



SURFACE VEHICLE RECOMMENDED PRACTICE

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Electromagnetic Immunity - Off-Vehicle Source (Reverberation Chamber Method) -
Part 16 - Immunity to Radiated Electromagnetic Fields

RATIONALE

This SAE Recommended Practice covers technology, products, or processes which are mature and not likely to change in the foreseeable future. In addition, this SAE Recommended Practice is being stabilized because the technical committee cannot find users of this recommended practice.

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Documents

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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. This part of SAE J551 specifies off-vehicle radiated source test methods and procedures for testing passenger cars and commercial vehicles within a Reverberation Chamber. The method is used to evaluate the immunity of vehicle mounted electronic devices in the frequency range of 80 MHz to 2 GHz, with possible extensions 20 MHz to 10 GHz, depending upon chamber size and construction. Three methods for calibrating and applying electromagnetic fields are described in the document: 1) Mode Tuned Reverberation Chamber method, 2) Mode Stir (Standard) Reverberation Chamber method and 3) Mode Stir (Hybrid) Reverberation Chamber method. Optional pulse modulation testing at HIRF (High Intensity Radiated Fields) test levels, based upon currently known environmental threats, has been included in this revision of the standard. Each method has its advantages and disadvantages which are discussed in each individual test section. All methods have been proven to be effective at finding potential field issues at the vehicle level. SAE J551-1 specifies general definitions, practical use, and basic principles of the test procedure. Specific chamber characterization procedures, formulas and calibration procedures for the Mode Tuned and Mode Stir (Standard) methods can be found in SAE J1113-28 and J1113-27 respectively. Chamber characterization procedures for the Mode Stir (Hybrid) method are described in 6.3 of this document.
- 1.2 This document provides vehicle manufacturers with a test procedure and performance requirements necessary to evaluate the immunity of vehicles early in the design stage as well as pilot and production stages. This method is an alternative to testing in an absorber lined chamber.

1.3 Rationale and Application

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. This part of SAE J551 specifies off-vehicle radiated source test methods and procedures for testing passenger cars and commercial vehicles within a Reverberation Chamber. The method is used to evaluate the immunity of vehicle mounted electronic devices in the frequency range of 80 MHz to 2 GHz, with possible extensions 20 MHz to 10 GHz, depending upon chamber size and construction. Three methods for calibrating and applying electromagnetic fields are described in the document: 1) Mode Tuned Reverberation Chamber method, 2) Mode Stir (Standard) Reverberation Chamber method and 3) Mode Stir (Hybrid) Reverberation Chamber method. Optional pulse modulation testing at HIRF (High Intensity Radiated Fields) test levels, based upon currently known environmental threats, has been included in this revision of the standard. Each method has its advantages and disadvantages which are discussed in each individual test section. All methods have been proven to be effective at finding potential field issues at the vehicle level. SAE J551-1 specifies general definitions, practical use, and basic principles of the test procedure. Specific chamber characterization procedures, formulas and calibration procedures for the Mode Tuned and Mode Stir (Standard) methods can be found in SAE J1113-28 and J1113-27 respectively. Chamber characterization procedures for the Mode Stir (Hybrid) method are described in 6.3 of this document.

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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 J551-1.

2.1.1 SAE Publications

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.

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|--------------|--|
| SAE J551-1 | Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz) |
| SAE J1812 | Function Performance Status Classification for EMC Immunity Testing |
| SAE J1113-27 | Electromagnetic Compatibility Measurements Procedure for Vehicle Components - Part 27 - Immunity to Radiated Electromagnetic Fields - Mode Stir Reverberation Method |
| SAE J1113-28 | Electromagnetic Compatibility Measurements Procedure for Vehicle Components - Part 28 - Immunity to Radiated Electromagnetic Fields - Reverberation Method (Mode Tuning) |

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

NBS Information Report 81-1638 - Evaluation of a Reverberation Chamber Facility for Performing EM Radiated Fields Susceptibility Measurements. Available from NIST, U.S. Department of Commerce, Gaithersburg, MD 20899.

