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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles

Limites et méthodes de mesure des caractéristiques des perturbations radioélectriques pour la protection des récepteurs utilisés à bord des véhicules

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Revision of this publication

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Information on the work of revision, the issue of revised editions and amendments may be obtained from IEC National Committees and from the following IEC sources:

- **IEC Bulletin**
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Terminology used in this publication

Only special terms required for the purpose of this publication are defined herein.

For general terminology, readers are referred to IEC 60050: *International Electrotechnical Vocabulary* (IEV), which is issued in the form of separate chapters each dealing with a specific field, the General Index being published as a separate booklet. Full details of the IEV will be supplied on request.

For terms on radio interference, see Chapter 902.

Graphical and letter symbols

For graphical symbols, and letter symbols and signs approved by the IEC for general use, readers are referred to:

– IEC 60027: *Letter symbols to be used in electrical technology;*

– IEC 60617: *Graphical symbols for diagrams.*

The symbols and signs contained in the present publication have either been taken from IEC 60027 or IEC 60617, or have been specifically approved for the purpose of this publication.

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FOREWORD

1) The formal decisions or agreements of the CISPR on technical matters, prepared by subcommittees on which all the National Committees and other member organizations of the CISPR having a special interest therein are represented, express, as nearly as possible, an international consensus on the subject dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees and other member organizations of the CISPR in that sense.

3) In order to promote international unification, the CISPR expresses the wish that all National Committees should adopt the text of the CISPR recommendation for their national rules in so far as national conditions will permit. Any divergence between the CISPR recommendations and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

International Standard CISPR 25 has been prepared by CISPR subcommittee D: Interference relating to motor vehicles and internal combustion engines.

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

DIS	Report on voting
CISPR/D(CO)25	CISPR/D(CO)27

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

This standard is expected to be amended in the future, as dictated by experience gained from its use.

Annex A forms an integral part of this standard.

Annexes B, C, D, E and F are for information only.

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 a test method 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.

NOTES

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.

2 Annex D provides helpful methodology for resolution of disturbance problems.

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

Section 1: General

1 Scope

This 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 large 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 Section 2 and the methods and limits for components/modules are in Section 3.

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 snow mobiles.

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 standard does not include protection of electronic control systems from radio frequency (r.f.) emissions, or from transient or pulse-type voltage fluctuations. These subjects are expected to be included in ISO Publications.

Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, Section 3 of this standard defines multiple limit levels. The level class to be used (as a function of frequency band) is to 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.

It is assumed that protection of services operating on frequencies below 30 MHz will most likely be provided if the limits for services above 30 MHz are observed.

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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.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50 (161): 1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

CISPR 12: 1990, *Limits and methods of measurement of radio interference characteristics of vehicles, motor boats, and spark-ignited engine-driven devices*

CISPR 16-1: 1993, *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):** The voltage generated by a source of radio disturbance and measured in dB(µV) by a radio disturbance measuring instrument conforming to the requirements of CISPR 16-1.

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

3.3 **antenna matching unit:** A unit for matching the impedance of an antenna to that of the 50 Ω measuring receiver over the antenna measuring frequency range.

3.4 **antenna correction factor:** The factor which is applied to the voltage measured at the input connector of the measuring instrument to give the field strength at the antenna. The antenna correction factor is comprised of an antenna factor and a cable factor.

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

3.6 **class:** A performance level agreed upon by the purchaser and the supplier and documented in the test plan.

3.7 **device:** A machine which is not self-propelled. Devices include, but are not restricted to chainsaws, irrigation pumps, air compressors, lawn mowers, and stationary or mobile concrete mixers. (See CISPR 12, clause 1, note 3.)

The following definitions are necessary for an understanding of this standard and are contained in IEC 50(161):

3.8 **artificial mains network [line impedance stabilization network (LISN, USA)]:** A network inserted in the supply mains 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 mains in that frequency range. [IEV 161-04-05]

NOTE – Artificial mains network is abbreviated AN.

3.9 **bandwidth**

3.9.1 **bandwidth (of an equipment):** The width of a frequency band over which a given characteristic of an equipment or transmission channel does not differ from its reference value by more than a specifed 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]

3.9.2 **bandwidth (of an emission or signal):** The width of the frequency band outside which the level of any spectral component does not exceed a specified percentage of a reference level. [IEV 161-06-10]

3.10 **broadband emission:** An *emission* which has a *bandwidth* greater than that of a particular measuring apparatus or receiver. [IEV 161-06-11]

3.11 **disturbance suppression:** Action which reduces or eliminates *electromagnetic disturbance*. [IEV 161-03-22]

3.12 **disturbance voltage; interference voltage** (deprecated in this sense): Voltage produced between two points on two separate conductors by an *electromagnetic disturbance*, measured under specified conditions. [IEV 161-04-01]

3.13 **narrowband emission:** An *emission* which has a *bandwidth* less than that of a particular measuring apparatus or receiver. [IEV 161-06-13]

3.14 **peak detector:** A detector, the output voltage of which is the peak value of an applied signal. [IEV 161-04-24]

3.15 **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]

3.16 **electromagnetic environment:** The totality of electromagnetic phenomena existing at a given location. [IEV 161-01-01]

3.17 **shielded enclosure; screened room:** A mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and the external environment. [IEV 161-04-37]

4 Requirements common to vehicle and component/module emissions measurement

4.1 General test requirements and test plan

4.1.1 Test plan note

A test plan should be established for each item to be tested. The test plan should 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 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.

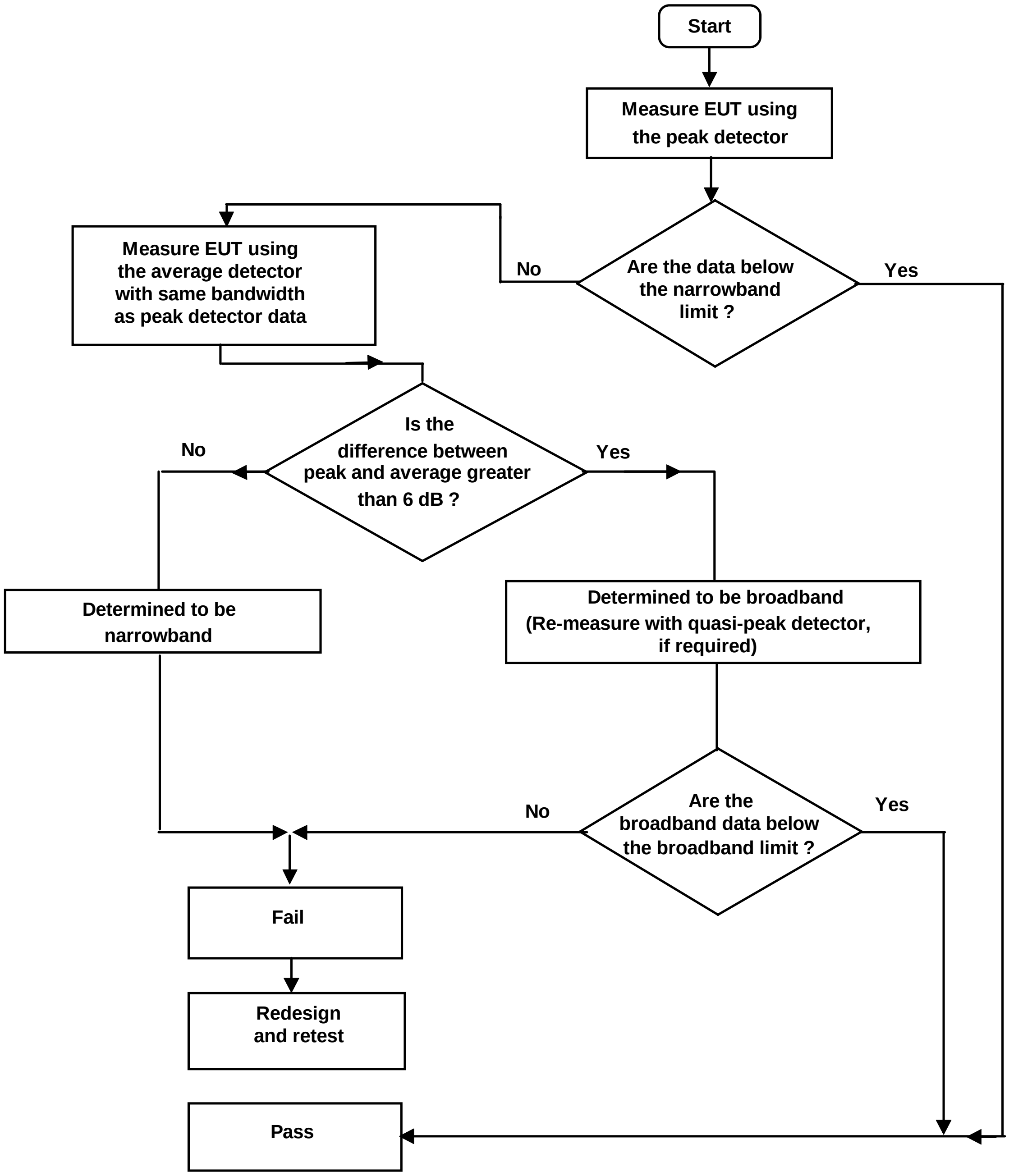


Figure 1 – Method of determination of conformance of radiated/conducted disturbance

4.1.4 Examples of broadband disturbance sources

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

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

When performing component/module tests, the equipment under test (EUT) shall be exercised using typical loads and conditions which simulate installation and operation in the vehicle.

