BRITISH STANDARD

BS EN 55025:2003
CISPR 25:2002

Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices — Limits and methods of measurement

The European Standard EN 55025:2003 has the status of a British Standard

ICS 33.100.10; 33.100.20

British Standards

National foreword

This British Standard is the official English language version of EN 55025:2003. It is identical with CISPR 25:2002.

The UK participation in its preparation was entrusted by Technical Committee GEL/210, EMC – Policy committee, to Subcommittee GEL/210/11, EMC – Product standards, which has the responsibility to:

— aid enquirers to understand the text;

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— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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EUROPEAN STANDARD

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English version

Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices - Limits and methods of measurement
(CISPR 25:2002)

Caractéristiques des perturbations radioélectriques pour la protection des récepteurs utilisés à bord des véhicules, des bateaux et des engins - Limites et méthodes de mesure
(CISPR 25:2002)

Funk-Entstörung zum Schutz von Empfängern in Fahrzeugen, Booten und Geräten - Grenzwerte und Messverfahren
(CISPR 25:2002)

This European Standard was approved by CENELEC on 2002-12-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 55025:2003 E

Foreword

The text of document CISPR/D/271/FDIS, future edition 2 of CISPR 25, prepared by CISPR SC D, Electromagnetic disturbances related to electric/electronic equipment on vehicles and internal combustion engine powered devices, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 55025 on 2002-12-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2003-09-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2005-12-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annexes C, E and ZA are normative and annexes A, B, D, F, G and H are informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard CISPR 25:2002 was approved by CENELEC as a European Standard without any modification.

CONTENTS

INTRODUCTION

This standard is designed to protect 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 1 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.

NOTE 2 Annex B provides helpful methodology for resolution of disturbance problems.

RADIO DISTURBANCE CHARACTERISTICS FOR THE PROTECTION OF RECEIVERS USED ON BOARD VEHICLES, BOATS, AND ON DEVICES – LIMITS AND METHODS OF MEASUREMENT

1 Scope

This International Standard contains limits[1] and procedures for the measurement of radio disturbances in the frequency range of 150 kHz to 1 000 MHz. The standard applies to any electronic/electrical component intended for use in vehicles 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[2]. The methods and limits for a complete vehicle are in Clause 5 and the methods and limits for components/modules are in Clause 6.

NOTE Achieving satisfactory compatibility with on-board radio reception will also in most cases provide satisfactory compatibility with adjacent radio receiver reception.

The receiver types to be protected are: sound and television receivers[3], land mobile radio, radio telephone, amateur and citizens' radio. For the purpose of this standard, a vehicle is a machine, which is self-propelled. 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 a 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 expected to be included in ISO publications.

The methods described in Clauses 5 and 6 apply to the suppression of on-board radio disturbances for motor vehicles, devices and working machinery, to achieve acceptable radio reception with on-board radio receivers. The requirements contained herein specify the maximum permissible disturbance voltage at the receiver end of the vehicle antenna transmission line in the frequency range of 150 kHz to 1 000 MHz.

On-board radio disturbance suppression reduces the radio disturbance energy which is applied by electrical equipment within the vehicle to the on-board power supply of a vehicle. Disturbances can also be coupled from vehicle wiring to the receiving antenna on the vehicle. Both articles describe methods of safeguarding radio reception in the same vehicle in which the disturbance arises. Annex B provides a helpful methodology for resolution of disturbance problems.

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[1] Only a complete vehicle test can be used to determine the component compatibility with respect to a vehicle's limit.

[2] Adjacent vehicles can be expected to be protected in most situations.

[3] Adequate television protection will result from compliance with the levels at the mobile service frequencies.

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) will be agreed upon between the vehicle manufacturer and the component supplier.

The World Administrative Radiocommunications 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.

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*

CISPR 12, *Vehicles, boats 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 16-1:1999, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

3 Definitions

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

3.1
receiver terminal voltage (antenna voltage)
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 16-1

3.2
component continuous conducted emissions
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

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

3.4
antenna correction factor
factor which is applied to the voltage measured at the input connector of the measuring instrument to give the field strength at the antenna

NOTE The antenna correction factor is comprised of an antenna factor and a cable factor.

3.5
compression point
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

3.6
class
performance level agreed upon by the purchaser and the supplier and documented in the test plan

3.7
device
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
RF boundary
element of an EMC test set-up that determines what part of the harness and/or peripherals are included in the RF environment and what is excluded

NOTE It may consist of, for example, ANs, BANs, filter feed-through pins, RF absorber coated wire, and/or RF shielding.

3.9
artificial network (AN)
line impedance stabilization network (LISN[4])
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

[IEV 161-04-05, modified]

3.10
bandwidth (of an equipment)
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]

3.11
bandwidth (of an emission or signal)
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]

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4 In the USA.

3.12
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.

3.13
disturbance suppression
action which reduces or eliminates electromagnetic disturbance

[IEV 161-03-22]

3.14
disturbance voltage
interference voltage (deprecated)
voltage produced between two points on two separate conductors by an electromagnetic disturbance, measured under specified conditions

[IEV 161-04-01]

3.15
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.

3.16
peak detector
a detector, the output voltage of which is the peak value of an applied signal

[IEV 161-04-24]

3.17
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]

3.18
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]

3.19
electromagnetic environment
the totality of electromagnetic phenomena existing at a given location

[IEV 161-01-01]

3.20
shielded enclosure
screened room
a mesh or sheet metallic housing designed expressly for the purpose of separating electro-magnetically the internal and the external environment

[IEV 161-04-37]

3.21
ground (reference) plane
a flat conductive surface whose potential is used as a common reference

[IEV 161-04-36]

4 Requirements common to vehicle and component/module emissions measurement

4.1 General test requirements and test plan

4.1.1 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, the disturbance classification (broadband long or short duration – or narrowband), antenna types and locations, test report requirements, supply voltage and other relevant parameters.

4.1.2 Determination of conformance of EUT with limits

If the type of disturbance is unknown, tests shall be made to determine whether measured emissions are narrowband and/or broadband to apply limits properly as specified in the test plan.

Figure 1 outlines the procedure to be followed in determining conformance with limits.

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

Electromagnetic disturbance sources can be divided into three types:

a) continuous/long duration broadband and automatically actuated short-duration equipment;

b) manually actuated short-duration broadband;

c) narrowband.

NOTE For examples, see 4.1.4 and 4.1.5 and table 1.

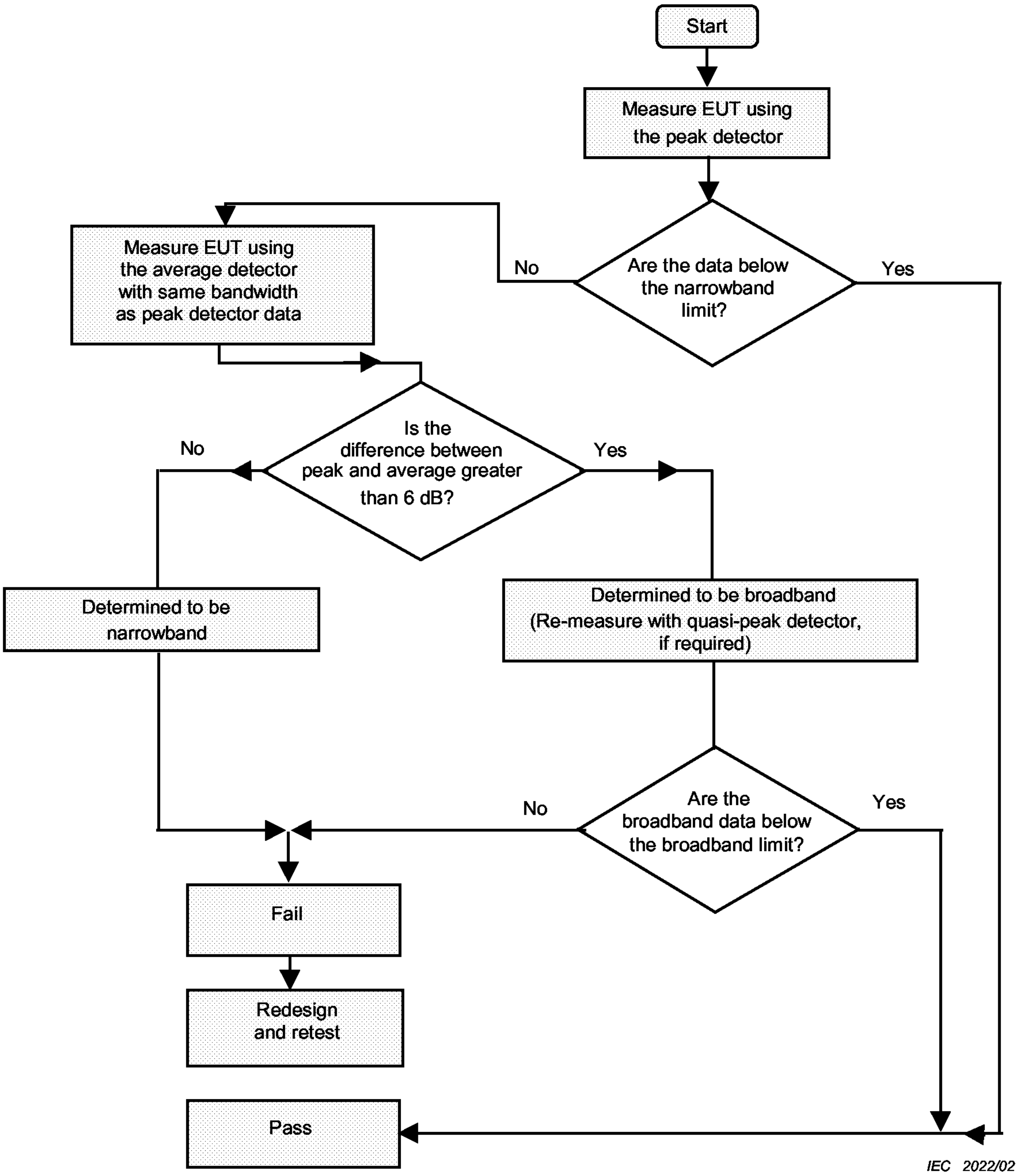


Figure 1 – Method of determination of conformance of radiated/conducted disturbance

4.1.4 Examples of broadband disturbance sources

NOTE 1 The examples in table 1 are intended as a guide to assist in determining which limits to use in the test plan.

NOTE 2 When testing components with short duration disturbances, the users of this standard may consider a lower performance class or an increased test level (6 dB difference typical).

Table 1 – Examples of broadband disturbance sources by duration

Continuous	Long duration *	Short duration *
Ignition system	Wiper motor	Power antenna
Active ride control	Heater blower motor	Washer pump motor
Fuel injection	Rear wiper motor	Door mirror motor
Instrument regulator	Air conditioning compressor	Central door lock
Alternator	Engine cooling	Power seat
* As defined in the test plan.		

4.1.5 Narrowband disturbance sources

Disturbances from sources employing microprocessors, digital logic, oscillators or clock generators, etc. cause narrowband emissions.

4.1.6 Operating conditions

Different operating conditions of the EUT can influence emission measurement results. When performing component/module tests, the EUT shall be exercised using typical loads and conditions, which simulate installation and operation in the vehicle. 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.

4.1.7 Test report

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

4.2 Measuring equipment requirements

All equipment shall be calibrated on a regular basis to assure continued conformance of equipment to required characteristics. The measuring equipment noise floor shall be at least 6 dB less than the limit specified in the test plan.

4.3 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.

4.4 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 emissions measurements. No absorber material should be placed on the floor for vehicle tests but the floor may be lined with absorber material for component tests. The following ALSE requirements shall also be met for performing radiated RF emissions measurements:

4.4.1 Reflection characteristics

The reflection characteristics of the ALSE shall be such that the maximum error caused by reflected energy from the walls and ceiling is less than 6 dB in the frequency range of 70 MHz to 1 000 MHz.

4.4.2 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 a) 2 m from the walls or ceiling, and b) 1 m to the nearest surface of the absorber material used, except that used on the floor.

4.4.3 Objects in ALSE

In particular, for radiated emissions measurements 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.

4.5 Measuring instrument

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

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 noise floor requirements.

When quasi-peak limits are being used, and a peak detector is used for time efficiency, any peak measurements with results at or above the test limit shall be re-measured using the quasi-peak detector.

4.5.1 Maximum scan rate

The scan rate of a spectrum analyser or scanning receiver shall be adjusted for the CISPR frequency band and detection mode used. The maximum scan rate is listed in table 2.

Table 2 – Maximum scan rate

Band [a]	Peak detection	Quasi-peak detection
A 9 kHz to 150 kHz	Does not apply	Does not apply
B 0,15 MHz to 30 MHz	100 ms/MHz	200 s/MHz
C, D 30 MHz to 1 000 MHz	1 ms/MHz or 100 ms/MHz [b]	20 s/MHz
NOTE Certain signals (e.g. low repetition rate signals) may require slower scan rates or multiple scans to ensure that the maximum amplitude has been measured. For the measurement of pure broadband emission with a scanning receiver, frequency steps greater than the measurement bandwidth are permitted, thus accelerating the measurement of the emission spectrum.		
[a] Band definition from CISPR 16-1. [b] When 9 kHz bandwidth is used, the 100 ms/MHz value shall be used.		

4.5.2 Measuring instrument bandwidth

The bandwidth of the measuring instrument shall be chosen such that the noise floor is at least 6 dB lower than the limit curve. The bandwidths in table 3 are recommended. For mobile service bands, the 9 kHz bandwidth shall be used for narrowband/broadband discrimination (described in figure 1) with peak and average detector.

NOTE 1 When the bandwidth of the measuring instrument exceeds the bandwidth of a narrowband signal, the measured signal amplitude will not be affected. The indicated value of impulsive broadband noise will be lower when the measuring instrument bandwidth is reduced.

NOTE 2 A pre-amplifier may be used between the antenna and the measuring instrument in order to achieve the 6 dB noise floor requirement.

Table 3 – Measuring instrument bandwidth (6 dB)

Service/Frequency range MHz		Broadband peak or quasi-peak kHz	Narrowband peak or average kHz
AM broadcast	0,15 to 30	9	9
FM broadcast	76 to 108	120	120
Mobile service	30 to 960	120	9 [a]
[a] In practice and in order to reduce the total sweep time duration in the mobile service frequency bands, it is allowed to perform the measurements with a bandwidth of 120 kHz. If the result of the measurement with a 120 kHz bandwidth is lower than the narrowband limit indicated in the test plan, then the test result is accepted. The value of the measurement bandwidth used in these frequency ranges shall be indicated in the test report.			

If a spectrum analyser is used for peak measurements, the video bandwidth shall be at least three times the resolution bandwidth.

For the narrowband/broadband discrimination according to figure 1, both bandwidths (with peak and average detectors) shall be identical.

4.6 Power supply

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

Vehicle tests: $U_S = \left(12^{+2}_{0}\right)$ V for systems with 12 V nominal supply voltage

$U_S = \left(24^{+4}_{0}\right)$ 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. The battery voltage shall be monitored during the tests.

