SURFACE VEHICLE RECOMMENDED PRACTICE

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Superseding J1113-27JUN2012

Electromagnetic Compatibility Measurements Procedure for Vehicle Components - Part 27 - Immunity to Radiated Electromagnetic Fields - Mode Stir Reverberation Method

RATIONALE

J1113-27 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

1.1 Vehicle electrical/electronic systems may be affected when immersed in an electromagnetic field generated by sources such as radio and TV broadcast stations, radar and communication sites, mobile transmitters, cellular phones, etc. The reverberation method is used to evaluate the immunity of electronic devices in the frequency range of 500 MHz to 2.0 GHz, with possible extensions to 200 MHz and 10 GHz, depending upon chamber size and construction. Optional pulse modulation testing at HIRF (High Intensity Radiated Fields) test levels, based upon currently known environmental threats, has been added to this revision of the standard. This document addresses the Mode Stir (Continuous Stirring) Reverberation testing method which has been successfully utilized as a design and production stage development tool for many years. The Mode Tuned (Stepped Tuner) Reverberation testing method is covered in the SAE J1113-28 document.

1.2 This document provides the component design and test engineers with a test procedure and the performance requirements necessary to quickly evaluate the immunity of electronic devices to radiated electromagnetic fields early in the design stage as well as pilot and production stages. This method is an alternative to testing in an absorber lined chamber. Ensuring electromagnetic compatibility early in the development stage will minimize costly changes later in the program and will prevent excessive component level hardening during full-vehicle level testing.

1.3 The reverberation test method performs a dual function:

1.3.1 The primary function of the method is to provide a bench test procedure correlative to vehicle-level radiated immunity testing in the anechoic chamber and at mobile transmitter sites.

1.3.2 The method can quickly evaluate the relative performance of different designs of the same device.

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2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

General information regarding this test, including general definitions, and safety considerations are found in SAE J1113-1.

2.1.1 SAE Publication

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1113-1 Electromagnetic Compatibility Measurement Procedures and Limits for Components of Vehicles, Boats (up to 15 m), and Machines (Except Aircraft) (16.6 Hz to 18 GHz)

2.1.2 NBS Publication

Available from National Institute of Standards and Technology, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

NBS Technical Note 1092 Design, Evaluation, and Use of a Reverberating Chamber for Performing Electromagnetic Susceptibility / Vulnerability Measurements

2.1.3 NIST Publications

Available from National Institute of Standards and Technology, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

NIST Technical Note 1506 Electromagnetic Theory of Reverberation Chambers

NIST Technical Note 1508 Evaluation of the NASA Langley Research Center Mode-Stirred Chamber Facility

2.1.4 IEC Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

IEC 61000-4-21 Electromagnetic compatibility (EMC) - Part 4-21: Testing and measurement techniques – Reverberation chamber test methods

2.1.5 ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 11452-11 Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 11: Reverberation chamber

2.1.6 Military Publications

Available from IHS Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, Tel: 800-854-7179, http://global.ihs.com/ or from http://dodssp.daps.dla.mil/.

MIL-STD-461F Department of Defense Interface Standard, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

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2.1.7 RTCA Publications

Available from RTCA Inc., 1828 L Street NW Suite 805, Washington, DC 20036-5133, Tel: 202-833-9339, www.rtca.org.

RTCA DO-160G Environmental Conditions and Test Procedures for Airborne Equipment

3. DEFINITIONS

Definitions specific to this test method are included.

3.1 REVERBERATION CHAMBER

A high *Q* shielded room (cavity) whose boundary conditions are changed via a rotating tuner. This results in a time-averaged uniform electromagnetic field. See Appendix A for additional information.

3.2 TUNER

A rotating metallic reflector that changes the boundary conditions in a reverberation chamber as it rotates. As the tuner rotates, the nulls and maximums in the field change location, ensuring the DUT and wiring harness are exposed to a time-averaged uniform field. See Appendix A for additional information.

3.3 MODE STIR

A reverberation method that rotates the tuner continuously while sampling the reference antenna received power, field probe response, and DUT response at rates much faster than the tuner revolution rate.

3.4 REVERBERATION CHAMBER QUALITY FACTOR (*Q*)

Q is the chamber quality factor and is a measure of how well the chamber stores energy. For a given chamber, *Q* varies as a function of frequency and can be calculated (See A.1.2).

