DRAFT INTERNATIONAL STANDARD
ISO/DIS 11451-5

ISO/TC **22**/SC **32** Secretariat: **JISC**

Voting begins on: **2022-06-24** Voting terminates on: **2022-09-16**

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

Part 5: **Reverberation chamber**

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

Partie 5: Chambre réverbérante

ICS: 43.040.10; 33.100.20

Reference number
ISO/DIS 11451-5:2022(E)

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

A list of all parts in the ISO 11451 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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

Part 5:
Reverberation chamber

1 Scope

This part of ISO 11451 specifies methods for testing the immunity of passenger cars and commercial vehicles to electromagnetic disturbances, regardless of the vehicle propulsion system (e.g. spark ignition engine, diesel engine, electric motor) using a reverberation chamber.

The electromagnetic disturbances considered are limited to narrowband electromagnetic fields.

While this standard refers specifically to passenger cars and commercial vehicles, generalized as "vehicle(s)", it can readily be applied to other types of vehicles.

ISO 11451-1 specifies general test conditions, definitions, practical use, and basic principles of the test procedure.

Function performance status classification guidelines for immunity to electromagnetic radiation from an off-vehicle radiation source are given in Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 11451-1, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11451-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
(mean) absorption cross section
ACS
average absorption cross section averaged over all polarizations and incident angles[17]

$$A_{\mathrm{acs}} = \langle \sigma_{\mathrm{a}} \rangle_{\Omega} = \frac{1}{8\pi} \iint_{4\pi} \left(\sigma_{\mathrm{a,TE}} + \sigma_{\mathrm{a,TM}} \right) d\Omega \tag{1}$$

where

σ_a is the absorption cross section for incident waves from a spatial direction averaged over TE and TM waves,

$\sigma_{a,TE}$ is the absorption cross section for incident TE waves from a spatial direction,

$\sigma_{a,TM}$ is the absorption cross section for incident TM waves from a spatial direction,

Ω is the solid angle which is 4π for the full sphere (i.e. waves from all angles).

Note 1 to entry: measure for the ability of a vehicle to absorb energy in a reverberation chamber. It gives the cross section area of an equivalent ideal absorber without any reflections or scattering, which absorbs the same energy as the vehicle in the reverberation chamber. In contrast to the CLF, the ACS is a property of the vehicle only and is the same for all reverberation chambers. Therefore, it allows determination of the necessary extra power to compensate the loading effects by the vehicle without a loading factor measurement or a new chamber characterization with vehicle.

Note 2 to entry: see Annexes H and L

3.2
antenna characterization factor
ACF
ratio of the average received power to forward power obtained in the antenna characterization of the empty chamber characterization

Note 1 to entry: see 8.5.2

3.3
cavity mode method
method adopting chamber modes to generate the required field strength with less power for the frequency between TLS method and LUF, typically 30-80 MHz, where the chamber has a lower mode density

Note 1 to entry: see Annex F

3.4
chamber characterization factor
CCF
normalized average received power with the vehicle present

Note 1 to entry: see 8.5.2

3.5
chamber loading factor
CLF
ratio of the antenna characterization factor to the chamber characterization factor

Note 1 to entry: see 8.5.2

Note 2 to entry: it is a measure for the additional loading of the chamber due to the test setup including, for example, the vehicle and the support equipment

3.6
chamber time constant
the mean time decay of the received power delay profile in a reverberation chamber

Note 1 to entry: see Annexes H and L

3.7
charging mode
mode of operation intended for charging the Rechargeable Energy Storage System (REESS)

3.7.1
charging mode 1
charging mode as defined in 6.2.1 of IEC 61851-1:2017

Note 1 to entry: in some countries, mode 1 charging can be prohibited or requires special precautions

3.7.2
charging mode 2
charging mode as defined in 6.2.2 of IEC 61851-1:2017, where the vehicle is connected to AC mains using a charging cable, which has an Electric Vehicle Supply Equipment (EVSE) box in-line (e.g. In-Cable Control Box / In-Cable Control and Protection Device), providing control pilot signalling between the vehicle and the EVSE box and personal protection against electric shock