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.

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.

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 r.f. absorber material to the walls and ceiling of a shielded enclosure that is to be used for radiated emissions measurements. No absorber material is required for the floor. The following ALSE requirements shall also be met for performing radiated r.f. 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 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 Receiver

Scanning receivers which meet the requirements of CISPR 16-1 are satisfactory for measurements. Either manual or automatic frequency scanning may be used. Special consideration shall be given to overload, linearity, selectivity, and the normal response to pulses.

NOTE – 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 with peak than with quasi-peak detection.

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

4.5.1 Minimum scan time

The scan rate of a spectrum analyser or scanning receiver shall be adjusted for the CISPR frequency band and detection mode used. The minimum sweep time/frequency, (i.e. most rapid scan rate) is listed in table 2:

Table 2 – Minimum scan time

Band [1]	Peak detection	Quasi-peak detection
A 9 - 150 kHz	Does not apply	Does not apply
B 0,15 - 30 MHz	100 ms/MHz	200 s/MHz
C, D 30 - 1000 MHz	1 ms/100 ms/MHz [2]	20 s/MHz

[1] Band definition from CISPR 16-1.

[2] When 9 kHz bandwidth is used, the 100 ms/MHz value shall be used.

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, scanning steps greater than the measurement bandwidth are permitted, thus accelerating the measurement of the emission spectrum.

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.

NOTE – 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.

Table 3 – Measuring instrument bandwidth (6 dB)

Frequency band MHz		Broadband peak or quasi-peak	Narrowband peak or average
0,15 - 30		9 kHz	9 kHz
30 - 1 000	FM broadcast	120 kHz	120 kHz
	Mobile service	120 kHz	9 kHz

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.

5 Antenna and impedance-matching requirements – Vehicle test

5.1 Type of antenna

An antenna of the type to be supplied with the vehicle shall be used as the measurement antenna. Its location and attitude are determined according to the production specifications.

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.

Table 4 – Antenna types

Band [1]	Antenna type
Broadcast	
LW - AM	1 m monopole
MW - AM	1 m monopole
SW - AM	1 m monopole
VHF - FM	1 m monopole
Mobile services (MHz)	
30 - 54	Loaded quarter-wave monopole
70 - 87	Quarter-wave monopole
144 - 172	Quarter-wave monopole
420 - 512	Quarter-wave monopole
800 - 1 000	Quarter-wave monopole
[1] LW: Long wave MW: Medium wave SW: Short wave VHF: Very high frequency	

5.2 Measurement system requirements

5.2.1 Broadcast bands

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

5.2.1.1 AM broadcast:

Long wave (150 – 300 kHz)

Medium wave (0,53 – 2,0 MHz)

Short wave (5,9 – 6,2 MHz) *

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 A.

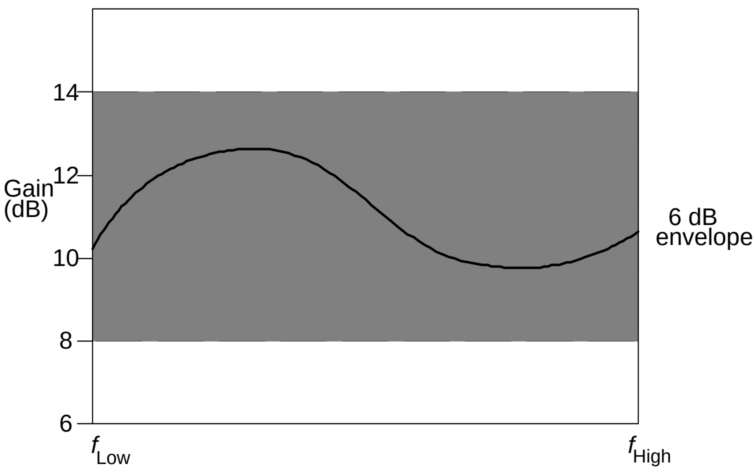


Figure 2 – Example of gain curve

* 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.

– *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 be at least 10 times the open circuit impedance of the artificial antenna network in annex A.

5.2.1.2 FM broadcast (87 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.

5.2.2 Communications bands (30 MHz to 1 000 MHz)

The test procedure assumes a 50 Ω measuring instrument and a 50 Ω antenna in the frequency range 30 MHz to 1 000 MHz.

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

6 Test equipment unique to component/module tests

6.1 Power supply

The EUT power supply shall have adequate regulation to maintain the supply voltage within the limits specified: 13,5 V ± 0,5 V for 12 V systems, 27 V ± 1,0 V for 24 V systems, unless otherwise specified in the test plan.

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

6.2 Battery

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

6.3 Ground plane

The ground plane shall be made of 0,5 mm thick (minimum) copper, brass or galvanized steel of the size specified in figures 7 through 12 for the measurement of conducted or radiated emissions.

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 0,9 m apart.

6.4 Test equipment unique to conducted emission measurements

6.4.1 Artificial mains network (AN)

6.4.1.1 AN impedance characteristics

The AN shall have a nominal 5 µH inductance and shall meet the impedance characteristics shown in figure 3 with a tolerance of ±10 %. A suggested schematic is shown in annex F. The measuring port of all ANs shall be terminated with a 50 Ω load (either a measuring instrument or a resistor). For the purpose of this standard, the AN may be used up to 108 MHz.

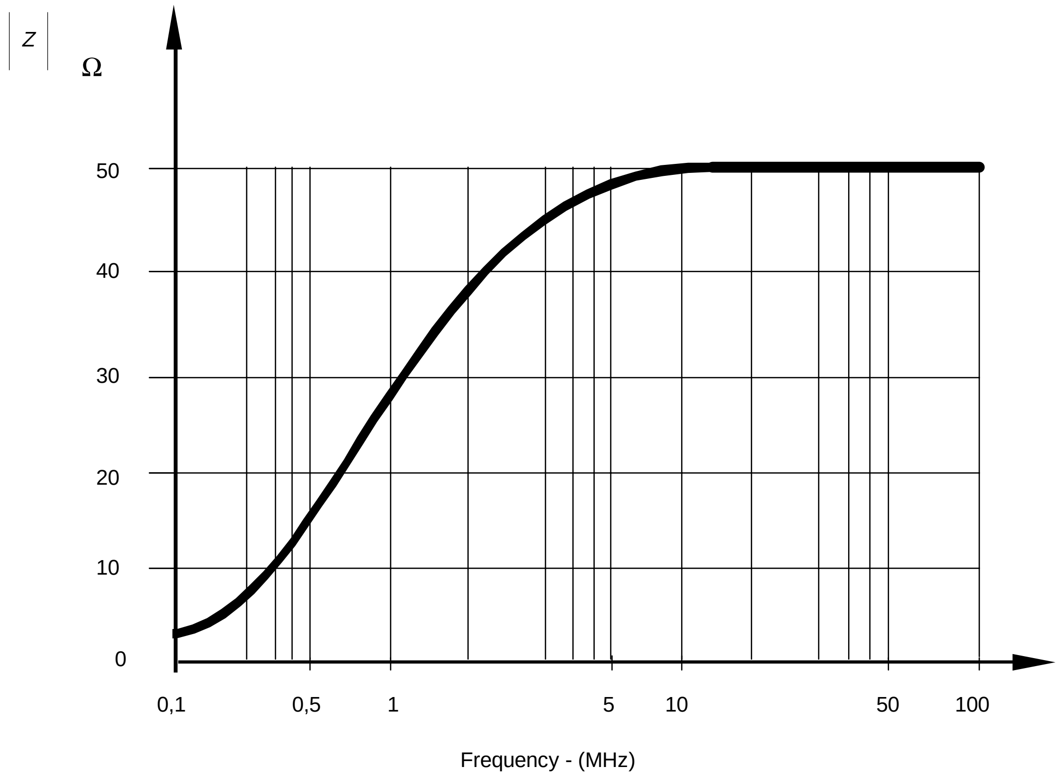


Figure 3 – Impedance characteristics for the 5 µH AN (measured between the EUT terminals)

6.4.1.2 AN connection

For the emissions test of clauses 11 and 13, a standard AN according to 6.4.1.1 shall be used. For the TEM cell emissions test of clause 15, an AN with a coaxial connector will facilitate connection to the TEM cell EUT power connector.

6.4.2 Current probe

The current probe shall be selected considering the following: the size of the harness to be measured, the frequency range required by the test plan, and the sensitivity of the probe necessary to measure signals at the limit level.

NOTE – Typically, a current probe is a transducer which converts current to voltage. As such, its calibration factor is often called a transfer impedance curve and is given in Ω or dB(Ω). (See annex C.)

6.5 Equipment unique to measurements of component/module radiated emissions

6.5.1 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 receiver. For the purposes of this standard, the limits shown in tables 10 and 11 are based upon the following antennas:

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

b) 30 to 200 MHz — a biconical antenna used in vertical and horizontal polarization;

c) 200 to 1000 MHz — a log-periodic antenna used in horizontal and vertical 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, annex A.

NOTE – A method for determining antenna factors is described in [1]*

6.5.2 Antenna matching unit

Correct impedance matching between the antenna and the measuring receiver 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.

NOTES

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 A.

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.

