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**Road vehicles - Component test methods for electrical /
electronic disturbances from narrowband radiated
electromagnetic energy - Part 11: Reverberation chamber**

(ISO 11452-11:2010, Road vehicles - Component test methods for electrical
disturbances from narrowband radiated electromagnetic energy - Part 11:

Reverberation chamber, MOD)

道路车辆 电气/电子部件对窄带辐射电磁能的抗扰性试验方法

第 11 部分:混响室法

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Table of Contents

Foreword	4
Introduction	6
1 Scope	8
2 Normative references	8
3 Terms and definitions	8
4 Test conditions	10
5 Test locations	11
5.1 General.....	11
5.2 Reverberation chamber	11
6 Test equipment and instruments.....	11
6.1 Isotropic electric field probe	11
6.2 RF signal source.....	12
6.3 Transmitting and receiving antennas	12
6.4 Power amplifier.....	12
6.5 Spectrum analyzer.....	12
6.6 Directional coupler	12
6.7 Power meter	12
6.8 Computer control	12
6.9 DUT actuator and monitoring equipment	13
7 Test layout	13
7.1 General.....	13
7.2 Ground plane and DUT grounding	13
7.3 Power and artificial network (AN)	14
7.4 Location of DUT and wiring harness.....	15
7.5 Location of artificial load.....	15
7.6 Location of transmitting antenna	15
7.7 Location of receiving antenna.....	16
8 Test methods	17
8.1 Test plan	17
8.2 Test procedures	18
8.3 Test report	20
Annex A (Informative) Function performance status classification (FPSC)	21
A.1 General.....	21

A.2 Severity levels	21
Annex B (Normative) Reverberation room validation under tuning mode	22
B.1 General	22
B.2 Test procedures	24
B.3 Reverberation chamber gain	25
B.4 Field uniformity	26
B.5 Receiving antenna characterization factor (ACF)	28
B.6 Lowest usable frequency (LUF)	28
B.7 Maximum chamber loading factor (MLF)	28
Annex C (Normative) Loading effect calibration of reverberation chamber	30
C.1 General	30
C.2 Test procedures	30
C.3 Chamber characterization factor	31
C.4 Chamber loading factor	31
C.5 Minimum pulse width	32
Annex D (Normative) Artificial network (AN)	34
D.1 General	34
D.2 Impedance of AN	34
Bibliography	36

Road vehicles - Component test methods for electrical / electronic disturbances from narrowband radiated electromagnetic energy - Part 11: Reverberation chamber

1 Scope

This document establishes the immunity test method for vehicle electrical/electronic components to continuous narrowband radiated electromagnetic disturbance – reverberation chamber.

This document establishes the test method for applying electromagnetic interference to the device under test (hereinafter referred to as DUT) and the wiring harness (real vehicle wiring harness or standard test wiring harness) in the reverberation chamber. During the test, the support equipment of the DUT can be arranged either inside the reverberation chamber or outside the reverberation room. The test shall be performed under the tuning mode.

This document applies to the immunity test of electrical/electronic components for M, N, O, and L category vehicles (not limited to vehicle power systems, such as spark ignition engines, diesel engines, and electric motors).

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 version corresponding to that date is applicable to this document; for undated references, the latest version (including all amendments) is applicable to this document.

GB/T 33014.1, Road vehicles - Component test methods for electrical/electronic disturbances from narrowband radiated electromagnetic energy - Part 1: General (GB/T 33014.1-2016, ISO 11452-1:2005, MOD)

3 Terms and definitions

Terms and definitions determined by GB/T 33014.1, and the following ones are applicable to this document.

3.1

antenna characterization factor; ACF

- test temperature;
- test voltage;
- modulation system;
- dwell time;
- test signal quality.

5 Test locations

5.1 General

The test shall be carried out in a reverberation chamber.

5.2 Reverberation chamber

The reverberation chamber used to test the DUT shall be so large that its working volume can accommodate the test bench, support equipment and receiving antennas.

Note 1: Reverberation chamber size will affect the lowest usable frequency (LUF).

The working volume is usually rectangular which, however, is not essential.

The reverberation chamber shall contain at least one mechanical tuner to stir the electromagnetic field in the chamber. Based on the reverberation chamber size and working volume, the size of the mechanical tuner shall be as large as possible. In addition, the shape of each tuner shall be such that during one rotation, the reverberation chamber obtains a non-repetitive field distribution.

Note 2: The number, size and shape of tuners will affect the lowest usable frequency (LUF).

After the reverberation chamber is built, the reverberation chamber validation shall be performed according to Annex B. The field uniformity shall meet the requirements of Table B.2, and the LUF of the reverberation chamber shall be confirmed. After any major renovation, reverberation chamber validation shall be performed again. Tuner changes shall be considered a major modification.

