clauses HV component limits and corresponding test methods have been described. This sub clause provides test methods to determine the influence of disturbances from the HV side to the LV side.

The coupling between HV and LV systems can be determined

- with measurements (voltage, current, electric field) based on the test setup as defined in I.5.2
- with direct measurement of scattering parameters as defined in I.5.3

The test method to be used shall be agreed between the vehicle manufacturer and the equipment supplier and documented in the test plan.

I.5.2 Measurement based on CISPR 25 test setup defined in the main part

These test setups are based on CISPR 25 test setups defined in the main part. The LV side remains unchanged. The HV side is modified. The EUT shall be in an operational mode as defined in the test plan.

In general, a test signal is injected at the HV+ and the HV- port consecutively. The test level is set to meet the specified HV limits from Table I.1 (average). Signal calibration and monitoring is mandatory.

The test signal shall be applied either by current probe or capacitive coupling. On the LV side the emission is determined using both conducted methods (voltage method and current probe method) and ALSE method.

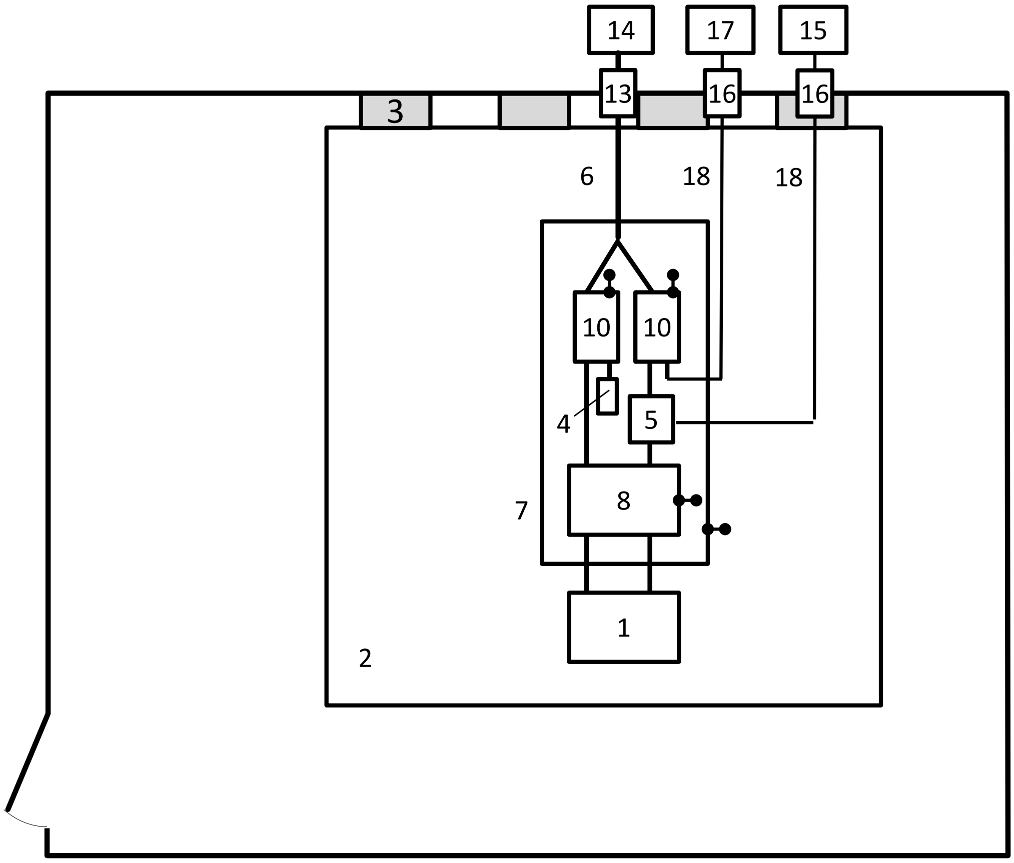
I.5.2.1 describes the calibration procedure to ensure that the test levels on the HV-side are met according to the HV limit class from Table I.1 (average). Test setups for conducted and radiated emission are described in I.5.2.2, I.5.2.3 and I.5.2.4. Coupling measurements shall be performed with all three test setups and the associated requirements.

I.5.2.1 Test Signal Injection and Calibration

The setup for the calibration of the test signal is shown in Figure I.10. The RF power of the test signal is supplied to the coupling element between HV AN and optional impedance matching network, either by injection probe (as defined in ISO 11452-4) or capacitive coupling (as defined in DCC method in ISO 7637-3). For calibration the EUT shall be unpowered.

Measure the output level at the measuring port of the HV AN. Terminate the measuring port of the other HV AN with 50 Ω. The measurement shall be performed in the frequency range from 150 kHz to 108 MHz with a bandwidth of 9 kHz using AV or PK detector. The test signal is set to the specified limit from Table I.1 (average).

Calibration of the test signal shall be performed at the HV+ and HV- ports consecutively.



1	EUT (or EUT simulator)	13	Power line filter
2	Ground plane	14	Shielded HV power supply (may be placed inside the shielded enclosure)
3	Ground straps	15	Tracked RF test generator (may be placed inside the shielded box)
4	50 Ω load		
5	Test signal coupling element		

(may be current clamp or capacitor)

6 HV supply lines (HV+, HV-)

7 Additional shielded box

8 Impedance matching network (optional)

10 HV AN

16 Bulk head connector

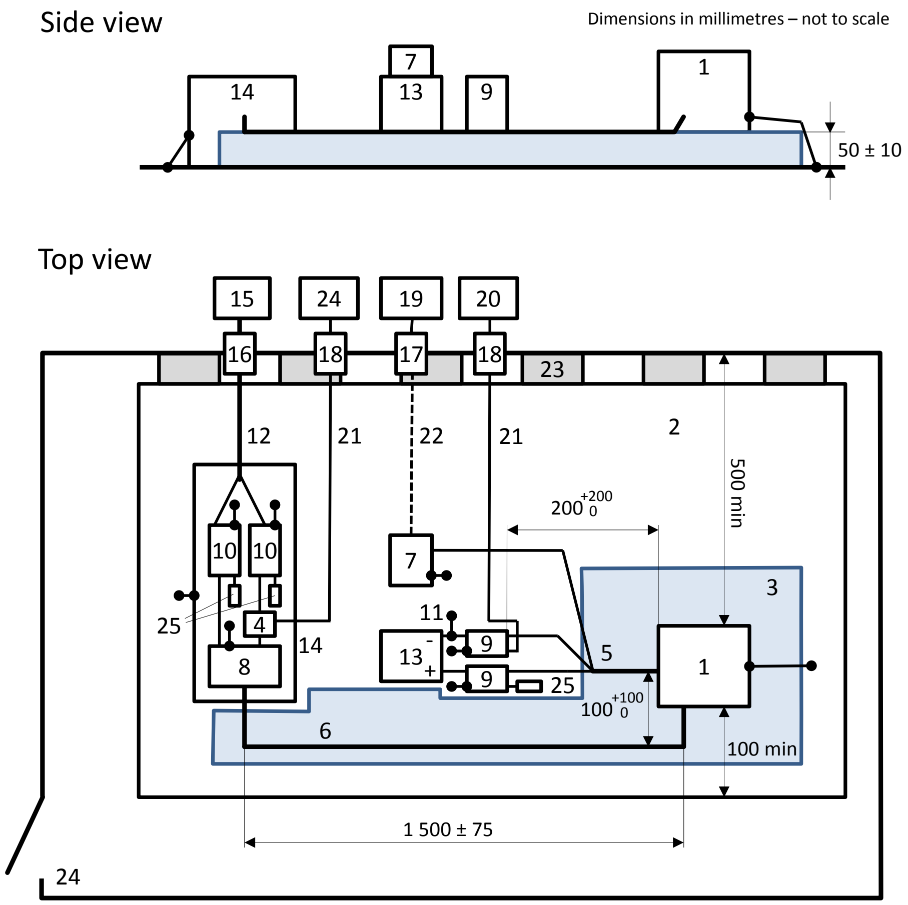
17 Measuring instrument

18 High quality coaxial cable e.g. double shielded (50 Ω)

Figure I.10 – Test setup for calibration of the test signal

I.5.2.2 Conducted Emission – Voltage Method

This method consists of measuring disturbance voltages at the LV side of the power supply. The emission level shall be measured on LV+ and LV- for each test signal injection configuration. The measured level shall not exceed the corresponding LV emission limits defined in 6.3, Table 5 (average). The setup is shown in Figure I.11. The reference ground plane conditions defined in 6.2.1 (radiated emissions) apply.



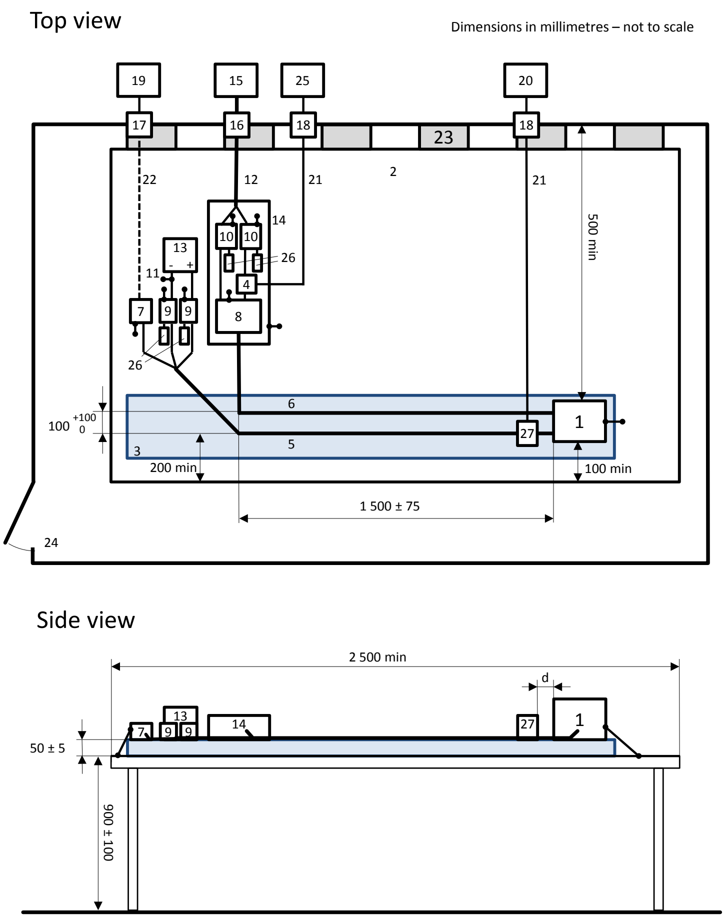
1	EUT	14	Additional shielded box
2	Ground plane	15	HV power supply (should be shielded if placed inside the shielded enclosure)
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm	16	Power line filter
4	Test signal coupling element (may be current clamp or capacitor)	17	Fiber optic feed through
5	LV harness	18	Bulk head connector
6	HV lines (HV+, HV-)	19	Stimulating and monitoring system
7	LV load simulator	20	Measuring instrument
8	Impedance matching network (optional)	21	High quality coaxial cable e.g. double shielded (50 Ω)
9	LV AN	22	Optical fibre
10	HV AN	23	Ground straps
11	LV supply lines	24	RF generator (may be placed inside the shielded box (14))
12	HV supply lines		

13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)	25	50 Ω load

Figure I.11 – Conducted emission – test setup for measurement decoupling factor between HV supply ports and LV port

I.5.2.3 Conducted Emission – Current Probe Method

This method consists of measuring disturbance currents at the LV harness side. The emission level shall be measured for each test signal injection configuration. The measured level shall not exceed the corresponding LV emission limits defined in 6.4, Table 6 (average). The setup is shown in Figure I.12.