3.5 NUMBER OF POSSIBLE MODES (*N*)

As a general rule, the lower frequency limit of the chamber is dependent on chamber size and the number of possible modes (*N*) which can exist at a given frequency.

3.6 LOADED REVERBERATION CHAMBER QUALITY FACTOR (Q_{Loaded})

Q_{Loaded} is the chamber quality factor and is a measure of how well the chamber stores energy with the DUT, wiring harness and support equipment. The chamber *Q* will be effected by the DUT, wiring harness and support equipment. Q_{Loaded} with the DUT, wiring harness and support equipment will need to be calculated in order to determine the chamber time constant (τ) for DUT test using pulse modulation.

3.7 REVERBERATION CHAMBER 3dB *Q* BANDWIDTH (BW_{3dB})

An approximate equivalent definition for *Q* is the ratio of the resonance frequency to the bandwidth between the frequencies on opposite sides of the resonance frequency (known as half-power points) where the response of the resonant structure differs by 3 dB from that at resonance.

3.8 CHAMBER TIME CONSTANT (τ)

For transients or pulsed signals, the rise or decay time constant τ is related to the *Q* of the chamber and frequency. τ is the minimum test pulse width that the loaded reverberation chamber can sustain.

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3.9 LOWEST USABLE FREQUENCY (LUF)

Is the lowest frequency for which the field uniformity requirements are met. The LUF is determined during the characterization of the chamber in accordance with Appendix B.

3.10 UNLOADED CHAMBER LOSS FACTOR ($L_{UNLOADED}$)

The ratio (in dB) of the maximum received power (in watts) to the average transmitted forward power (in watts) over one tuner rotation without the DUT and supporting equipment present. The $L_{UNLOADED}$ is determined to provide a baseline for comparison with a loaded chamber.

3.11 DUT LOADED CHAMBER LOSS FACTOR (L_{DUT})

The ratio (in dB) of the maximum received power (in watts) to the average transmitted forward power (in watts) over one tuner rotation with the DUT and supporting equipment present.

3.12 RECEIVE POWER MAXIMUM TO MINIMUM RATIO ($P_{r\ max/min}$)

The difference (in dB) between the maximum received power ($P_{r\ max}$) and the minimum received power ($P_{r\ min}$) over one full rotation of the tuner. This shows the ability of the chamber and tuner to reverberate.

3.13 PEAK FIELD STRENGTH INSIDE THE CHAMBER (E_{max})

The maximum field strength inside the chamber (V/m) which is calculated based upon the maximum receive power ($P_{r\ max}$) measured over one tuner rotation.

3.14 FORWARD POWER REQUIRED TO ACHIEVE THE TEST FIELD STRENGTH (P_{Test})

The forward power required, in dBm, to achieve the test field strength is calculated based upon the desired field test field strength ($E_{desired}$), the maximum field strength (E_{max}) measured in the loaded chamber, and the maximum forward power ($P_{f\ max}$) measured in the loaded chamber over one tuner rotation.

3.15 WORKING VOLUME

The working volume is defined as being a distance of $\lambda/4$ from the chamber walls and from any antenna, tuner, or other object at the lowest frequency of operation. For a chamber operating above 100 MHz, this would be 0,75 m. This is the volume within the reverberation chamber that contains the test bench, the DUT, the harness, the support equipment that is located on the test bench and the receiving antenna.

3.16 DUT

Device Under Test.

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4. TEST EQUIPMENT

4.1 RF Signal Generator

500 MHz to 2.0 GHz (200 MHz to 10 GHz optional). Pulse modulation capability optional.

4.2 Broadband Power Amplifier(s)

500 MHz to 2.0 GHz (200 MHz to 10 GHz optional). Power requirements: 50 W minimum below 1 GHz, 250 W above 1 GHz (pulse capability optional). The amplifier should be able to drive a load of any impedance mismatch for at least 15 s without damage to itself.

4.3 RF Circulator with 50 Ω RF Load

An RF Circulator with 50 Ω RF Load is recommended on the output of the Broadband Power Amplifier. The RF Circulator with 50 Ω RF Load shall be rated properly (power handling and frequency range) for use with the Broadband Power Amplifier that it is being used. As the tuner rotates, it will change the boundary conditions of the chamber and will eventually cause a considerable amount of RF power to be reflected back into the Broadband Power Amplifier output port (high VSWR condition). An RF Circulator with a 50 Ω RF Load, on the output of the amplifier, will revert the reflected power back to the 50 Ω RF load instead of the Broadband Power Amplifier RF output port. This will prevent amplifier ”fold-back” and/or “tripping” due to the high VSWR condition and will provide for a more consistent forward power condition throughout the full rotation of the tuner.