6.6 Equipment unique to the TEM cell method

6.6.1 TEM cell size

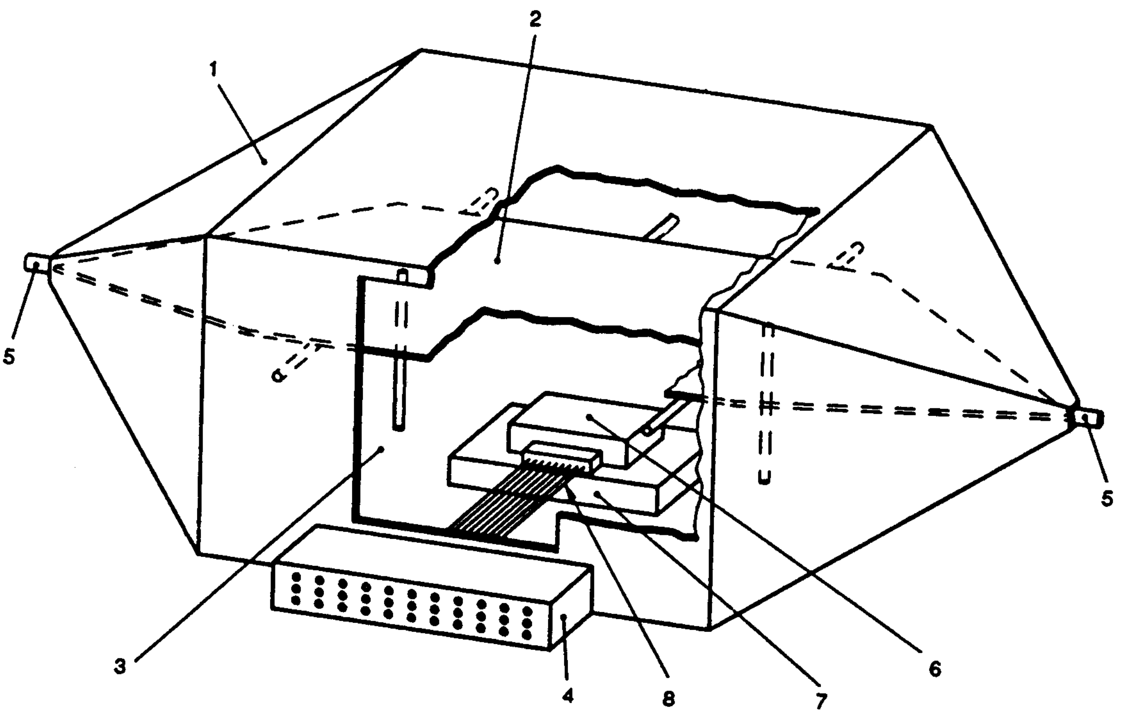
An example of a TEM cell is shown in figure 4. Information relating to the size and construction of a TEM cell for component measurement is given in annex E.

6.6.2 TEM cell test set-up (EUT with leadframe)

6.6.2.1 TEM cell

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

* [1] 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.



1 Outer shield
2 Septum (inner conductor)
3 Access door
4 Connector panel
5 Coaxial connectors
6 EUT
7 Dielectric equipment support
8 Artificial harness

Figure 4 – TEM cell (example)

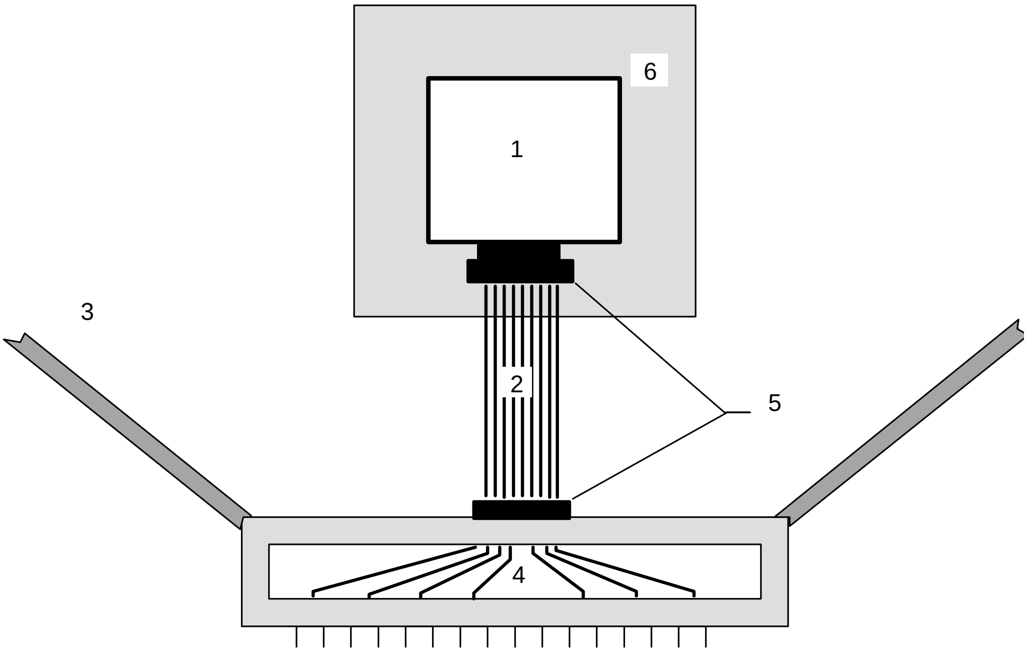
6.6.2.2 Supply and signal leads

The TEM cell shall have a connector panel connected as close as possible to a plug connector (see figure 5).

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 r.f.-tight.

The connection of the positive power lead shall be through the AN (see 6.4.1.2), direct at the connector panel.

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



1 EUT
2 Artificial harness (e.g. lead frame)
3 TEM cell wall
4 Connector panel
5 Connector
6 Dielectric equipment support ($\varepsilon_r \leq 1{,}4$)

Figure 5 – Example of arrangement of leads in the TEM cell and to the connector panel

6.6.3 TEM cell test set-up (EUT without lead frame)

The test set-up is similar to the method shown above, except that the leads to the EUT are positioned and shielded to minimize 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 minimize the radiation from the wiring further, shielding foil tape can be applied over the leads.

6.7 Special test for integrated circuits

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 minimize extraneous effects of leads and test circuitry mask changes.

Section 2: Measurement of emissions received by an antenna on the same vehicle

Clauses 1 through 5 apply to this section.

7 Field of application

This method applies 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. This section describes the method of safeguarding radio reception in the same vehicle in which the disturbance arises.

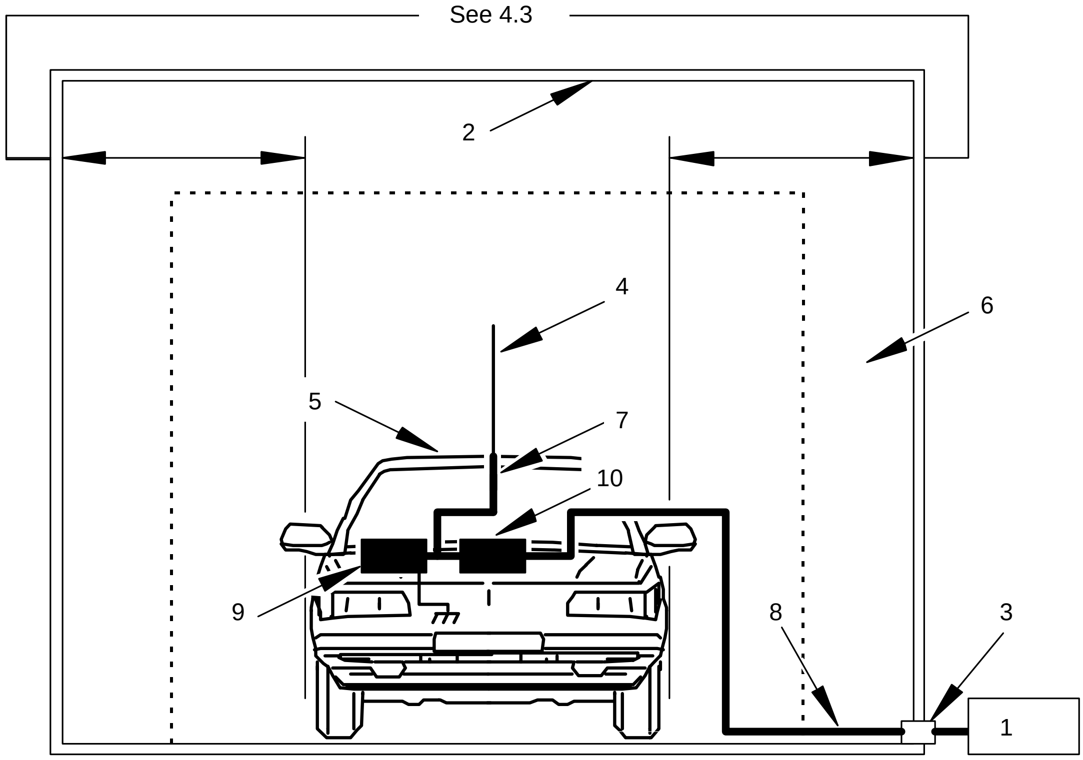
8 Method of measurement

As a general principle, the disturbance voltage shall be measured at the terminals of the radio receiving antenna placed at the correct vehicle location(s).

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. The use of a high-quality double-shielded cable for connection to the measuring receiver is recommended as well as the use of ferrite rings on the cable for suppression of surface currents. A coaxial bulkhead connector shall be used for connection to the measuring receiver outside the shielded room. See figure 6.

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.



