INTERNATIONAL STANDARD

ISO 11452-8

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Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy —

Part 8: **Immunity to magnetic fields**

Véhicules routiers — Méthodes d'essai d'un équipement soumis à des perturbations électriques par rayonnement d'énergie électromagnétique en bande étroite —

Partie 8: Méthodes d'immunité aux champs magnétiques

Reference number
ISO 11452-8:2007(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11452-8 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

ISO 11452 consists of the following parts, under the general title *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy*:

— *Part 1: General principles and terminology*

— *Part 2: Absorber-lined shielded enclosure*

— *Part 3: Transverse electromagnetic mode (TEM) cell*

— *Part 4: Bulk current injection (BCI)*

— *Part 5: Stripline*

— *Part 7: Direct radio frequency (RF) power injection*

— *Part 8: Immunity to magnetic fields*

The following parts are under preparation:

— *Part 9: Portable transmitters*

— *Part 10: Conducted immunity in the extended audio frequency range*

— *Part 11: Radiated immunity test method using a reverberation chamber*

Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy —

Part 8:
Immunity to magnetic fields

1 Scope

This part of ISO 11452 specifies tests for the electromagnetic immunity of electronic components for passenger cars and commercial vehicles, regardless of the propulsion system (e.g. spark-ignition engine, diesel engine, electric motor), to magnetic fields generated by power transmission lines and generating stations and some powerful electrical equipment, such as motors. To perform this test, the device under test (DUT) is exposed to a magnetic disturbance field.

The radiating loop method can be applied to small DUTs or to larger DUTs by positioning the coil in multiple locations.

The Helmholtz coil is sometimes used as an alternative method. This technique is limited by the relationship between the size of the DUT and the size of the coils.

The electromagnetic disturbances considered in this part of ISO 11452 are limited to continuous narrowband electromagnetic fields.

Immunity measurements of complete vehicles can generally only be carried out by the vehicle manufacturer for reasons including the high cost of an absorber-lined shielded enclosure preserving the secrecy of prototypes or the large number of different vehicle models. Consequently, for research, development and quality control, a laboratory measuring method is used by the vehicle manufacturer and equipment suppliers to test electronic components.

ISO 11452-1 specifies general test conditions, definitions, practical use and basic principles of the test procedure.

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.

ISO 11452-1, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

3 Test conditions

3.1 General

The applicable frequency range of this test method is 15 Hz to 150 kHz.

The users shall specify the test severity level(s) over the frequency range. Suggested test severity levels are included in Annex A.

Standard test conditions are given in ISO 11452-1 for the following:

— test temperature;

— supply voltage;

— dwell time;

— definition of test severity levels.

3.2 Frequency step sizes

The tests shall be conducted at the following frequencies: 16,67 Hz, 50 Hz, 60 Hz, 150 Hz and 180 Hz and with frequency step sizes (logarithmic or linear) not greater than those specified in Table 1. The step sizes agreed upon by the users of this part of ISO 11452 shall be documented in the test report.

Table 1 — Maximum frequency steps sizes

Frequency band kHz	**Linear steps** kHz	**Logarithmic steps** %
0,015 to 0,1	0,01	10
0,1 to 1	0,1	10
1 to 10	1	10
10 to 150	10	10

NOTE The 5th harmonic of 16,67 Hz, 50 Hz and 60 Hz can also be tested.

If it appears that the susceptibility thresholds of the DUT are very near to the chosen test level, these frequency step sizes should be reduced in the frequency range concerned in order to find the minimum susceptibility thresholds.

4 Test location

A shielded room is not required.

IMPORTANT — The appropriate guidelines (national regulation, ICNIRP[3], etc.) shall be followed for the protection of the test personnel.

5 Test apparatus description and specification

5.1 General

The test apparatus shall consist of the following:

— field generating device(s): radiating loop or Helmholtz coil;

— magnetic field intensity monitor;

— low frequency (LF) generator;

— low frequency (LF) amplifier (capable of driving inductive load);

- voltmeter;
- current monitor;
- artificial network(s) (AN) (optional, see ISO 11452-4 for characteristics).