6 Test equipment and instruments

6.1 Isotropic electric field probe

The electric field probe shall be able to measure the electrical field strength on three orthogonal axes.

6.2 RF signal source

The RF signal source shall be able to cover the specified frequency range and modulation system.

6.3 Transmitting and receiving antennas

Linear polarizing antennas that meet the transmitting and receiving frequency requirements respectively shall be used. Antenna efficiency shall be at least 75% (log-periodic antennas and horn antennas usually meet this requirement). It is allowable to use multiple antennas to cover the entire frequency range of the reverberation chamber.

6.4 Power amplifier

Power amplifiers are used to amplify radio frequency signals and provide the necessary power to the transmitting antenna to generate the specified field strength.

6.5 Spectrum analyzer

The spectrum analyzer shall be able to cover the specified frequency range. Confirm and test the reverberation chamber using a spectrum analyzer and receiving antenna with and without a DUT.

6.6 Directional coupler

The directional coupler shall be able to cover the specified frequency range. It shall be able to withstand the RF output of the power amplifier without damage. The directional coupler is used in conjunction with the power meter to measure the forward power delivered to the transmitting antenna.

6.7 Power meter

The power meter shall be able to cover the specified frequency range. The power meter is used in conjunction with the directional coupler to measure the forward power delivered to the transmitting antenna.

6.8 Computer control

The computer control system shall have the following functions: Before the DUT test, special software combined with the computer and radio frequency test equipment needs to be used for reverberation chamber validation according to Annex B. The software needs to store the reverberation chamber validation information for use during the test. During the DUT test, the software shall be able to control the RF test equipment and tuner for testing as described in Chapter 8.

If the DUT's enclosure is grounded to the vehicle's metal structure, the DUT enclosure should be grounded during the test (either through a ground plane or through a ground plate placed on the test bench). The ground state of the DUT enclosure shall simulate the actual vehicle configuration.

The ground plane (if used) of the test bench shall be made of copper, brass or galvanized steel. The minimum size of the ground plane depends on the size of the system under test and shall be able to fully accommodate the wiring harness and DUT system components. The ground plane (excluding the ground connection) shall be placed within the working volume of the reverberation chamber at a minimum distance of $\lambda/4$ corresponding to the lowest usable frequency from any walls and the tuner. The ground plane shall be connected to the reverberation chamber using a ground strap, and its DC resistance shall not exceed 2.5 m Ω . In addition, the edge distance between ground strips shall not be greater than 0.3 m.

Note: Using a ground surface as the ground plane is an alternative currently under investigation.

7.3 Power and artificial network (AN)

When DC power is required to maintain battery voltage, the DC power source shall be located outside the reverberation chamber. All power lines entering the reverberation chamber shall be filtered. The DC power line used to maintain the battery voltage can be shielded from the reverberation chamber filter to the battery connecting point. The DC power leads in the reverberation chamber should be routed along the walls and reverberation chamber floor to minimize field coupling of the leads.

AN shall not be used if a ground plane is not used. The DUT's power cord shall be connected directly to the battery terminals.

If a ground plane is used, each power cord shall be connected to the power source via AN. The DUT shall be powered through 5 $\mu\text{H}/50\Omega$ AN. Annex D gives the schematic circuit diagram of artificial network (AN). The number of ANs required depends on how the DUT is expected to be installed in the vehicle.

- DUT far-end grounding (vehicle power return wire larger than 200 mm): Use two ANs, one of which is connected to the positive pole of the power supply, and the other is connected to the power return wire. The negative terminal of the power supply shall be connected to the ground plane on the AN power (input) side of the return wire.
- DUT near-end grounding (vehicle power return wire not larger than 200 mm): Use an AN and connect it to the positive pole of the power supply. The DUT power return wire shall not be larger than 200 mm and shall be connected to the ground plane. The negative terminal of the power supply shall be connected to a ground plane near the AN enclosure ground.

AN shall be installed directly on the ground plane, and the housing shall overlap the ground plane.

The measurement port of each AN shall be connected to a 50 Ω load.

7.4 Location of DUT and wiring harness

Unless otherwise specified in the test plan, a wiring harness of $1\ 700^{+300}_0$ mm length shall be used. The type of wiring harness should be determined according to the actual system usage (shielded, unshielded, twisted pair, etc.). The length of the wiring harness shall be recorded in the test report.

The wiring harness shall be arranged in a “U shape” so that the straight length of the wiring harness between the DUT and the artificial load is (1500 ± 75) mm. The wiring harness bending angle shall be $(90^{+45}_0)^\circ$.