Component/module tests: $U_S = (13{,}5 \pm 0{,}5)$ V for systems with 12 V nominal supply voltage

$U_S = (27 \pm 1)$ V for systems with 24 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. The antennas of table 4 shall be used for all other bands.

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 4 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 clause 5.3).

Table 4 – Antenna types

Service/Band [a]	Frequency MHz	Antenna type
Broadcast		
LW AM	0,15 to 0,3	1 m monopole
MW AM	0,53 to 2,0	1 m monopole
SW AM	5,9 to 6,2	1 m monopole
VHF FM	76 to 108	1 m monopole
Mobile services		
VHF	30 to 54	Loaded quarter-wave monopole
VHF	68 to 87	Quarter-wave monopole
VHF	142 to 175	Quarter-wave monopole
UHF	380 to 512	Quarter-wave monopole
UHF	820 to 960	Quarter-wave monopole

[a] LW: Long wave; MW: Medium wave; SW: Short wave; VHF: Very high frequency; UHF: Ultra high frequency; AM: Amplitude modulation; FM: Frequency modulation

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 2,0 MHz)

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

[5] Although there are several other short-wave broadcast bands, this particular band has been chosen because it is most commonly used in vehicles. It is expected that other short-wave bands will be protected by conformance to the limits in this band.

The measuring system shall have the following characteristics:

– output impedance of impedance matching equipment: 50 Ω resistive;
– gain: the gain (or attenuation) of the measuring equipment shall be known with an accuracy of ±0,5 dB. The gain of the equipment shall remain within a 6 dB envelope for each frequency band as shown in figure 2. Calibration shall be performed in accordance with annex C;

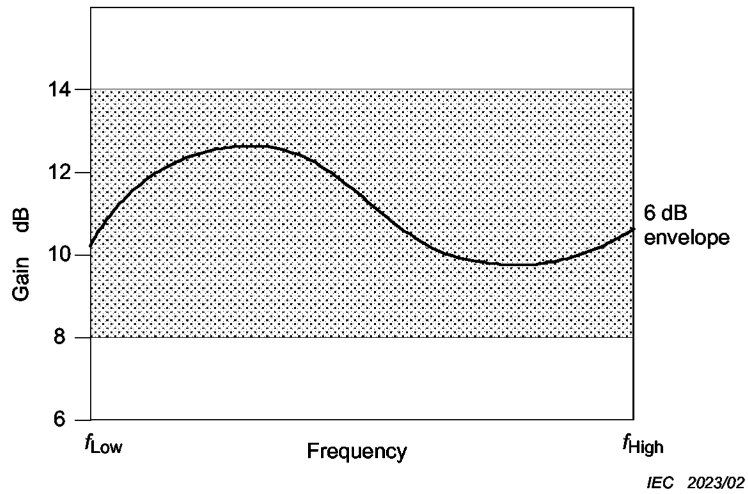


Figure 2 – Example of gain curve

– compression point: the 1 dB compression point shall occur at a sine wave voltage level greater than 60 dB(μV);
– measurement system noise floor: the noise floor of the combined equipment including measuring instrument, matching amplifier, and preamplifier (if used) shall be at least 6 dB lower than the limit level;.
– dynamic range: from the noise floor to the 1 dB compression point;
– Input impedance: the impedance of the measuring system at the input of the matching network shall have a resistance of at least 100 kΩ in parallel with a maximum capacitance of 10 pF.

Active antennas, in general, will increase the noise floor.

5.1.2.1.2 FM broadcast (76 MHz to 108 MHz)

Measurements shall be taken with a measuring instrument which has an input impedance of 50 Ω. If the standing wave ratio (SWR) 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 (30 MHz to 960 MHz)

The test procedure assumes a 50 Ω measuring instrument and a 50 Ω antenna in the frequency range 30 MHz to 960 MHz.

If a measuring instrument and an antenna with differing impedances are used, an appropriate network and correction factor shall be used.

5.2 Method of measurement

To determine the disturbance characteristics of individual disturbance sources or disturbance systems, all sources shall be forced to operate independently across their range of normal operating conditions (transient effects to be determined).

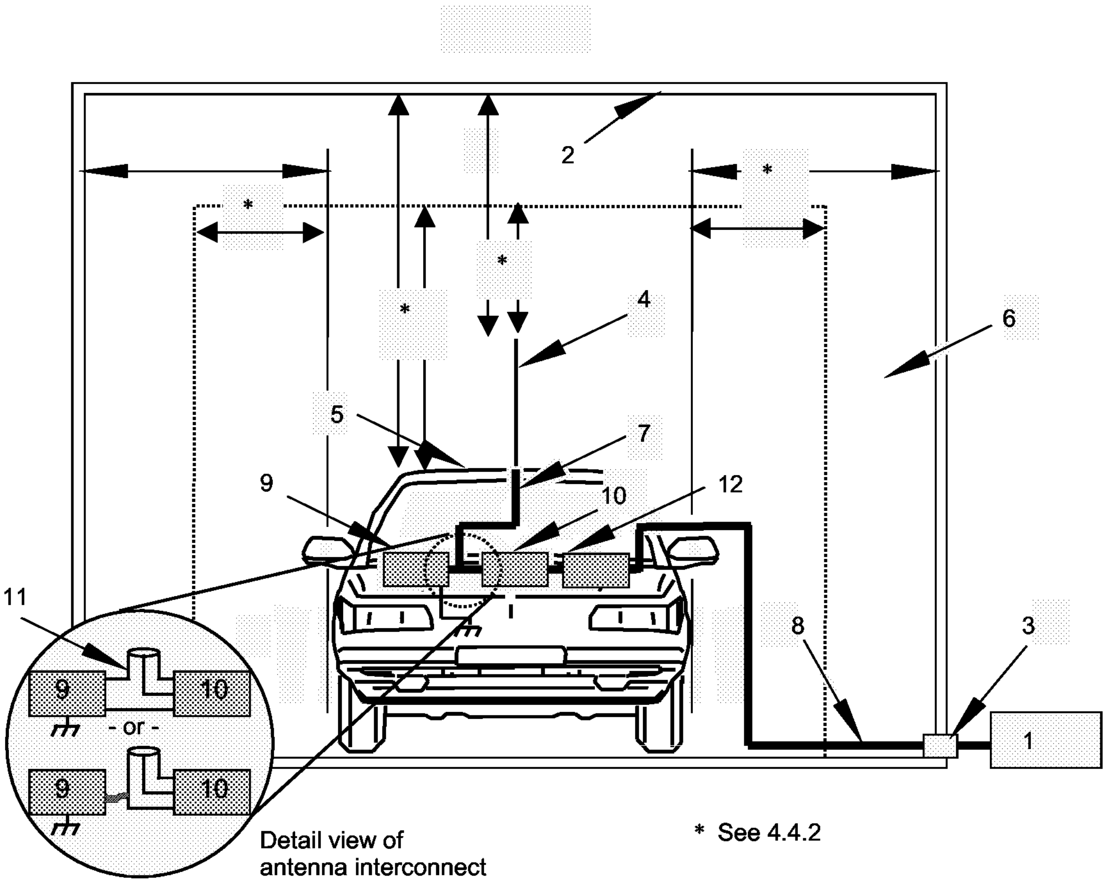
The disturbance voltage shall be measured at the receiver end of the antenna coaxial cable using the ground contact of the connector as reference. The antenna connector shall be grounded to the housing of the on-board radio. The radio housing shall be grounded to the vehicle body using the production harness. A coaxial bulkhead connector shall be used for connection to the measuring instrument outside the shielded room. See figure 3. 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 H for an example of a sheath-current suppressor).

NOTE The use of a high-quality 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.

When vehicle measurements are made without the engine running, the power supply of 4.6 shall be used, when needed, to maintain the system voltage within its required range.



Key

1 Measuring instrument
2 ALSE
3 Bulkhead connector
4 Antenna (see 5.1.1)
5 EUT
6 Typical absorber material
7 Antenna coaxial cable
8 High-quality double-shielded coaxial cable (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)

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

5.3 Limits for vehicle-radiated disturbances

For acceptable radio reception in a vehicle using typical radio receivers, the disturbance voltage at the end of the antenna cable shall not exceed the values shown in table 5. Where different receivers are used, the limits may be changed and detailed in the vehicle manufacturers' own specification.

Table 5 – Limits of disturbance – Complete vehicle

Service/Band [b]	Frequency MHz	Terminal disturbance voltage at receiver antenna terminal dB(μV)				
		Broadband continuous		Broadband short duration		Narrowband
		Quasi-peak	Peak	Quasi-peak	Peak	Peak
Broadcast						
LW	0,15 to 0,30	9	22	15	28	6
MW	0,53 to 2,0	6	19	15	28	0
SW	5,9 to 6,2	6	19	6	19	0
VHF	76 to 108	6(15 [a])	28	15	28	6
Mobile services						
VHF	30 to 54	6(15 [a])	28	15	28	0
VHF	68 to 87	6(15 [a])	28	15	28	0
VHF	142 to175	6(15 [a])	28	15	28	0
UHF	380 to 512	6(15 [a])	28	15	28	0
UHF	820 to 960	6(15 [a])	28	15	28	0

[a] Limit for ignition systems only.

[b] LW: Long wave, MW: Medium wave, SW: Short wave (amplitude modulation, AM)
VHF: Very high frequency, UHF: Ultra high frequency (frequency modulation, FM)

NOTE 1 All broadband values listed in this table are valid for the bandwidths specified in table 3.

NOTE 2 Stereo signals may be more susceptible to disturbance than monaural signals in the FM broadcast band. This phenomenon has been factored into the VHF (76 MHz to 108 MHz) limit.

NOTE 3 When possible it may be advisable to switch broadband only disturbance sources off for the measurement of narrowband disturbance.

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 added to the limits in table 5. 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 compliance. This topic remains under study.

6 Measurement of components and modules

6.1 Test equipment

6.1.1 Ground plane

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

The minimum size of the ground plane for conducted emissions shall be 1 000 mm × 400 mm.

The minimum width of the ground plane for radiated emissions shall be 1 000 mm. The minimum length of the 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 ground plane (test bench) shall be (900 ± 50) mm above the floor.

The ground plane shall be bonded to the shielded enclosure such that the d.c. resistance shall not exceed 2,5 mΩ. In addition, the bond straps shall be placed at a distance no greater than 0,3 m apart.

6.1.2 Power supply and AN

For the tests defined in 6.2, 6.3, 6.4 and 6.5, each EUT power supply lead shall be connected to the power supply through an artificial network. For the TEM cell emissions tests of 6.2.3 and 6.5, an AN with a coaxial connector will facilitate connection to the TEM cell EUT power connector.

Power supply is assumed to be negative ground. If the EUT utilizes a positive ground then the test set-ups shown in the figures need to be adapted accordingly. Power shall be applied to the EUT via 50 Ω/50 µH artificial network (see annex D for artificial network schematic). 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 ground plane. The case(s) of the AN(s) shall be bonded to the ground plane.

The power supply return shall be connected to the 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.

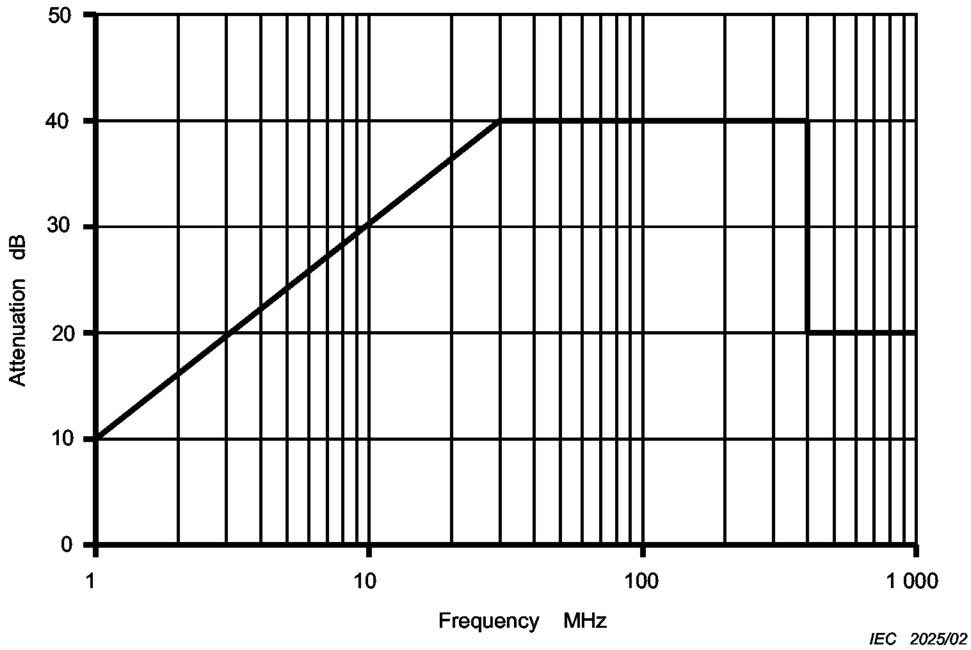


Figure 4 – Example for the required minimum attenuation of the AN

6.1.3 Signal/control lines network

The simulation interface which includes sensors and actuators, terminates the artificial harness connected to the EUT.

This termination will influence the test results. To ensure sufficient reproducibility, the same termination must be used for each measurement either by using special termination (e.g. artificial network, filters) or by using the same peripheral EUT interface.

The AN shall have a nominal 5 μH inductance. The impedance characteristics and a suggested schematic are shown in annex D.

The measuring port of all ANs shall be terminated with a 50 Ω load. The attenuation of the AN shall be specified for the whole frequency range of the intended component/module test (see clauses 6.2 to 6.5) according to the requirements shown in figure 4. 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 4 shows e.g. an upper cut off frequency (f_c) of the chosen test method of 400 MHz.

Other low pass RF filter configurations may be used if the AN characteristics are not applicable to special wanted signals of the EUT's inputs or outputs (e.g. high speed network data interfaces). For these cases, repeated tests have to be performed with identical RF filters. The filters shall be specified in the test plan.

6.2 Conducted emissions from components/modules – Voltage method

6.2.1 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 performed on the printed board of electronic components and to characterize the efficiency of shieldings. Therefore, voltage measurements are not able to characterize the complete emission of EUT´s. At lower frequencies (e.g. in the AM-bands) voltage measurements usually ensure more dynamic range than radiated measurements.

6.2.2 Ground plane arrangement

6.2.2.1 Test set-up

6.2.2.1.1 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 ground plane.

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

The face of the EUT shall be located at a minimum distance of 200 mm from the edge of the ground plane.

6.2.2.1.2 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.

It 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 ground plane.

If, for particular EUT (multi-connectors, special connectors, etc.), this standard length for the power supply line(s) cannot be met, the minimum necessary length to be used shall be defined in the test plan. This minimum length shall satisfy the requirement of $f_c \geq 108$ MHz, or the measurements shall be limited to f_c.

The following equation defines f_c:

$$f_c \approx 30/l_p \qquad (1)$$

where

f_c is the frequency in MHz

l_p is the length in m

(This equation is based on $l_p \leq \lambda_{min}/10$).

To minimize the coupling between power and input/output leads, the space between those lead types has to 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 ground plane.