5.2 Field generating device

5.2.1 Radiating loop

The radiating loop of MIL STD 461E[2] is recommended, but any similar coil may be used. The MIL STD 461E coil has the following characteristics:

- diameter: 120 mm
- number of turns: 20
- wire: approx. 2,0 mm (AWG12)

The magnetic flux density at a distance of 50 mm from the plane of the loop is given by Equation (1):

$$B = \mu_0 H = 9{,}5 \times 10^{-5}\, I \tag{1}$$

The unperturbed magnetic field at a distance of 50 mm from the plane of the loop is given by Equation (2):

$$H = 75{,}6\, I \tag{2}$$

The radiating loop should be characterized over the frequency range. Non-linear characteristics shall be considered in determining the calculated current value for the DUT test.

5.2.2 Helmholtz coil

Ideally, Helmholtz coils set up a region of uniform magnetic fields. The primary usage of the coils is to expose the DUT to a uniform magnetic field.

The radius of the coils is determined by the size of the DUT. In order to obtain a uniform magnetic field (± 10 %), the relationship between the coils and the DUT should be met, as shown in Figure 3. The uniform field region shown in Figure 3 should be a minimum of 300 mm × 300 mm × 300 mm.

For a pair of Helmholtz coils spaced one radius apart, the magnetic flux density at the centre of the system is given by Equation (3):

$$B = \mu_0 H = \frac{8{,}992 \times 10^{-7}\, NI}{R} \tag{3}$$

where

B is the magnetic flux density, in tesla;

N is the number of wire turns on the coil;

R is the coil radius, in metres;

I is the coil current, in amperes;

H is the magnetic field, in amperes per metre;

μ_0 is the magnetic constant, permeability of the vacuum, in henry per metre.

The unperturbed magnetic field, H, at the centre of the system is given by Equation (4):

$$H = \frac{0{,}715\,5 \times NI}{R} \tag{4}$$

The current-carrying capability and number of turns of the coils should be selected such that the test specification can be met.

The coils shall not have a self-resonant frequency at or lower than the upper frequency of 150 kHz.

The Helmholtz coil should be characterized over the frequency range.

5.3 Current monitor

The current monitor shall ensure that true RMS current measurement is made within the frequency range 15 Hz to 150 kHz, either by using a clamp-on probe or by measuring voltage across a shunt resistor.

An oscilloscope, a true RMS a.c. voltmeter or a true RMS a.c. current meter may be used.

5.4 Magnetic field intensity monitor

For the radiating loop method, the magnetic field intensity monitor shall be a loop sensor having the following specifications:

— diameter: 40 mm

— number of turns: 51

— wire: approx. 0,071 mm (7 strand 41 AWG)

— shielding: electrostatic

— correction factor: see manufacturer's data for factor to convert sensor coil voltage to magnetic intensity.

The open-circuit voltage, U, measured in volts by means of a high-impedance voltmeter, is induced in the loop sensor and is calculated as shown in Equation (5):

$$U = 2 \times \pi \times f \times N \times A \times B$$

where

f is the frequency, in hertz;

N is the number of wire turns in the coil;

A is the cross-sectional area of the coil, in square metres, calculated with the average diameter of the coil;

B is the magnetic flux density, in tesla.

A typical magnetic field intensity monitor should be capable of measuring a magnetic field intensity of at least 1 000 A/m across the frequency range 15 Hz to 150 kHz.

5.5 Stimulation and monitoring of the DUT

If required in the test plan, the DUT shall be operated by actuators which have minimum effect on the electromagnetic characteristics, e.g. plastic blocks on the push buttons or pneumatic actuators with plastic tubes.

Connections to equipment monitoring electromagnetic interference reactions of the DUT may be accomplished by using fibre optics or high-resistance leads. Other types of leads may be used but require extreme care to minimize interactions. The orientation, length and location of such leads shall be carefully documented to ensure repeatability of test results.

Any electrical connection of monitoring equipment to the DUT may cause malfunction of the device. Extreme care shall be taken to avoid such an effect.

6 Test set-up

6.1 General

The test area should be of a suitable size to house all of the required test equipment and shall be free from disturbances that may affect the test results. The magnetic field generator (radiating loop or Helmholtz coil) should be at least 2 m away from the test apparatus. The magnetic field generator shall be maintained at a minimum of 1 m from metal surfaces parallel to the plane of the coil(s).