1 Measuring instrument
2 ALSE
3 Bulkhead connector
4 Antenna (see 5.1)
5 EUT
6 Typical absorber material
7 Antenna coaxial cable
8 High-quality double-shielded coaxial cable
9 Housing of on-board radio
10 Impedance matching unit (when required)

Figure 6 – Vehicle-radiated emissions – Example for test layout (end view with monopole antenna)

9 Limits for vehicle-radiated disturbances

The limits of disturbance may be different for each disturbance source. Long-duration disturbance sources such as a heater blower motor must meet a more stringent requirement than short-duration disturbance sources. Short-duration disturbance sources may be decided upon by the vehicle manufacturer. For example, door mirror operation may be allowed at a higher level of disturbance, as it is operated for only one or two seconds at a time. Coherent energy from microprocessors is more objectionable because it resembles desired signals and is continuous.

For acceptable radio reception in a vehicle, the disturbance voltage at the end of the antenna cable shall not exceed the values shown in table 5.

Table 5 – Limits of disturbance – Complete vehicle

		Terminal noise voltage at receiver antenna terminal dB(μV)				
Band	Frequency	Broadband continuous		Broadband short duration		Narrowband
(* *)	MHz	Quasi-peak	Peak	Quasi-peak	Peak	Peak
LW	0,15 - 0,30	9	22	15	28	6
MW	0,53 - 2,0	6	19	15	28	0
SW	5,9 - 6,2	6	19	6	19	0
VHF	30 - 54	6(15*)	28	15	28	0
VHF	70 - 87	6(15*)	28	15	28	0
VHF	87 - 108	6(15*)	28	15	28	6
VHF	144 - 172	6(15*)	28	15	28	0
UHF	420 - 512	6(15*)	28	15	28	0
UHF	800 - 1000	6(15*)	28	15	28	0

NOTES

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

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 (87 MHz to 108 MHz) limit.

* Limit for ignition systems only.

(* *) LW: Long wave
MW: Medium wave
SW: Short wave
VHF: Very high frequency
UHF: Ultra high frequency

Section 3: Measurement of vehicle components and modules

Clauses 1 through 4 and 6 apply to this section.

10 Field of application

This method applies 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 voltage, current and field strengths 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. This section describes methods of safeguarding radio reception in the same vehicle in which the disturbance arises.

11 Conducted emissions from component/module

11.1 General

Emissions on power leads shall be measured using an artificial mains network as an isolator. Emissions on control/signal leads shall be measured using a current probe.

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.

11.2 Test procedure

11.2.1 Voltage measurements

Voltage measurements on all power leads shall be made relative to the case of the EUT (when the case provides the ground return path) or the ground lead as close to the EUT as practical.

For the EUT with return line remotely grounded, the voltage measurements shall be made on each lead (supply and return) relative to the ground plane.

The test harness shall be spaced 50 mm above the ground plane.

11.2.2 Current probe measurements

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. The test harness length shall be nominally 1,5 m (or as agreed upon in the test plan), spaced 50 mm above the ground plane. The test harness wires shall be nominally parallel and adjacent unless otherwise defined in the test plan.

Position the current probe 50 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 mm from the EUT connector;

b) 1 000 mm from the EUT connector;

c) 50 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.

11.2.3 Equipment arrangement

For voltage measurements, the arrangement of the EUT and measuring equipment shall be as shown in figures 7, 8 and 9 depending on the intended EUT installation in the vehicle:

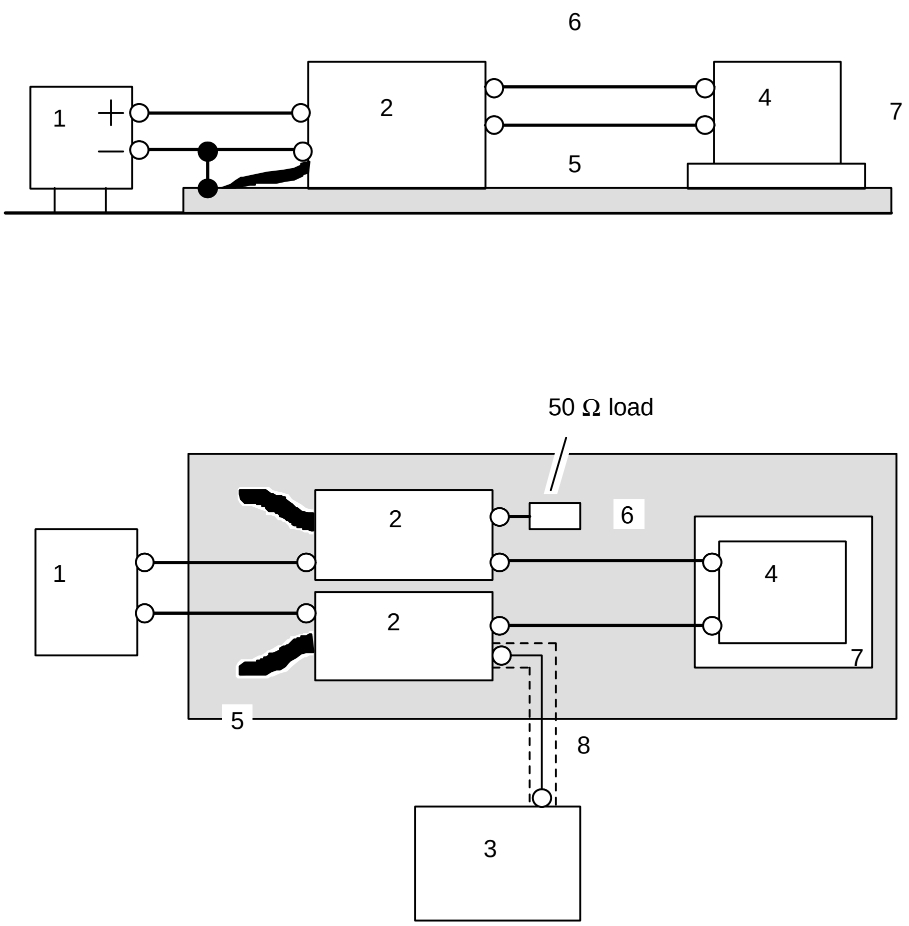
a) EUT remotely grounded (power return line longer than 200 mm) – use figure 7;

b) EUT locally grounded (power return line 200 mm or shorter) – use figure 8;

c) alternators and generators – use figure 9.

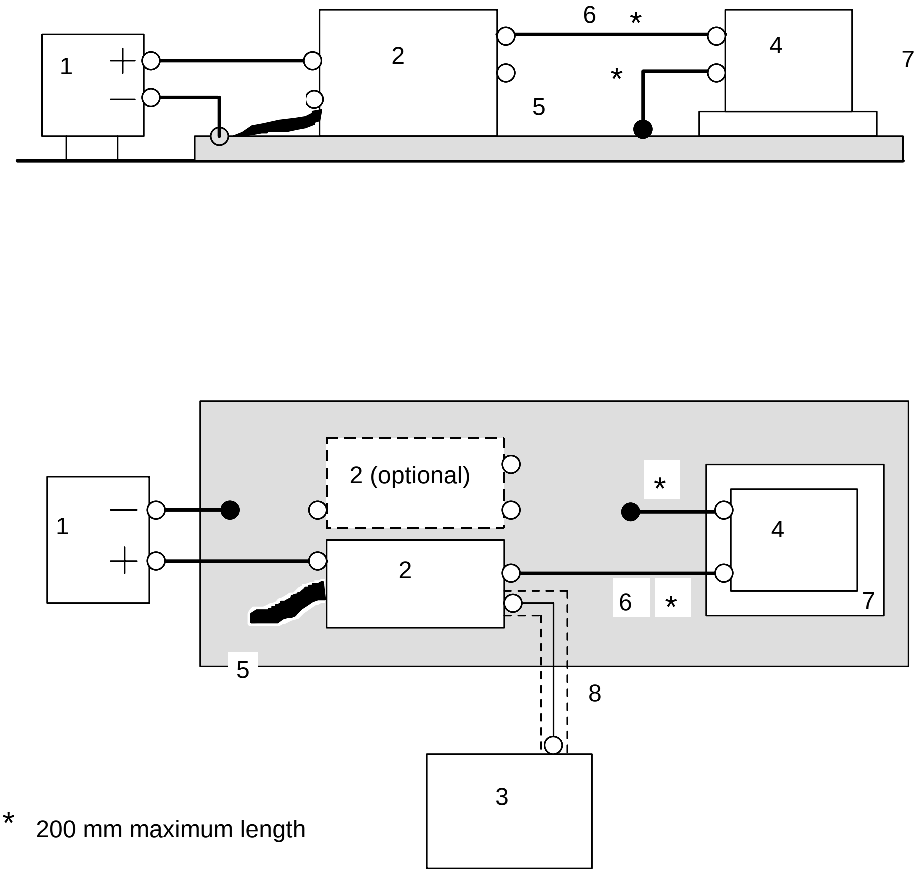
The test plan shall simulate the actual vehicle configuration and shall specify: remote versus local grounding, the use of an insulating spacer, and the electrical connection of the EUT case to the ground plane.

For current measurements, the measuring equipment shall be as shown in figure 10.