1	EUT	15	HV power supply (should be shielded if placed inside the shielded enclosure)
2	Ground plane	16	Power line filter
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50mm	17	Fiber optic feed through
4	Test signal coupling element (may be current clamp or capacitor)	18	Bulk head connector
5	LV harness	19	Stimulating and monitoring system
6	HV lines (HV+, HV-)	20	Measuring instrument
		21	High quality coaxial cable e.g. double

7 LV load simulator

8 Impedance matching network (optional)

9 LV AN

10 HV AN

11 LV supply lines

12 HV supply lines

13 LV power supply 12 V / 24 V / 48 V (should be placed on the bench)

14 Additional shielded box

shielded (50 Ω)

22 Optical fibre

23 Ground straps

24 Shielded enclosure

25 RF generator (may be placed inside the shielded box (14))

26 50 Ω load

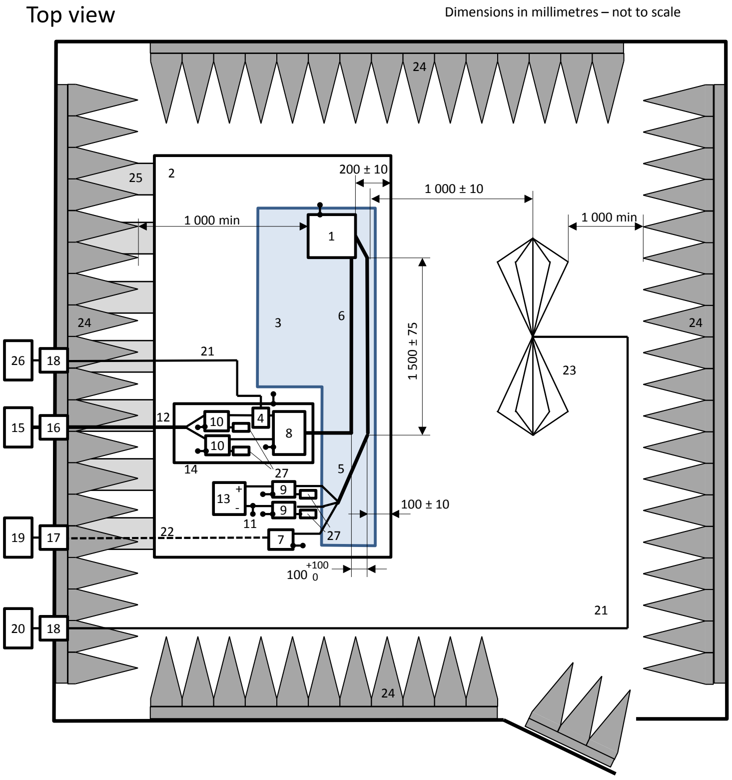
27 Current clamp

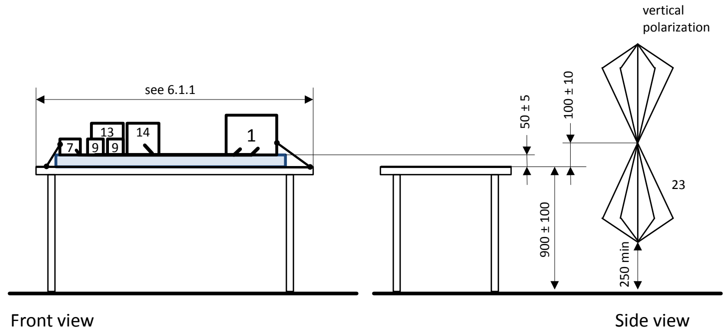
Figure I.12 – Conducted emission - test setup for measurement decoupling factor between HV supply ports and LV ports with current probe

I.5.2.4 HV-specific Radiated Emission Test

This method consists of measuring radiated emissions from the whole set up. The emission level shall be measured for each test signal injection configuration. The measured level shall not exceed the corresponding LV emission limits defined in 6.5, Table 7 (average). The setup is shown in Figure I.13.

The antenna to be used for the measurements shall be as defined in 6.5.2.1. In this clause the test setup is shown with a biconical antenna as an example.





1	EUT	15	HV power supply (should be shielded if placed inside ALSE)
2	Ground plane	16	Power line filter
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50mm	17	Fiber optic feed through
4	Test signal coupling element (may be current clamp or capacitor)	18	Bulk head connector
5	LV harness	19	Stimulating and monitoring system
6	HV lines (HV+, HV-)	20	Measuring instrument
7	LV load simulator	21	High quality coaxial cable e.g. double shielded (50 Ω)
8	Impedance matching network (optional)	22	Optical fibre
9	LV AN	23	Biconical antenna
10	HV AN	24	RF absorber material
11	LV supply lines	25	Ground straps
12	HV supply lines	26	RF generator (may be placed inside the shielded box (14))
13	LV power supply 12 V / 24 V / 48 V		

	(should be placed on the bench)	27	50 Ω load
14	Additional shielded box		

Figure I.13 – Radiated emission - test setup measurement decoupling factor between HV supply ports and LV ports with biconical antenna

I.5.3 Measurement of the HV-LV Scattering parameters

I.5.3.1 General

Clause I.5.3 describes the measurement of the decoupling factors between high voltage d.c. lines and the low voltage lines of electric/electronic components.

This part provides information on how the decoupling factor (attenuation level) can directly be measured.

The measurements shall be performed with a network analyser in two steps

- full-port calibration
- measurement with the EUT unpowered

I.5.3.2 Network analyser parameter

The following parameters should be used for a network analyser

- power level: 0 dBm (recommended; depending on needed dynamic range, higher values may be necessary)
- minimum averaging factor: 8
- minimum number of points (with logarithmic sweep) : 401
- maximum IF bandwidth : 1 kHz

I.5.3.3 Calibration

A full-port calibration shall be performed including only the network analyser coaxial measuring cables.

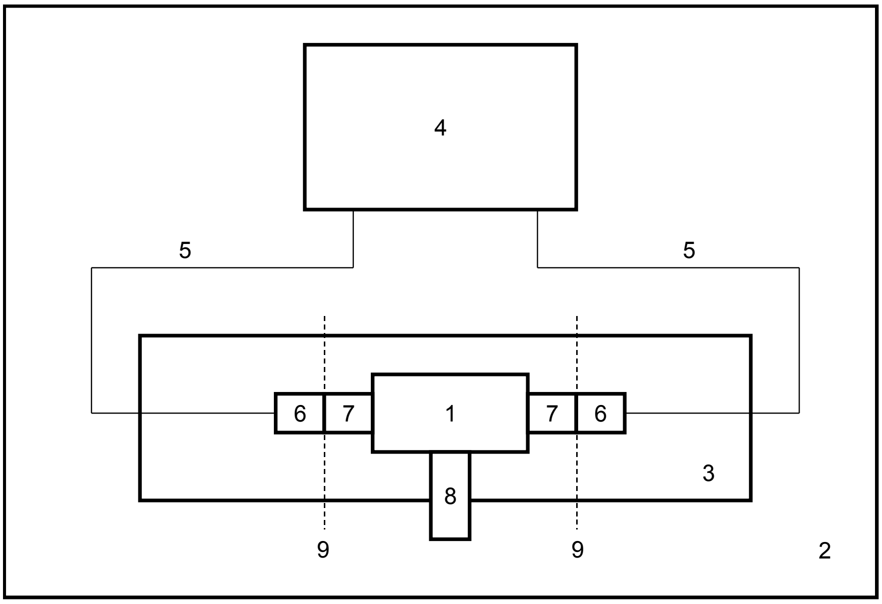
I.5.3.4 EUT measurement

The EUT measurement shall be performed according to Figure I.14 with the EUT unpowered (with only network analyzer measuring coaxial cables and without any LV/HV lines).

The EUT is placed on an insulating support (50 ± 5) mm above the ground plane.

Unless otherwise specified in the test plan the EUT case shall be bonded to the ground plane with a copper strap (maximum length to width ratio of 4:1). The d.c. resistance between the EUT case and ground plane shall not exceed 2,5 mΩ.

Care shall be taken concerning the adaptors used between the EUT terminals and the network analyser coaxial measuring cables particularly to ensure the lowest possible impedance between the coaxial measuring cable shield and the EUT case.



1 EUT
2 Ground plane
3 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$) thickness 50 mm
4 Network analyzer
5 High quality coaxial measuring cable e.g. double shielded (50 Ω),
6 Network analyzer coaxial measuring cable connector
7 Adaptors
8 EUT Bonding connection
9 Reference plane for network analyzer calibration

Figure I.14 – Test setup for EUT measurements

Coupling attenuation measurements S_{21EUT} shall be performed for the configurations defined in Table I.2 (for equipment without negative LV line) or to Table I.3 (for equipment with negative LV line).

The test plan shall define the EUT internal configuration(s) to be tested in order to ensure that the S_{21EUT} worst case is measured (e.g. mechanical or electronic switches state)

Table I.2 – Configurations for equipment without negative LV line

Measuring configuration		
	Port 1	**Port 2**
Configuration 1	Positive d.c. HV line	Positive LV line
Configuration 2	Negative d.c. HV line	Positive LV line