If a ground plane is used, the DUT and wiring harness shall be placed (50 ± 5) mm above the ground plane on a non-conductive, low-dielectric-constant material (relative dielectric constant, $\epsilon_r \leq 1.4$).

7.5 Location of artificial load

If a ground plane is used, the artificial load should be placed directly on the ground plane. If the artificial load is a metal enclosure, the enclosure shall be directly connected to the ground plane.

The artificial load can be arranged near the reference ground plane (the artificial load enclosure overlaps the ground plane) or the artificial load can be arranged outside the reverberation chamber. At this time, the test harness of the DUT passes through the RF boundary that overlaps the reference ground plane.

When the artificial load is placed on a ground plane, the DC power line of the artificial load shall be connected through AN.

7.6 Location of transmitting antenna

The location of the transmitting antenna shall remain unchanged during reverberation chamber validation and testing. The transmitting antenna shall not illuminate the working volume directly. If possible, the transmitting antenna shall be pointed at a certain corner of the reverberation chamber (see Figure 1 for the location of the transmitting antenna), or at the tuner. The transmitting antenna should be supported by a non-conductive support (e.g., non-conductive tripod or polystyrene clamp) and kept at a distance of at least $\lambda/4$ corresponding to the lowest usable frequency from any walls and corners.

Note: Tilt the antenna upward to avoid the incident wave vertically irradiating the reverberation chamber wall, which causes the standing wave ratio to be too high.

The frequency step size shall at least comply with the requirements of GB/T 33014.1.

The dwell time of the tuner at each test frequency point shall be at least 2 s, excluding the response time of the test equipment and the time required to rotate the tuner until it completely stops. Additional dwell time can be added to each test frequency point to ensure that the DUT can operate in the appropriate operating mode and to ensure “off time” during low-frequency modulation.

8.2.5 Pulse test signal requirements

The loading state of the reverberation chamber determines the minimum pulse width that can be achieved in the pulse modulation test.

Within the test frequency range, if the pulse modulation width exceeding 10% of the test frequency points is less than the minimum pulse width $T_{p,min}$ specified in Annex C, absorbing materials shall be added or the pulse width shall be increased. If absorbing materials are added, the loading effect shall be remeasured and calculated according to Annex C until a minimum number of absorbing materials is used to make the time constant meet the requirements.

8.2.6 DUT test

Calculate the forward power value $P_{Forw,Test}$ required for each test frequency point to meet the test field strength requirements.

The tuner step size used for testing shall be at least the tuner step size used for reverberation chamber validation in Annex B. The tuner shall rotate once at an equal step angle at each frequency point. Ensure that the DUT is exposed to field strength levels for an appropriate dwell time.

The corresponding receiving antenna during the reverberation chamber validation shall be used to monitor and record the maximum and average values of the received power $P_{Rec,Test}$ (i.e., $P_{Rec,Test,max}$ and $P_{Rec,Test,avg}$) to ensure that the required field strength is generated. Use $P_{Rec,Test,avg}$ to ensure that the loading state of the reverberation chamber during the test has not changed compared with the time when the loading factor is confirmed. When the difference between values of $P_{Rec,Test,avg}$ is greater than 3 dB, it shall be resolved.

Monitor the forward power $P_{Forw,Test}$ of the transmitting antenna, and record the average value $P_{Forw,Test,avg}$ during the tuner rotation. When the tuner rotates for one revolution, if the change of $P_{Forw,Test}$ is greater than 3 dB, it shall be recorded in the test report.

Modulate the carrier as specified in the test plan. Unless otherwise specified, the peak constant principle shall be adopted in accordance with GB/T 33014.1.

Monitor the DUT operation for any deviations.

Annex B

(Normative)

Reverberation room validation under tuning mode

B.1 General

Carry out an empty chamber (without DUT) validation according to the procedure in B.2 to get a preliminary understanding of the reverberation chamber performance and forward power requirements. Validation shall be carried out according to the procedure in C.2 before each test. In the frequency range that meets the field uniformity requirements of Table B.2 and above, the reverberation chamber can be used for testing.

When modifying the reverberation chamber (for example, adding absorbing materials, replacing antennas, etc.) or the reverberation chamber validation procedure (for example, changing the number of tuner steps, etc.) in order to obtain the desired reverberation chamber validation, the same configuration or procedure shall be maintained during the test as when the reverberation chamber was re-validated during modification, to ensure that the reverberation chamber validation is valid.

During the reverberation chamber validation, for a cuboid working volume, 8 electric field probe locations shall be used for determination. For the working volume of other shapes, it may be necessary to add more electric field probe locations to define the working volume.