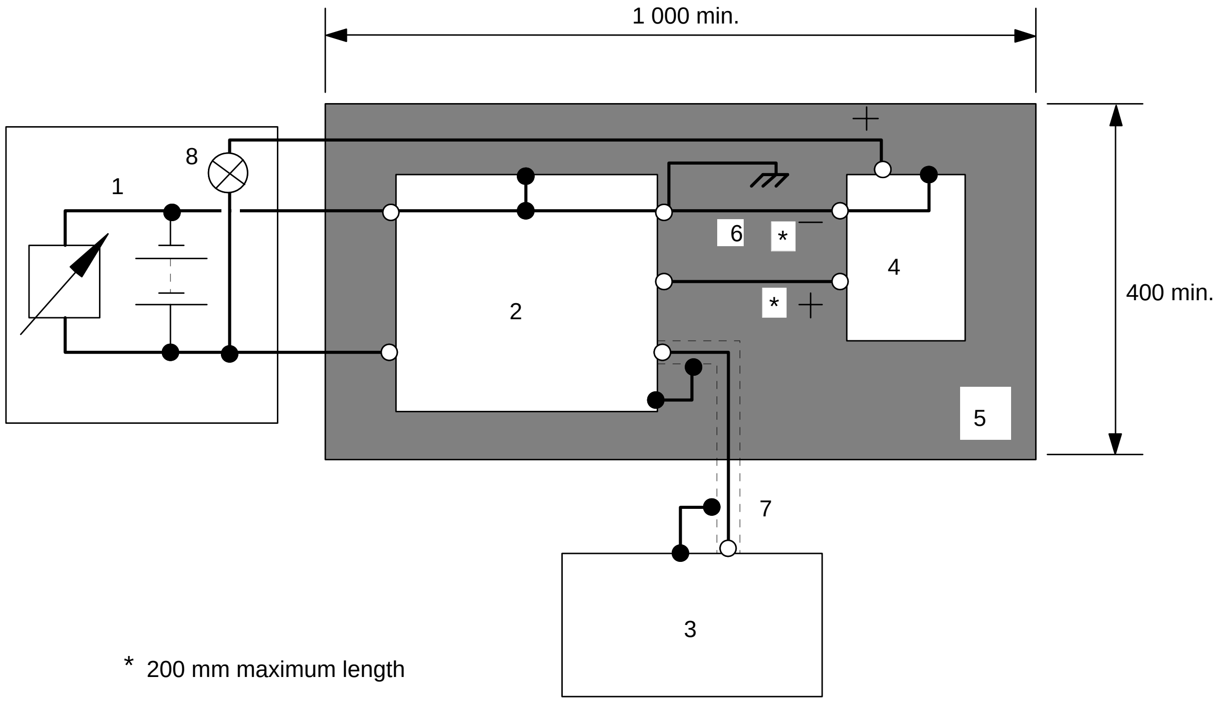
1 Power supply
2 Artificial mains network (two units)/control box/loads
3 Measuring instrument
4 EUT
5 Ground plane
6 Test harness (power leads 200 mm maximum length)
7 Insulating spacer (50 mm thick), when required in test plan
8 Coaxial cable (50 Ω)

Figure 7 – Conducted emissions – EUT with power return line remotely grounded



1 Power supply
2 Artificial mains network (one unit, second optional)/control box/loads
3 Measuring instrument
4 EUT
5 Ground plane
6 Test harness (power leads 200 mm maximum length)
7 Insulating spacer (50 mm thick), when required in test plan
8 Coaxial cable (50 Ω)

Figure 8 – Conducted emissions – EUT with power return line locally grounded



Dimensions in millimetres

1 Load (battery and resistor)
2 Artificial mains network
3 Measuring equipment
4 EUT
5 Ground plane
6 Test harness (power leads 200 mm maximum length)
7 Coaxial cable (50Ω)
8 Indicator lamp/control resistor (where applicable)

Figure 9 – Conducted emissions – Test layout for alternators and generators

11.2.4 Test procedure for generators/alternators

Generators/alternators shall be loaded with a battery and parallel resistor combination, and connected to the artificial mains network in the manner shown in figure 9. The load current, operating speed, harness length and other conditions shall be defined in the test plan.

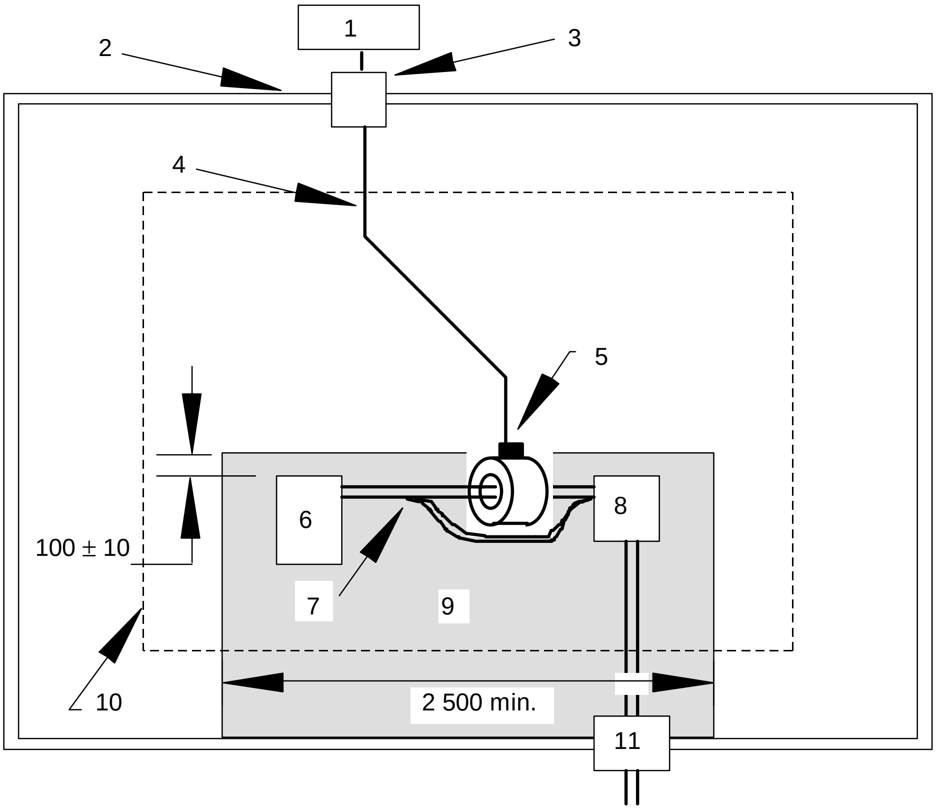
12 Limits for conducted disturbances from components

12.1 Limits for power leads

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.

12.2 Limits for control/signal lines

The limits for r.f. currents on control/signal lines are given in table 8 (broadband) and table 9 (narrowband).



Dimensions in millimetres

1 Measuring instrument (allowed in shielded enclosure if ambient requirement is met)
2 Shielded enclosure
3 Bulkhead connector
4 Double-shielded coaxial cable
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
8 Artificial network
9 Test bench - 2 500 mm long by 900 mm high
10 Typical r.f. absorber (optional)
11 Filter to power supply

Figure 10 – Conducted emissions – Example of test layout for current probe measurements

Table 6 – Limits for broadband conducted disturbances on power input terminals (peak or quasi-peak detector)

Class	Levels in dB(µV)									
	0,15 – 0,3 MHz		0,53 – 2,0 MHz		5,9 – 6,2 MHz		30 – 54 MHz		70 – 108 MHz	
	P[1)]	QP[2)]	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

NOTES

For short duration disturbances, add 6 dB to the level shown in the table.

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

1) Peak

2) Quasi-peak

Table 7 – Limits for narrowband conducted disturbances on power input terminals (peak detector)

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

NOTE – For 87 MHz to 108 MHz, add 6 dB to the level shown in table.

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

Class	Levels in dB(μA)									
	0,15 – 0,3 MHz		0,53 – 2,0 MHz		5,9 – 6,2 MHz		30 – 54 MHz		70 – 108 MHz	
	P [1)]	QP[2)]	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

NOTES

For short duration disturbances, add 6 dB to the level shown in the table.

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

1) Peak

2) Quasi-peak

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

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

NOTE – For 87 MHz to 108 MHz, add 6 dB to the level shown in the table.

13 Radiated emissions from component/module

13.1 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 B.

NOTE – Disturbance to the vehicle on-board receiver can be caused by direct radiation from more than one lead 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.

13.2 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 harness (power and control/signal lines) shall be supported 50 mm above the ground plane by non-conductive material, and arranged in a straight line (see figures 11 and 12).

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. Depending on the intended EUT installation in the vehicle:

– EUT with power return line remotely grounded: two artificial networks are required - one for the positive supply line and one for the power return line;

– EUT with power return line locally grounded: one artificial network is required for the positive supply line.

The EUT shall be wired as in the vehicle (see figures 7 and 8). The measuring port of the artificial mains network shall be terminated with a 50 Ω load.