Phillips Laboratory Report PL-TR-91-1036 - Frequency Stirring: An Alternate Approach to Mechanical Mode-Stirring for the Conduct of EM Susceptibility Testing

Commission Directive 2004/104/EC

IEC 61000-4-3 - Electromagnetic Compatibility (EMC) Part 4-3: Testing and Measurement Techniques - Radiated, Radio-Frequency, Electromagnetic Field Immunity Test

IEC 61000-4-21—Electromagnetic Compatibility (EMC) Part 4-21: Testing Measurement Techniques - Reverberation Chamber Test Method

GMW3097 (General Motors), "General Specification for Electrical/Electronic Components and Subsystems; Electromagnetic Compatibility (EMC)"

EMC-CS-2009 (Ford Motor Company), "Component and Subsystem Electromagnetic Compatibility, Worldwide Requirements and Test Procedures"

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

NIST Technical Note 1506, "Electromagnetic Theory of Reverberation Chambers"

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

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 (either stepped or continuous). This results in a time-averaged uniform electromagnetic field. The chamber size and construction determines the type of tests to be performed, the size of the vehicle to be tested, and the usable frequency range. See Appendix A for additional information.

3.2 TUNER

A large metallic reflector capable of changing the electromagnetic boundary conditions in a reverberation chamber as it rotates or moves. As the tuner moves, the nulls (E_{min}) and maximums (E_{max}) of the field change location, ensuring the vehicle is exposed to a time-averaged uniform field. Several examples of tuner designs are shown in Appendix B.

3.3 MODE TUNED REVERBERATION CHAMBER METHOD

During Mode Tuned Reverberation testing, the tuner is operated in a step/stop/step/stop fashion (instead of a continuous rotation). The field generating antenna is pointed into a corner of the chamber to eliminate direct coupling to the vehicle. A constant field can be applied to the vehicle for a specified dwell time at each tuner position, frequency, and modulation tested. Multiple test positions about the vehicle are no longer required since the entire vehicle is immersed in the applied field. This method requires characterization of the chamber (per IEC 61000-4-21 also described in SAE J1113-28) with and without the vehicle.

3.4 MODE STIR (STANDARD) REVERBERATION CHAMBER METHOD

During Mode Stir (Standard) Reverberation testing, the tuner is operated in a continuous rotating manner (Typically 10-20 s/revolution). The field generating antenna is pointed into a corner of the chamber to eliminate direct coupling to the vehicle. The dwell time at each frequency and modulation tested is typically the time it takes for one full rotation of the tuner. Multiple test positions about the vehicle are no longer required since the entire vehicle is immersed in the applied field. Characterization of the chamber, with and without the vehicle (per SAE J1113-27), is required for this method.

3.5 MODE STIRRED (HYBRID) REVERBERATION CHAMBER METHOD

During Mode Stir (Hybrid) Reverberation testing, the tuner is operated in a continuous rotating fashion (Typically 10-20 s/revolution). Unlike the methods described in 3.3 and 3.4, a combination of direct illumination of the vehicle by the RF generating antenna and mode stirring are utilized. This method is typically used to evaluate larger vehicles (i.e., Class 8 trucks, Agriculture Equipment, Earth Moving Equipment, etc.) in large chambers where the other indirect illumination methods are not practical. Multiple test positions about the vehicle should be utilized, since direct illumination of the vehicle is being utilized. The dwell time at each frequency tested is typically the time it takes for one full rotation of the tuner. Field uniformity characterization of the chamber without the vehicle, using methods and requirements derived from IEC-61000-4-3 is required to show the useful frequency range and the performance of the chamber.

3.6 EMAX

The peak level (maximum) RF field being generated and moved about the chamber.

3.7 EMIN

The minimum level (null) RF field being generated and moved about the chamber.

4. TEST CONDITIONS

The following test conditions should be considered during the testing. See SAE J551-1 Section 6 for additional guidance on test conditions.

4.1 Test Temperature and Supply Voltage

(See SAE J551-1) In addition, heat is generated in the test facility when the vehicle is operated during the performance of the test. Sufficient cooling must be provided to ensure that the engine does not overheat. The ambient temperature in the test facility shall be recorded if it is outside the $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ range. The electrical charging system shall be functional for tests that require the vehicle engine to be running. For tests where the vehicle engine is not required to be running, the battery voltage shall be maintained above 12.2 V and 24.4 V for 12 V and 24 V systems, respectively.

4.2 Frequency Range

(See SAE J551-1) In addition, to test automotive electronic systems, the applicable frequency range of this test method is 20 MHz to 10 GHz. Testing over the full frequency range is not required and should be done at the engineering judgment of the vehicle manufacturer. At a minimum, the testing should be performed over the frequency range of 80 MHz to 2 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 will be limited to the chamber performance and the method being utilized.

4.3 Modulation

(See SAE J551-1) In addition, the characteristics of the systems of the vehicle determine the type and frequency of modulation. If no values are agreed upon 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 Tables C2 and C3 of Appendix C for suggested Pulse Modulations, test severity levels and Function Performance Status Classification associated with those pulse modulations).

