

SURFACE VEHICLE STANDARD

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(R) Immunity to Radiated Electromagnetic Fields - Bulk Current Injection
(BCI) Method

RATIONALE

The test method is being revised to reflect the latest changes in the corresponding international standard (ISO 11452-4). The equation for calculating the threshold of induced current based on measured calibration power for the substitution test method is also added. The preferred test method (Substitution Method) is listed before the alternate test method (Closed Loop Method). Appendix A, Function Performance Status Classification (FPSC), is also revised to include latest changes in SAE J1812, SAE J1113-1 and ISO 11452-4. Additional examples for applications of FPSC are also incorporated in Appendix A.

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1. SCOPE

This SAE Standard defines a method for evaluating the immunity of automotive electrical/electronic devices to radiated electromagnetic fields coupled to the vehicle wiring harness. The method, called Bulk Current Injection (BCI), uses a current probe to inject RF onto the wiring harness in the frequency range of 1 to 400 MHz. BCI is one of a number of test methods that can be used to simulate the electromagnetic field.

2. REFERENCES

General information regarding this document, including definitions, references, and general safety considerations is found in SAE J1113-1.

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.

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.

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

SAE J1812 Function Performance Status Classification for EMC Immunity Testing

2.1.2 IEEE Publication

Available from IEEE Customer Service 445 Hoes Lane, Piscataway, NJ 08855-1331 or standards.ieee.org/.

IEEE Std C95.1 IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

2.1.3 ISO Publication

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

ISO 11452-4 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy—Component test methods: Bulk current injection (BCI)

3. DEFINITIONS

See SAE J1113-1.

4. MEASUREMENT PHILOSOPHY

As a vehicle is driven near high power transmitting antennas or when a mobile transmitter is used on a vehicle, the radiated electric field couples, either directly or through the wiring harness, into electronic devices on the vehicle. In the frequency range of 1 to 400 MHz, coupling occurs mostly through the wiring harness. To simulate this coupling, BCI can be used. BCI provides a method of compatibility evaluation by inducing high-frequency current into the wiring harness. It is a non-intrusive method since there is no galvanic connection to the wiring harness.

5. FUNCTION PERFORMANCE STATUS CLASSIFICATION

See SAE J1812 and SAE J1113-1.

6. TEST EQUIPMENT, TEST SETUP AND TEST PROCEDURE

6.1 Test Equipment

6.1.1 RF Signal Generator

1 to 400 MHz.

6.1.2 Broadband Power Amplifier

1 to 400 MHz, 50 W minimum. The amplifier should be able to:

- a. Drive a load of any impedance mismatch without damage to itself
- b. Drive enough power into injection probe to meet specified injection levels

6.1.3 Current Injection Probe

1 to 400 MHz high power capability. More than one type of probe may be required to cover frequency range of interest.

6.1.4 Current Monitoring Probe

1 to 400 MHz. The monitor probe output voltage (V_{out}) should be converted to the induced current (I_{ind}) by the following relationship:

$$I_{ind}[dB_{mA}] = V_{out}[dB_{mV}] - Z_t[dB_{\Omega}] \quad (Eq. 1)$$

where:

Z_t = Is the Current probe transfer impedance in Ω .

The transfer impedance of the current monitoring probes shall be verified and/or updated yearly.

6.1.5 Spectrum Analyzer or Equivalent

(For use with monitoring probe.)

6.1.6 Directional Coupler (Optional)

6.1.7 Power Meter

6.1.8 Computer Control (Optional)

6.1.9 Injection Probe Calibration Fixture

6.2 Test Setup

The test setup is shown in Figure 1.

NOTE 1: When a battery is used, a charging source may be required to maintain the specified supply voltage.

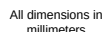
NOTE 2: Deviation of ± 50 mm height dimension in region of probe to center the wire harness is acceptable.

6.2.1 The test shall be performed in a shielded room.

6.2.2 The ground plane requirements are specified in SAE J1113-1.

6.2.3 The grounding of the DUT and/or its outer case depends on its application in the vehicle. If the DUT will be grounded when installed in the vehicle, then it must be bonded to the ground plane in the bench test the same way it will be attached in the vehicle. If not, the DUT shall be placed on an insulated support.

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1. Device under test (connected to ground if specified in the test plan)
2. Wiring harness (1700 mm +300/-0 mm)
3. Load simulator (placement and ground connection according to ISO 11452-4)
4. Stimulation and monitoring system
5. Power supply
6. AN or 50 Ω LISN
7. Optical fibers
8. High frequency equipment
9. Current Injection probe (represented at 2 positions)
10. The distance from the DUT to the closest probe position
11. Ground plane (connected to the shielded room)
12. Insulating support
13. Shielded room.

6.2.4 A 1700 mm + 300 / - 0 mm test harness including any permanently attached pigtail shall be used for both substitution method and closed – loop method unless otherwise specified in the test plan. Any variance from the standard harness shall be documented in the test report.

6.2.5 The bottom of the wiring harness bundle shall be positioned 50 mm $\pm$ 10 mm above the ground plane along its entire length. If the wiring harness positioning cannot be achieved due to harness constraints, the distance should be chosen as close as possible to the 50mm and be included in the test report.