IMPORTANT — The appropriate guidelines (national regulation, ICNIRP[3], etc.) shall be followed for the protection of the test personnel.

6.2 Power supply

The power supply of ISO 11452-1 shall be used.

6.3 Location of the test harness

The test harness should be designed in order to minimize different coupling effects inside the harness (e.g. twisted pairs) and to minimize interference to the load box and power supply. The test harness shall be placed on a non-conductive, low permeability support.

6.4 Radiating loop method

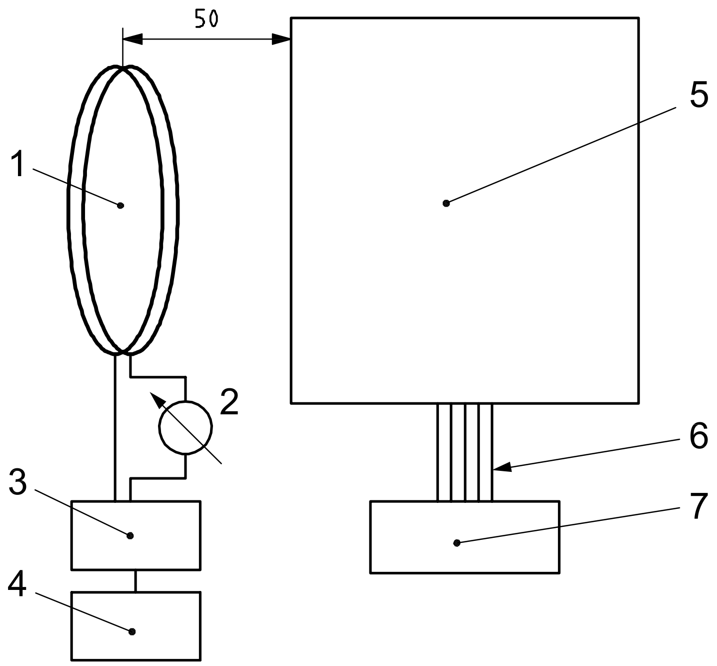
The test configuration should be as shown in Figure 1.

Each face of the DUT shall be partitioned into equal areas of 100 mm × 100 mm or less. The radiating loop shall be positioned 50 mm from the centre of each of these areas and parallel to the face of the DUT.

In addition, the radiating loop shall be placed at each electrical interface connector and at any attached magnetic sensor(s). The radiating loop shall be placed so that maximum coupling occurs between it and any attached magnetic sensor(s).

All wires in the harness shall be terminated or open according to the vehicle application. If possible, the actual loads and actuators shall be used.

Dimensions in millimetres



Key

1 radiating loop
2 current monitor
3 LF amplifier
4 LF generator
5 DUT
6 wiring harness
7 peripheral

Figure 1 — Radiating loop configuration

6.5 Helmholtz coil method

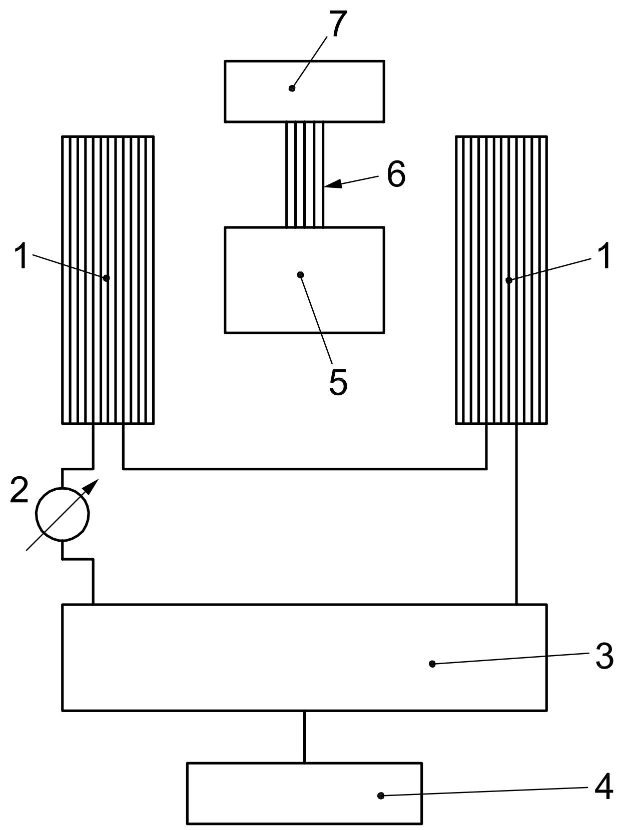
The test configuration should be as shown in Figures 2 and 3.