Table I.3 – Configurations for equipment with negative LV line

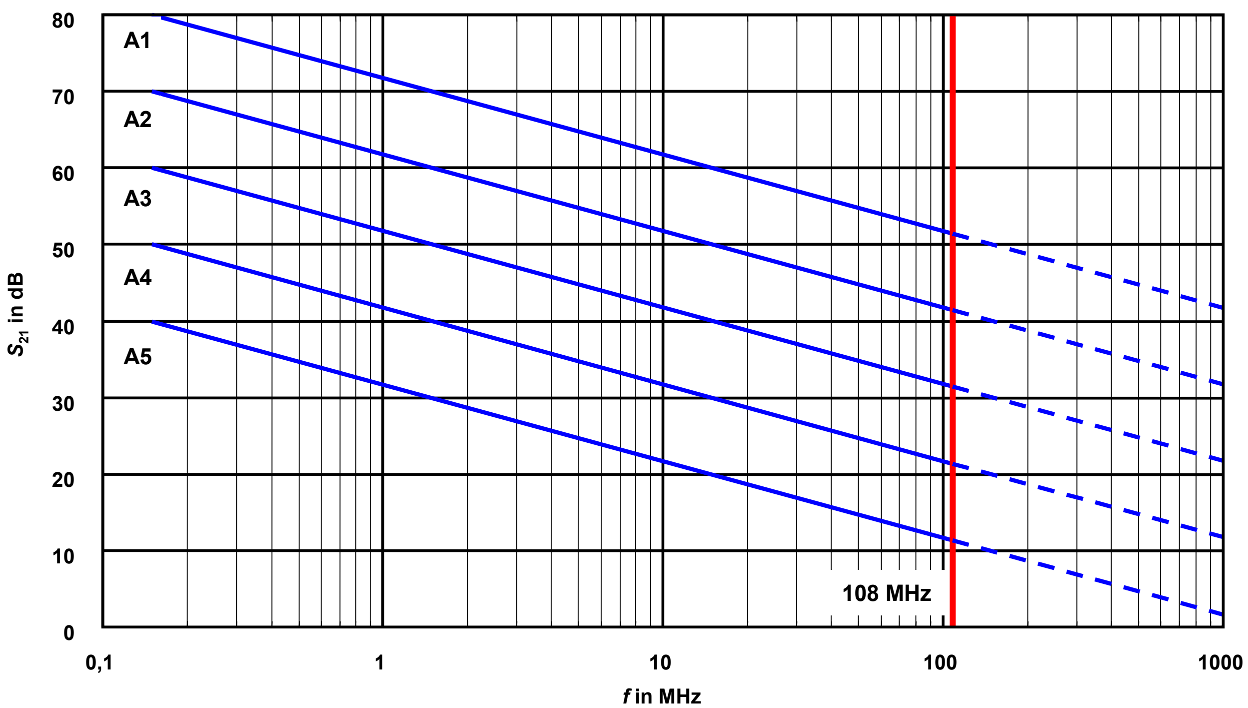
Measuring configuration		
	Port 1	**Port 2**
Configuration 1	Positive d.c. HV line	Positive LV line
Configuration 2	Negative d.c. HV line	Positive LV line
Configuration 3	Positive d.c. HV line	Negative LV line
Configuration 4	Negative d.c. HV line	Negative LV line

I.5.3.5 Requirement

Examples for requirements are given Table I.4 and Figure I.15.

Table I.4 – Examples of requirements for S_{21EUT}

Frequency in MHz	Class	Minimum attenuation S_{21} in dB
0,15 - 1000	A1	80 - 10 × lg (f_{MHz}/0,15)
	A2	70 - 10 × lg (f_{MHz}/0,15)
	A3	60 - 10 × lg (f_{MHz}/0,15)
	A4	50 - 10 × lg (f_{MHz}/0,15)
	A5	40 - 10 × lg (f_{MHz}/0,15)



The decoupling factor above 108 MHz is informative

Figure I.15 – Examples of requirements for S_{21EUT}.

Annex J
(informative)

ALSE Performance Validation 150 kHz – 1 GHz

J.1 Introduction

This annex contains requirements for the validation of the ALSE used for component tests described in 6.5. This annex contains two procedures, either of which can be used for validation of the ALSE (both methods are not required). See flowchart in Figure J.2 for a visual representation of the ALSE validation process. The validation procedures are designated as follows:

Reference Measurement Method: This method uses a reference test site for the reference measurements. A reference test site is an OATS or alternative test site, (e.g. weather-protected OATS or semi-anechoic chamber) which meets the requirements of CISPR 16-1-4. Reference measurements, which are similar to Normalized Site Attenuation (NSA) measurements, are made on the reference test site with a standard ground plane (site or ALSE floor ground plane below 30 MHz, elevated 2,5 m x 1 m validation reference ground plane at 30 MHz and above). Corresponding measurements are then made in the ALSE. The reference measurements are compared to the ALSE measurements to determine if the ALSE measurements are within a defined tolerance (see J.2.4).

Modelled Long Wire Antenna Method: This method uses a 50 cm “long wire” antenna as the transmitting antenna. At frequencies below 30 MHz, the long-wire antenna was modelled using a floor (non-elevated) ground plane. At frequencies 30 MHz and above, the long-wire antenna was modelled with an elevated validation reference ground plane of a standard size (2,5 m x 1 m). Measurements are made on the long-wire antenna in the ALSE. The ALSE measurements are compared to the modelled fields in order to determine if the ALSE measurements are within a defined tolerance (see J.3.4).

Both the Reference Measurement Method and Modelled Long Wire Antenna Method utilize a standard size validation reference ground plane for the reference measurements and modelling. At frequencies below 30 MHz, a floor (non-elevated) ground plane (e.g. the floor of an ALSE, OATS or alternative test site is the standard. The decision to use the same type of validation reference ground plane for both methods was based on the research work described in the first reference document of section J.4, where a standard environment using a TEM cell was investigated, and found to give the same results as those from measurements using the floor ground plane approach. At frequencies above 30 MHz, an elevated validation reference ground plane with the dimensions of 2,5 m x 1 m is the standard. The validation reference ground plane size and grounding used during the reference measurements and modelling will be different than what a laboratory would use in the ALSE during EUT measurements. Not all ALSEs are constructed and setup identically and will therefore be different from the standardized validation reference setup in some way. The purpose of this validation procedure is to compare the standardized validation reference setup data (either measured or modelled) with the results from an ALSE used for CISPR 25 radiated emissions testing on an EUT to assure that the deviations due to the ALSE setup differences are within a reasonable tolerance.

The ALSE configured as it normally used during EUT test may not initially meet the requirements specified in this annex.

The following setup parameters have a significant influence on the results obtained for chamber validation:

- Reference ground plane size
- Reference ground plane bonding straps (number, size, horizontal versus vertical)

– Absorber performance

If the chamber validation requirements are not met, modifications on one or more of the previous influent parameters should help to improve the ALSE performance within the tolerance specified in this annex.

Some parameters, their specifications and tolerances defined in CISPR25 are known to be influent in the setup and could lead to excessive deviations. On the frequency range between 10 MHz and 100 MHz, the ground plane size, its connections and the absorbers performances, even with the CISPR specifications are the most important ones. Figure J.1 summarizes the influence levels of these parameters over the particular 10 – 100 MHz frequency range.

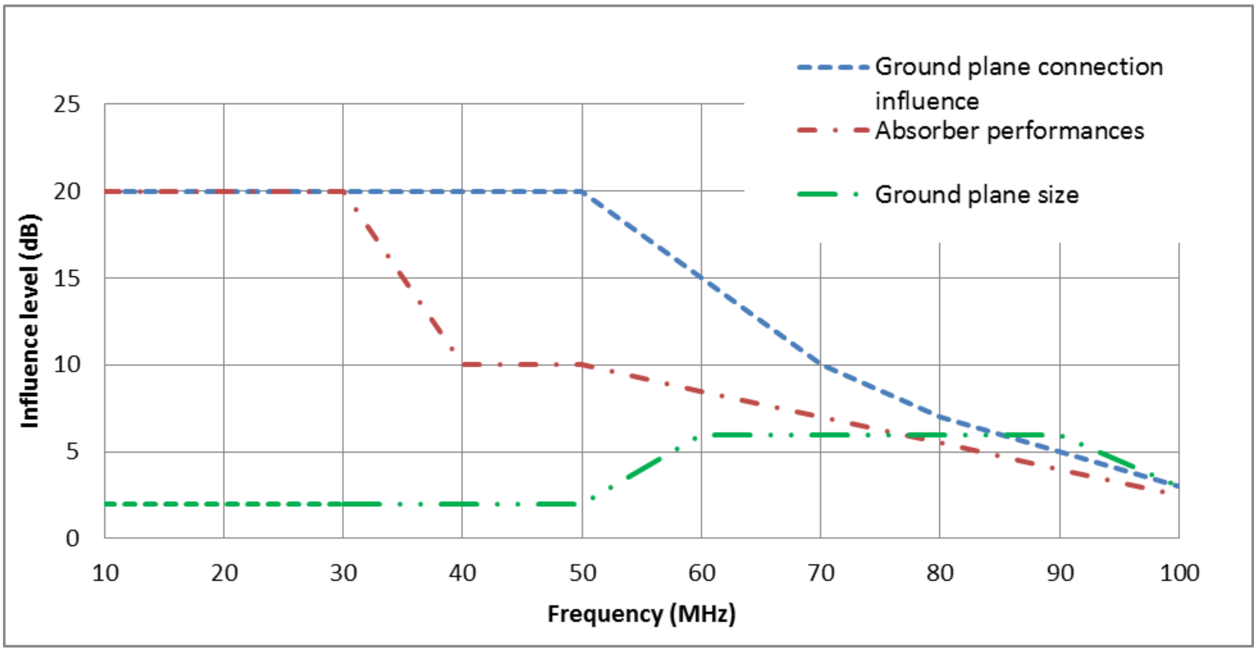


Figure J.1 – ALSE influence parameters over the 10 – 100 MHz frequency range

Note 1 Between 10 and 30 MHz the most important parameters are the ground plane connection and the absorbers performances. The influence of the ground plane size is more a shift in the resonances observed linked to the first previous parameters.

Note 2 The influence of each parameter had been evaluated individually. When mixed together their influence can be more important.

The validation procedures of this annex have intentionally been limited to the frequency range of 150 kHz to 1 GHz. Studies performed during the development of this annex showed that the absorber materials and reference ground plane grounding utilized in the ALSE will generally create the largest measurement deviations at frequencies below 200 MHz. Therefore, it was decided to limit the chamber validation upper frequency to 1 GHz. Validation methods above 1 GHz are being considered as future work.