Note 1 to entry: in some countries, special restrictions have to be applied for mode 2 charging

Note 2 to entry: there is no communication with the vehicle

3.7.3
charging mode 3
charging mode as defined in 6.2.3 of IEC 61851-1:2017, where the vehicle is connected to a fixed installation (EVSE, e.g. AC charging station, AC wallbox) providing AC power to the vehicle, with communication between the vehicle and the EVSE (through signal/control lines and/or through wired network lines)

3.7.4
charging mode 4
charging mode as defined in 6.2.4 of IEC 61851-1:2017, where the vehicle is connected to a fixed installation (EVSE, e.g. DC charging station), providing DC power to the vehicle (with an off-board charger), with communication between the vehicle and the EVSE (through signal/control lines and/or through wired network lines)

3.8
coherence time of the reverberation chamber
time interval between two independent stirring configurations in stirred mode. The field in the reverberation chamber conserves its statistical properties (e.g. the positions of the field maxima and minima in the working volume) during the coherence time.

3.9
cumulative distribution function
CDF
probability that the electromagnetic field strength is less or equal to a specific value. A value of this function can be used as levelling target (e.g. 100 V/m at CDF 0,2 means 20 % of the measured electric field strength values are less or equal to 100 V/m and 80 % are higher than 100 V/m).

3.10
EV supply equipment
EVSE
equipment or a combination of equipment, providing dedicated functions to supply electric energy from a fixed electrical installation or supply network to an EV for the purpose of charging

3.11
lowest usable frequency
LUF
lowest frequency for which the field uniformity requirements are met for the reverb method and at least 12 independent stirring configurations can be achieved

Note 1 to entry: the LUF is determined in accordance with C.6 in Annex C

3.12
maximum chamber loading factor
MLF
maximum chamber loading factor for which the field uniformity has been demonstrated

Note 1 to entry: see 8.5.2

3.13
periodization
a method to define an analysis time window for the calculation of autocorrelation coefficients based on the complete period of a periodic stirring process sequence

3.14
power delay profile
PDP
temporal behaviour of the power decay in a reverberation chamber after switch-off of the power source

3.15
quasi-tuned mode
an operating mode of a reverberation chamber where the response time of the DUT to the external field is shorter than the coherence time of the reverberation chamber

3.16
rechargeable energy storage system
RESS
storage system that provides electric energy for electric propulsion which can be recharged

Note 1 to entry: components of the REESS may be high voltage (HV) batteries

3.17
reverberation chamber
high Q shielded room (cavity) whose boundary conditions are changed via one or several rotating tuners or moving walls (including VIRCs with or without conductive contact to the floor) or repositioning of the transmitting antenna(s)

Note 1 to entry: this results in a statistically uniform electromagnetic field

3.18
reverb method
usage of a reverberation chamber above LUF

3.19
stirred mode
an operating mode of a reverberation chamber where a tuner or a VIRC shaker is moved continuously while the test is running

3.20
stirring configuration
a unique set of conditions that defines the RF environment. It might stand for a single tuner in a fixed position as in classical reverberation chambers, it might stand for a position of a VIRC at a point in time, for a momentary frequency in case of frequency stirring, or a transmitting antenna configuration.

3.21
stirring scheme
operating mode of a reverberation chamber that is a stirred mode or a tuned mode or a combination thereof

3.22
support equipment
equipment associated with performing an EMC test on a vehicle including (but not all inclusive) load simulator, charging cables, AMN(s), HV-AN(s), AAN(s), DUT monitoring equipment including fibre optic interface modules and TV camera

3.23
TLS method
method using a TLS (similar as in ISO 11451-2) inside a reverberation chamber and extends the usage beyond TEM-waveguide testing up to the LUF of the reverberation chamber

Note 1 to entry: see Annex E

3.24
total antenna efficiency
ratio of radiated power to forward power at antenna port, it is less than 1 or 100 % due to mismatching and losses of the antenna (e.g. ohmic loss of metallic material and dielectric loss of insulation)