6.2.2.1.3 Location of the load simulator

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

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

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

The load simulator which includes sensors and actuators, terminates the artificial harness connected to the EUT. All the used lines have to be terminated according to the requirements of 4.1.6. 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.

All the unused lines, according to the test plan, can be left open-circuited.

6.2.2.2 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.

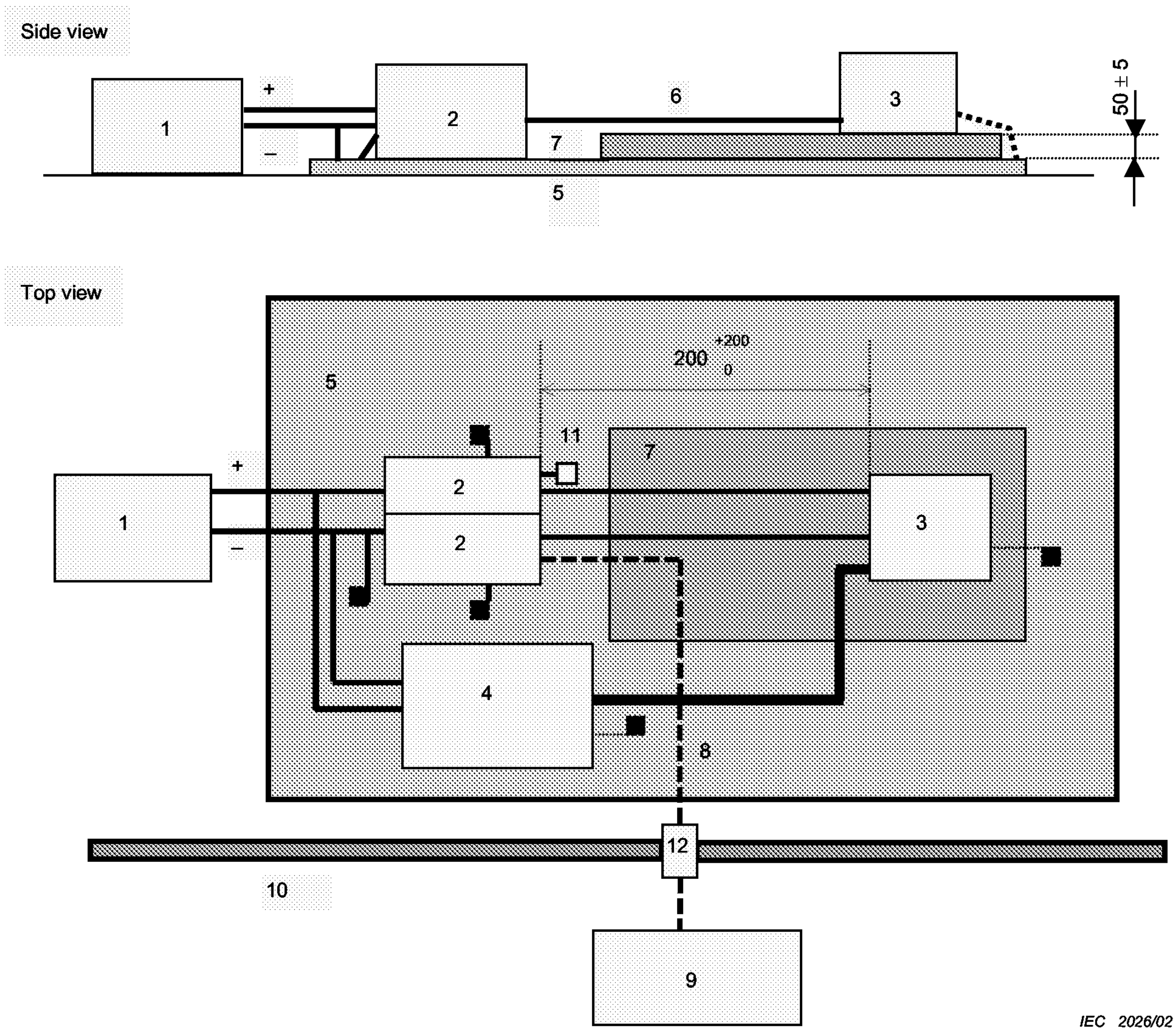
- For EUT remotely grounded (vehicle power return line longer than 200 mm), the voltage measurements shall be made on each lead (supply and return) relative to the ground plane.
- For EUT locally grounded (vehicle power return line 200 mm or shorter), voltage measurements on power supply leads shall be made relative to the ground plane.
- Generators/alternators shall be loaded with a battery and parallel resistor combination, and connected to the artificial network in the manner shown in figure 7. The load current, operating speed, harness length and other conditions shall be defined in the test plan.

The common mode 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 inserted in the other supply line being terminated with a 50 Ω load.

For EUT 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 side and all power return connections tied together at the other AN side. The configuration shall be defined in the test plan.

For voltage measurements, the arrangement of the EUT and measuring equipment shall be as shown in figures 5, 6 and 7 depending on the intended EUT installation in the vehicle.

Dimensions in millimetres



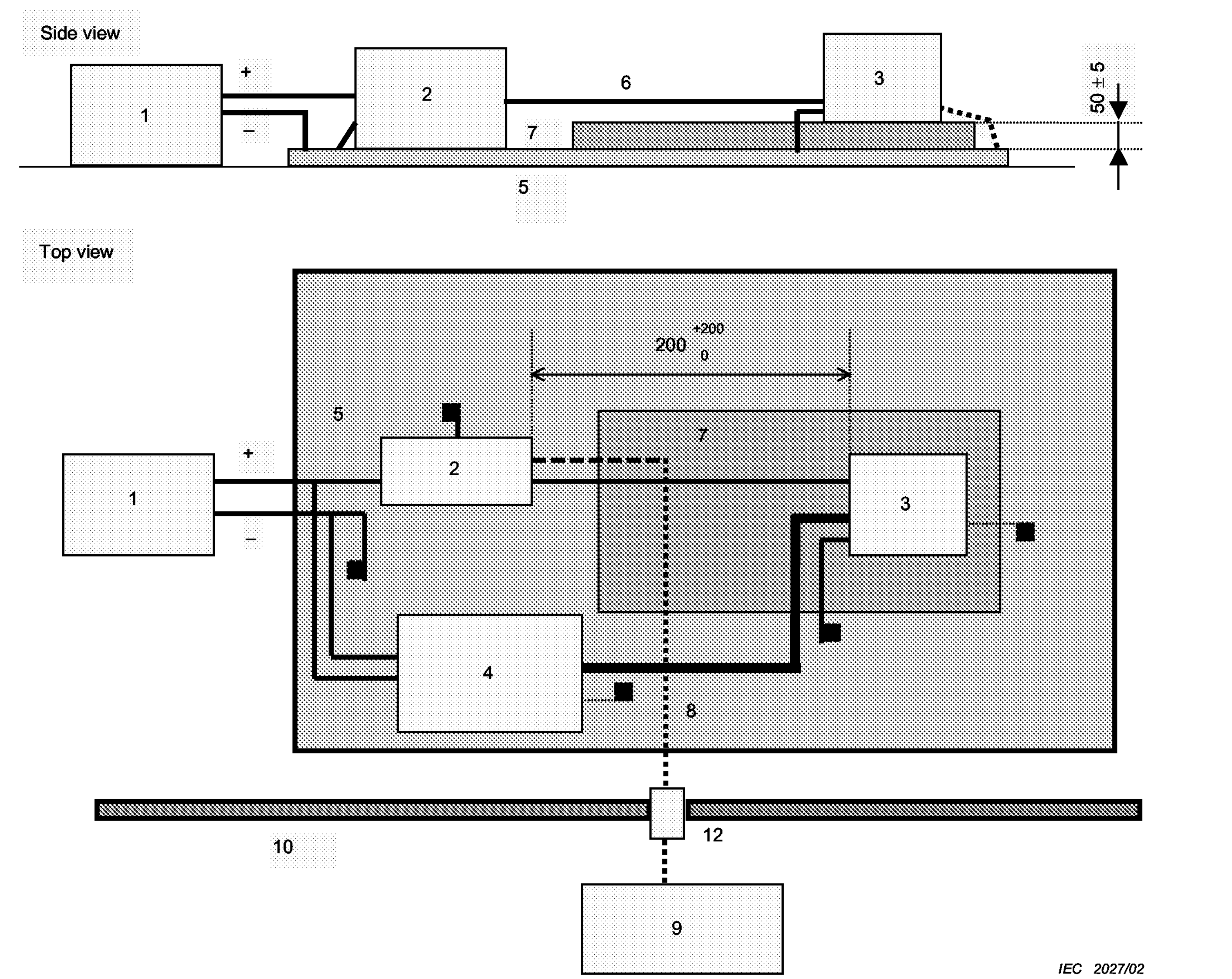
Key

1 Power supply
2 Artificial network
3 EUT (housing grounded if required in test plan)
4 Load simulator (return line grounded if required in test plan)
5 Ground plane
6 Power supply lines
7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)
8 Double shielded or solid shielded coaxial cable (50 Ω)
9 Measuring instrument
10 Shielded enclosure
11 50 Ω load
12 Bulkhead connector

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

Figure 5 – Conducted emissions – EUT with power return line remotely grounded

Dimensions in millimetres



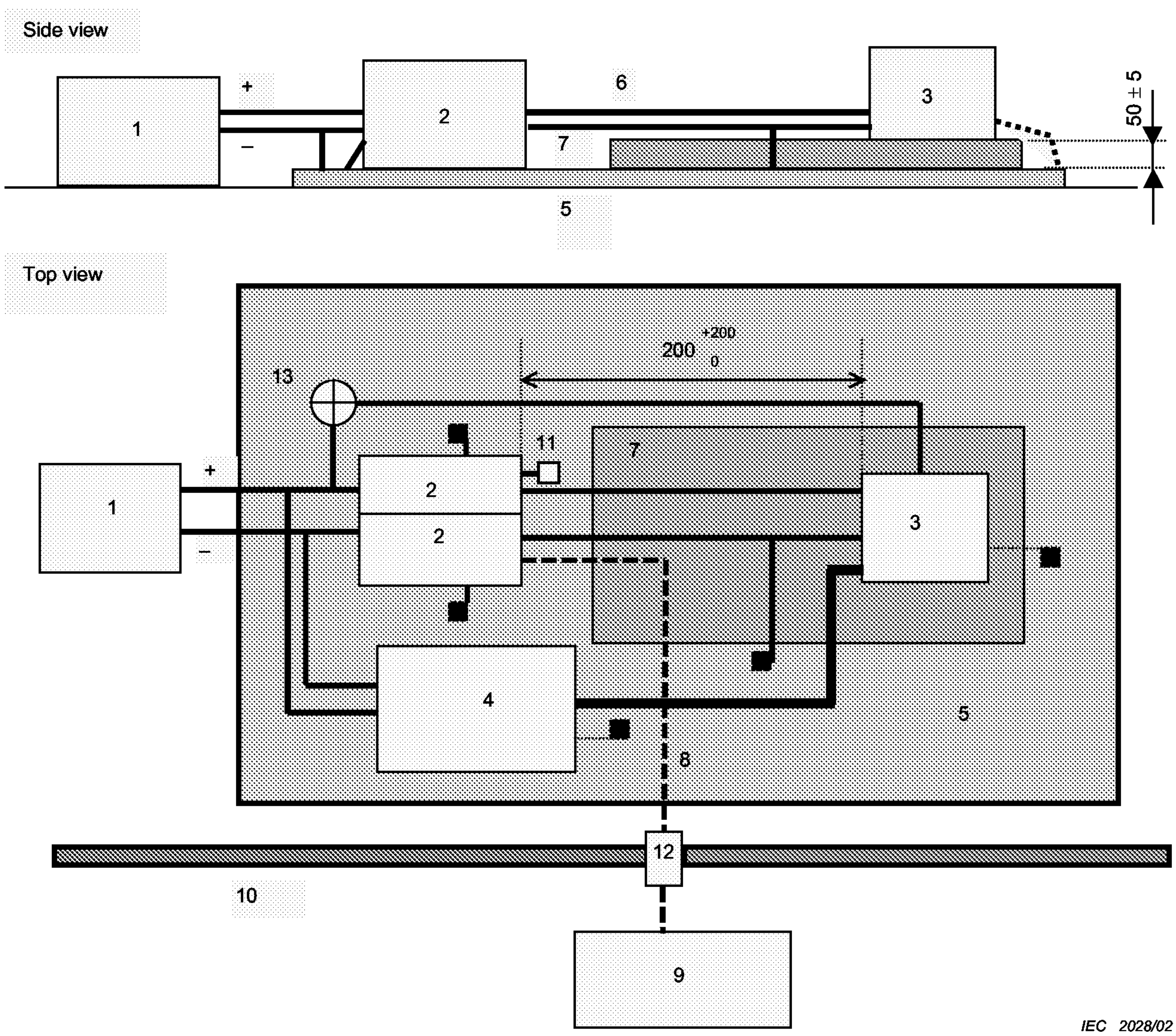
Key

1 Power supply
2 Artificial network
3 EUT (housing grounded if required in test plan)
4 Load simulator (return line grounded if required in test plan)
5 Ground plane
6 Power supply lines
7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)
8 Double shielded or solid shielded coaxial cable (50 Ω)
9 Measuring instrument
10 Shielded enclosure
12 Bulkhead connector

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

Figure 6 – Conducted emissions – EUT with power return line locally grounded

Dimensions in millimetres



IEC 2028/02

Key

1 Battery and resistor
2 Artificial network
3 EUT
4 Load simulator
5 Ground plane
6 Power supply lines
7 Low relative permittivity support ($\varepsilon_r \leq 1,4$) – typically not installed
8 Double shielded or solid shielded coaxial cable (50Ω)
9 Measuring instrument
10 Shielded enclosure
11 50 Ω load
12 Bulkhead connector
13 Test lamp/control resistor (if applicable)

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

Figure 7 – Conducted emissions – Test lay-out for alternators and generators

6.2.3 TEM cell arrangement

6.2.3.1 Test set-up

The TEM cell arrangement is shown in figure 8. It is identical to the one used for radiated emission measurements which is described in 6.5.

The measuring port of the AN(s) not connected to the measuring instrument shall be terminated with a 50 Ω load. The septum of the TEM cell has to be terminated with 50 Ω impedance on both sides.

6.2.3.1.1 EUT lead connection

The power supply and the simulation interface (load simulator), which includes sensors and actuators, terminates the artificial harness connected to the EUT according to 4.1.6. 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 TEM cell's connector panel – or by using the same peripheral EUT interface. The termination shall be the artificial network described in annex D if no other configuration is described in the test plan.

6.2.3.1.2 Location of the EUT

The location of the EUT is identical to that specified in 6.5.

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.

6.2.3.1.3 Location of the test harness

The location of the test harness is identical to that specified in 6.5.

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

If, for particular EUT (multi-connectors, special connectors, etc.), this standard length for the power supply line(s) cannot be met, the minimum necessary length to be used shall be defined in the test plan. This minimum length shall satisfy the requirement of $f_c \geq 108$ MHz, or the measurements shall be limited to f_c.

For the definition of f_c see 6.2.2.1.2.