- 6.2.6 The negative side of the power supply/battery shall be bonded to the ground plane using a low resistance ground strap having less than 2.5 milliohms resistance.
- 6.2.7 The simulator shall be bonded to the ground plane as shown in figure 1
- 6.2.8 The current injection and current monitoring probes shall be insulated from the ground plane and supported (if needed) to keep the probes concentric about the harness.
- 6.2.9 For the "Calibrated Injection Probe (Substitution)" Method, the current monitoring probe is optional. If used, it shall be located $50 \text{ mm} \pm 5 \text{ mm}$ from the outermost edge of the DUT connector (measured from the center of the probe) as shown in Figure 1.
- 6.2.10 The current injection probe shall be positioned $150 \text{ mm} \pm 5 \text{ mm}$ from the outermost edge of the DUT connector (measured from the center of the probe) as shown in Figure 1. The test can be repeated with the injection probe at $450 \text{ mm} \pm 5 \text{ mm}$ and $750 \text{ mm} \pm 5 \text{ mm}$ from the connector.

NOTE: Performing the RF current injection at three different locations minimizes wiring harness resonance effects. The number of injection probe positions shall be documented in the test report.

- 6.2.11 The DUT shall be operated in its designed modes. Therefore, appropriate control signals shall be provided and actual or simulated loads used.
- 6.2.12 DUT performance criteria shall be accurately defined. Appropriate instrumentation to monitor for anomalies shall be provided.
- 6.2.13 Proper steps shall be taken to prevent the RF energy from coupling into control and/or monitoring equipment.

6.3 Test Procedure

6.3.1 General Information

6.3.1.1 Test Plan

Prior to performing the tests, a test plan shall be generated which shall include interface test points, DUT mode of operation, DUT acceptance criteria, and any special instructions and changes from the standard test.

6.3.1.2 Operational Modes

Every DUT shall be verified under the most significant situations; i.e., at least in stand-by and in a mode where all the actuators can be excited.

6.3.1.3 Test Environment and Conditions

Test temperature, supply voltage, modulation, dwell time and frequency steps are given in 6.1 of SAE J1113-1.

6.3.1.4 Alternative Modes

Two alternative modes exist to inject RF into the harness:

- Common mode injection for all frequencies (1 to 400 MHz). In this mode, all lines of the harness shall remain inside the injection probe.
- Differential mode injection for frequencies below 30 MHz. In this injection mode, all ground lines (power ground and signal return lines) are to be routed outside of the injection probe. The power ground and signal return lines are to be reintegrated into the test harness as close to the injection probe and as straight (inline) as harness makeup allows. The harness routing shall be described in the test report.

The test plan shall define when the differential mode alternative is to be used.

6.3.1.5 Test Methods

The frequency range of the BCI test method is 1 to 400 MHz. The frequency range of the BCI test method is a direct function of the current probe characteristic. More than one type of current probe may be required.

There are two test methods for the BCI test:

- a. Calibrated Injection Probe (Substitution) Method
- b. Current monitoring probe method (closed-loop) with power limitation

For both tests, the test equipment shall be connected in a manner similar to that shown in Figure 1.

CAUTION: Hazardous voltages and fields may exist within the test area. Care should be taken to ensure that the requirements for limiting the exposure of humans to rf-energy are met. (i.e., IEEE Std C95.1)

6.3.2 Calibrated Injection Probe Method (Substitution Method)

6.3.2.1 The substitution method is based upon the use of forward power as the reference parameter for calibration and test. This test is performed in two phases:

- Calibration (on fixture)
- Test of the DUT

6.3.2.1.1 Calibration:

The specific test level (current) shall be calibrated periodically by recording the forward power required to produce a specific current measured into a 50 Ω calibration fixture (see Appendix B) at frequency steps no greater than the maximum frequency step size defined in SAE J1113-1.

For smaller incremental test frequency steps, interpolation between calibration frequencies is allowed with a maximum interpolation error of 0.5 dB.

This calibration shall be performed with an unmodulated sinusoidal RF signal (CW).

The value of RF power recorded during the calibration should be included in the test report.

The calibration fixture should be terminated with a 50 Ω (high power) load at one end and by a 50 Ω RF power measuring instrumentation at the other end, protected by a 50 Ω attenuator of adequate power rating.

The test current level I_{Test} is applied to the fixture and the corresponding forward power calibration $P_{Calibration}$ is recorded.

6.3.2.1.2 Test of the DUT:

The DUT, harness and associated equipment are installed on the test bench as shown in Figure 1.

The test is conducted by subjecting the DUT to the test signal based upon the calibrated test current as predetermined in the test plan.

Mount the current injection probe around the harness as defined in 6.2.10. Where the harness contains a number of branches, the test shall be repeated with the current probe(s) clamped around each of the branches. Under these test conditions, the monitoring probe, if used, shall be left at the defined distance from the DUT.

Using the pre-calibrated level of forward power, search for anomalies over the specified test frequency range.