The DUT shall be positioned in one of its three principal axes (X, Y and Z) on a non-conducting, low permeability ($\mu_r \approx 1$) material into the uniform field region of the Helmholtz coil.

The wiring harness of the DUT shall be routed vertically down and then away from the coils to the support/monitoring equipment.

All wires in the harness shall be terminated or open according to the vehicle application. If possible, the actual loads and actuators shall be used.

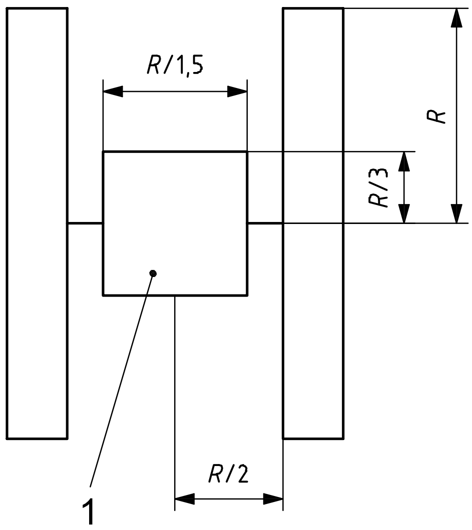
Power may be applied to the DUT via a 5 μH/50 Ω artificial network.



Key

1 coil
2 current monitor
3 LF amplifier
4 LF generator
5 DUT or magnetic field meter (for characterization or verification)
6 wiring harness
7 peripheral

Figure 2 — Test set-up



Key

1 uniform field region

R coil radius

Figure 3 — Helmholtz coil configuration

7 Test procedure

7.1 General

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

The DUT shall be made to operate under typical loading and other conditions as in the vehicle. These operating conditions shall be clearly defined in the test plan to ensure that the test is repeatable.

For the radiating loop method, the DUT test points shall be defined in the test plan.

For the Helmholtz coil method, the orientations (X, Y and Z axes) of the DUT for the test shall be defined in the test plan.

7.2 Test plan

Prior to performing the tests, a test plan shall be generated which shall include the following:

— test method;

— test set-up;

— test points for the radiating loop method;

— DUT axes for the Helmholtz coil method;

— specific test frequencies and frequency range;

— DUT mode of operation;

- DUT acceptance criteria;
- DUT monitoring conditions;
- definition of test severity levels;
- test report content;
- any special instructions and changes from the standard.

Every DUT shall be tested under the most significant conditions, i.e. at least in stand-by mode and in a mode where all functions can be excited.

7.3 Test method

CAUTION — Caution shall be exercised when operating high-power amplifiers to avoid hazards to the apparatus. Apparatus in the near vicinity of the coils shall be shielded to prevent interference from magnetic fields.

NOTE Most apparatus shielding is not effective for magnetic fields.

7.3.1 Radiating loop method

7.3.1.1 General

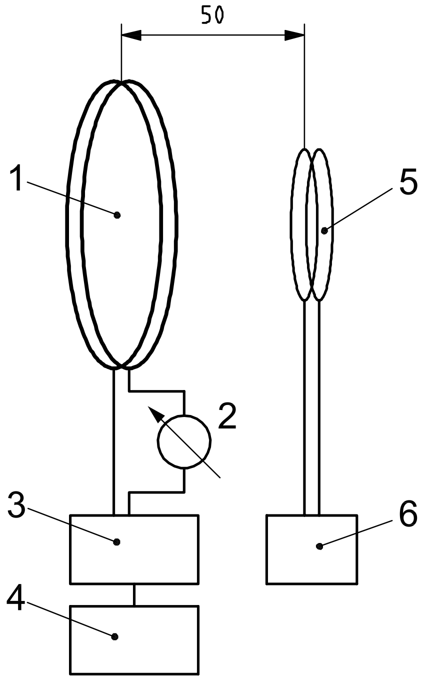
The radiating loop method is based on the use of coil current as the reference parameter for verification and testing.