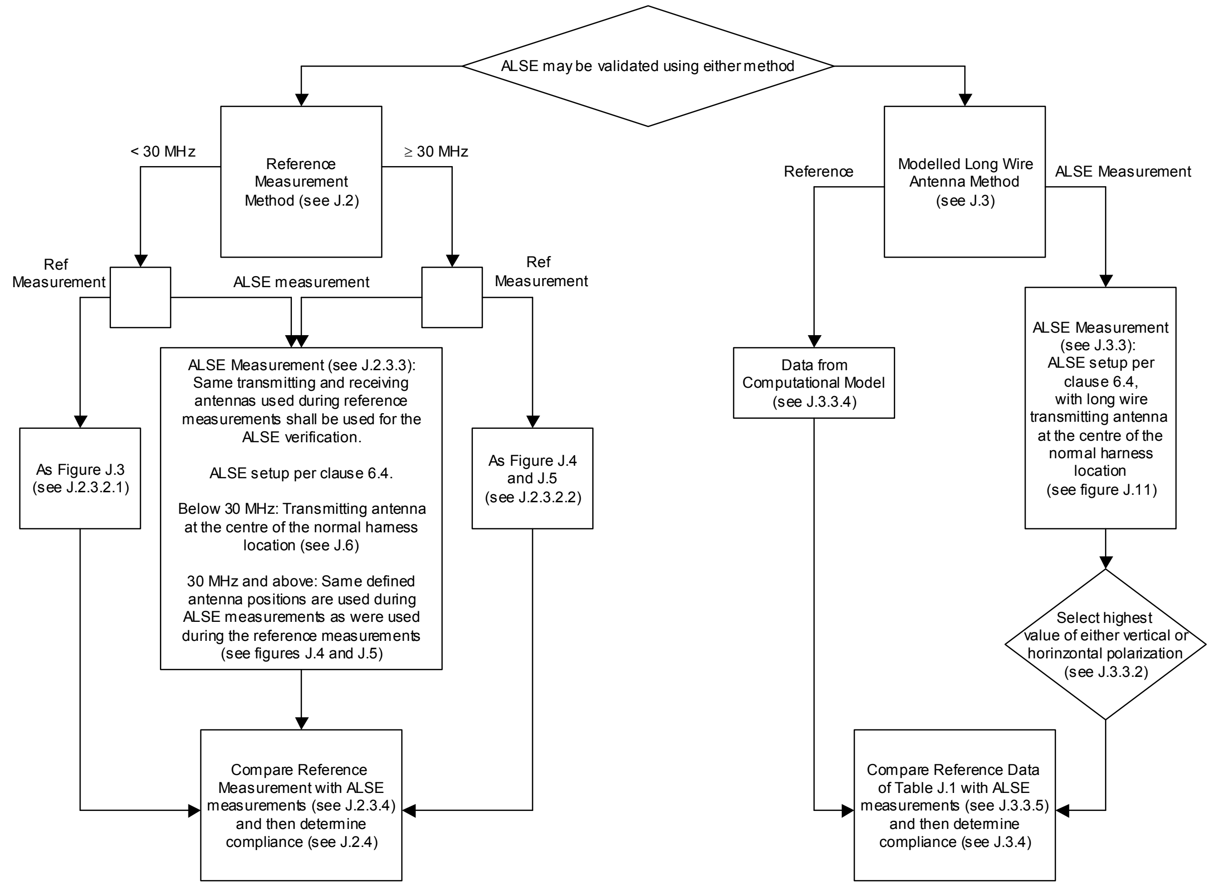


Figure J.2 – Visual Representation of ALSE Performance Validation Process

J.1.1 Purpose

During a component test, the measured electric field should be characteristic of the EUT only and the impact of the ALSE should be minimized. The EUT measurement data should vary as little as possible if the measurements are performed in different ALSEs and/or at different locations. The aim of this annex is to control the effects of the ALSE. ALSEs which meet the requirements of this annex will show less deviation in EUT data.

J.1.2 Repetition period of ALSE validation measurements

The measurements described in this annex should be performed after any major changes to the ALSE, EUT reference ground plane bonding, and/or test facility layout.

J.2 Reference measurement method

J.2.1 Overview

The validation method described below has the following aspects:

- A small monopole, biconical or shortened dipole transmitting antenna is used.

- A reference (ideal) measurement is taken in an Open Area Test Site (or similar) environment with a standardized setup that differs from the setup used in the ALSE that is to be evaluated as defined in J.2.3.2 (see J.1 for more information).
- An ALSE measurement is taken with the setup as described in 6.5
- The deviation of the reference and ALSE measurements are to be within a defined tolerance (see J.2.4).

J.2.2 Equipment

J.2.2.1 Transmission and measuring equipment

The methods in this annex define measurements of the transmission coefficient (see J.2.3.1.1) between a transmitting and receiving antenna. These measurements should be made with RF instrumentation having a nominal output or input impedance of 50 Ω. Examples include:

- a network analyser,
- a spectrum analyser or measurement receiver with a tracking generator,
- a signal generator and a spectrum analyser or measurement receiver,

J.2.2.2 Transmitting antenna

The cable connecting the transmitting antenna to the signal source may affect the verification results of the ALSE. Ferrites are to be used on the cable to minimize coupling effects. The cable should also be routed immediately towards the back of the reference ground plane, away from the receiving antenna and placed directly on the reference ground plane.

Note It is highly recommended that ferrites, with a minimum impedance of 50 Ω at 25 MHz and 110 Ω at 100 MHz, be placed on the transmitting and receiving antenna cables every 20 cm along its entire length within the ALSE being validated.

In the frequency range below 30 MHz, a short passive monopole transmitting antenna is used in vertical polarization as the transmitting antenna. It should have the following characteristics:

- Overall height of monopole, including drive unit < 500 mm
- Monopole diameter < 10 mm
- Optional top loading disc diameter < 120 mm

Note It is possible to construct a suitable transmitting monopole using the photographs in Figure J.3. Three ports are shown on this antenna base. During use as a radiator, the third port may be terminated with 50 Ω or may be unterminated. Leaving the third port un-terminated will result in an increase of the reference signal by approximately 6 dB. This could be useful in cases where reference signal amplitude adjustments are needed to overcome ambient or measurement system sensitivity issues. In either case, the same transmitting antenna loading is used during the reference and ALSE measurements.

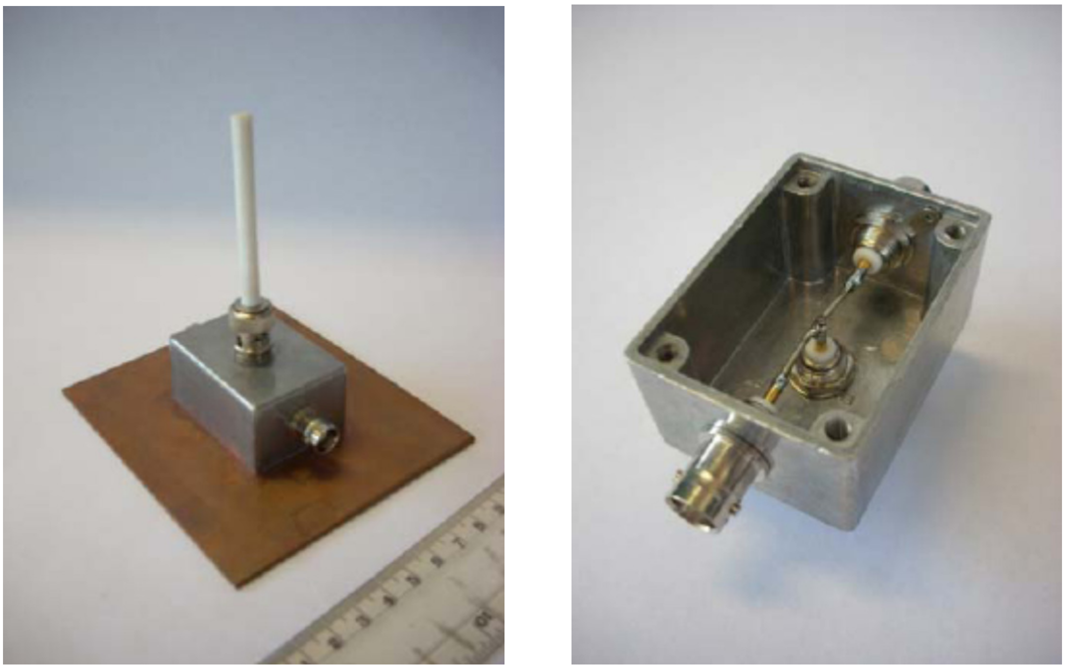


Figure J.3 – Example of construction of a transmitting monopole

In the frequency range 30 MHz and above, a small transmitting antenna (e.g. small biconical or shortened dipole) is used in the same location as the EUT harness is normally placed during component measurements. Verification measurements are made in horizontal and vertical polarization. The maximum dimension (tip to tip) of the small transmitting antenna shall be ≤ 40 cm.

Note Care should be taken to use the same element orientation for both the reference and validation testing.

J.2.2.3 Receiving antenna

The receiving antenna used is the same as described in 6.5. Because relative measurements are performed, the antenna factors of the transmitting and receiving antenna do not need to be considered.

The transmitted power should be chosen such that an overload condition does not occur in the measurement system. This can be verified by reducing the transmitted power by 10 dB and verifying that the transmission coefficient does not vary.

J.2.3 Procedure

J.2.3.1 General requirements

J.2.3.1.1 Transmission coefficient measurement

The measurements described in this annex serve the purpose to determine the transmission coefficient (C_T in dB) between the input of a transmitting antenna and the output of a receiving antenna. This includes a “direct” measurement (M_0 in dB(µV)) with the RF feed cable and receiving antenna cable connected directly together. A separate measurement (M_A in dB(µV)) is then made with the RF feed cable connected to the transmitting antenna and the receiving antenna cable connected to the receiving antenna. The transmission coefficient is then calculated as follows:

$$C_T = M_A - M_0 \qquad \text{(J.1)}$$

Note 1 The magnitude of an S21 network analyser measurement that has a valid “thru” calibration has the same value as C_T.

Note 2 C_T has the same magnitude but opposite sign to insertion loss.

J.2.3.1.2 Frequency step size

The frequencies to be used for the measurements are given in Table J.1. The same frequencies will be used for the reference and ALSE measurements. A total of 481 frequencies are used during the measurements; 150 frequencies 150 kHz – 29.95 MHz (step size: 200 kHz), 170 frequencies 30 MHz – 199 MHz (step size: 1 MHz), and 161 frequencies 200 MHz – 1000 MHz (step size: 5 MHz).

J.2.3.1.3 Noise floor

An initial “noise floor” transmission coefficient measurement will be made. For this measurement the receiving antenna will be connected to the test instrumentation, but the transmitting antenna will be disconnected from the RF feed cable. All subsequent transmission measurements will be made with the same measurement instrumentation settings (e.g. transmitted power level, resolution bandwidth, video bandwidth, detector, input attenuation, etc.) and must be at least 10 dB above the level measured in this “noise floor” measurement.

J.2.3.2 Reference measurements

A reference transmission coefficient measurement ($C_{T\ Reference}$) will be made with the antennas setup as shown in Figures J.4, J.5 and J.6.

J.2.3.2.1 Reference measurements below 30 MHz

Because the decay of the electric field at these frequencies in the vicinity of the monopole is proportional to $1/r^3$, it is permissible in the following circumstances to use the conductive floor (non-elevated ground plane) of an ALSE, instead of an OATS, to make the reference measurement. If the floor is covered with some type of material (e.g. floor tiles or carpeting), then a minimum 1,5 m x 1 m ground surface is placed on and grounded to the ALSE floor (d.c. resistance ≤ 2,5 mΩ). The transmitting and receiving monopole antenna counterpoises are bonded to the conductive floor or ground surface during the reference measurements in an ALSE and/or OATS. If a receiving monopole antenna with elevated counterpoise is used, then the counterpoise shall be grounded to the floor at the front of the counterpoise nearest the transmitting monopole antenna (for the entire width of the counterpoise). When the reference measurements are performed in an ALSE, then the following sequence applies:

1) With the monopole antennas on the grounded floor surface, at least three transmission coefficient reference measurements will be made with each measurement having the pair of antennas moved more than 0,3 m from any other measurement position.
2) If the difference (Δ) of the three reference measurements is less than 2 dB, any one of them can be used as the reference measurement.
3) If the difference (Δ) of the three reference measurements is greater than 2 dB, then the ALSE site cannot be used for the reference measurements. The reference measurements must then be made at a different site (ALSE and/or OATS) which meets the conditions of #2.

