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Road vehicles — Electrical disturbances by narrowband radiated electromagnetic energy — Component test methods —

Part 3:
Transverse electromagnetic mode (TEM) cell

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Véhicules routiers — Perturbations électriques par rayonnement d'énergie électromagnétique en bande étroite — Méthodes d'essai d'un composant —

Partie 3: Cellule TEM

Reference number
ISO 11452-3:1995(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.

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.

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

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

— *Part 1: General and definitions*

— *Part 2: Absorber-lined chamber*

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

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

— *Part 5: Stripline*

— *Part 6: Parallel plate antenna*

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

Annex A forms an integral part of this part of ISO 11452. Annexes B and C are for information only.

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Road vehicles — Electrical disturbances by narrowband radiated electromagnetic energy — Component test methods —

Part 3:
Transverse electromagnetic mode (TEM) cell

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1 Scope

This part of ISO 11452 specifies transverse electromagnetic mode (TEM) cell test methods and procedures for testing 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). The electromagnetic disturbances considered in this part of ISO 11452 are limited to continuous narrowband electromagnetic fields.

This test can be used for two purposes:

— testing the immunity of the component with the field coupling to the wiring harness;

— testing the immunity of the component by itself with minimum exposure to the wiring harness.

Immunity measurements of complete vehicles are generally only possible by the vehicle manufacturer. The reasons, for example, are the high costs of an absorber-lined chamber, preserving the secrecy of prototypes or the large number of different vehicle models. Therefore, for research, development and quality control a laboratory measuring method is used by the manufacturer.

Part 1 of ISO 11452 gives general information, definitions, practical use and basic principles of the test procedure.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 11452. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 11452 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7637-1:1990, *Road vehicles — Electrical disturbance by conduction and coupling — Part 1: Passenger cars and light commercial vehicles with nominal 12 V supply voltage — Electrical transient conduction along supply lines only.*

ISO 7637-2:1990, *Road vehicles — Electrical disturbance by conduction and coupling — Part 2: Commercial vehicles with nominal 24 V supply voltage — Electrical transient conduction along supply lines only.*

ISO 11452-1:1995, *Road vehicles — Electrical disturbances by narrowband radiated electromagnetic energy — Component test methods — Part 1: General and definitions.*

3 Test conditions

3.1 Test temperature and supply voltage

The ambient temperature during the test shall be (23 ± 5) °C.

The supply voltage during the test shall be (13,5 ± 0,5) V for 12 V electrical systems and (27 ± 1) V for 24 V electrical systems.

If other values are agreed by the users of this part of ISO 11452, the values shall be documented in the test report.

3.2 Frequency range

The upper frequency range of the TEM cell is a direct function of the TEM cell dimensions.

For testing automotive electronic systems it is recommended to use a TEM cell from 0,01 MHz to 200 MHz.

NOTE 1 The dimensions for the suggested TEM cells are given in table B.1 in annex B.

3.3 Modulation

The device under test determines the type and frequency of modulation. If no values are agreed between the users of this part of ISO 11452, the following shall be used:

— no modulation (CW);

— 1 kHz sine-wave amplitude modulation (AM) of 80 %.

3.4 Dwell time

At each frequency, the device under test shall be exposed to the test level for the minimum response time needed to control it. In all cases, this minimum time of exposure shall not be less than 2 s.

3.5 Frequency step sizes

All tests in this part of ISO 11452 shall be conducted with frequency step sizes not greater than those specified in table 1.

Alternatively, logarithmic frequency steps, with the same minimum number of frequency steps in each frequency band, may be used. The values, as agreed by the users of this part of ISO 11452 shall be documented in the test report.

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

Table 1 — Frequency step sizes

Frequency band MHz	**Maximum frequency step size** MHz
>0,01 to ≤0,1	0,01
>0,1 to ≤1	0,1
>1 to ≤10	1
>10 to ≤200	2

3.6 Test severity levels

The user should specify the test severity level(s) over the frequency range. Suggested test severity levels are given in annex C.

These test severity levels are expressed in terms of the equivalent root-mean-square value of the unmodulated wave.