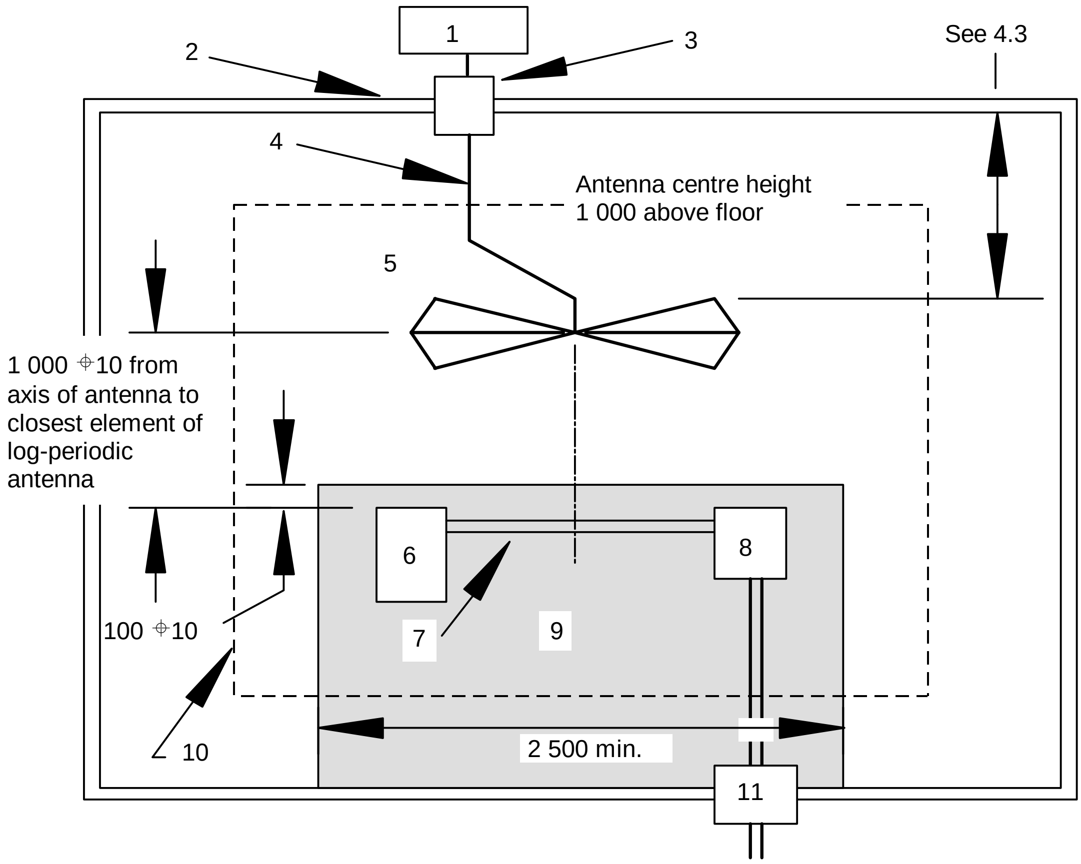
The face of the disturbance source causing the greatest r.f. emission shall be closest to the antenna. Where this face changes with frequency, measurements shall be made in three orthogonal planes, and the highest level at each frequency shall be noted in the test report.

NOTE – If the EUT is small in comparison to the wave length, orientation in three planes may be omitted.

At frequencies above 30 MHz the antenna shall be oriented in horizontal and vertical polarization to receive maximum indication of the r.f. noise level at the measuring receiver. See figures 11 and 12 for further test requirements. The distance between the wiring harness and the antenna shall be (1 000 ± 10) mm. This distance is measured from the centre of the wiring harness to:

- the vertical monopole element; or
- the midpoint of the biconical antenna; or
- the nearest part of the log-periodic antenna.

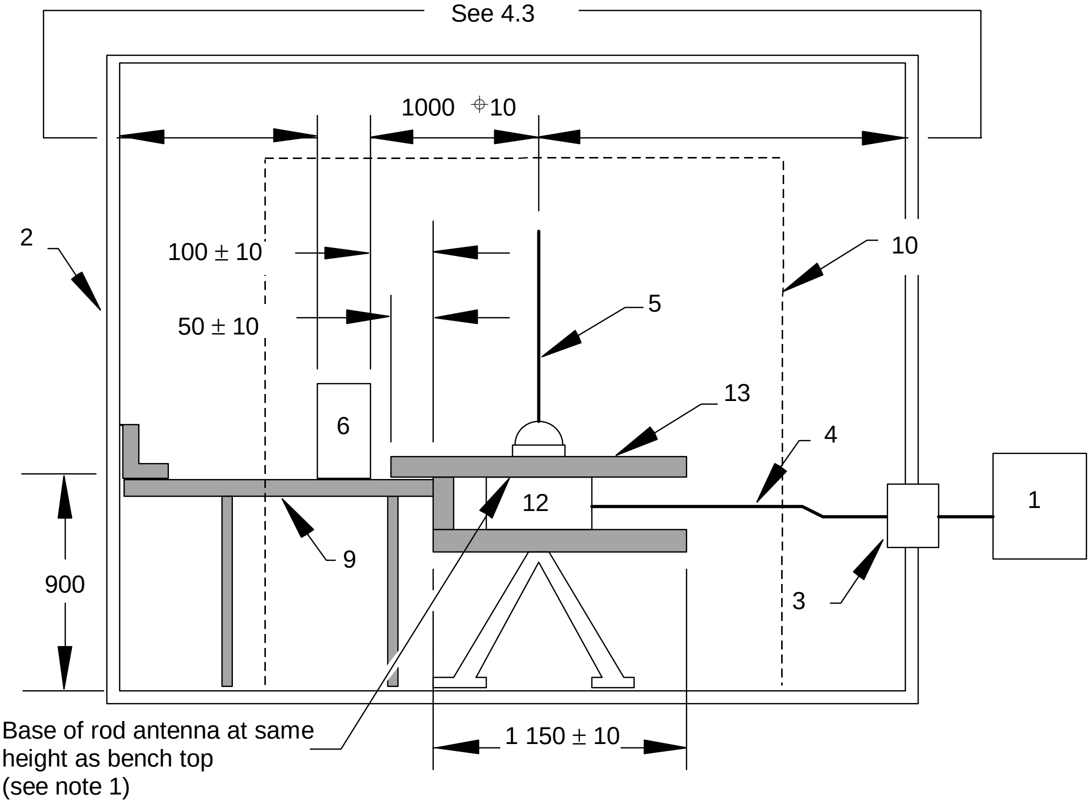
The EUT shall be mounted (100 ± 10) mm from the edge of the test bench as shown in figure 10.



Dimensions in millimetres

1 Measuring receiver
2 ALSE
3 Bulkhead connector
4 Double-shielded coaxial cable
5 Antenna (see 6.5.1)
6 EUT
7 Test harness (1 500 ± 75) mm long (or as specified up to 2000 mm long), (50 ± 5) mm above ground plane.
8 Artificial network(s)
9 Test bench - 2500 mm long by 900 mm high
10 Typical r.f. absorber material
11 Filter to power supply

Figure 11 – Radiated emissions – Example of test layout (general plan view)



Dimensions in millimetres

1 Measuring receiver
2 ALSE
3 Bulkhead connector
4 Double-shielded coaxial cable
5 Antenna (see 6.5.1)
6 EUT
9 Test bench - 2 500 mm long by 900 mm high
10 Typical r.f. absorber material
12 Antenna matching unit
13 Counterpoise - 600 mm by 600 mm typical with full width bond to ground plane

NOTES

1 The preferred location for antenna matching unit is below the counterpoise. As an alternative, the matching unit may be above the counterpoise, but the base of the antenna rod shall be at the height of the bench ground plane.

2 Numbers 7, 8 and 11 not used to maintain numbering scheme used in figure 11.

Figure 12 – Radiated emissions – Example for test layout (side view with monopole antenna)

14 Limits for radiated disturbances from components

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 in dB(µV/m)									
	0,15 – 0,3 MHz		0,53 – 2,0 MHz		5,9 – 6,2 MHz		30 – 54 MHz		70 – 108 MHz 144 – 172 MHz 420 – 512 MHz 820 – 960 MHz	
	P[1)]	QP[2)]	P	QP	P	QP	P	QP	P	QP
1	96	83	83	70	60	47	60	47	49	36
2	86	73	75	62	54	41	54	41	43	30
3	76	63	67	54	48	35	48	35	37	24
4	66	53	59	46	42	29	42	29	31	18
5	56	43	51	38	36	23	36	23	25	12

[1)] Peak

[2)] Quasi-peak

NOTES

1 For short duration disturbances, add 6 dB to the level shown in the table.

2 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 in dB(µV/m)				
	0,15 – 0,3 MHz	0,53 – 2,0 MHz	5,9 – 6,2 MHz	30 – 54 MHz	70 – 108 MHz 144 – 172 MHz 420 – 512 MHz 820 – 960 MHz
1	61	50	46	46	36
2	51	42	40	40	30
3	41	34	34	34	24
4	31	26	28	28	18
5	21	18	22	22	12

NOTE – For 87 MHz to 108 MHz, add 6 dB to the level shown in the table.

15 Radiated emissions from component/module – TEM cell method

15.1 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. For further details, see annex E.

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 r.f. 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 E, table E1, 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.