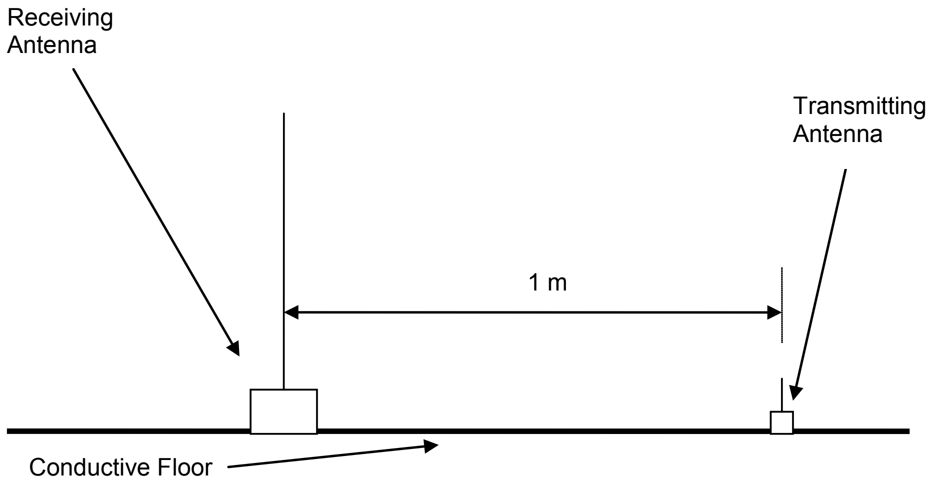


Figure J.4 – Side view of antenna configuration for reference measurement below 30 MHz

J.2.3.2.2 Reference measurements at 30 MHz and above

The reference measurements at 30 MHz and above will be made on a reference test site. A reference test site is an OATS or alternative test site (e.g. weather-protected OATS or semi-anechoic chamber) which meets the requirements of CISPR 16-1-4, Clauses 5.6.2 and 5.3.2 respectively.

An elevated validation reference ground plane (see 3.27) is required for the reference measurements at 30 MHz and above. The elevated validation reference ground plane will have a standard dimension of 2,5 m x 1 m and is bonded to the reference test site ground plane floor surface. Grounding of the elevated validation reference ground plane to the reference test site ground plane will be achieved by using single strap with a width of 100 -0/+100 mm which is centred on the centre point of the rear length of the validation reference ground plane (see Figure J.13 for a drawing of the validation reference ground plane and the single strap grounding). The bond between the validation reference ground plane and the reference test site ground plane should be less than 2.5 mΩ. The 2,5 m x 1 m elevated validation reference ground plane is a standard size that is used for all reference measurements. This is not necessarily the same reference ground plane which is used during EUT testing and the ALSE measurements of J.2.3.3 (see J.1 for more information). The transmitting and receiving antennas will remain in one location (centred on the centre point of the elevated reference ground plane) for all measurements.

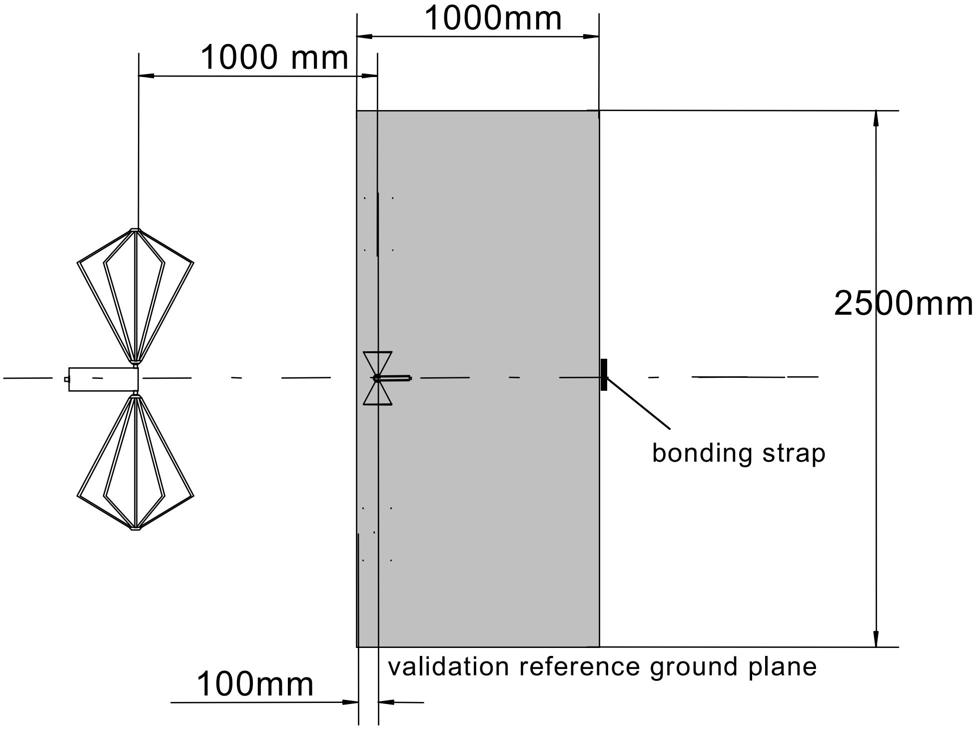


Figure J.5 – Top view of antenna configuration for reference measurement 30 MHz and above (with the biconical antenna shown as example)

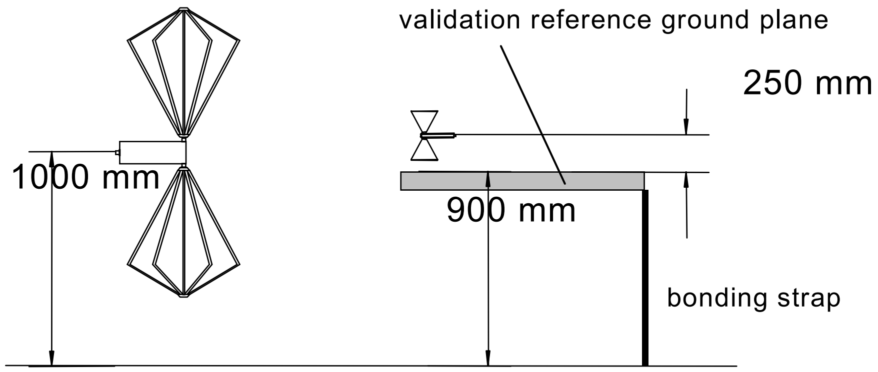


Figure J.6 – Side view of antenna configuration for reference measurement 30 MHz and above (with the biconical antenna shown as example)

J.2.3.3 ALSE measurements

The ALSE transmission coefficient ($C_{T\,ALSE}$) measurements are made with the same ALSE configuration (physical layout, reference ground plane size, reference ground plane grounding, RF absorber, etc.) that will be used during measurements of an EUT. It also includes the connection between antenna counterpoise and table for monopole antenna measurements below 30 MHz.

NOTE The battery and AN(s) will not be part of the validation setup and therefore are not placed on the elevated reference ground plane during the ALSE validation.

At frequencies below 30 MHz, the transmitting antenna will be positioned directly on the reference ground plane at the position where the centre of the test harness would normally be, opposite the receiving antenna. This is shown in Figure J.7.

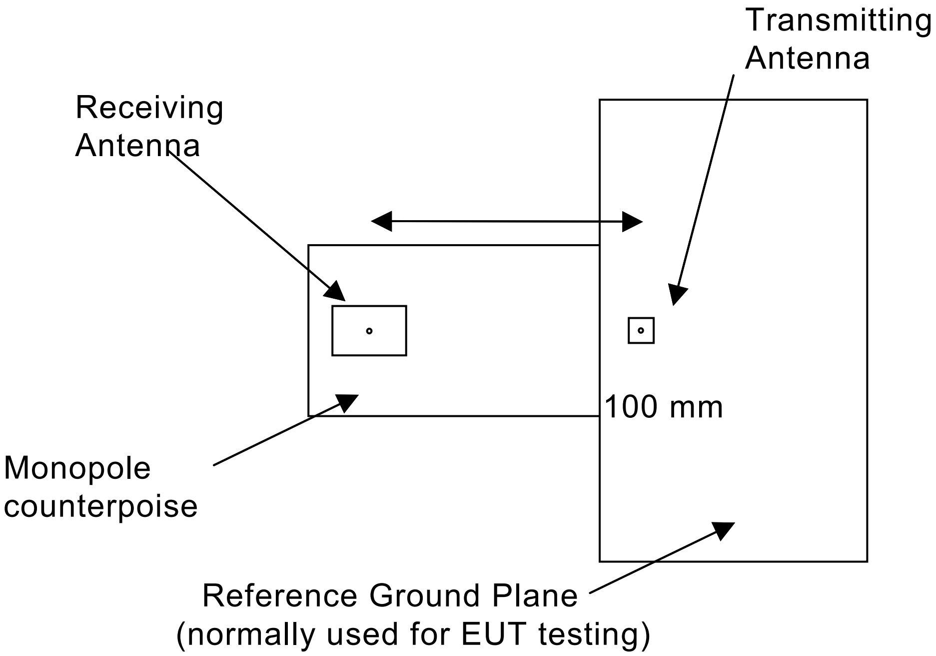


Figure J.7 – Top view of antenna configuration for the ALSE measurement below 30 MHz

At 30 MHz and above, the transmitting antenna should be positioned as in the reference measurements. This is shown in Figure J.5 and Figure J.6. The transmitting and receiving antennas will remain in one location (centred on the centre point of the ALSE reference ground plane) for all measurements.

J.2.3.4 Deviation of the ALSE measurement and reference data

At frequencies below 30 MHz, the reference measurement (with antennas on the ALSE floor) is compared to the ALSE (typical EUT test setup) measurement.

The delta of the measurement data obtained in J.2.3.3 from the reference data obtained in J.2.3.2 will be calculated for each frequency below 30 MHz.

$$\Delta_{<30\ MHz} = C_{T\ Reference} - C_{T\ ALSE} \qquad \Delta \text{ in dB} \qquad \text{(J.2)}$$

At each frequency 30 MHz and above, the reference data obtained at each antenna polarization in J.2.3.3, will be compared to the corresponding antenna polarization data obtained in the ALSE. This will result in two Δ data sets at 30 MHz and above:

$$\Delta_{\geq 30\ MHz\ Vert} = C_{T\ Reference\ Vertical} - C_{T\ ALSE\ Vertical} \qquad \Delta \text{ in dB} \qquad \text{(J.3)}$$

$$\Delta_{\geq 30\ MHz\ Horiz} = C_{T\ Reference\ Horizontal} - C_{T\ ALSE\ Horizontal} \qquad \Delta \text{ in dB} \qquad \text{(J.4)}$$

J.2.4 Requirements

To determine compliance, first calculate the % In Tolerance (*%IT*) data points for each data set:

$$\%IT_{<30\ MHz} = \left(\frac{\text{data points of } \Delta_{<30\ MHz} \text{ within} \pm 6\text{ dB}}{481}\right)\cdot 100 \qquad \text{(J.5)}$$

$$\%IT_{\geq 30\ MHz\ Vert} = \left(\frac{\text{data points of } \Delta_{\geq 30\ MHz\ Vert} \text{ within} \pm 6\text{ dB}}{481}\right)\cdot 100 \qquad \text{(J.6)}$$

$$\%IT_{\geq 30\ MHz\ Horiz} = \left(\frac{\text{data points of } \Delta_{\geq 30\ MHz\ Horiz} \text{ within} \pm 6\text{ dB}}{481}\right)\cdot 100 \qquad \text{(J.7)}$$

Next, find the minimum % In Tolerance (*%IT*) data points for the two data sets at ≥ 30 MHz:

$$\%IT_{\geq 30\ MHz\ \min} = \min\left(\%IT_{\geq 30\ MHz\ Vert}, \%IT_{\geq 30\ MHz\ Horiz}\right) \qquad \text{(J.8)}$$

Finally, calculate the total percentage of data points within the ±6 dB requirement over the entire frequency range of 150 kHz to 1 000 MHz ($Total\ \%IT_{150\ kHz\ to\ 1000\ MHz\ Ref\ Method}$) by:

$$Total\ \%IT_{150\ kHz\ to\ 1000\ MHz\ Ref\ Method} = \%IT_{<30\ MHz} + \%IT_{\geq 30\ MHz\ \min} \qquad \text{(J.9)}$$

The ALSE and its installation (physical layout, reference ground plane size, reference ground plane grounding, RF absorber, etc.) is compliant with the requirements of this validation method if $Total\ \%IT_{150\ kHz\ to\ 1000MHz\ Ref\ Method}$ is ≥ 90 %. This compliance may be included in a statement in the test report.