6.2.3.1.4 Load simulator/simulation interface

To ensure correct operation of EUT according to 4.1.6, a peripheral interface unit (load simulator/simulation interface) shall be used which simulates the vehicle installation.

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

If the load simulator has a metallic case, this case shall be bonded to TEM cell ground.

6.2.3.2 Test procedure

The general arrangement of the disturbance source and connecting harnesses etc. represents a standardized 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.

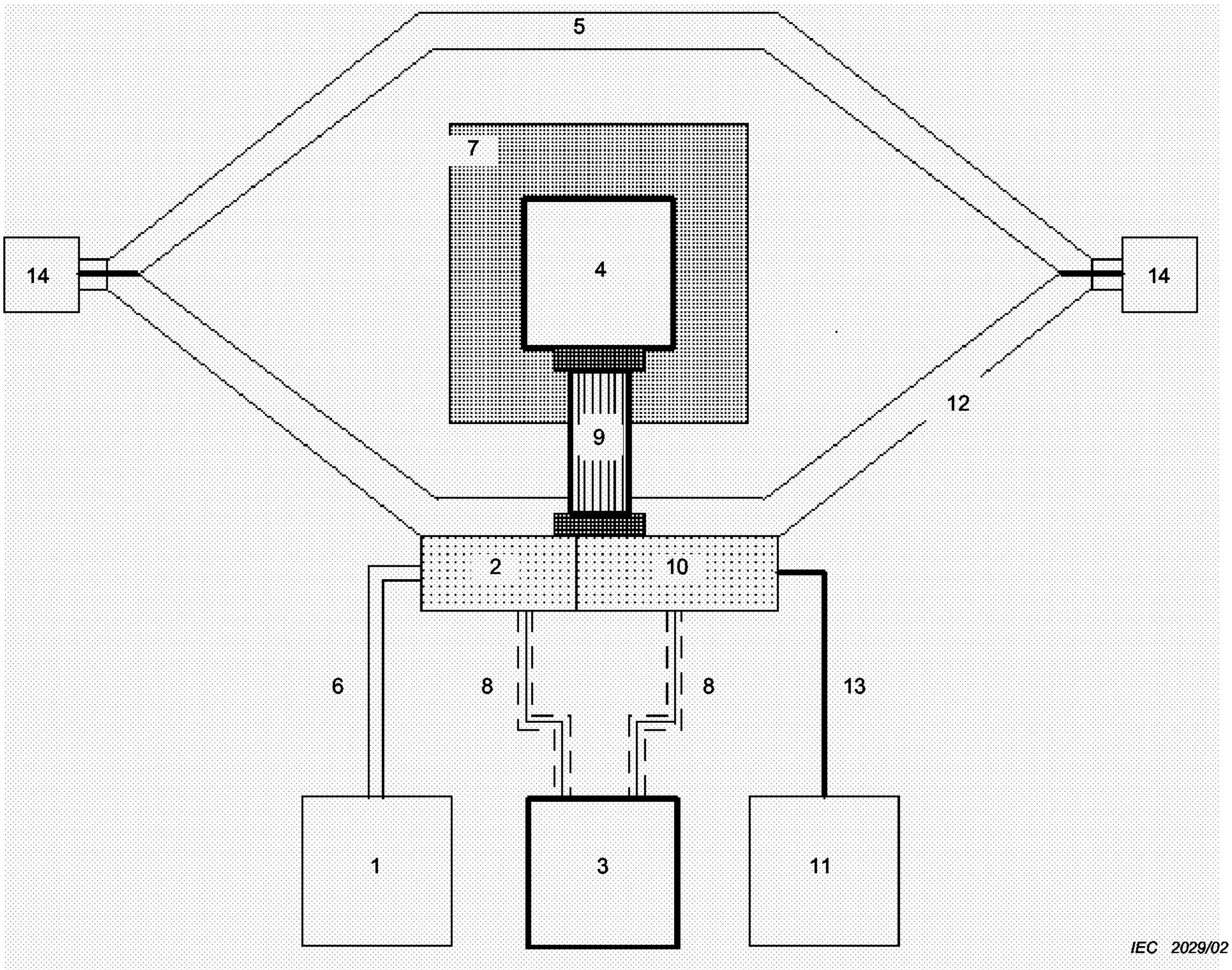
- For EUT remotely grounded (vehicle power return line longer than 200 mm), the voltage measurements shall be made on each lead (supply and return) relative to the TEM cell's shielding.
- For EUT locally grounded (vehicle power return line 200 mm or shorter), voltage measurements on all power leads shall be made relative to the TEM cell's shielding.

The common mode conducted emissions on power lines may be 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 inserted in the other supply line being terminated with a 50 Ω load. The configuration shall be defined in the test plan.

For EUT with multiple positive power supply connections and/or multiple power return connections, the measurements (on power supply and on power return) are performed with all power supply connections tied together and all power return connections tied together. These connections have to be performed inside the TEM cell at the artificial harness close to the connector panel.

All the unused lines, according to the test plan, can be open-circuited.

For voltage measurements, the arrangement of the EUT and measuring equipment shall be as shown in figure 8.



Key

1	Power supply	8	Coaxial cables (50 Ω)
2	Artificial network	9	Artificial test harness (e.g. lead card)
3	Measuring instrument	10	Termination, configured like artificial network
4	EUT	11	EUT interface, equipment for simulation of operating mode
5	TEM cell (ground plate)	12	TEM cell (side wall)
6	Power leads	13	Harness to EUT interface
7	Low relative permittivity support ($\varepsilon_r \leq 1{,}4$), when required in test plan	14	50 Ω terminating resistor

Figure 8 – Conducted emissions – TEM cell arrangement

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

For acceptable radio reception in a vehicle, the conducted noise shall not exceed the values shown in tables 6 and 7, broadband and narrowband limits, respectively. Refer to footnote 1, Scope, for statement on limits. When using the limits provided, no correction factors for the AN shall be used.

Table 6 – Limits for broadband conducted disturbances (peak or quasi-peak detector)

Class	Levels in dB(μV)									
	0,15 MHz to 0,3 MHz		0,53 MHz to 2,0 MHz		5,9 MHz to 6,2 MHz		30 MHz to 54 MHz		68 MHz to 108 MHz	
	P[a]	QP[b]	P	QP	P	QP	P	QP	P	QP
1	113	100	95	82	77	64	77	64	61	48
2	103	90	87	74	71	58	71	58	55	42
3	93	80	79	66	65	52	65	52	49	36
4	83	70	71	58	59	46	59	46	43	30
5	73	60	63	50	53	40	53	40	37	24

[a] Peak
[b] Quasi-peak

NOTE All values listed in this table are valid for the bandwidths in table 3.

Table 7 – Limits for narrowband conducted disturbances (peak detector)

Class	Levels dB(μV)					
	0,15 MHz to 0,3 MHz	0,53 MHz to 2,0 MHz	5,9 MHz to 6,2 MHz	30 MHz to 54 MHz	68 MHz to 87 MHz Mobile services	76 MHz to 108 MHz Broadcast
1	90	66	57	52	42	48
2	80	58	51	46	36	42
3	70	50	45	40	30	36
4	60	42	39	34	24	30
5	50	34	33	28	18	24

6.3 Conducted emissions from components/modules – Current probe method

6.3.1 General

Current probe measurements shall be made on the control/signal leads as a single cable or in sub-groups as is compatible with the physical size of the current probe. For details see CISPR 16-1.

6.3.2 Test set-up

6.3.2.1 Location of the EUT

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

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

The face of the EUT shall be located at a minimum distance of 200 mm from the edge of the ground plane.

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 ground plane.

The measuring equipment shall be as shown in figure 9.

6.3.2.2 Location of the test harness

The test harness shall be (1 500 ± 75) mm long (or as agreed upon in the test plan), and shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \le 1,4$), positioned (50 ± 5) mm above the ground plane. The test harness wires shall be nominally parallel and adjacent unless otherwise defined in the test plan.

6.3.3 Test procedure

Position the current probe (50 ± 10) mm from the EUT connector and measure the emissions. To assure that the maximum level is measured at frequencies above 30 MHz, position the current probe in the following additional positions:

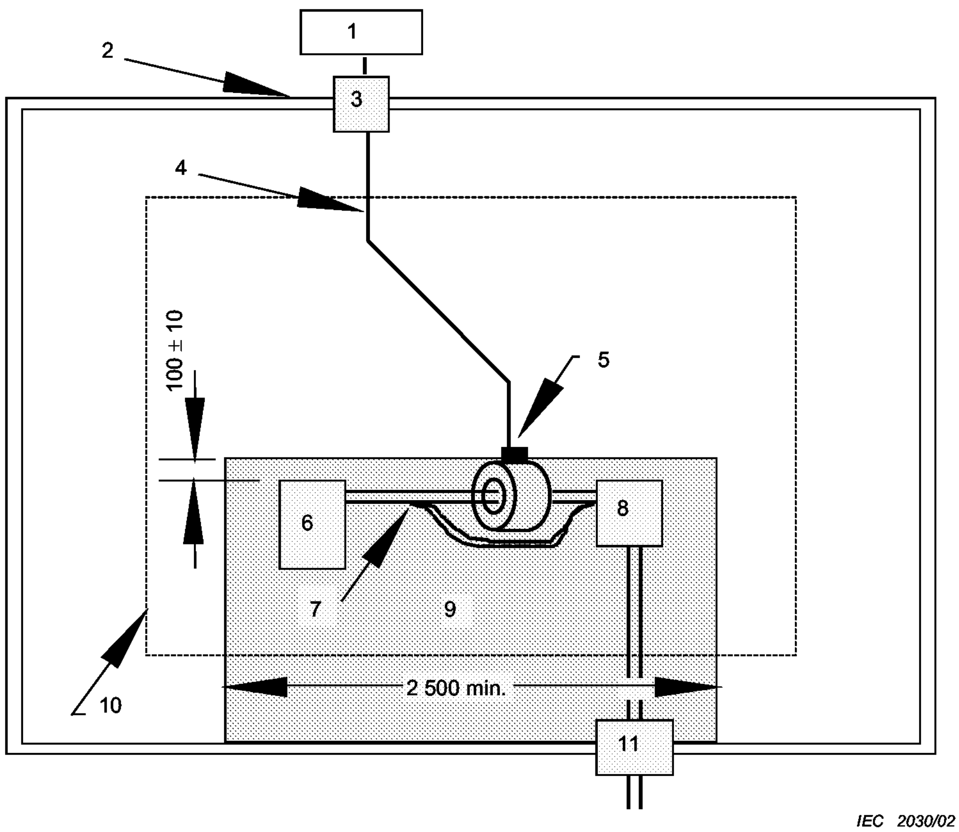
a) (500 ± 10) mm from the EUT connector;

b) (1 000 ± 10) mm from the EUT connector;

c) (50 ± 10) mm from the AN terminal.

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 and all parts of the test set-up shall be a minimum of 100 mm from the edge of the ground plane.

Dimensions in millimetres



Key

1 Measuring instrument (allowed in shielded enclosure if ambient requirement is met)
2 Shielded enclosure
3 Bulkhead connector
4 Double shielded or solid shielded coaxial cable (50 Ω)
5 Current probe for signal/control line test
6 EUT
7 Test harness (1 500 ± 75) mm long or as specified up to 2 000 mm long, (50 ± 5) mm above ground plane on low relative permittivity support ($\varepsilon_r \leq 1,4$)
8 Artificial network
9 Test bench – 2 500 mm long by 900 mm high
10 Typical RF absorber (optional)
11 Filter to power supply

Figure 9 – Conducted emissions – Example of test layout for current probe measurements

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

For acceptable radio reception in a vehicle, the conducted noise shall not exceed the values shown in tables 8 and 9, broadband and narrowband limits, respectively. Refer to footnote 1, Scope, for statement on limits.

Table 8 – Limits for broadband conducted current disturbances on control/signal lines (peak or quasi-peak detector)

Class	Levels dB(μA)									
	0,15 MHz to 0,3 MHz		0,53 MHz to 2,0 MHz		5,9 MHz to 6,2 MHz		30 MHz to 54 Hz		68 MHz to 108 MHz	
	P[a]	QP[b]	P	QP	P	QP	P	QP	P	QP
1	100	87	92	79	74	61	74	61	68	55
2	90	77	84	71	68	55	68	55	62	49
3	80	67	76	63	62	49	62	49	56	43
4	70	57	68	55	56	43	56	43	50	37
5	60	47	60	47	50	37	50	37	44	31

[a] Peak
[b] Quasi-peak

NOTE All values listed in this table are valid for the bandwidths specified in table 3.

Table 9 – Limits for narrowband conducted current disturbances on control/signal lines (peak detector)

Class	Levels dB(μA)					
	0,15 MHz to 0,3 MHz	0,53 MHz to 2,0 MHz	5,9 MHz to 6,2 MHz	30 MHz to 54 MHz	68 MHz to 87 MHz Mobile services	76 MHz to 108 MHz Broadcast
1	80	66	57	52	52	58
2	70	58	51	46	46	52
3	60	50	45	40	40	46
4	50	42	39	34	34	40
5	40	34	33	28	28	34

6.4 Radiated emissions from components/modules – ALSE method

6.4.1 General

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

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.

The reflection characteristics of the shielded enclosure shall be checked by performing comparative measurements in an open field test site and in the ALSE. The difference of results shall comply with 4.4.1. For further details see annex G.

NOTE 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.

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 require a radiated emissions test. 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.

6.4.2 Test set-up

6.4.2.1 Antenna systems

The limits shown in tables 10 and 11 are listed in dB(μV/m), and thus theoretically any antenna can be used, provided that it has adequate sensitivity, the antenna correction factor is applied, and the antenna provides a 50 Ω match to the measuring instrument. For the purposes of this standard, the limits shown in tables 10 and 11 are based upon the following antennas:

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 200 MHz a biconical antenna used in vertical and horizontal polarization;

c) 200 MHz to 1 000 MHz a log-periodic antenna used in vertical and horizontal polarization.

Commercially available antennas with known antenna correction factors (see 3.4) may be used. The cable loss factor can be determined in accordance with CISPR 12.

The method to be used for characterization of the vertical monopole (rod) antenna is given in annex E.

NOTE A method for determining biconical and log-periodic antenna factors is described in SAE ARP 958.[6]

6.4.2.2 Antenna matching unit

Correct impedance matching between the antenna and the measuring instrument of 50 Ω shall be maintained at all frequencies. There shall be a maximum SWR of 2:1. Appropriate correction shall be made for any attenuation/gain of the antenna system from the antenna to the receiver.

NOTE 1 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. For further information see annex C.

NOTE 2 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 input (if possible) will keep this additional error low.

6.4.2.3 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 ground plane.

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

The face of the EUT shall be located at a distance of (200 ± 10) mm from the edge of the ground plane.

6.4.2.4 Location of the test harness

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

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

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 ground plane.

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.

6.4.2.5 Location of the load simulator

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

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

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6 SAE ARP 958: Dec. 1992, *Electromagnetic Interference Measurement Antennas: Standard Calibration Method;* Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA.

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

6.4.2.6 Location of the measuring antenna

The height of the phase centre of the measuring antenna shall be within (100 ± 10) mm of the height *h* of the ground plane for the biconical and log-periodic antenna.