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4 Test instrument description and specifications

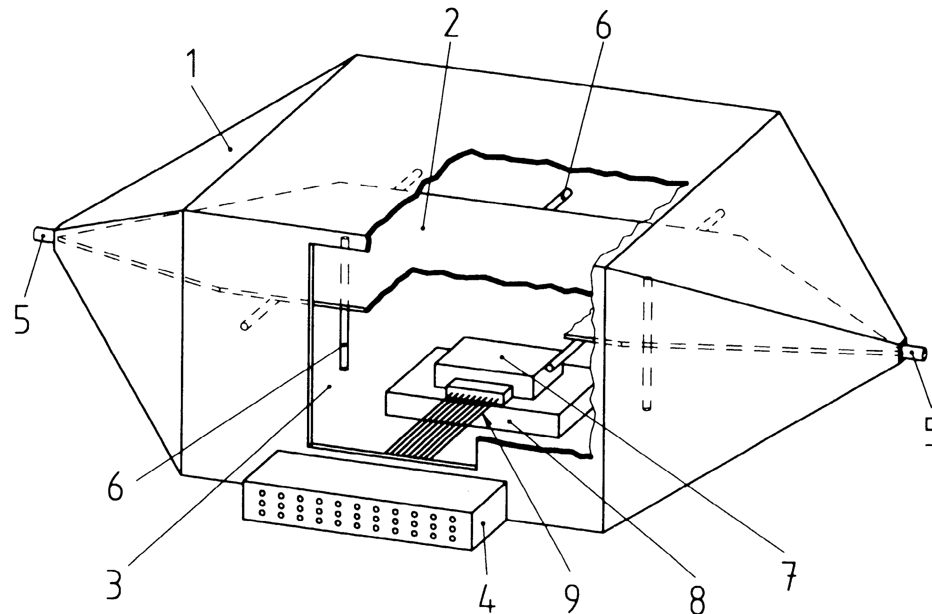
4.1 TEM cell

The TEM cell used in this test method is a rectangular coaxial line with a 50 Ω characteristic impedance as shown in figure 1. The device under test is exposed to a uniform TEM field.

The TEM cell is a laboratory measurement system. It can be used to generate test fields within 2 dB of the theoretical value if the device under test does not occupy an excessive portion of the test volume (see 4.3).

The TEM cell test method cannot be used to determine absolute test field levels, polarization and frequency for device immunity. Only comparative measurements can be performed.

The TEM cell method has the major advantage of not radiating energy into the surrounding space.



Key

1 Outer shield
2 Septum (inner conductor)
3 Access door
4 Connector panel (optional)
5 Coaxial connectors
6, 8 Dielectric supports
7 Device under test
9 Input/output power leads

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Figure 1 — TEM cell

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4.2 Instrumentation

Figure 2 shows an example of a TEM cell test set-up. The TEM cell has high resonances in the region greater than the recommended upper useful frequency. A low pass filter with an attenuation of at least 60 dB at frequencies above 1,5 times of the cut-off frequency of the TEM cell shall be installed (e.g. 200 MHz TEM cell: 60 dB for frequencies above 300 MHz).

4.3 Test set-up

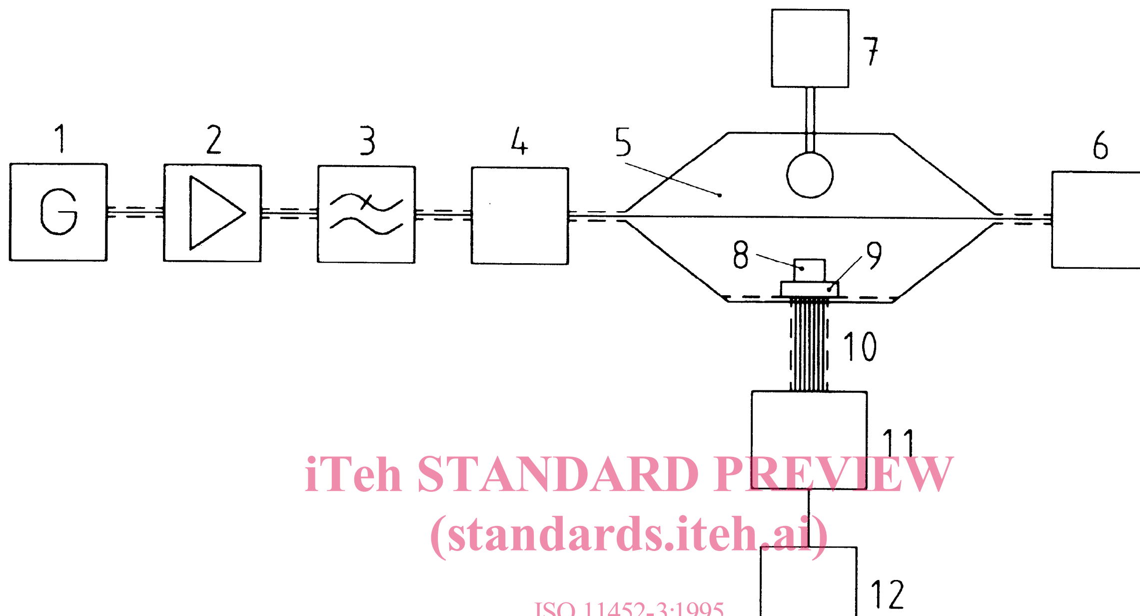
In order to maintain the homogeneous field in the TEM cell and to obtain reproducible measurement results, the device under test or field probe shall not be larger than one-sixth of the cell height (inside height). The device under test should be placed in the centre of the cell on a dielectric equipment support.