Note Only those frequency ranges (Table J.1) are to be evaluated in which the ALSE is used for component testing in which case the value 481 in eq. J.5 through eq. J.9 will be replaced by the total number of points for the reduced frequency range.

The difference between the reference and ALSE measurements will not be used

- as a correction factor for emissions measurements of an EUT, or
- to produce an antenna factor for the Receiving antenna.

J.3 Modelled long wire antenna method

J.3.1 Overview

The validation method described below has the following aspects:

- a line source based on a rod between two metallic sheet angles is used in the location of the cabling harness,
- the reference values are determined through numerical simulations,
- an ALSE measurement is performed with the setup as described in 6.5,
- the reference and ALSE measurements should be similar, within a defined tolerance.

J.3.2 Equipment

J.3.2.1 Transmission and measuring equipment

Examples of transmission and measuring equipment are described in J.2.2.1.

J.3.2.2 Transmitting antenna

The cable connecting of the transmitting antenna to the signal source may affect the verification results of the ALSE. Ferrites are to be used on the cable to minimize coupling effects. The cable should also be routed immediately towards the back of the reference ground plane, away from the receiving antenna and placed directly on the reference ground plane.

Note It is highly recommended that ferrites, with a minimum impedance of 50 Ω at 25 MHz and 110 Ω at 100 MHz, be placed on the transmitting and receiving antenna cables every 20 cm along its entire length within the ALSE being validated.

The radiation source consists of a brass rod with (4 ± 0,2) mm diameter located at (50 ± 2) mm height (between the ground plane and the closest point of the rod) above the ground reference plane parallel to the front edge. The horizontal distance between the edge of the ground reference plane and the rod is (100 ± 2) mm. The rod is held by two metallic sheet angles (see Figure J.8), which are separated by (500 ± 5) mm. Type-N-connectors are integrated in the angles as support for the rod. The centre of the rod is located at the same position as the centre of the cabling harness used for EUT testing.

The metallic sheet angles are mounted on the ground reference plane to establish a low inductive, low resistive connection between angle and ground (see Figure J.10).

Note It is recommended to use mounting clamps made of plastic or to screw the sheet angles directly to the ground plane.

At the load end of the radiator, the rod is terminated with a (50 ± 7,5) Ω RF load (max VSWR 1.2:1 over the frequency range of 150 kHz to 1000 MHz) through the Type-N-connector mounted in the metallic sheet angle. At the RF feed end of the radiator, the rod is connected to a 10 dB, 50 Ω attenuator (max VSWR 1.2:1 over the frequency range of 150 kHz to 1000 MHz) through the Type-N-connector mounted in the other metallic sheet angle. See Figure J.9 for a side view of the radiator and the RF terminations.

The RF feed cable is used to connect the signal source to the 10 dB, 50 Ω attenuator at the source end of the radiator using an angle connector as shown in Figure J.9.

The construction of the radiation source allows a reliable modelling for numerical calculations, which establishes the reference data. It is important that the construction of the radiation source is followed closely. Typical VSWR curves (without the 10 dB attenuator) of a properly constructed radiation source are shown in Figure J.11.

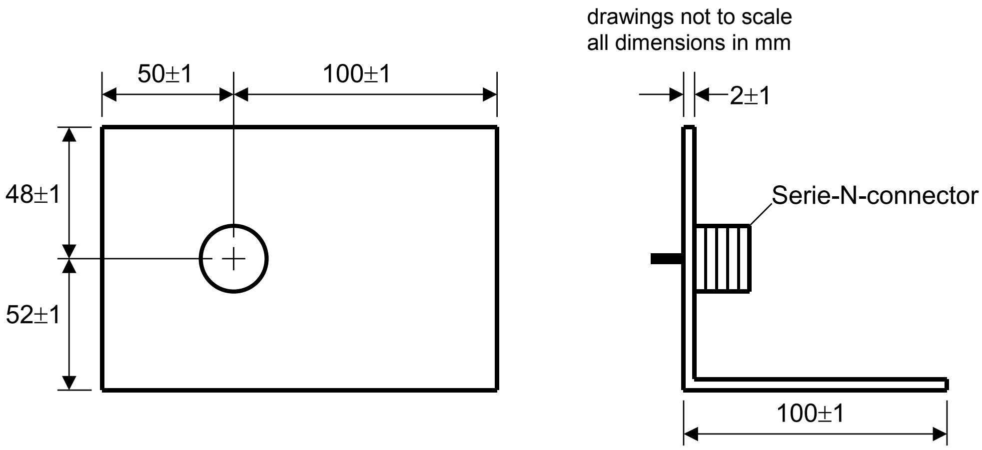


Figure J.8 - Metallic sheet angles used as support for the rod

Note The two metallic sheet angles are mirror-inverted to each other.

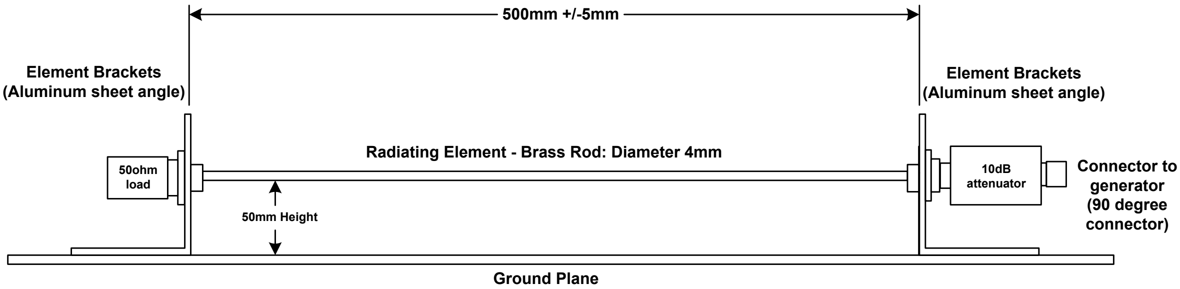


Figure J.9 - Radiator side view 50 Ω terminations

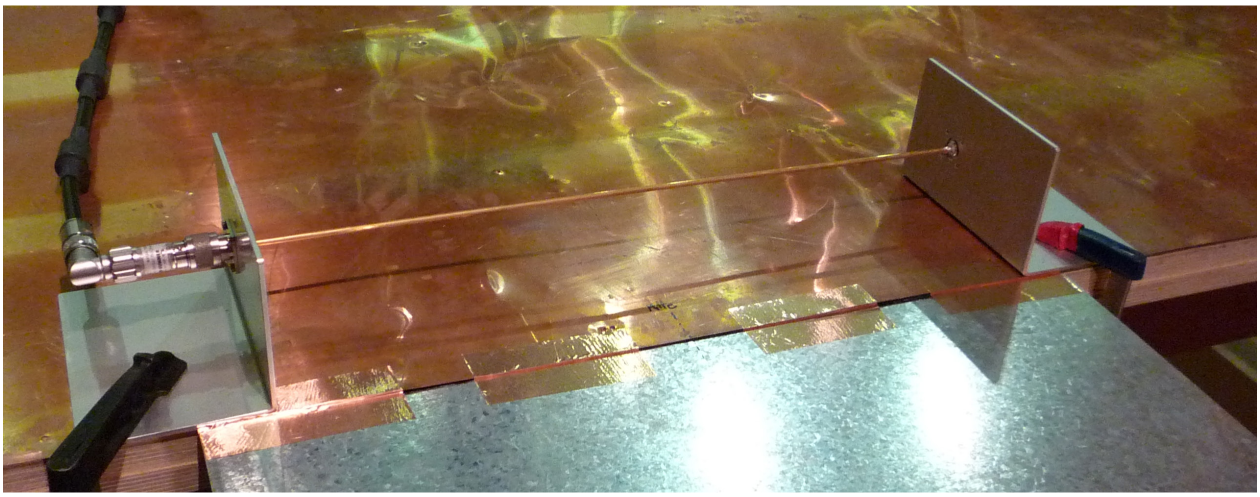


Figure J.10 - Photo of the radiator mounted on the ground reference plane

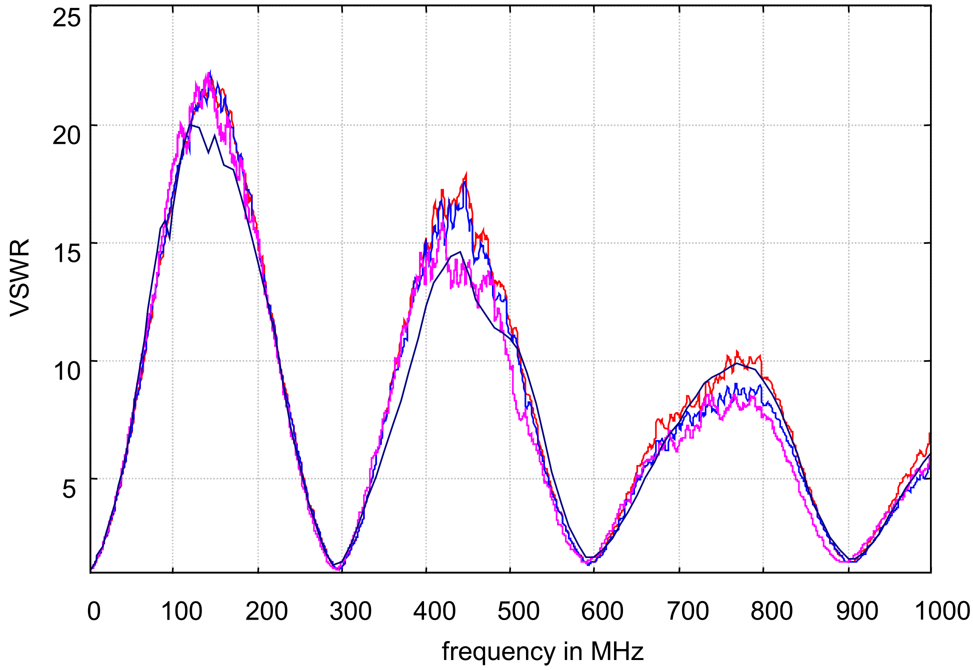


Figure J.11 - Example VSWR measured from four radiation sources (without 10 dB)

J.3.2.3 Receiving antenna

The receiving antennas used are the same as described in 6.5. The antenna factor(s) must be known and considered in the calculations below.

The transmitted power should be chosen so that an overload condition does not occur in the measurement system. This can be verified by reducing the transmitted power by 10 dB and checking that the received power is also reduced by 10 dB.