7.3.1.2 Verification of field strength (substitution method)

Prior to the actual test with the DUT present, the coil current required to generate a specific field strength (measured with a magnetic field intensity monitor) shall be determined at one frequency, e.g. 1 kHz.

Connect the set-up according to Figure 4.

Dimensions in millimetres



Key

1 radiating loop
2 current monitor
3 LF amplifier
4 LF generator
5 sensor coil
6 high-impedance voltmeter

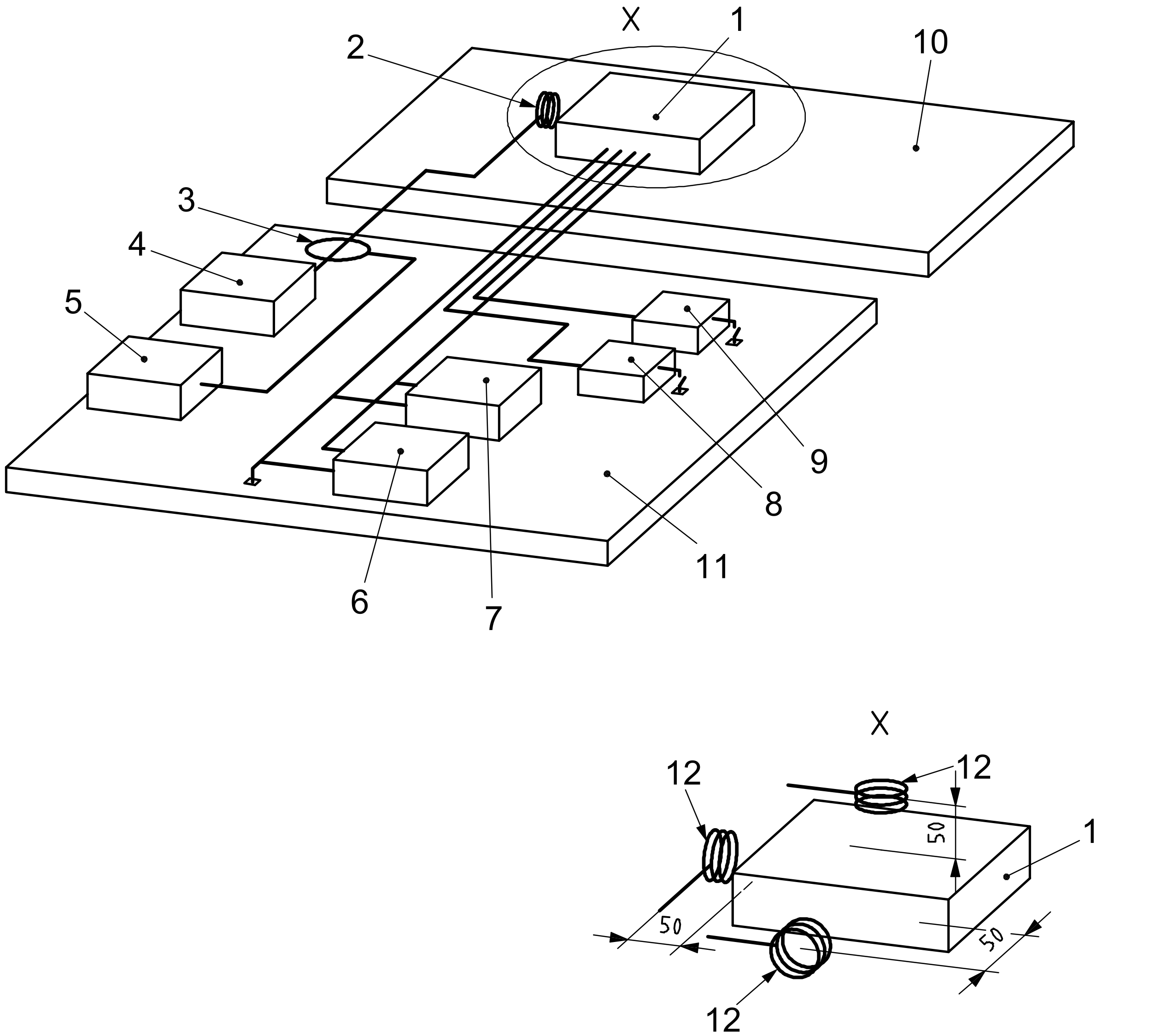
Figure 4 — Radiating loop verification

7.3.1.3 DUT test

The test is conducted by subjecting the DUT to the test signal based on the calculated value as defined in the test plan.