4.4 Antennas

Two antennas are needed, one for transmission and one for reception.

4.4.1 Suggested antennas:

a. 500 (200 optional) MHz to 1 GHz - Log periodic

b. 1 GHz to 2 (10 optional) GHz Double ridged guide

4.5 Spectrum Analyzer

500 MHz to 2.0 GHz (200 MHz to 10 GHz optional).

4.6 Directional Couplers

500 MHz to 2.0 GHz (200 MHz to 10 GHz optional). Average power 500 W, peak power 10 kW, coupling factor 20 dB minimum, and directivity 20 dB minimum.

4.6.1 Two directional couplers are needed for the following use:

a. Transmit forward power

b. Transmit reflected power

4.6.2 Typical Bands

a. 0.5 (0.2 optional) to 1 GHz

b. 1 to 2 GHz

c. 2 to 10 GHz (optional)

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4.7 10 dB Attenuator

500 MHz to 2.0 GHz (200 MHz to 10 GHz optional), power rating 50 W average, 1 kW peak.

4.8 Power Meter

500 MHz to 2.0 GHz (200 MHz to 10 GHz optional), including power sensor heads (peak power sensor heads optional).

4.8.1 Two power meters are needed, one for transmit forward power and one for transmit reflected power.

4.8.2 The power meters should have a sample rate sufficient to capture at least 400 samples per tuner revolution.

4.9 Computer Control (recommended)

Specialized software used in conjunction with a computer and the RF test equipment should be utilized to characterize the chamber performance per Appendix B, prior to any testing. The software should store the characterization information for use during testing. The computer and software will then be used to control the RF test equipment and tuner during the testing. The software shall be capable of performing the tests as described in Section 7 of this document.

4.10 Mode Stir Chamber

Reverberation chamber with a tuner (see Appendix A). The room shall be constructed of steel (preferably galvanized, but cold rolled steel is allowed). Minimum recommended room dimensions are 4.88 m x 3.66 m x 3.05 m (16 ft L x 12 ft W x 10 ft H). Key characteristics of the chamber shall be verified to ensure an accurate and valid test (see Appendix B).

4.11 RF Field Monitoring

Two broadband electric field probes are needed for the empty chamber characterization. The probes should be a single linear axis or, if isotropic, should allow access to each individual axis. An isotropic probe with only the root-sum-squares (total field) output may be used but will generally indicate a higher electric field than the receive power calculations. The probes should have a sample rate sufficient to capture at least 400 samples per tuner revolution.

4.12 Tuner

A three-dimensional, asymmetrical tuner is recommended. See A.1.4. of Appendix A for design considerations. The tuner shall be made of conductive material (e.g., aluminum or galvanized steel) and capable of changing the electromagnetic boundary conditions in a reverberation chamber as it rotates or moves. The tuner's capability, along with the chamber's interaction, is determined by the receive power max/min ratio ($P_{r\,max/min}$) requirements specified in Table B1, Step B7.

4.13 Artificial Network

See Appendix D for the schematic and impedance curve of the 5uH/50 Ω AN.

5. TEST CONDITIONS

See SAE J1113-1 Section 6 for additional guidance on test conditions.

5.1 Test Temperature and Supply Voltage

The ambient temperature in the test facility shall be recorded. A battery with an electrical charging system shall be used to provide power to the DUT. The supply voltage to the DUT shall be in accordance with Section 6 of SAE J1113-1.

5.2 Frequency Range

To test automotive electronic systems, the applicable frequency range of this test method is 500 MHz to 2 GHz (200 MHz to 10 GHz optional). Testing over the full frequency range is not required and should be done at the engineering judgment of the component manufacturer. At a minimum the testing should be performed over the frequency range of 500 MHz to

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2.0 GHz. Different field-generating devices may be required for testing over the full frequency range. This does not imply that testing of overlapping frequency ranges is required. Ultimately, the frequency range may be limited to the chamber performance and the method being utilized.