The minimum spacing distance between different electric field probes shall be at least $\lambda/4$ of the wavelength corresponding to the lowest reverberation chamber validation frequency.

The electric field probe shall be located around the working volume, as shown in Figure B.1. The boundary surface of the working volume shall be at least $\lambda/4$ of the wavelength corresponding to the lowest reverberation chamber validation frequency from the reverberation chamber surface, transmitting antenna or tuner.

The maximum working volume of the reverberation chamber should be used for reverberation chamber validation to avoid the need for additional reverberation chamber validation when testing larger samples.

Reverberant chamber validation shall be performed using an isotropic electric field probe that reads field strength data for each axis separately. A calibrated electrically short dipole antenna (i.e., less than $\lambda/3$) can be used instead of the isotropic electric field probe if it can be located in three mutually perpendicular directions at each location. Care should be taken to ensure that the dipole antenna is not affected by its connecting cable. Optically isolated measurement systems (isotropic electric field probes or dipole

adding absorbing materials to reduce the Q value. The characteristics (dimensions, construction methods, wall materials) of the reverberation chamber itself shall also be evaluated to assess whether the laboratory is likely to pass the requirements.

When the number of modes of the reverberation chamber at the lowest test frequency point does not reach 60 ~ 100, or the quality factor Qs of the reverberation chamber is very high (for example, in a reverberation chamber with aluminum plate welding), it will be difficult to meet the field uniformity requirements.

B.5 Receiving antenna characterization factor (ACF)

The receiving antenna characterization factor (ACF) in the empty chamber state is used as the benchmark for the receiving antenna characterization factor after loading (as described in Annex C). It is necessary to use a characterization factor to correct the antenna measurement values to avoid the influence of various factors such as antenna efficiency.

Referring to Formula (B.4), obtain the reverberation chamber characterization factors of at least 8 electric field probe locations, and average them to calculate the receiving antenna characterization factor (ACF) of each frequency, according to Formula (B.17):

$$A_{ACF} = A_{CCF,i,avg} \dots\dots\dots (B.17)$$

B.6 Lowest usable frequency (LUF)

The lowest usable frequency f_{LUF} of the reverberation chamber is the lowest frequency that meets the field uniformity requirements of Table B.2.

B.7 Maximum chamber loading factor (MLF)

In order to determine whether the reverberation chamber is adversely affected by the “loading effect”, the field uniformity of the reverberation chamber can be checked under artificial loading conditions. During the life cycle of the reverberation chamber, the reverberation chamber validation in the “loading” state only needs to be carried out once. In addition, the reverberation chamber validation in the “loading” state shall also be carried out after major modifications to the reverberation chamber. Before each test, the procedure in Annex C shall be used for validation.

In the working volume of the reverberation chamber, install a sufficient amount of absorbing material to bring the reverberation chamber loading level to the level during normal testing [a 16-fold change in ACF (12 dB) shall be considered the rated loading level].

Note: Every reverberation chamber is different and the easiest way to determine the required absorbing material is trial and error.

Annex C

(Normative)

Loading effect calibration of reverberation chamber

C.1 General

This Annex describes the calibration procedures for the reverberation chamber due to loading effects caused by DUT, wiring harness, support equipment, test bench, etc. The loading effect is characterized by the chamber loading factor A_{CLF} and the minimum pulse width $T_{p,min}$.

This procedure shall be performed before each test. When the test uses an already used (same or similar type) test arrangement, recalibration is not required.

C.2 Test procedures

Place the receiving antenna somewhere in the working volume of the reverberation chamber and maintain a distance of $\lambda/4$ the wavelength corresponding to the lowest usable frequency from the DUT, support equipment, etc.

Use the following procedure to measure the maximum and average received power P_{Rec} of the receiving antenna and the average forward power P_{Forw} of the transmitting antenna for all test frequencies.

- Adjust the RF signal source, and inject an appropriate forward power P_{Forw} into the transmitting antenna. It shall be ensured that the harmonics of the RF input to the reverberation chamber are at least 15 dB lower than the fundamental wave.
- Set up the measuring instrument to read the receiving antenna signal amplitude in the correct frequency range.
- When the reverberation chamber and tuner are operating, other possible characteristics defined in B.1 shall meet the requirements for field uniformity. Each frequency point shall have sufficient dwell time to ensure the correct response of the measuring instrument.
- Record the maximum and average received power P_{Rec} of the receiving antenna, and the average forward power P_{Forw} of the transmitting antenna. In order to obtain accurate average data, the noise floor of the instrument measuring P_{Rec} shall be at least 20 dB lower than the maximum received power P_{Rec} .

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