The height of the counterpoise h_{cp} of the rod antenna shall be within ±10 mm of the height of the ground plane *h*. The rod antenna counterpoise shall be bonded to the ground plane.

No part of any antenna radiating element shall be closer than 250 mm to the floor. The radiating elements of the measuring antenna shall not be closer than 1 000 mm to any absorber material, except that used on the floor, and shall not be closer than 2 000 mm to the walls or ceiling of the shielded enclosure.

The distance between the wiring harness and the reference point of the antenna shall be (1 000 ± 10) mm.

The reference point of the antenna is defined as:

– the vertical monopole element for rod antenna,
– 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.

The antenna shall be calibrated for this reference point for a 1 000 mm measuring distance.

The phase centre of the antenna shall be in line with the centre of the longitudinal part (1 500 mm length) of the wiring harness.

NOTE 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 polarisation.

6.4.3 Test procedure

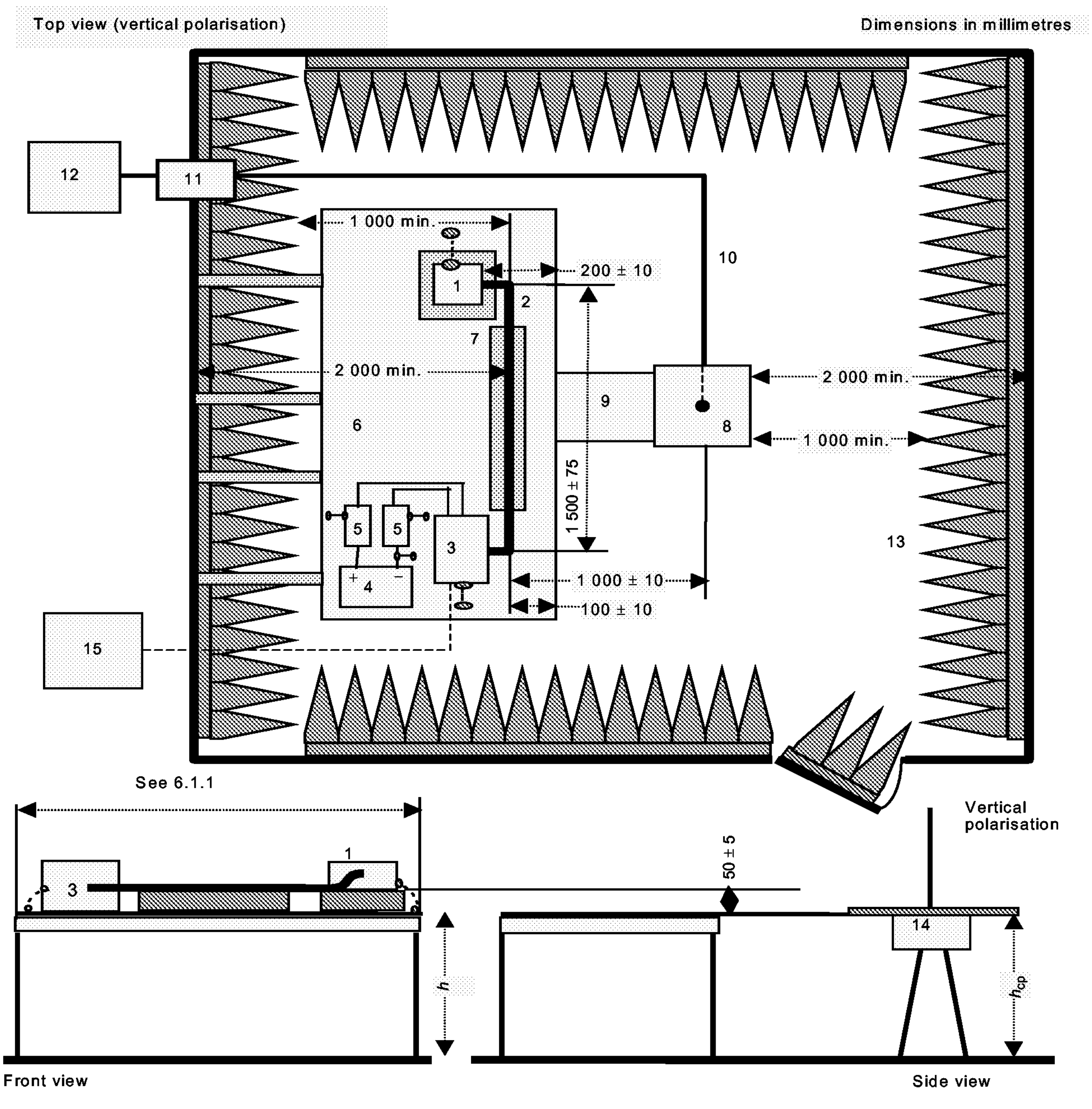
The general arrangement of the disturbance source and connecting harnesses etc. represents a standardised test condition. Any deviations from the standard test harness length etc. shall be agreed upon prior to testing and recorded in the test report.

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 are performing 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 1 GHz measurements shall be performed in vertical and horizontal polarisation.

For radiated emission measurements, the arrangement of the EUT and measuring equipment shall be functionally equivalent to the examples shown in figures 10 to 12.



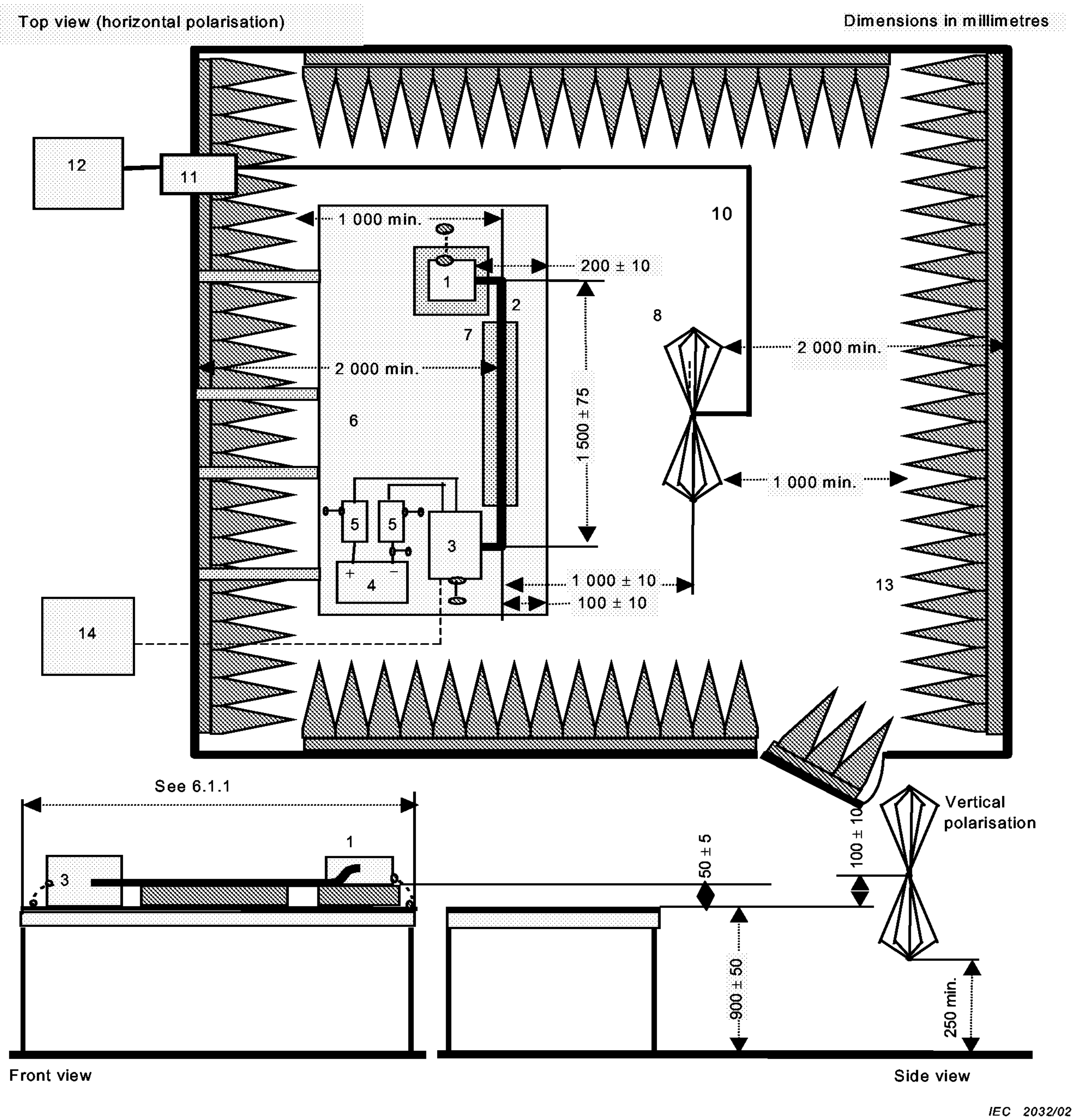
Key

1	EUT (grounded locally if required in test plan)	9	Grounding connection (full width bond between counterpoise and ground plane)
2	Test harness	10	High quality double-shielded coaxial cable (50 Ω)
3	Load simulator (placement and ground connection according to 6.4.2.5)	11	Bulkhead connector
4	Power supply (location optional)	12	Measuring instrument
5	Artificial network (AN)	13	RF absorber material
6	Ground plane (bonded to shielded enclosure)	14	Antenna matching unit (the preferred location is below the counterpoise; if above the counter-poise then the base of the antenna rod shall be at the height of the ground plane)
7	Low relative permittivity support ($\varepsilon_r \leq 1,4$)	15	Stimulation and monitoring system
8	Rod Antenna with counterpoise (dimensions: 600 mm by 600 mm typical)		

h = (900 ± 50) mm

h_{cp} = (h ± 10) mm

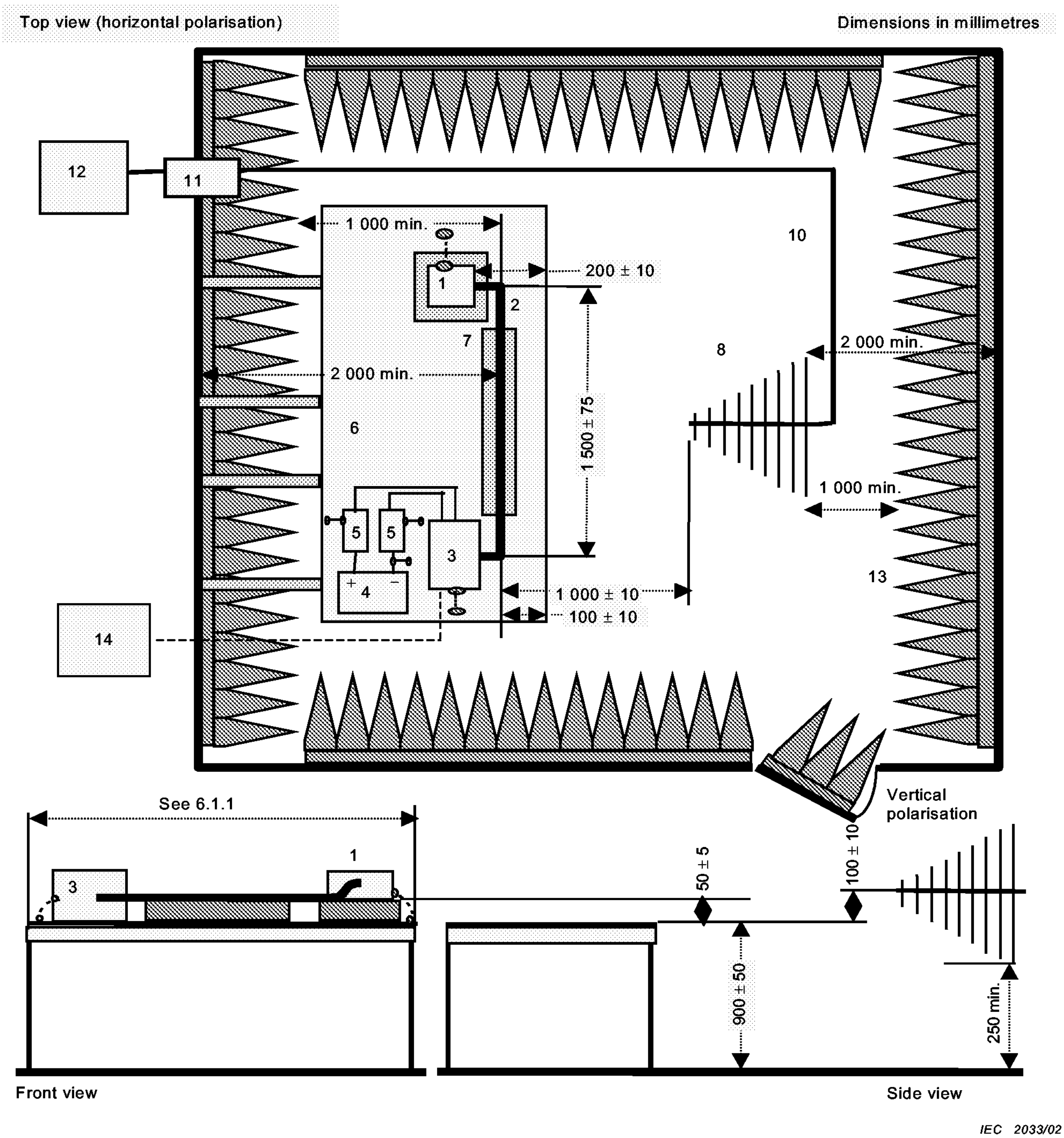
Figure 10 – Example of test set-up – rod antenna



Key

1	EUT (grounded locally if required in test plan)	8	Biconical antenna
2	Test harness	–	–
3	Load simulator (placement and ground connection according to 6.4.2.5)	10	High quality double-shielded coaxial cable (50 Ω)
4	Power supply (location optional)	11	Bulkhead connector
5	Artificial network (AN)	12	Measuring instrument
6	Ground plane (bonded to shielded enclosure)	13	RF absorber material
7	Low relative permittivity support ($\varepsilon_r \leq 1,4$)	14	Stimulation and monitoring system

Figure 11 – Example of test set-up – biconical antenna



Key

1	EUT (grounded locally if required in test plan)	8	Log-periodic antenna
2	Test harness	–	–
3	Load simulator (placement and ground connection according to 6.4.2.5)	10	High quality double-shielded coaxial cable (50 Ω)
4	Power supply (location optional)	11	Bulkhead connector
5	Artificial network (AN)	12	Measuring instrument
6	Ground plane (bonded to shielded enclosure)	13	RF absorber material
7	Low relative permittivity support ($\varepsilon_r \leq 1,4$)	14	Stimulation and monitoring system

Figure 12 – Example of test set-up – log-periodic antenna

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

Some disturbance sources are continuous emitters and require a more stringent limit than a disturbance source which is only on periodically or for a short time. The limits in tables 10 and 11 have been adjusted to take account of this fact. Measurements need only be performed with one detection type. (Refer to footnote 1, Scope, for statement on limits.)