Note 1 to entry: see Annex J

3.25
tuned mode
operating mode of a reverberation chamber where the tuner is moved stepwise to fixed positions and the test is repeated successively at each of those fixed tuner positions

3.26
tuner
large metallic reflector capable of changing the electromagnetic boundary conditions in a reverberation chamber as it rotates or moves

Note 1 to entry: as the tuner moves, the nulls and maximums in the field change location, ensuring the vehicle is exposed to a statistically uniform field

3.27
windowing
method to define an analysis time window for the calculation of autocorrelation coefficients based on a part of a stirring process sequence

3.28
working volume
volume within the reverberation chamber that contains the vehicle, the support equipment, and the receiving antenna, if used

3.29
VIRC
vibrating intrinsic reverberation chamber (a tent-like structure formed by conductive fabrics where movements of the walls are excited e.g. by moving arms which push and pull corners or edges of the tent)

4 Test conditions

The applicable frequency range for the reverb method is LUF to 18 000 MHz. Testing over the full frequency range could require different field-generating devices, but this does not imply that testing of overlapping frequency ranges is required.

NOTE The applicable frequency range is 0,01 MHz to LUF for the TLS method (see Annex E), 30 MHz to LUF for the cavity mode method (see Annex F), and LUF to 18 000 MHz for the other reverb methods (see Annexes G, H and I).

The user shall specify the test severity level or levels over the frequency range. Suggested test severity levels are given in Annex A of this International Standard.

Standard test conditions are given in ISO 11451-1 for the following:

— test temperature;

— supply voltage;

— modulation;

— dwell time;

— frequency step sizes;

— definition of test severity levels;

— test signal quality.

5 Test location

5.1 Reverberation chamber description

The test shall be performed in a reverberation chamber.

The aim of using a reverberation chamber is to create statistically homogeneous and isotropic electromagnetic fields within the working volume.

These conditions are not valid close to the ground floor in the working volume (see 5.2).

A reverberation chamber for vehicle testing consists of a shielded enclosure, one or several field generating devices, and some mechanical apparatus to change the boundary conditions for the electromagnetic fields. This mechanical apparatus may for example contain one or several rotating tuners or moving walls, or may even be realized by using conductive fabrics as shielded enclosure (e.g. a VIRC).

The chamber may contain a vehicle dynamometer, a turntable or both.

It may also contain a TLS (see Annex E) or other type of field generators (e.g. tunable monopoles, see Annex F) as field generating device for testing from 0,01 MHz to the LUF.

The chamber may also contain one or several receiving antennas and one or more field probes.

The size, shape, and construction of the reverberation chamber can vary considerably. The minimum size of the shielded enclosure is determined by the size of the test region needed, the size of the field generation device or devices, the size and shape and location of the tuner or tuners, the needed clearances between all these and the largest vehicle to be tested, and the intended LUF of the chamber. An example of a rectangular reverberation chamber with one mechanical tuner and one field generating antenna is shown in Figure 1.

After initial construction, the reverberation chamber shall be characterized in accordance with the test methods intended to be used. For the reverb method, the chamber shall fulfil the field uniformity requirements of Table C.2. The LUF of the reverberation chamber is determined during this initial characterization. Following any major modifications, a new chamber characterization shall be carried out again. Changes to the tuners shall be considered a major modification.

5.2 Working volume

The working volume is the volume that contains the vehicle, any support equipment and the receiving antenna, if used. The form of the working volume shall be a cuboid.

The minimum distance between the working volume and the walls and ceiling of the shielded enclosure or any tuner or any transmitting antenna shall be at least λ/4 at the lowest used frequency of the reverb method.

The working volume for testing vehicles starts directly on the ground plane in order to contain the full vehicle. Although this differs from IEC 61000-4-21 working volume definition, for the purpose of chamber calibration, the reverb reference points described in IEC 61000-4-21 shall be used.

NOTE 1 For TLS method (see Annex E), and cavity mode method (see Annex F), the λ/4 minimum distance requirement does not apply.