4.4 Dwell Time

(See SAE J551-1) In addition, at each frequency the vehicle shall be exposed to the test level for the minimum response time needed to control the subsystems of the vehicle. The dwell time will also be dependent upon the method being utilized. The minimum dwell times are discussed in more detail in the test procedure for each method (See 6.1, 6.2 or 6.3).

4.5 Frequency Steps

(See SAE J551-1) In addition, the tests will be conducted with the maximum frequency step sizes shown in Table 1. Alternatively, logarithmic frequency steps (shown in Table 2), with the same minimum number of frequency steps in each frequency band, can be used. The values, as agreed upon by the users of this document, shall be documented in the test report.

NOTE If it appears that the susceptibility thresholds of the vehicle 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 J551-1.)

TABLE 1 - LINEAR FREQUENCY STEPS

Frequency Band	Maximum Frequency Step Size
20 MHz to 200 MHz	2 MHz
200 MHz to 1 GHz	5 MHz
1 GHz to 2.0 GHz	10 MHz
2.0 GHz to 10 GHz	50 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...<10000	1000	50

4.6 Test Signal Quality

(See SAE J551-1).

4.7 Threshold of Response

(See SAE J551-1) In addition, for continuously stirred test methods; as a responding frequency is being thresholded, the amplitude shall slowly be increased to allow time for tuner rotation so that the unit is allowed to be subjected to the high point of the field. The peak field point shall be recorded as the threshold amplitude level. During mode tuned testing, if deviations are observed, the field shall be reduced until the vehicle functions normally. The field shall then be increased in 1 dB increments and the tuner rotated to all positions for a full rotation. This process would be repeated until the deviation occurs. This level shall be reported as deviation threshold.

4.8 Test Severity Levels

(See SAE J551-1) In addition, the vehicle manufacturer shall specify the test severity level(s) over the frequency bands to be tested. Examples of test severity levels are included in Appendix C of this document. A full description and discussion of the Function Performance Status Classification including Test Severity Levels are given in SAE J1113-1 Appendix A. Please review it prior to using the suggested Function Performance Status Classification objectives presented in Appendix C. These test severity levels are expressed in terms of equivalent root-mean-square (RMS) value of an unmodulated wave. Peak conservation shall be used during amplitude and pulse modulated tests.

5. TEST INSTRUMENT DESCRIPTION AND SPECIFICATION

5.1 Test Plan

Prior to performing the tests, a test plan shall be generated which shall include, vehicle mode of operation, vehicle acceptance criteria, vehicle test positions (if applicable) and any other special instructions and/or changes from the standard test. Every vehicle shall be verified under the most significant situations, e.g., at least in stand-by and in a mode where all the actuators can be excited.

5.2 Reverberation Radiated Immunity System

Reverberation Radiated Immunity is a method of carrying out immunity tests by applying disturbance signals onto the vehicle by means of a radiated RF electric field. An appropriate RF field generating device is used in conjunction with an RF amplifier and signal source. Depending upon the method being utilized, the RF electric field intensity level is established from either a previous chamber characterization or a closed loop leveling system. If the mode stirred method is being utilized, a field monitoring antenna in conjunction with a spectrum analyzer, should be used to measure the generated RF field. If electric field probes are used for mode stirred tests, they should be capable of making measurements at a rate of 50Hz or greater. The immunity tests are then carried out by varying the test severity level and frequency of the disturbance. The radiated electric field shall be applied to the entire vehicle either simultaneously or at multiple test positions, depending upon the method being utilized.

5.3 Test Setup and Instrumentation

A sample set-up for each test method is shown in Appendix A. All equipment used, shall be capable of operating over the test frequency range required. The field generating device (antenna) shall be capable of withstanding a continuous input power over the test frequency range regardless of the system loading. The RF measurement equipment shall be capable of operating over the test frequency range. Prior to testing, the RF measurement devices shall be characterized per manufacturer's instructions. During testing, the RF measurement devices shall be operated in the same manner as during pretest characterization. Any variations shall be documented and noted in the test report.

5.4 Vehicle Set-Up

The vehicle should be tested as built and no additional grounding connections are allowed between the vehicle and the chamber. Tests should be performed inside a shielded room. The distance between vehicle and all other conductive structures, such as walls of a shielded room (with the exception of the ground plane underneath the vehicle), shall be a minimum of 0.5 m.

5.5 Vehicle Monitoring Equipment

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 monitoring equipment shall 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 vehicle.