The test set-up should be as shown in Figure 5.

Dimensions in millimetres



Key

1 DUT
2 radiating loop
3 current probe
4 generator and amplifier
5 oscilloscope
6 power supply
7 battery
8 sensors
9 actuators
10 insulating support
11 ground plane (if required in the test plan)
12 three orthogonal positions (see 6.4)

Figure 5 — Radiating loop test set-up

7.3.1.4 Procedure

Place the radiating coil 50 mm from a test point on the operating DUT (see Figure 1).

Generate the defined magnetic field levels from the calculated values (see 5.2.1).

At each frequency, expose the DUT for a minimum of 1 s.

Monitor the DUT and record the respective field intensity for

a) malfunction,

b) degradation of performance, or

c) deviation from predefined tolerances.

Repeat the above steps for the other test points of the DUT.

7.3.2 Helmholtz coil method

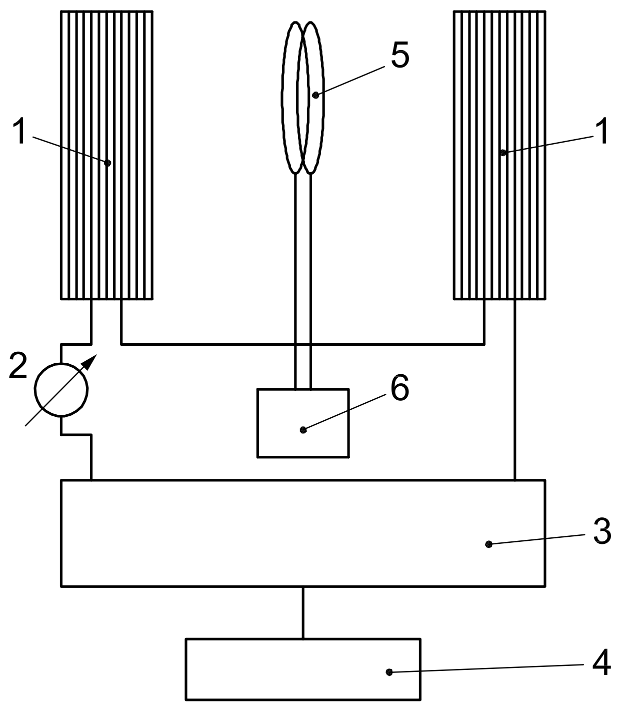
7.3.2.1 General

The Helmholtz coil method is based upon the use of coil current as the reference parameter for verification and testing.

7.3.2.2 Verification (substitution method)

Prior to the actual test with the DUT present, the coil current required to generate a specific field strength (measured with a magnetic field intensity monitor) shall be determined for each frequency.

Connect the set-up according to Figure 6.



Key

1 coil(s)

2 current monitor

3 LF amplifier

4 LF generator

5 sensor coil

6 high-impedance voltmeter

Figure 6 — Helmholtz coil verification

7.3.2.3 DUT test

The test is conducted by subjecting the DUT and the associated harness to the test signal based on the calculated value as predetermined in the test plan.

7.3.2.4 Procedure

Place the operating DUT in the uniform field region of the Helmholtz coil (see Figure 3).

Generate the desired magnetic field levels from the calculated values. At each frequency, expose the DUT for a minimum of 1 s. Monitor the DUT and record the respective magnetic field intensity for

a) malfunction,

b) degradation of performance, or

c) deviation from predefined tolerances.

Repeat the above steps for the other two orientations (X, Y or Z axes) of the DUT.

7.4 Test report

As required in the test plan, a test report shall be submitted detailing information regarding the test equipment, test area, systems tested, frequencies, test levels, system interactions and any other relevant information regarding the test.