J.3.2.4 ALSE configuration

The measurements are made with the same ALSE configuration (physical layout, reference ground plane size, reference ground plane grounding, RF absorber, etc.) that will be used during measurements of a DUT. This also includes the connection between antenna counterpoise and table for monopole antenna measurements.

Note The battery and AN(s) will not be part of the validation setup and therefore are not placed on the elevated reference ground plane during the ALSE validation.

J.3.3 Procedure

J.3.3.1 Frequency step size

The frequency step size requirements are described in J.2.3.1.2.

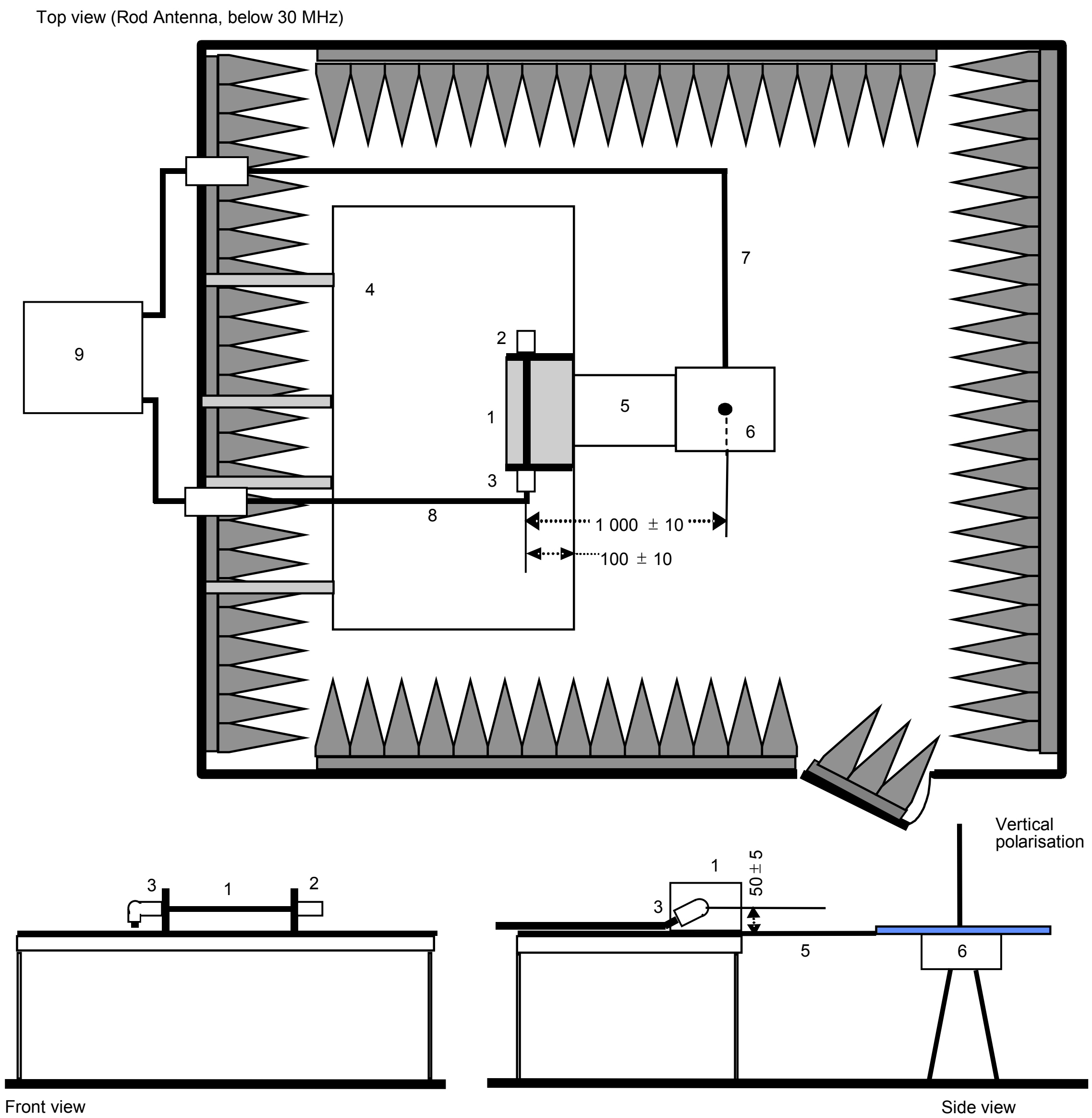
J.3.3.2 ALSE equivalent field strength measurements

An initial “direct” measurement is made with the radiator feed cable directly connected to the receiving antenna output cable. The amplitude of signal generation equipment is set to deliver 1 Vrms (120 dB(µV)). The reading of the receiving instrument is recorded as quantity M_0 in dB(µV).

Note Since the difference between the initial measurement M_0 and the measurement M_A is calculated in equation J.18 the absolute value of the generator output will not directly influence the result. However, it is recommended to use the level of 1 V to obtain sufficient measurement dynamic range.

If a network analyser is used, the “direct” measurement is replaced by a full two-port calibration with the end of the radiator RF feed cable and the end of the antenna cable defining the reference plane.

For the measurement of the transmission coefficient, the radiator feed cable is connected to the input of the 10 dB attenuator and the antenna cable is connected to the receiving antenna (see Figure J.12). Again the amplitude of signal generation equipment is set to deliver 1 Vrms (120 dB(µV)) to the input of the 10 dB attenuator. The reading of the receiving instrument is recorded as quantity M_A in dB(µV).



Key

1 radiation source

2 50Ω termination

3 10dB attenuator

6 rod antenna

7 cable from receiving antenna to measurement instrument (e.g. network analyzer)

8 cable from measurement instrument (e.g.

4 reference ground plane

5 grounding connection

network analyzer) to radiator

9 measurement instrument (e.g. network analyzer)

Figure J.12 - Example setup for ALSE equivalent field strength measurement (rod antenna shown for the frequency range below 30 MHz).

From the two values and the antenna factor of the receiving antenna (k_{AF}, in dB(1/m)), the equivalent field strength (E_{eq}, in dB(µV/m)) can be derived for each frequency:

$$E_{eq} = 120\text{dB}(\mu\text{V}) + \left(M_A - M_0\right) + k_{AF} \qquad \text{(eq. J.10)}$$

Note The equivalent field strength is the field strength that would be received, when a signal with 1 Vrms is injected in the input of the 10 dB attenuator.

In case of the network analyser, which measures the scattering parameter S_{21} (in dB), the equivalent field strength ($E_{\text{eq in dB}(\mu\text{V/m})}$) can be derived as

$$E_{eq} = 120\text{dB}(\mu\text{V}) + S_{21} + k_{AF} \qquad \text{(eq. J.11)}$$

In the frequency range above 30 MHz, the measurements should be performed both for horizontal and vertical polarisations. The results are $E_{eq,hor}$ and $E_{eq,ver}$.

For each frequency, the maximum equivalent field strength $E_{eq,max}$ is derived as maximum of the $E_{eq,hor}$ and $E_{eq,ver}$.

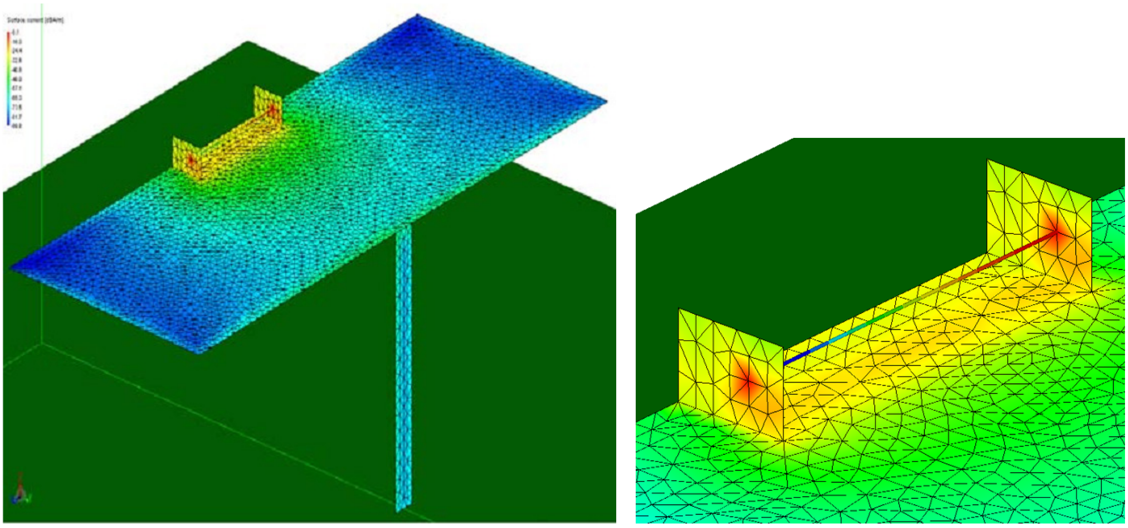
For reliable results the noise floor should be at least 10 dB below the measured signal levels. This can be verified by connecting the receiving antenna to the receiving instrument but disconnecting the signal source from the radiation source.

J.3.3.3 Techniques used to generate the reference data

In the model below 30 MHz, the ground plane is a non-elevated ground plane (e.g. the floor of an ALSE, OATS or alternative test site) which is similar to the setup shown in Figure J.4 (using the long wire transmitting antenna instead of the transmitting monopole). In the model for 30 MHz and above, the standard size 2,5 m x 1 m reference ground plane is elevated and located in an ideal free field with perfectly conducting ground properties. Grounding of the elevated reference ground plane to the floor is achieved by using a single strap with a width of 100 mm which is centred on the centre point of the rear length of the reference ground plane. Calculations were done with a Method of Moments (MoM) code. Figure J.13 shows the computer model used for MoM in the frequency range 30 MHz to 200 MHz.

Note Comparative simulations have been done in the past with FDTD.

At frequencies below 30 MHz, the monopole antenna was part of the model since the connection between monopole antenna and the ground plane has an influence on the antenna factor. At frequencies above 30 MHz, the electric field strength at the point where the receiving antennas reference point is located has been used and is the maximum of vertical and horizontal polarisations.



a) Complete model b) Detail of the radiator

Figure J.13 - MoM-Modell for the frequency range 30MHz to 200 MHz

J.3.3.4 Reference data

The numbers shown in Table J.1 are used as the standard set of reference data. The information shown in Table J.1 is the numerical reference data that is compared to the equivalent field strength measurement data obtained in the ALSE being validated. This reference data is also applicable to evaluations of ALSEs that deviate in their setup from the configuration the modelling was based on. Hence, no further modelling is required and users need not perform their own simulations. Although modelling of a user’s chamber is possible, only the numbers shown in Table J.1 are allowed to be used to determine chamber acceptance.

The simulation data already includes the 10 dB attenuator.