NOTE 2 More than one vehicle can be tested in one immunity test (e.g. testing of communication between vehicles). If the distance between the vehicles is closer than λ/4 at the lowest tested frequency there could be significant interaction between the vehicles. This may be desirable for investigating proximity effects. If the distance between the vehicles is larger than λ/4 at the lowest tested frequency there will be scattering between the vehicles similar to the scattering from walls etc. Therefore this test can be interpreted as the simultaneous independent test of multiple vehicles. in either case, the field homogeneity requirements need still to be fulfilled with multiple vehicles present and the loading needs to be compensated appropriately as defined in the applicable test method

6 Test instrumentation

Testing consists of generating radiated electromagnetic fields using antenna sets with radio frequency (RF) sources capable of producing the desired field strength over the range of test frequencies.

The following test instrumentation is used:

— field generating device(s): e.g. antenna(s);

— field probe(s);

— RF signal generator with internal or external modulation capability;

— high power amplifier(s);

— power meter (or equivalent measuring instrument) to measure forward power and reflected power;

— optional: receiving antenna(s) and spectrum analyser;

— optional: vector network analyser.

6.1 Field generating device

A transmitting antenna is used as the field generating device for the reverb method.

NOTE The TLS method (see Annex E) uses a TLS as field generation device, and the cavity mode method (see Annex F) uses tunable monopoles.

Multiple antennas, amplifiers and directional couplers may be necessary to cover the complete frequency range.

The transmitting antenna(s) shall be linearly polarized antenna(s) capable of satisfying the frequency requirements. The antenna efficiency should be at least 75 % (log periodic and horn antennas typically fulfil this requirement). An example with a horn antenna is shown in Figure 1.

6.2 Field probes

Field probes shall be capable of measuring electric field strength in three orthogonal axes. The communication lines from the probes shall be fibre optic links. The sampling rate, bandwidth and dynamic range of the probe shall be capable to measure accurately the field. This is especially important for fast stirred mode techniques.

At high frequencies, the radiation characteristics of the field probes will deviate from the ideal one, due to size relative to wavelength, symmetry, and other properties. Above which frequency, this happens or if it is relevant in the frequency range of the probe, depends on the probe properties. For application in the reverberation chamber, the directivity and isotropy of the field probe itself does not matter, since for measuring the mean and maximum values, only the total radiation efficiency of the probe axis is important not the gain. Annex K describes a method, how to measure and compensate diffuse-field correction factors for field probes. If the properties of a field probe in the diffuse-field are not known, it is recommended to determine the diffuse-field correction factor according to Annex K, and in case deviations are identified, to correct them.