Table 10 – Limits for broadband radiated disturbances from components (peak or quasi-peak detector)

Class	Levels dB(μV/m)															
	0,15 MHz to 0,3 MHz		0,53 MHz to 2,0 MHz		5,9 MHz to 6,2 MHz		30 MHz to 54 MHz		68 MHz to 108 MHz		142 MHz to 175 MHz		380 MHz to 512 MHz		820 MHz to 960 MHz	
	P[a]	QP[b]	P	QP	P	QP	P	QP	P	QP	P	QP	P	QP	P	QP
1	96	83	83	70	60	47	60	47	49	36	49	36	56	43	62	49
2	86	73	75	62	54	41	54	41	43	30	43	30	50	37	56	43
3	76	63	67	54	48	35	48	35	37	24	37	24	44	31	50	37
4	66	53	59	46	42	29	42	29	31	18	31	18	38	25	44	31
5	56	43	51	38	36	23	36	23	25	12	25	12	32	19	38	25

[a] Peak
[b] Quasi-peak

NOTE All values listed in this table are valid for the bandwidths specified in table 3.

Table 11 – Limits for narrowband radiated disturbances from components (peak detector)

Class	Levels dB(μV/m)								
	0,15 MHz to 0,3 MHz	0,53 MHz to 2,0 MHz	5,9 MHz to 6,2 MHz	30 MHz to 54 MHz	76 MHz to 108 MHz Broad-cast	68 MHz to 87 MHz Mobile services	142 MHz to 175 MHz	380 MHz to 512 MHz	820 MHz to 960 MHz
1	61	50	46	46	42	36	36	43	49
2	51	42	40	40	36	30	30	37	43
3	41	34	34	34	30	24	24	31	37
4	31	26	28	28	24	18	18	25	31
5	21	18	22	22	18	12	12	19	25

6.5 Radiated emissions from components/modules – TEM cell method

6.5.1 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 broadcast stations. The TEM cell works as a shielded enclosure. An example of a TEM cell is shown in figure 13. Information relating to the size and construction of a TEM cell for component measurement is given in annex F.

The TEM cell method of emission measurements is more suited to narrowband measurements than broadband.

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 in the region of the TEM cell resonances.

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 annex F, table F.1, 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.

Methods are under development in Europe and in North America for directly measuring the emissions from integrated circuits using a TEM cell or other equipment. The intent is to minimise extraneous effects of leads and test circuitry mask changes.

6.5.2 Test set-up

6.5.2.1 Set-up with major field coupling to the wiring harness

The TEM cell shall have a connector panel connected as close as possible to a plug connector (see figure 14/figure 15).

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 (see 6.1.2), 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.

6.5.2.2 Set-up with major field coupling to the EUT

The test set-up 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.

6.5.3 Test procedure

The general arrangement of the EUT, the harness, the filter system at the TEM cell's wall, etc. represents a standardised test condition. Any deviations from the standard test configuration shall be agreed upon prior to testing and recorded in the test report.

The EUT shall be supported *b*/6 (see figure 15) 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 mm and positioned as shown in figures 14 and 15.

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 definitions between the users are necessary.

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 are performing identical tests.

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

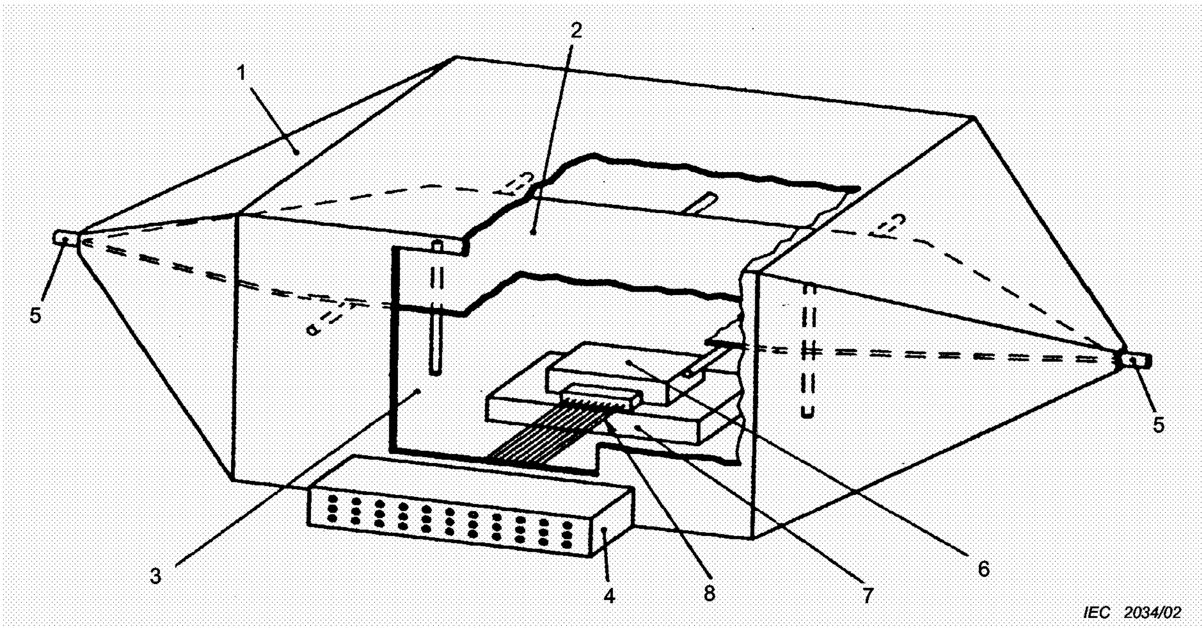
The positive supply line shall have an RF filter at the TEM cell input. The artificial network (AN) of 6.1.2 shall be used as this filter. The AN shall be connected directly to the TEM cell and shall be screened, so that the negative supply line is grounded at the connector panel.

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 D.

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.

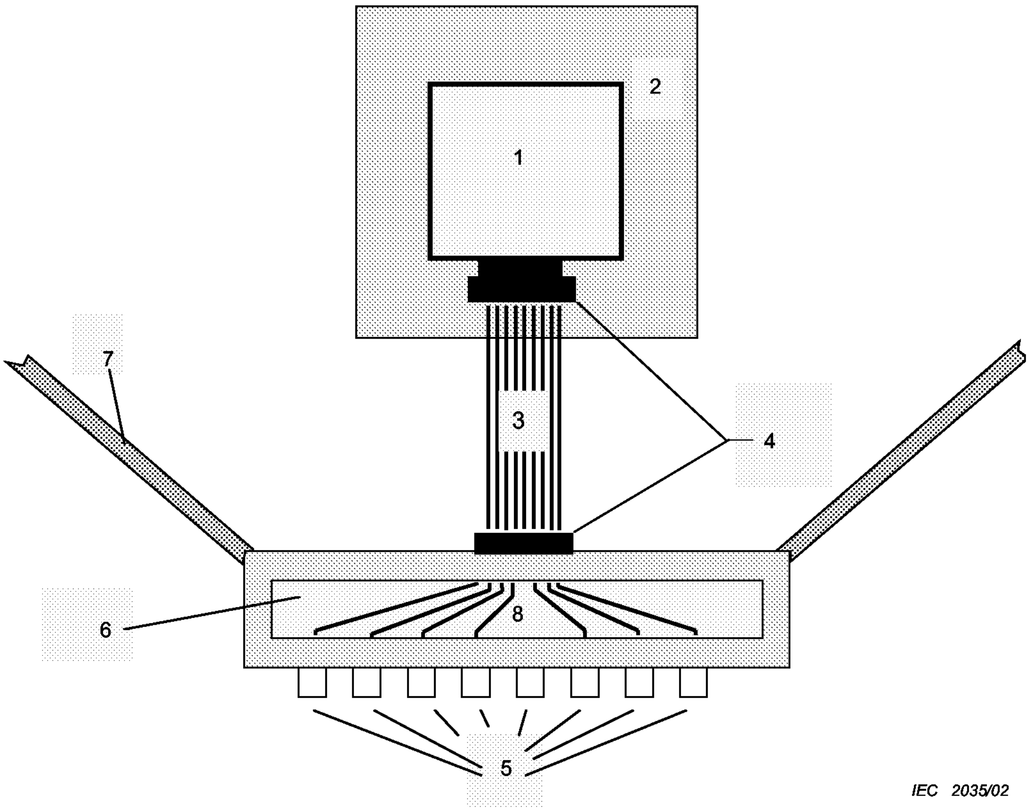


Key

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 shell.

Figure 13 – TEM cell (example)

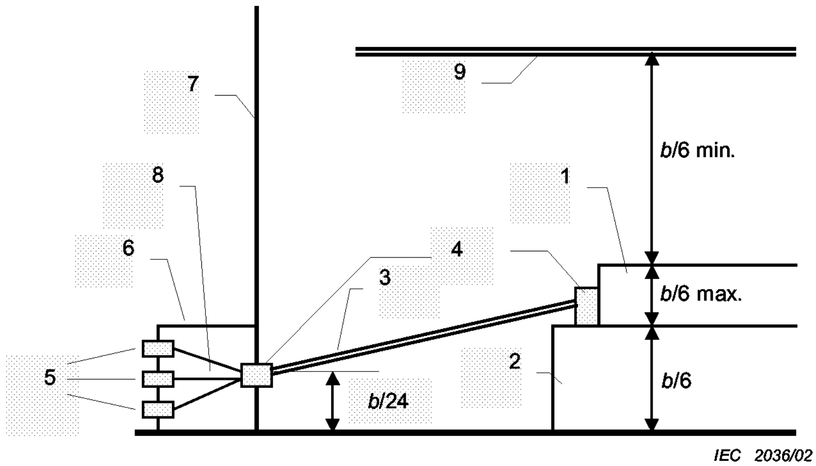


NOTE All leads to the EUT shall pass through an RF boundary. The RF boundary is either at the wall of the TEM cell or extended through RF coaxial cable (8) and coaxial connectors (5). The boundary is terminated by RF-filters which can be connected inside the connector panel (6) or directly outside to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

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

Figure 14 – Example of arrangement of leads in the TEM cell and to the connector panel



Key

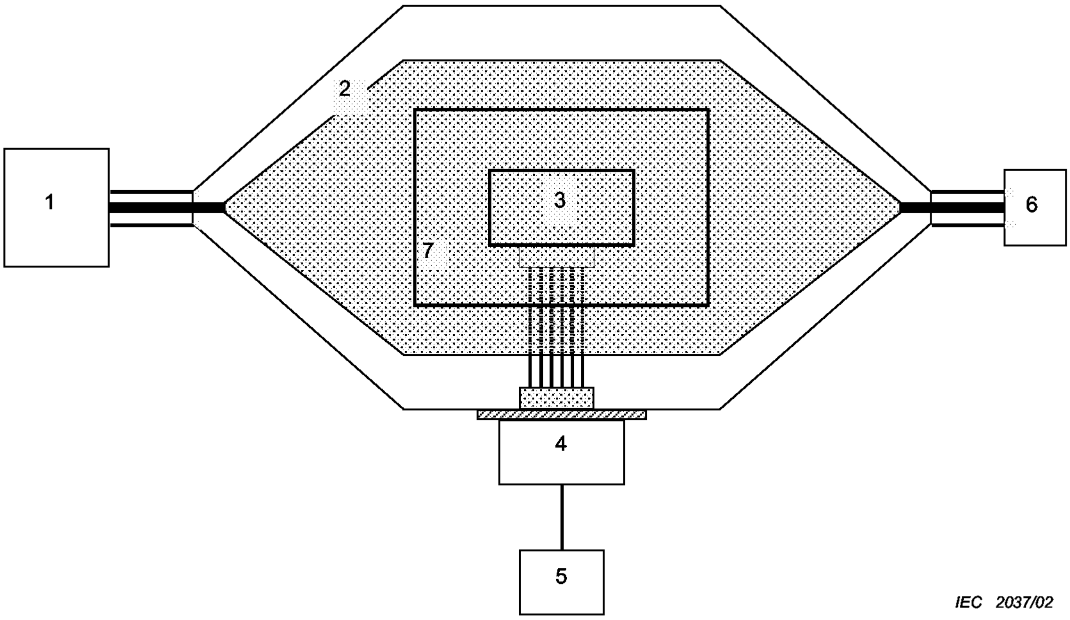
1 EUT
2 Low relative permittivity support ($\varepsilon_r \leq 1,4$)
3 Printed circuit board (no ground plane) or wiring harness, not shielded
4 Connector
5 Coaxial connectors
6 Connector panel (optional)
7 TEM cell wall
8 Cables
9 Septum

b is the TEM cell height (see annex F)

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

Figure 15 – Example of the arrangement of the connectors, the lead frame and the dielectric support

Figure 16 shows a typical example of a TEM cell method test layout.



Key

1 Measuring instrument
2 TEM cell
3 EUT
4 AN (see 6.1.2)
5 Power supply
6 50 Ω termination resistor
7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

Figure 16 – Example of the TEM cell method test layout

6.5.4 Limits for radiated disturbances from components/modules – TEM cell method

Limits for radiated disturbances from components (both the set-up with major field coupling to the wiring harness (6.5.2.1) and the set-up with major field coupling to the EUT (6.5.2.2)) are given in table 12.

Table 12 – Limits for broadband and narrowband radiated disturbances from components in a TEM cell (peak or quasi-peak detector)

Class[a]	**Levels** in dB(μV) in the following frequency bands: 0,15 MHz to 0,3 MHz, 0,53 MHz to 2 MHz, 5,9 MHz to 6,2 MHz, 30 MHz to 54 MHz, 68 MHz to 87 MHz (Communication), 76 MHz to 108 MHz (Broadcast), 142 MHz to 175 MHz			
	Broadband		**Narrowband (peak)**	
	All bands – Peak	All bands – Quasi-peak	All bands except 76 MHz to 108 MHz Broadcast	76 MHz to 108 MHz Broadcast
1	83	70	60	66
2	73	60	50	56
3	63	50	40	46
4	53	40	30	36
5	43	30	20	26
6	33	20	10	16
7	23	10	0	6

NOTE 1 Levels were established by application of engineering judgement to empirical values obtained from international testing.