Table J.1 Reference data to be used for chamber validation

Frequency range 150 kHz – 30 MHz		Frequency range 30 MHz – 200 MHz		Frequency range 200 MHz – 1000 MHz	
Frequency in MHz	$E_{eq,max,ref}$ in dB(μV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(μV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(μV/m)
0,15	61,14	30	71,24	200	87,9
0,35	61,14	31	71,39	205	88,58
0,55	61,14	32	71,51	210	89,59
0,75	61,14	33	71,62	215	90,61
0,95	61,14	34	71,71	220	91,47
1,15	61,14	35	71,81	225	92,24
1,35	61,14	36	71,92	230	93,05
1,55	61,14	37	72,09	235	93,96
1,75	61,13	38	72,36	240	94,94
1,95	61,13	39	72,84	245	95,9
2,15	61,13	40	73,61	250	96,81
2,35	61,13	41	74,76	255	97,66
2,55	61,12	42	76,28	260	98,46
2,75	61,12	43	78,03	265	99,22
2,95	61,12	44	79,76	270	99,92
3,15	61,11	45	81,16	275	100,53
3,35	61,11	46	82,04	280	101,03
3,55	61,11	47	82,43	285	101,4
3,75	61,10	48	82,48	290	101,65
3,95	61,10	49	82,37	295	101,76
4,15	61,09	50	82,2	300	101,74
4,35	61,09	51	82,03	305	101,59
4,55	61,08	52	81,87	310	101,34
4,75	61,08	53	81,75	315	100,99
4,95	61,07	54	81,65	320	100,55
5,15	61,07	55	81,57	325	100,05
5,35	61,06	56	81,52	330	99,62
5,55	61,05	57	81,48	335	99,38
5,75	61,05	58	81,47	340	99,17
5,95	61,04	59	81,46	345	98,93
6,15	61,03	60	81,47	350	98,61
6,35	61,02	61	81,49	355	98,14
6,55	61,02	62	81,52	360	97,67
6,75	61,01	63	81,55	365	97,48
6,95	61,00	64	81,59	370	97,49
7,15	60,99	65	81,63	375	97,58

Frequency range 150 kHz – 30 MHz		Frequency range 30 MHz – 200 MHz		Frequency range 200 MHz – 1000 MHz	
Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)
7,35	60,98	66	81,68	380	97,68
7,55	60,98	67	81,73	385	97,73
7,75	60,97	68	81,79	390	97,74
7,95	60,96	69	81,85	395	97,74
8,15	60,95	70	81,91	400	97,78
8,35	60,94	71	81,97	405	97,86
8,55	60,93	72	82,03	410	97,96
8,75	60,92	73	82,1	415	98,07
8,95	60,91	74	82,17	420	98,19
9,15	60,90	75	82,24	425	98,33
9,35	60,89	76	82,31	430	98,48
9,55	60,88	77	82,38	435	98,64
9,75	60,86	78	82,45	440	98,8
9,95	60,85	79	82,53	445	98,95
10,15	60,84	80	82,61	450	99,06
10,35	60,83	81	82,69	455	99,11
10,55	60,82	82	82,77	460	99,09
10,75	60,81	83	82,85	465	98,99
10,95	60,79	84	82,94	470	98,86
11,15	60,78	85	83,03	475	98,72
11,35	60,77	86	83,12	480	98,59
11,55	60,76	87	83,22	485	98,49
11,75	60,74	88	83,32	490	98,38
11,95	60,73	89	83,42	495	98,25
12,15	60,72	90	83,53	500	98,12
12,35	60,70	91	83,64	505	97,97
12,55	60,69	92	83,75	510	97,74
12,75	60,67	93	83,87	515	97,54
12,95	60,66	94	83,99	520	97,55
13,15	60,65	95	84,11	525	97,43
13,35	60,63	96	84,23	530	97,24
13,55	60,62	97	84,35	535	97,15
13,75	60,60	98	84,47	540	97,22
13,95	60,59	99	84,59	545	97,36
14,15	60,57	100	84,71	550	97,33
14,35	60,56	101	84,83	555	96,96
14,55	60,54	102	84,94	560	96,3
14,75	60,52	103	85,05	565	95,59

Frequency range 150 kHz – 30 MHz		Frequency range 30 MHz – 200 MHz		Frequency range 200 MHz – 1000 MHz	
Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)
14,95	60,51	104	85,15	570	94,92
15,15	60,49	105	85,25	575	94,26
15,35	60,48	106	85,35	580	93,6
15,55	60,46	107	85,43	585	92,94
15,75	60,44	108	85,52	590	92,33
15,95	60,43	109	85,59	595	91,8
16,15	60,41	110	85,67	600	91,34
16,35	60,39	111	85,73	605	90,95
16,55	60,38	112	85,79	610	91,06
16,75	60,36	113	85,85	615	91,81
16,95	60,34	114	85,9	620	92,51
17,15	60,33	115	85,95	625	93,15
17,35	60,31	116	85,99	630	93,7
17,55	60,29	117	86,03	635	94,15
17,75	60,28	118	86,06	640	94,5
17,95	60,26	119	86,09	645	94,74
18,15	60,24	120	86,12	650	94,88
18,35	60,22	121	86,15	655	94,92
18,55	60,21	122	86,17	660	94,88
18,75	60,19	123	86,18	665	94,76
18,95	60,17	124	86,2	670	94,51
19,15	60,15	125	86,21	675	94,08
19,35	60,14	126	86,22	680	94,55
19,55	60,12	127	86,22	685	95,18
19,75	60,10	128	86,22	690	95,8
19,95	60,08	129	86,22	695	96,14
20,15	60,07	130	86,22	700	95,98
20,35	60,05	131	86,21	705	95,85
20,55	60,03	132	86,2	710	95,83
20,75	60,02	133	86,18	715	95,69
20,95	60,00	134	86,16	720	95,28
21,15	59,98	135	86,14	725	94,8
21,35	59,96	136	86,12	730	94,65
21,55	59,95	137	86,09	735	94,71
21,75	59,93	138	86,06	740	94,86
21,95	59,91	139	86,03	745	95,23
22,15	59,90	140	85,99	750	95,8
22,35	59,88	141	85,95	755	96,4

Frequency range 150 kHz – 30 MHz		Frequency range 30 MHz – 200 MHz		Frequency range 200 MHz – 1000 MHz	
Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)
22,55	59,87	142	85,9	760	96,89
22,75	59,85	143	85,85	765	97,24
22,95	59,83	144	85,8	770	97,47
23,15	59,82	145	85,75	775	97,61
23,35	59,80	146	85,69	780	97,7
23,55	59,79	147	85,63	785	97,73
23,75	59,77	148	85,56	790	97,71
23,95	59,76	149	85,49	795	97,63
24,15	59,74	150	85,41	800	97,49
24,35	59,73	151	85,33	805	97,3
24,55	59,72	152	85,24	810	97,08
24,75	59,70	153	85,14	815	96,84
24,95	59,69	154	85,04	820	96,61
25,15	59,68	155	84,93	825	96,39
25,35	59,67	156	84,82	830	96,19
25,55	59,66	157	84,69	835	96
25,75	59,65	158	84,55	840	95,86
25,95	59,63	159	84,41	845	95,56
26,15	59,62	160	84,25	850	96,51
26,35	59,62	161	84,07	855	97,5
26,55	59,61	162	83,88	860	98,42
26,75	59,60	163	83,68	865	99,23
26,95	59,59	164	83,45	870	99,9
27,15	59,58	165	83,21	875	100,51
27,35	59,58	166	83,02	880	101,09
27,55	59,57	167	83,28	885	101,61
27,75	59,56	168	83,54	890	102,09
27,95	59,56	169	83,8	895	102,54
28,15	59,56	170	84,05	900	102,95
28,35	59,55	171	84,29	905	103,31
28,55	59,55	172	84,53	910	103,6
28,75	59,55	173	84,77	915	103,84
28,95	59,55	174	85	920	104,03
29,15	59,55	175	85,22	925	104,18
29,35	59,55	176	85,44	930	104,26
29,55	59,55	177	85,65	935	104,28
29,75	59,55	178	85,86	940	104,24
29,95	59,55	179	86,06	945	104,14

Frequency range 150 kHz – 30 MHz		Frequency range 30 MHz – 200 MHz		Frequency range 200 MHz – 1000 MHz	
Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(µV/m)
		180	86,26	950	104
		181	86,44	955	103,84
		182	86,62	960	103,68
		183	86,78	965	103,53
		184	86,94	970	103,39
		185	87,07	975	103,27
		186	87,2	980	103,17
		187	87,31	985	103,08
		188	87,4	990	102,98
		189	87,48	995	102,86
		190	87,54	1000	102,69
		191	87,6		
		192	87,64		
		193	87,67		
		194	87,69		
		195	87,72		
		196	87,74		
		197	87,77		
		198	87,81		
		199	87,87		

J.3.3.5 Deviation of the ALSE measurement from the reference data

The deviation of the measurement data obtained in J.3.3.2 from the reference values given in Table J.1 is calculated for each frequency.

$$\Delta_{Long\ Wire\ Method} = E_{eq,max} - E_{eq,max,ref} \qquad \Delta \text{ in dB} \qquad \text{(J.12)}$$

J.3.4 Requirements

To determine compliance, calculate the total percentage of data points within the ± 6 dB requirement over the entire frequency range of 150 kHz to 1000 MHz ($Total\ \%IT_{150\ kHz\ to\ 1000MHz\ Long\ Wire\ Method}$) by:

$$Total\ \%IT_{150\ kHz\ to\ 1000\ MHz,\ Long\ Wire\ Method} = \left(\frac{\text{data points } 150\ kHz\ to\ 1000\ MHz \text{ where } \Delta_{Long\ Wire\ Method} \text{ is within } \pm 6\ dB}{481} \right) \cdot 100 \qquad \text{(J.13)}$$

The ALSE and its installation (physical layout, reference ground plane size, reference ground plane grounding, RF absorber, etc.) is compliant with the requirements of this validation method if $Total\ \%IT_{150\ kHz\ to\ 1000MHz\ Long\ Wire\ Method}$ is ≥ 90 %. This compliance may be included in a statement in the test report.

Note Only those frequency ranges (Table J.1) need to be considered, for which the ALSE is to be used in which case the value 481 in eq. J.13 will be replaced by the total number of points for the reduced frequency range..

The difference between the reference and ALSE measurement is not to be used as a correction factor for emissions measurements of an EUT.

J.4 References

"THE GROUNDPLANE RESONANCE – PROBLEMS WITH RADIATED EMISSIONS MEASUREMENTS BELOW 30 MHz". Dr Luke Turnbull, 2007 Automotive EMC Conference, Newbury UK. (http://www.conekt.co.uk/news-and-events/92-emc-groundplane-paper)

"MESSTECHNISCHE UNTERSUCHUNG DES EINFLUSSES DER ERDUNG VON CISPR-25-EMISSIONSMESSPLÄTZEN". Alexander Kriz, Wolfgang Müllner, Friedrich-Wilhelm Trautnitz, Jochen Riedelsheimer , Herbert Seitle, Test Kompendium 2004, Messen-Prüfen-Verifizieren, publish-industry Verlag GmbH, München, 2003. http://www.seibersdorf-rf.com

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Annex K
(informative)

Items Under Consideration

K.1 Introduction

This annex contains future work items that are under consideration.

K.1.1 Measurement techniques and limits

As further work progresses in CISPR A, CISPR H and TC 69 this will be reviewed and CISPR 25 updated accordingly.

K.1.2 Measurement Uncertainty

This topic will be considered for future revisions of this standard.