6.3 Stimulation and monitoring of the device under test (DUT)

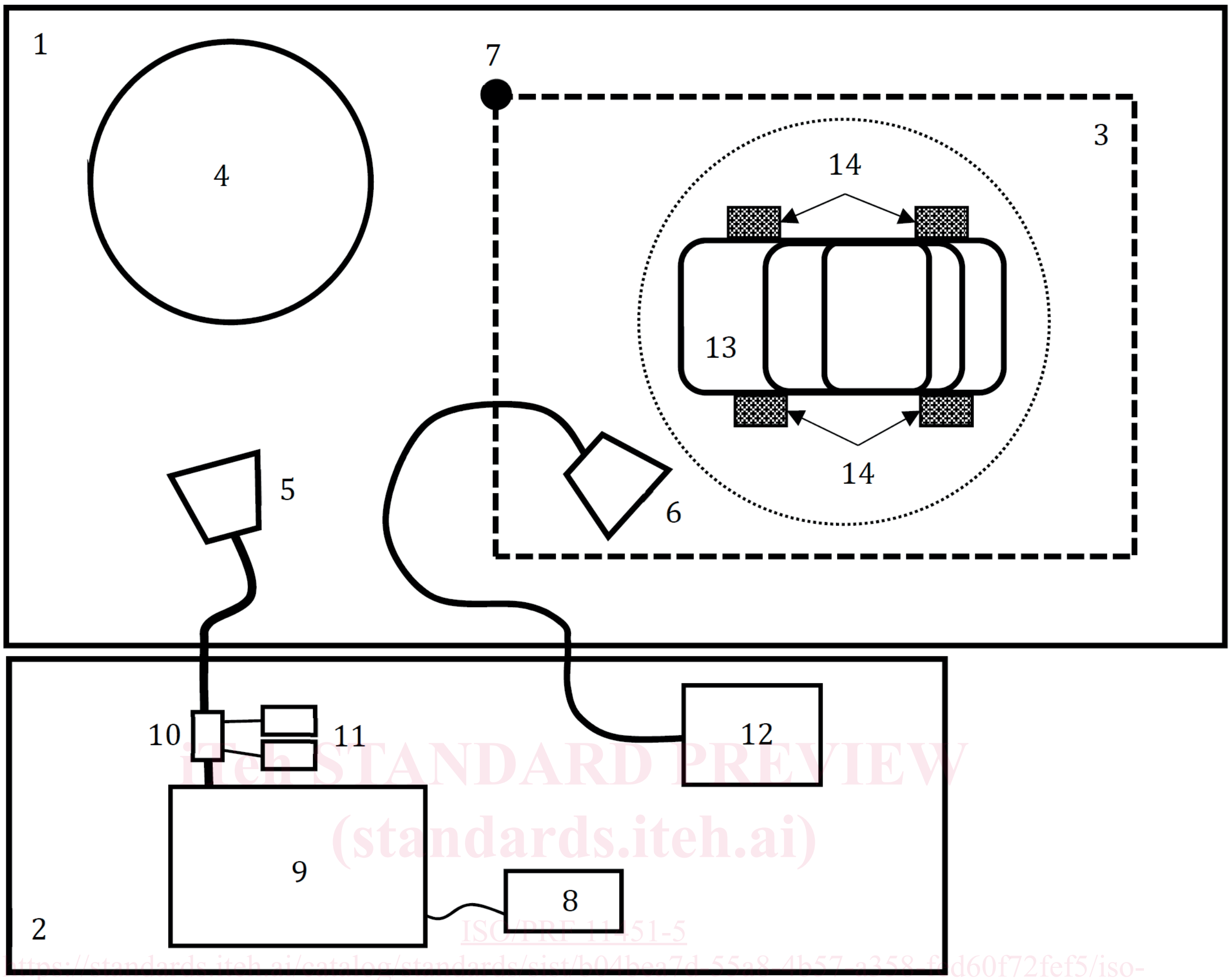
The vehicle shall be operated as required in the test plan by using actuators which have a minimum effect on the electromagnetic characteristics, e.g. plastic blocks on the push-buttons, pneumatic actuators with plastic tubes.

Connections to equipment monitoring electromagnetic interference reactions of the vehicle may be accomplished by using fibre-optics, or high resistance leads. Other type 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 vehicle may cause malfunctions of the vehicle. Extreme care shall be taken to avoid such an effect.

6.4 Optional: receiving antenna(s) and spectrum analyser

For chamber characterization and test, receiving antenna(s) and a spectrum analyser may be used to measure the received power. This measurement may be used to determine the chamber loading factor due to the vehicle and the support equipment (see 8.5.2).



Key

1 reverberation chamber / VIRC
2 amplifier / operator room
3 working volume
4 tuner, if used
5 transmitting antenna
6 receiving antenna, if used
7 field probe(s), if used
8 RF signal generator
9 RF amplifier
10 directional coupler
11 power meters
12 spectrum analyser, if used
13 vehicle
14 dynamometer (with or without turn-table)

Figure 1 — Example of a reverberation chamber

6.5 Optional: vector network analyser

For the VNA method (Annex I) and measurement of the chamber time constant with the spectral method (Annex L), and of antenna efficiencies (Annex J), a vector network analyser shall be used.

7 Test set-up

Four test setups are described:

— one for all type of vehicles when they are not in charging mode,

— one for vehicles in charging mode 1 or mode 2 (AC powered, without communication),