Annex A
(informative)

Function performance status classification (FPSC) and test severity levels

A.1 General

This annex gives examples of test severity levels which should be used in line with the principle of functional performance status classification (FPSC) described in ISO 11452-1.

A.2 Classification of test severity levels

A.2.1 General

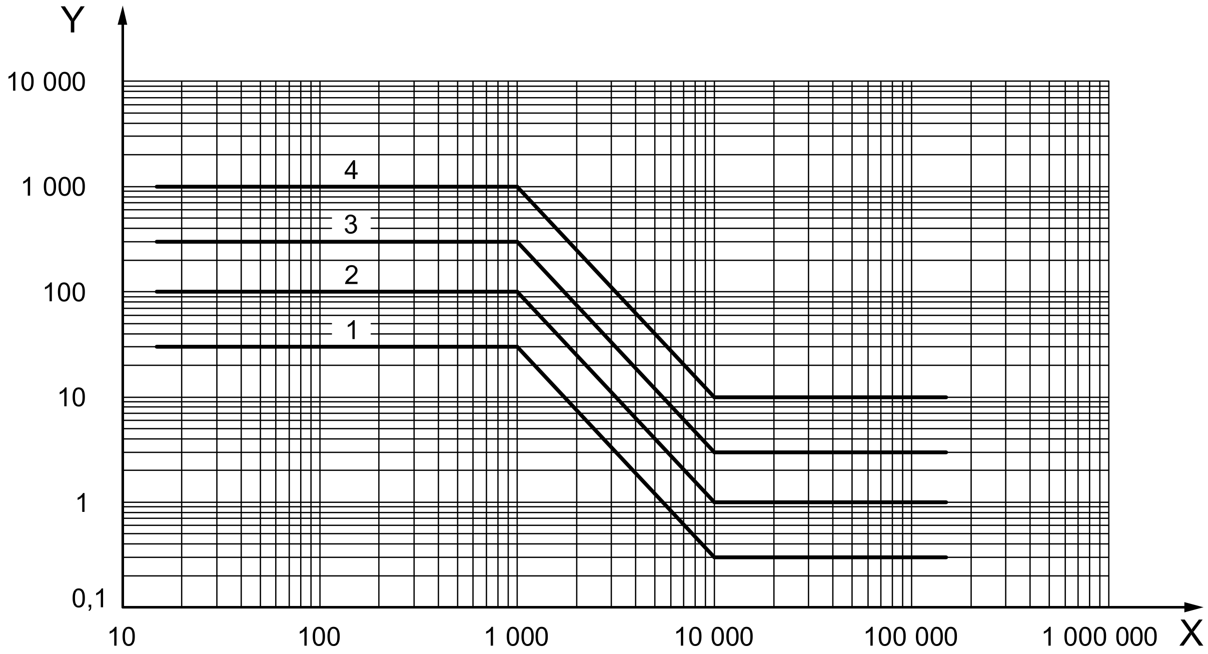
The suggested minimum and maximum severity levels are given in Tables A.1 and A.2 and in Figures A.1 and A.2.

A.2.2 Internal field

The suggested levels are given in Table A.1 and Figure A.1.

Table A.1 — Suggested test severity levels (internal field)

Frequency band Hz	**Test level 1** A/m	**Test level 2** A/m	**Test level 3** A/m	**Test level 4** A/m	**Test level 5** A/m
15 to 1 000	30	100	300	1 000	Specific value agreed between the users of this part of ISO 11452
1 000 to 10 000	$30/(f/1\,000)^2$	$100/(f/1\,000)^2$	$300/(f/1\,000)^2$	$1\,000/(f/1\,000)^2$	
10 000 to 150 000	0,3	1	3	10	



Key

X frequency (Hz)
Y magnetic field (A/m)
1,2,3,4 test severity levels (see Table A.1)

Figure A.1 — Test severity levels and frequency bands (internal field)

A.2.3 External field

The suggested levels are given in Table A.2 and Figure A.2.