NOTE 2 The limits correspond with a typical TEM cell height (*b*) equal to 600 mm as proposed in annex F, table F.1. For other TEM cell height (*b*) use other limit values

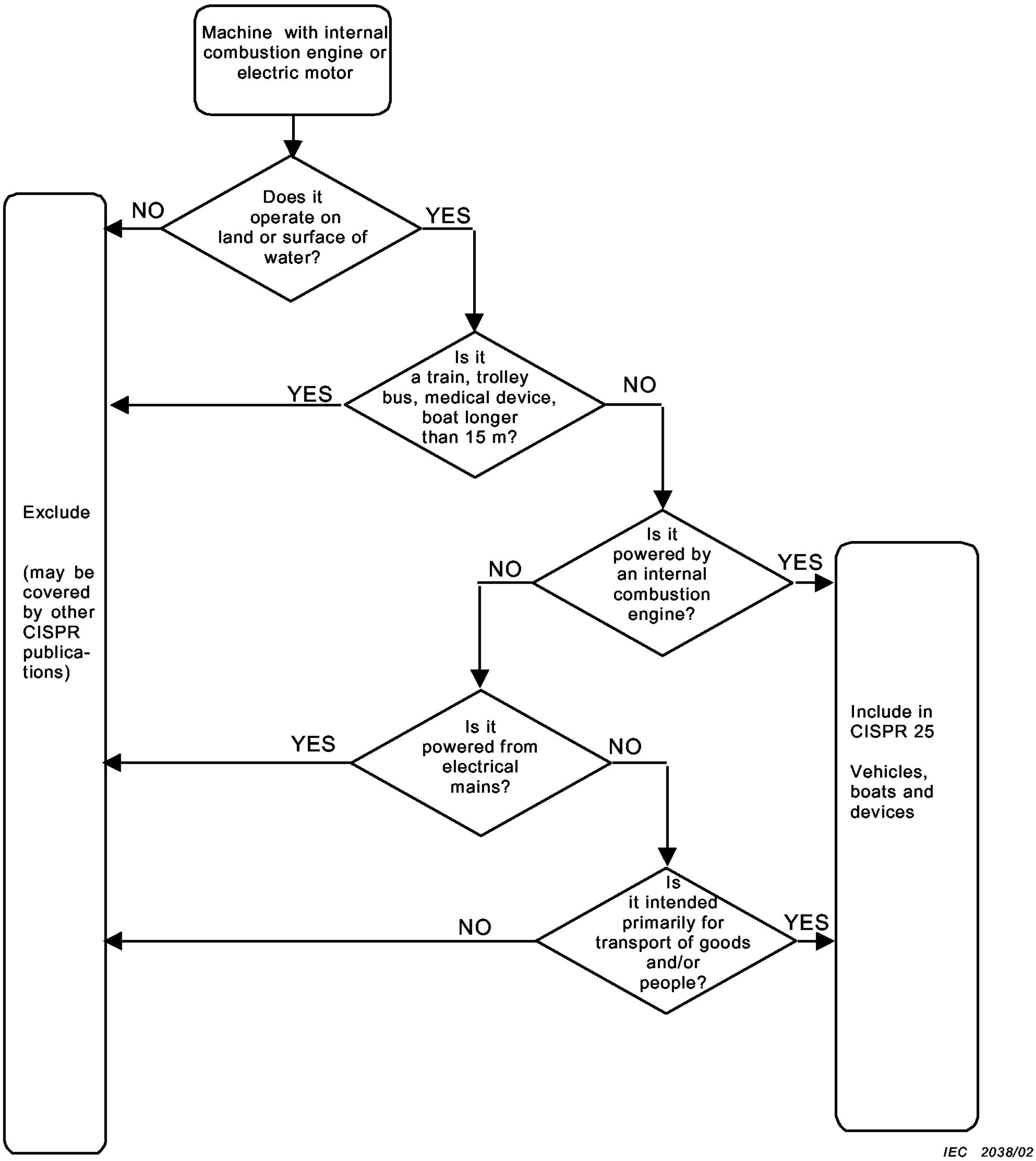
[a] Different classes may be attributed to different frequency bands

6.5.5 Disturbances radiated from integrated circuits

Refer to the work of IEC TC47.

Annex A
(informative)

Flow chart for checking the applicability of CISPR 25



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

Annex B
(informative)

Notes on the suppression of disturbances

B.1 Introduction

Success in providing radio disturbance suppression for a vehicle requires a systematic investigation to identify sources of disturbance which can be heard in the loudspeaker or detected as a malfunction of other telecommunication services. This disturbance may reach the receiver and loudspeaker in various ways:

a) disturbances coupled to the antenna;
b) disturbances coupled to the antenna cable;
c) penetration into the receiver enclosure via the power supply cables;
d) direct radiation into the receiver (immunity of an automobile radio to radiated disturbance);
e) disturbances coupled to all other cables connected to the vehicle RF receivers.

Before the start of the investigation, the receiver housing, the antenna base and each end of the shield of the antenna cable must be correctly grounded.

B.2 Disturbances coupled to the antenna

Most types of disturbances reach the receiver via the antenna. Suppressors can be fitted to the sources of disturbances to reduce these effects.

B.3 Coupling to the antenna cable

To minimize coupling, the antenna cable should not be routed parallel to the wiring harness or other electrical cables, and should be placed as remotely as possible from them.

B.4 Clock oscillators

Radiation/conduction from on-board electronic modules may affect other components on the vehicle. Significant harmonics of the clock oscillator shall not coincide with duplex transceiver spacings, nor with receiver channel frequencies. The fundamental oscillator frequency of automotive modules/components shall not interfere with adjacent mobile transceivers. That is, the oscillator frequency shall not be an integer fraction of the duplex frequency of any mobile transceiver system used in the country where the vehicle is operated.

B.5 Other sources of information

Corrective measures for penetration by receiver wiring and by direct radiation are covered in other publications. Similarly, tests to evaluate the immunity of a receiver to conducted and direct radiated disturbances are also covered in other publications (e.g. CISPR 20[7]).

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[7] CISPR 20:2002, *Sound and television broadcast receivers and associated equipment – Immunity characteristics – Limits and methods of measurement*

Annex C
(normative)

Antenna matching unit – Vehicle test

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

The requirements for the measurement equipment are defined in 5.1.2.1.

C.2 Antenna matching unit – Calibration

The 10 pF and 60 pF values for the artificial antenna network of figure C.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.

C.2.1 Gain measurement

The antenna matching unit shall be measured to determine whether its gain meets the requirements of 5.1.2.2 using the test arrangement shown in figure C.1.

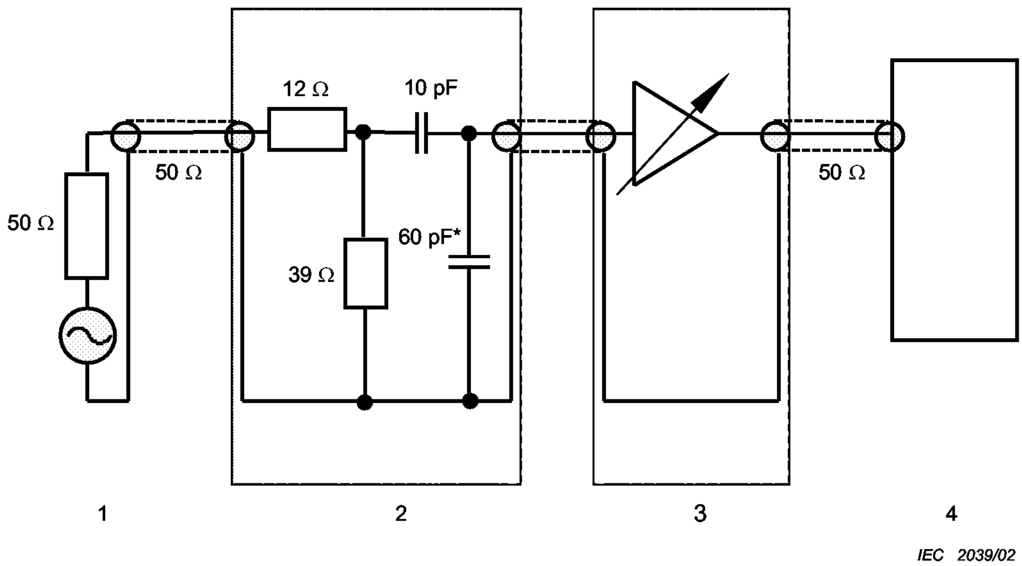
C.2.2 Test procedure

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 artificial antenna network (AAN) 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.

C.3 Impedance measurement

Measurement of the output impedance of the antenna and antenna matching unit 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 network
3 Antenna matching unit
4 Measuring instrument

* Includes connector capacitance and, if used, cable capacitance

Figure C.1 – Calibration set-up

Annex D
(informative)

Artificial network schematic

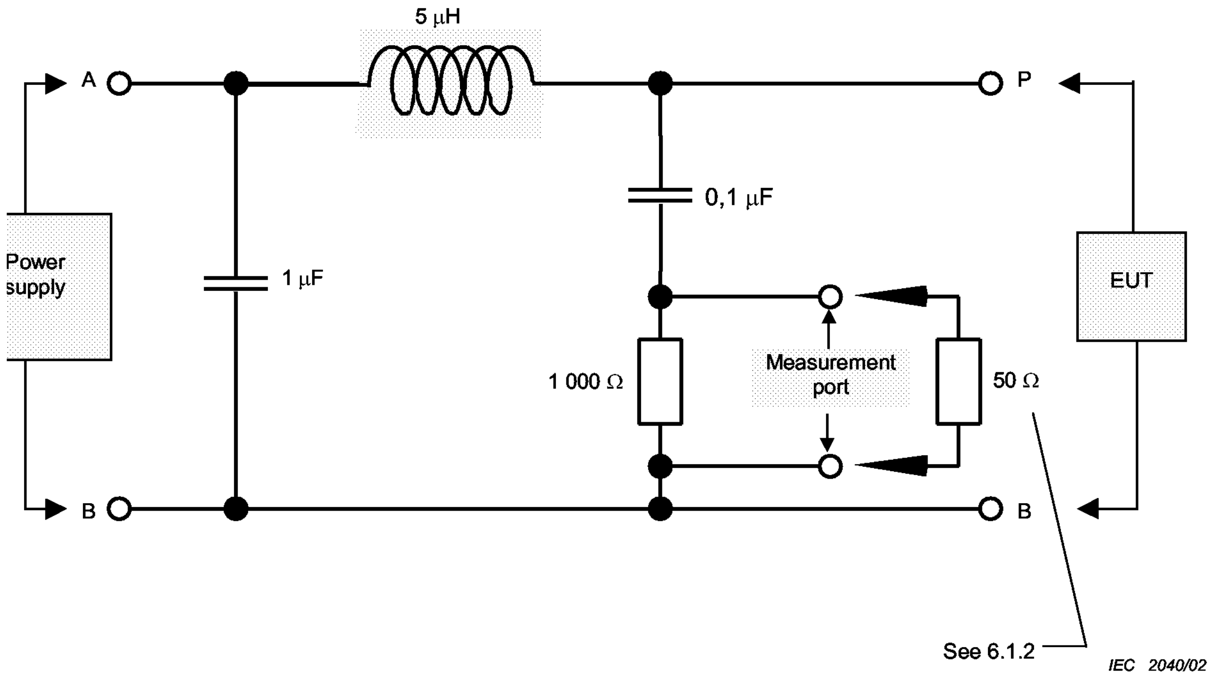


Figure D.1 – Example of 5 µH AN schematic

The AN impedance | Z_{PB} | □□(tolerance +/- 20%) in the measurement frequency range of 0,1 MHz to 100 MHz is shown in figure D.2. It is measured between the terminals P and B (of figure D.1) with a 50 Ω load on the measurement port and with terminals A and B (of figure D.1) short-circuited.

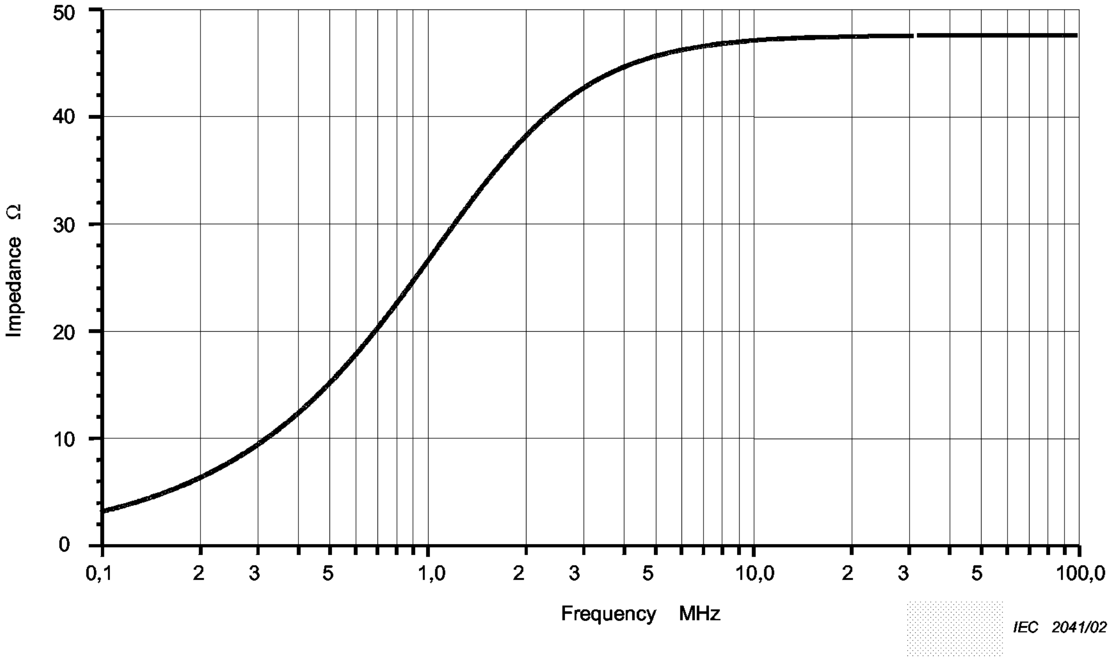


Figure D.2 – Characteristics of the AN impedance

Annex E
(normative)

Rod antenna characterization – The equivalent capacitance substitution method[8]

E.1 Characterization method

The equivalent capacitance substitution method uses a dummy antenna in place of the actual rod element. The primary component of the dummy antenna is a capacitor equal to the self-capacitance of the rod or monopole. This dummy antenna is fed by a signal source and the output from the coupler or base unit of the antenna is measured using the test configuration shown in figure E.2. The antenna factor (AF) in dB(1/m) is given by equation (E.1).

$$AF = V_D - V_L - C_h \qquad \text{(E.1)}$$

where

V_D is the measured output of the signal generator in dB(μV);

V_L is the measured output of the coupler in dB(μV);

C_h is the height correction factor (for the effective height) in dB(m).

For the 1 m rod commonly used in EMC measurements, the effective height (h_e) is 0,5 m, the height correction factor (C_h) is –6 dB(m) and the self-capacitance (C_a) is 10 pF.

NOTE See clause E.3 to calculate the effective height, height correction factor and self-capacitance of rod antennas of unusual dimensions.

Either of two procedures shall be used: E.1.1 the network analyzer method, or E.1.2 the signal generator and radio-noise meter method. The same dummy antenna is used in both procedures. See clause E.2 for guidance in making a dummy antenna. Measurements shall be made at a sufficient number of frequencies to obtain a smooth curve of antenna factor vs. frequency over the operating range of the antenna or 9 kHz to 30 MHz, whichever is smaller.

E.1.1 Network analyzer procedure

a) Calibrate the network analyzer with the cables to be used in the measurements.

b) Set up the antenna to be calibrated and the measuring equipment as shown in figure E.2a.

c) Subtract the signal level (in dB(μV)) in the reference channel from the signal level (in dB(μV)) in the test channel and subtract C_h (–6 dB for the 1 m rod) to obtain the antenna factor (in dB(1/m)) of the antenna.

NOTE Attenuator pads are not needed with the network analyzer because the impedances of the channels in the network analyzer are very nearly 50 Ω and any errors are corrected during network analyzer calibration. Attenuator pads may be used, if desired, but including them complicates the network analyzer calibration.