The positioning of the device under test and wiring harness may be in one of two ways, depending on the purpose of the test (see 4.3.1 and 4.3.2).

4.3.1 Exposure of device under test and wiring harness

The height of the dielectric support is one-sixth of the cell height ($h = 1/6\ b$, see figure 3). In order to obtain reproducible measurement results, the device under test, including its wiring harness, shall be placed in the same position in the TEM cell for each measurement.

A connector panel should be attached to the TEM cell as close as possible to the printed lead system. The supply and signal leads from the connector in the cell wall are directly connected to the device under test via a printed lead card with a length as required to position the device under test in the allowed working region of the TEM cell or a set of leads secured to a breadboard assembly (see figures 3 and 4). The printed lead card or supported wiring harness between the connector and the device under test will yield reproducible measurement results if the position of the leads and the device under test in the TEM cell are fixed.



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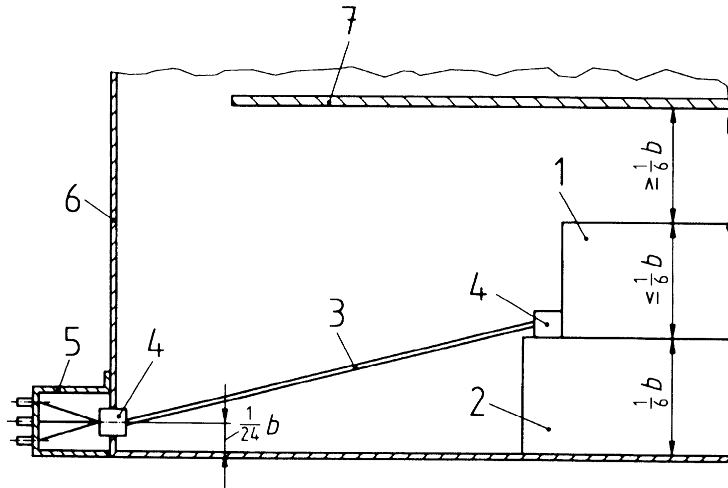
Key

1 Signal generator
2 Broadband amplifier
3 Low pass filter
4 Bidirectional coupler (30 dB decoupling ratio min.)
5 TEM cell
6 High power load (50 Ω)
7 Electric field sensor system
8 Device under test
9 Dielectric support
10 Shielded leads
11 Shielded peripheral, RF filter, artificial network (see ISO 7637-1 and 7637-2)
12 Power supply

Figure 2 — Example of TEM cell configuration



Key

1 Device under test
2 Dielectric support
(relative permittivity, $\varepsilon_r \leqslant 1{,}4$)
3 Printed lead card or wiring harness
4 Connector
5 Connector panel
6 TEM cell wall
7 Septum

b TEM cell height (see annex B)

Figure 3 — Example of test set-up

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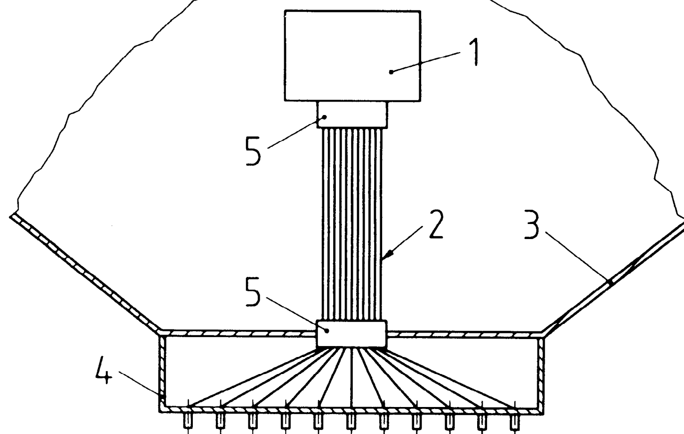

Key

1 Device under test
2 Printed lead card or wiring harness
3 TEM cell wall
4 Connector panel
5 Connector

Figure 4 — Example of test set-up (detail)

4.3.2 Exclusive exposure of device under test

The height of the dielectric support is 50 mm (see figure 5). In order to obtain reproducible measurement results, the device under test shall be placed in the same position in the TEM cell for each measurement.

A connector panel should be attached to the TEM cell. The arrangement and nature of supply and signal leads shall be chosen to minimize the coupling on these leads. These leads shall be secured on the floor of the TEM cell and shielded between the connector in the cell wall and the device under test (see figure 5). This can be done by using metal tape with conductive adhesive to cover the leads on the floor of the TEM cell.