Table A.2 — Suggested test severity levels (external field)

<table>
<tr><th>Frequency band
Hz</th><th>Test level 1
A/m</th><th>Test level 2
A/m</th><th>Test level 3
A/m</th><th>Test level 4
A/m</th><th>Test level 5
A/m</th></tr>
<tr><td>15 to 60</td><td>30</td><td>100</td><td>300</td><td>1 000</td><td rowspan="6">Specific value agreed between the users of this part of ISO 11452</td></tr>
<tr><td>60 to 180</td><td>30/(f/60)</td><td rowspan="2">100/(f/60)</td><td rowspan="3">300/(f/60)</td><td rowspan="4">1 000/(f/60)</td></tr>
<tr><td>180 to 600</td><td rowspan="4">10</td></tr>
<tr><td>600 to 1 800</td><td rowspan="3">10</td></tr>
<tr><td>1 800 to 6 000</td><td rowspan="2">10</td></tr>
<tr><td>6 000 to 150 000</td><td>10</td></tr>
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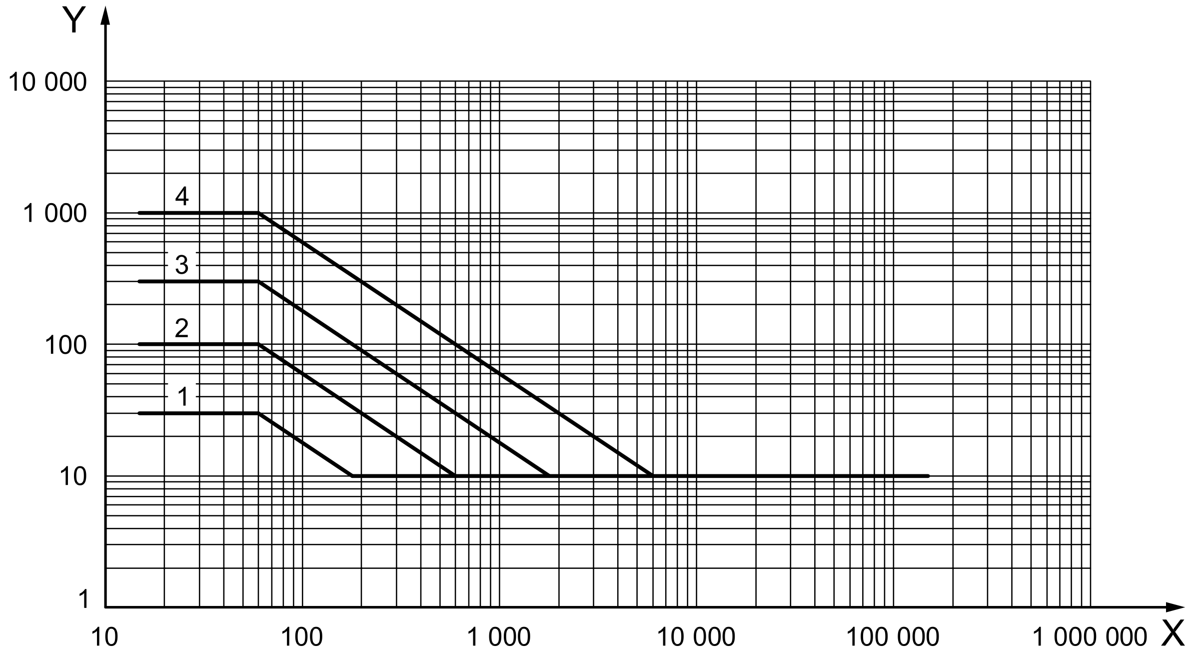

Key

X frequency (Hz)
Y magnetic field (A/m)
1,2,3,4 test severity levels (see Table A.2)

Figure A.2 — Test severity levels and frequency bands (external field)

A.3 Example of FPSC application using test severity levels

An example of severity levels is given in Table A.3. This table can be different for internal and external fields (levels from Tables A.1 and A.2).

Table A.3 — Example of test severity levels with FPSC application

	Category 1	**Category 2**	**Category 3**
$\mathbf{L_{4i}}$	Level 3	Level 3	Level 4
$\mathbf{L_{3i}}$	Level 2	Level 3	Level 3
$\mathbf{L_{2i}}$	Level 1	Level 2	Level 2
$\mathbf{L_{1i}}$	Level 1	Level 1	Level 2

Bibliography

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

[2] MIL STD 461E:1999, *Department of Defense Interface Standard; Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*

[3] *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)*. Health Physics **74** (4): pp. 494-522, 1998

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