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8 This annex is based on IEEE 291-1991, *IEEE standard methods for measuring electromagnetic field strength of sinusoidal continuous waves*, 30 Hz to 30 GHz. IEEE, Inc., 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331 USA, p. 28-29.

E.1.2 Radio-noise meter and signal generator procedure

a) Set up the antenna to be calibrated and the measuring equipment as shown in figure E.2b.

b) With the equipment connected as shown and a 50 Ω termination on the T-connector (A), measure the received signal voltage V_L in dB(μV) at the RF port (B).

c) Leaving the RF output of the signal generator unchanged, transfer the 50 Ω termination to the RF port (B) and transfer the receiver input cable to the T-connector (A). Measure the drive signal voltage V_D in dB(μV).

d) Subtract V_L from V_D and subtract C_h (–6 dB for the 1 m rod) to obtain the antenna factor (in dB(1/m)) of the antenna.

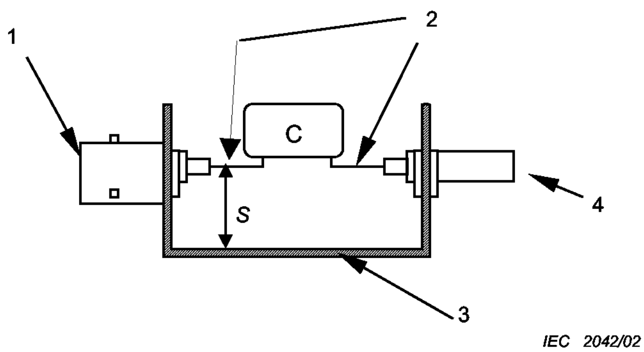
The 50 Ω termination shall have very low standing wave ratio (SWR) (less than 1,05:1). The radio-noise meter shall be calibrated and have low SWR (less than 2:1). The output of the signal generator shall be frequency and amplitude stable.

NOTE The signal generator need not be calibrated, since it is used as a transfer standard.

E.2 Dummy antenna considerations

NOTE The capacitor used as the dummy antenna should be mounted in a small metal box or on a small metal frame. The leads should be kept as short as possible, but no longer than 8 mm, and spaced 5 mm to 10 mm from the surface of the metal box or frame. See figure E.1.

The T-connector used in the antenna factor measurement set-up may be built into the dummy antenna box. The resistor pad to provide matching to the generator may also be built into the dummy antenna box.



Key

1 Connector, e.g. BNC
2 Capacitor leads '*L*' (both ends); lead length *L* as short as possible, but not greater than 8 mm (total lead length not greater than 40 mm including both capacitor leads and length of rod port connector); lead spacing *S* = 5 mm to 10 mm (10 mm from all surfaces if enclosed in a box)
3 Metal mounting frame
4 Low capacitance connector to mate with rod input port

C Capacitor 10 pF 5 %, silver mica

Figure E.1 – Example of mounting capacitor in dummy antenna

E.3 Rod (monopole) antenna performance equations

The following equations are used to determine the effective height, self-capacitance and height correction factor of rod or monopole antennas of unusual dimensions. They are valid only for rod antennas shorter than $\lambda/4$.

$$h_e = \frac{\lambda}{2\pi} \tan \frac{\pi h}{\lambda} \tag{E.2}$$

$$C_a = \frac{55{,}6h}{\ln\left(\frac{2h}{a}\right) - 1} \quad \frac{\tan \frac{2\pi h}{\lambda}}{\frac{2\pi h}{\lambda}} \tag{E.3}$$

$$C_h = 20 \lg h_e \tag{E.4}$$

where

h_e is the effective height of the antenna, in metres;

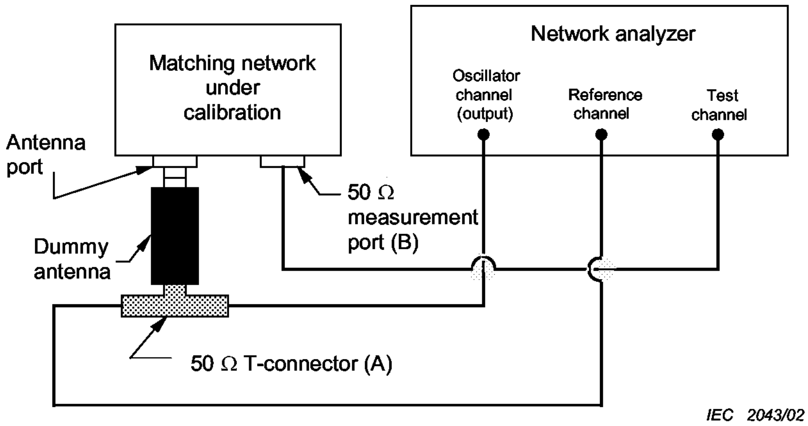
h is the actual height of the rod element, in metres;

λ is the wavelength, in metres;

C_a is the self-capacitance of the rod antenna, in picofarads;

a is the average radius of the rod element, in metres;

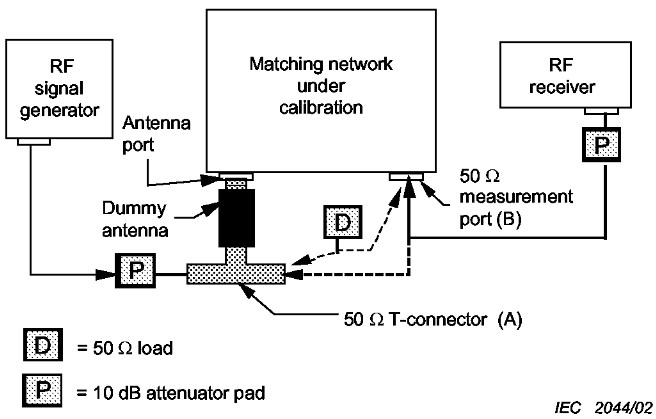
C_h is the height correction factor, in dB(m).



NOTE 1 Place the dummy antenna as close to the EUT port as possible. Place the T-connector as close to the dummy antenna as possible. Use the same length and type of cables between the T-connector and the reference channel input, and the T-connector and the 50 Ω measuring port test channel.

NOTE 2 Attenuator pads are not needed with the network analyzer and are not recommended.

Figure E.2a – Method using network analyzer



NOTE 1 Place the dummy antenna as close to the EUT port as possible. Place the T-connector as close to the dummy antenna as possible.

NOTE 2 If SWR of receiver and signal generator is low, pads may not be needed or may be reduced to 6 dB or 3 dB.

NOTE 3 The dummy antenna may incorporate other matching components to control SWR at its input and signal generator level measuring ports.

Figure E.2b – Method using radio-noise meter and signal generator

Figure E.2 – Determination of 1 m monopole antenna factor

Annex F
(informative)

TEM cell dimensions

The dimensions of a TEM cell are shown in the figure F.1 and given in table F.1.

Drawing not to scale

Dimensions in millimetres

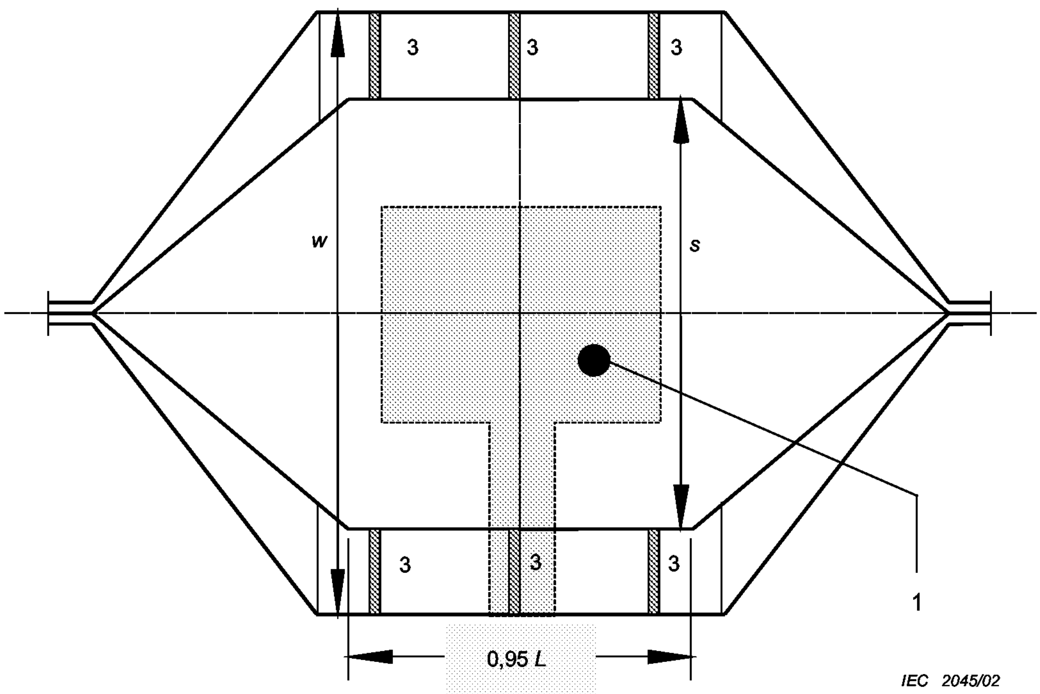


Figure F.1a – Horizontal section view at septum

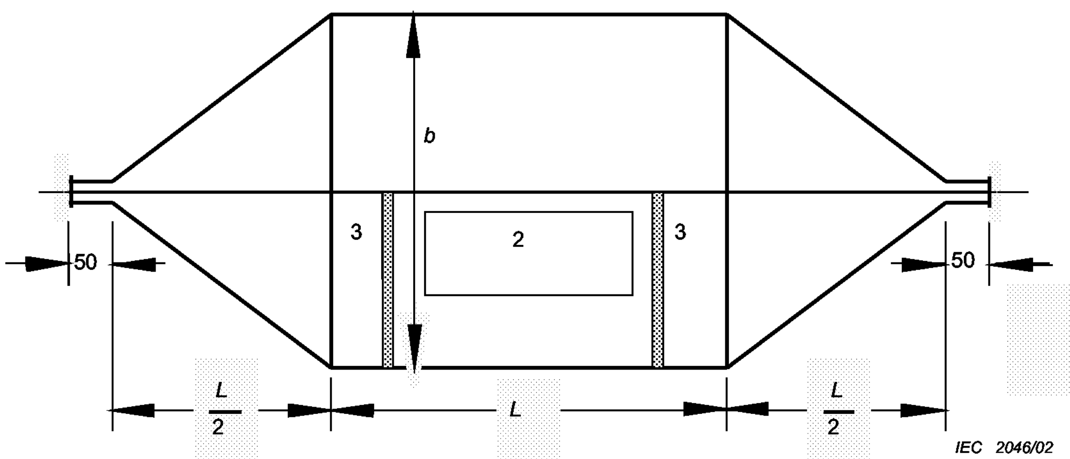


Figure F.1b – Vertical section view at septum

Key

1 Allowed working region: 0,33 *W*, 0,60 *L*
2 Access door
3 Dielectric supports

b = TEM cell height
L = TEM cell parallel section length
S = TEM cell septum width
W = TEM cell width

Figure F.1 – TEM cell

Table F.1 shows the dimensions for constructing TEM cells with specific upper frequency limits.

Table F.1 – 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)

Characterization procedure for shielded enclosure for component testing

G.1 Shielded enclosure reflection test and characterization procedure

The following test procedure is recommended for characterization of any shielded enclosure of dimensions not less than 7,0 m × 6,5 m × 4,0 m (length × width × height) for radiated emission measurements.

G.2 Standard noise source

A standard noise source with defined output characteristics shall be used for characterization purposes. A characterization curve shall be obtained with the standard noise source for field strength at 1 m distance in an open field test site, using the same test set-up, i.e. antennas, characterization harness, artificial network, etc.

G.3 Standard noise source characteristics

The standard noise source shall have a stable output amplitude spectrum throughout the frequency range of interest.

G.4 Characterization procedure

Arrange the standard noise source in place of the EUT in the test set-up shown in figures 10, 11 and 12. The noise source shall be attached to the artificial network by the standard 1 500 mm wiring harness supported 50 mm above the ground plane.

Measurements shall be made at the same frequencies and with the same antennas as will be used for the subsequent testing of the EUT. A plot of field strength versus frequency shall be produced.

The difference between the open test site curve and that taken in the ALSE shall be used to check whether the reflection characteristics of the ALSE comply with 4.4.1, but they cannot be used as a calibration factor.

To ensure uniformity of testing, steps shall be taken to reduce any reflections in the shielded enclosure which may cause variations in measured levels.

NOTE Radio-frequency absorbent material, properly applied, will reduce reflections at the higher frequencies.

Annex H
(informative)

Sheath-current suppressor

H.1 General information

This annex provides information on a 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.

H.2 Suppressor construction

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

Material:	N30; AI = 5 400 nH
Size:	Toroidal core 58 mm × 40 mm × 17 mm
Manufacturer:	Siemens Order No.: B64290-A40-X830
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. If two identically wound toroidal cores are used, the attenuation will increase by approximately 6 dB.

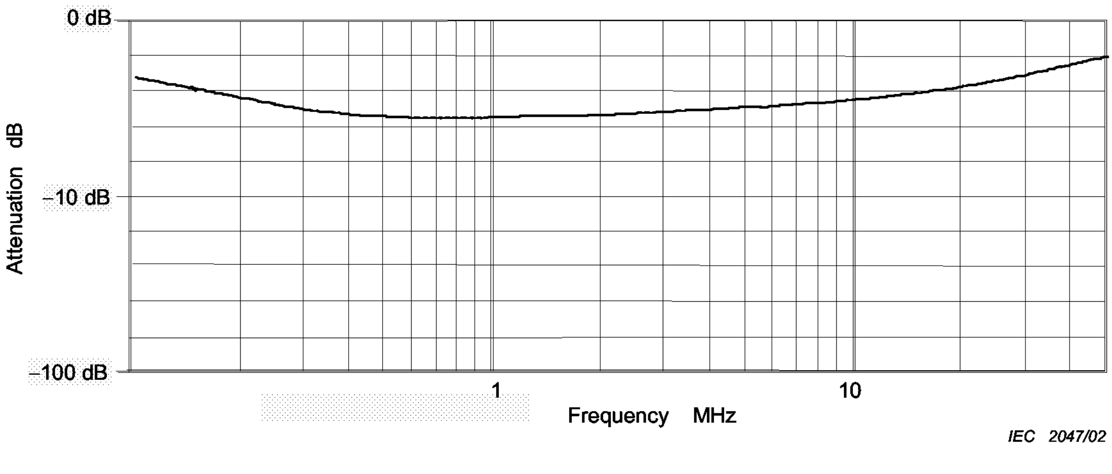


Figure H.1 – Attenuation vs. frequency

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050-161	1990	International Electrotechnical Vocabulary (IEV) Chapter 161: Electromagnetic compatibility	-	-
CISPR 12	- [1]	Vehicles, boats 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	EN 55012	2002 [2]
CISPR 16-1	1999	Specification for radio disturbance and immunity measuring apparatus and methods Part 1: Radio disturbance and immunity measuring apparatus	-	-

[1] Undated reference.

[2] Valid edition at date of issue.

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