At each probe position:

- The desired test level shall be attained by increasing RF signal generator level in such a manner to avoid overshoots. Overshoots shall be limited to 1 dB over the desired test limit.
- A search for performance anomalies shall be conducted over the frequency range of the injection probe using CW with ON-to-OFF and OFF-to-ON transitions. All performance anomalies found during the transitions and during the CW dwell time shall be recorded.
- The ON-to-OFF and OFF-to-ON RF level difference shall be at least 20 dB. The ON-to-OFF, OFF-to-On transition rise/fall times shall be 3 msec or faster. Record the threshold of immunity (lowest RF power level applied to the current injection probe and the current as measured by the current monitor probe if used) as a function of frequency for each anomaly.

For each anomaly, the lowest forward power to the injection probe (and the current measured by the monitor probe if used) which produces the anomaly shall be recorded as the threshold of immunity even if this is found with the injection probe in different positions and at different frequencies [In SAE J1113-1]. The threshold level $I_{Threshold}$ (mA) can be calculated from the calibration power $P_{Calibration}$ (dBm) and the threshold power $P_{Threshold}$ (dBm) using the following formula:

$$I_{Threshold} = 10^{\left(\frac{(20 \log I_{Test}) - (P_{Calibration} - P_{Threshold})}{20} \right)} \quad (\text{Eq. 2})$$

where: $I_{Threshold}$ = Threshold Current in mA

I_{Test} = Test Current in mA

$P_{calibration}$ = Calibrated power level (dBm) required to achieve the test current

$P_{Threshold}$ = Power level (dBm) measured at the DUT response threshold

6.3.3 Current Monitoring Probe Method (Closed-Loop Method) with Power Limitation

6.3.3.1 The closed-loop method with power limitation method is based upon the use of forward power as the reference parameter for calibration and test. This test is performed in two phases:

- Calibration (on fixture)
- Test of the DUT

The power limit $P_{CWlimit}$ is determined using the calibration fixture.

The test current limit I_{Test} applied to the DUT is determined using a limit curve versus frequency.

6.3.3.1.1 Calibration

This procedure determines the power limit applicable for the test with DUT.

The specific test level (current) shall be calibrated periodically by recording the forward power required to produce a specific current measured into a 50 Ω calibration fixture (see Appendix B) at frequency steps no greater than the maximum frequency step size defined in SAE J1113-1.

For smaller incremental test frequency steps, interpolation between calibration frequencies is allowed with a maximum interpolation error of 0.5 dB.

This calibration shall be performed with an unmodulated sinusoidal RF signal (CW).

The value of RF power recorded during the calibration should be included in the test report.

The calibration fixture should be terminated with a 50 Ω (high power) load at one end and by a 50 Ω RF power measuring instrumentation at the other end, protected by a 50 Ω attenuator of adequate power rating.

The test current level I_{Test} is applied to the fixture and the corresponding forward power $P_{calibration}$ calibration is recorded. The power limit $P_{CWlimit}$ to be used during test of the DUT is $P_{calibration} + 6$ dB (unless otherwise specified in the test plan).

6.3.3.1.2 Test of the DUT

The DUT, harness and associated equipment are installed on the test bench as shown in Figure 1.

The test is conducted by subjecting the DUT to the test signal based upon the measured test current I_{Test} applied to the DUT or the power limit $P_{CWlimit}$ (whichever is achieved first) predetermined in the test plan.

Mount the current injection probe around the harness as defined in 6.2.10. Where the harness contains a number of branches, the test shall be repeated with the current probe(s) clamped around each of the branches. Under these test conditions, the monitoring probe, shall be left at the defined distance from the DUT.

Using the power limit $P_{CWlimit}$ and the desired test current I_{Test} measured on the cable being tested, search for anomalies over the specified test frequency range

At each probe position:

- The desired test level shall be attained by increasing RF signal generator level in such a manner to avoid overshoots. Overshoots shall be limited to 1 dB over the desired test limit.
- A search for performance anomalies (see 6.2.12) shall be conducted over the frequency range of the injection probe using CW with ON-to-OFF and OFF-to-ON transitions. All performance anomalies found during the transitions and during the CW dwell time shall be recorded.
- The ON-to-OFF and OFF-to-ON RF level difference shall be at least 20 dB. The ON to OFF, OFF to On transition rise/fall times shall be 3 msec or faster. Record the threshold of immunity (lowest induced current as measured by the Current Monitoring Probe) as a function of frequency for each anomaly.

The search for performance anomalies shall continue by incrementing the power level until either one of the following stop criteria is met:

- a. The specified induced test current I_{Test} level is achieved,
- b. The power limit $P_{CWlimit}$ to the injection probe is achieved, or
- c. Any of the first 5 harmonics (up to 400 MHz) is within 9 dB of the fundamental frequency.

Criterion c as identified above should be an optional criterion to be specified in the test plan.

7. TEST SIGNAL SEVERITY LEVEL FOR FUNCTION PERFORMANCE STATUS CLASSIFICATION (FPSC)

The test signal severity level is the stress level (current) applied to the device under test for any given test method and region of performance during the test.

The test signal severity level should be determined by the vehicle manufacturer and supplier. Examples for how the test signal severity level could be applied are included in Appendix A.