The shield shall be in electrical contact with the cell floor, but not in contact with the case of the device under test.

4.3.3 External components

The external components such as sensors, power supply and control elements may be connected

— via a shielded peripheral (see figure 2);

— via the vehicle next to the TEM cell;

— directly to the connector panel.

To control unwanted radio frequency (RF) emissions and preclude interference to the test set-up, shielded leads shall be connected from the TEM cell to the peripherals, or a RF filter shall be installed on the connector panel of the TEM cell.

For example, power supply leads can be laid without a shield to the connectors on the connector panel which is fitted with feed-through capacitors.

The length of the external signal and control leads shall be agreed by the users, as they may affect the measurement results.

Unshielded leads without RF filters at the TEM cell connector panel shall not be used since they may emit considerable amounts of radiation and therefore influence measurement and results.

The conductor on the printed lead card shall be designed to handle the load currents.

The doors of the TEM cell shall be closed at all times during the measurement.

If possible, the actual vehicle loads, sensors and actuators shall be used.

Unused connectors shall be shielded, so that they do not emit radiation.

The device under test shall not be grounded to the TEM cell floor unless it is intended to simulate the actual vehicle configuration. Care should be taken not to create a ground loop.

5 Test procedure

5.1 Test plan

Prior to performing the tests, a test plan shall be prepared; it shall include interface test points, mode of operation for the device under test, acceptance criteria for the device under test, and any special instructions and modification of the standard test. Each device under test shall be verified under the most significant situations, i.e. at least in stand-by mode and in a mode where all the actuators can be excited.

5.2 Test methods

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CAUTION — Hazardous voltages and fields may exist within the test area. Take care to ensure that the requirements for limiting the exposure of humans to RF energy are met.

The TEM cell test method shall be installed as described in 4.2 and 4.3 and as defined in the test plan.

The field can be determined according to one of the two methods in 5.2.1 and 5.2.2.

5.2.1 Calculation method

To determine the electric field by calculation, make a net power measurement (net power is equal to forward power minus reflected power) and calculate the field using:

$$|E| = \frac{\sqrt{P \times Z}}{d}$$

where

$|E|$ is the absolute value of the electric field, in volts per metre;

P is the net power, in watts;

Z is the characteristic impedance of the TEM cell, in ohms (50 Ω);

d is the separation distance, in metres, between the floor and the septum of the TEM cell ($b/2$ in figure B.1).

NOTE 2 A small field probe may be used to verify the calculated calibration curve between the net power into the TEM cell and the field in the uniform field region.

5.2.2 Field strength measurement method

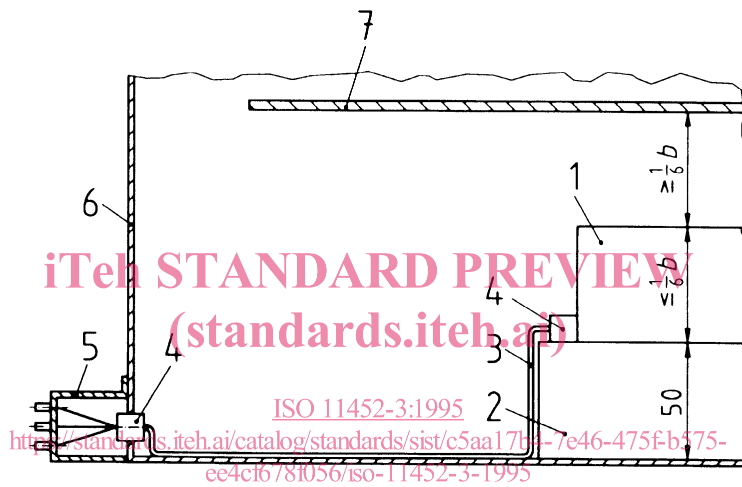
Alternatively the field strength may be monitored by using a calibrated field probe (see annex A). The probe shall be centred in the upper half of the TEM cell, symmetrical to the placement of the device under test in the lower part of the TEM cell.

During the actual test with the device, the test level (electric field) is measured by this calibrated field probe and fed back to the signal generator either to increase or to decrease the test level until the predetermined test severity level is achieved.

5.3 Test report

A test report shall be submitted detailing information regarding the test equipment, systems tested, frequencies, power levels, system interactions and other relevant information regarding the test.

Dimensions in millimetres



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Key

1 Device under test
2 Dielectric support (relative permittivity, $\varepsilon_r \leqslant 1,4$)
3 Shielded wiring harness
4 Connector
5 Connector panel
6 TEM cell wall
7 Septum

Figure 5 — Example of test set-up