15.2 Test procedure

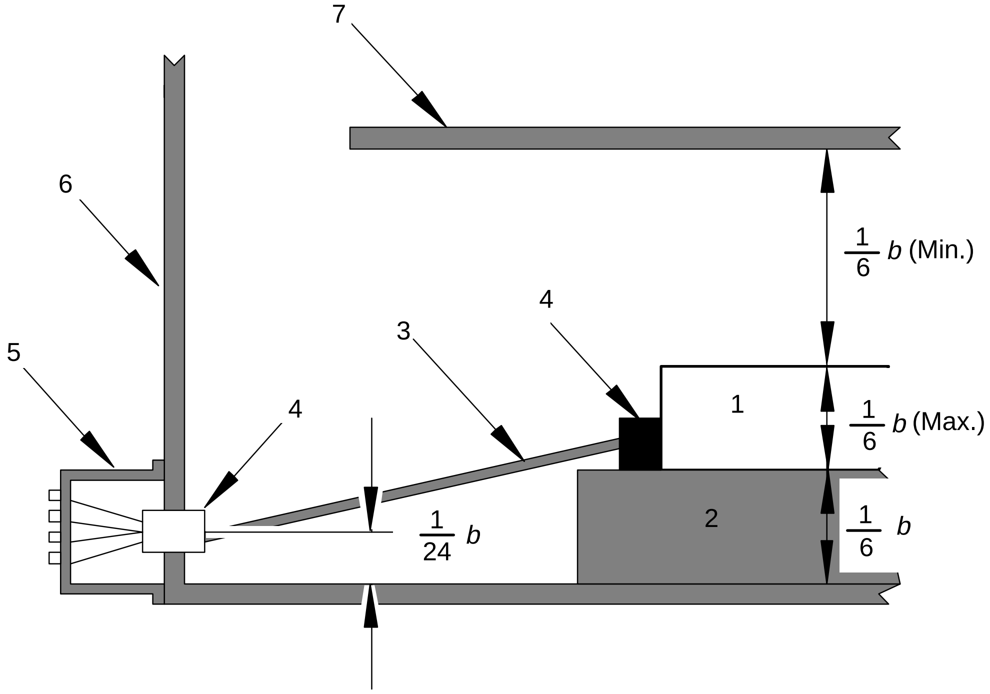
The general arrangement of the EUT, the harness, the filter system at the TEM cell's wall, etc. represents a standardized test condition. Any deviations from the standard test configuration shall be agreed upon prior to testing and recorded in the test report.

The EUT shall be supported *b*/6 (see figure 13) above the TEM cell floor by non-conductive 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 figure 5.

As far as possible, the electrical loop between the EUT and the connector panel shall not be influenced by the connector system at the EUT. Variations of the loop can be balanced with transfer measurements. 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.

The positive supply line shall have an r.f. filter at the TEM cell input. The artificial network (AN) of 6.4.1.2 shall be used. 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.

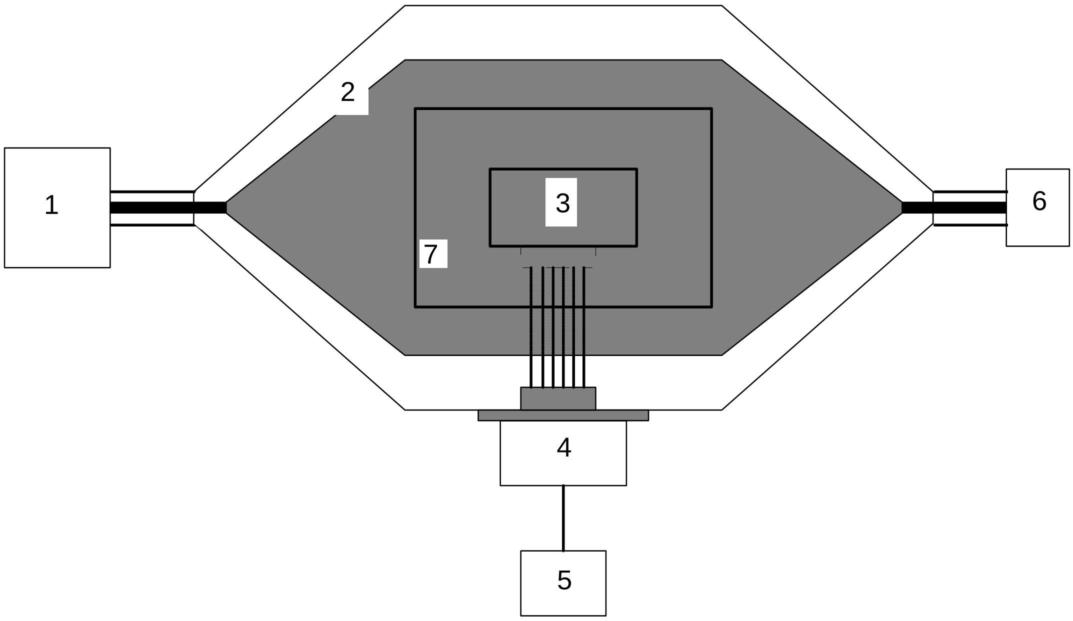


b TEM cell height

1 EUT
2 Dielectric equipment support ($\varepsilon_r \leq 1,4$)
3 Artificial harness (e.g. lead frame)
4 Connectors
5 Connector panel (optional)
6 TEM cell wall
7 Septum

Figure 13 – Example of the arrangement of the connectors, the lead frame and the dielectric support

Figure 14 shows a typical example of a TEM cell method test layout.



1 Measuring instrument
2 TEM cell
3 EUT
4 AN (see 6.4.1)
5 Power supply
6 50 Ω termination resistor
7 Dielectric equipment support

Figure 14 – Example of the TEM cell method test layout

16 Limits for radiated disturbances from components – TEM cell method (both the lead frame and EUT and the EUT-only methods)

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

The limits of the radiated electromagnetic energy may be different for each disturbance source and arrangement (coupling between antenna and electronic equipment in the vehicle). The class from table 12 for each applicable band in table 13 shall be selected by the vehicle manufacturer and the component supplier, and documented in the test plan. For continuous emitters, it is recommended to use class 5 in bands E and F. The class 6 and 7 limits are used for special protection cases.

Table 12 – Disturbance limits

Class	Levels dB(μV)
0	User defined
1	60
2	50
3	40
4	30
5	20
6	10
7	0

Table 13 – Frequency bands

Band	Frequency (MHz)
A	0,15 - 0,3
B	0,53 - 2,0
C	5,90 - 6,2
D	30,0 - 54,0
E	70,0 - 108,0
F	144,0 - 172,0
G	User defined
H	User defined

NOTES

1 The limits in table 12 are for narrowband measurements (peak, and quasi-peak detector) and continuous emitters.

2 For broadband measurements with quasi-peak detector add 10 dB and with peak detector add 23 dB to the levels in table 12.

3 For broadband measurements of short duration disturbances with quasi-peak detector add 16 dB to the levels in table 12, for similar peak measurements add 29 dB.

4 Levels in table 12 were established by application of engineering judgment to empirical values obtained from national testing.

17 Limits for disturbances radiated from integrated circuit – TEM cell method

Under consideration.

Annex A
(normative)

Antenna matching unit – Vehicle test

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

The requirements for the measurement equipment are defined in 5.2.1.

A.2 Antenna matching unit – Calibration

The artificial antenna network of figure A1 is used to represent the antenna including the coaxial cable. The 60 pF capacitor represents the capacitance of the coaxial cable between the vehicle antenna and the input of the vehicle radio.

A.2.1 Gain measurement

The antenna matching unit shall be measured to determine whether its gain meets the requirements of 5.2.1.1 using the test arrangement shown in figure A1.

A.2.2 Test procedure

1) Set the signal generator to the starting carrier frequency with 1 000 Hz, 30 % amplitude modulation and 40 dB(μV) output level.

2) Plot the gain curve for each frequency segment.

A.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 to 1).

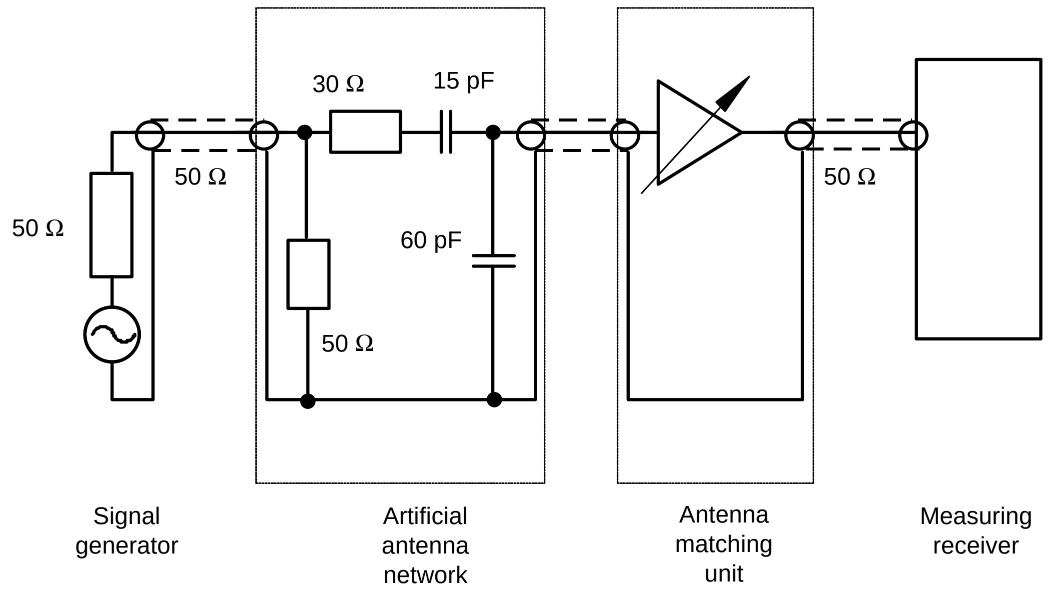


Figure A.1 – Calibration set-up

Annex B
(informative)

Calibration procedure for shielded enclosure for component testing

B.1 Shielded enclosure reflection test and calibration procedure

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

B.2 Standard noise source

A standard noise source with defined output characteristics shall be used for calibration purposes. A calibration 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, calibration harness, artificial mains network, etc.