5.3 Modulation

See SAE J1113-1. In addition, the characteristics of the DUT shall be used to determine the type and frequency of modulation. If no values are agreed between the users of this document, the following shall be used: (a) No modulation (CW), (b) 1 kHz sine wave amplitude modulation (AM) 80%, and (c) Pulse Modulation should also be considered at frequencies above 800 MHz (see Table C1 of Appendix C for suggested Pulse Modulations and test severity levels associated with those pulse modulations).

5.4 Dwell Time

See SAE J1113-1. In addition, at each frequency, the DUT shall be exposed to the test level for at least one rotation of the tuner. Tuner revolution rate is typically 10 to 20 s/rev (3 to 6 rpm). If multiple tuners are used, the dwell time shall be at least one rotation of the slowest tuner. It is assumed that, during any measurement, the DUT is exposed to a constant field for the duration of the dwell time. Since, in a mode-stirred measurement, the tuner is constantly turning, it is not possible to hold the fields perfectly constant. Therefore, care must be taken to ensure that the tuner is turned slowly enough that the fields remain approximately constant for the duration of the dwell time. This may require a tuner rotation period that is several hundred times longer than the dwell time, and will be a function of frequency.

The rotation rate used at each frequency, as well as the method used to determine the rotation rate, must be documented in the test report.

5.5 Frequency Steps

See SAE J1113-1. The tests will be conducted with the maximum frequency step sizes shown in Table 1. Alternatively, logarithmic frequency steps, with the same minimum number of frequency steps in each frequency band, can be determined using the formula and Table 2. The values, as agreed by the users of this document, shall be documented in the test report. In either case, if it appears that the susceptibility thresholds of the DUT are very near the chosen test level, these frequency step sizes should be reduced in the concerned frequency range in order to find the minimum susceptibility thresholds. (Refer to SAE J1113-1.)

TABLE 1 - LINEAR FREQUENCY STEPS

Frequency Band	Maximum Frequency Step Size
200 MHz to 1 GHz	20 MHz
1 GHz to 10 GHz	200 MHz

TABLE 2 - LOGARITHMIC TEST FREQUENCY CALCULATION

$$f_{test} = f_0 * 2^{\left(\frac{k}{n}\right)}$$

where:
f_0 is base frequency
k is Frequency index number (1,2,3,…)
n is Number of steps per octave

Frequency Range (MHz)	fo (MHz)	n
1…<30	1	7
30…<400	30	25
400…<1000	400	25
1000…<10 000	1000	50

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5.6 Test Signal Quality

See SAE J1113-1.

5.7 Threshold of Response

See SAE J1113-1. In addition for this continuously stirred test method; as a responding frequency is being thresholded, gradually increase the signal amplitude in discrete steps and allow time for one full tuner rotation at each step. This will allow the DUT to be subjected to the high point of the field. The peak field point shall be recorded as the threshold amplitude level.

5.8 Test Severity Levels

The DUT manufacturer shall specify the test severity level(s) over the frequency bands to be tested. Suggested test severity levels are included in Appendix C. A full description and discussion of the Function Performance Status Classification including Test Severity Levels are given in SAE J1113-1 Appendix A and should be reviewed prior to using the suggested Test Severity Levels presented in Appendix C. These test severity levels are expressed in terms of equivalent root-mean-square (RMS) value of an un-modulated wave. Peak power conservation shall be used during amplitude and pulse modulated tests. (Refer to SAE J1113-1.)

6. TEST SETUP

6.1 A typical layout drawing of a reverberation chamber and its working volume is shown in Figure 1. A general drawing of a DUT test setup is show in Figure 2.

6.2 The DUT shall be operated in its designed modes. Appropriate control signals shall be provided. Actual loads should be used for a subsystem test and simulated loads may be used for a component test.

6.3 DUT nominal condition and deviation criteria shall be clearly defined in the test plan. Appropriate instrumentation for monitoring and actuating the DUT shall be provided by the component supplier.

6.4 Steps shall be taken to prevent RF energy from coupling into control and monitoring equipment to prevent erroneous readings. This may require RF hardening of the simulator and the control/monitoring equipment. The simulator may be placed outside the room. Either filtering or fiber optic cables may be required. If filters are used, care should be taken to ensure that the filters do not present additional loading or affect the immunity of the DUT.

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