B.3 Standard noise source characteristics

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

B.4 Calibration procedure

Arrange the standard noise source in place of the EUT in the test set-up shown in figures 11 and 12. The noise source shall be attached to the artificial mains 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 C
(informative)

Current probe requirements

C.1 General information

An r.f. current probe is a clamp-on type r.f. current transformer used as a transducer with a calibrated EMI meter (receiver), oscilloscope, or other voltage-sensitive instrument to determine the intensity of r.f. current present in an electrical conductor or cable.

Direct connection to a conductor is not required. The probe is clamped around the test conductor which then becomes a one-turn primary with the probe as a multi-turn secondary.

The design of the core of the probe must be such that it will not saturate under the most severe current which will be contained within the bundle it is measuring. Core saturation will produce erroneous readings as long as the core remains in the saturated condition.

C.2 Electrical characteristics

a) circuit:	current transformer;
b) transfer impedance:	see C.3;
c) frequency range:	0,15 MHz to 108 MHz;
d) saturation current:	saturation shall not occur at 1,25 times the maximum expected current;
e) maximum primary voltage:	subject to cable insulation;
f) rated output load impedance:	(50 + j0) Ω;
g) output connector:	coaxial;
h) window size:	adequate for the cable to be tested.

C.3 Transfer impedance

The r.f. current in microamperes (I_p) in a conductor under test is determined from the electromagnetic disturbance meter reading of the current probe output in microvolts (E_s) divided by the current probe transfer impedance (Z_t), or,

$$I_p = E_s / Z_t$$

The transfer impedance in Ω of the current probe throughout the frequency range is determined by passing a known r.f. current I_p through the primary test conductor and noting the voltage E_s developed across a 50 Ω load. Then:

$$Z_t = E_s / I_p$$

C.4 Transfer factor

For practical reasons, the term "transfer admittance" is frequently used instead of transfer impedance. The logarithm of transfer admittance is:

$$y_t\,[\mathrm{dB}(1/\Omega)] = 20\,\lg\,Y_t = 20\,\lg\,(1/Z_t)$$

Current in dB(μA) is obtained from the voltage level in dB(μV) from the following formula:

$$I\,[\mathrm{dB}(\mu\mathrm{A})] = V[\mathrm{dB}(\mu\mathrm{V})] + y_t\,[\mathrm{dB}(1/\Omega)]$$

Annex D
(informative)

Notes on the suppression of disturbance

D.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. 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 automobile receiver.

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.

D.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.

D.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.

D.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 of vehicle.

D.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).

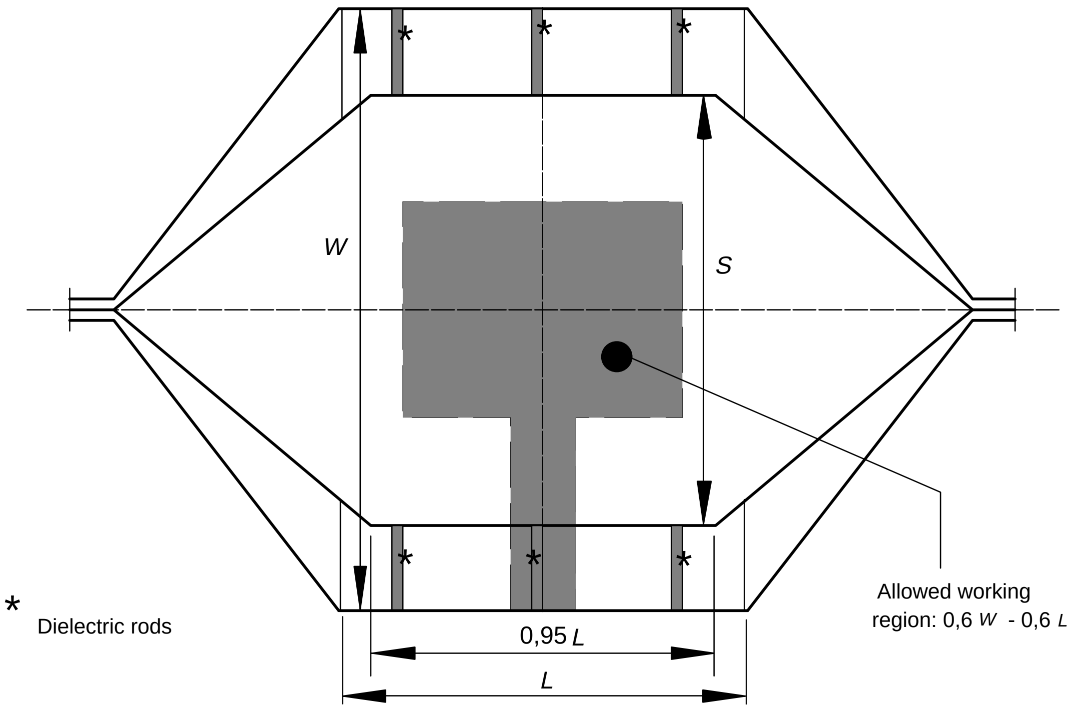
D.6 Reference document

CISPR 20: 1990, *Limits and methods of measurement of immunity characteristics of sound and television broadcast receivers and associated equipment*

Annex E
(informative)

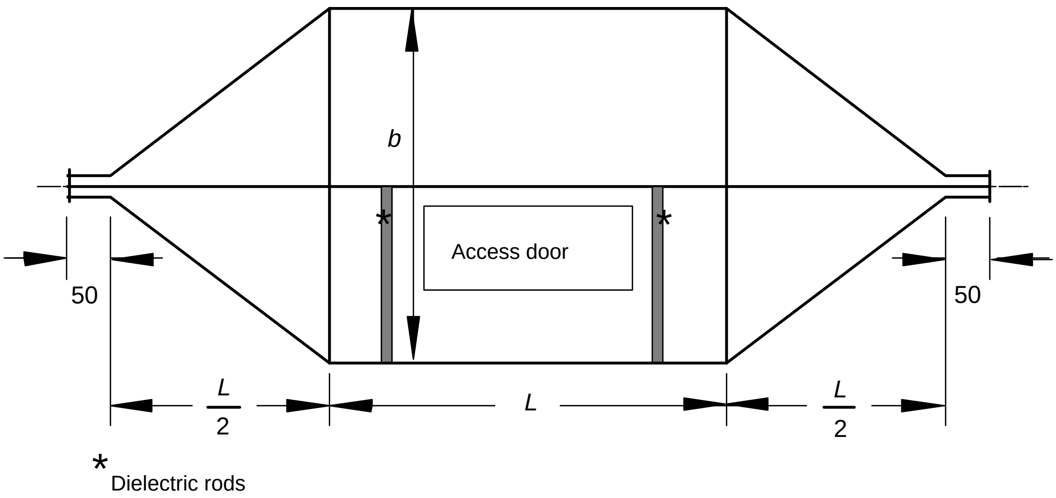
TEM cell dimensions

The dimensions for designing a rectangular TEM cell are shown in figures E.1 and E.2 and in table E.1



Dimensions in millimetres

Figure E.1 – TEM cell – Horizontal section view at septum



Dimensions in millimetres

Figure E.2 – TEM cell – Vertical section view at septum

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

Table E.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	1200	1000
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 F
(informative)

Artificial network schematic

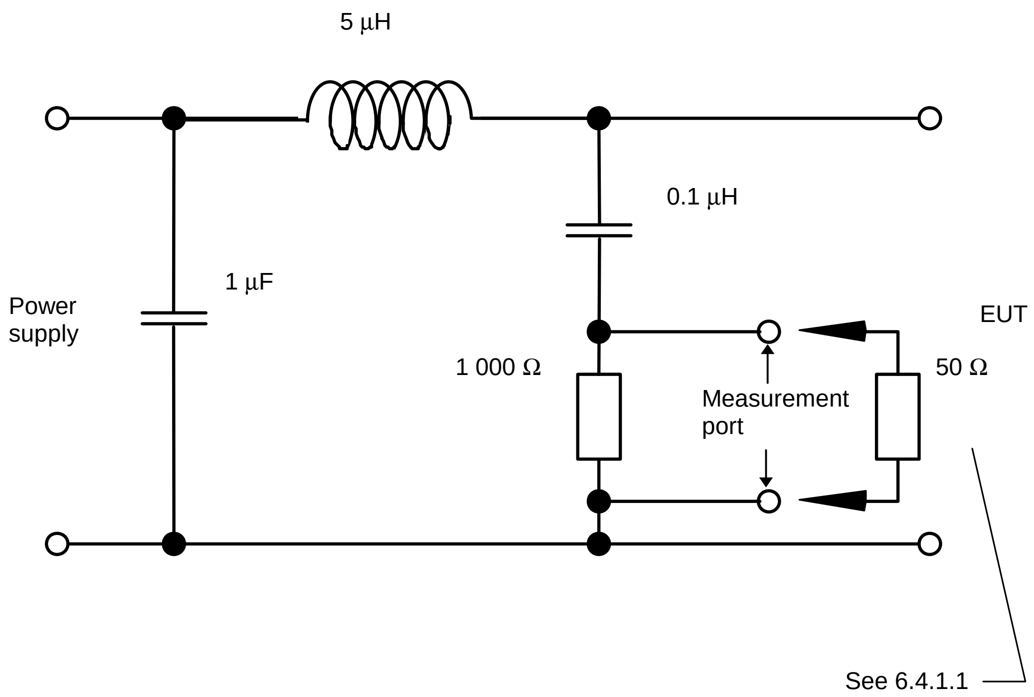


Figure F.1 – Example of 5 µH AN schematic
